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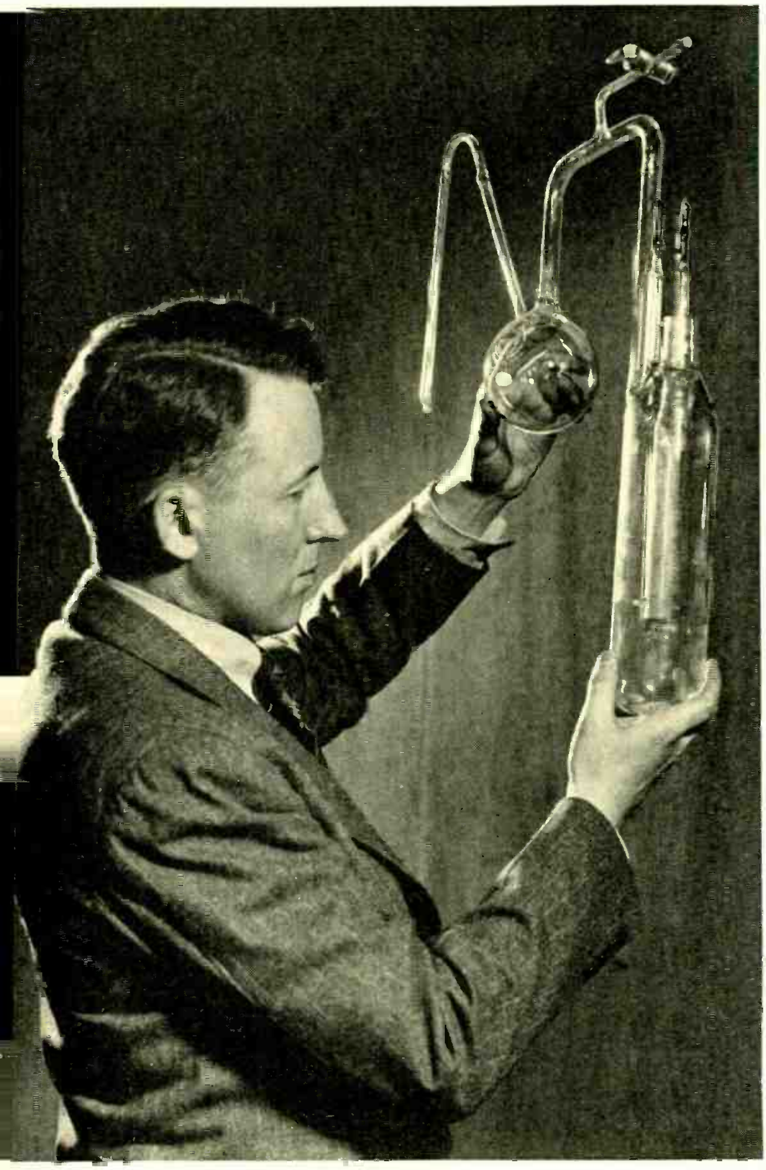

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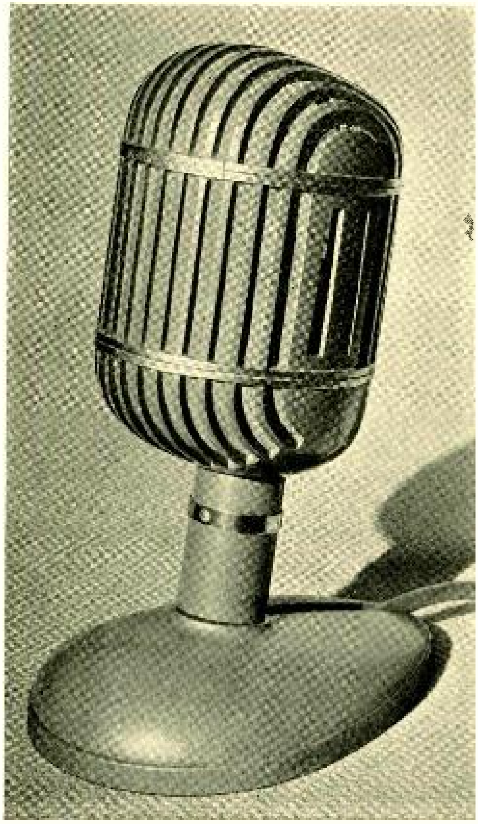


A Cardioid Directional Microphone

By R. N. MARSHALL
Transmission Instruments Research

WHEN a microphone is used in radio or sound pictures it is often important to pick up sounds coming from a particular direction to the exclusion of other sounds such as reflections, audience noise, camera click or feedback from loudspeakers. For these situations the microphone should be more sensitive to sounds coming from the desired direction. In a model that has recently been developed in these Laboratories, there is a possible discrimination of 20 db against unwanted sounds.

The new microphone, known as the Western Electric No. 639AA, uses a diaphragm transmitter and a ribbon transmitter in combination. The ribbon type operates on the difference in pressure developed by the sound wave between the front and back of a ribbon which moves only in the direction perpendicular to its surface. The effective force on the ribbon, for sound approaching at some angle to this direction, is proportional to the cosine of that angle. When sound strikes the ribbon on edge the pressure is the same on both sides; there is no motivating force and no response. This gives the directivity a two-looped characteristic which is shown by the dotted lines in Figure 1. The motion of the ribbon is in phase with the motion or velocity of the air particles, hence the term "velocity" microphone is frequently applied to the ribbon type. The control obtainable with this type alone is limited, however, because unwanted sounds very often come from the opposite direction from the desired sounds and not at right angles to them.

A pressure-type microphone consists essentially of a movable diaphragm closed on one side by a hollow housing. When the sound pressure increases outside of the diaphragm it moves inward. This motion depends on the pressure at the outer surface and not on the direction from which the sound comes, since the sound flows around the housing. The pressure type is essentially non-directional and diaphragm's motion is in phase with the pressure in the sound field.

By connecting a pressure and ribbon microphone in series so that the pressure microphone is 180 degrees out of phase with one of the loops of the ribbon microphone, that loop can be cancelled. The response of the other loop will be increased then, because the ribbon reverses its direction of motion as the source moves through the plane of zero response, while the output of the pressure microphone does not change. The output of the two together has the shape shown by the solid line in Figure 1. Due to the fact that it is heart shaped, this curve has been called the "cardioid" and this characteristic is a satisfactory approximation to that desired for a directional microphone.

Combining a ribbon and dynamic instrument is complicated in practice because neither type follows completely the simple conditions assumed above. The size of the elements required to give an adequate output level is so large that the dimensions are not small compared with the wave length of the sound at the higher frequencies, and these sounds will not flow around the microphone. The magnitude and phase of the outputs is not the same over the frequency range, hence cancellation of one response loop of the ribbon microphone cannot be achieved in simple fashion. By incorporating new design features and careful equalization, however, a satisfactory solution of these difficulties was attained.

A compact pressure type unit was already available in the Western Electric 630A* or 633A† microphones. A special ribbon element was developed, which uses for its magnet a highly efficient alloy steel. The housing of the dynamic unit was reshaped and streamlined so that its presence does not affect the operation of the ribbon. This housing encloses also the ribbon transformer and a three-way switch as illustrated in Figures 2 and 6. It supports the wind-screen housing for the ribbon and provides the mounting and terminal facilities in the form of a projecting plug. The result is the microphone shown in the headpiece, a compact instrument smaller than the usual ribbon microphone of comparable efficiency. Its overall height, including the plug terminal mounting, is 7½ inches; and it weighs approximately 3½ pounds. The housing of the microphone is made of cast aluminum finished grey with the horizontal lines in polished metal.

The cardioid microphone can be mounted either on a floor or a desk

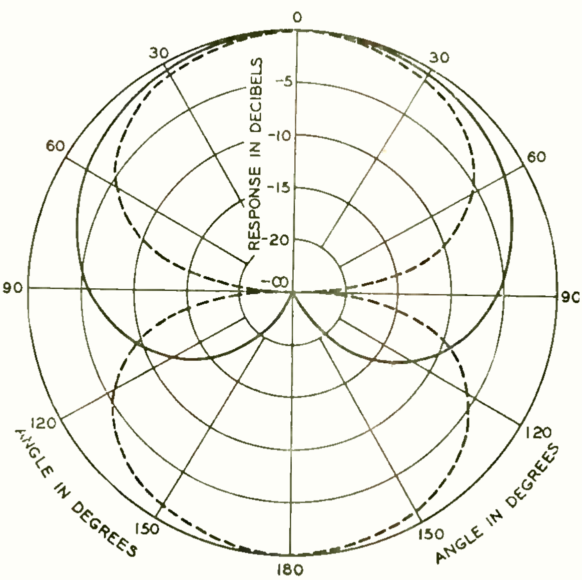


Fig. 1—The bi-directional characteristic of the pressure-gradient microphone is illustrated by the dotted lines; the characteristic of the cardioid microphone by the solid line

*Record, *Oct.*, 1935, *p.* 34.

†Record, *Nov.*, 1937, *p.* 80.

stand. No tilting is normally necessary because its vertical pickup angle is broad. For special cases a universal swivel mounting is available. A three-way switch at the rear of the housing allows the dynamic or ribbon units to be used individually as well as in combination to give the cardioid directional characteristic. Thus the cardioid is three microphones in one: non-directional dynamic, bi-directional ribbon and cardioid-directional when the two elements are used together.

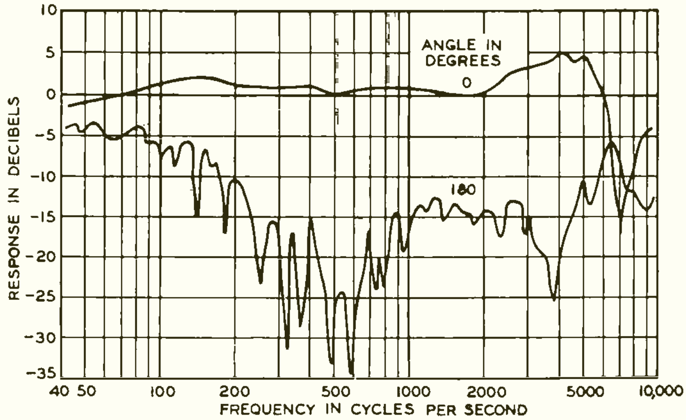


Fig. 3—Typical response characteristic of a combined unequalized-dynamic and ribbon microphone

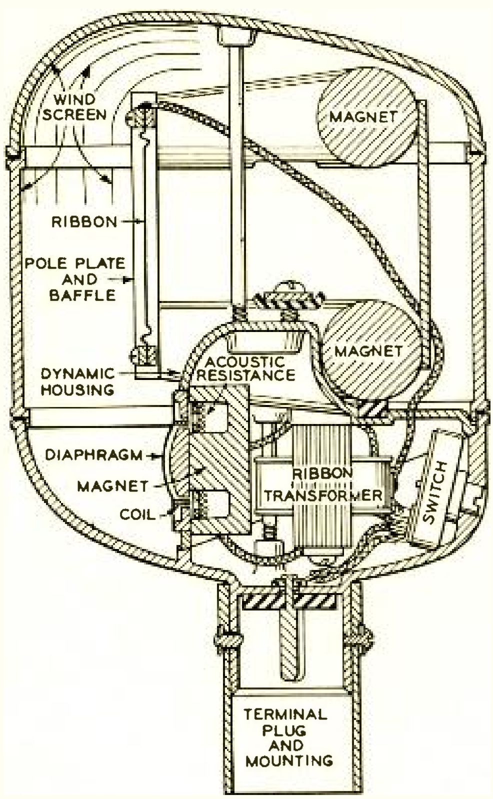


Fig. 2—Simplified cross-sectional view of the cardioid directional microphone

To increase the stability of the ribbon a new design was developed for the velocity microphone by W. R. Harry of the Laboratories Staff. This ribbon is thicker than usual and has a cylindrical curvature over most of its length. It is corrugated at each end so that it acts like a bar with spring supports and by this means other modes of vibration than the fundamental that may be encountered are effectively suppressed.

Besides achieving a smooth response, which matches that of the dynamic both in magnitude and phase, the stiff ribbon reduces wind noise to a level approximately ten db lower than that of other ribbon microphones. This permits using the microphone more freely outdoors where breezes are often unavoidable. Damaging the ribbon, by exposure to a sudden gust of wind, is also unlikely especially since mechanical stops have been provided in order to prevent its motion beyond the elastic limit of the material.

In Figure 3 is illustrated the response for 0° and 180° incidence of a typical combination of dynamic and ribbon elements when connected with-

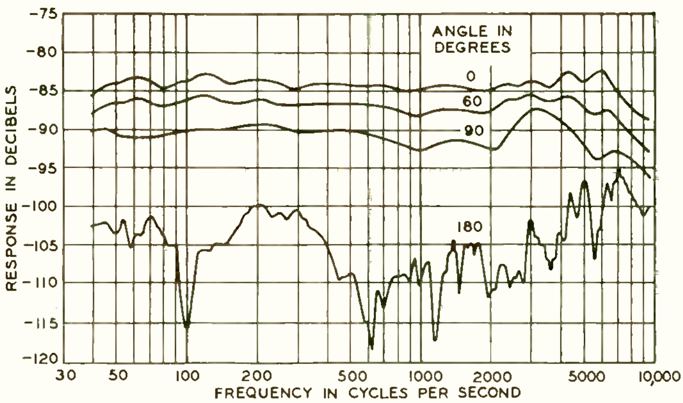


Fig. 4—Typical response of laboratory model of the cardioid microphone with equalization

out equalization. The curves cross at about 7000 cycles and at low frequencies they come close together, because the electrical outputs of the two elements are out of phase at these frequencies. To correct this limitation and extend the useful range to 10,000 cycles a network was designed by Mr. Harry. The improvement is shown in the response curves of the equalized microphone, Figure 4.

The output level of the cardioid microphone is unusually high, eighty-four db below one volt per dyne per square centimeter. This level is four to six db higher than that of the Western Electric 630A or 633A dynamic types and only two db lower than that of the highly efficient Western Electric 618A dynamic microphone. The new microphone is designed to operate into an impedance of from thirty to fifty ohms. The normal-incidence response of the cardioid combination is smooth over the frequency range from 40 to 10,000 cycles and there is hardly any perceptible quality change for any angle of incidence up to 120 degrees. The quality of the response at angles greater than 120 degrees is of little importance because the sensitivity in this region is low. The performance of the dynamic and ribbon microphones when used alone is similar to that of other commercial instruments of their respective types.

A visual indication of the variation of sensitivity with angle is given in the chart of Figure 5 by shading from light to dark. The "wide pick-up" zone of 120 degrees represents the region in front of the microphone where there is practically no variation in quality or sensitivity. In the "fading" zone from 60 degrees to 150 degrees on either side the sensi-

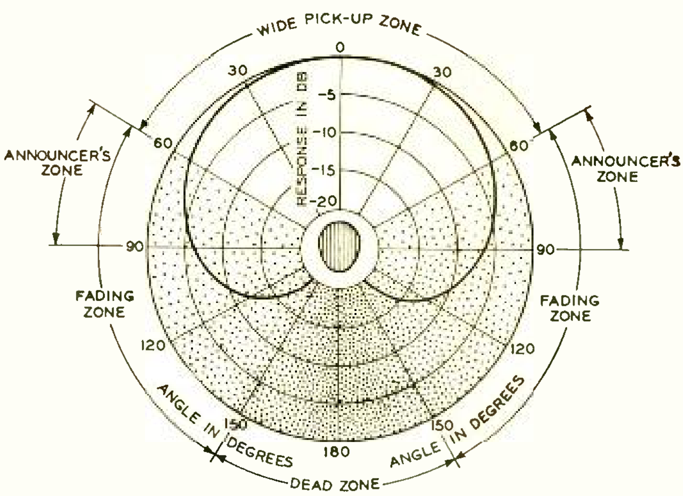


Fig. 5—Chart illustrating the directional characteristics of the 639A cardioid microphone

tivity changes rapidly with angle and care must be exercised to keep within range of the microphone. Sounds are discriminated against by approximately twenty db in the dead zone of 60 degrees behind the microphone. In addition to these three principal zones, the sector from 60 degrees to 90 degrees on either side has been selected as the "announcer's" or close talking zone. Since the ribbon microphone contributes very little in this sector, the characteristic "boomy" reproduction of unequalized ribbon microphones has been avoided.

In sound studios and public address installations the directional characteristics of the cardioid microphone are particularly useful. When located near a studio wall it suppresses sound reflected from behind; and in a theatre it automatically divides the audience from the stage, thus eliminating noise and reducing feedback so that more sound reinforcement can be used. The microphone has been thoroughly tested under practical conditions which have demonstrated its superiority in pick-up situations long baffling to sound engineers.

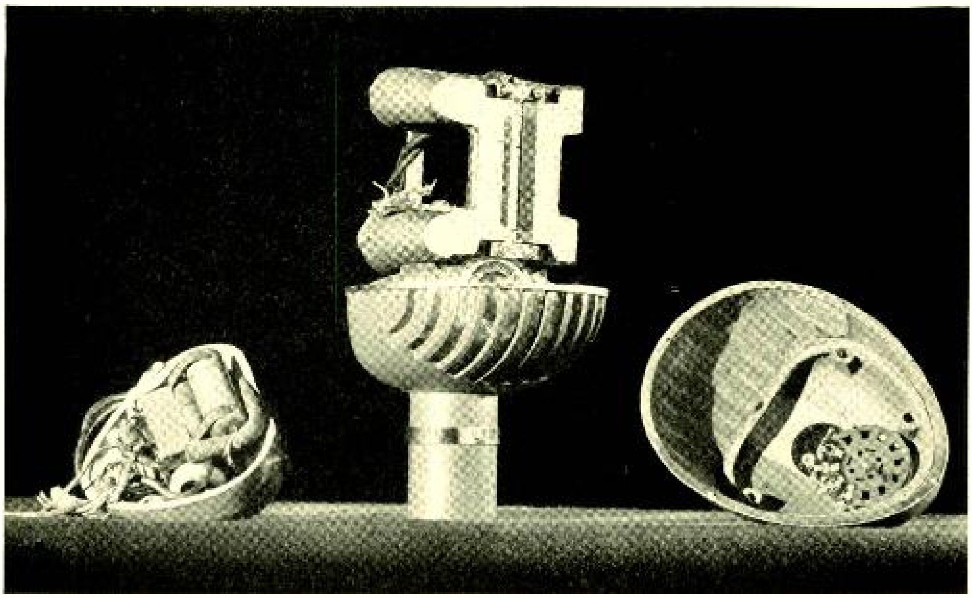


Fig. 6—Cardioid microphone disassembled

Optical Properties of the Alkali Metals

By H. B. BRIGGS
Electro-Optical Research

SOME metals, notably sodium, potassium, cesium and others of the alkali group, liberate electrons freely when light falls on them. This behavior is the basis of photoelectric cell activity; it has been studied in detail not only on this account but also because it bears on recent theories of the metallic state.

Between the photoelectric and the optical properties of a metal there exists so close a relation that the photoelectric behavior of a metal can be predicted from its index of refraction and its absorbing power for light. These optical constants can be found by allowing a beam of plane polarized light to fall on a polished surface and determining how much the incident light has been elliptically polarized by reflection. Previous measurements of these constants for the alkali metals have been confined to the visible spectrum but the Laboratories has extended them into the ultraviolet region where the maximum photoelectric emission occurs.

Elliptically polarized light may be thought of as consisting of two beams of light plane polarized at right angles and differing both in phase and amplitude. With an optical device, called a Babinet compensator, which retards one of these beams more than the other, elliptically polarized light can be restored to plane polarized light. The compensation required to do this measures the phase shift on which the ellipticity depends. The azimuth of the plane of vibration of the restored light differs from that of the incident light and the difference can be measured in the visible range with an analyzer of the Nicol prism type. This prism extinguishes plane polarized light entirely when the plane of vibration is oriented at right angles to certain crystallographic directions in the prism.

By substituting values of the phase shift and azimuth in equations as developed by Drude or by T. C. Fry there may be found the index of refraction N of a metal, and the extinction coefficient K_0 which measures the damping the light experiences on entering the metal. With the values of N and K_0 for a particular wavelength there can be calculated the reflecting power, transmission for various thicknesses, and the absorbing power of the metal either in bulk condition or as a thin film supported by another metal. The last is of special interest because the photosensitive surfaces of ordinary photoelectric cells are of this type. Experiment shows that the rate of emission of photoelectrons from such a surface is proportional to the rate at which it absorbs light.

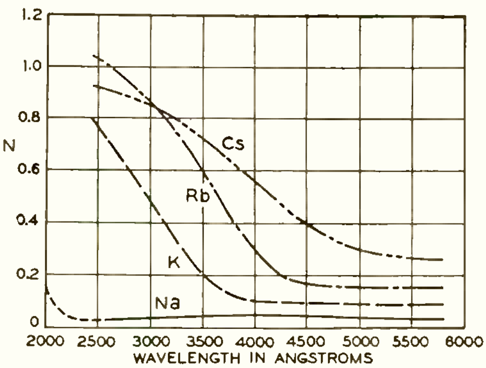


Fig. 1—Dispersion measurement curves of the index of refraction, N, for sodium, potassium, rubidium and cesium

In the ultraviolet region the method of measurement must be modified so that phase and azimuth changes are recorded photographically. This is accomplished by a pair of optical wedges, one of right and the other of left rotary quartz, which are introduced between the Babinet compensator and the Nicol analyzer. The result is a rectangular pattern of dark spots on a bright background which may be recorded photographically. A comparison of the spot patterns for light before and after reflection from the metal surface shows that each spot of the reflection pattern has undergone a shift from the position it occupied before reflection. By analysis the x-component of the shift may be identified with the phase change introduced by reflection, and the y-component with the azimuth change, or the rotation of the plane of vibration. These two measurable quantities when substituted in the Drude

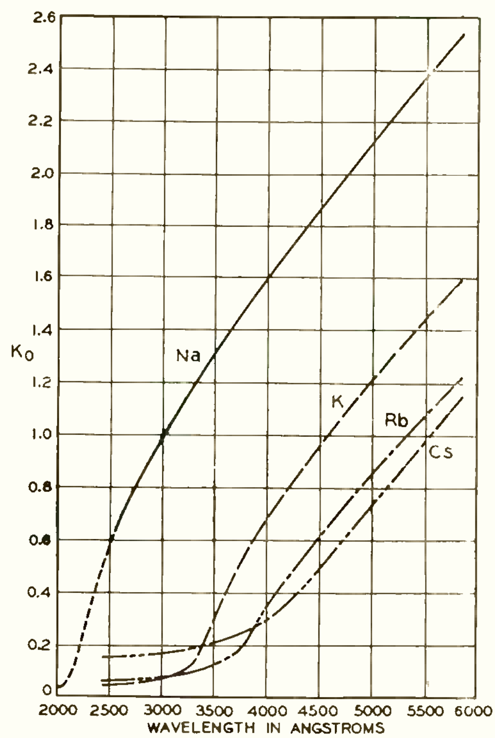


Fig. 2—Dispersion measurement curves of the extinction coefficient, K_0, for sodium, potassium, rubidium and cesium

or Fry equation give the required N and K_0 factors.

Mirror surfaces of alkali metal have to be prepared in vacuum and protected from the air to prevent oxidation, which dulls them. For measurements on potassium and rubidium, a heavy deposit of the metal was collected on a quartz plate in an exhausted bulb. The metal surface was protected by covering it with a second plate while still in the exhausted bulb, by raising the second plate by magnetic action on the iron

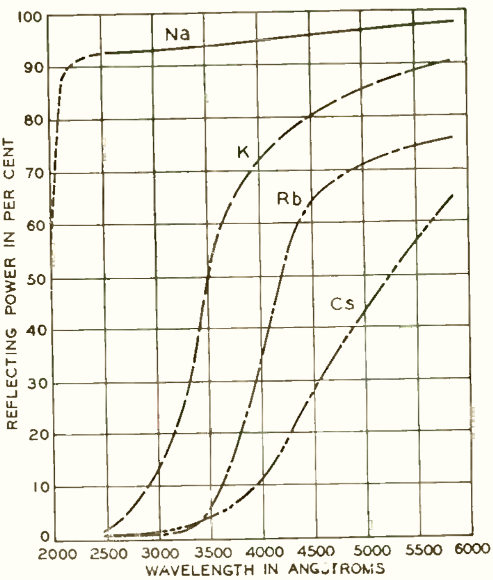


Fig. 3—Reflecting power at normal incidence for sodium, potassium, rubidium and cesium

tip at the lower end of its holder. A strain-free 60-degree quartz prism was then sealed to the upper plate with paraffin oil; and the edges were protected with paraffin wax, where the alkali metal was exposed. Measurements could then be made in air.

In a second method, used for sodium and cesium, the metal was deposited on an optically flat surface enclosed in an evacuated bulb which

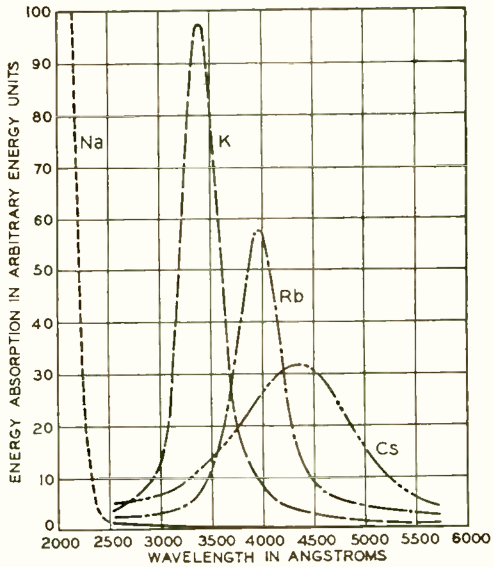


Fig. 4—Rate of absorption of energy for equal thickness (ca. 10^{-8} cms.) of sodium, potassium, rubidium and cesium on platinum-iridium. Light incident at 60 degrees, polarized parallel to the plane of incidence

was provided with quartz windows. The arrangement had the advantage that reflection occurred at the free surface of the metal under investigation but special precautions were necessary to provide that sealing and evacuation of the tube should not produce strains in the windows.

The values of N and K_0 computed from measurements of the phase shift and the azimuth of the restored beam of plane polarized light are shown in Figures 1 and 2. In the visible range sodium has the lowest index of refraction and the highest extinction coefficient of the group, potassium is next, followed by rubidium and cesium. The relative values of N and K_0 in the ultraviolet are reversed, the extinction coefficients being low and the refractive indices higher.

Figures 3 and 4 show properties of the alkali metals, calculated from the values of their optical constants.

Figure 3 gives the reflecting powers for normal incidence. The wave length for which $N = K_0$ divides the range of high reflecting powers from that of low reflecting powers.

The rate of absorption of energy by thin films of the alkali metals deposited on platinum-iridium is illustrated in Figure 4. The absorption is moderately selective in cesium; becomes increasingly so for rubidium and potassium, and is extremely high in the extrapolated range for sodium. The wave length for which $N = K_0$ here gives the peak absorption.

A comparison between the rate of absorption of energy and the rate of emission of photoelectrons is of particular interest. Rubidium illustrates this correlation. Curve 1 of Figure 5 shows the photoelectric emission of a thin film of rubidium on platinum-iridium and Curve 2 gives the calculated rate of absorption of energy at the surface of such a film, 10^{-6} cms. thick. Part of the energy absorbed at the surface of the metal is expended in effecting the escape of the photoelectrons. The amount may be calculated approximately by multiplying the ordinates of Curve 2 by a factor which depends on the longest wave length at which rubidium emits photoelectrons. Curve 3, in which this correction has been carefully incorporated, fits Curve 1 closely and so shows conclusively that the photoelectric emission of thin films may be accurately predicted from a knowledge of their optical constants.

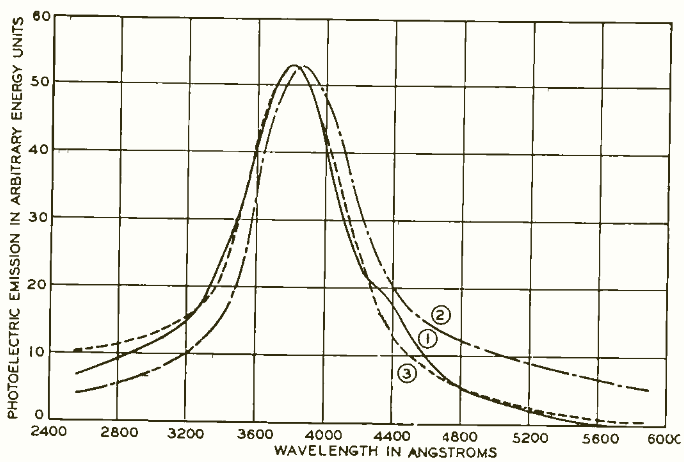


Fig. 5—Comparison of photoelectric emission and calculated energy absorption of rubidium on platinum-iridium

The Anti-Sidetone Station Circuit

By J. W. FOLEY
Transmission Standards Department

THE subscriber telephone set is used to provide a connection between the line and both the transmitter and receiver. A function of the two-winding transformer, which has been widely used in this set, is to improve the efficiency of these connections. With such an arrangement, the subscriber hears not only the speech coming over the line from the distant end, but also his own speech, since the voltages generated in the transmitter by his voice affect his own receiver. The sound picked up by a transmitter and heard through its associated receiver is called "sidetone." It is possible, however, to design the circuit of a two-way telephone set so that under ideal conditions the sound picked up by the transmitter is not heard through the associated receiver. Such an arrangement, known as an anti-sidetone circuit, involves some complications over the two-winding transformer circuit. In recent years an anti-sidetone subscriber set employing a three-winding transformer has come into wide use in the Bell System.

Sidetone has several detrimental effects on telephone transmission. A person naturally regulates the volume of his speech by the apparent loudness of his own voice in his ear. The presence of sidetone increases the apparent loudness, and there is a tendency to decrease his talking volume, which reduces the level of the outgoing voice signals. Sidetone also interferes with incoming transmission, because it allows room noise, picked up by the transmitter, to mingle with and partially mask the incoming speech.

The first anti-sidetone circuit in commercial use was invented by C. E. Scribner in 1893, and was used for some of the operator telephone sets. In 1906, G. A. Campbell showed that there were a large number of possible anti-sidetone circuits employing a single transformer and a single balancing network. To be practicable for general use, the circuit must be applicable to existing conditions and apparatus, and should require a minimum of additional expense. Considerable development work was necessary to secure an arrangement which provided the desired transmission improvements, and which, at the same time, could be economically incorporated in new or existing telephone apparatus. The circuit adopted meets these various requirements and necessitates—besides the equipment of the sidetone subscriber sets—an additional condenser, an additional winding on the transformer, and, where the combined station set is not used, one extra conductor in the cord to the telephone set.

The circuit for the standard sidetone subscriber set is shown in the upper diagram of Figure 1. The condenser serves two purposes. It prevents the bell from placing a d-c path across the line when the set is not in use, and it confines all the direct current to the path through the transmitter when the set is in use. Omitting the bell and the switchhook, which play no essential part under talking conditions, this circuit can be arranged schematically as shown in the middle sketch. Since the receiver and the B winding of the induction coil are in series, they can be interchanged in position without affecting the operation of the circuit; and since the condenser, under ideal conditions, would be of infinite capacitance, it would have no effect on the talking circuit and may thus be omitted in this explanation of the operation of the circuit. With these two changes the circuit would be as shown in the lower sketch.

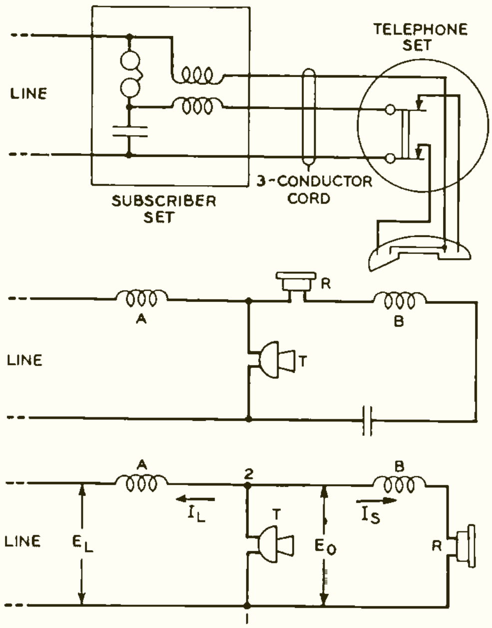


Fig. 1—*Wiring arrangement of sidetone subscriber set, above; equivalent diagram, center; and ideal diagram, below*

Under talking conditions, a voltage —marked Eo on the diagram—is generated across the transmitter. Current flows through the transmitter from 1 to 2, where it divides—part, marked I_L, passing out over the line; and part, marked I_S, passing around the circuit including the receiver. It is the latter current that causes the sidetone. Received speech current also will pass through both the transmitter and the receiver.

For many years a modified arrangement of this circuit, known as the sidetone-reduction connection and involving only a simple interchange of connections, was frequently used on the shorter station loops to obtain a reduction of sidetone, although it is not strictly what is termed an anti-sidetone circuit. The arrangement is shown in Figure 2. It gives a reduction in sidetone of about 7 db, and a gain in receiving efficiency of about 1 db, but it causes a loss of about 5 db in transmitting efficiency.

In the anti-sidetone set now being employed, the sidetone circuit is modified by shunting another path around the receiver, as shown in Figure 3. In this anti-sidetone circuit also, under transmitting conditions shown in the lower diagram, the current from the transmitter divides—part going over the line and part around the local circuit. If the additional circuit element, consisting of winding C of the transformer and the network N, can be made to carry all of I_S, however, there will be none left to pass through the receiver, and there will thus be no sidetone. This is exactly what this additional circuit element is designed to do; and al-

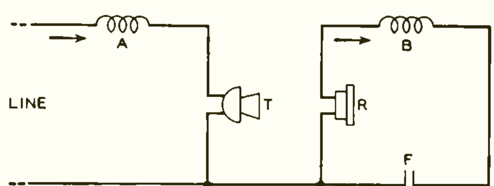


Fig. 2—*Schematic of sidetone reduction circuit used for short station loops* though under commercial conditions the action is not perfect, the sidetone is greatly reduced.

This condition, and the further condition that there shall be no current in the network during receiving, is brought about by a proper design of the windings A, B, and C and the network N in relation to the impedances of the receiver, transmitter, and line. The calculations, and the relationships that must exist, are somewhat complicated, but the qualitative behavior of the circuit is not difficult to see.

In the lower diagram of Figure 3, which shows the transmitting condition, arrows indicate the relative directions of current flow at an arbitrary instant. The windings are so poled—A and B in the same sense and B in the opposite sense—that the voltage E_c tends to make current flow through the network to an amount just equal to the current I_S flowing through winding B. Hence no current flows to or from the junction (4) in the branch which contains the receiver. Another way to visualize the situation is to consider that the circuit is designed so that the voltage drop from point 2 to point 4 is just equal to the drop from point 2 to points 1 or 3. As a result there is no voltage drop from point 4 to point 3 and no current flows through the receiver. As already pointed out, these ideal conditions are not completely met, but the sidetone current that passes through the receiver is greatly reduced.

For received speech, the relative directions of the currents in the circuit are shown by the arrows in the central diagram. The currents in windings A and B, as in the transmitting case, induce opposing voltages in winding C, the voltage from winding A being the greater. The net voltage in winding C is just sufficient to counteract the tendency of the voltage drop across the receiver, due to the current I_S, to send a current through the network. As a result there is no current in the network during receiving, a condition which must be fulfilled if the circuit is to be ideally efficient.

In the actual set, the network N is a simple resistance, and is incorporated in the winding C, so that there

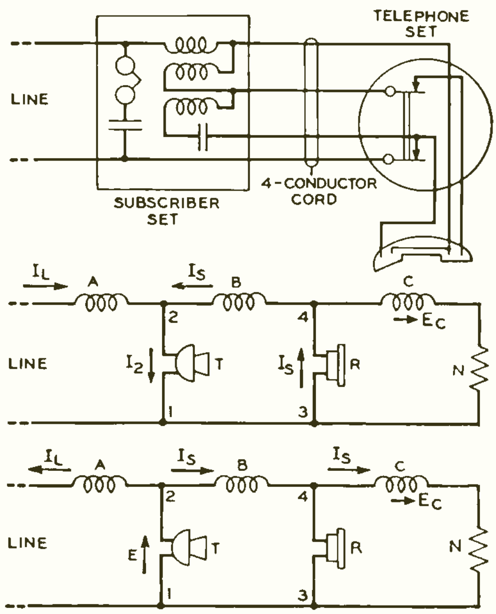


Fig. 3—Schematic circuit of anti-sidetone subset, with currents indicated for receiving conditions, center; and for transmitting conditions, below

is no separate physical element in the circuit corresponding to N. The actual circuit is shown in the upper diagram. Instead of using the same condenser for both ringing and talking, as is done with the sidetone set, two condensers are used—one of small capacitance in series with the ringer and one of larger capacitance for the talking circuit. This gives better transmission, dialing, and ringing performance, and permits fewer switch-hook contacts.

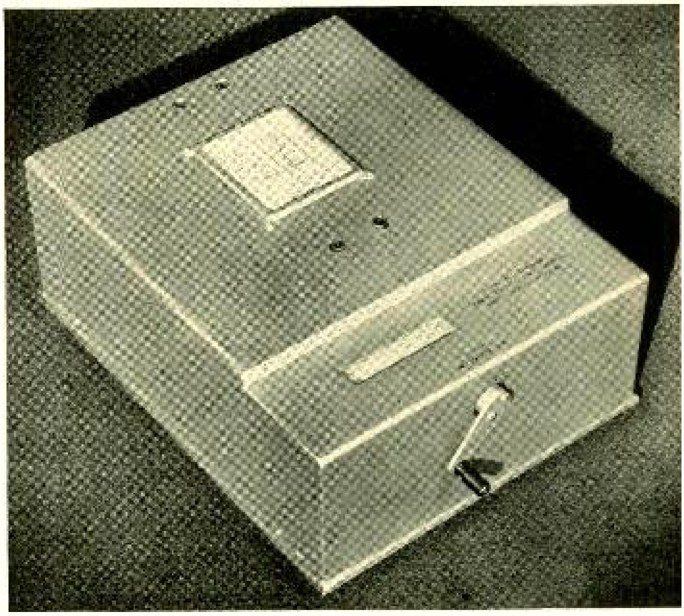
The new anti-sidetone set is slightly lower in transmitting and receiving volume efficiency than is the sidetone set, since the ideal requirements can only be partially fulfilled; but its large reduction in sidetone, amounting to some 10 db, results in an effective overall gain in transmission of about 6 db. The reduction in sidetone also makes it possible to get greater benefit from the improvements afforded by modern transmitters and receivers. The anti-sidetone set described above is that used for common battery systems, but a set has also been developed for local-battery systems, so that this equipment is now available for all kinds of service.

First Transcontinental Line Placed in Operation Twenty-Five Years Ago

When, on July 29, 1914, *Theodore N. Vail, then President of the American Telephone and Telegraph Company, took his telephone receiver from its hook in New York and spoke to G. E. McFarland, President of The Pacific Telephone and Telegraph Company, at San Francisco, another epoch-making achievement in telephone communication became a fact.*

Previous to 1911, *by using as large wires as were economically practicable, the telephone would talk reasonably well over a distance about as long as New York to Chicago. With the development and practical application of loading coils this distance was doubled in* 1911 *and New York and Denver were interconnected. The desirability, however, of a transcontinental telephone system had long been apparent. It was accomplished in* 1914 *through extensive research work under the direction of F. B. Jewett. There was extensive research on transmission lines, on repeater circuits and on amplifiers for repeaters, all of which culminated in a transcontinental system.*

In the early days of the New York-San Francisco line three types of repeaters were successfully demonstrated: a mechanical repeater, a mercury arc repeater and the vacuum tube repeater. The latter proved to be one of the most powerful and flexible tools in the communication art; and in succeeding years it has been vital in carrier current transmission, transatlantic radio telephony, radio broadcasting and sound pictures.



A Precise High-Frequency Inductometer

By L. E. HERBORN
Transmission Apparatus Development

THE development of modern broad-band carrier systems has required extensive measurements of impedance at transmission frequencies much higher than those used for earlier carrier systems. Over the usual range of impedance, these measurements are made on the five-megacycle bridge recently described in the RECORD.* With this bridge, the inductance component of the impedance is measured by a capacitance standard, but for inductances less than ten microhenrys this method is unsatisfactory because of the very large size of capacitance required. To cover this low range, therefore, a special inductometer has been developed for use with the bridge.

The conventional inductometers are not satisfactory at these high frequencies because of the relatively large distributed capacitance of the coils. In addition, the large residual inductance, the limitations of range, and the low ratio of inductance to effective resistance at low settings further restrict their usefulness. The new inductometer avoids these difficulties by employing a helical coil whose self inductance is changed by a trolley contactor that varies the number of active turns between the terminals.

As actually constructed, two such coils are employed to provide electrical symmetry with respect to ground, which is necessary in measuring balanced circuits. A partition through the center of the cover, as shown in Figure 1, completes the shielding provided by the mounting plate and cover, so that there is no

*RECORD, *April*, 1937, *p.* 261.

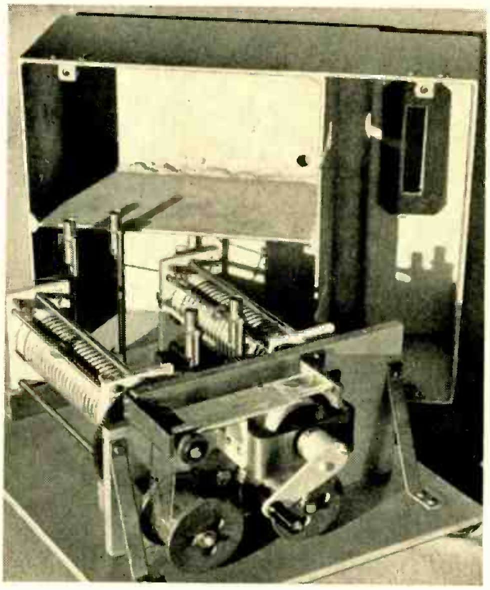


Fig. 1—A crank on the front of the inductometer drives the two coils through non-back lash gears and the sprocket wheel

capacitive or inductive coupling between the two coils or between the coils and any adjacent apparatus.

Each coil consists of a number of widely spaced turns wound helically on an insulating spool, and a trolley slides along the turns as the coil is rotated. The arrangement is clearly shown in Figure 2. Collector rings, not evident in the photographs, bring out a connection from each end of each coil, and the trolleys are connected to the terminals connected to one end of the coils. All of the contact parts are silver plated to give a low and stable contact resistance, and the four terminals are brought to coaxial jacks for connection to the standard high-frequency bridge.

The coils are rotated in unison through a crank and non-back-lash gears, and as the coils rotate the trolleys slide along the turns of the coils, giving a continuous adjustment. Another set of gears on the front of the mounting plate drives two spools that carry the film on which the calibration is marked. This film is coupled to the coils by a sprocket wheel mounted on the same shaft as the crank. The range of inductance is from one to twelve microhenrys, and the film employed is twenty feet long, thus permitting very small changes to be accurately read. The smallest divisions of the scale are two-tenths of an inch apart, and represent a change of 0.01 microhenry.

Since with the construction employed only that part of the coil necessary for the inductance being measured is in the circuit, it is possible to secure a high ratio of induction to effective resistance. Measurements indicate that settings are reproducible to within a hundredth of a microhenry and to a ten-thousandth of an ohm of effective resistance.

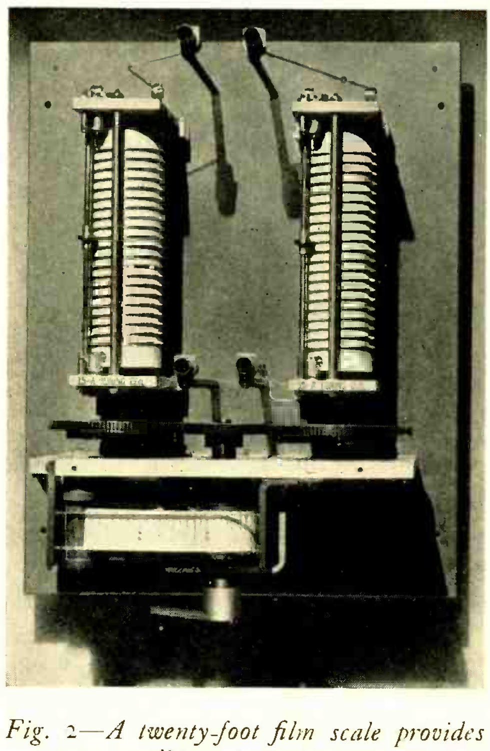
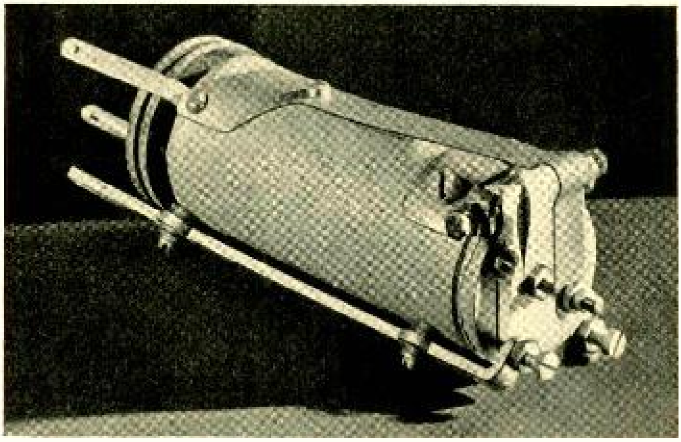


Fig. 2—A twenty-foot film scale provides easy reading over the entire range



Increasing the Range of Tripping Relays

By L. J. STACY
Central Office Switching Development

IN the early manual systems, all ringing was under the control of an operator. She would operate a key to start it, and restore the key to stop it. Manual ringing has long been replaced by machine ringing on all but small, light-traffic boards. With this system the operator starts the ringing, as before, but it is cut off automatically when the subscriber answers by a "tripping" relay. The ringing current passes through its winding, but the relay must not operate on it under even the most unfavorable conditions, such as a very short line and two ringers bridged across it. When the subscriber answers, however, the relay must operate to stop the ringing, again under the most unfavorable conditions of a line that is extremely long.

A ringing circuit is shown in simplified form in Figure 1. Under ringing conditions, relay A is operated and ringing current passes through the winding of the tripping relay, a front contact on relay A, the "ring" side of the subscriber's line, condenser C, the ringer, the "tip" side of the line, another front contact on relay A, and to ground.

Low-frequency alternating current is used for ringing, and at the time machine ringing was introduced was at 110 volts. The amount of current that flows depends on the impedance of the ringer, the condenser, and the subscriber's loop. Under most unfavorable conditions this current may be as great as 100 milliamperes, and thus the relay should not operate on this amount of ringing current.

When the receiver is lifted from the hook, the condenser and ringer are practically short-circuited by the transmitter, and the lower impedance resulting should allow enough current to pass to operate the tripping relay. With a maximum loop resistance of 750 ohms, including the station resistance, however, and some 250 ohms in the relay winding and the rest of the circuit, the current is only about 100 milliamperes, which as noted above is the value at which it should not operate. To insure satisfactory tripping, therefore, two things are done. One consists in putting a battery in series with the ringing machine; and the other, in making the tripping relay more sensitive to direct than to alternating current. This does not affect the ringing, since the d-c component is blocked by the condenser, but it increases the current that flows when the call is answered, since the path through the transmitter has no condenser in series.

Ringing is supplied through an interrupter that gives a short interval of ringing followed by a longer interval of silence. To make it possible for the tripping relay to operate during the silent as well as during the ringing interval, battery is also connected during this silent interval. A simplified schematic diagram of the arrangement is shown in Figure 2. To make the tripping relay less sensitive to alternating than to direct current, a copper sleeve is placed over the core. With alternating current in the winding, an opposing current is induced in this sleeve, so that the net effect of the current is less, while with direct current in the winding, the sleeve has little effect. As a result, the relay is from three to five times more sensitive to direct current than it is to alternating. The lowest operate current—or a 750-ohm external circuit loop during the silent interval—is about 50 milliamperes d-c; the highest non-operate current—for a minimum length of loop and two parallel ringers—is some 100 milliamperes a-c. Since the relay is at least three times more sensitive to d-c than to a-c, however, it can readily be made to operate on 50 milliamperes d-c and not to operate on 100 milliamperes a-c.

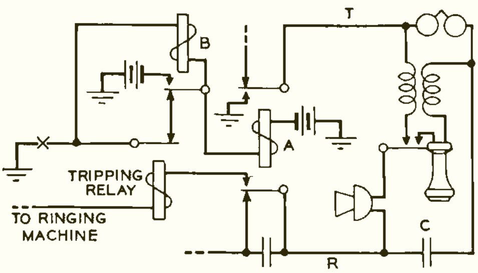


Fig. 1—Simplified schematic of the usual type of ringing circuit

In recent years there has been a trend toward the use of smaller conductors in cables, with the result that the resistance of subscriber loops has tended to increase. Because of this tendency, the new crossbar system has been designed to give service over 1500-ohm external circuit loops. As part of the crossbar development, therefore, it has been necessary to provide a tripping system for this increased range. With a 1500-ohm loop, the operate current under the most unfavorable conditions will be only about 25 milliamperes. The former relay, if adjusted to operate on this very small current, would have unstable contact, and so it was necessary to redesign its structure to provide the necessary contact stability at 25 milliamperes. Since this requires that the relay be more sensitive to direct

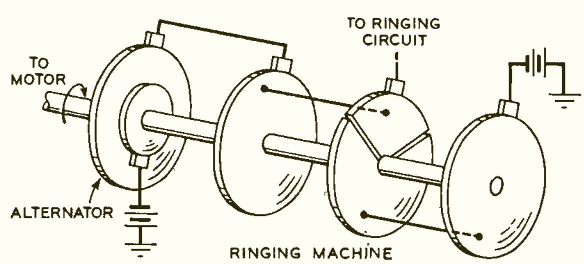


Fig. 2—Simplified schematic showing arrangements of ringing interrupters

current, something also had to be done to make it less sensitive to alternating current.

This was accomplished by a design modification due to H. N. Wagar. Its major features are shown in comparison with those of the former relay in Figure 3. Both relays are alike in having a central core on which the winding is placed, a cylindrical iron shell surrounding the winding, and a circular armature that bridges the annular space between the core and the outer shell. In the earlier form a copper sleeve was placed over the core to carry the opposing current.

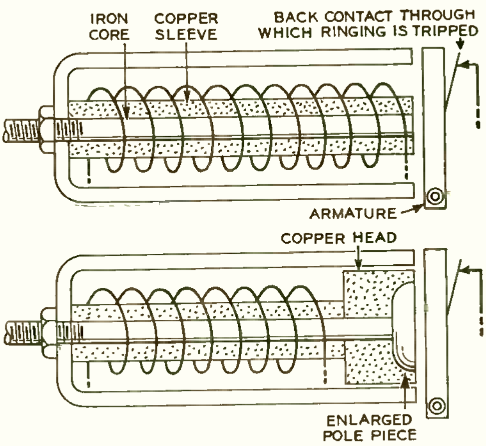


Fig. 3—Cross-sections of former "tripping" relay, above, and new one, below

In the new relay, known as the 114KA, the sensitivity is increased by an enlarged pole piece at the end of the core nearest the armature. This larger area reduces the reluctance of the air gap, and thus permits a larger flux to flow for the same magnetizing force. This larger flux, in turn, results in a greater pull. To prevent this increased sensitivity from being effective on alternating current, a large copper ring is placed adjacent to the added pole piece to allow a larger opposing current to flow. This added copper ring is evident in Figure 4.

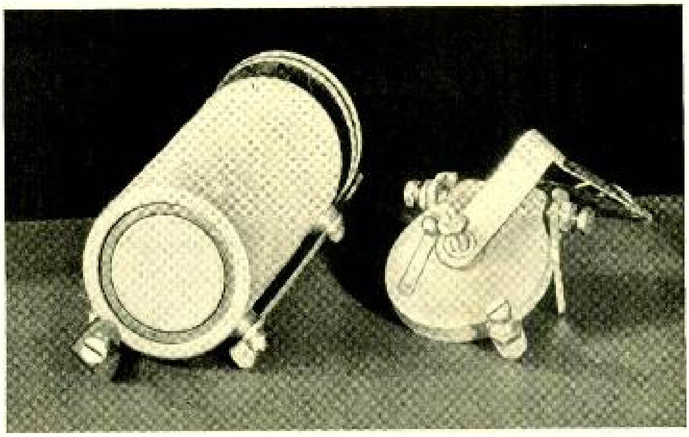


Fig. 4—The 114KA tripping relay with armature removed to show the copper ring around the pole piece

This modified construction has not changed the general appearance of the relay, so that the new relay—shown in the photograph at the head of this article—looks like the former one except for a few minor changes in spring and contact arrangement. A front contact has been provided in addition to the back contact, but it is used in only a few cases. With this new relay, the ratio of a-c to d-c current necessary to operate is from seven to fifteen—a substantial increase over the former ratio.

Number Decoding by Terminating Markers

By J. W. DEHN
Central Office Switching Development

As has been explained in a previous article, the functions of terminating markers are in general similar to those of originating markers. The differences arise chiefly from the difference in type of circuits which they control. While the originating markers must find an idle trunk out of several hundred groups of trunks, the terminating marker must be able to find one particular line out of a possible ten thousand. It must first test this line for busy, and, if the line is found idle, must then establish a connection to the crossbar switch to which that line is run, so that it may find an idle path to it from the incoming trunk, and in this manner establish the talking connection.

The particular number called, however, may be that of a private branch exchange, instead of an individual or party line. In such a case it is not sufficient to test only one line; since there will a group of trunks to the PBX, the marker's task is to select the first one in the group that is idle. One of the fundamental features of the crossbar system is to test a group of paths and trunks simultaneously so as to reduce the holding time of the markers to a minimum. To carry out this principle, the terminating marker is arranged to test twenty lines at a time where the number called is that of a PBX; while when it is that of an individual line, only the desired line will be tested, although the entire group of twenty consecutively numbered lines, including the desired one, will be brought to the marker.

The possible 10,000 subscriber numbers of the office are therefore arranged in blocks of twenty, and a block relay is provided for each such group. In function the block relays are similar to the route relays of the originating marker, but they are controlled and operated in a different manner. The route relays are part of the originating marker, and one or more for each office code is provided in each marker. The block relays, on the other hand, are not part of the terminating marker, and there is only one for each group of twenty subscriber numbers in the office. They are multi-contact relays assembled ten in a row, and four such rows are mounted on the upper part of a frame as shown in the photograph at the head of this article. When operated, each block relay closes sixty contacts, three for each of twenty line numbers. Twenty of these, one for each line, are in the leads used for the busy test. There may be as many as 500 of these relays in an office, and, to simplify the selection of the desired one, they are grouped into sets of five, and operated through hundred-block relays. Each of the latter has five contacts, one for the winding of each of the twenty-block relays in that hundred-block. These hundred-block relays are mounted under one of the long cans that are mounted above the four rows of twenty-block relays.

Several of the hundred-block relays are formed into a "number group" and by means of a number-group connector can be temporarily connected to any one of the terminating markers in the office. The number-group connector relays are of the same type as the twenty-block relays, and are also assembled in rows of ten, eight rows being mounted on a frame as shown in Figure 1. Four of these relays, operated simultaneously, are required to connect a number group to one marker—the four being mounted one above the other. Since each number group must have access to all of the terminating markers, of which there may be as many as ten, ten sets of four relays may be furnished for each number group. Each frame of Figure 1 has connector relays for two number groups, the upper four rows serving one number group and the lower four the other.

This division of lines into number groups permits a number of markers to be locating lines at the same time. If two markers should receive calls for numbers in the same number group at the same time, one marker must wait for the other to set up its connection. This delay is ordinarily a small fraction of a second. To prevent unreasonable delays, however, the hundred-blocks formed into a number group usually represent only about one thousand terminating calls during the busy hour. For simplicity

Fig. 1—Number-group connector frames in the Murray Hill-6 Office on East Thirtieth Street

and economy in cabling, the hundred-blocks assembled into a number group are usually formed of consecutive subscriber numbers. If it is impractical to select consecutive hundred-blocks to give the desired load, however, non-consecutive hundred-blocks may be grouped, at some sacrifice in simplicity and cost of cabling.

When a marker is seized by a sender, it must determine—from the number that has been dialed—the

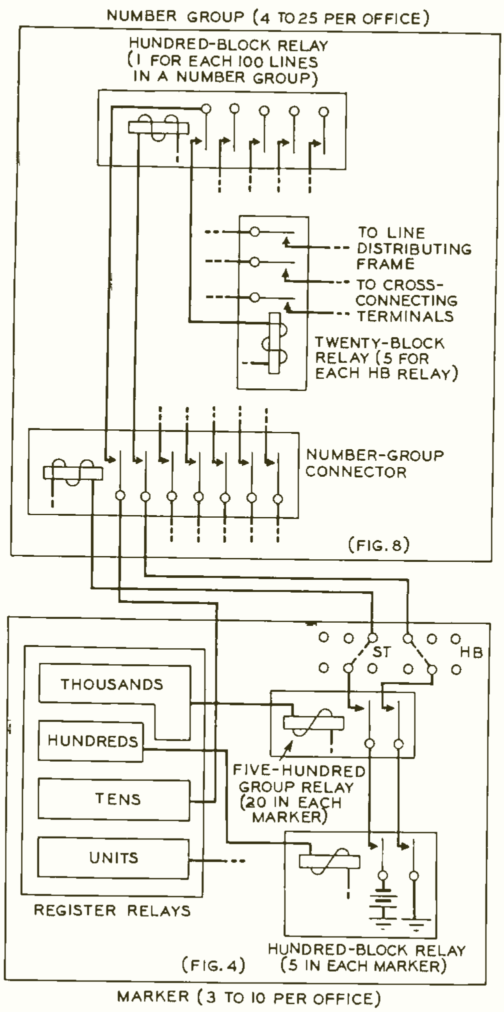


Fig. 2—Synoptic diagram of the decoding features of the terminating marker and number-group circuit

correct number-group connector to operate, and also the correct hundred-block and twenty-block relays to operate in this number group. This process is known as decoding, because

Digits	Relays Operated in Either H, T or U Set	Relays Operated in Th Set
0	0	0
1	1	1
2	2	2
3	1+2	1+2
4	4	4
5	5	4+1
6	5+1	4+2
7	5+2	4+2+1
8	5+2+1	8
9	5+4	8+1

Fig. 3—Combinations of operated register relays to give the various digits

the decimal directory number it received, 2845 to take a concrete example, must be translated or decoded into terms designating a number-group, a hundred-block relay, and a twenty-block relay.

A synoptic diagram of the circuits involved in this part of the marker's work is shown in Figure 2, where reference is made to two following illustrations giving sections of the circuit in greater detail. As a basis for its action, the marker has recorded on four groups of register relays the number that has been dialed by the subscriber. The proper register relays in each group were operated by the terminating sender when the marker was seized, as described in the previous article. These relays are similar in arrangement and function to those of the originating markers used for recording the office code, except that four sets of relays are required instead of three because the subscriber number consists of four numerals. The relays of the group for the first, or thousands digit, also differ in being numbered 1, 2, 4, and 8, instead of 1, 2, 4, and 5, as are the other groups in the terminating marker and all the groups in the originating marker. The combinations of the relays within a group to give the various digits are shown in Figure 3.

Since a number group is made up of hundred-blocks, a determination of the hundred-block indicated by the registered number is sufficient to designate the number group desired. This hundred-block designation will also, of course, indicate which hundred-block relay in the number group to operate. The marker is designed to determine the hundred-block by first picking a group of 500 numbers — or five-hundred group — and then narrowing its selection to one of the five, although the two operations are carried out simultaneously, not successively. Due to the fact that there are twenty groups of 500 subscriber numbers in a 10,000 number office, the marker is equipped with twenty 500-group relays, one for each of the twenty groups of five hundred numbers. It also has five hundred-block relays, one for each of the hundred-blocks in a 500-group, and leads from contacts of hundred-block relays are multipled to a set of corresponding contacts in each five-hundred group relay. The arrangement is shown in greater detail in Figure 4. These hundred-block relays in the marker should not be confused with those in the number-groups. The latter are individual to a set of

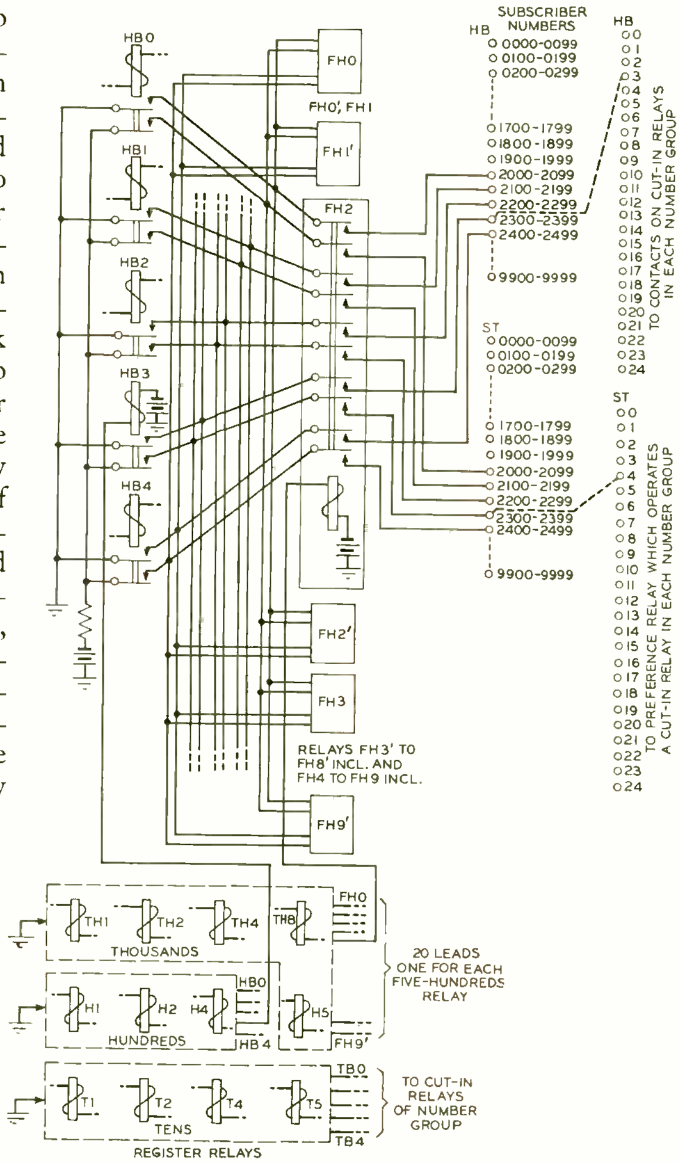


Fig. 4—Simplified schematic of 500-group and hundred-block relay circuit in the marker

Five-Hundred Groups	FH Relay	Register Relays Operated Th1	Th2	Th4	Th8	H5
0000–0499	0	–	–	–	–	–
0500–0999	0′	–	–	–	–	x
1000–1499	1	x	–	–	–	–
1500–1999	1′	x	–	–	–	x
2000–2499	2	–	x	–	–	–
2500–2999	2′	–	x	–	–	x
3000–3499	3	x	x	–	–	–
3500–3999	3′	x	x	–	–	x
4000–4499	4	–	–	x	–	–
4500–4999	4′	–	–	x	–	x
5000–5499	5	x	–	x	–	–
5500–5999	5′	x	–	x	–	x
6000–6499	6	–	x	x	–	–
6500–6999	6′	–	x	x	–	x
7000–7499	7	x	x	x	–	–
7500–7999	7′	x	x	x	–	x
8000–8499	8	–	–	–	x	–
8500–8999	8′	–	–	–	x	x
9000–9499	9	x	–	–	x	–
9500–9999	9′	x	–	–	x	x

– not operated
x operated

Fig. 5—Register relays in the crossbar system operated for the various five-hundred groups

one group being primed to make the distinction. In each case, the primed relay is for the 500-group whose hundreds digit is 5 or greater. For number 2845, for example, the No. 2′ FH relay will be operated, the 2 indicating that the thousands digit is 2, and the prime, that the hundreds digit is five or above.

Which hundred-block relay is operated depends on the first three relays of the hundreds register relays as shown in Figure 6. It will be noticed that each combination of the H relays corresponds to two hundred-blocks, one below and one above 500. For the number 2845, the No. 3 HB relay would be operated, in conjunction with the No. 2′ FH relay. This determines the number as between 2800 and 2899, but had the same HB relay been operated in conjunction with the No. 2 FH relay, the number would have been between 2300 and 2399. In this way a single set of five HB relays, in conjunc-

100 directory numbers, while those in the markers merely designate the five sets of 100 numbers into which any group of 500 may be divided.

The five-hundred group relay to be operated is determined from the thousands-group and the No. 5 relay of the hundreds-group of the register relays, as shown in Figure 5. From this table it will be noted that the number of the 500-group relay is determined by the thousands digit of the number dialed, but since there are two 500-groups in each thousand numbers, there are two 500-group relays for each of the ten "thousand" digits from 0 to 9, the number for

Hundred-Blocks	HB Relay	Register Relays Operated H1	H2	H4
000–099 or 500–599	0	–	–	–
100–199 or 600–699	1	x	–	–
200–299 or 700–799	2	–	x	–
300–399 or 800–899	3	x	x	–
400–499 or 900–999	4	–	–	x

Fig. 6—Register relays that are operated for the various hundred-block groups

tion with twenty FH relays, can be made to designate any hundred-block in the office.

The operation of one HB and one FH relay in the marker closes paths to two sets of terminal strips—one marked ST, and the other HB. These terminal strips form part of one of the marker bays as shown in Figure 7. Since there are twenty FH relays, each carrying a pair of contacts for each of the five HB relays, there are one hundred terminals in each of the two terminal sets, one corresponding to each possible hundred-block in the office. Adjacent to the one hundred ST terminals is a group of terminal strips, each strip representing a number group. Each of the one hundred ST terminals is cross-connected to the strip representing the number group containing that hundred-block of subscriber numbers, and closure of this path in the marker will cause the number group to be connected to the marker. Adjacent to the one hundred HB terminals is a similar group of terminal strips, each strip representing one of the hundred-blocks of subscriber numbers in the selected number group. Each of the one hundred HB terminals is cross-connected to the strip which will operate the hundred-block relay in the selected number group that gives access to the corresponding hundred subscriber numbers.

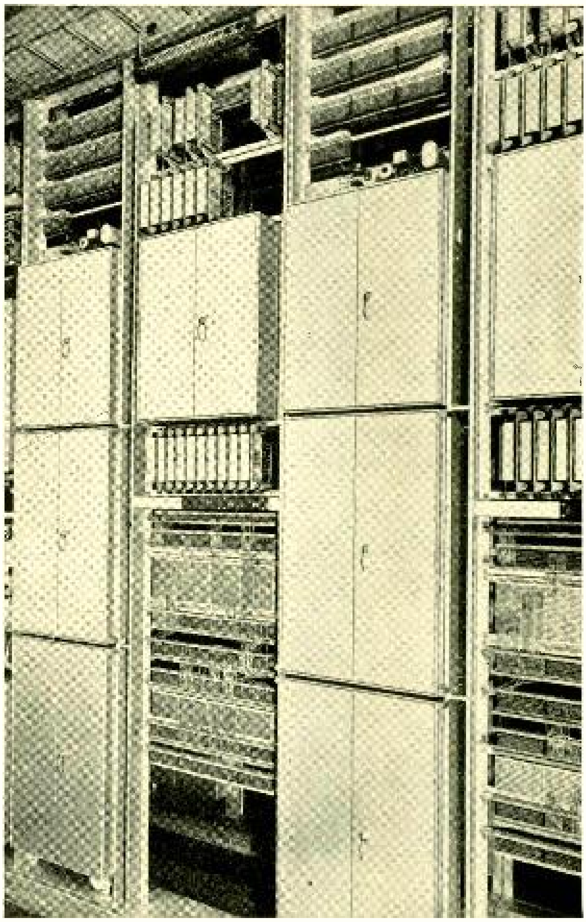


Fig. 7—Each terminating marker consists of two bays, one consisting chiefly of three cabinets of relays, and the other of one relay cabinet and the cross-connecting terminals

So far, a particular number-group connector has been selected, and a hundred-block relay in that group has been operated. Which particular twenty-block relay is operated is determined by the combinations of operated relays of the tens-group of register relays in the marker. Five leads are carried from this set of register relays through the number-group connector to the number group, where they are multipled to the five contacts of all the HB relays assembled in that number group, as shown in Figure 8. From this relay they run to the windings of the twenty-block relays—the contacts of each hundred-block relay being connected to the five twenty-block relays it controls. The circuits through the tens register relays are so arranged that when no relay or the No. 1 relay is operated, ground will be placed on the lead that runs to the first twenty-block relay—indicating that the last two digits are between 00-19, and when the No. 2 relay, or the No. 1 and No. 2 relays, are operated, ground will appear on the lead running to the second twenty-block relay—indicating the terminal digits are between 20 and 39, and so on.

By this decoding process, a particular block relay has been operated, and three contacts have been closed for each number of the block that includes the one called. One of these contacts for each line will be used for a busy test, and the other two will be used in the process of establishing the call if the line is found idle.

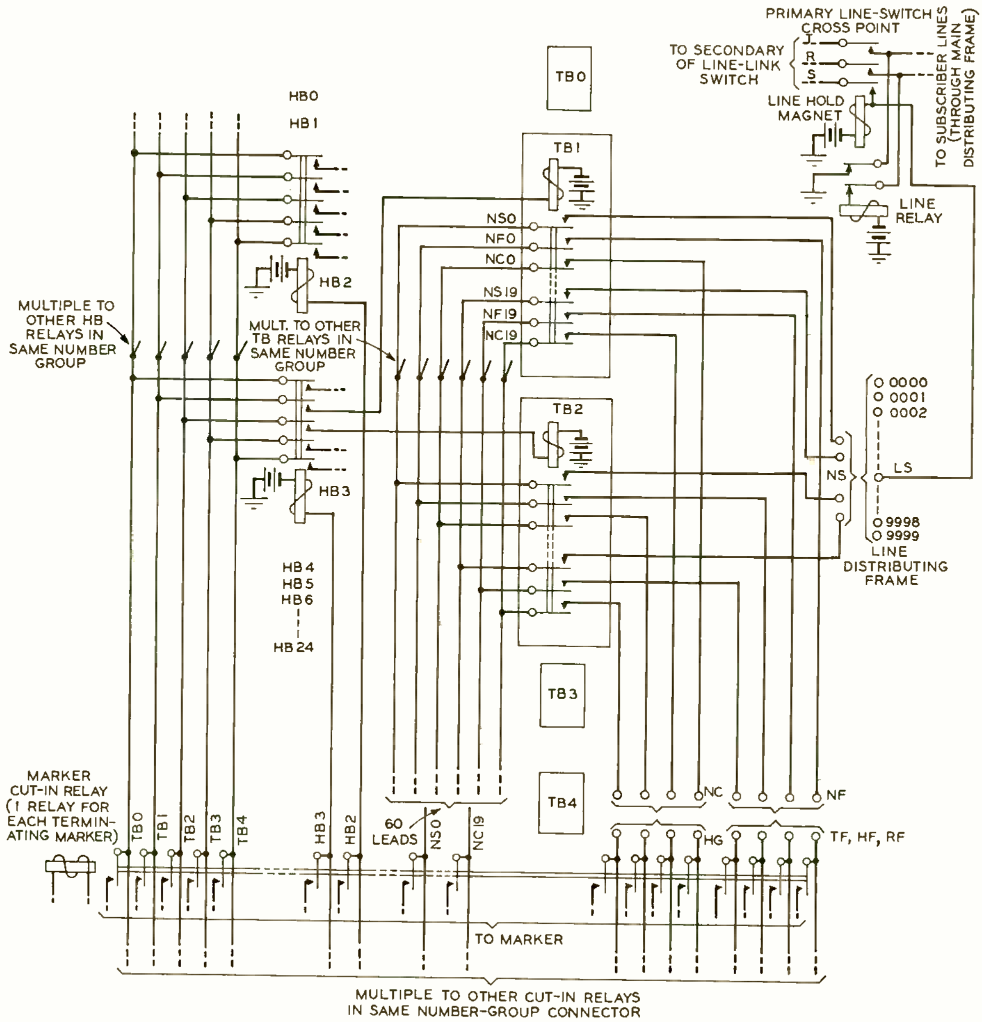


Fig. 8—Simplified schematic of the number-group circuit

A Ringing Machine for Small Offices

By R. D. de Kay
Power Development Department

IN large central offices a variety of tone signals are required to expedite the operating procedure, and these as well as ringing current are supplied by motor-generator sets as already described.* For private branch exchanges and for the smaller central offices ringing and tone supply are also required, but the load is much lighter so that the large motor-generators are not economical to use. To meet the requirements of these smaller offices a number of types of equipment have been employed, depending on the size and requirements of the office, and for the most part have given excellent service. None of them, however, have sufficient tone and interrupter equipment for some of the new community dial offices; and for the most part they permit a greater variation in output voltages than is desirable for some applications. A new small ringing machine thus seemed necessary.

What was desired was an assortment of tone and interrupter circuits comparable to that of the larger motor-generator sets but without the large size and cost of the more extensive installations. To meet this need, the KS-5510 ringing machine, shown in Figure 1, was developed. Instead of being a motor-generator as the larger sets are, it is a rotary converter like the QD design, one of the smaller machines. A rotary converter combines a d-c motor and an a-c generator in the same unit, having a common set of field coils and a single armature, with a commutator on the motor end and slip rings on the generator end. The converter runs on current from the office battery, and 20-cycle a-c is taken from the slip rings, through a step-up transformer, for the ringing supply.

On a shaft extension at the commutator end are four rings for supplying the high and low tones,* from which

*Record, *Dec.*, 1938, *p.* 111.

*Record, *April*, 1931, *p.* 385.

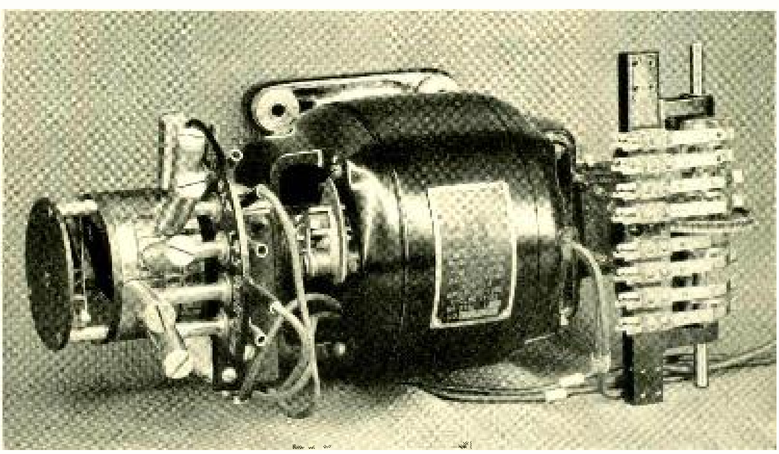


Fig. 1—*The KS-5510 ringing machine with interrupter shaft shown at the right* the various tone signals are derived by interrupting the continuous tones at various rates. Each basic tone is produced by a slip ring and a segmented ring with its alternate segments connected to the slip ring. The number and width of the segments are proportioned so that battery current passing in through the slip ring is interrupted at the proper rate. The changes in current are converted by means of repeating coils into alternating voltages or tones having frequencies equal to the revolutions per second of the machine times the number of interrupting segments in each ring. Beyond the tone rings is the centrifugal speed regulator, which maintains the speed of the set within the required limits.

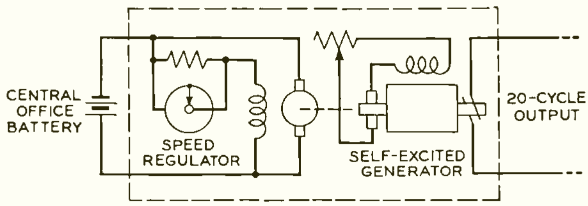


Fig. 2—Simplified control circuit for a motor-generator set

At the other end of the converter, beyond the main slip rings, is a worm driving a gear on a counter shaft, which rotates at 10 rpm. This is the interrupter shaft. It is arranged to mount as many as six disks, each drilled around its periphery to take on each side one or more pins with sleeves over them to act as rollers. Each such disk has a set of contact springs that the pins raise and lower as the shaft rotates, and each set of springs acts as an interrupter for ringing current or for one type of tone. As many are mounted as needed up to a maximum of twelve.

Although a rotary converter has the advantage of being a smaller and less expensive machine than a motor-generator, speed regulation with it becomes more difficult. With a motor-generator set, there are two separate machines, each with its own field, and an adjustment of the field of the motor—made to hold a constant speed—has no effect on the voltage of the generator. The speed regulator of such a set has a contact that opens and closes a short circuit around a resistance in the motor field circuit. As the motor slows down, the period of short circuit is reduced and that of open circuit increased, so that there is a net decrease in average field current and a corresponding increase in the speed of the motor. A simplified schematic of such a set is shown in Figure 2.

With a rotary converter, however, the same field serves for both motor and generator, and if the field current is decreased to offset a falling speed, the generated voltage will decrease. To avoid this, a resistance is inserted in the armature circuit, as shown in Figure 3, and the regulator contact is allowed to short circuit this resistance for longer or shorter periods as the motor slows down or speeds up. Both speed and voltage vary directly with the voltage across the armature, and thus increase as the armature resistance is shorted out for longer intervals. A series field is also used with

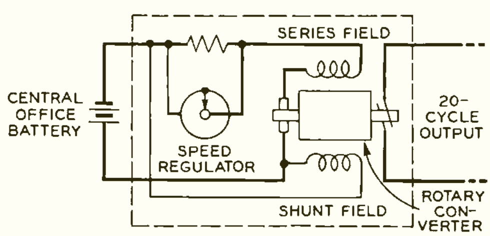


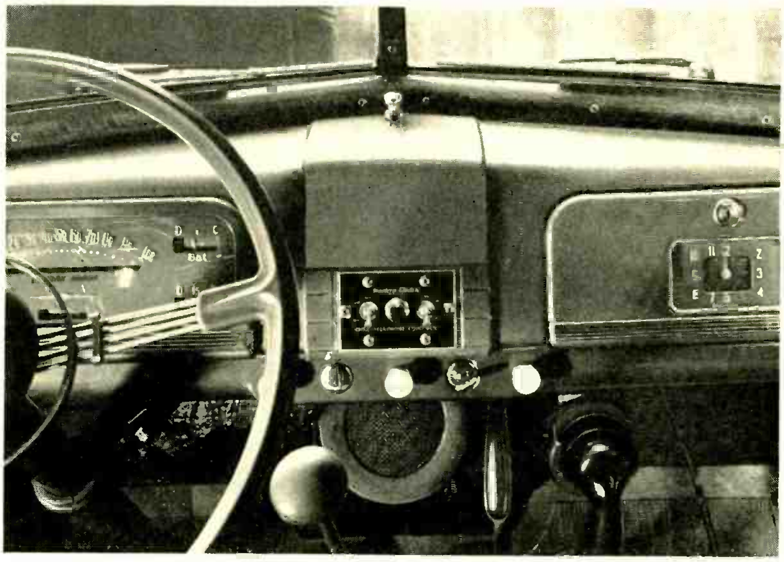
Fig. 3—Control circuit for converter set

the rotary converter, and brings in an additional stabilizing factor.

A modified form of this machine, called the KS-5546 code-ringing machine, is arranged to give the code ringing commonly used on rural lines. Since as many as twenty parties may be connected on such a line more interrupter springs are required. For this reason the interrupter shaft is made long enough to accommodate eighteen spring pile-ups, eleven of which are used to furnish the codes alone. Since cost is particularly important in these small offices, the speed regulator has been omitted. This results in wider voltage variations in the ringing output, and the rating of the machine has been slightly decreased, which is permissible because of the light load under which these offices operate. For the same reasons it has been possible to use smaller brushes on the tone rings, and thus make another small saving. As a result of the accumulated savings this code-ringing machine will give a greater variety of signaling interruptions than the KS-5510 machine, and at the same time will cost less.

Modern business management should be, and I believe for the most part is, imbued with an interest in the public welfare. It provides the basis of satisfaction to educated men, for industry is the basis of the well-being of the nation and commerce the chief hope of an economy in which the nations of the world can live in peace. Business is not a simple calling. It requires skill of a high order, capacity and a sense of responsibility. Business today is not based on the conception of a world of a limited amount of goods in which, if one man gets more, another man must get less. Its objective, whether conscious or not, is to create more for all. And in doing so it must reconcile the interests of the workers, the owners and the consumers. Especially today it must carry on with sympathetic understanding of the necessary restrictions to its complete freedom that grow out of what is called the "public interest"—the interest of the general public, whether or not workers, owners or customers of the particular industry.

—From an address by Walter S. Gifford at the Commencement Exercises of Union College, June 12, 1939.



New Mobile Radio Equipment

Increased power and better quality of reception is provided for police cars and other mobile units by the new Western Electric 228A radio telephone equipment. Its major units are a short-wave receiver and 15-watt transmitter, each with its own high-voltage power supply operated from the car battery. In addition, a small control unit, a loudspeaker, and a telephone handset are mounted in front of the driver. Besides its threefold increase in power, this new Laboratories apparatus includes a greatly improved codan to disable the receiver when no signal is being received, and a device to reduce noise peaks.

Contributors to this Issue

J. W. Dehn joined the Engineering Department of the Western Electric Company in the fall of 1919, and at first engaged in laboratory testing and analysis of manual and panel telephone circuits. Subsequently he worked on the design of manual circuits and later of automatic testing circuits for panel offices. Since 1933 he has been engaged in the design of automatic testing circuits and marker circuits for the crossbar system. During this period, he has attended classes at the Polytechnic Institute of Brooklyn from which he received the degree of Electrical Engineer in 1932.

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J. W. Foley graduated from the University of Illinois in 1911, receiving the degree of B.S. in Electrical Engineering, and immediately joined the Western Electric Company at Hawthorne. Upon the completion of the student course, he entered the Transmission Laboratory at New York, where he was concerned with general transmission studies. His work soon became centered upon telephone sets and their associated circuits. He has been intimately associated with the development of the anti-sidetone telephone sets now standard for both subscribers and operators as well as many sets for special purposes such as train dispatching, amplifier sets for the hard of hearing, and loudspeaker systems for both intercommunicating and regular telephones. More recently he has participated in the development of closed-core induction coils for operator and subscriber sets, of acoustic shock prevention devices, and in further studies for the improvement of subscriber telephone sets and their associated apparatus.

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L. J. Stacy

R. N. Marshall

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.

H. B. Briggs received the B.A. and M.A. degrees from the University of Wisconsin in 1919 and 1921, and the Ph.D. degree in Physics from the University of Chicago in 1925. His undergraduate work was interrupted by two years spent in France as a Lieutenant of Infantry. From 1921 to 1923, and again from 1925 to the time he joined the Laboratories in 1929, he was a member of the teaching staff at the State College of Washington. Until the past year and a half he has carried on fundamental research in the fields of photoelectricity and the optical constants of metals. At present he is working on electron optical problems associated with television.

R. D. de Kay was graduated from the United States Naval Academy in 1918. He served in the war as engineer officer on destroyers, and after the war as commanding officer. In 1922 he left the Navy and joined the power development group of the Laboratories, where he supervises rectifier and machine development.

L. J. Stacy received the A.B. degree from St. Lawrence University in 1909. After six years of school teaching, he entered the University of Chicago for two years of graduate study in physics and mathematics. In the radio division of the Signal Corps in 1918 he rose to a second lieutenancy, then returned to Chicago to receive the Ph.D. degree in 1919, and later that year entered the Systems Development Department of these Laboratories. He has been concerned with ringing and tone studies and other special technical problems in the local central office laboratory, and later was placed in charge of a group devoted to this work. Since early in 1937 he has also been in charge of the step-by-step and manual testing groups.

R. N. Marshall joined the Laboratories' Technical Staff immediately after graduating from Princeton University with the B.S. degree in 1930. He assisted in developing the first commercial Western Electric moving-coil microphone and undertook acoustic studies on microphones, mostly at Whippany. Later he worked on non-directional microphones and more recently directed the development of the cardioid directional microphone described in his article in this issue of the Record.