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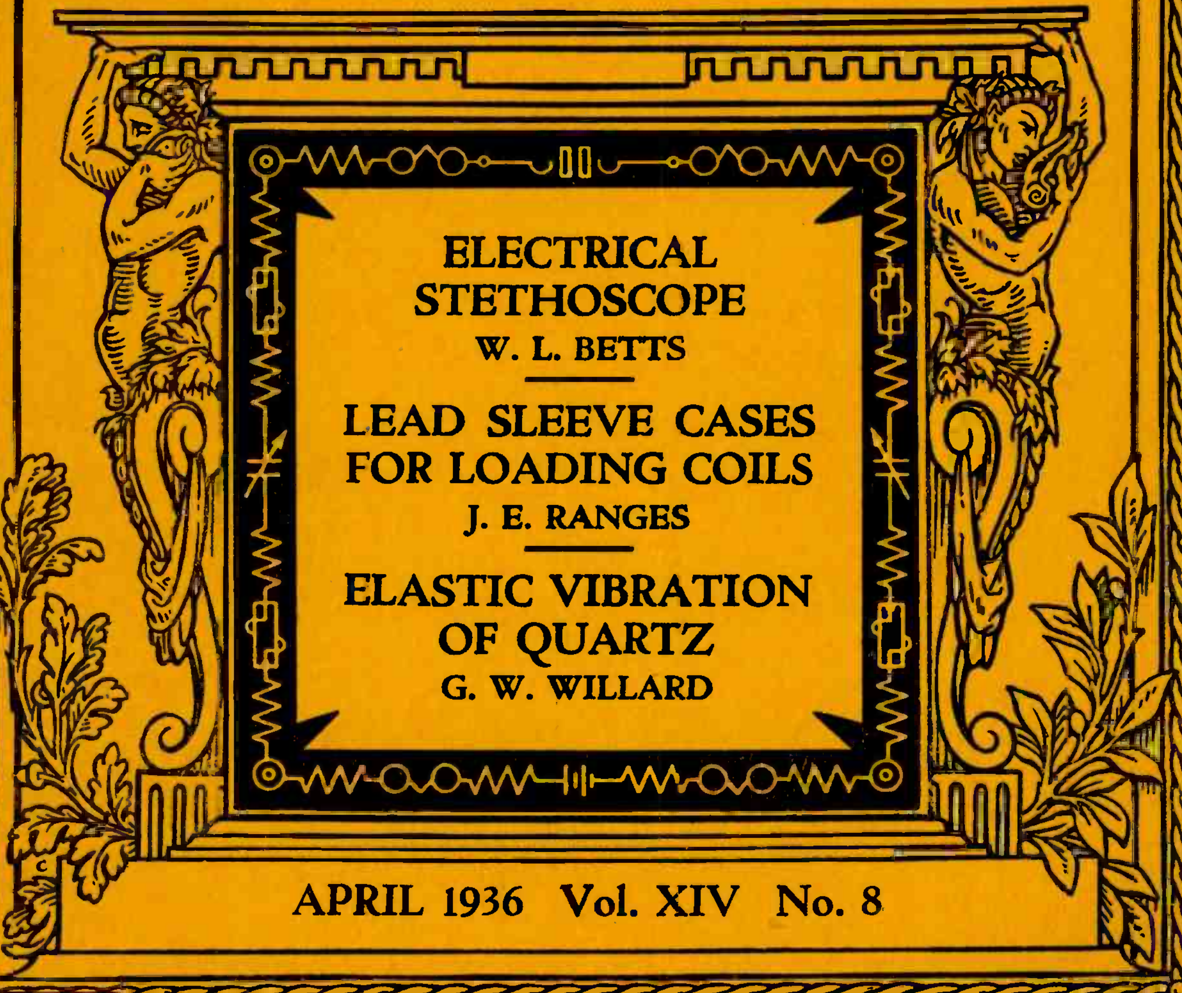

ELECTRICAL STETHOSCOPE

W. L. BETTS

LEAD SLEEVE CASES FOR LOADING COILS

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ELASTIC VIBRATION OF QUARTZ

G. W. WILLARD

APRIL 1936 Vol. XIV No. 8

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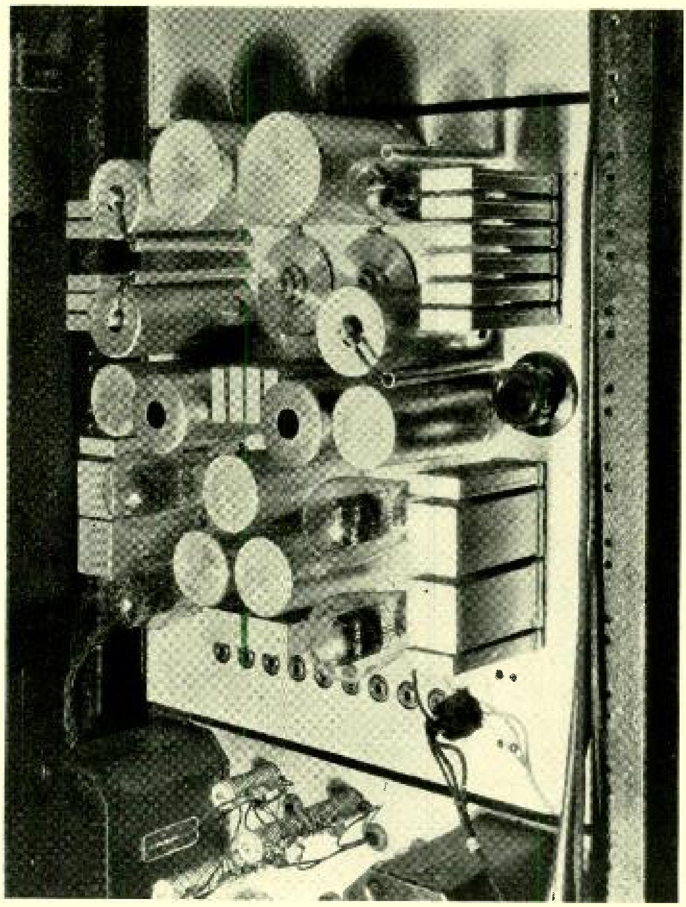

Experimental set-up of synchronizing apparatus for common-frequency broadcasting

VOLUME FOURTEEN—NUMBER EIGHT

for

APRIL

1936

Elastic Vibrations of Quartz

By G. W. WILLARD
Radio Research

THE great utility of quartz crystals, in stabilizing the frequency of oscillators, and as elements in filters and other electrical networks, is due primarily to two properties of quartz. In the first place the substance, when in a crystalline form, is piezo-electric: it may be set into vibration by applying an alternating potential across it, and conversely its vibration reacts upon the circuit through which the potential is applied. In the second place, its internal losses are extremely low. These two virtues result in circuit elements which, though mechanical, are intimately associated with the electrical circuit; and which, because of the low losses, show very little damping.

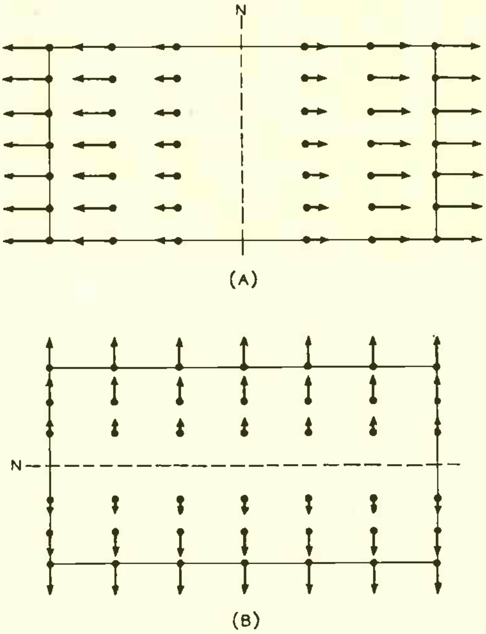

Fig. 1—The simple compressional modes of vibration of a quartz crystal plate (A and B) are elastically coupled so that the plate tends to exhibit a combined form of vibration

Roughly speaking a quartz plate, like any other physical object, has a natural frequency of vibration, dependent on its dimensions, its density, and its elasticity. In this respect it is mechanically analogous to a tuned circuit, and this is the feature of it that is put to practical use. But, again, like any other physical object, a quartz plate has not only one but many natural frequencies of vibration. In other words, such a plate has quite a few modes of vibration; there are many different ways in which the plate can vibrate at a fundamental frequency and various overtones, when appropriately excited. Moreover, many of these modes are so coupled to one another mechanically that the excitation of one tends to excite others, and their combined behavior under excitation is of the complicated sort whose electrical analog is provided by coupled circuits.

A simple illustration of such behavior is given in Figure 1. At A in that figure is shown a thin plate, face on, which is supposed to be vibrating along one direction in its fundamental compressional mode. Arrows indicate what the motion of the particles of the plate would be during one-half of the cycle of vibration; during the other half the direction of motion would reverse. The crystal expands and contracts, as though it were a block of rubber. The dotted line N is the nodal region, in which the particles would remain stationary.

Evidently there is possible another compressional mode of vibration, in the other direction across the crystal as shown at B, similar to the first except that its natural frequency is in general different. It can readily be seen that these two are closely interconnected, for when the plate is elongated in one direction, it tends to grow thinner in the other. The actual resulting motion involves both modes, elastically coupled. Indeed, simple compressional vibrations such as those diagrammed can only be approximated in very long thin bars.

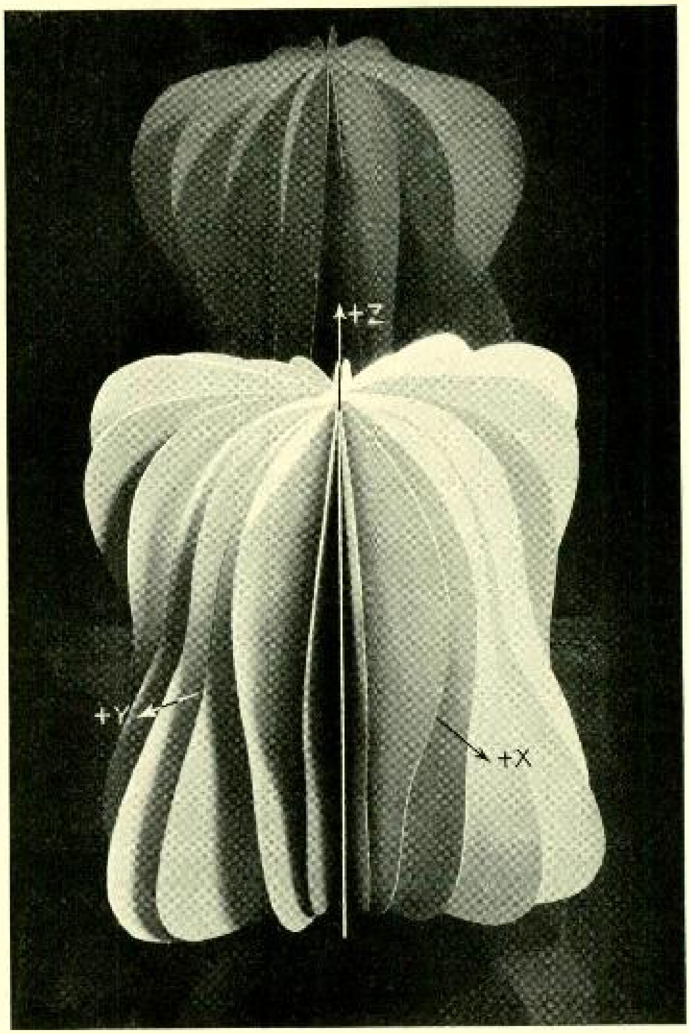

Fig. 2—Young's modulus in crystalline quartz varies greatly with direction, as shown by this model of a three-dimensional polar diagram

The modes of vibration shown in Figure 1 are called *longitudinal* because the particles move along the direction in which the vibration wave is propagated, as they do in sound waves. There are other possible modes, called *transverse* or *shear*, in which the particles move perpendicularly to the direction of propagation of the wave. In Figure 3 is shown such a mode of vibration in a plate. Between most of these and many other modes, elastic couplings exist.

These considerations apply, no matter what the substance of the plate may be. So also does the fact that the elastic constants, determining the vibration characteristics of the various modes and the couplings between them, vary with temperature. In the case of quartz, as of many other crystalline substances, there is the further complication that these elastic constants, and the piezo-electric constants as well, vary with the direction in which they are measured with respect to the crystal axes. For example, Figure 2 shows for different directions through quartz the variation of Young's modulus, the constant which determines how much a given compressive force will compress the material. The range of variation is so large that it includes the values of the moduli for aluminum, brass, copper, gold and silver. Since the value of this constant is obviously one of the factors determining the frequency of vibration in the modes diagrammed in Figure 1, the natural frequency of compressional vibrations in a quartz plate may be expected to vary considerably according to the orientation of the plate with respect to the axes of the crystal from which it was cut.

The complexity of this situation makes one wonder how it could ever be possible to manufacture quartz plates of predictable properties, simple to operate. For ease of manufacture, the frequency of a quartz plate should be a simple continuous function of the dimensions, preferably of a single dimension. It is desirable that the frequency be independent of temperature, or if there is a change that it be linear and continuous. Moreover the plate must be associated with a holder comprising the electrodes; and in the many uses where it must be held rigidly in position with respect to those electrodes, the rigid clamping must be accomplished without appreciably increasing the naturally low damping of the quartz plate.

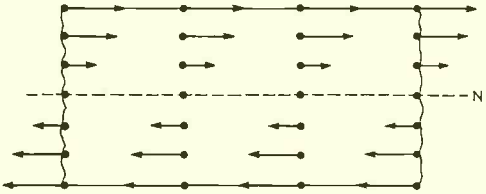

Fig. 3—In contrast to the longitudinal modes of vibration of quartz crystals (Figure 1) there are the transverse modes

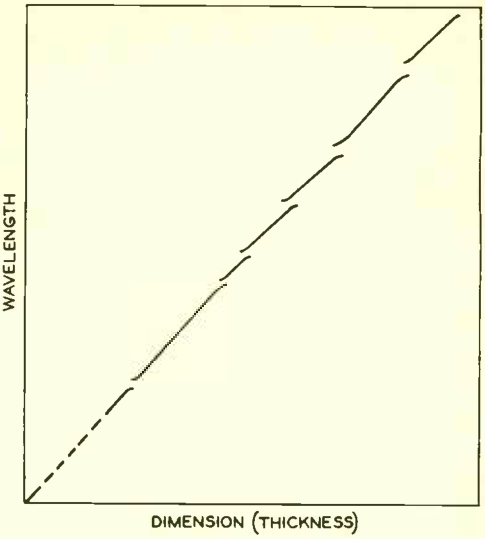

Fig. 4—As the dimension controlling a high-frequency mode is varied, the frequency will "hop" as it reaches the values of the successive overtones of low-frequency modes to which the high-frequency mode of the quartz plate is coupled

Theoretically it is possible to clamp a plate at its vibration nodes without affecting its vibration. Moreover, in many of the simple modes of vibration, the frequency is a continuous function of a single dimension. When, for example, the simple compressional mode diagrammed in Figure 1A is approximated, the frequency varies inversely as the horizontal dimension of the plate. The values of the various elastic constants are also simple functions of the temperature.

In practice, however, the various modes of vibration are often so coupled that the vibration of a plate will "hop" from one frequency to another as the controlling dimension or the temperature is changed. The effects of coupling are most marked when the frequencies of the several modes would be so close to one another if

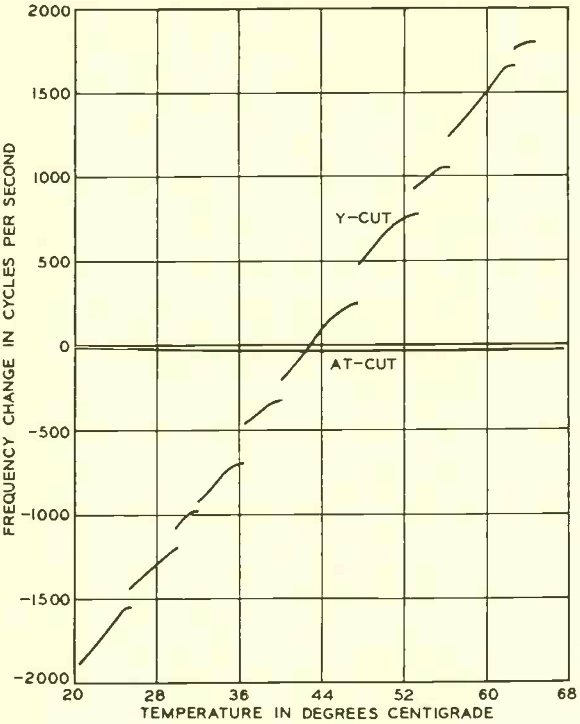

Fig. 5—The difference between the high and discontinuous frequency-temperature coefficient of the Y-cut plate and the low and continuous coefficient of AT-cut plate is due to their different orientations with respect to the crystal axes

uncoupled. If these frequencies depend on different dimensions, the effects of coupling can be somewhat reduced by changing the dimensional ratio. But the prevalence of overtones limits the value of this expedient. The curve in Figure 4 typifies the behavior of a plate in which the upper overtones of several low-frequency modes are coupled to a high-frequency mode, and the dimension controlling the latter is varied. The discontinuities, which arise when the high frequency is close to the various overtones, make it difficult to prepare such a plate for operation at a given frequency. For the same sort of oscillator (the Y-cut), Figure 5, shows the large and discontinuous variation of frequency with temperature, which would require extremely close temperature control when the oscillator was operated. To minimize both these difficulties, the coupling must be reduced.

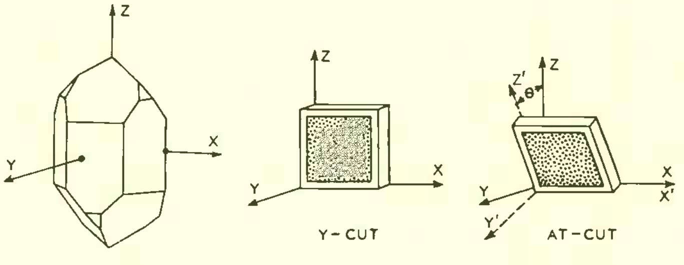

Fig. 6—The orientations of the Y-cut and AT-cut plates, referred to the X (electric), Y (mechanical), and Z (optic) axes of the quartz crystal. See Figure 5 for characteristics

Fortunately one of the complications of quartz can be turned to advantage in such an attempt. The fact that the elastic properties of quartz vary in different directions makes it possible to vary the values of the different elastic coupling constants by varying the orientation of the plate when it is cut. Of course, it is not possible to vary all these constants independently, nor without limit. Moreover care must be taken that a favorable decline in coupling is not accompanied by an unfavorable decline in the piezo-electric constant.

A simple example of how the vibrating properties of a quartz oscillator can be varied by changing merely its orientation is furnished by a very thin quartz bar twelve millimeters long, vibrating in the compressional mode diagrammed in Figure 1. By cutting such bars at different orientations, Young's modulus, its temperature coefficient, and the coefficient of thermal expansion, all take on different values. The varying modulus changes the frequency from 200 to 300 kilocycles, and the varying coefficients change the variation of frequency with temperature from zero to fifteen cycles per degree Centigrade.

A more complicated example, but one of great practical interest, is the AT-cut quartz oscillator developed in these Laboratories. In contrast to the familiar Y-cut plate, which is perpendicular to the Y-mechanical axis, the AT-cut is rotated thirty-five angular degrees in a positive direction from this about the X-electric axis, as shown in Figure 6. Both vibrate primarily in a transverse mode at a high frequency, of which the piezo-electric constant is high, and the vibration is not seriously damped by clamping at the edges of the plate. But a great improvement has been obtained merely by the new orientation, in the frequency-temperature relation, as shown in Figure 5, and in the frequency dimension relation.

A large part of the misbehavior of the Y-cut plate is due to a single elastic coupling constant. It was the discovery that this constant could be reduced to zero, without introducing other couplings, by rotating the cut thirty-one degrees in a positive sense, that led to the invention of the AT-cut. At the thirty-five-degree rotation actually used, the frequency-temperature coefficient also reduces to zero, while the coupling still remains inappreciable.

The AT-cut plate is already finding wide application in controlling the frequency of oscillators. It can be accurately manufactured with greater ease than its predecessors, and in many applications can be operated without temperature regulation over a wide range of temperatures. It forms an excellent instance of the fruitful results which may be expected from research into the elastic and piezoelectric properties of quartz plates.

Dialing Ships at Sea

By P. W. WADSWORTH
Toll Development

WITH the first applications of the radio telephone to ships at sea (RECORD, January, 1930), the ship receivers, connected to either a loud speaker or an operator's headset, were at all times "on the air," and thus heard all calls. This was usual practice with most radio circuits at that time. Stations were called by name and all other stations listening on the same frequency would hear the call. With the increasing use of ship-to-shore radio service, however, some method of signalling only a single ship seemed desirable, so as to make it unnecessary to keep the loud speakers or telephone receivers connected to the circuit at all times. Development work was undertaken as a result, and it is now possible to provide equipment which will permit calling a single ship without the others hearing the call.

With the system developed, each ship has a three-digit number assigned to it, and when the operator at the telephone switchboard wishes to place a call, she merely dials the number of the ship wanted. This sends out a series of tone pulses which are received by all the ships within range. No audible signal is heard, however, except by the ship called. On this ship a telephone bell will ring, and the operator will pick his handset off the hook and answer in the usual manner.

This achievement has been made possible by using the 60 type selector employed for railway dispatch work (RECORD, December, 1926), and by the development of an entirely new circuit for operating it. The 60 type selector, shown in Figure 1, consists of a polarized magnet, the armature of which advances a ratchet wheel one step for each impulse received, providing consecutive pulses are of opposite polarity and occur at a definite rate. Mounted on the ratchet wheel shaft is another wheel, which has holes drilled around its rim. Pins may be dropped into these holes, and a stop arm is provided which will hold

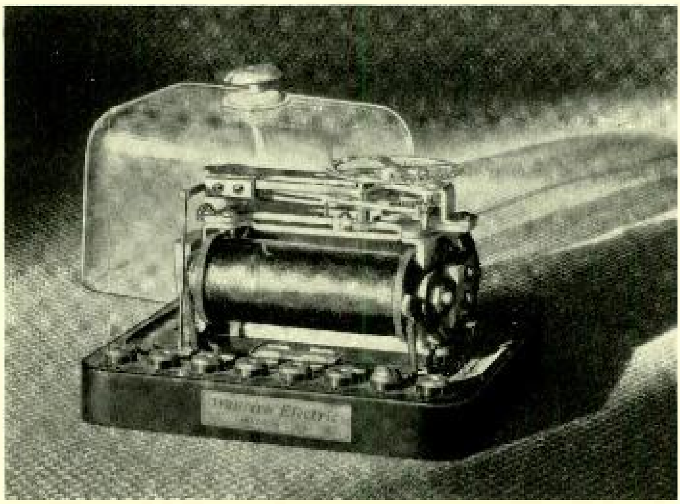

Fig. 1—The 60 Type Selector

the wheel at the position to which it has been turned provided a pin is in the hole opposite the arm at the time the series of pulses ceases. If there is no pin at this point the wheel will be returned to the initial position by a spring. After the wheel has rotated a definite amount, which is adjustable, it makes an electrical contact.

As it is commonly used for ship signalling, this contact is made after a rotation equivalent to seventeen holes on the rim of the wheel. Since three sets of pulses are sent, the sum of the three pulse groups must total seventeen if the contact is to be made, and the pins must be in such positions that the wheel will be held at the position attained after each of the three sets of pulses. Thus such combinations as 2-8-7, 4-7-6, 9-3-5, and some 57 others are capable of closing the contact provided the wheel is held in its position after each pulse group. The pins in the wheels of the selector on each ship are placed in holes corresponding to its particular code number. Thus a ship whose code number is 9-3-5 will have pins in the ninth, twelfth, and seventeenth holes. When this sequence of pulses reaches the selector, therefore, the wheel will be held after each group, and the contact will be made at the end of the final group. The pins in the wheels of the selectors on other ships, however, will be in other holes, so that after one or more of the groups has been received, the wheel will not be held but will return to the initial position and no contact will be made.

The general principle of operation is to transmit tone pulses spaced at the proper intervals by the action of the dial at the calling station. It is just as important, however, to insure that the station will not be signalled except when properly dialed as it is to make sure that it will be called when the proper pulses are sent. In the voice signals and in static picked up by the radio receivers all audible frequencies are present, and if the ringing signals were pulses of a single frequency, it might happen that there would be enough of this particular frequency in voice conversations to other ships or in static to operate the selector and ring the bell. For this reason the system is designed to transmit alternate pulses of 600 and 1500 cycles, and the bell at the called station will be rung only when alternate pulses are received at the proper rate.

The equipment required at the shore station for this system, and its association to the terminal apparatus, is shown in Figure 2. It consists of a vacuum-tube oscillator for producing

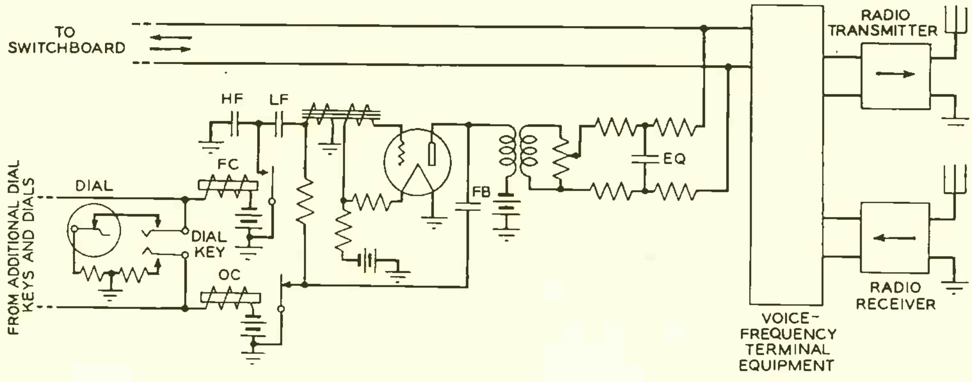

Fig. 2—Sending equipment at shore station and its association to terminal apparatus

both the 600 and 1500-cycle tones, and a key and dial for controlling it. The dial used has a special impulse cam arranged so that a single pulse of the dial either opens or closes the pulsing contacts depending upon the last number dialed. With this arrangement successive pulses alternately open and close the pulsing contacts.

Except during the signalling period, the feedback circuit of the oscillator is grounded through back contacts of relay OC to prevent it from oscillating. The frequency is controlled by the two condensers LF and HF and the relay FC, which short-circuits condenser HF when operated. With relay FC not operated the two condensers in series tune the oscillator to 1500 cycles and with condenser HF shorted the oscillator is tuned to 600 cycles by condenser LF alone. In signalling, relay OC is operated and the oscillator is started by action of the dial key, which also completes the circuit through the pulsing contacts for controlling relay FC and the oscillator frequency. The output level of the oscillator is controlled by a potentiometer and a network consisting of resistances and an adjustable condenser, which causes the outputs for both the 600 and 1500-cycle frequencies to be the same.

The equipment used on board ship is known as the 103A selector set. A simplified schematic of the equipment and its association to the radio apparatus is shown on Figure 3, and a photograph of the selector set is shown in Figure 4. The selector set, consisting principally of a filter, rectifier, pulsing relay, and selector, is normally connected to the radio receiver output through contacts of a transfer relay under control of the switchhook of a telephone set.

From the transfer relay, the output of the radio receiver passes through a double band-pass filter—which is really two filters, one passing 600 cycles and the other 1500 cycles. A rectifier is connected to the output of each filter, and the output of each rectifier is, in turn, connected to a separate winding on the pulsing relay. This relay is polarized by a third winding connected to battery, and the two windings from the rectifier are equal and oppositely poled. When

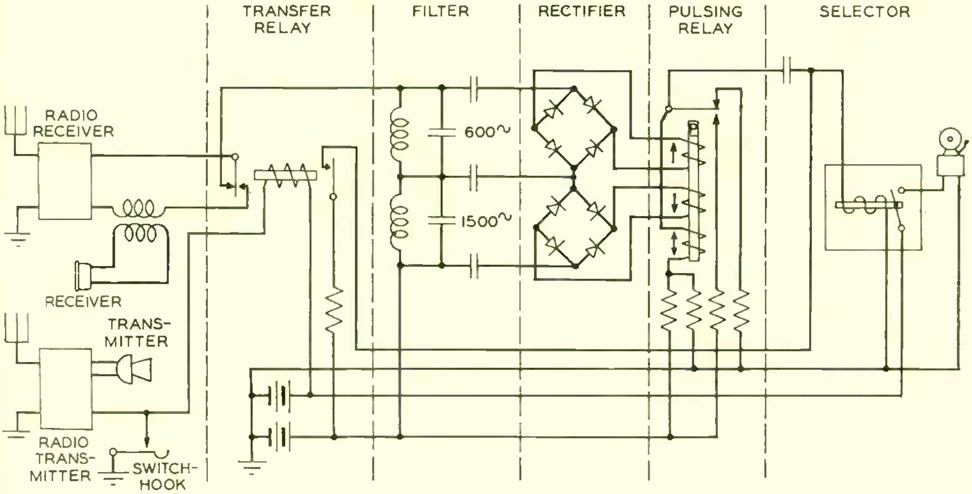

Fig. 3—Receiving equipment on board ship and its association to radio apparatus

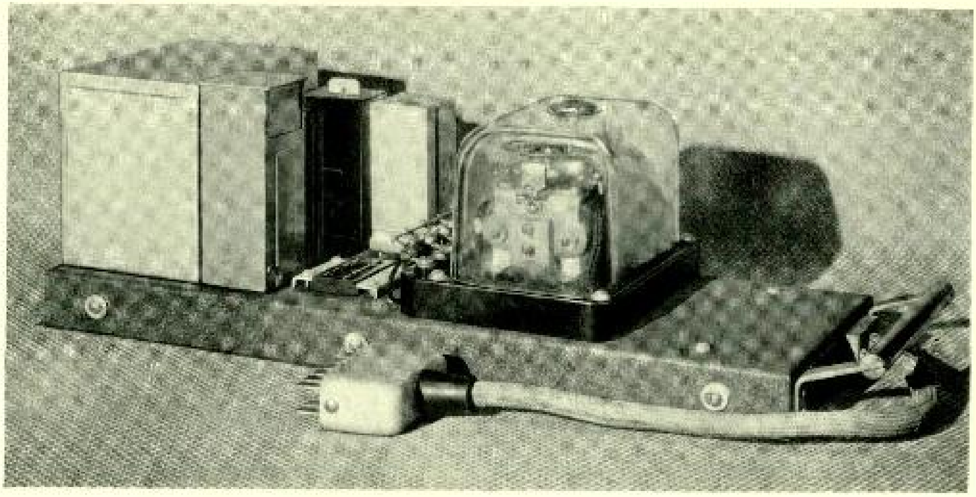

Fig. 4—103A Selector Set. As installed, a dust cover fits over the chassis shown and is fastened to it by three screws along each side of the base

approximately equal amounts of both 600 and 1500-cycle current are flowing, therefore, the two windings oppose each other and the relay does not operate. When 1500-cycle current alone flows, however, the relay is operated to its front contact and current flows through the bias winding in the direction to hold the relay in this position. When 600-cycle current alone flows the relay is operated to its back contact and the current in the bias winding is reversed, holding the relay in this position. Thus alternate pulses of 600 and 1500-cycle current operate and release the pulsing relay and charge and discharge a condenser connected in series with the selector winding. It happens, moreover, that both in voice signals and in static the 600 and 1500-cycle components are nearly equal, and thus the relay will operate only on the signal pulses.

The reversals of current flowing through the selector winding due to charging and discharging the condenser step the selector once for each reversal received. After each series of reversals corresponding to a digit dialed at the sending station, the charging current reduces to zero, and the selector returns to normal unless a pin is in such a position on the rim of the 60 type selector as to be held by the stop arm. The time constant of the circuit composed of the selector winding and condenser is made to respond to frequencies corresponding to the normal speed of the dials used at the sending station. In this way interfering frequencies which might cause false operation of the selector in addition to having their effect equalized by the opposing windings of the relay are further prevented from falsely operating by the necessity of their occurring at a definite frequency.

When a call is answered, the handset receiver is removed from its switchhook, thus operating the transfer relay. This removes the selector set from the radio receiver output and connects the telephone receiver in its place. Also, direct current is connected through the selector winding, which moves the selector off the bell contact and stops the bell from ringing. When the telephone conversation is completed the handset is returned to its switchhook and the transfer relay is released. This returns the selector to normal and reconnects the signal-receiving set to the output of the radio receiver in preparation for receiving calls.

This signalling system is now being used by a number of coastwise and harbor craft, and promises to be applicable to a wider field than the one for which it was designed. Because it uses signals at voice frequency instead of the direct-current signals of the original dispatching service, it is applicable to telephone lines. A signalling system very similar to this one has been developed for use on order wires and private line service, which have a large number of subscribers connected together. The 60 type selector itself is not limited to the ability to respond to 60 codes. Besides the contact at the seventeenth hole others may be placed at the nineteenth, twenty-first, twenty-third, etc., which not only give the possibility of many more code numbers but make it possible to perform different operations at each selector station such as turning on or off lights or starting any type of machine desired.

Telephone Service During the Recent Floods

Gas-filled cables convincingly demonstrated their value in maintaining long-distance telephone service during the recent floods throughout the northeastern section of the country. Due to the information which falling gas pressure gives about minute cracks in the sheath, it has been possible to maintain the continuity of the sheath to a high standard, and the flooding water found few cracks through which to reach the insulation. When battered by floating debris or strained by slipping poles, a sheath began to give way, the gas under pressure delayed the entrance of water. So much nitrogen gas was used to maintain the pressure that a shortage of supply was threatened. When aerial wire lines of the telephone, telegraph and power companies were torn out, long-distance telephone cables continued to function, although in many cases they were deeply submerged for days.

To restore service over the normal routing between the transatlantic control room in New York and the radio telephone station at Houlton, Maine, short-wave radio telephone receiving and transmitting sets designed for airplanes were employed. They were used to bridge the crossing over the Penobscot River at Oldtown, Maine, which was swollen from its ordinary three-quarter mile width to a width of over six miles. Until this equipment was installed, service was maintained by an alternate routing through Calais.

Long-distance calls over the week-end during the time of the worst floods rose to twice the usual volume. On Sunday the traffic handled at Buffalo was 245 *per cent above normal, at Pittsburgh* 211 *per cent, at Cleveland* 137 *per cent, at Philadelphia* 95 *per cent, and at New York* 86 *per cent above normal. To handle this volume of traffic, double the usual number of operators were working at the switchboards at most points. Improvement in repair work had enabled the telephone companies over the week-end to give service at practically the usual speed except to the worst affected points where, due to the local telephone situation, there was some delay in completing calls.*

Lead Sleeve Cases for Loading Coils

By J. E. RANGES
Telephone Apparatus Development

FROM the very beginning of the art of loading, every precaution has been taken in the design of cases for housing the loading coils to promote a long life of uninterrupted service. Since the cases are designed to be used either underground or on poles, this means both that water, or even moist air, must be kept out of them, and that the cases themselves must be protected from corrosion. Leads from the loading coils are brought out through a short length of lead cable, which at the time of installation is spliced into the telephone cable. This "stub" cable, as it is called, is an important feature in the design of the case since a tight seal must be provided where it enters the case. In addition the cable must be protected from possible damage during manufacture, shipment, and handling prior to installation.

For many years the cases were made of high-grade cast iron because of its ruggedness and resistance to deterioration by corrosion. They consisted of cylindrically shaped tanks with tightly sealed covers. The stub cable was brought through and fastened to the cover by a design which permitted a soldered connection between the cable sleeve and a fitting attached to the cover. Metal brackets were provided to protect the stub prior to and after its installation. More recently—in order to obtain lighter, stronger, and less expensive cases—welded copper-bearing steel has been employed, as described in the RECORD for July, 1931.

Both of these types of cases have been made in various sizes to accommodate different numbers of coils, but up to about 1931 the rapid expansion of telephone facilities, involving the extensive use of large-size cables, resulted in greatest demand for the larger sizes of cases. The smaller cases were used chiefly for repair work and special installations. The cessation of large-scale expansion caused by the

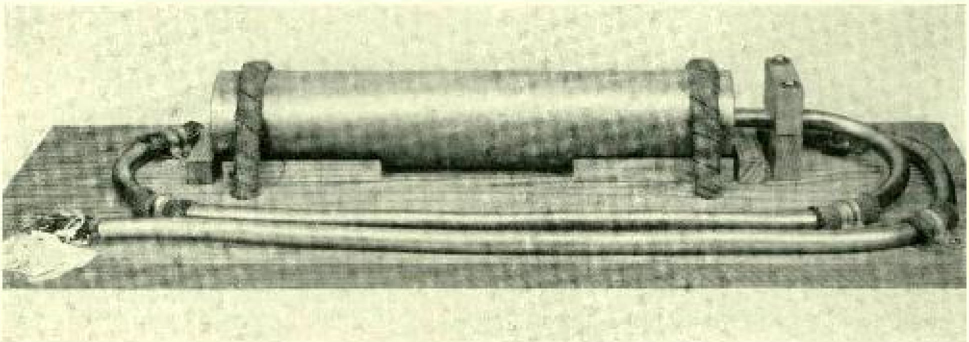

Fig. 1—A lead sleeve loading-coil case for fifteen coils mounted on a board for shipment

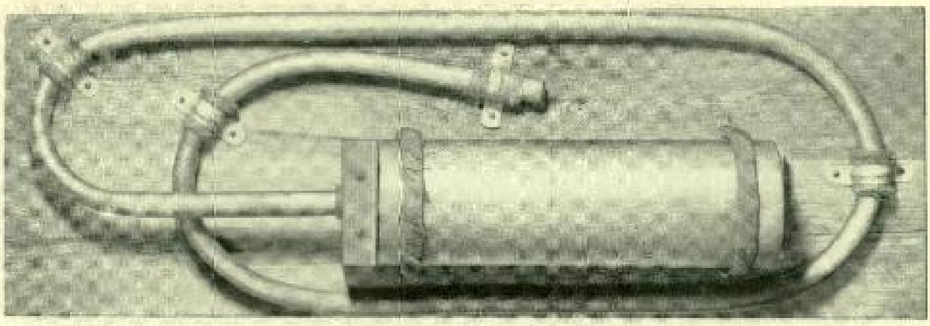

Fig. 2—A six-coil program loading-coil case of the lead sleeve type

business depression resulted in smaller installations of loading coils, and in conjunction with certain changes in loading practice, caused a large relative increase in the demand for complements of loading coils smaller than had been used heretofore. While the former design was economical for large complements of coils, it seemed likely that if a case were designed primarily for a few coils, considerable economies could be obtained. Such a development was undertaken by the Laboratories and a case of distinctly different design was produced.

The new case consists of a lead alloy sleeve, of the type used for splicing telephone cables, with a small stub cable soldered in one end. Cases for fifteen exchange area coils and for six program coils, mounted on boards for shipping, are shown in Figures 1 and 2 respectively.

A lead alloy for housing loading coils has many advantages over other materials which could be used. Sleeves of lead-antimony alloys are made of the correct size and in large quantities for cable splicing, and as a result of the large production, the cost is relatively low. Its properties are well known also, and it is a material that can be easily worked with simple tools. In addition it permits a ready seal between the case and the stub cable. Another important advantage of this alloy is its ability to withstand the corrosive effects of the elements encountered either in aerial or underground installations. No expensive finishes are required to prolong its life. Lead antimony is not so strong as cast iron or steel, but freedom from corrosion, ease of working, and low cost are the controlling factors for the smaller size cases.

Another advantage of the lead case is the greater ease with which it may be installed. With the heavier and more bulky welded case it had been standard practice for the cases to be transported to the point of installation and set in place by a construction gang, specially equipped for heavy work. A splicing gang would come along later to connect the loading with the cable. With the much lighter lead sleeve cases it became the accepted practice for the splicing gang itself to transport and place the cases as well as to splice them into the cable. A comparison in size and appearance of the lead sheath and sheet-steel cases is shown in Figure 4, where both are 5-coil complements, shown arranged for shipment. The steel case is in the form used for underground installations, a different

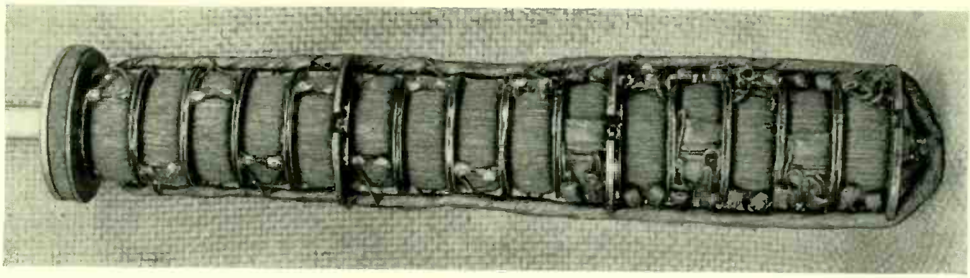

Fig. 3—Coil assembly for 15-coil exchange-area cable as arranged for the lead sheath design

protective coating being used for aerial installations. The lead sheath cases may be used for either type of installation without change. They are also small enough so that they may be suspended from the same steel strand that carries the cable to be loaded.

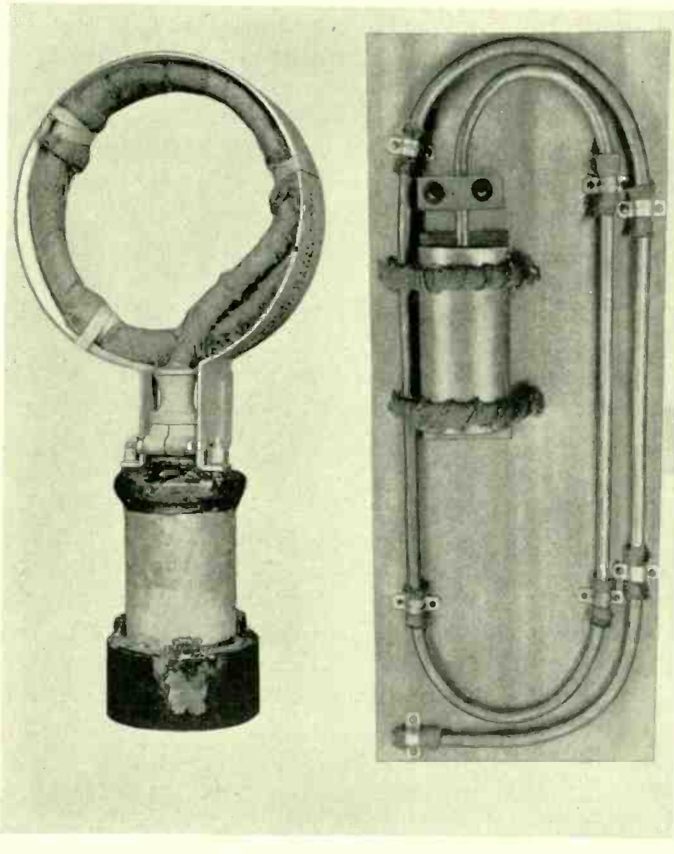

Fig. 4—Comparison in shipping size of sheet steel, left, and lead-sheath loading-coil cases, each housing five coils

An assembly for a 15-coil case, housing the smallest size exchange area coil, is shown in Figure 3. The lead cable that serves to carry the connections to the coils out of the case is employed as the supporting spindle that runs through the center of the coils. The wires of the cable come out at the bottom and are formed into cables running up opposite sides of the coils with leads taken out at each coil. A washer soldered to the sheath of the cable at the bottom, and a cover to the case soldered to the sheath at the top, serve to hold the assembly in position.

The case itself has a lead bottom plate soldered to it, and after the coil assembly has been placed in it, the top is also soldered to form a strong and air-tight joint. When completely assembled, the case is tested with air pressure to insure its tightness, and is then placed in a tank where any moisture that may have been taken up by the textile insulation during assembly is removed by alternate applications of dry air and vacuum at elevated temperatures. This testing and drying is accomplished by means of a small hole left in the cover, and after the drying period, while still under vacuum, the case is filled with an insulating compound through the same hole. The case is then removed from the tank and the hole in the cover plate is sealed.

The new cases employed for program-circuit loading coils are of the same general construction as those described above for exchange area coils. They are somewhat longer and larger in diameter, however, because of the larger coils and increased spacing between them. A special shielding construction is also used in these cases to reduce the effect of cross-talk to a minimum, but in spite of these facts a substantial reduction in size and weight was possible compared to the welded steel cases. The comparative size of the two types is shown in Figure 5. The difference in weight, however, is greater than would be inferred from the photograph, since the lead cases weigh only about one-half as much as the steel ones.

The internal arrangement of these cases is shown in Figure 6. The coils are separated by both steel and insulating washers, and by wood terminal blocks. An inner steel sleeve, shown at the right, slips over the assembly and within the sheath, which it reënforces, thus lessening the likelihood of damage from improper handling. The wood terminal blocks between adjacent coils serve two purposes. They provide the necessary separation between coils to reduce cross-talk, and also, by means of terminal punchings, simplify the connection of coil leads to the wires of the stub cable.

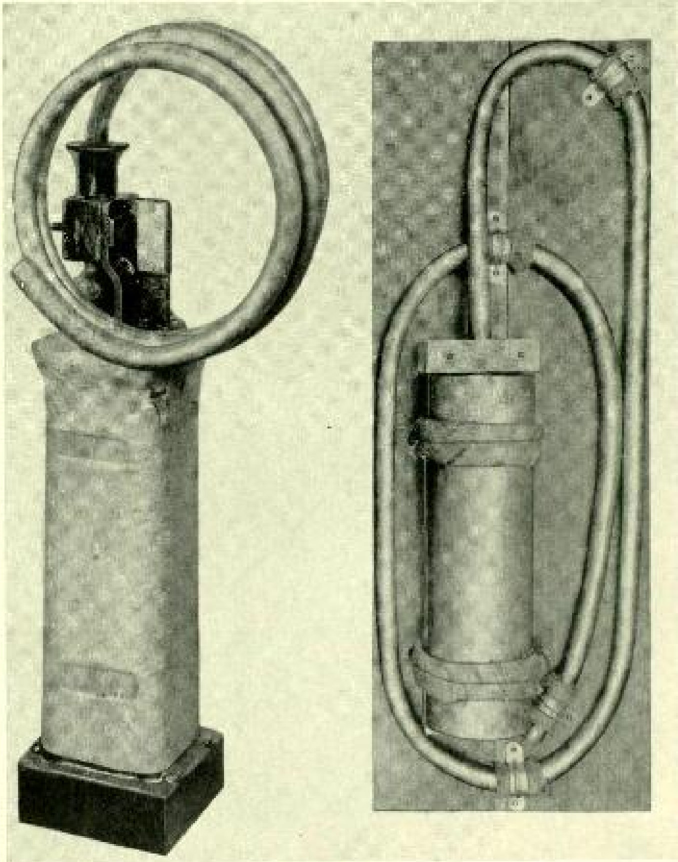

Fig. 5—Comparison of welded-steel and lead sheath loading-coil cases for loading program circuits, each case housing six coils. The lead case weighs one-half as much as the steel

The program loading coil cases are of two types, each containing either four or six coils. These two types differ only in the method of impregnating the coil assembly and in the filling of the case. With one type, the drying, impregnating, and filling the case with compound is carried out in the same manner as described for exchange-area cable cases. This type is designed primarily for use in underground installations. For aerial cables, the filling compound is omitted, and instead, specially dried air is employed to fill the spaces around the coils. With this latter type the coil assembly is dried and impregnated with compound before it is assembled in the lead housing. After the case has been sealed it is tested for leaks under pressure and then filled with air at a pressure of ten pounds per square inch. These cases also may be suspended directly from the cable.

These new cases are available for complements of fifteen or less coils of the sizes for which the design has been completed. Their light weight, small size, and low cost should prove of great advantage wherever only a small complement of coils is required.

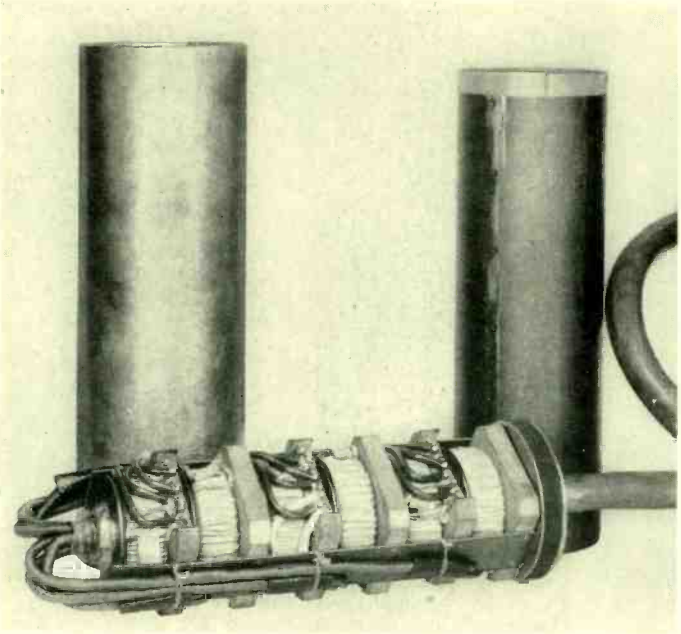

Fig. 6—The internal arrangement of the program loading-coil cases differs because of the more effective spacing and shielding required for this type of service

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esting the stability of uning-fork oscillators, in he carrier telephone laboratory.

II

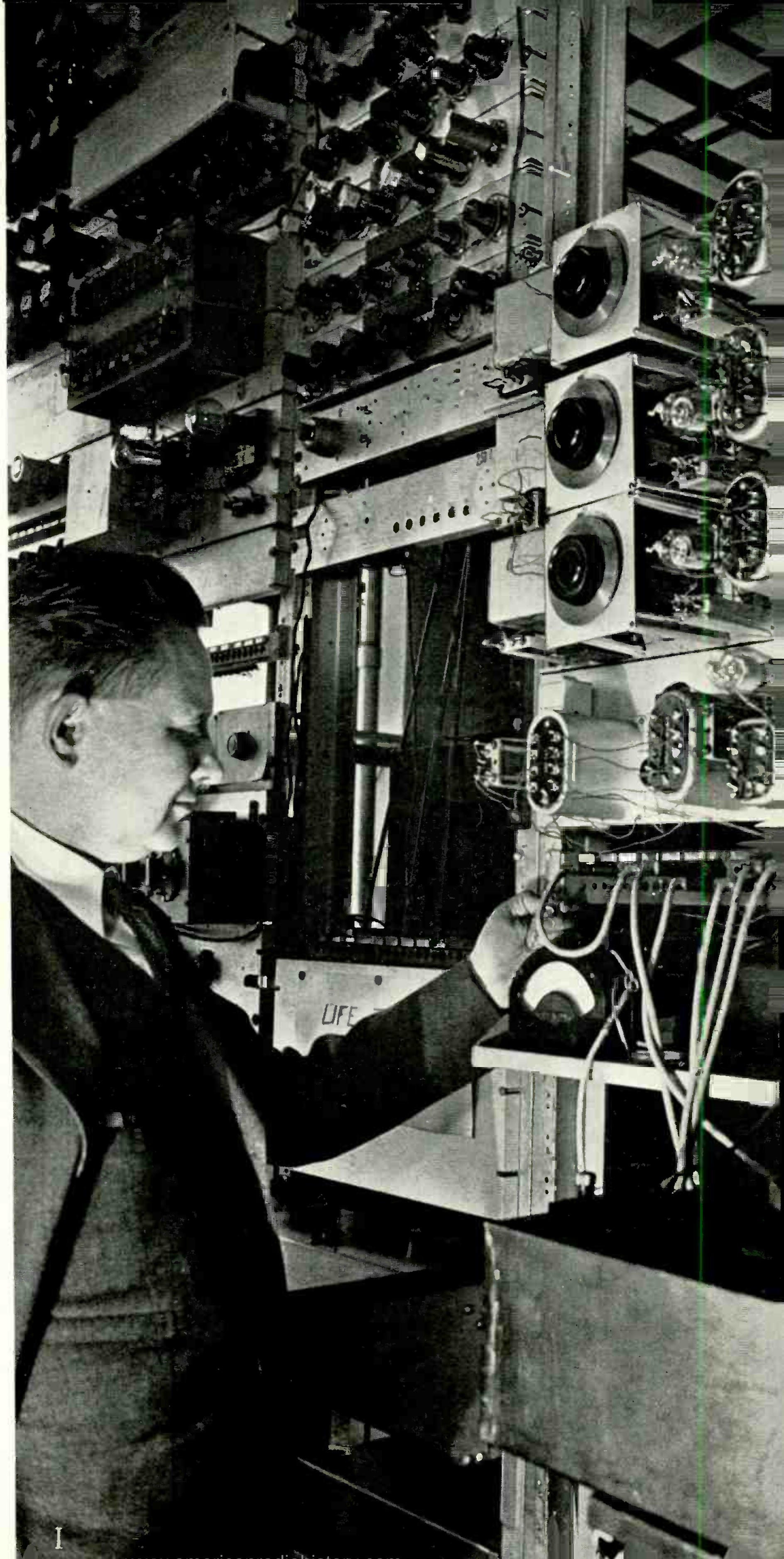
Equalizing network.

III

Cleaning quartz crystals.

IV

Patching panel for testing toll lines.



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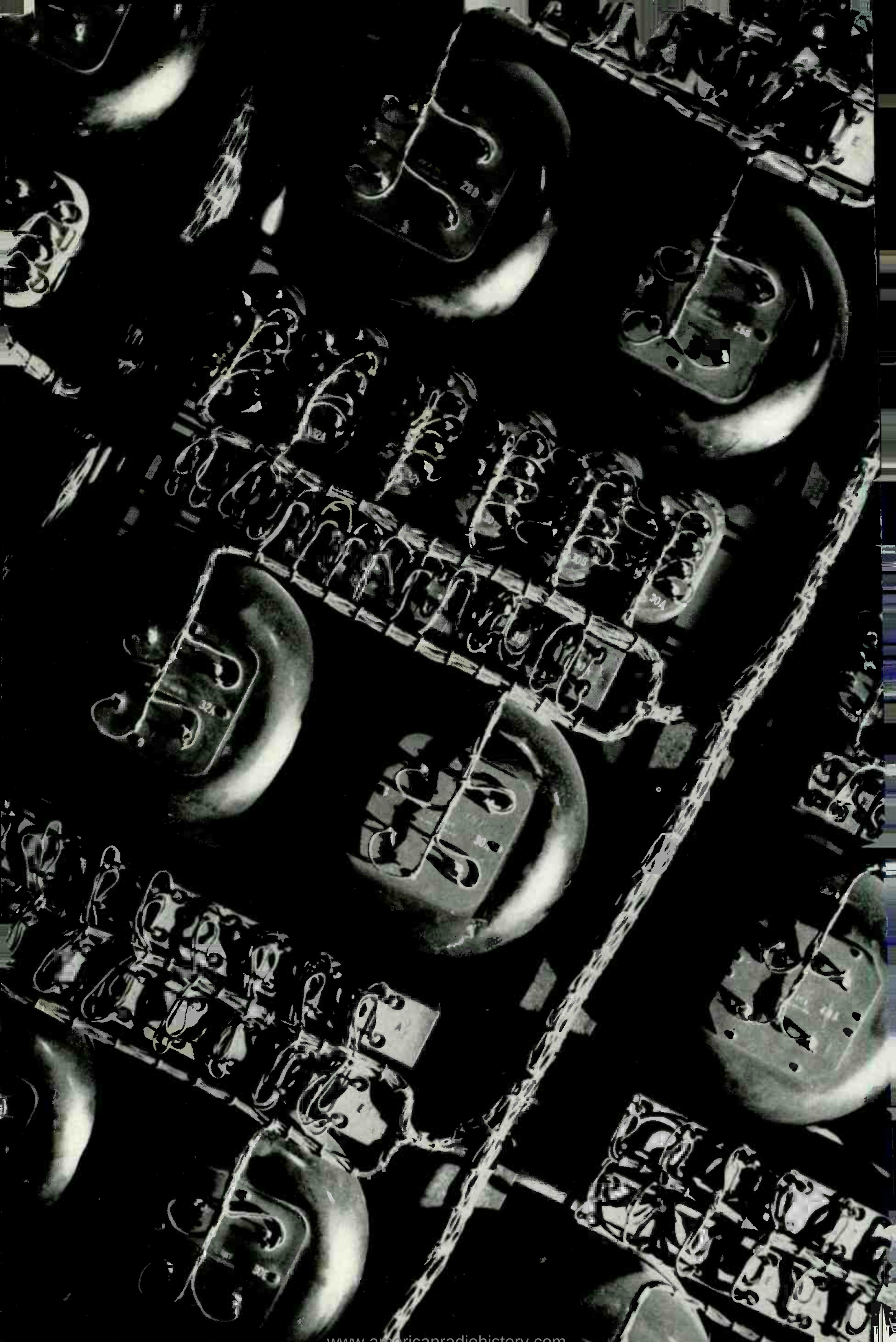
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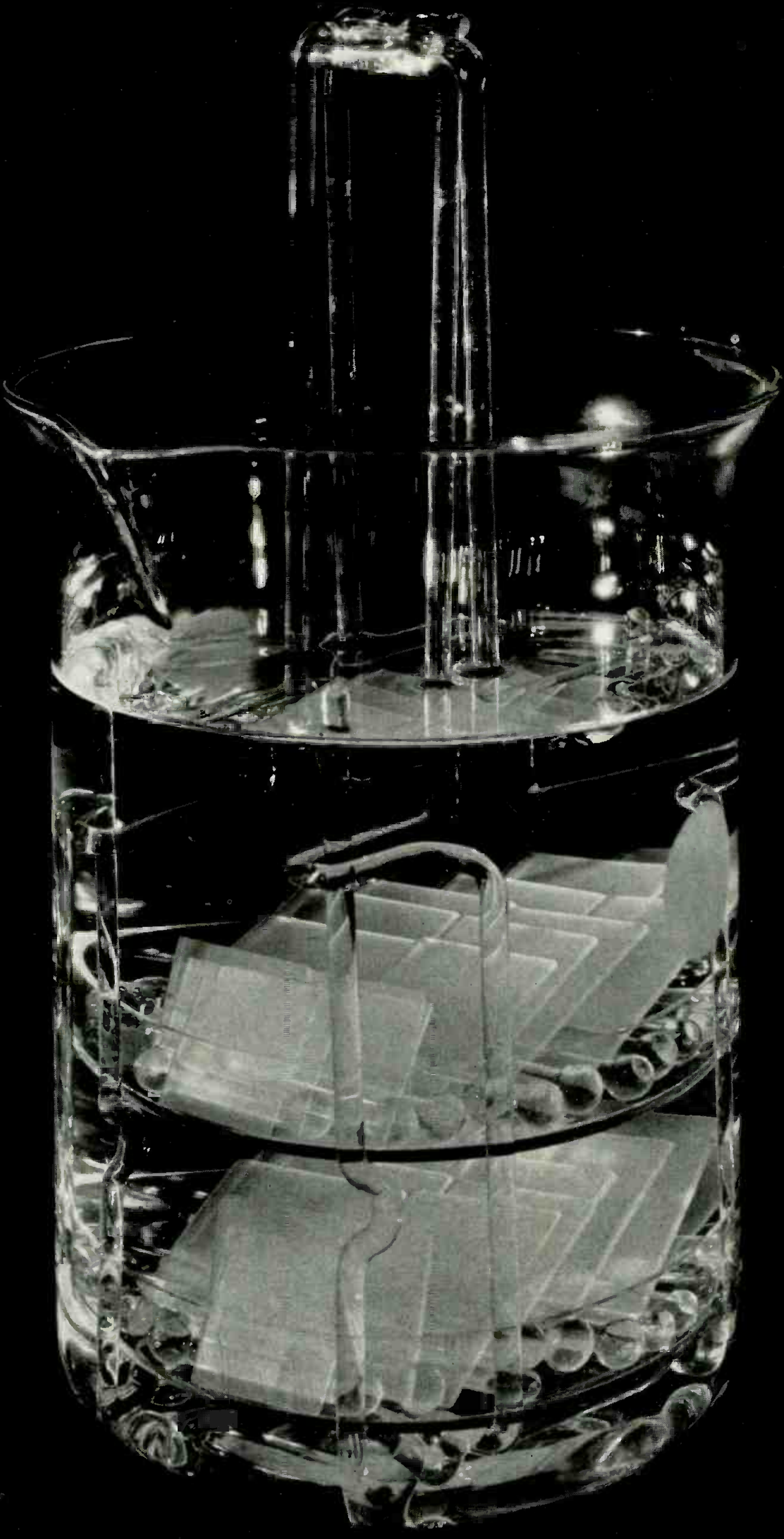

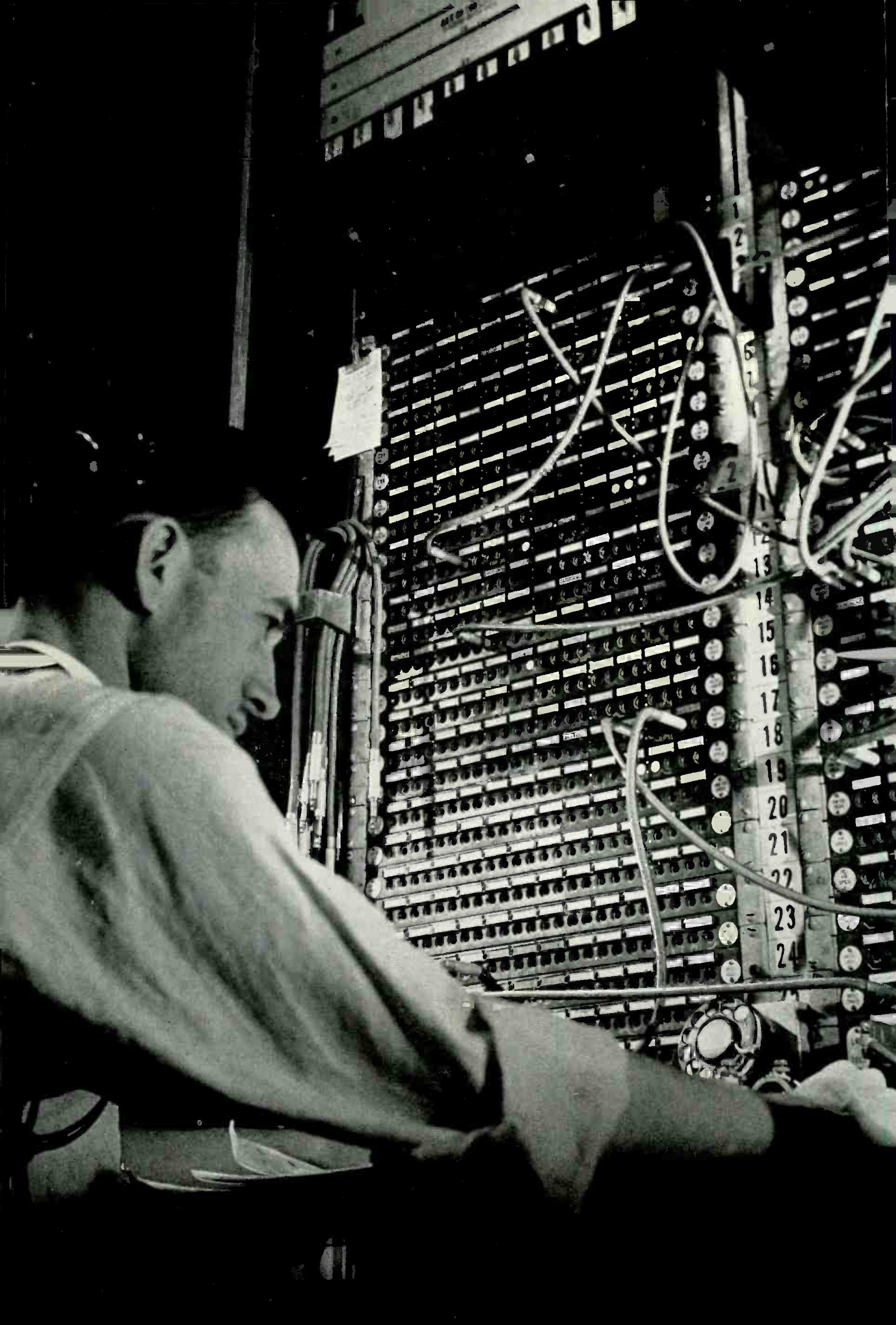
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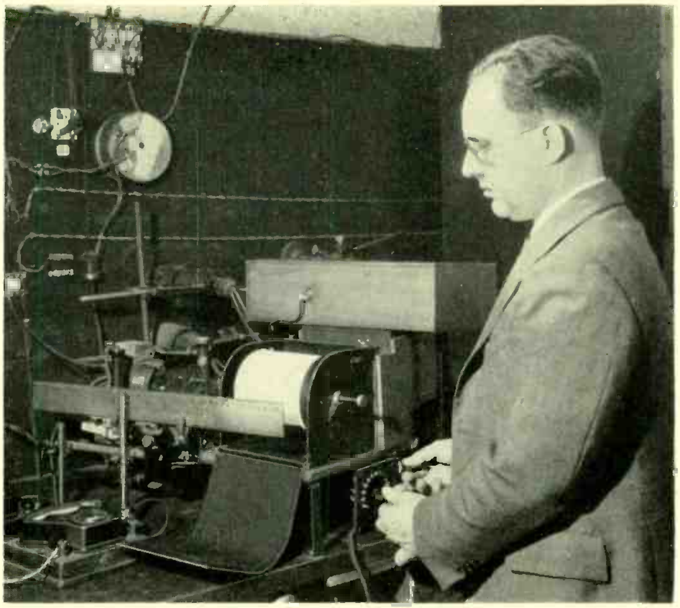

High Permeability and Plastic Flow in Magnetic Fields

By JOY F. DILLINGER
Physical Research

THE curious fact that the magnetic properties of iron and silicon steel are somewhat affected by cooling from high temperatures in a magnetic field has been known for years. Recent experiments have uncovered this effect in greatly accentuated degree in some of the new magnetic alloys of iron, nickel and cobalt, where the maximum magnetic permeability has been increased from 20,000 to 600,000. Experiments on other materials lead to the conclusion that this effect will be observed only when the material, in cooling, passes the Curie point and becomes magnetic at a temperature at which plastic flow can take place. Iron and other materials which harden before becoming magnetic show only very small changes in permeability when cooled in a magnetic field.

The lowest temperature at which the heat treatment is effective can be identified with that at which plastic flow begins to occur as the result of the forces brought into play by magneto striction. This plastic flow hypothesis is in accord with all the experimental data provided we can show how plastic flow in the presence of a field increases the permeability in the direction of that field. In order to understand this we start with the idea, as first proposed by Weiss many years ago and recently discussed by Webster, Heisenberg, Becker and others, that a magnetic material is composed of small domains, in each of which the material is magnetized to saturation in some direction. In iron and permalloy this direction is one of the cubic axes of the crystals but in an unmagnetized polycrystalline specimen, in which the crystals are oriented at random, some domains are magnetized in every possible direction. As the field is applied the magnetization of the various domains changes by 90 or 180 degrees to become more closely aligned with the field.

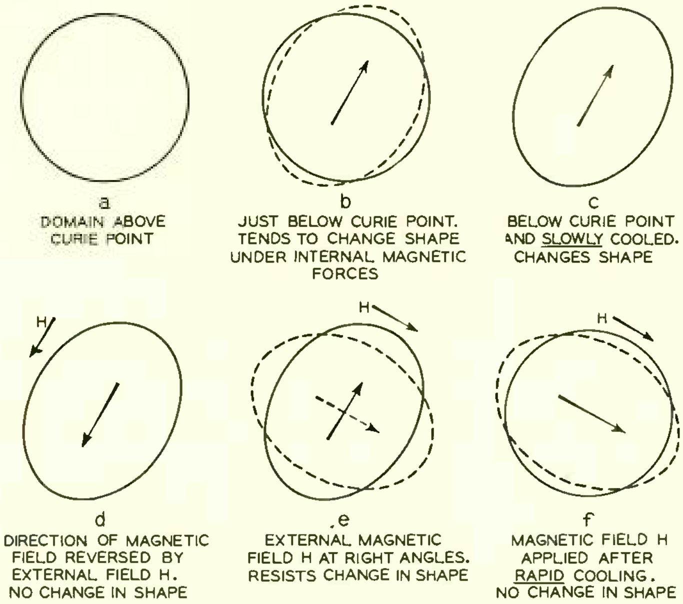

Fig. 1—A magnetic alloy may be assumed to consist of small domains each magnetized to saturation. These domains orient themselves in a magnetic field and permanently change shape if the alloy is at a sufficiently high temperature to permit plastic flow. Subsequent magnetization takes place more readily in the direction of the original field

Now consider what will happen to these regions as the material is heated above the magnetic transformation point. More specifically let us take, as shown in Figure 1 (a) a region, assumed spherical for convenience, which is above the magnetic transformation point, but which will form a magnetized domain when cooled below this temperature. As shown in (b), it will become magnetized along one of the cubic axes; but as it does so it will tend to change its shape. If time is allowed, it may actually assume by plastic flow an ellipsoidal shape as shown in an exaggerated form in (c). Then when the material is cooled to room temperature and is magnetized in the direction indicated in (d), the magnetization in this domain will reverse by 180 degrees to one of its other stable positions more closely aligned with the field. No change in shape will occur during this change in magnetization. If, however, still at room temperature, we apply the field at right angles as indicated in (e), the domain will tend to change its shape as shown by the dashes. But this change will be opposed by the mechanical constraints due to the surrounding material and will be effected with very much more difficulty than when the field is applied in the direction shown in (d). If in another experiment the material is cooled rapidly enough through the magnetic transformation point down to a temperature less than 400 degrees Centigrade, there will be insufficient time for any change in shape to occur by plastic deformation and the domain will maintain more or less its original spherical form. In such a condition (f) the magnetization of the domains may change from 90 or 180 degrees with equal facility.

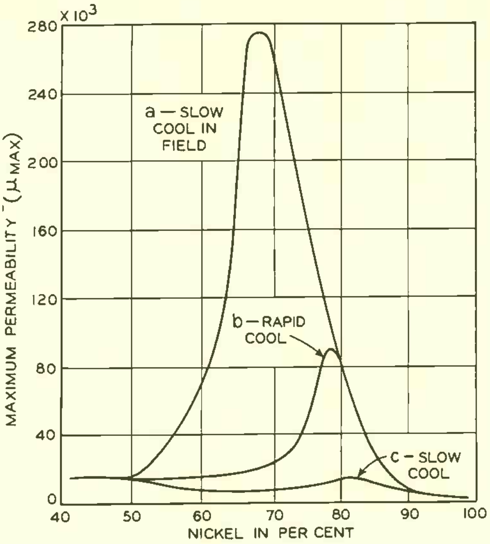

Fig. 3—The increase in permeability which results from heat treating in a magnetic field is very large for some permalloys as is shown in curve (a). The other curves give for comparison the permeability when the same alloys are cooled rapidly (b) or slowly (c) without applying a magnetic field

When a material is magnetized the domains will try to orient themselves as nearly as possible in the direction of the applied field, and if the temperature is sufficiently high, plastic flow will occur to relieve the strains produced by the magnetization. Under these conditions after the material is cooled to room temperature and demagnetized the domains will still retain their preferred directions and it will be relatively easy to remagnetize the specimen in the direction in which the magnetic field was applied during heat treatment. To magnetize the material at right angles to that direction, however, each domain must change by 90 degrees and very large mechanical forces will be operative to resist this change. This simple picture, then, indicates why the permeability should be higher in a field applied in the direction of the field used during heat treatment and lower when applied perpendicular to that direction. Actually the ratios of these permeabilities may be as much as 150.

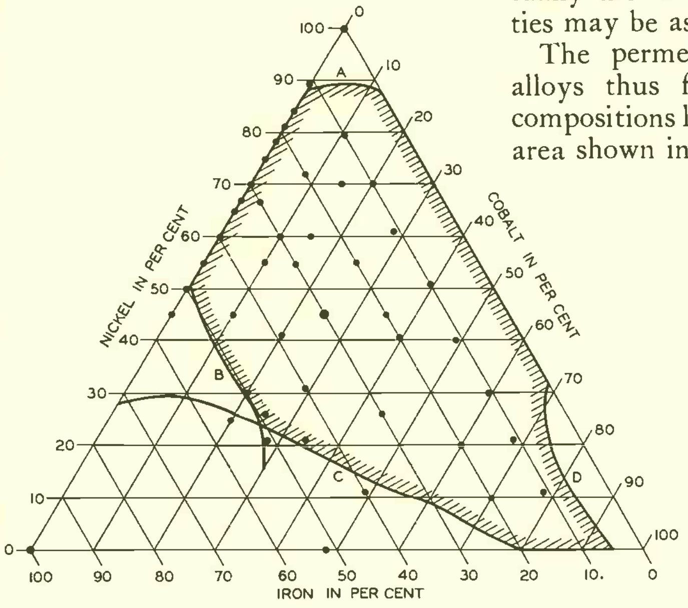

Fig. 2—The permeability of alloys whose compositions lie within the area enclosed by the heavy line is increased by heat treating in a magnetic field

The permeabilities of all of the alloys thus far tested which have compositions lying within the outlined area shown in Figure 2 are increased by such heat treatment in a magnetic field. The magnitude of the result and the bearing of the composition of the alloy on the effect is illustrated in Figure 3, where the maximum permeability of a series of iron-nickel alloys is given. Curves b and c show for comparison the permeabilities obtained when similar alloys are rapidly or slowly cooled without an applied field.

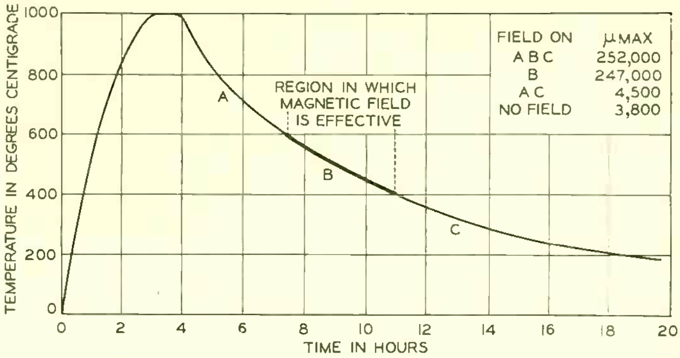

Fig. 5—The temperature range in which the effect of cooling in a magnetic field is most effective in increasing the permeability of 65 per cent nickel permalloy is from 600° C. to 400° C.

The experimental procedure in studying these effects was to prepare rings of the material 8 cm. in diameter, 0.015 cm. in radial thickness and 0.3 cm. wide, made from one turn of tape overlapped about 0.4 cm. and spot welded. Each ring was placed in a toroidal lavite box and wound with deoxidized copper wire for magnetizing. It was then annealed in hydrogen at about 1000 degrees Centigrade for one hour and cooled in the furnace while a magnetizing field of 16 oerteds was applied. After annealing, each sample was placed in a second toroidal box to protect the specimen from strain and two windings were applied on the outside of this box for the magnetic measurements. These were made with a Haworth fluxmeter.* Hysteresis loops were photographically recorded with the same instrument. The shapes of the loops obtained with alloys annealed in a magnetic field are often very different from those usually found as is shown in Figure 4.

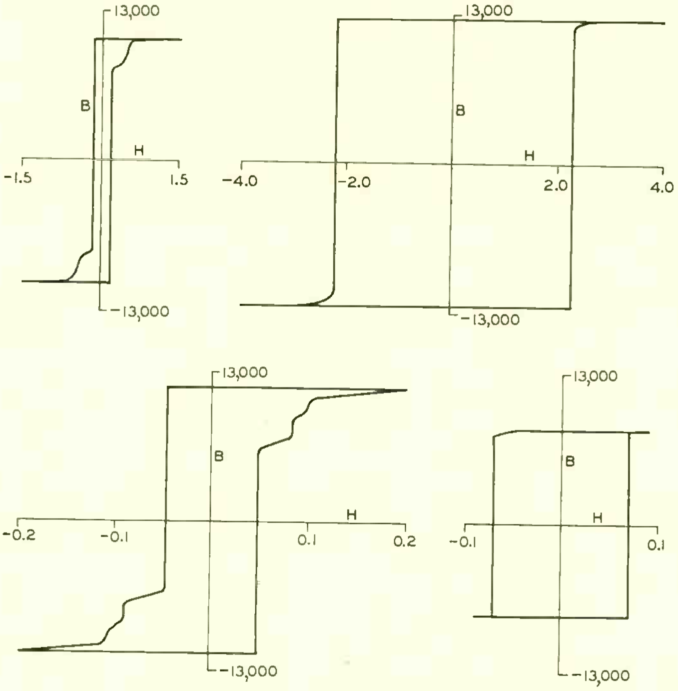

Fig. 4—Hysteresis loops obtained with alloys cooled from a high temperature in a magnetic field are often very different in appearance from those normally found. The vertical sides represent changes in magnetic flux which are not instantaneous

To find the temperature range in which the application of the field is important, several specimens of permalloy from the same casting were heated to 1000 degrees Centigrade and cooled to room temperature while a magnetic field of 10 oersteds was applied during the temperature intervals indicated in Figure 5. The

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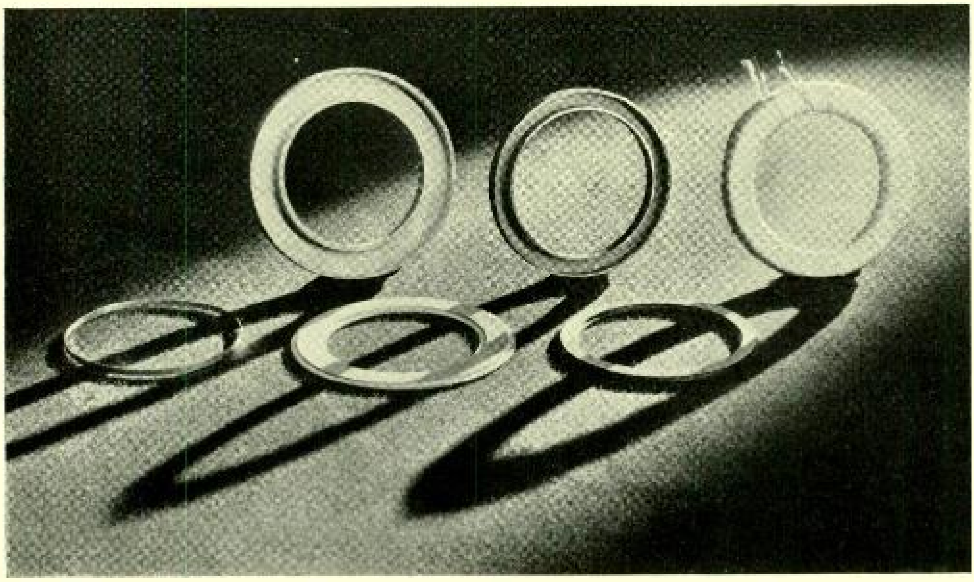
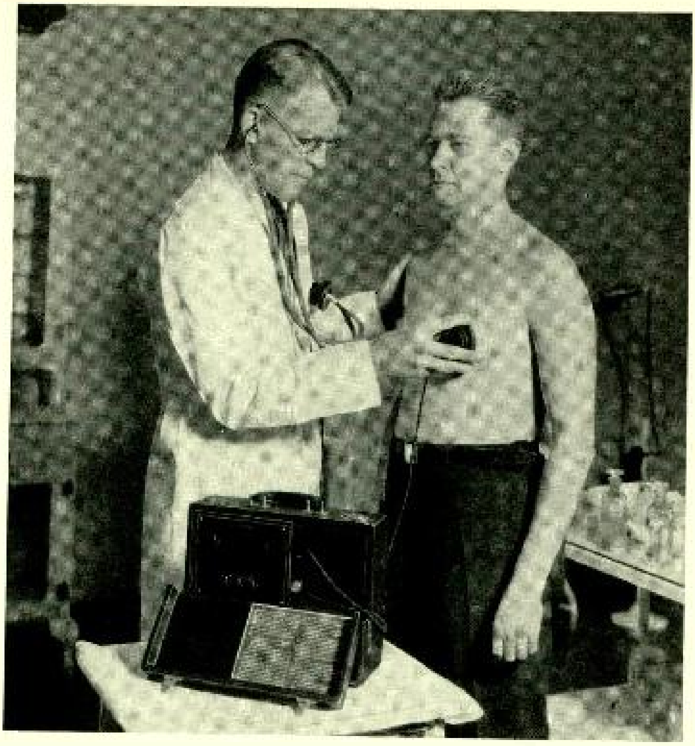
*Record, *December*, 1930, *p.* 167.

effect upon the maximum permeability, as measured at room temperature, shows that application of the field as the specimen cools from 600 to 400 degrees Centigrade, increases the maximum permeability from about 5000 to 250,000, or by a factor of 50. By very carefully annealing permalloy containing 65 per cent nickel at temperatures just below its melting point in an atmosphere of hydrogen and then heat treating in a magnetic field, the high permeability of 600,000 has been attained.



In studying hysteresis effects a ring of the material is placed in a toroidal box which is wound with copper wire for magnetizing



An Electrical Stethoscope for the General Practitioner

By W. L. BETTS
Special Products Development

FOR a number of years the Western Electric Company has had available an electrical stethoscope suitable for diagnosing heart ailments and for all other forms of auscultation in places such as hospitals, where portability of the apparatus is of minor consideration. This instrument is of the "tea wagon" type, and, besides being equipped with a number of filters to permit the isolation of various bands of frequencies, is arranged for multiple listening, so that a group of students can listen to sounds while their cause and significance are explained by the instructing physician. The great advantage of amplification, possible by the use of an electrical stethoscope, was brought out by experience with this instrument and has indicated the desirability of an electrical stethoscope arranged in a more portable form. As a result the Laboratories has recently developed a new stethoscope, known as the 3A, which is small and light enough to be carried around by the general practitioner.

In this new instrument, size and weight have been decreased by limiting the number of possible listeners to two, by eliminating most of the filters employed by the former type, and by a careful design and selection of apparatus with the objective of reducing weight without affecting the usefulness of the instrument. The new stethoscope consists primarily of a magnetic "pick-up" and receiver and a two-stage amplifier operated by dry batteries. It is completely housed in a small carrying case about a foot long, nine inches high, and less than five inches deep.

The pick-up employed for the stethoscope is a modified telephone receiver. A projection from the diaphragm, in the form of a truncated cone, is pressed against the patient's chest and the heart sounds vibrate the diaphragm, thus producing in the windings of the magnets weak electrical pulsations which are increased in strength a million-fold by the amplifier. The case of the pick-up is held by a flexible rubber ring to prevent vibrations being transmitted to it from the physician's hand, and the case itself is made heavy so as to remain practically motionless while the light diaphragm is vibrating. This pick-up is remarkably unresponsive to extraneous sounds, and has a frequency range running from 60 cycles to 1500 cycles, which easily covers the heart sounds.

The amplifier has a maximum gain of 60 db, and a power capacity sufficient to supply several receivers at acoustic-stethoscope loudness. Its frequency-gain characteristic is essentially flat over a range in excess of that covered by the pick-up. It is mounted in a compartment directly behind the control panel, and is accessible by unscrewing a thumb screw, which allows the entire metal chassis, shown in Figure 1, to be removed from the carrying case. A front view of the control panel and battery assembly is shown in Figure 2. A single volume control is provided which turns the amplifier off at the extreme left position and gives increased volume as it is turned to the right. The only other control is a filter switch, which cuts in or out a filter that diminishes the response at both the higher and lower frequencies. The effect of this filter is to diminish the normal heart sounds but to leave unaffected any murmur sounds that may be present, thus making them more plainly audible.

The batteries are installed in the two bottom compartments of the chassis. These are a filament battery, consisting of four flashlight cells, No. 950, and two No. 768 plate bat-

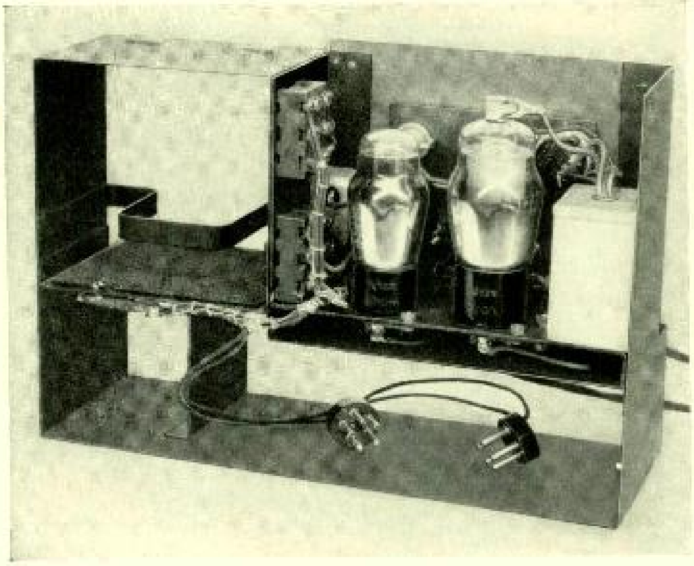


Fig. 1—The component parts of the portable electric stethoscope for diagnosing heart ailments are carried on a metal chassis, which fits into a small carrying case

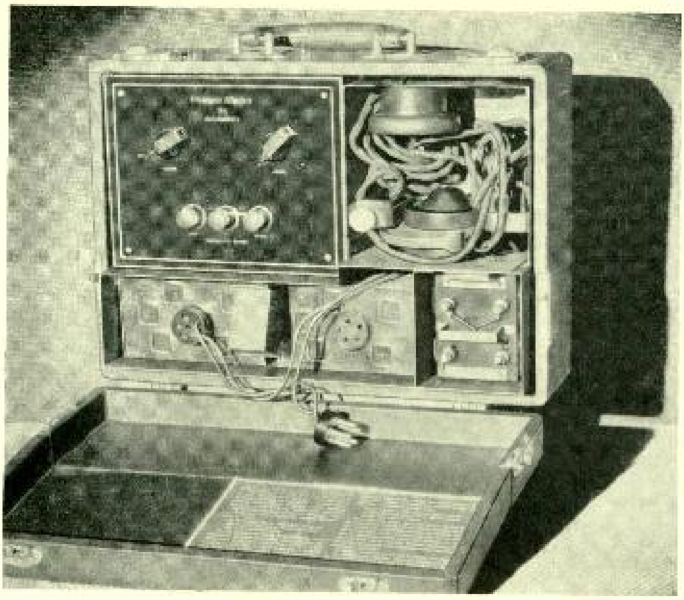


Fig. 2—Filament and plate batteries occupy the lower part of the chassis, the amplifier is behind the control panel at the upper left, while at the upper right is space for the pick-up and the receiver

teries. The latter are of the plug-in type, having their terminals brought to receptacles mounted in the top of the battery. This simplifies replacement, since the leads used to connect to them are terminated in polarized plugs so that they cannot be incorrectly inserted. The arrangement of the batteries in the chassis is shown in Figure 2.

Like the pick-up, the receiver is also of the usual telephone type, but is provided with a special cap to allow the attachment of the tubes of an acoustic stethoscope. These tubes somewhat modify the quality of the sounds heard, and they are employed with the electrical stethoscope instead of headphones so that the sounds heard will be as nearly as possible like those heard with the usual acoustic stethoscope. This receiver is directly connected to the amplifier, but a set of binding posts is provided on the front of the control panel so that a second receiver may be connected if desired, thus permitting two physicians to listen simultaneously to sounds being picked up. Such an arrangement is often of considerable value in consultation work.

The operation of the stethoscope is very simple. The physician attaches the tubes of his acoustic stethoscope to the receiver, fastens the receiver to his coat by means of the clip provided on its back, and turns the set on by moving the volume knob clockwise until the desired loudness is reached. He holds the pick-up by means of the rubber ring, and presses it lightly against the patient's body as he would the bell of a regular acoustic stethoscope. For certain types of diagnosis, such as of murmur sounds, the knob on the front of the case marked "Filter" may be turned to its "In" position.

It has been observed that with a portable electrical stethoscope of this type, the loudness of heart sounds can be increased about 20 db, or to an intensity 100 times that obtainable with an acoustic stethoscope. Such an instrument will perform invaluable service for the physician and medical student whose hearing is impaired, and will also allow one of normal hearing to listen to sounds which would be inaudible with an acoustic stethoscope. The electrical stethoscope thus becomes an invaluable aid to the physician by enlarging the field of possible diagnosis.

Life Test Recorder

By D. A. McLEAN
Chemical Laboratories

IN researches dealing with materials for use in telephone apparatus such as condensers, it is often necessary to make life tests. When test conditions are severe and the life correspondingly short, it is frequently helpful to know within relatively narrow limits the time at which each unit under test failed to perform. A recorder especially adapted for such purposes has been developed by the Laboratories in which the record is made on a circular waxed paper disc. A metal stylus, mounted on a radial arm which rotates above the record, does the recording. This stylus is advanced radially $^1/_{32}$ inch per revolution by a screw attached to the rotating arm.

The outer extremity of the radial arm holds a commutator spring which contacts successively as it rotates with each of a series of 120 points on the periphery of the base plate of the recorder. Each of these contacts corresponds to one condenser unit under test. The recording stylus is attached to the armature of an electromagnet which is mounted on the radial arm.

If a condenser has failed a signal fuse completes the circuit when it is tested. This actuates the electromagnet and causes the stylus to make a single rapid movement back and forth radially, thus making a short line at right angles to the record spiral. The closed circuit and the corresponding condenser are identified in this manner and the time of occurrence is determined by the distance of the mark from the center of the record. The recorder can be set to rotate either once per hour or four times per hour. The record covers four days on the former basis.

The recorder is driven by a small 110-volt a-c. motor which connects directly to the lighting circuit. The speed reduction is approximately 100,000 for the slower speed and is obtained by using worm gears. The accuracy with which the time can be determined depends on the speed of rotation of the commutator arm. This speed can be varied over wide limits if desired by changing the reduction ratio of the driving motor.

Recorders of this type can be adapted to show the time of occurrence of any phenomena which can be indicated by an electrical impulse and will be found useful for various purposes of this general character.

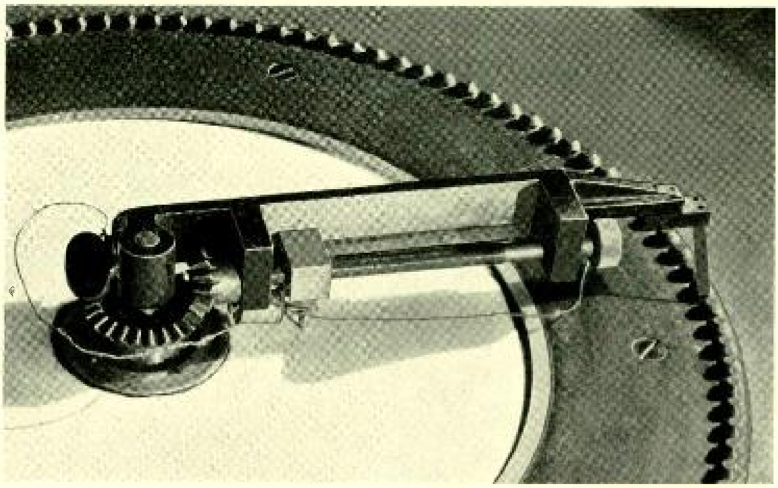


Fig. 1—The record is made on a disc of waxed paper by a metal stylus mounted on a radial arm which rotates above the record. Each circuit in question is tested in succession by a spring which contacts with the buttons on the periphery of the recorder as the arm rotates

Field Trial for New Two-Wire Toll Circuits

By H. A. ETHERIDGE, JR.
Toll Transmission Development

IN recent years it has been found desirable to design a new short-haul two-wire system for toll cables which would be in step with the present trend of the toll plant as regards both transmission performance and economics. A study was therefore undertaken to determine the requirements for all parts of such circuits, and from these studies a new short-haul system was developed which is a decided improvement over the existing two-wire facilities.

To meet the requirements for the great majority of toll-cable layouts, where the repeater spacings are under fifty miles, the H-88-50 loading system was designed, the 88-millihenry coils for the side circuits and the 50-millihenry coils for the phantom circuits being spaced six thousand feet apart. To meet, in addition, the condition frequently encountered where the repeater spacings exceed fifty miles, and of necessity range up to as much as sixty-five miles in length, the B-88-50 loading system was designed. This system employs coils having the same inductance as the H-88-50 system, but the spacing between coils is three thousand feet.

For use on these new loading systems there was made available for trial a new two-wire repeater which provided improved transmission performance. To allow existing repeaters to be used on these systems, slight modifications in the existing standard repeaters were worked out, which by improving their transmission performance made them suitable for these new systems.

Development work on new circuits includes laboratory tests on all the various parts involved, but before such a system can be approved for Bell System use, extensive field trials must be made to determine the operation of the system as a whole under field conditions. These trials must be made on a large number of circuits so that manufacturing variations in the various elements may be studied statistically. Only after field trials of this type can the performance of the circuit under all conditions be satisfactorily predicted.

For the field trials of the new two-wire system, nineteen quads of one of the cables running between Newark and Philadelphia were employed. About half of them had the 6000-foot loading-coil spacing, and half the 3000-foot spacing. At Newark, Princeton, and Philadelphia twelve repeaters of the latest type, together with six repeaters of the modified type, each with its associated office equipment, were also made available for the trial. The purpose of using this large number of quads was not only to get statistical information, made possible by the large number of the various circuit elements, but to secure longer circuits by looping back between repeater points, and to secure the equivalent of longer repeater sections by splicing back at certain loading points.

Field trials of this type are not short undertakings. Tests must first be made on individual pieces of apparatus and on the lines, then on the office apparatus, then on the overall performance of a repeater section, then on the circuit as a whole between terminals, and finally on the circuits when employed as links in built-up connections. These tests include measurements of impedance, of noise and crosstalk, of the change in attenuation with frequency, and of return loss between the line and network circuits, which is a measure of their impedance similarity. Conditions of balance must be determined at all points and singing margins ascertained, and talking tests must be made to check the estimated effects of echoes on overall transmission. The information gathered must then be analyzed and the results compared with the requirements originally laid down. Any failure to meet specifications must be analyzed so that recommendations can be made as to the needed improvements.

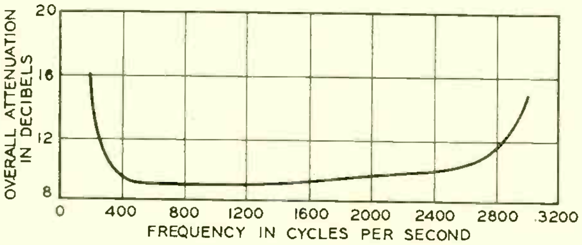


Fig. 1—A typical attenuation-frequency characteristic for a 200-mile circuit

One of the important tests is the measurement of return loss, and a new technique was developed for this trial. The 3A return-loss measuring set was already available, and in combination with the 13A oscillator had already greatly speeded up measurements compared to former methods. A complete return-loss-frequency run could be made in about fifteen minutes, but after the measurements were made they had to be plotted in the form of a curve to permit complete analysis of the data. The new method employed the same measuring set and oscillator, but a motor drive was provided that varied the frequency of the oscillator continuously over the desired frequency range. A new recording meter* was used in conjunction with it, which automatically recorded the return-loss data in the form of a curve ready for analysis. With this arrangement a complete return-loss-frequency run could be made and recorded in a minute and a half. By the use of this equipment a large amount of fundamental information was made available which would have been impracticable to obtain by former methods and which was extremely useful—not only for this trial but for further studies of toll systems.

An important part of the installation of a communication circuit of the two-wire type is the adjustment of the building-out capacitances of the balancing networks. Whether the circuit will sing or not and whether or not there will be objectionable echoes depends in part on how closely this balancing network together with its associated building-out capacitance approximates the impedance of the section of line it is designed to balance. The final adjustment of the building-out capacitances had been done formerly by the 21-type circuit test. For this test the line and network circuits are connected to the terminals of a hybrid coil associated with a two-wire repeater, and the gain is raised

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*Record, *July*, 1934, *p.* 367.

until singing occurs. The better the balance, the higher will be the gain required, and the building-out capacitances are adjusted, therefore, to give a maximum gain.

It will be noted, however, that this method guarantees the best balance only at the point at which the test is made and for the frequency at which singing occurs. It is quite possible, therefore, that such an adjustment, while generally satisfactory for field procedures, may not in certain cases be the optimum from the standpoint of overall singing and echoes. It thus seemed very desirable for the more exacting purposes of field trials to determine how nearly a capacitance adjustment by the 21 test approached this optimum condition. Such information could be obtained from the ordinary return-loss measurements made with various adjustments of the building-out capacitances, but the labor involved would be almost prohibitive in this case.

To decrease the amount of time and labor involved, the 3A return-loss measuring set was employed as before except that in place of the 13A oscillator two other sources of measuring power were tried in an effort to find a source that would satisfactorily include the entire band of frequencies in a single reading. One of these sources was resistance noise* arising from thermal agitation in a resistance terminating a special amplifier. Such a noise includes all frequencies, so that the measurement was an integration of the return loss over the entire band of frequencies transmitted. The other method employed the 13A oscillator but with a motor-driven air condenser in parallel with the normal tuning condenser. This condenser was rotated fast enough so that the readings obtained represented an integration of the return losses over the desired frequency range. With both sources a weighting network was employed whose attenuation-frequency characteristic was such that it weighted the return losses at the various frequencies according to the importance of these frequencies from overall singing and echo standpoints.

By these methods it was possible to adjust the building-out capacitances for optimum overall singing and echo conditions instead of the optimum local singing condition. An extensive study was made so that the three methods could be intercompared.

When a system goes on trial there are frequently certain factors whose magnitudes are not exactly known but which nevertheless affect the design of the system. An example in this instance was the singing conditions prevailing above the cut-off of the filters associated with the repeaters. The balancing networks cannot be economically designed to balance the line except for the transmitted frequency band—at higher frequencies the balance may be poor, with the possibility of singing if the loss in the filters is not great enough. During this trial it was found that the filters proposed for the new two-wire repeaters were not entirely satisfactory in this respect. In fact four designs were tried before one was obtained that met all requirements.

One of the objects of a field trial is to determine the reason for any departure from anticipated results, and to suggest possible remedial measures. This phase of the work is frequently the most interesting since it taxes the engineer's ingenuity and imagination. Means for making special tests are not generally available, and methods

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*Record, *February*, 1927, *p.* 185.

must be improvised with existing field apparatus. The determination of the cause of a certain trouble often requires a study of all possible causes and then the determination of the correct one by the rather lengthy process of elimination.

During the recent trial, for example, it was found that the return losses at low frequencies on the Philadelphia-Princeton section were lower than those on the Princeton-Newark section. These lower return losses were still within the original requirements, but since they indicated a distinct difference in the two sections of line, it seemed desirable to determine their cause. An analysis was made of all factors that might result in such a difference in return loss, and then one by one they were checked against known conditions and recently obtained test information. By this process it was finally determined that the cable capacitance per loading section must be lower than expected. This might be caused either by lower capacitance per unit length of cable or by shorter loading sections. Measurements made at the time of the original installation were then studied, and it was found that the cable capacitance per unit length was about four per cent lower than average, and in addition that the loading sections were one per cent shorter than normal between Philadelphia and Princeton and one per cent longer than normal between Princeton and Newark. The net result of course was a lower capacitance per loading section on the Philadelphia-Princeton section.

Having determined these facts, it was found that the return loss at low frequencies could be improved about 3 db by the addition of a small amount of resistance in series with the building-out section. It was therefore recommended that an adjustable resistance unit be included in the building-out section so that when occasion arose, such situations could be cared for in the field.

In general, the results of the trial indicated that the circuits performed even better than had been anticipated. The systems have proved satisfactory from the standpoint of noise, crosstalk, return loss, echoes, and singing as well as in the overall net-loss-frequency characteristics.

Contributors to this Issue

W. L. Betts received the degree of M.E. from the Polytechnic Institute of Brooklyn in 1915, and after a year with the Remington Arms Company joined the Research Department of the Western Electric Company. His early work was on telephone repeaters, but during the war period he was with the Apparatus Development Department, working on submarine detectors, and later on carrier telephone and telegraph apparatus. Since 1921 he has been supervisor of various development groups. Carrier apparatus, rheostats, potentiometers, vacuum tubes, and special products such as hearing aids have successively engaged his attention. He also supervises the development of apparatus for Western Electric sound picture systems, and of a wide variety of other special equipment such as public address systems, audiometers, and the like.

W. L. Betts

J. E. Ranges entered the physical Laboratory of the Western Electric Company as a technical assistant in 1913, and in the course of a few years became associated with the development of telephone cords, switchboard wire, and cable. During the war he served in France with the Research and Inspection Division of the Signal Corps for some two years. In 1919 he again took up his work on telephone cords and wires, but two years later transferred to the design of loading coil cases and condensers. Since 1928 he has devoted his time to the design of loading coil cases.

J. F. Dillinger received the degree of B.S. from Otterbein College in 1925 and an A.M. in Physics from Ohio State University in 1927. After spending the following year as an assistant in Physics at Ohio State he joined the Research Department of the Laboratories where he became as-

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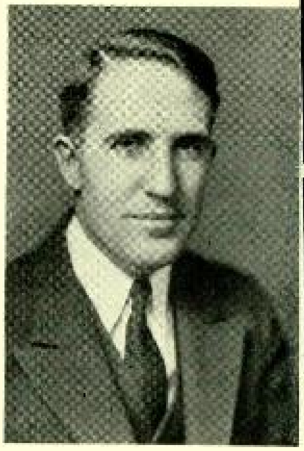

D. A. McLean

sociated with the Special Research group investigating magnetic materials. Several years were spent making a thorough investigation of the Barkhausen effect before he became interested in annealing materials in a magnetic field. Recently he has been studying recovery of materials from strains produced by hard working.

Since his entrance into the Laboratories in 1930, G. W. Willard has been engaged in theoretical studies of piezoelectric circuit elements. From his study of the effects introduced by changes in orientation he has been able to propose a number of new types of crystal circuit elements. As a result there have been produced the new high frequency AT and BT quartz circuit elements which are now finding such wide application in radio communication. Mr. Willard holds the Bachelor's and Master's Degrees from the University of Minnesota, and for two years was a graduate student at the University of Chicago.

H. A. Etheridge left Princeton to serve in the U. S. Army in 1917, but returned on receiving his discharge, and received the B.S. degree in 1919. For a short period he was in business for himself, but in 1921 he joined the Southern Bell Telephone and Telegraph Company. His work there was with the Transmission Department until 1923 when he transferred to the Department of Development and Research of the American Telephone and Telegraph Company. Here he has since been concerned chiefly with transmission problems arising from the use of repeaters on long telephone circuits.

P. W. Wadsworth received the B.S. degree in Electrical Engineering from Ohio Northern University in 1927 and immediately joined the Technical Staff of the Laboratories. With the Systems Development Department he spent two years in the design of circuits for toll switchboards, but since 1929 has been engaged largely in the development of terminal and signalling circuits for toll lines and radio telephone links. This has included work on echo suppressors, two and four-wire repeaters, and terminal circuits for transoceanic and ship-to-shore radio telephone systems. He has also engaged in the development of a toll conference system, and of selective signalling systems for toll lines and radio circuits.

D. A. McLean joined the staff of the Chemical Laboratories in 1929, immediately after receiving a B.S. degree in chemical engineering from the University of Colorado. For the following three years he was interested chiefly in problems of plasticity, viscosity, and the wetting of solids by liquids. During his work on these problems, he contributed to the theory of capillary penetration of liquids into fibrous solids. More recently he has been engaged in studies of dielectric breakdown, particularly in condensers.