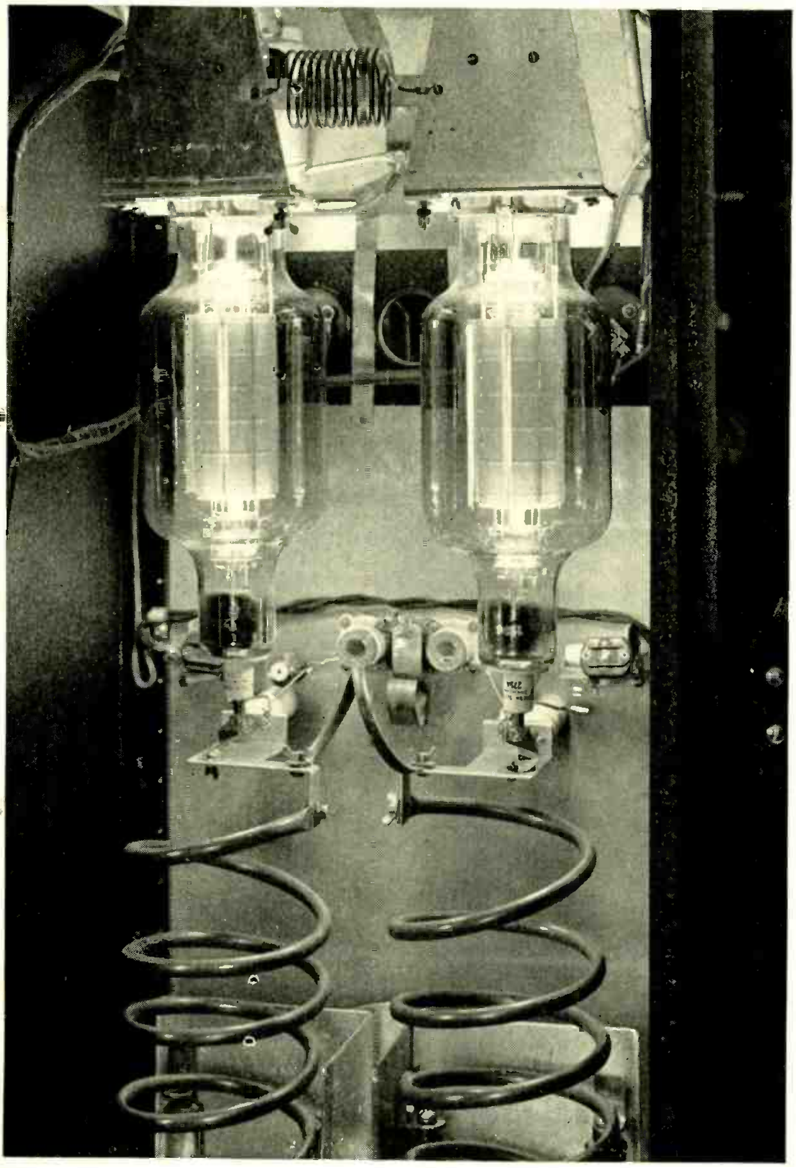
BELL LABORATORIES RECORD



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A Test Oscillator at the Deal Radio Laboratory

The Type-H Carrier Telephone System

By A. C. DICKIESON
Toll Development Department

SEVERAL carrier telephone systems have been developed for open-wire lines to fit the various fields of use in the telephone plant. Of these the type-G is a single-channel system recently developed for distances up to about twenty-five miles. The type-D system is a single-channel system for distances up to about 125 miles and a modification of this system known as DA will cover distances up to about two hundred miles. The type-C* system is a three-channel system that was designed principally for much longer hauls.

Since the type-D system was developed there have been a number of technical advances that could be applied advantageously to carrier systems. Among these are the copper-oxide modulator, the heater-type

*The type-C system was described in the RECORD for December, 1925; the type-G in March, 1937; and the type-D in July, 1928.

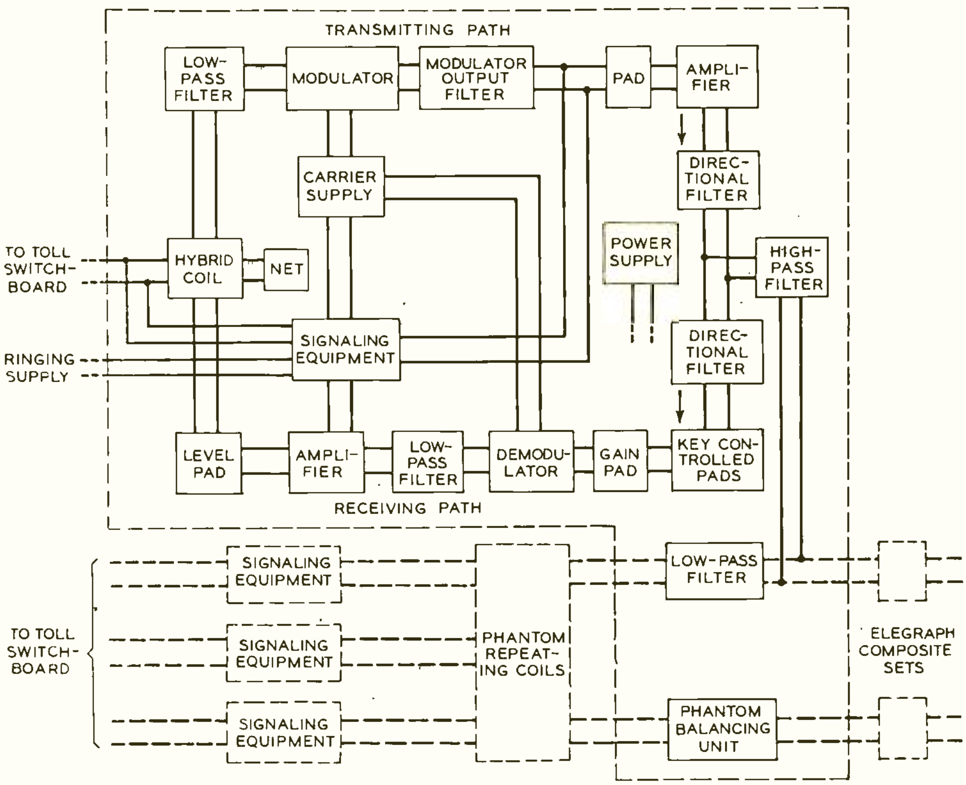


Fig. 1—Simplified block schematic of a type-H carrier terminal

p e tube, stabilized feedback, and new magnetic alloys from which better and smaller filters may be built. To take advantage of these improvements a new single-channel system has been developed which will span the longer distances of the DA system, and which will still be economical for distances shorter than the D system. It is known as the type-H, and is expected to find its greatest field of application for distances of about fifty to two hundred miles, although the repeater which has been made available with this system will enable greater distances to be spanned.

The type-H system differs from the D system in that it employs a common-carrier frequency, 7150 cycles, for both directions of transmission. The upper sideband is transmitted from east to west, and the lower sideband from west to east. Unlike the type-D system which operates only on batteries, it may be operated either from an a-c power supply or from batteries. A block schematic for a single terminal is given in Figure 1, with the aid of which the operation of the circuit may be followed.

Speech outgoing from the switchboard passes through the usual terminating hybrid coil to a low-pass filter, which removes any high-frequency noise or crosstalk that may be present. Thence speech passes to the double-balanced modulator, which produces the wanted and unwanted sidebands. The modulator-output filter supplies enough discrimination against the unwanted sideband and other unwanted frequencies to prevent the transmitting amplifier from being loaded unnecessarily. Next is the transmitting gain-control pad, adjustable in steps of 0.5 db from 0 to 31.5 db, and connected to give the required level on the line. The transmitting directional filter supplies the remainder of the discrimination necessary to select only the wanted sideband for transmission. The high-pass and low-pass line-filter combination separates the carrier and voice-frequency channels at the beginning of the open-wire line.

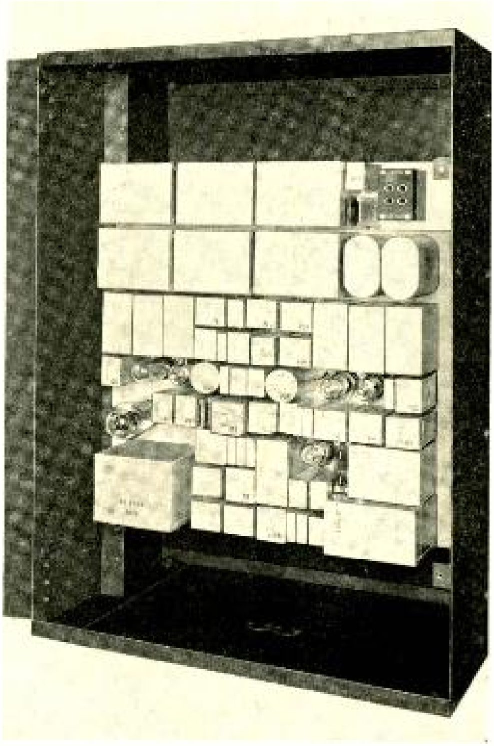


Fig. 2—The type-H terminal may be installed either on a relay rack bay or in a metal cabinet as shown above

In the other direction, the sideband from the distant terminal arrives over the wire line, and passes through the high-pass line-filter and receiving directional filter. The receiving gain-control pad, also adjustable in 0.5 db steps up to 31.5 db, adjusts for the length of line on the particular circuit. There is also a key-controlled pad covering a range of six db, in steps of two db, for taking care of changes in net loss due to weather and to temperature variations on the line. The demodulator brings the sideband back to voice frequencies, unwanted products being removed by the demodulator low-pass filter ahead of the receiving amplifier. The output transformer of the amplifier is a hybrid coil to separate the signal-receiving circuit from the main transmission path, which passes through a pad adjusted in 0.5 db steps to give the desired circuit net loss, and thence to the terminating hybrid coil and switchboard.

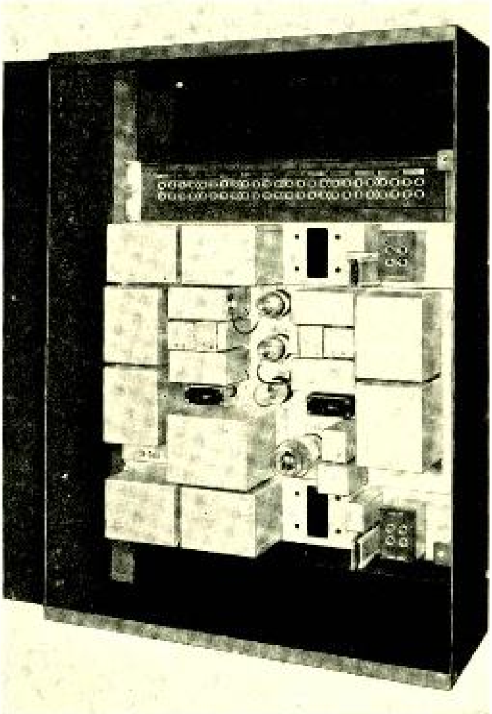


Fig. 3—Repeater for the type-H system

A signal outgoing from the switchboard operates relays which shift the carrier oscillator frequency by one thousand cycles, interrupt it at a twenty (or 16⅔) cycle rate, and send it to the open-wire line adjusted to the desired magnitude. At the receiving end, this signal is picked up at the output of the receiving amplifier, where it has become one thousand cycles interrupted at a twenty-cycle rate. After rectification, the twenty-cycle resultant is selected, amplified, and rectified to operate a relay. After a short period, determined by a slow-operate relay circuit to guard against the possibility of false signals, a signal is sent to the switchboard.

The general arrangement of circuit elements of the new carrier system is nearly the same as in the type DA: the improvement lies largely in applying the new tools to the design. In addition, type H has been designed so that the same terminal equipment can be arranged by optional strapping to fit any of the various conditions. It can be used with No. 1 or No. 3 switchboards, batteries, or 110-volt a-c power supply, 20 or 16⅔ cycle ringing, and has soldered adjustable pads to give a wide range of transmitting and receiving gains.

Copper-oxide varistors are used for modulators, and for several rectifiers in the power supply and signalling circuits. Besides permitting smaller size, the copper-oxide varistors provide better balanced modulators and have the advantage of long life and small power consumption. Employing heater type pentodes allows a single tube in the transmitting amplifier to work at approximately the same output level as two tubes used with the DA system. They also permit grid biases to be obtained from the voltage drop across a resistance in the cathode circuit, rather than from separate batteries, and simplify the problem of working from 110-volt a-c supply. The filters employed are much smaller than those used with the type-D system. As a result of the various reductions in size, the type-H terminal occupies but nineteen inches of relay rack space, while the type-D system required fifty-one, and the type DA sixty-five inches. The appearance of the type-H terminal may be seen in Figure 2, which shows an optional arrangement in which the terminal is mounted in a metal cabinet.

The repeater for the type-H system employs for the greater part elements that were designed for the terminals. The same filters are used for separating the two directions of transmission, and the amplifiers are essentially the same as the terminal transmitting amplifiers. The gain in each direction is controlled by pad circuits adjustable over a range of 31.5 db in steps of 0.5 db. To take care of line variations, a manually adjusted pad is provided in each amplifier covering a range of zero to eight db in steps of four db. The total gain available in each direction is about twenty-three db. The maximum output level is the same as at the terminal. The repeater panel itself, as shown in Figure 3, is mounted on a 10½-inch panel. Allowing for the line filters that go with it the total rack space required for this repeater equipment is 17½ inches.

Besides the reductions in size and cost, the type-H system includes a number of improvements in transmission performance. One of these is the extension of the channel bands to include frequencies up to about three thousand cycles. This is shown in Figure 4 which shows a representative transmission-frequency characteristic for a type-H system without a repeater. All in all, the type-H carrier terminal, by taking advantage of new developments and experience with the earlier system, offers a distinctly improved communication system—not only as a part of the regular plant but for temporary or emergency circuits.

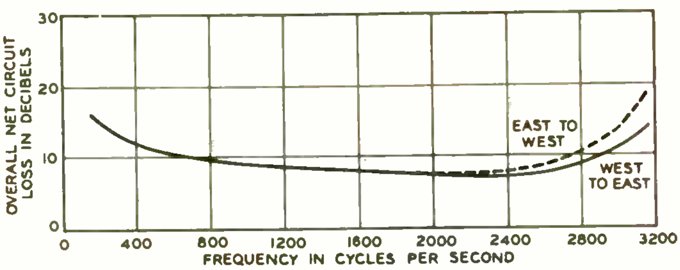
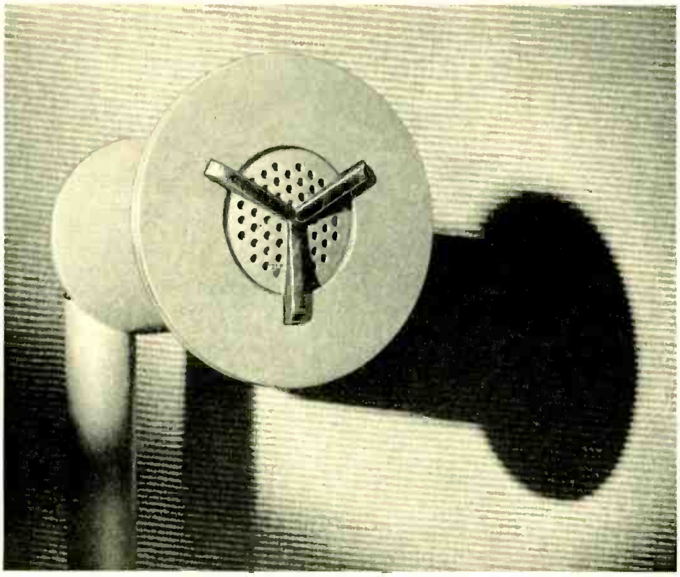


Fig. 4—Transmission characteristics of the type-H system



Low-Cost Microphone for Varied Application

By R. N. MARSHALL
Transmission Instruments Development

FOR a long time the radio-broadcasting, public-address, and sound-picture fields were the largest in which high-quality microphones were required; and the Western Electric 618A* and 630A† microphones were developed with the needs of these industries particularly in mind. Since the microphone is only a small part of the equipment they require, and high quality was the objective chiefly sought, the actual cost of the microphones was of secondary importance. In recent years, however, there has been a growing need for microphones in schools, hotels, restaurants, and for a variety of miscellaneous uses. It has been necessary for these users either to buy very high-quality microphones, or to purchase inferior instruments. To provide for these diversified applications an instrument that was of high quality at lower cost, the Laboratories have recently developed a new "general purpose" microphone known as the 633A. This microphone has a diaphragm and magnet unit that in their main structural features are the same as those of the 630A, and this fact helped to make it possible to keep the development cost to a minimum. To reduce the manufacturing costs of the new instrument, certain of the requirements placed on the 630A microphone have been somewhat modified, and other simplifications have been made without seriously impairing the quality of the microphone.

Since the manufacturing requirements do not affect the major structural features of the diaphragm, a general description of this unit will apply to both the 630A and the 633A

*RECORD, *May*, 1932, *pp*. 314, 319, *and* 323.
†RECORD, *October*, 1935, *p*. 34.

m ones. Its diaphragm is of a hard aluminum alloy rolled to about one-sixth of the thickness of the paper on which this is printed. A special process of punching, heat treating, and forming was developed to obtain low production costs. The surface of the diaphragm is lacquered to prevent corrosion.

The diaphragm is so light and fragile that it cannot be handled by hand or even with light tweezers without risk of damage. Consequently, a special suction tool, shown in Figure 1, was designed to allow quick handling without damage. Damage to the diaphragm after it is in the microphone has been avoided by cementing it directly to the outer pole-piece, and by providing spacing washers so that the diaphragm is not in contact with the case of the instrument. In the event of a shock, therefore, such as dropping the microphone, the only force that can be transmitted to the diaphragm is that due to its own inertia, and this—because of the diaphragm's extreme lightness—is insignificant.

One of the simplifications made in the 633A microphone is the omission of a connecting plug; the cord is connected directly to screw terminals within the instrument. As in the ordinary electric plug, the stress on the cord is carried to the frame of the microphone rather than to the terminals, so that the microphone may be suspended by the cord without danger of loosening or breaking a contact. When the microphone is mounted on its associated desk or floor stand, the cord is normally brought through the center of the mounting tube. However, if quick interchangeability of instruments is desired, the cord may be brought outside of the stand at the opening in an intermediate swivel called the 9A attachment, and the cord terminated after a short distance in a standard plug connector.

The housing of the 633A microphone differs from that of the 630A in being cylindrical in shape and about two inches in diameter and three inches long. It consists of a one-piece aluminum casting with three fins on the front, which not only strengthen the part of the shell in front of the diaphragm, but prevent damage to the diaphragm due to sudden application of air pressure such as might be caused by slapping the front of the instrument. The fins pre-

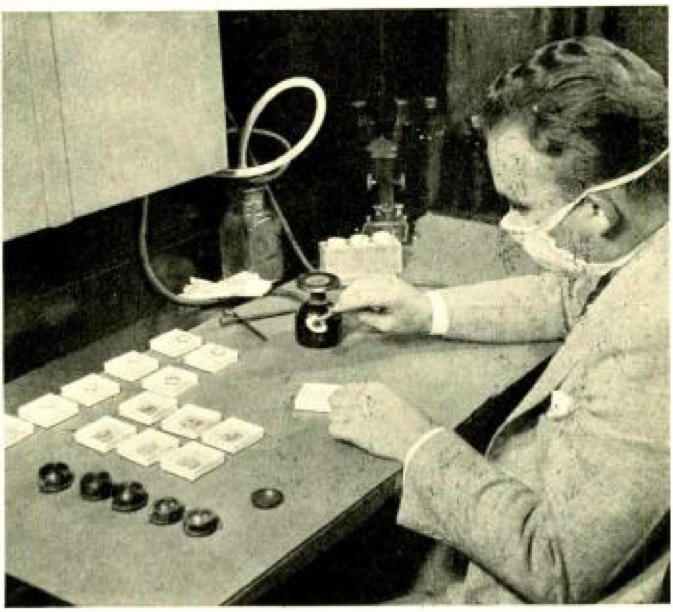


Fig. 1—A special suction tool permits the diaphragm to be handled during assembly without touch by the hand

vent an air seal under these conditions, and thus high pressures cannot be built up. The appearance of the fins is shown in Figure 2, and of the microphone on its floor stand which is equipped with a swivel attachment is shown in Figure 3.

The sensitivity of the microphone at the higher frequencies is greatest to sound arriving "front on" to the diaphragm, and thus when the microphone is pointed in the direction of the desired source of sound it exhibits an appreciable degree of directivity for this source. When the microphone is mounted vertically, however, it has nearly equal sensitivity to all sounds that approach from any direction in the horizontal plane because of its structural symmetry.

When mounted in the vertical position the non-directional feature may be utilized and a group of performers may be "picked up" with little discrimination against any individual. The directional characteristics, on the other hand, may be enhanced by slipping over the front end of the microphone the baffle shown in the photograph at the head of this article. This is helpful, for example, in cutting out auditorium noise when picking up the address of a speaker.

Fig. 3—The 633A microphone is designed to serve as an "all-purpose" instrument

The baffle itself is similar to the one developed by F. F. Romanow for the 630A microphone to allow the user to choose between a non-directional and a directional characteristic. In Figure 2 are shown two forms of this attachment. The first, the 8A, is held in place on the microphone by the friction of the leather

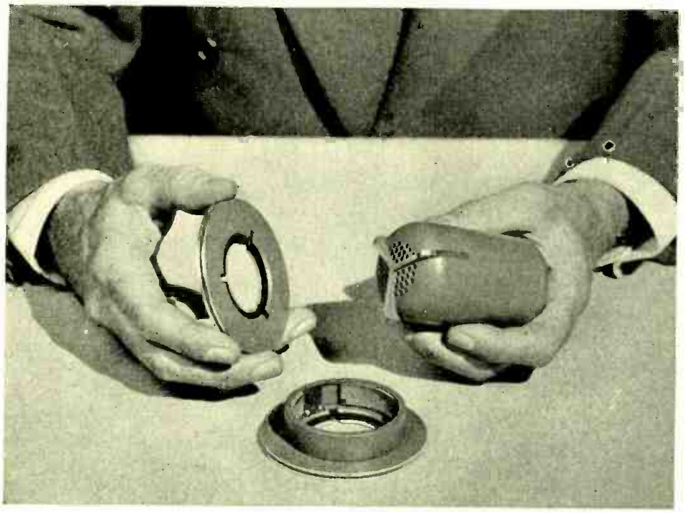


Fig. 2—The baffle consists of two disks with a leather washer between them, which holds the baffle to the microphone

washer. The other type, the 8B, consists essentially of the 8A plus a twist locking device. It is provided for those cases in which a more rigid combination is required.

In discussing directional effects, sound arriving "front on" to the instrument is referred to as of zero incidence, and other incidences are specified by giving the angle between the incident sound and the "front on" direction. These angles run from zero degree for "front on" sound to 180 degrees for sound arriving directly from the rear. Thus ninety degrees incidence specifies sound arriving from any direction in the plane of the diaphragm, which is the horizontal plane when the microphone is mounted vertically. Thus the response for ninety degrees incidence is that for the microphone mounted for non-directional pick-up, and is shown in Figure 4. This non-directional characteristic applies, however, only to the horizontal plane, since when the microphone is mounted vertically sounds coming from above or below meet the microphone at other than ninety degrees incidence and thus have different responses. The directive nature of the microphone is best shown by plotting the response for various degrees of incidence relative to the response at ninety degrees. Such curves are shown in Figure 5 for zero degree and 150 degrees, both with and without the baffle. Here the horizontal line represents the ninety degree response. Below one thousand cycles there is little difference between the curves, but above one thousand cycles, there is a decided increase in efficiency for sounds coming from the front of the instrument, and a decrease for sounds coming from the rear.

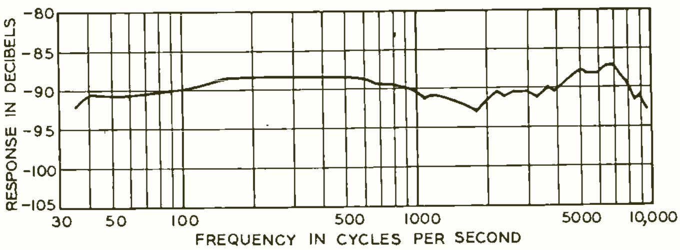


Fig. 4—Response characteristic of 633A microphone for sound at 90-degree incidence

When the microphone is used in the non-directional position, these differences are of secondary importance, since all the major sound sources, either the speakers, singers, or orchestra, are in approximately the same horizontal plane as the diaphragm, and there is little discrimination against any of them. It is largely the reflected sound from above or below, that is increased or diminished by the directive characteristics of the microphone.

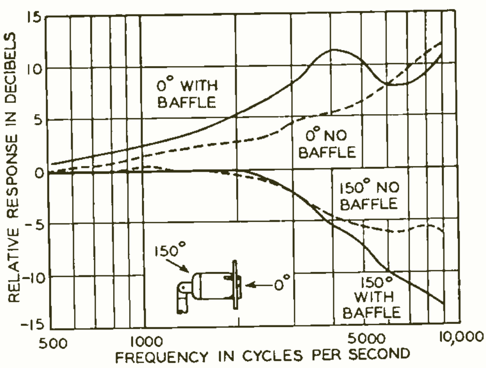


Fig. 5—Response of the 633A microphone for 0-degree and 150-degree incidence relative to that for 90-degree incidence, represented by the horizontal line

When the microphone is used to obtain a directional effect, however, these differences become important, because the response from the front is increased and that from the rear is decreased, so that the net difference in response between front and rear becomes considerable. This difference in response between incidences of zero degree and 150 degrees is plotted in Figure 6 as the loss at 150 degrees incidence compared with that at zero

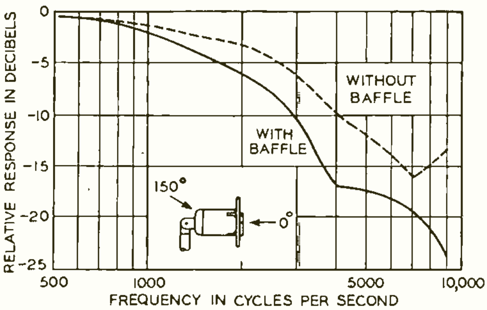


Fig. 6—Decrease in response at 150 degrees relative to that at zero degree, both with and without the baffle

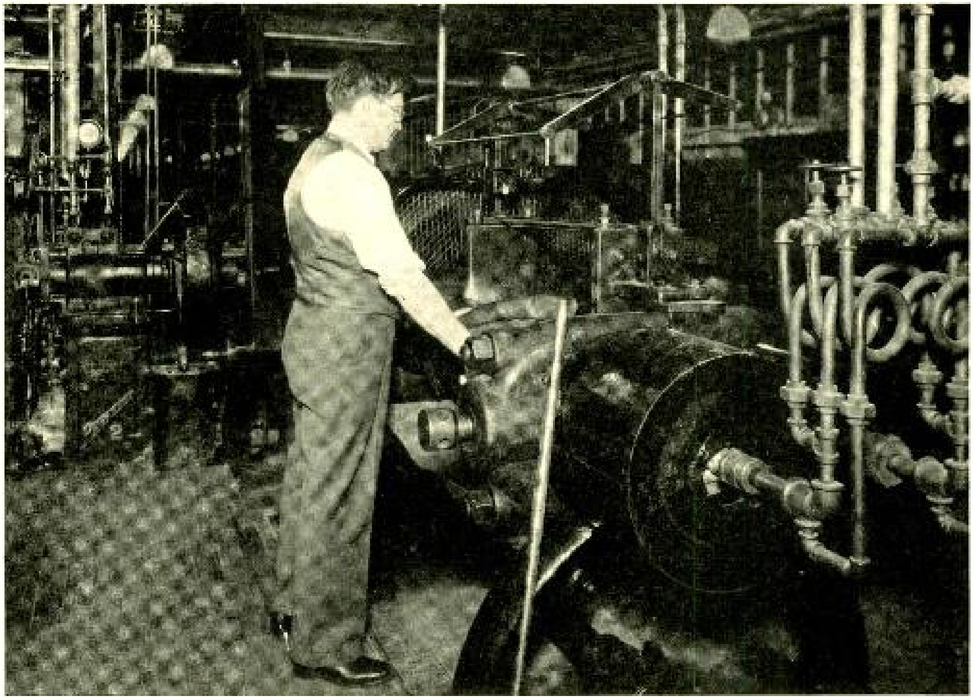
degree incidence, and is a measure of the directive effect. It is quite appreciable even without the use of the baffle, but when the baffle is added it becomes much more pronounced.

Studies have shown that whereas about eighty per cent of the sound power of speech is carried by the frequencies below one thousand cycles, articulation depends chiefly on the frequencies above one thousand cycles. It was with this fact in mind that the 633A microphone was designed to give an increasing normal incident response to frequencies above one thousand cycles. The discrimination obtained in this way, increasing steadily from five hundred cycles up to the highest frequencies, proves effective. Although curves showing this difference are given only for ninety and 150 degrees, other angles have more or less intermediate values; the discrimination is very slight at 30 degrees but at 60 degrees becomes pronounced, and increases for the larger angles.

The attractive appearance of the new microphone, its convenient mountings, and small size and weight should make it of wide appeal. Coupled with these features, its quality, efficiency, and ability to handle various type "pick-ups" give it a prominent place in the low-price field.

Dr. Ives Honored by Optical Society

For distinguished work in optics, the Frederic Ives Medal of the Optical Society of America has been presented to Herbert E. Ives, son of the man in whose honor it was established.



Non-Corroding Rubber Insulation for Telephone Cords

By J. H. INGMANSON
Chemical Laboratory

MORE or less difficulty has always been experienced in making satisfactory soldered connections to the rubber insulated telephone cords. One of the principal causes of this difficulty has been the presence of corrosion on the tinsel conductors, caused by the sulfur that is used as the vulcanizing agent in the rubber compound.

After the development of solderless cord tips for textile-insulated cords, already described in the RECORD,* it seemed desirable to extend their use to rubber-insulated cords, but the sulfur corrosion made it even more difficult to obtain suitable electrical connections by this method than by soldering. A satisfactory connection might be made on a newly manufactured conductor, but the formation of corrosion at the point of contact soon produced a high-resistance contact which would result in noise if used in a telephone circuit. It seemed very desirable, therefore, to develop a non-corroding rubber insulation.

The process known as vulcanization was discovered in the year 1839 by Charles Goodyear while working in a factory in Woburn, Massachusetts. He found that when a mixture of rubber and sulfur was heated, the

*RECORD, *July*, 1926, *p.* 196.

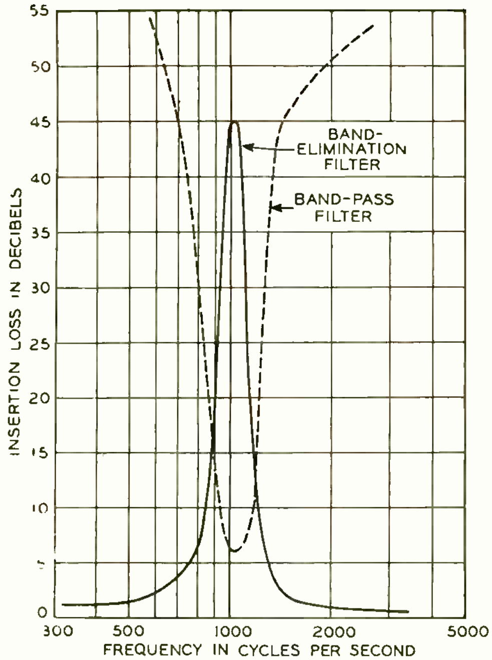


Fig. 3—Characteristics of the band-pass and band-elimination filters

voice announcements, and leave the range signals clear. If, however, he wants the weather announcements and can get along without the range signals for a short time, he will turn the switch to the voice position, which will eliminate the range signals and leave the voice clear. The filter makes it possible for the pilot to select whichever is the most important to him at the time, and thus permits full advantage to be taken of the new system that has been developed of superimposed weather and range signals.

A schematic of the two filters is given in Figure 4, and their characteristics in Figure 3. The band elimination filter in eliminating the range signals also eliminates the voice frequencies in the neighborhood of 1020 cycles. It has been found, however, that the loss of this very narrow band of voice frequencies does not appreciably affect the intelligibility of the weather announcements. The band-pass filter passes only the radio range signal of 1020 cycles because voice frequencies which would come within the narrow pass-band of this filter are eliminated by a narrow-band elimination filter in the weather announcing circuit at the transmitter.

The use of the band-pass filter for the range signals has a further advantage. During times of severe static, it cuts out much of the noise that would otherwise tend to interfere with the reception of the signals, since only the static associated with the very narrow band of frequencies passed by the filters is heard.

Although the filter incorporates twelve reactances, it is housed in the small metal container shown in the photograph at the head of this article. Its comparatively light weight and small size, and the ease with which it may be connected into the receiver circuit make it easily applicable to any plane using the airway range system.

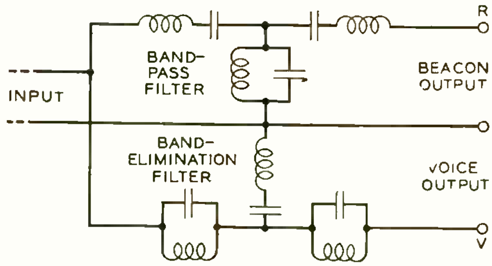
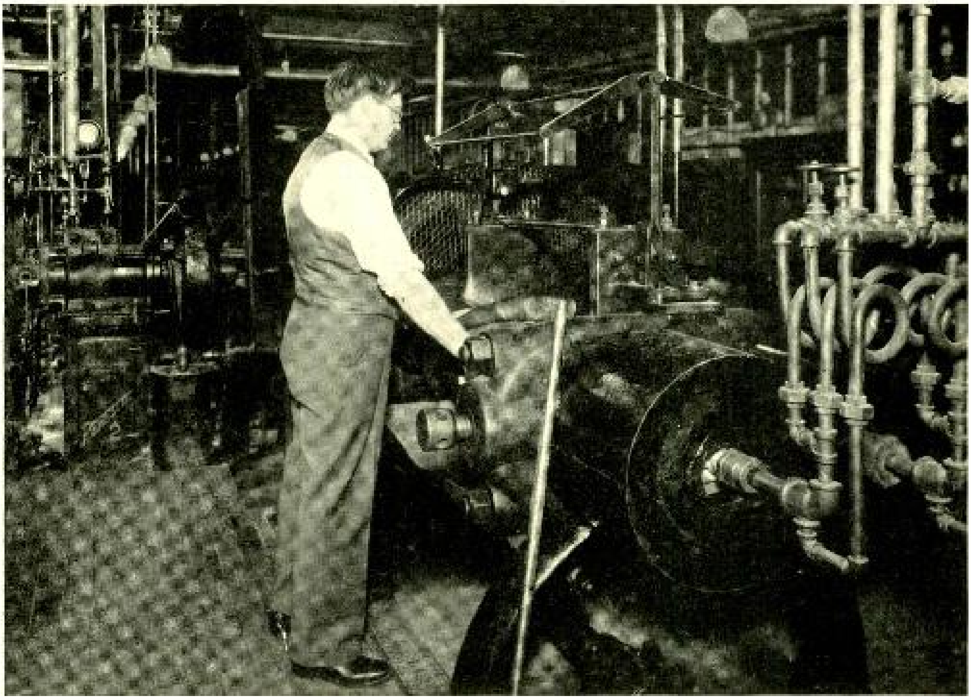


Fig. 4—Schematic of the 724A filter unit



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After the development of solderless cord tips for textile-insulated cords, already described in the RECORD,* it seemed desirable to extend their use to rubber-insulated cords, but the sulfur corrosion made it even more difficult to obtain suitable electrical connections by this method than by soldering. A satisfactory connection might be made on a newly manufactured conductor, but the formation of corrosion at the point of contact soon produced a high-resistance contact which would result in noise if used in a telephone circuit. It seemed very desirable, therefore, to develop a non-corroding rubber insulation.

The process known as vulcanization was discovered in the year 1839 by Charles Goodyear while working in a factory in Woburn, Massachusetts. He found that when a mixture of rubber and sulfur was heated, the

*RECORD, *July*, 1926, *p.* 196.

properties of the rubber were entirely altered. From a soft, plastic material which became sticky in sunlight and at warm room temperatures, the rubber was changed to a tough elastic material which was no longer so sensitive to temperature changes. Down to very recent times, this has been the essential principle involved in the vulcanization of rubber.

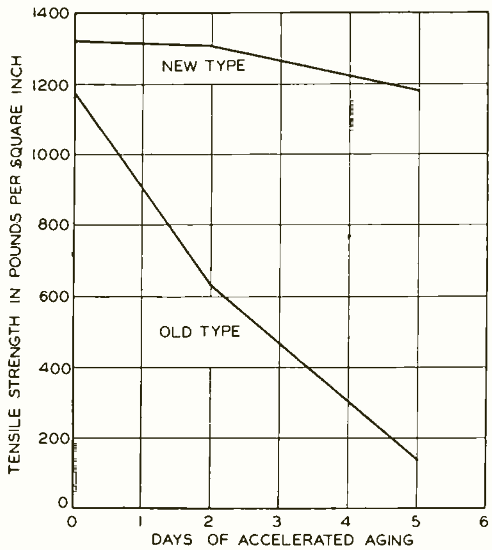


Fig. 1—Aging characteristics of old and new types of rubber insulation—one day of accelerated aging with this type of stock is equivalent to about two years of actual life

More recently it has been found that certain other materials can bring about changes in rubber which convert it to a greater or less extent to the condition called "vulcanized." Among these materials are organic nitro compounds, one of which, tri-nitrobenzene, is a high explosive. Organic peroxides such as benzoyl peroxide also serve the purpose. Other materials such as selenium and tellurium, elements occurring in the same periodic group as sulfur, when mixed with rubber cause vulcanization on heating. None of these materials when used alone, however, results in vulcanized rubbers having physical properties and aging characteristics equivalent to those obtained with sulfur.

In modern soft-rubber compounding it is customary to add to the mix small amounts of certain nitrogenous organic materials. These materials accelerate the vulcanization process and from their action derive their name, "accelerators." They may be liquids, resins, or crystalline solids, and vary as regards temperature of maximum activity, and speed of reaction. Some accelerators cause vulcanization to take place at room temperature while others are effective only at temperatures above 140 degrees Centigrade. In addition to speeding up the vulcanization process, accelerators cause a given state of cure to result with a smaller amount of sulfur than is necessary when accelerators are not used.

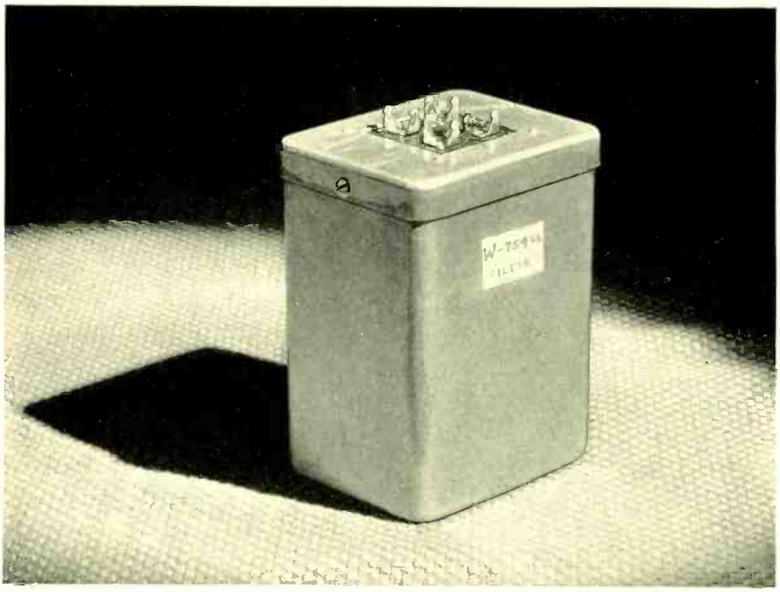
It is known that the corrosion of tinsel conductors insulated with rubber may occur during the vulcanizing process due to the presence of sulfur in the compound which combines comparatively slowly with rubber when heated. Corrosion also results, however, from the subsequent action on the tinsel conductor of any residual uncombined sulfur. It is seldom that all of the sulfur combines with the rubber during vulcanization. In ordinary practice the complete combination of the vulcanizing agent is not desirable because of the susceptibility of such over-vulcanized compounds to deterioration.

By employing certain accelerators or combinations of accelerators in considerably larger quantities than is customary, it is possible to vulcanize rubber to the condition of best physical properties with less than 0.5 per cent of sulfur. With certain accelerators no sulfur need be added, that necessary for vulcanization being made available by decomposition of the accelerator, which contains sulfur in its molecule. By employing larger quantities of a suitable accelerator or accelerator combinations and a small amount of sulfur, vulcanization takes place rapidly, and practically all of the sulfur combines with the rubber. Resistance to aging of the rubber has been found to be greatly enhanced in this type of compound even though all the sulfur is combined. The short time of cure and the absence of free sulfur in the rubber both contribute to greatly decreased tendency for corrosion of the tinsel.

On the basis of these facts, development work was undertaken which finally resulted in a compound that, when properly processed, proved a suitable insulation for tinsel cords and allowed satisfactory connection to be made with solderless cord tips. Not only did the new insulation reduce corrosion to a negligible amount, but its mechanical and aging characteristics were distinctly superior to those of the former insulation.

Because of the greater resistance to wear of the new insulation, it was suggested that the textile braids, used as mechanical protection over each conductor of the earlier waterproof cords, might be eliminated. These braids, however, carried colored tracers which served to distinguish one conductor from another, so that if they were eliminated, some other means of conductor identification would have to be provided. This was accomplished by incorporating colors into the white base compound. The traditional color scheme was preserved by preparing red, green, yellow, black, and white insulations.

The development of these new cords was carried on in coöperation with the Apparatus Development Department, who laid down the mechanical requirements for the cords and made tests to determine their suitability. As a result of this work, a rubber insulation has been made available that is improved both mechanically and chemically over the older product. The non-corroding characteristics, making possible the employment of solderless cord tips, and the improved mechanical characteristics which permit the elimination of the covering braids, result in an overall cost substantially less than that of the older rubber-covered cores. The application of continuous vulcanization to the new cords has reduced their manufacturing cost, and this, combined with their greatly improved characteristics, has made it possible to use rubber insulated cords in place of the textile cords that had been used previously.



A Filter for Airway Range Systems

By W. H. BOGHOSIAN
Transmission Networks

TO permit the nation's airways to be flown safely under all conditions of visibility, there has been established a highly developed system of radio ranges which is operated by the Department of Commerce. Each radio-range station employs two directional antennas to give a transmission pattern of two intersecting figure eights as shown in Figure 1. The letter "A," "dot-dash" in telegraph code, is sent from one antenna and the letter "N," "dash-dot," from the other antenna. The timing and spacing of these two groups of signals is such that in those locations where the field strengths from the two antennas are equal, the signals interlock to form a continuous tone for an "on course" indication. When a pilot is on his course he will hear a steady tone, but if he deviates to one side or the other he will receive a stronger signal from one antenna and a weaker signal from the other antenna, and will therefore hear either the "A" or the "N" in greater volume. He thus knows from the character of the signal that he receives whether he is to the right or the left of the particular course he is following.

In conjunction with the range signals, the Department of Commerce also sends out weather broadcasts. Since 1927, when the range system was inaugurated, several methods of transmitting the weather broadcasts have been used. Until recently, however, the method used at major terminals was to interrupt the range signals for brief intervals to give broadcasts of the local weather conditions. Longer and more complete weather broadcasts were given over a different freq to which the pilot could tune if he wished. This arrangement was satisfactory in that the pilot always had his head set tuned to the range signals, and thus always heard the local weather announcements when they came on. It had the disadvantage, however, that the range might be interrupted just at the time when it was most needed. To avoid this difficulty, the Bureau of Air Commerce is now modifying the system so that the range signals are not interrupted. The weather broadcasts or other announcements are superimposed on the range signals so that the pilot hears both at the same time.

The radio-frequency carriers of all the new simultaneous radio range stations are modulated with a 1020-cycle tone. To make it possible for the pilot to secure clear reception of either the range signals or weather announcements when they are both being transmitted at the same time, the Laboratories—following a design of the Department of Commerce—have developed a small filter, known as the 724A. This really consists of two filters: a band-pass filter that passes only a narrow band centered at 1020 cycles, and a band-elimination filter

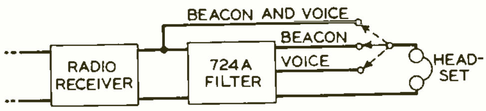


Fig. 2—Block schematic showing the method of connecting the 724A filter into the radio-range receiver circuit

that eliminates a narrow band centered at 1020 cycles. The band-pass filter passes the range signals and eliminates the weather announcements, while the band-elimination filter eliminates the range signals and passes the announcements. The connection of these two filters into or out of the circuit is controlled by a three-position switch. In one position of the switch both range and weather signals are heard; in the second position, only the range signals; and in the third position, only the weather announcements. The method of connecting the filter is indicated in Figure 2.

When flying the range, the pilot will normally have his filter switch turned to the range-and-voice position, and thus will hear the weather announcements as soon as they come on. If at that time the range signals are more important to him than the weather announcements, he will turn his switch to the range position, which will cut out the

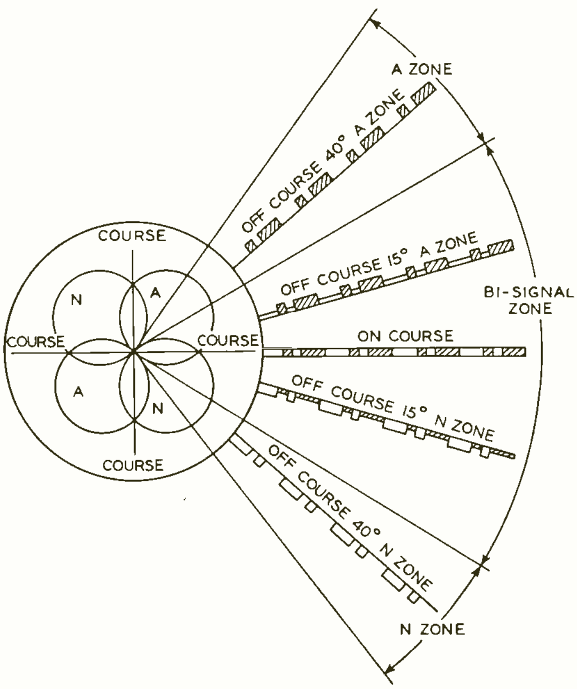


Fig. 1—Diagram of radio range system

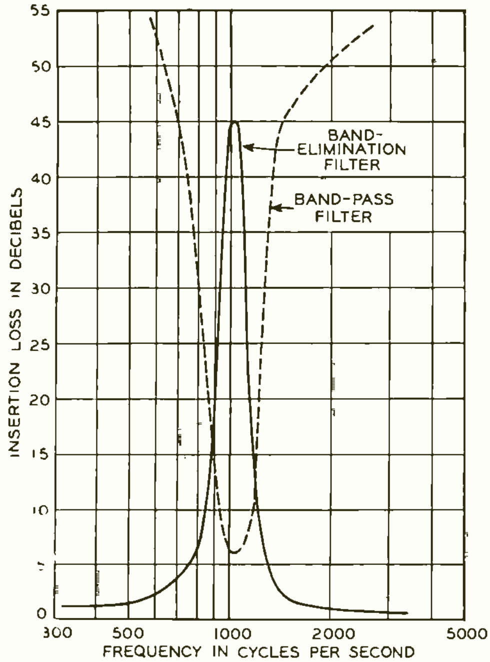


Fig. 3—Characteristics of the band-pass and band-elimination filters

voice announcements, and leave the range signals clear. If, however, he wants the weather announcements and can get along without the range signals for a short time, he will turn the switch to the voice position, which will eliminate the range signals and leave the voice clear. The filter makes it possible for the pilot to select whichever is the most important to him at the time, and thus permits full advantage to be taken of the new system that has been developed of superimposed weather and range signals.

A schematic of the two filters is given in Figure 4, and their characteristics in Figure 3. The band elimination filter in eliminating the range signals also eliminates the voice frequencies in the neighborhood of 1020 cycles. It has been found, however, that the loss of this very narrow band of voice frequencies does not appreciably affect the intelligibility of the weather announcements. The band-pass filter passes only the radio range signal of 1020 cycles because voice frequencies which would come within the narrow pass-band of this filter are eliminated by a narrow-band elimination filter in the weather announcing circuit at the transmitter.

The use of the band-pass filter for the range signals has a further advantage. During times of severe static, it cuts out much of the noise that would otherwise tend to interfere with the reception of the signals, since only the static associated with the very narrow band of frequencies passed by the filters is heard.

Although the filter incorporates twelve reactances, it is housed in the small metal container shown in the photograph at the head of this article. Its comparatively light weight and

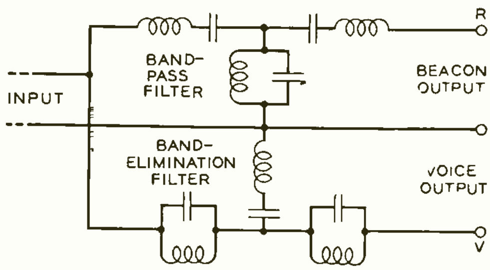


Fig. 4—Schematic of the 724A filter unit

small size, and the ease with which it may be connected into the receiver circuit make it easily applicable to any plane using the airway range system.

I — RELAYS

for various communication circuits

II — D-99739

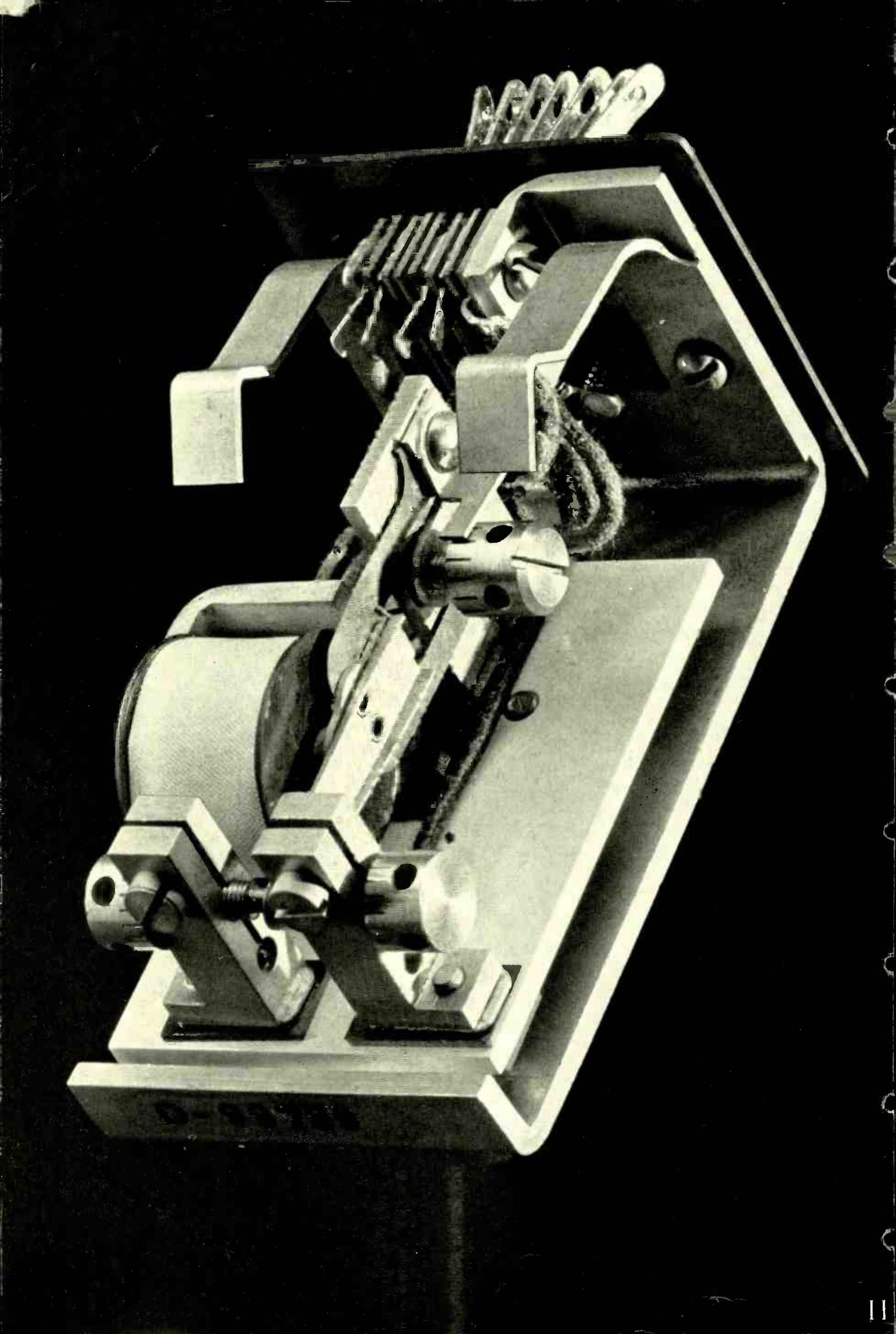
A high-speed relay used in voice-operated circuits

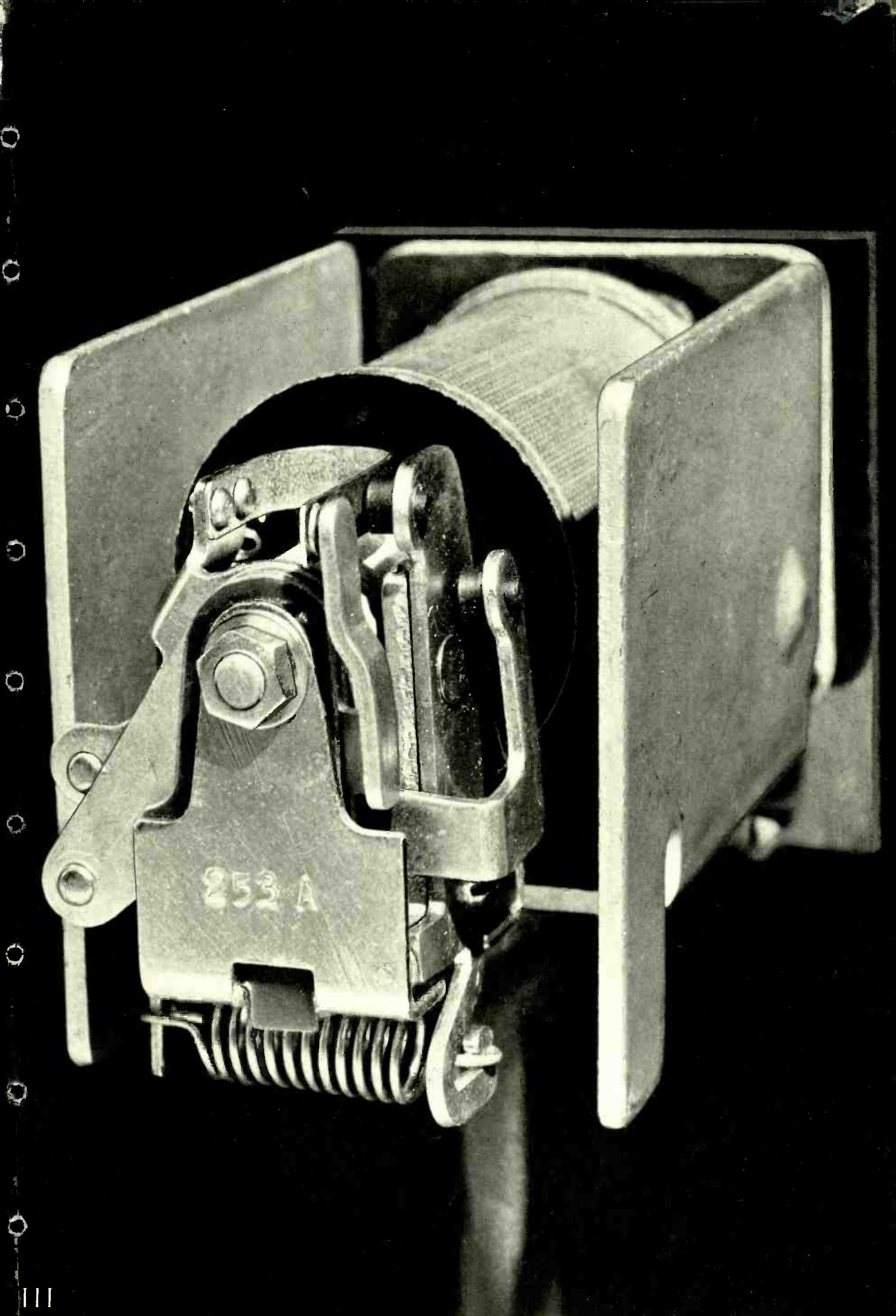
III — 253A

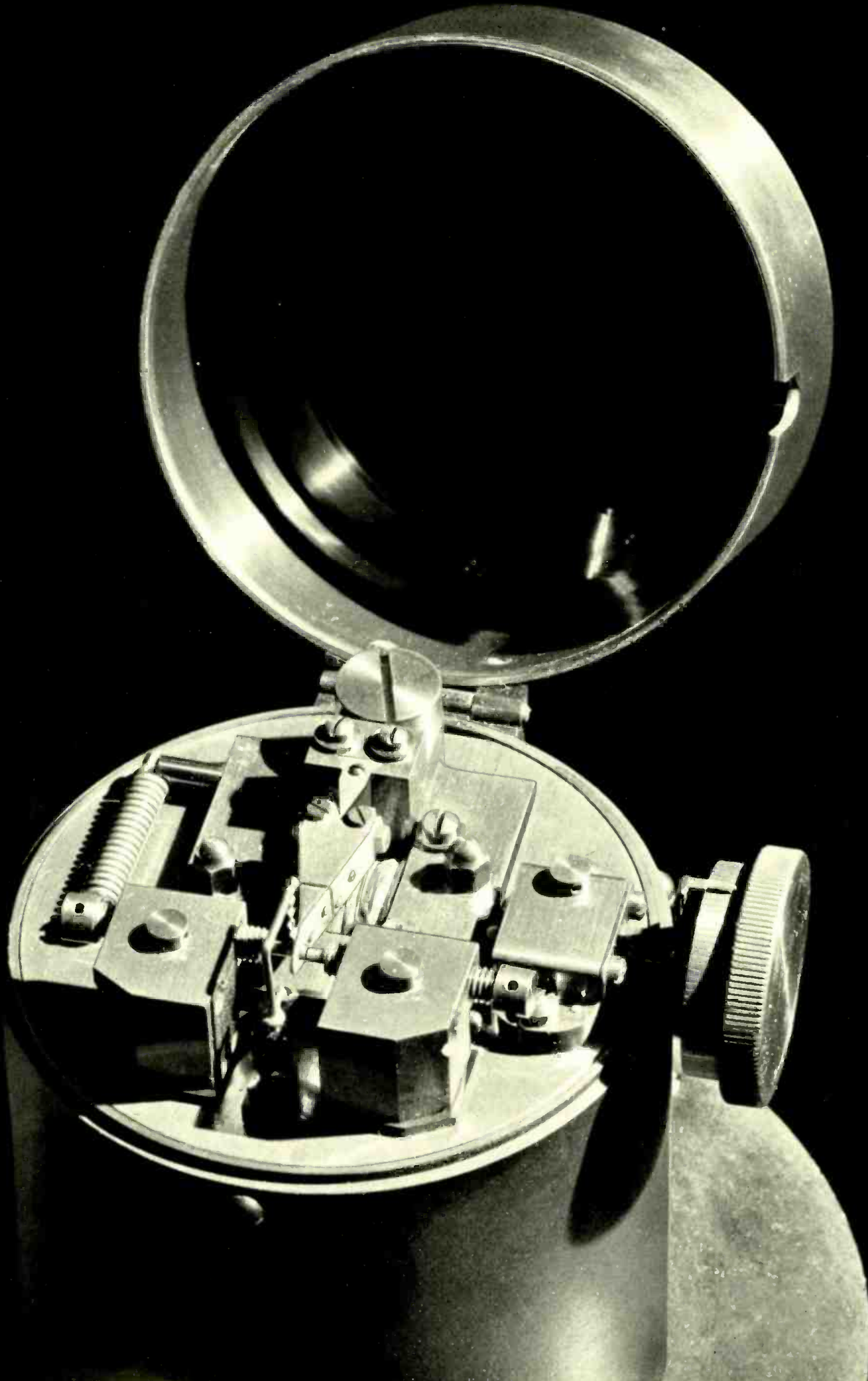
Operating voltage of this relay is altered by changes in ambient temperature, through a bimetallic strip which controls the tension of a spiral armature-restoring spring

IV — D-81431

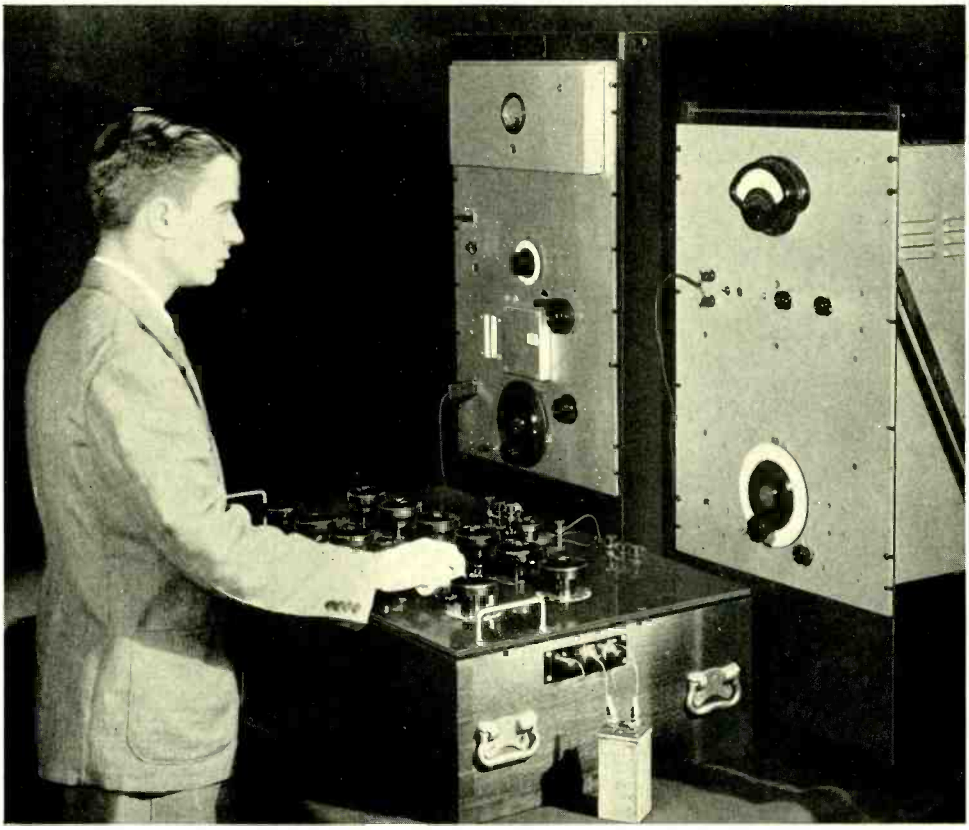
Telegraph relay for high-speed submarine cables




253 A



IV



An Inexpensive Bridge for Capacitance and Conductance Measurements

By L. E. HERBORN
Telephone Apparatus Development

IN the development laboratory, measurements of capacitance and conductance of condensers have until recently been made exclusively on a general-purpose, wide-range precision bridge. Such bridges are of the comparison type, and may be used at either audio or carrier frequencies and for either grounded or balanced-to-ground measurements. The high quality of design and construction of these bridges is indispensable for any measurements that are made where high precision is required over a wide range of conditions and frequencies.

Recently, there has been considerable development activity on condensers on which only grounded measurements are made, and these only at frequencies within the voice range. In considering the problem of providing additional testing equipment needed for these measurements, it seemed desirable, therefore, to provide a new type of bridge which would be inexpensive to build and economical to operate over the restricted range required. A review of the possible circuits available indicated that a modified Schering, or product-arm, type of bridge provided possibilities for low initial and operating costs in the given frequency range.

The basic circuit of the modified Schering Bridge with the shielding omitted is shown schematically in

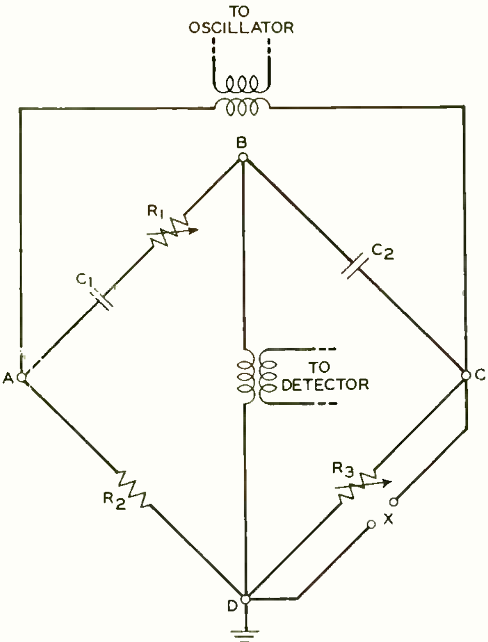


Fig. 1—Simplified schematic diagram for the product-arm bridge

Figure 1. It is seen that the fixed arms, which consist of a resistor and a condenser, are diagonally opposite, instead of adjacent as in the more common ratio-arm bridges. With this arrangement the unknown, connected across the C-D arm, is directly related to the standards through the impedances of the fixed elements, and both the capacitance and the conductance of the unknown condenser are measured in terms of resistance: the capacitance in terms of R_1 and the conductance in terms of R_3. Since R_1 is proportional to the capacitance of the condenser, its settings may be marked in microfarads instead of in ohms, by choosing appropriate values for the bridge constants.

Two bridge balances are required to obtain the values of the capacitance and conductance of the unknown condenser; one with the unknown connected to the bridge and one when it is disconnected. The changes in the settings of the standards for these two balances give the capacitance and conductance of the unknown condenser in accordance with the expressions:

$$C_X = K(R_1' - R_1'') = C' - C''$$

$$G_X = \frac{R_3' - R_3''}{R_3' \times R_3''}$$

Here the prime mark indicates the readings obtained with the unknown

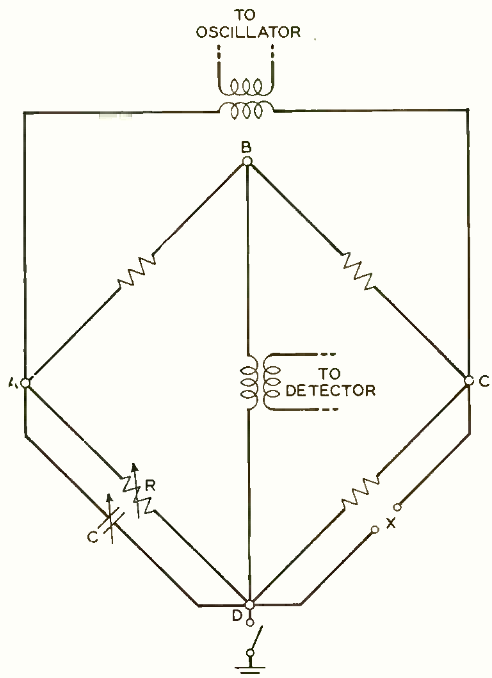


Fig. 2—Simplified schematic of the precision-comparison type bridge

connected, and the double prime mark with the unknown disconnected. The second part of the equation for determining the capacitance of the unknown condenser is given in terms of capacitance since the R_1 dials are actually marked in microfarads.

This operating procedure is the same as the one for the wide-range comparison-type precision bridge which is shown schematically in Figure 2. In this type of bridge, however, the components of the unknown are measured in terms of a resistance and a capacitance standard connected across the A-D arm. Because the product-arm type bridge virtually replaces the capacitance standard with a resistance standard, there is effected a considerable saving in the initial cost of the bridge.

In the comparison bridge, because of the high degree of precision desired, it is impracticable commercially to manufacture capacitance standards to their nominal values, especially when these nominal values are to be maintained over a wide range of frequency. For this reason the values of capacitance employed in the equations are not those read on the bridge, but are secured by applying corrections obtained from calibrations. In the product-arm type bridge the standards are resistances, and these are easily manufactured to their nominal values, and remain constant both with frequency and time. It is these features that allow the R_1 standard to be direct reading in microfarads, without requiring corrections, resulting in a saving in the time required for each measurement.

In the measurement of conductance, a further correction is avoided

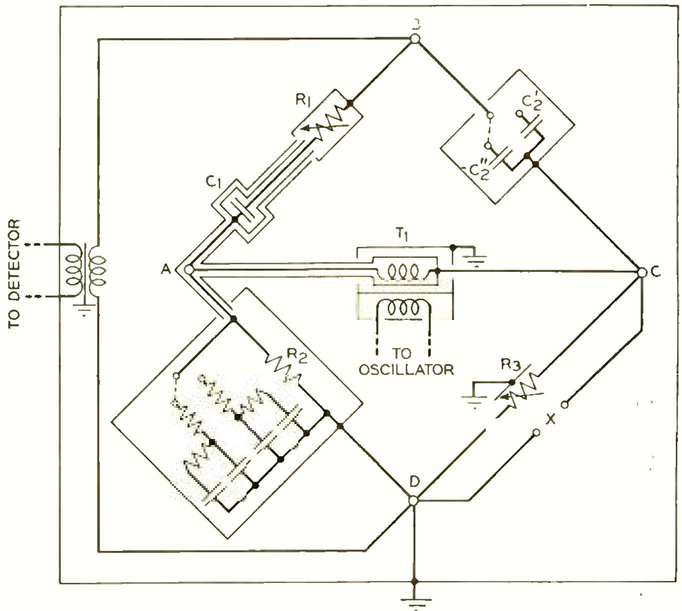


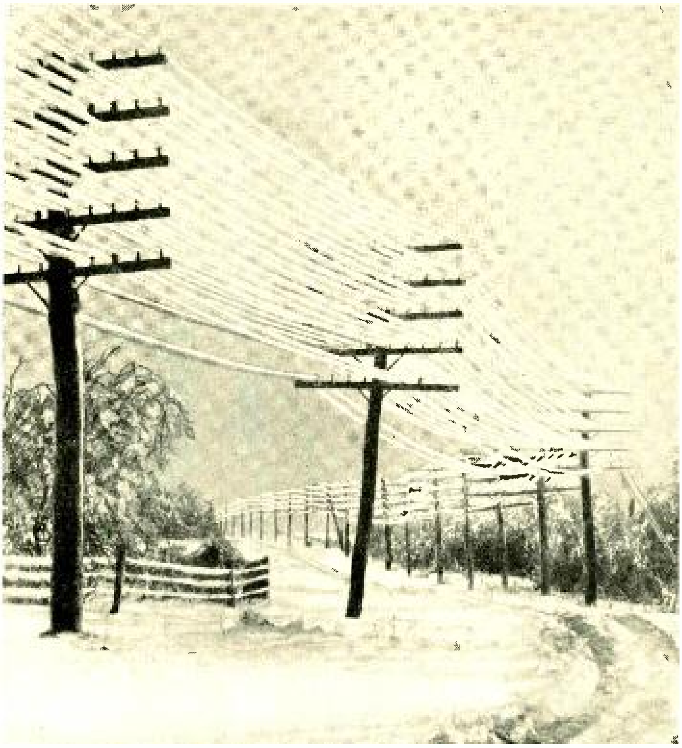
Fig. 3—Schematic diagram of the new bridge for measuring capacitance and conductance of condensers

because the resistance standard, R_1, may be readily compensated to eliminate the effect of its residual reactance. In a capacitance standard, the corresponding effect of its residual loss cannot be readily eliminated by compensation and must be allowed for by correcting the readings.

To realize the full advantages of the product-arm bridge, special care must be taken in carrying out the initial adjustment of the fixed arms. In the ratio-arm bridge the fixed arms are adjacent resistors, which are adjusted for equality of resistance and phase angle by adding fixed resistance and capacitance to the arm having the lower values. Because of their similarity, these resistors maintain equality over a wide range of frequencies. In the product-arm bridge the fixed arms, which are a resistor and a condenser, are diagonally opposite, and for accurate balances, the sum of their phase angles must be —90 degrees at all frequencies. This relation would obviously hold if the condenser were a pure capacitance, with a phase angle of —90 degrees, and the resistor were a pure resistance with a phase angle of zero, but these ideal conditions can never be obtained. Although the phase angle of the condenser is not —90 degrees, it does remain constant with frequency because both its "quadrature" and "in phase" components are proportional to frequency. The phase angle of the resistor increases with frequency, however, because only its reactance, due to the distributed capacitance, increases with frequency. To maintain the correct quadrature relationship over the desired voice frequency range, a phase-compensating device consisting of a ladder type network has been connected across the terminals of R_2.

To maintain the desired precision over a wide range of capacitance, the bridge has been provided with two ranges. This is accomplished by the provision of two C_2 condensers and two compensating networks for R_2, and a two-position switch which selects one of each in each position. This provision is evident in Figure 3, which is a schematic diagram of the new bridge. With the range dial in one position, the bridge measures capacitances up to eleven microfarads and conductances up to one thousand micromhos with a maximum sensitivity of two micro-microfarads and 0.02 micromho. With the range dial in the other position, measurements are possible up to 1.1 microfarads and twenty micromhos, with a sensitivity of 0.2 micro-microfarad and 0.002 micromho.

A photograph of the new bridge is shown on page 97. The twelve controls for the two six-dial standards cover the front part of the top and the range dial is in the middle at the rear. Because it eliminates capacitance standards, and uses only resistance standards, the bridge is compact and comparatively inexpensive; also, because it dispenses entirely with correction calibrations, it offers a rapid method of measuring capacitance and conductance at frequencies that are found within the voice range.



Open-Wire Line Losses

By L. T. WILSON
Transmission Development

THE widespread use of carrier systems has within recent years completely changed the relative importance of the various kinds of energy loss in open-wire lines. In the earlier days of telephony, currents of frequencies above the voice range were not transmitted. As the leakage loss was small in the range used even in wet weather, it was natural that the series, or resistance, loss demanded most consideration. In fact, for many purposes, it was possible to ignore the shunt losses with little resulting error. At carrier frequencies, however, very rarely can the shunt losses be neglected with small error and then only under the most favorable conditions. At these frequencies not only must these losses be taken into account but under certain conditions of ice on the wires, as will be shown, they may outweigh the series losses.

The magnitude of the series component for a pair of 128-mil copper wires spaced eight inches apart and its variation with frequency at twenty degrees Centigrade is shown by curve A in Figure 1. Since the resistance of copper—the material commonly used for line wires—changes with temperature, the series loss varies with the temperature of the line. Moreover, the changes in resistivity alter the skin effect at the same time, which complicates the result of temperature changes when carrier frequencies are involved. This is illustrated in Figure 1 by Curve B which shows the amount of attenuation to be added to the previous curve for an increase in temperature of twenty degrees Centigrade or to be subtracted for an equal decrease. The initial rise of the curve, then its fall to a valley and thereafter its rise again with increasing frequency are characteristic. The frequencies at which the peak and valley occur are shifted higher as the size of the wires is reduced. Fortunately, the magnitude of these changes in the frequency range where they are irregular is small. They are mainly of interest in connection with high-quality program circuits.

It is convenient to divide the shunt losses into those due to insulators and those due to various ice formations on the wires. Each type of shunt loss will be discussed separately.

The effect of insulator shapes and materials on the insulator shunt losses have been carefully studied by the Bell System. The results of such tests made at Phoenixville, Pennsylvania, have been incorporated in the design of a standard insulator generally used for carrier circuits. That design is known as the CS type and is shown with its steel pin in Figure 2. Since this type has found wide application on carrier lines it will be used as an example in the present discussion of insulator shunt losses.

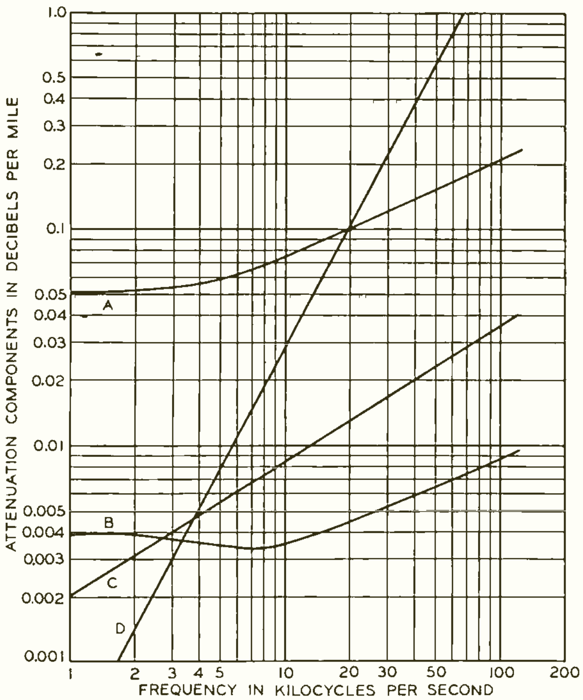


Fig. 1—Attenuation losses on open-wire lines. A, series loss; B, change in series loss for 20 degrees Centigrade change in temperature; C, shunt loss with CS insulator in moderate rain; D, shunt loss with one centimeter of ice on wires

The shunt losses of this insulator in dry weather are almost negligible since they amount to only a per cent or two of the series losses. In wet weather, however, they become appreciable. This is shown in Figure 1 where the shunt component of the attenuation of 128-mil wires spaced eight inches apart on CS insulators is given by curve C. These results are based on the amount of leakage conductance of these insulators in a moderately hard rain. It may be seen that the absolute magnitude of the insulator losses in this case never reaches a value as great as one-fifth of the series losses. But since fully ninety per cent of this shunt loss represents the increase over what it would have been in dry weather its variations may readily exceed those of the s component. In fact, a comparison shows the shunt variations to be less than the series variations only at frequencies below about three kilocycles. The shunt variations increase relatively with frequency until at one hundred kilocycles they are four times the series variation. Such wide fluctuations between wet and dry conditions are, as a result, more difficult to correct for than the larger but more constant series losses.

Comparison of the frequency characteristics of the series losses and the insulator losses at carrier frequencies shows that the series losses increase substantially as the square root of the frequency but that in general there is no fixed relationship for the insulator losses. Frequently the insulator losses follow approximately a 0.6 power rate, as in the example cited here. This value varies, however, with weather conditions, frequency, insulator design and other factors. In the tests on short lines at Phoenixville it is generally found to lie between the half and the first power in the carrier range. This range of variation may be narrowed considerably on a long line where a given storm may not extend over the entire line as it would on a short line or, if it does, may not be of uniform intensity. On this account some smoothing-out action in long lines may be expected.

At one hundred kilocycles and under the condition of moderate rain previously referred to, the total leakage for the CS insulator measured 0.26 micromho for each pair of insulators. This total may be arbitrarily considered to consist of three parts. First, there is the conductance from wire to wire over the surface of the insulator. In the present example, this part of the conductance is less than one per cent of the total conductance and there is some evidence to indicate that it does not vary substantially with frequency.

A second loss arises from the fact that the dielectric material of which

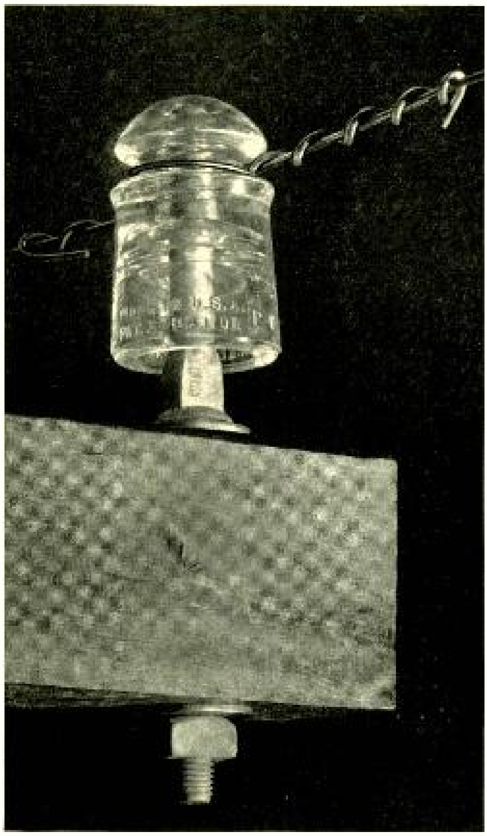


Fig. 2—Insulator, CS type, with steel pin and lead thimble

the insulator is composed lies in the electric field between the wire and pin. This results in some loss which depends on the dielectric properties of the material but it amounts to only about eight per cent of the total loss at one hundred kilocycles.

The third and most important loss, which accounts for about ninety per cent of the total leakage, results from displacement: that is, charging currents which flow through the high resistances of thin water films on the insulator surface. These currents are, of course, dependent on the frequency and they primarily account for the frequency characteristic of the total losses. In general, this type of loss will increase at very low frequencies as the square of the frequency, but the slope decreases until at extremely high frequencies the loss should approach a constant value independent of the frequency. In view of the nature of this third loss and its importance, no definite and fixed relationship between insulator losses and frequency can reasonably be expected.

The other source of shunt loss is due to ice on the wires; and that is of considerable importance. If one could imagine the line wires supported on insulators which had no leakage conductance whatever there would still be a high leakage conductance whenever the wires become coated with ice, hoarfrost or wet snow. These three forms of ice are all imperfect dielectrics and when any one coats the wires, and thus lies in the electric field around them, dielectric losses occur and appear as a shunt loss.

The frequency characteristic of this loss is not identical for all three types of coating; and for simplicity only that for ice will be considered. The outstanding characteristic in that case is the rapid increase of loss with frequency as illustrated by curve D in Figure 1. This shows the calculated loss for ice of one centimeter radial thickness at a temperature of —12 degrees Centigrade. The ice loss increases with the thickness of the ice and decreases with increasing temperature at the frequencies shown. At the higher frequencies this shunt loss can exceed the series loss considerably. An experimental verification of this was obtained by H. H. Benning and L. F. Staehler of these Laboratories in field tests of open-wire lines. The steep frequency characteristic makes this loss particularly difficult to deal with. Ice also increases the series component at all frequencies by increasing the line capacitance. For one centimeter of ice this increase in attenuation is about 25 per cent.

In general, wet insulators and various forms of ice on the wires themselves are the more important causes of variations in the transmission of carrier currents over open-wire lines. The problem of transmission variations at carrier frequencies on open-wire lines is quite different from that on cable circuits where transmission variations are largely due to changes in wire resistance with temperature.

High-Frequency Attenuator

By S. A. LEVIN
Transmission Development

CARRIER transmission at very high frequencies encounters a number of difficulties that at more moderate frequencies are not serious obstacles. Because of this fact, the development of the new coaxial conductor* over which frequencies as high as several million cycles may be transmitted, has required a large amount of new apparatus, not only for the coaxial system itself, but for transmission studies and testing pertaining to it. One need was for attenuators that would maintain constant loss characteristics and low phase angle over this wide range of frequency. Such attenuators were designed and built some time ago to meet the special and exacting requirements of the transmission group.

The high constancy and low phase angle required are secured by very thorough shielding and by an arrangement that maintains the same number of attenuation units in the circuit at all times by employing the substitution method: a unit of one value being replaced by one of another value when the desired loss is to be changed. The attenuator is designed so that the units in use are always in the same position with respect to the frame of the instrument. As the total attenuation is adjusted, a new unit of the desired value is moved physically into the space previously occupied by the old one. Carefully constructed T-type resistance networks are used, mounted in three shielding drums, each of which may be rotated independently of the other two. One drum is a decade with units from naught to ten db. Another has units of ¼, ½, ¾, and fifty db, and a third, units of ten, twenty, thirty, forty, and fifty db. Such an arrangement makes the attenuation variable in ¼-db steps from naught to sixty-one db and in one-db steps up to 110 db.

The three drums are mounted to rotate around a common axis, and the electrical path through the attenuator is always in a straight line through the bottom unit of each drum. The appearance of the attenuator with

*Record, *July*, 1935, *p.* 322; *April*, 1937, *p.* 242; *May*, 1937, *p.* 274.

outer cover removed is shown in Figure 1. The interior construction of the three drums may be seen in Figure 2. The three resistances comprising a unit of the decade drum are wound on a single spool, as evident at the right of Figure 2. The shunt arm is connected to the drum, and the series arms are soldered to insulated contacts set flush with the end faces of the drum. External connections to these contacts are made by metal plungers mounted within large threaded brass sleeves fastened in the insulating sheets that comprise the vertical structural members of the attenuator. These sleeves shield the connections between units, while the drums shield the units themselves. Together with the plungers, the sleeves form a metallic coaxial path between the drums. Coaxial input and output jacks complete the shielding of the system. Besides obtaining a straight-line path, this construction reduces the amount of wiring required to a minimum.

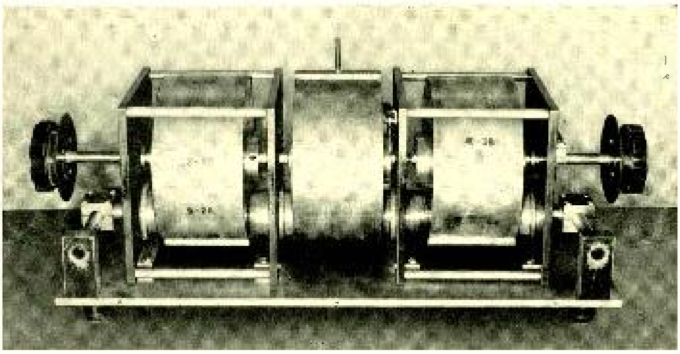


Fig. 1—The electrical path through the high-frequency attenuator, shown here with its dust cover removed, is a straight line through the lower part of the three drums

The construction of the drum carrying the ten, twenty, thirty, forty, and fifty-db units, shown at the left of Figure 2, is similar to the decade drum except that because of the larger loss involved, two sections of T-network are used for each of the thirty and forty-db units and three sections for the fifty-db unit. Three spools are used to mount the resistances of each unit except the fifty-db unit which has four spools; and metal discs, which may be seen in the illustration, are employed to shield the spools from one another in each unit. The middle drum which has ¼, ½, ¾, and fifty-db units, also has the inner shielding because of the one fifty-db unit.

The two end drums are turned by knobs at each end of the assembly. These knobs are marked to indicate the size of the unit in the circuit. The middle drum of the attenuator is turned by a handle moving in a slot in the dust cover, as shown in the photograph at the head of this article.

An attenuator of this type may be built so that the loss change at the full nominal attenuation of 110 db is only about 0.5 db as the frequency is increased from a low value to five megacycles. This change is reduced to 0.1 or 0.2 db as the upper frequency limit is decreased to three megacycles. By determining such changes it is possible to obtain the actual loss quite accurately from the nominal loss. Phase-shift measurements show an insertion phase shift of only a few degrees at five megacycles, the exact value depending on the setting. At naught and forty db, for instance, the phase shift is about —6 degrees and +3 degrees, respectively, so that the phase shift change is approximately nine degrees when the attenuation is changed from naught to forty db at five megacycles. Since their construction these attenuators have been in constant use in the Laboratories where new broad-band apparatus is under development. Experience obtained indicates that these units are very useful and satisfactory testing tools.

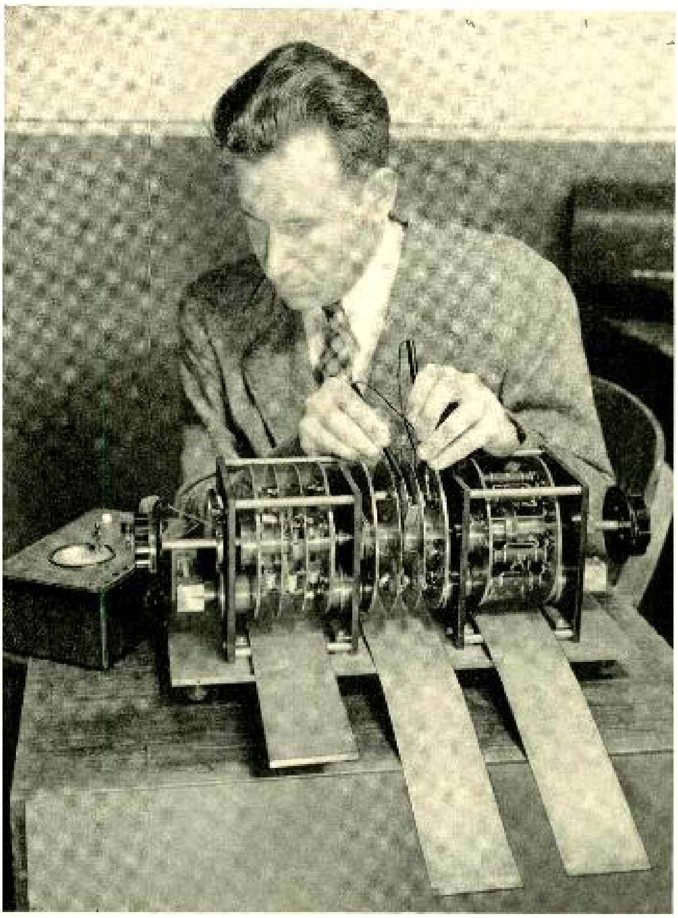


Fig. 2—For the low-loss units on the decade drum, the three resistances forming each of the T-networks are wound on a single spool; for the higher-loss units two or three T-sections are used which are wound on spools with shields between them

Vapor-Pressure Humidostat and Thermostat

By E. B. WOOD
Telephone Apparatus-Electrical

ONE of the important factors to consider in the design of communication apparatus is the effect of moisture on the materials used and on the operating characteristics and life of the assembled apparatus. Practically all of the insulating materials employed in telephone equipment absorb moisture in varying amounts which depend on the relative humidity of the atmosphere surrounding them. In most cases the electrical properties of the materials vary widely with their moisture content. Moisture also tends to shorten the useful life of apparatus through the corrosion of metal parts and progressive deterioration of the materials used for insulation by electrolytic action under operating voltages.

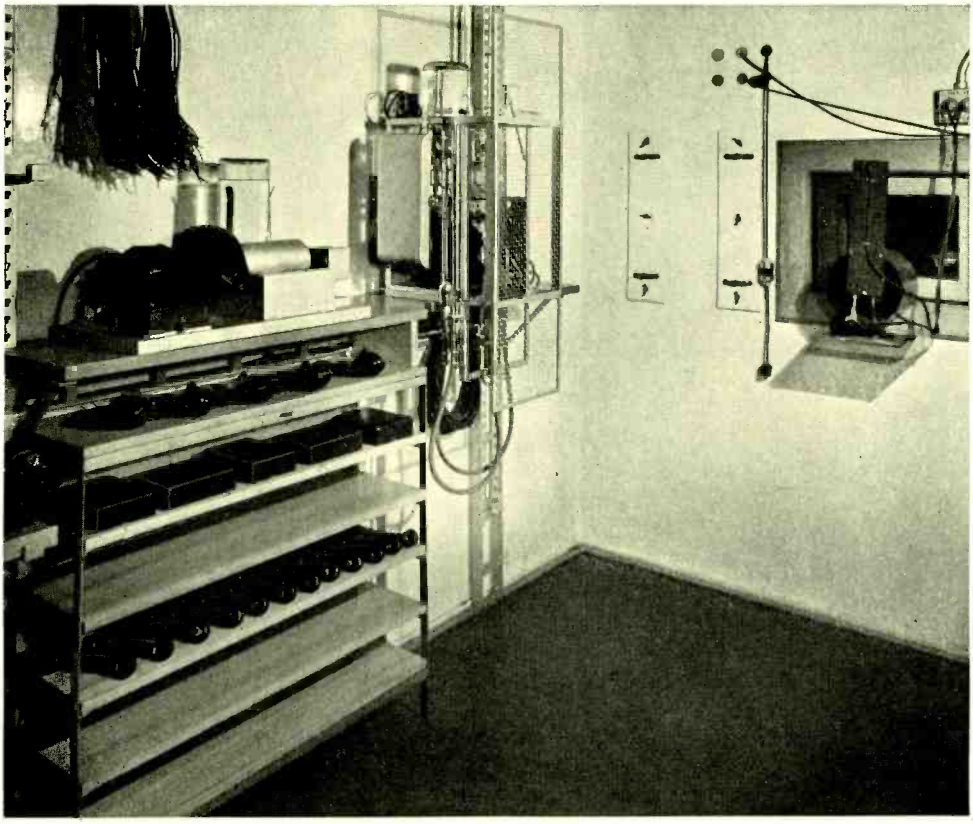


Fig. 1—The temperature and humidity of this test room, used to determine the effect of moisture on telephone apparatus, are accurately controlled by the vapor-pressure thermostat and humidostat shown mounted on the left wall beyond the apparatus rack

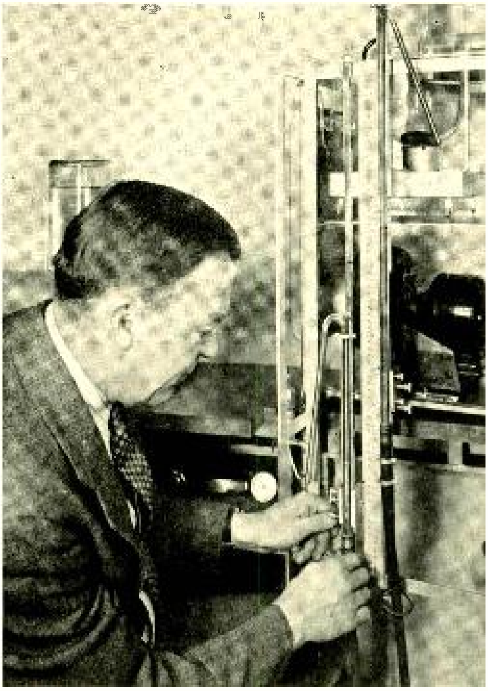


Fig. 2—W. A. Bunzel adjusting the vapor-pressure thermostat and humidostat

It is necessary, therefore, for the development engineer to know the characteristics of available materials, finishes and protective treatments for the range of humidity and temperature conditions to which apparatus will be exposed in the communication field. He must develop new types as required and test completed designs under conditions which simulate those of actual service to insure satisfactory operation and life.

To carry out this development program, laboratory test rooms are provided in which the atmospheric conditions can be controlled with precision at any desired value within the range of conditions found in all climates where telephones are used. The heart of the air-conditioning system which is used to control these humidity test rooms is the vapor-pressure thermostat and humidostat shown in the illustrations. Although this instrument was developed in the Laboratories in 1920 it is still considered the most satisfactory device available for the purpose.

The humidostat consists of a wet bulb and dry bulb, each partially filled with ethyl chloride and connected to the legs of a U-tube mercury manometer. Air is excluded from the system so that the pressure in each bulb is the vapor pressure of the ethyl chloride at the temperature of the liquid in the bulb. A cloth wick covers one of the bulbs and dips into a reservoir of distilled water to keep that bulb wet. Air which is circulated by a small fan over the wet bulb main-

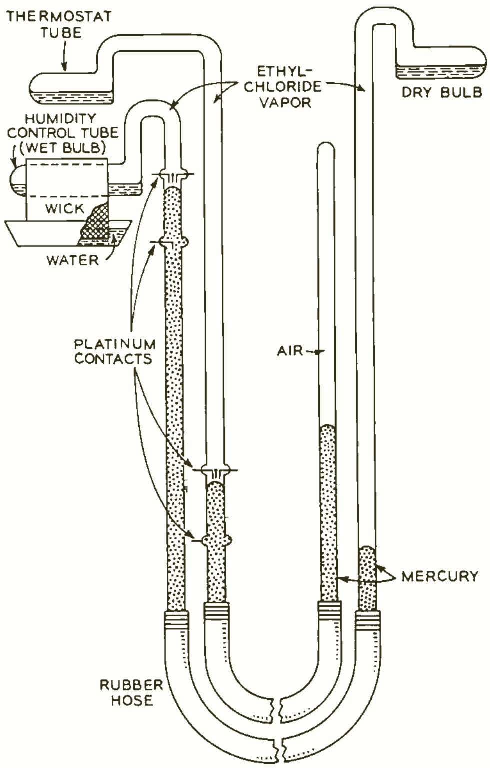


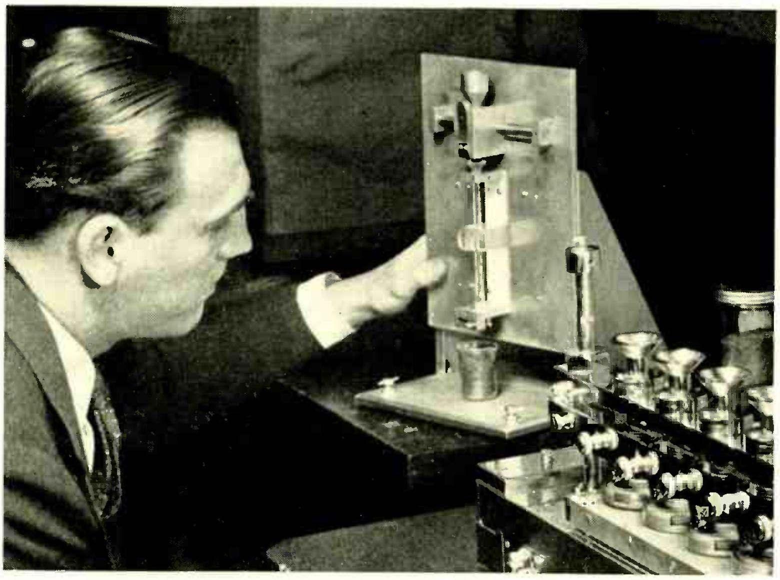
Fig. 3—When the humidity decreases or the temperature rises the mercury columns break contact with the platinum points. This actuates control mechanisms which restore the air to the required condition

tains the bulb at the true "wet bulb" temperature. The other bulb is at the temperature of the room.

Under these conditions the vapor pressure of the ethyl chloride will be less in the wet bulb by an amount which depends on the humidity of the atmosphere, and the mercury will stand higher in the corresponding arm of the manometer. If the moisture content of the air decreases below the required amount the mercury column falls and breaks contact with metal points which are sealed into the glass tube. This operates the control mechanism which acts to restore the humidity. The two legs of the manometer are connected by a rubber tube which permits the dry bulb side to be moved upward or downward to change the setting of the instrument for different values of relative humidity.

The thermostat operates on the same principle as the humidostat but it has only one ethyl chloride bulb. This is attached to one arm of a manometer the other arm of which is a closed tube partly filled with air. Thus the vapor pressure in the ethyl chloride bulb balances the air pressure in the closed tube together with the difference in weight of the two mercury columns of the manometer. Since the change in vapor pressure of ethyl chloride with changes in temperature is about twenty-two millimeters of mercury per degree Fahrenheit this instrument has high sensitivity.

Humidostats and thermostats which require less space for installation have been placed on the market since the ethyl chloride type was developed, but none has been found which combines as satisfactorily the high degree of sensitivity, reliability and adaptability needed for the large variety of test conditions which are required in telephone development work.



The volume of carbon used in a handset transmitter being measured by A. P. Besier of the Telephone Transmitter Laboratory

W. H. Boghosian

R. N. Marshall

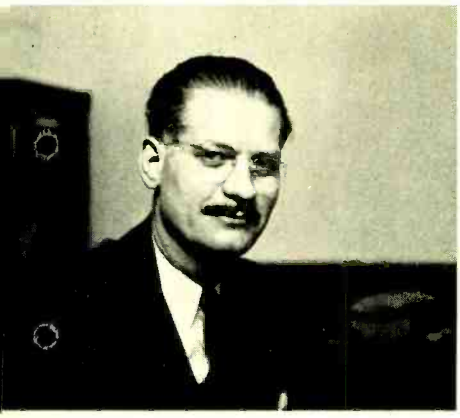
Contributors to this Issue

W. H. Boghosian received the B.S. degree in electrical engineering from the University of Pennsylvania in 1934, and the M.S. degree the following year. He then spent a year as graduate assistant in the Department of Electrical Engineering of Ohio State University. In 1936 he joined the Technical Staff of these Laboratories where he has been engaged in transmission network development.

J. H. Ingmanson entered the dyestuffs industry with the Sherwin-Williams Company in 1917 and three years later went with the Conley Foil Company as development engineer. In 1925 he re-entered the dyestuffs field as works manager for the Crown Chemical Corporation, and in 1928 joined the Chemical Research group of the Laboratories. He holds a B.S. degree in chemistry from the University of Chicago. His work with the Laboratories has been the study and development of rubber and allied materials.

R. N. Marshall received a B.S. degree from Princeton in 1930, and at once joined the Technical Staff of the Laboratories, where he assisted in the development of the 618A moving coil microphone. He later engaged in acoustic studies relating to microphones which were for the most part carried on at Whippany to secure sufficiently quiet surroundings. More recently he worked on the development of the 630A non-directional microphone and the new low-cost microphone which is described in this issue.

A. C. Dickieson joined the Laboratories in 1923, and for six years engaged in development work on carrier telephone systems. In 1929 he became associated with the Fox-Case Corporation where he engaged in investigations of recording systems. He returned to the Laboratories in 1930, and at present is in charge of a group developing single-channel carrier telephone systems, radio-telephone control terminals, voice-operated devices, and other auxiliaries to long toll systems.



J. H. Ingmanson

A. C. Dickieson

S. A. Levin

L. T. Wilson

S. A. Levin received the E.E. degree from the Chalmers Technical Institute of Gothenburg in 1919, and then for three years studied at the Technische Hochschule at Berlin and that at Dresden. In 1923 he came to this country, and spent about two years with the radio department of the General Electric Company. From 1926 to 1930 he was associated with the National Electric Light Association engaged in work on inductive coördination. In 1930 he joined the Technical Staff of these Laboratories where he has since been engaged in the development of high-frequency measuring equipment for carrier systems.

L. T. Wilson has been associated with insulation and other transmission problems on open wire lines since 1923, when he joined the Department of Development and Research of the American Telephone and Telegraph Company. Following his graduation from Yale with the degree of Ph.B. in Electrical Engineering in 1915, he continued at that institution as graduate student, instructor and research fellow until 1923, excepting one and a half years with the Signal Corps during the war and one and a half years with the American Radio and Research Corporation. He received the degree of Electrical Engineer from Yale in 1919.

L. E. Herborn received a B.S. degree in E.E. from Cooper Union in 1925. Two years prior to his graduation, he had joined the Technical Staff of the Laboratories, and until 1928 was associated with the Research Department in connection with the development of terminal equipment for high-speed submarine cables. At the completion of this work he transferred to the Apparatus Development Department where he has been engaged in the development of precise impedance measuring equipment.

E. B. Wood was graduated from Princeton University in 1915 with the B.S. degree and received an A.M. there the following year. He served overseas during the war as a captain in command of a battery of coast artillery. On returning he taught physics for a year at Pratt Institute and then joined the Laboratories in 1920. Here his work has been largely on central-office wire, cable and cords, including the development of purified textile insulation and cellulose acetate treatment. In connection with these problems he has developed methods and apparatus for precise control of humidity.

L. E. Herborn

E. B. Wood