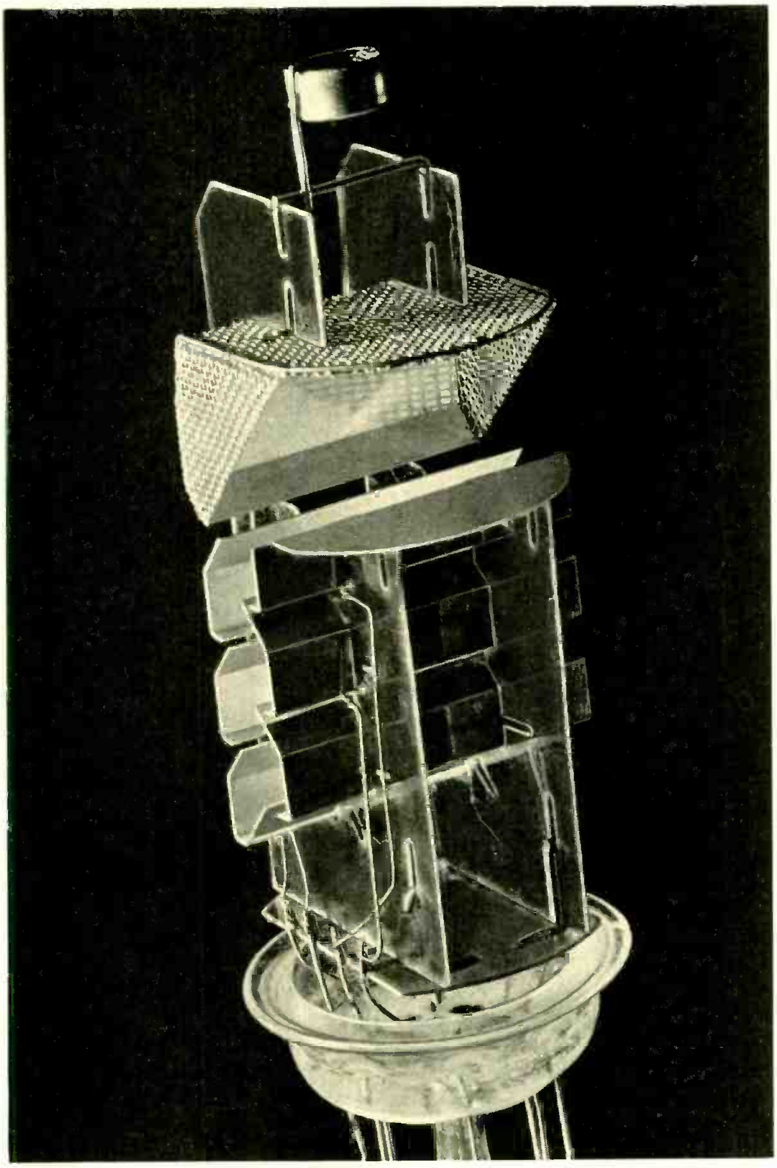
ELL LABORATORIES RECORD



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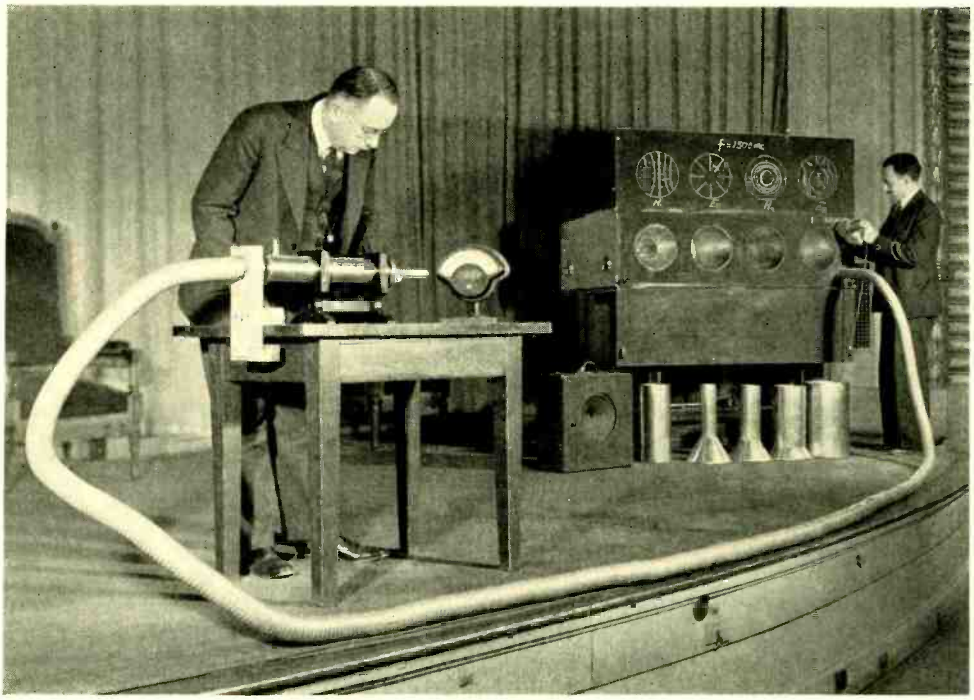
NUMBER VII

Internal structure of the new Western Electric electron multiplier, electrostatically focussed

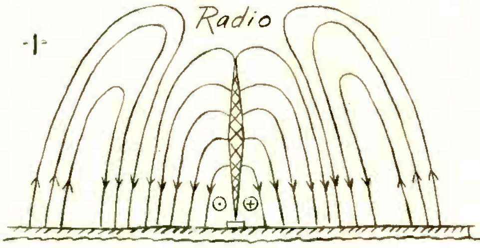


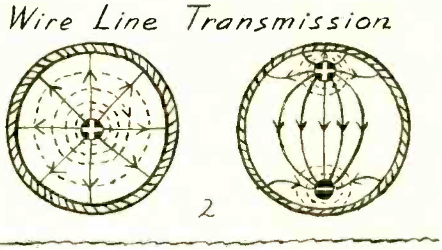
A Demonstration of Guided Waves

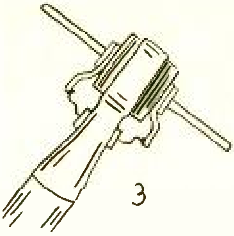
ELECTRICAL waves which can be guided by metal pipes and even by insulating rods have aroused so much interest that G. C. Southworth and his associates have given a number of lecture-demonstrations based on their researches. To create the illusion of discovery, the audience sees at first only a blackboard mounted on a table; the nature of the apparatus behind it is not at first disclosed.

1—Referring to the sketch of an antenna and the conventional picture of waves leaving it, the lecturer points out that electrical energy can be radiated into free space.

2—At the left is sketched a coaxial system and at the right, a shielded pair. In both of these, energy is confined to the structure. Other modes of transmission are possible; the speaker suggests an exploration to see if any are now present.

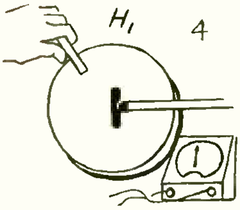


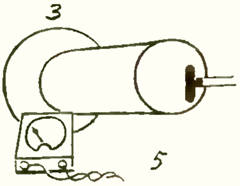


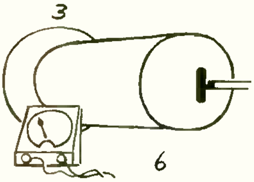


3—The speaker takes in his hand a wand tipped by a minute antenna and a crystal detector, and connected by wires to an amplifier, a meter and a loudspeaker. Moving this wand, or electric probe, over the surface of the blackboard he locates four zones in which the probe causes the meter needle to deflect; also a tone sounds from the loudspeaker. Each zone is circular, and about ten inches across. As he withdraws the probe from the board, the deflection becomes less.

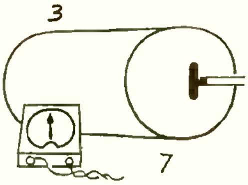
4—Holding a metal-covered paddle between the probe and each zone, successively, the lecturer shows that the energy is cut off in each case. It penetrates a nonmetallic paddle, however; so the audience infers its electrical nature. When the foil-covered paddle is held beyond the probe, the deflection is increased, so reflection is occurring. When the probe is moved back and forth, successive maxima and minima are observed, characteristic of standing waves.

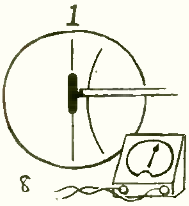




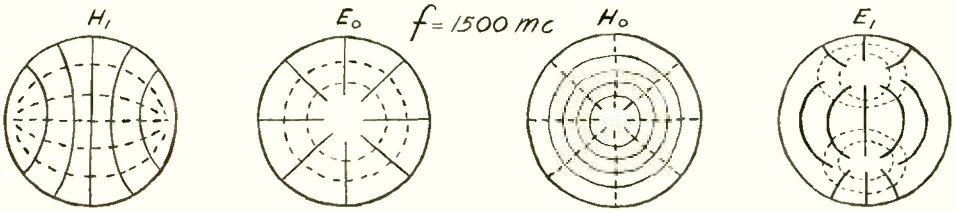


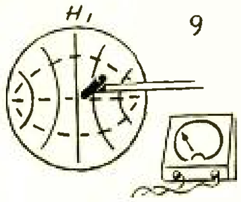
5, 6, 7—Zone No. 3 is selected for the next experiment and a four-inch metal pipe is placed in front of it. When the probe is held at the open end of the tube, there is no deflection of the meter. Evidently nothing gets through. An eight-inch pipe is tried, with no better result. Finally a ten-inch pipe is put in place and the waves come through vigorously. Similar experiments show that the eight-inch pipe will do for zone 2, but the four-inch pipe will serve for zone 1 alone.

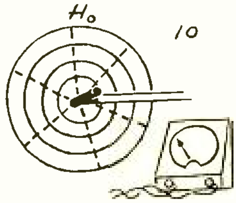




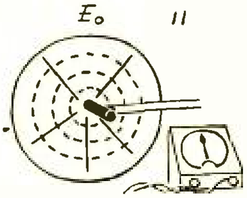
8—The probe is then held in front of zone 1 and rotated. Along the vertical center-line, a maximum meter reading is found with the probe vertical; a solid line is drawn to symbolize this. Along the horizontal center line a minimum is found with the probe horizontal; a dotted line is drawn. At other parts of the zone, the "maximum" orientation of the probe is at some other angle. When the orientations are marked, a field of solid and dotted lines results. Such a plot is marked for all zones as below.

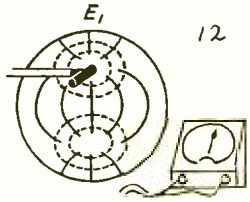






9, 10—"Is there a component of the electric field at right angles to the blackboard?" The probe and meter say not, in these two zones.

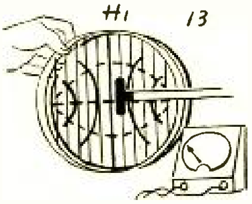


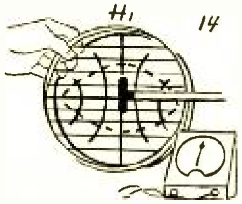


11, 12—But in the two other zones, such a component was found.

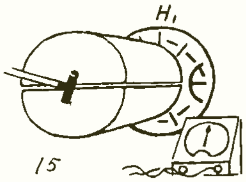
From these experiments and certain theoretical deductions, the zones are designated E_0, E_1, H_0, H_1 as shown.

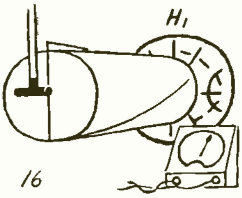
The wave-type designations in use at the time of this lecture have now been superseded. In the future E waves will be known as transverse magnetic (TM) waves and H waves will be known as transverse electric (TE) waves. Suitable subscripts will designate the order and mode.



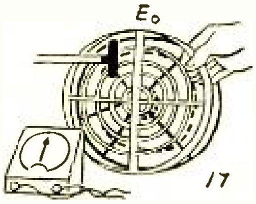


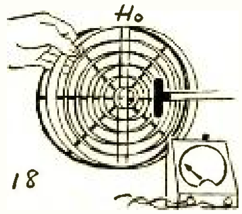
13, 14—If the electric force in H_1 is up and down as sketched, it will induce currents in vertical metal conductors; these currents will reflect the energy and the probe will pick up nothing. This conclusion was found to be true; and also the converse: horizontal plates allow the waves to pass. Evidently these waves are polarized, as light waves can be.





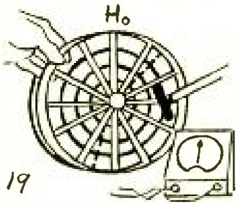
15, 16—A pipe with a partition down its length will pass H_1 waves when the partition is horizontal (left) but not when it is vertical. However, a spiral partition (right) which begins horizontally and ends vertically will rotate the plane of polarization just as certain crystals do with light.

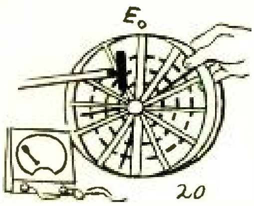




17, 18—Returning to the study of gratings, the experimenter shows that a circular grating will pass the radial waves of E_0 but not the circular waves of H_0.

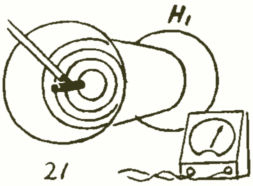
19, 20—Conversely, a radial grating will pass H_0 waves but not E_0 waves.

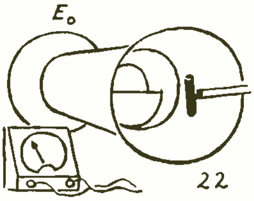




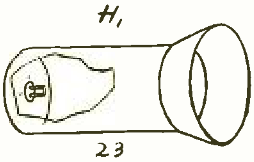
21—A pipe containing a particular arrangement of baffles is next applied to the H_1 zone. The probe shows that the lines of force have been changed from transverse to radial, and that there is now a substantial axial component. Both of these observations persuade him that the H_1 waves have been converted to E_0 waves.

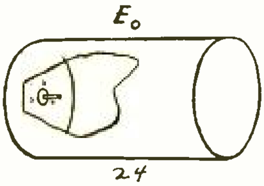
22—The process is reversible: when the pipe is turned end for end and placed in front of an E_0 zone, H_1 waves are detected.



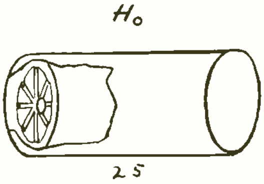


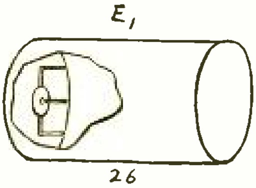
23, 24 — The blackboard is lifted, as in the headpiece; there are seen behind it four copper pipes, with small antenna structures at the bottom. That for the H_1 wave is a simple Lecher frame; for the E_0 wave, a short axial conductor.





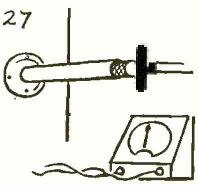
25, 26—For the H_0 wave, a cartwheel arrangement is used in which the spokes are coaxials and therefore inactive, and the rim is a series of wires emerging from the coaxials. All of the radiation is from the rim. Two longitudinal conductors radiate the E_1 wave; the short axial conductor is tuned to suppress a spurious E_0 component.

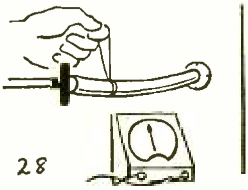


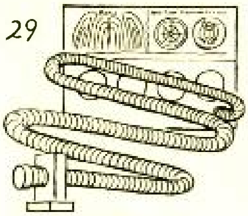


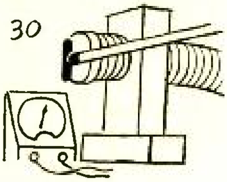
27—From a fifth source come waves which are shown to be about 9.4 cm length. A one-inch pipe will carry these waves, if it is filled with insulating material of high dielectric constant.

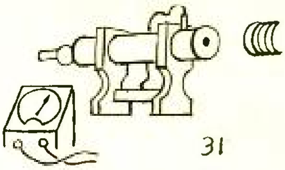
28—The metal sheath is not essential; the dielectric alone will transmit these waves.





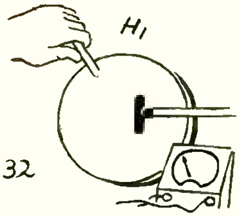


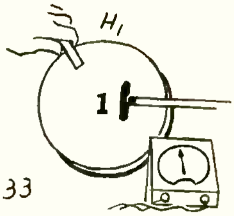


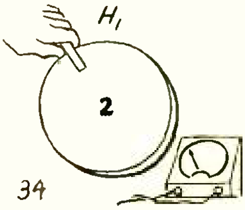


29, 30—About fifty feet of 2¼-inch flexible metal tubing is now connected to the higher frequency source. Tests at the remote end give deflections comparable with those at the source, indicating some possibility of transmitting the waves over considerable distances.

31—When a short section of wave guide is fitted with an iris and an adjustable metal piston, it behaves much like an acoustical resonator. A receiver based on this principle proves to be much more sensitive than the probe: a greater separation is possible between receiver and wave guide.

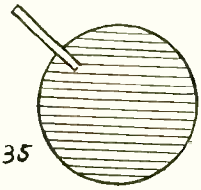




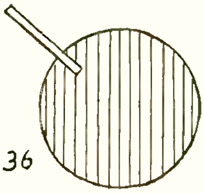


32—At the end of the demonstration, several electrical tricks are performed. It was shown earlier that a foil-covered paddle stops the waves and that a second paddle of ordinary plywood is electrically transparent. This is of course as might be expected. However, upon further experimentation a third wooden paddle proves to be opaque and the lecturer suggests that its innocent exterior might conceal a layer of metallic foil.

33, 34—The lecturer now shows a fourth paddle, apparently of plywood, since it offers no opposition to H_1 waves. The paddle, however, appears to be "two-faced"; for on turning it over, the waves are blocked. How a paddle can block the waves when in one facing but not in the other mystifies the audience. After the applause and the questions, many of the audience come onto the platform and examine the paddle.

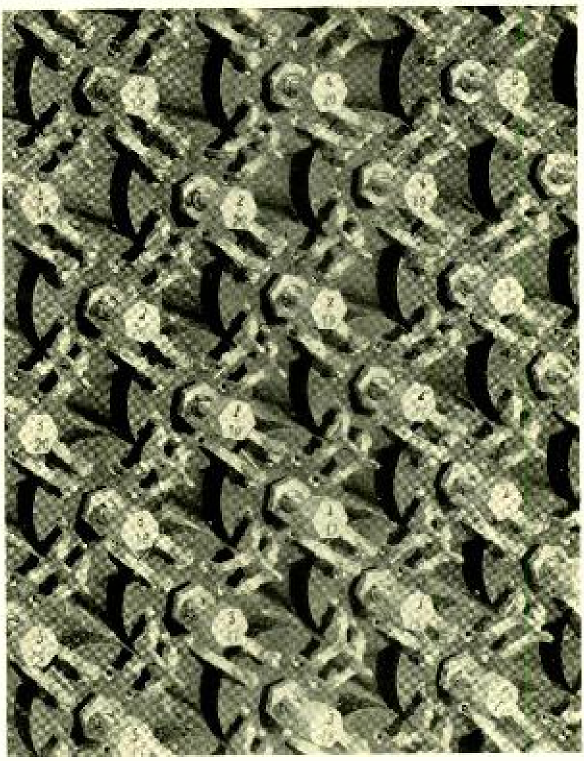


35, 36—The mystery is dispelled only when they see an X-ray photo of the paddle and discover that it contains a grid of wires at 45° to the handle. With the handle itself held at 45° to the horizontal, and the No. 1 side out, the wires are horizontal, and absorb no energy from the H_1 waves. With the No. 2 side out, the wires are vertical and the waves are blocked.



Crosstalk Balancing Coils for the Type-K Carrier System

By B. SLADE
Transmission Apparatus Development



BECAUSE of the high frequencies at which the type-K carrier system operates, extending to a maximum of 60,000 cycles, crosstalk reduction becomes a difficult problem. In general, two kinds of crosstalk occur between channels operating at the same carrier frequency. One, known as near-end crosstalk, is that heard by a listener at the same end as the talker, and occurs between circuits transmitting in opposite directions. This is kept within proper bounds by using separate cables for transmission in opposite directions or by suitably shielding circuits used in one direction from circuits used in the opposite direction. The other type is known as far-end crosstalk. It is the crosstalk heard at the end remote from the talker, and occurs between circuits transmitting in the same direction. To reduce this latter type of crosstalk in the type-K system, mutual inductance coils are used, which introduce the proper amounts of balancing voltage between such circuits. The use and arrangement of these coils has already been described in the RECORD.* They represent a novel type of telephone apparatus, and their design has required considerable care to make sure that the connection of these elements into the circuit did not itself introduce undesirable effects.

The problem is to construct a multi-winding transformer having adjustable mutual inductance such that if the primary is connected in series with one cable pair and the secondary is connected in series with another cable pair, it will be possible to induce a voltage of adjustable amount from one pair to the other, and thus neutralize the net inductive crosstalk component induced elsewhere in the cable between the same pairs. Since the inductive crosstalk component is random in magnitude, and may be either positive or negative, it is essential that the balancing coil be capable of providing a mutual inductance which can be easily adjusted to meet these conditions. The balancing coil by itself should also have very little pair-to-

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*February, 1939, page 185.

pair capacitance unbalance since this might add to the existing cable-pair capacitance unbalances and increase the existing crosstalk, due to such unbalances. Furthermore, the self-inductance of the coil windings should be substantially independent of the setting for mutual inductance, since it is important that the phase shift of each coil be a fixed amount.

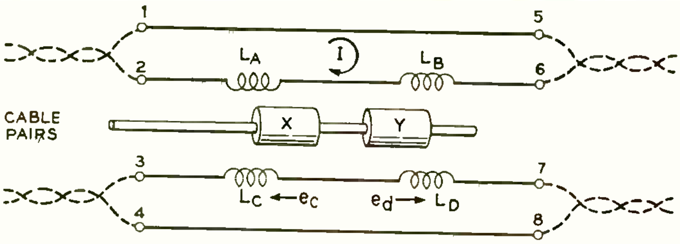


Fig. 1—Simplified schematic of the circuit arrangement for crosstalk balancing

To obtain the desired reduction in crosstalk between cable pairs thus far used for K carrier transmission, the 1A and 1B balancing coils have been designed. The essential difference between these two coils is one of mutual inductance range. The principle of their operation is shown schematically in Figure 1. Winding 2-6 may be considered as the primary, and is composed of two windings, L_a and L_b, both of the same size but wound in opposite directions. Winding 3-7 may be considered as the secondary, and is composed of two windings, L_c and L_d, which are the same size and wound in the same direction. Winding L_c is wound over L_a; and L_d over L_b. Mutual inductance exists between L_a and L_c, and also between L_b and L_d by virtue of winding proximity and aided by the magnetic cores X and Y respectively. No appreciable coupling exists between windings L_a and L_b or between windings L_c and L_d.

If a current I is flowing in winding 2-6, voltages e_c and e_d of opposite sign will be induced in windings L_c and L_d. As shown in Figure 1, core X is about half way under windings L_a and L_c, and core Y is about half way under windings L_b and L_d. With the cores in these positions the two induced voltages e_c and e_d will be of the same magnitude but opposite in sign, and the net induced voltage in 3-7 will be zero. Cores X and Y are fixed to a common non-magnetic shaft and may be moved as a unit either to the left or right. If the core movement is to the left, e_c will be increased, and e_d will be decreased, the net result e_c-e_d being a voltage directed to the left. Similarly core motion to the right will give a net voltage that is directed to the right

The primary 2-6 of the coil may be connected in series with one cable pair, the secondary 3-7 in series with another pair as shown in Figure 1, 1-5 and 4-8 acting as connectors for the other wire in each pair. Thus it is possible by movement of the magnetic cores to induce from one line to the other a voltage, either positive or negative and controllable in amount,

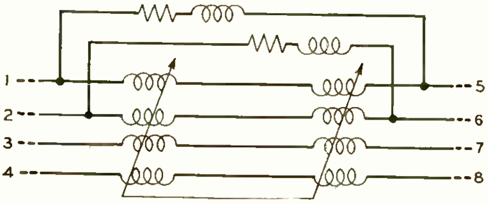


Fig. 2—As actually arranged, each balancing unit has two coils for each wire of each of the two pairs, and two shunt coils for the two wires of one pair

which can be used to counteract the inductive crosstalk component. When the core system is moved to the left, inductances L_a and L_c are increased by the presence of more core material in their fields, while inductances L_b and L_d are decreased because of less core material in their fields. By the proper positioning of the magnetic plugs in respect to each other and to the windings, it is possible to make this increase in the inductance of L_a approximately equal to the decrease in L_b and thus keep the total inductance in 2-6 substantially constant for the usual range of travel of the magnetic cores. When this constancy of inductance with core movement is arranged for winding 2-6, it will also apply to winding 3-7.

In actual practice it is undesirable to have the coil impedance confined to one wire of the side-circuit pair, since such an arrangement results in an unbalanced circuit, and longitudinal crosstalk currents on one pair may induce crosstalk currents that circulate in the other pair. Furthermore, the arrangement of windings shown in Figure 1 has an inherent side-to-side capacitance unbalance. For these two reasons the windings of the balancing coil are divided, and half put in each wire of the circuit.

The mutual impedance between cable pairs is not constant with frequency but decreases with increasing frequency and shifts somewhat in phase. This is due to a non-uniform distribution of current in the cable wires, and is usually referred to as "proximity effect." To provide balancing coils with the same characteristics as the cable pairs themselves, additional windings are added in shunt with the main windings which are in series with one of the cable pairs. The complete schematic winding arrangement for the coil is shown in Figure 2. The major structural features of the 1B balancing coil for the type-K system are illustrated in the accompanying photographs.

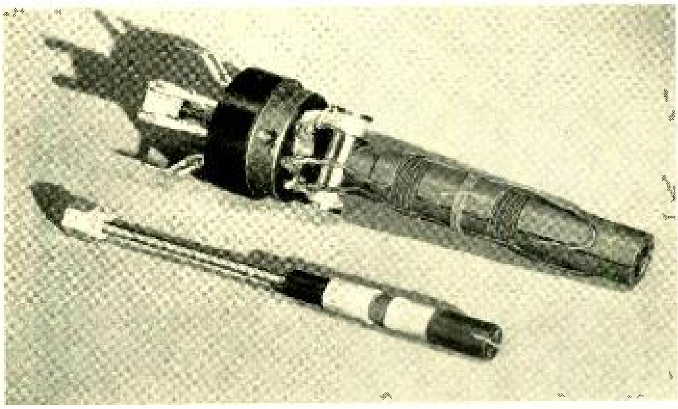


Fig. 3—The balancing unit with cores removed

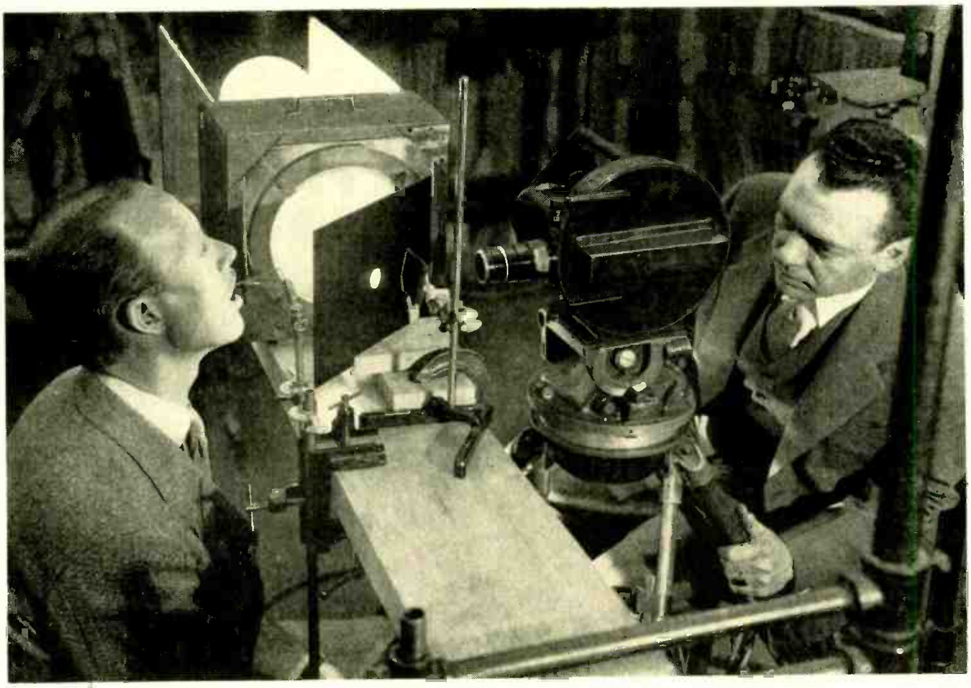
The main windings are wound on a hollow insulating cylinder with two slots for windings, as shown in Figure 3. Coils A and C, wound one over the other, are placed in one slot, and coils B and D in the other. Each winding has two layers separated by an insulator: the lower one comprising coils 1-5 and 2-6, and the upper, coils 3-7 and 4-8. The windings are so arranged as to secure inductive and capacitance balance. The insulating cylinder with its windings is attached to a head on which are mounted the eight terminals. The shunt coils are mounted directly beneath the terminal head, as shown in the illustration, and have their common axis perpendicular to the axis of the main windings to minimize extraneous coupling. After the coil assembly has been treated with wax, an extruded aluminum container about 1⅜ inches in diameter and 4½ inches long is slipped over it, and serves as a shield. The completed coil is shown in Figure 4.

The magnetic cores are mounted on a threaded metal rod and locked in position with non-magnetic spacers as shown in Figure 3. This rod passes through a threaded bushing in the terminal head, and is capped by a hexagonal nut—locked in position—by which the rod may be turned. As this nut is turned, the rod and the two cores are moved bodily along the axis of the cylinder. On the face of the nut are stamped a pair of numbers indicating the cable pairs which are being balanced by that particular coil.

The shape of the coil containers readily permits compact assembly on panels as shown in the headpiece. The panels are provided with aluminum cups which receive the coils and hold them by a friction fit. The coil terminals are so bent that the terminals of adjacent coils may be soldered together directly without the use of connecting wires, thus minimizing the number of soldered connections needed.

The dual magnetic cores and the unusual winding arrangement combine to constitute a device in which the mutual inductance may be adjusted to either a positive or a negative value within the desired range, which is ±1.4 microhenries for the 1A balancing coil and ±1.0 microhenry for the 1B coil. Good longitudinal balance is obtained by the inherent symmetry between the positions of each wire of a pair of windings, and the pair-to-pair capacitance unbalance is limited to less than 5 mmf by the method of winding. By virtue of the arrangement of the magnetic cores with respect to the windings, the self-inductance of each pair varies less than ± 2 per cent over the useful range of the coil. The coil has no internal splices, and employs no movable connections which might affect the proper functioning of the many coils in a complete K system.

Fig. 4—Assembled 1B *balancing coil showing adjusting nut and rod at the right*



High-Speed Motion Pictures of the Human Vocal Cords

By D. W. FARNSWORTH
Acoustical Research

SPEECH, to the telephone engineer, is a commodity that must be picked up in one place and delivered promptly, cheaply, and in good condition in another. His first concern is with the means of transport, or transmission, but since this is affected by the peculiarities of the human voice, he must interest himself as well in the characteristics of speech itself. For a number of years members of the Laboratories have been investigating the properties of speech: the frequency of occurrence, for instance, of various sounds; pitch and intensity changes; frequency distribution of energy; and the importance of these and other characteristics to intelligibility. More recently the study has been extended to include the mechanism of speech production, especially the action of the vocal cords in the generation of voiced sounds.

By means of a mirror held at the back of the throat and suitable lighting arrangements, it is easy to view the vocal cords in action; but as the motion of the cords is exceedingly rapid, little can be learned by simply viewing them. To obtain more detailed information, use has been made of high-speed motion-picture photography, which has enabled photographs of the rapidly vibrating cords to be taken at rates up to 4000 pictures per second. When such pictures are projected at normal viewing rates, about sixteen frames per second, the motion is slowed down by a factor of 250 to one. Thus, if the cords are making 250 vibrations per second, they appear to make one vibration per second, so that the details of the motion can be clearly seen. This compares with a ratio of only five to one that is used in taking ordinary newsreel slow-motion pictures of sporting events and the like.

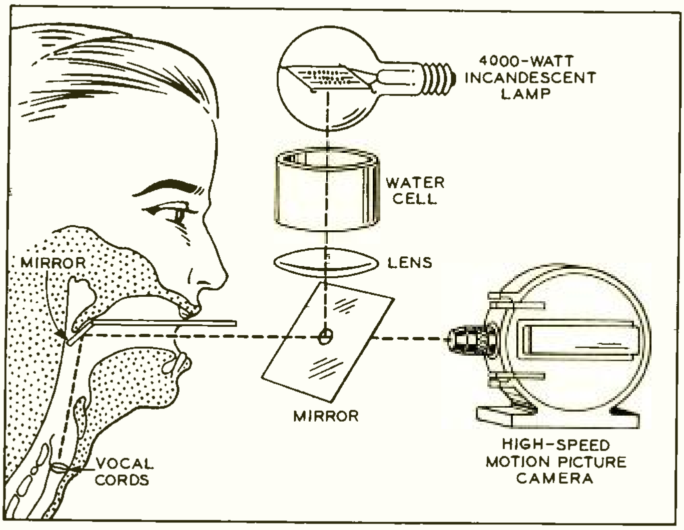


Fig. 1—*Arrangement of equipment for making motion pictures of the vocal cords*

To provide illumination for the pictures, light from a powerful incandescent lamp is concentrated on the vocal cords by a small laryngeal mirror held in the throat. The same mirror reflects light back from the vibrating cords to the camera. A diagram of the apparatus is shown in Figure 1, and a photograph of the equipment with subject and operator in position is shown in the headpiece. The camera itself is a development* of the Laboratories; its film moves continuously rather than intermittently, a small cube of optical glass rotating at high speed between the lens and the film serving to move the image of the object at the same rate as the film, thus rendering the film and the image stationary with respect to each other. Effective exposure time for each picture is of the order of 1/10,000 second, at a taking rate of 4000 pictures per second. The film may be projected with a conventional sixteen-millimeter projector.

Typical "stills" from films taken in the Laboratories are shown in Figures 4, 5, 6 and 7. So that these pictures may be more easily understood, a conventional anatomical drawing of the complete mouth and throat region is shown in Figure 2. The cartilaginous structure known as the larynx, within which are the vocal cords, is indicated by the arrow. A part of the larynx is the prominence at the front of the throat known as the "Adam's apple"—the thyroid cartilage, shaped like two sides of a triangular box with the apex at the front. A palm-leaf-like structure called the epiglottis attaches to the upper part of the thyroid cartilage. The epiglottis is very flexible and may be either upright, behind the base of the tongue, or folded down to cover the top of the larynx. The rear wall of the larynx is formed by the cricoid and the two arytenoid cartilages. The vocal cords have a common point of attachment to the thyroid cartilage at the front and each is attached to a process of one arytenoid at the rear

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*Record, *April,* 1938, *page* 279.

(Figure 3). The larynx forms the upper boundary of the trachea or windpipe and opens into the throat or pharynx.

In normal respiration the vocal cords or folds are widely separated at one end, forming a triangular opening of considerable area through which air passes easily. In the production of a voiced sound the cords are drawn close together but not entirely closed. When the lungs are compressed, as in exhaling, a current of air is caused to flow past the almost closed cords and they are set in vibration.

The breathing position is illustrated in Figure 4, which also shows the cords being drawn together to begin a sound. Once set into vibration, the vocal cords modulate the direct current of air and generate an alternating air current or sound wave. The sound wave consists of a fundamental and numerous harmonically related overtones. Pitch is determined by the frequency of the fundamental, while the voice is given its characteristic quality by the overtones, which are reinforced in varying ways by the oral cavities. It is this ability of the cavities to reinforce various overtones at will that enables one to produce various speech sounds.

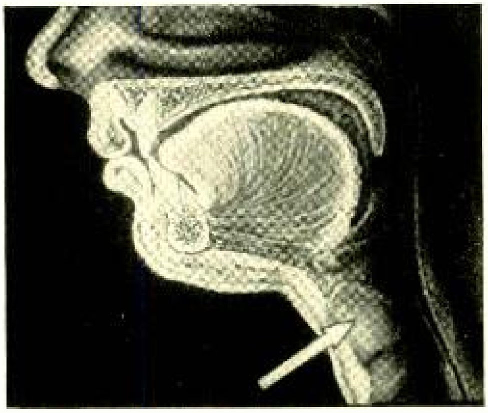

Fig. 2—*The larynx is indicated by the arrow*

For the pictures the pitch and intensity of the voicing have been varied; but because of the necessity of maintaining the wide-open mouth position, the vowel sound has not been changed. This is the sound "ae," one which gives a particularly favorable view of the larynx. The pitch range covered is from about 120 to 350 cycles per second, and intensities of sound vary from soft to loud conversational speech.

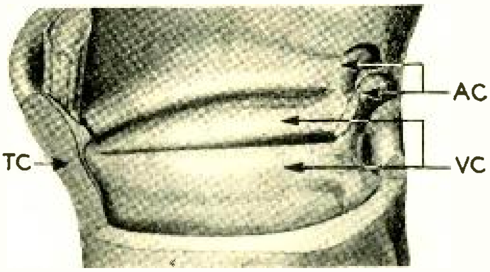

Fig. 3—Vocal cords, VC; *thyroid cartilage*, TC; *arytenoid cartilages*, AC

The motion of the cords appears to be rather complex at low pitch, becoming less so as the tone is raised, till at extremely high pitches only the edges of the cords nearest the glottis (as the slit between the cords is called) are seen to vibrate, resulting in a slight change in width of the opening. Vibration also tends to be confined more and more toward the forward portion of the vocal cords. This confined motion is known as the falsetto mechanism. Figure 5 illustrates the changes in going from a low to a high pitch.

At a very low pitch the cords appear to be completely relaxed, as may be seen in Figure 6, which shows one cycle of the cord motion at about 120 cycles per second. Without taking up completely the anatomical explanation it suffices to say that the tension is small, both in the thyro-arytenoid

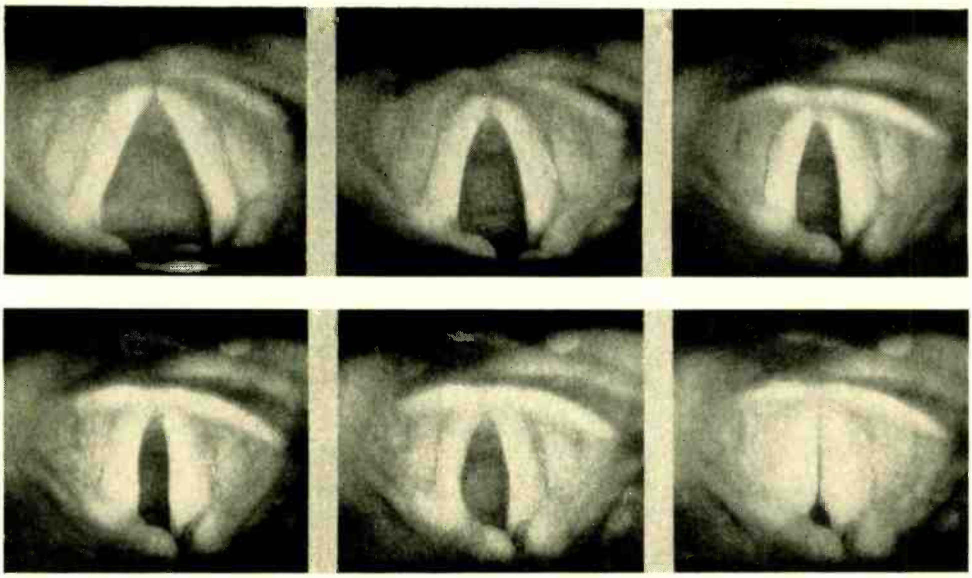

Fig. 4—Change in positions of vocal cords from breathing to voicing

muscle underlying the vocal cords throughout their length and in the muscles which act on the cords by moving the cartilages to which they attach. As the tension in the various muscles increases, two things take place: the cords become firmer due to contraction of the underlying thyro-arytenoid, and they are stretched to a greater length by the action of the other muscles. At the low pitch, assuming that they are at the closed portion of the cycle, the cords begin to open from underneath (toward the lungs), the opening progressing upward and outward. The lower portion is also first to close. In other words, there exists a phase difference in the motion between different vertical positions. Horizontally the opening along the length of the cords may also have a phase displacement. When

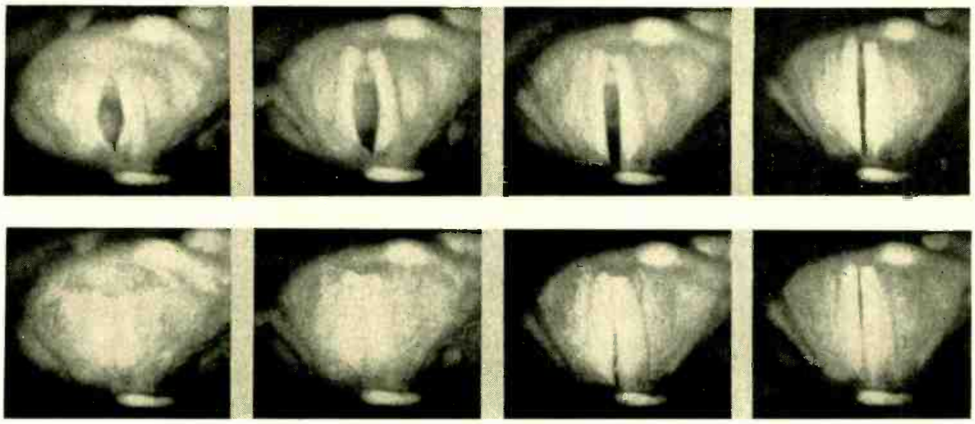

Fig. 5—Open and closed positions of vocal cords at 124, 174, 248, *and* 330 *cycles*

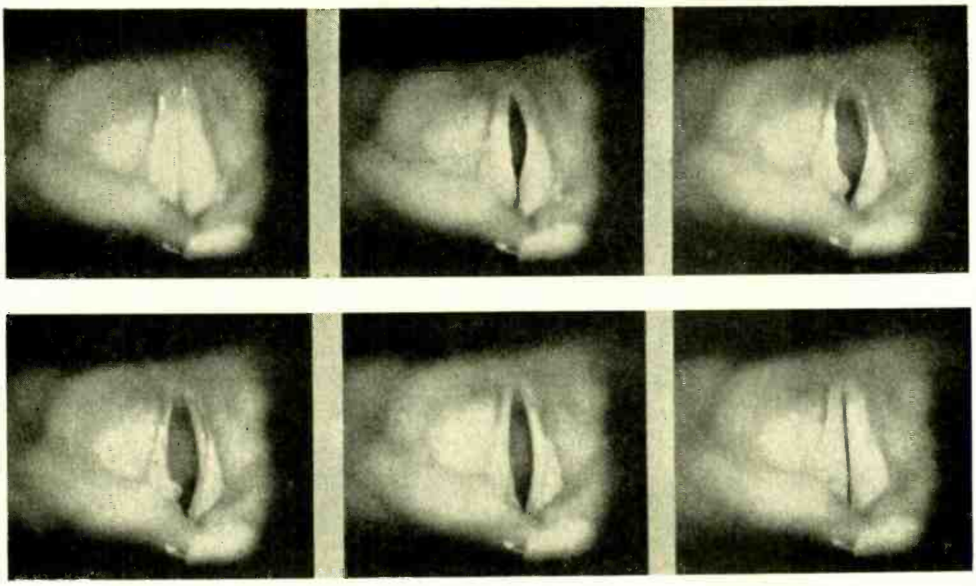

Fig. 6—One cycle of cord movement at low frequency

the cords close, a wave-like motion or ripple is seen to pass over the top surface from the glottis toward the walls of the larynx, as the edges of the cords press firmly together.

When the voice is in this range the cords may be tightly closed for as long as half of the cycle. The length of the cords when vibrating at about 120 cycles is from one-half inch to five-eighths inch (for the subjects studied). The widest opening is nearly three-sixteenths inch.

As the pitch is raised the motion be-

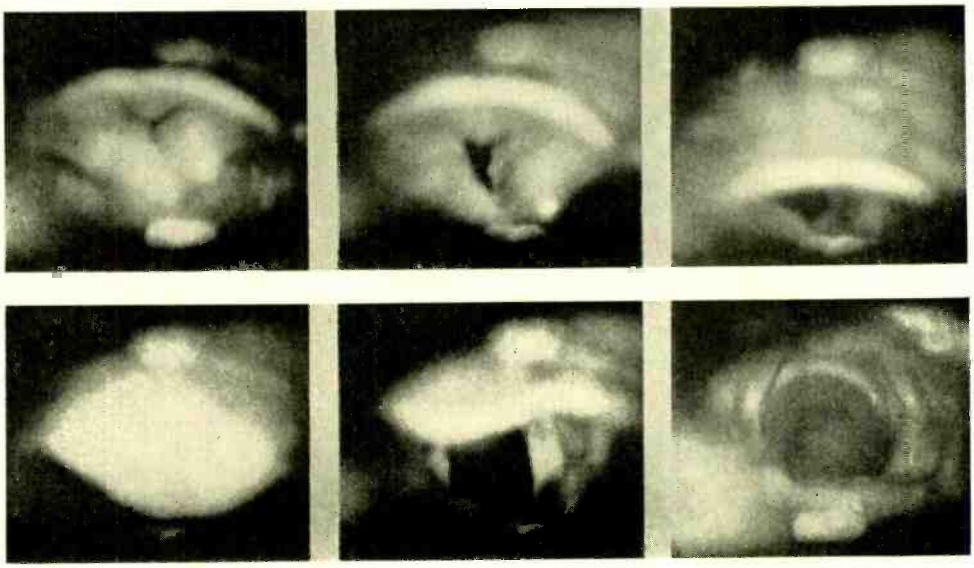

Fig. 7—Some pictures showing the larynx during a cough

comes somewhat simpler; when the folds become firmer due to muscular tension they move more nearly as a unit, so that the opening from below upward is less and less apparent. The length of time they remain tightly closed becomes smaller, until in the falsetto complete closure is usually not attained at all. The length of the cords increases to about three-quarters of an inch and the width of opening decreases to about three-thirty-seconds of an inch at 240 cycles. All of these dimensions of course vary from subject to subject and change with the intensity of the sound.

The chief variation evident as intensity is changed, without changing the pitch, is that the cords close together very feebly or not at all at very low intensities, while at high intensities they close firmly and may remain closed for an appreciable time even when vibrating at a high frequency.

One of the most interesting of all the pictures is Figure 7 showing the production of a cough. Here not only the vocal cords but the entire larynx is in movement. At the beginning of the cough the walls of the larynx are greatly constricted, closing completely over the vocal cords. Then air is forced out of the lungs and sudden expansion takes place; the vocal cords are forced apart to a greater extent than ever occurs in normal breathing, and the epiglottis is blown about by the current of air. It is thus apparent how the cough acts to expel any foreign bodies in the larynx.

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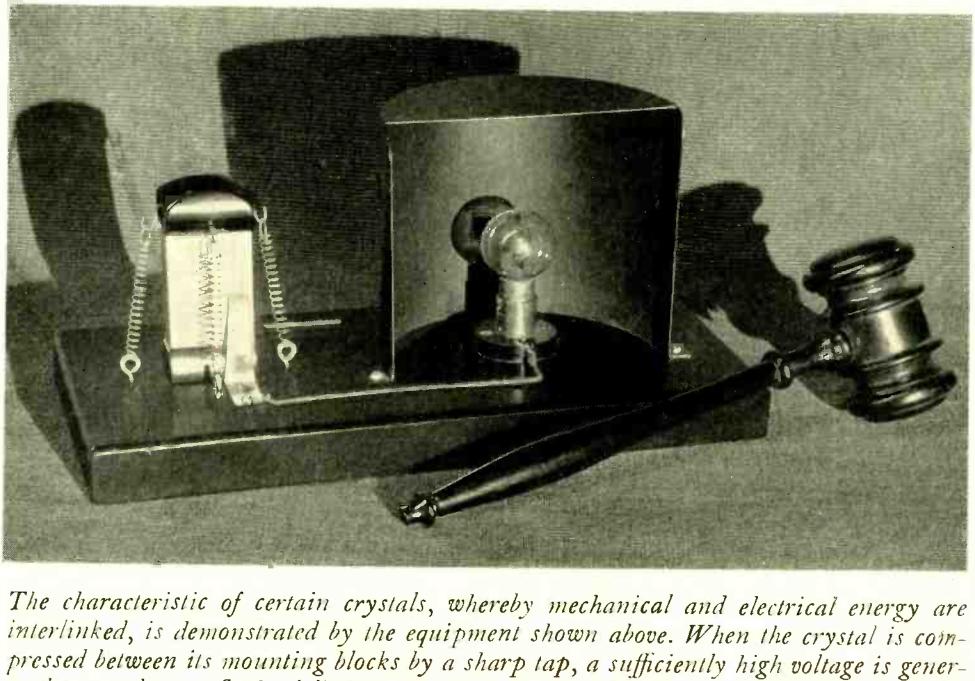
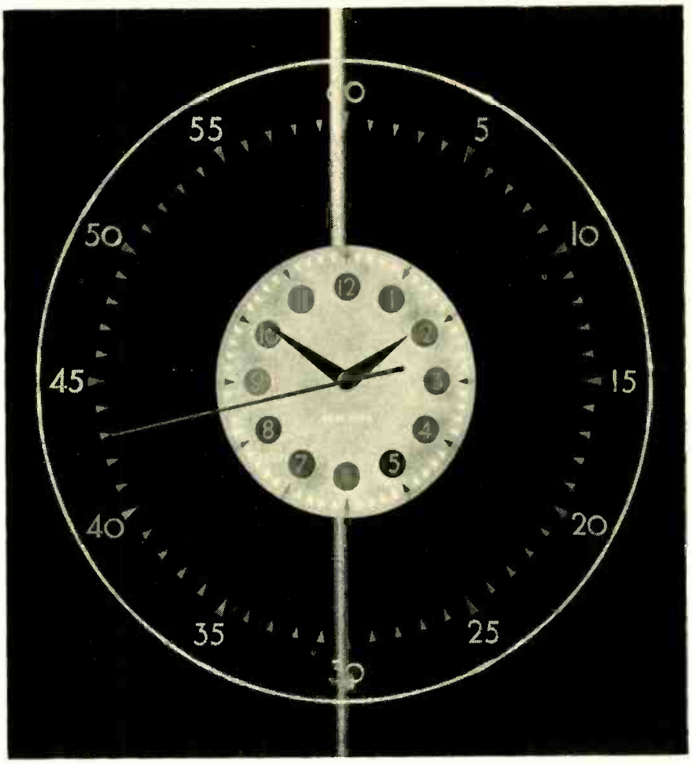


The characteristic of certain crystals, whereby mechanical and electrical energy are interlinked, is demonstrated by the equipment shown above. When the crystal is compressed between its mounting blocks by a sharp tap, a sufficiently high voltage is generated to produce a flash of light in the neon lamp. This characteristic, known as the piezo-electric effect, has important applications in filters and in frequency control of oscillators. Quartz crystals are used in the actual applications as they are rugged and stable, but for this demonstration Rochelle salt is used as it is more active. With the equipment shown, a sharp tap generates over 2,000 volts



The "Telephone Clock"

By W. A. MARRISON
Circuit Research

THE new "Telephone Clock" in one of the Broadway windows of the American Telephone and Telegraph Company headquarters building has aroused wide public interest by its accuracy and its striking appearance. Designed by the Laboratories, it is intended to symbolize the importance of time measurement in the engineering and operation of the telephone plant.

The clock's accuracy is emphasized by a large dial on which the sweep-second hand moves in a graduated circle nearly three feet in diameter. Hour and minute hands move in smaller circles at the center in order to allow an unobstructed view of the precision dial. Mechanisms for driving the clock from current accurately controlled by the Bell System Frequency Standard, and for synchronizing the motion of the hands with signals from the New York Telephone Company's Time Bureau, are mounted compactly in a hemispherical case behind the inner dial. The principle of operation is illustrated in the schematic diagram of Figure 1; only the basic elements are represented, the alarms, power facilities, and some details of the control system being omitted for clarity.

Control of rate originates at the Laboratories, where the primary frequency standard is maintained. Here, in the clock-maker's sense, is the real clock—the element which takes the place of the pendulum in the usual precision clock being a vibrating crystal of quartz, so carefully constructed and so precisely controlled that, when used to measure time directly, it is accurate to better than one hundredth of a second a day. Precise submaster oscillators* at 32 Sixth Avenue, under the control of this standard, supply sixty-cycle constant-frequency current to the clock and to the New York Telephone Company's Time Bureau. The current is so regulated that synchronous clocks operated continuously from it will deviate less than one-twentieth of a second from Naval Observatory time. The performance is checked frequently and precisely at the Time Bureau by comparison with radio time signals received via Arlington.

The sixty-cycle current supply is carried from 32 Sixth Avenue over two separate cable pairs following different routes. As long as either circuit is complete the clock will continue to function normally, so that a high degree of reliability is assured. Even if both of these circuits should fail, the clock will continue in operation, because an automatic switch not shown in the schematic will substitute an input from the commercial a-c power supply, which in New York City is normally adjusted from the same constant-frequency source that supplies the Time Bureau and the clock.

The clock contains two motors. One of these, having two similar windings, is used for the regular drive and is constructed so that sixty-cycle current from both or either supply circuit operates the hands at the normal rate. The other motor also has two windings, so arranged that they will produce forward or reverse rotations respectively; it is geared to the clock mechanism in such a way that while in operation it produces a change in rate of about one per cent. The two motors are geared to the clock through a differential, the reversible one being used solely for preliminary manual setting and for precise automatic synchronization.

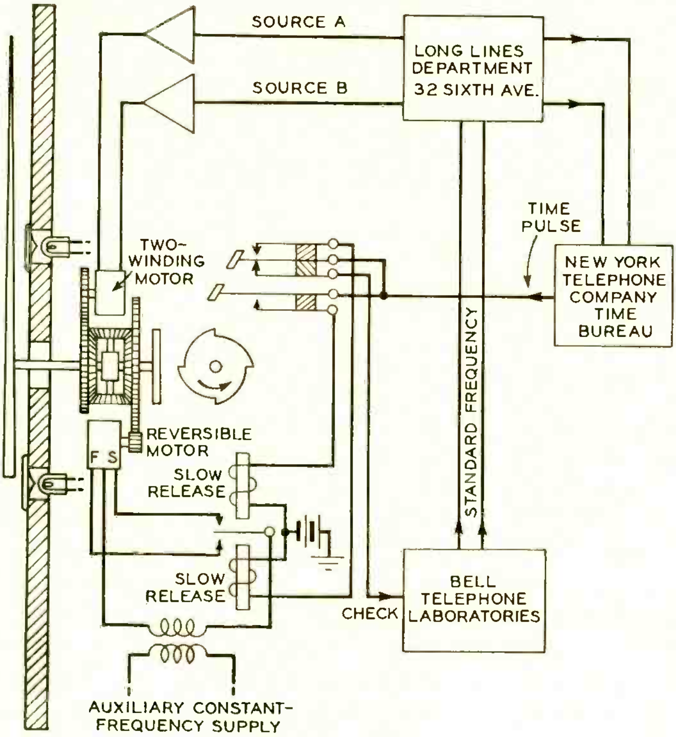


Fig. 1—Simplified schematic diagram of the clock

Synchronization of

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*Record, *January*, 1939, *page* 138.

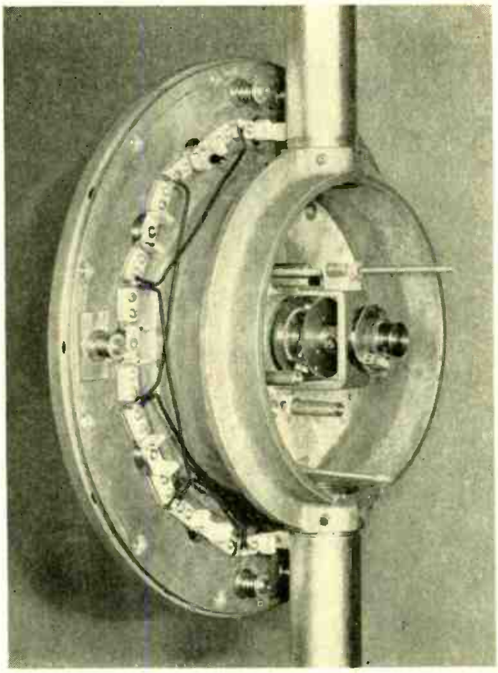


Fig. 2—Partial assembly of the clock without dial, photographed from the back

the clock with signals from the Time Bureau is accomplished through the use of contacts operated from a cam mounted rigidly on the same shaft with the second hand. Four times each minute two sapphire pallets drop in close succession from raised portions on this cam. The operation of the first pallet opens a circuit normally closed, and the operation of the second pallet closes a circuit normally open. During a brief interval both of the circuits are open. A short pulse, generated at the beginning of each signal from the Time Bureau, is normally received in the interval between the functioning of these two contacts. But if it should arrive before the first contact has opened, or after the second one has closed, it is directed to a relay which starts the reversible motor in the appropriate direction to restore normal operation. Thus at all times the second hand should indicate the same time as that distributed by the Time Bureau; the departures from synchronism are expected not to exceed one or two-hundredths of a second.

Provision is made to call attention to incipient trouble which might in time affect the operation of the clock. One indicator shows whether the power is removed from any part of the system. Another calls attention to the omission of synchronizing pulses from the Time Bureau in case of circuit failure or any other irregularity. Others operate if the synchronizing device is called upon to function more often than is normal, if any part of the standby equipment is called into action, if the voltage of the constant-frequency supply falls below normal or if, for any reason whatsoever, the clock should stop.

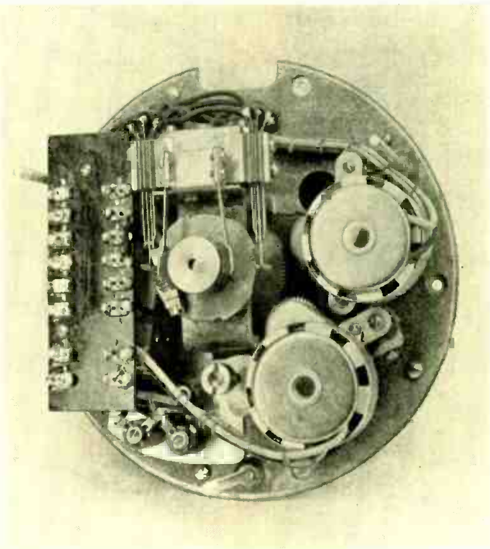


Fig. 3—A rear view of the clock showing the cam and sapphire pallets and the two motors

To insure continuity of operation, the standby equipment is arranged so that adjustments may be made on any part of the system, exclusive of the clock itself, without affecting the

Fig. 4—"Timing the Time Ball." This illustration, which was reproduced from a 1905 *advertisement of the Waltham Watch Company, shows the Time Ball on top of the old Western Union building at the top center of the drawing*

accuracy of the indicated time. Tubes can be changed in the amplifiers, the regular power source may fail, or either control circuit may be interrupted, with no more effect than to light a lamp which localizes the irregularity and to ring an alarm bell calling attention to it.

The mounting of the seventy-pound glass dial was accomplished in an interesting way. A metal ring was made having a diameter somewhat less than that of the inner dial circle, and to it were attached twelve thin-walled steel tubes at positions corresponding exactly to the five-minute markers. These tubes were machined to fit snugly into small holes drilled through the glass behind the markers. As they are somewhat flexible, the weight of the glass is distributed more or less equally among them. The dial is held fast to the metal ring by steel screws which go through the tubes and into the metal five-minute markers. The ring, in turn, is fastened to the main supporting casting by a separate set of screws inserted from the rear.

The dial is illuminated by a set of twelve small lamps supported in holes drilled through the glass behind the metal discs bearing the hour numerals. By the use of special mirrors, not visible from the front, nearly all of the light is directed laterally into the glass so that it does not appear until it strikes surfaces which reflect it in other directions. Thus the engraved graduations and numerals at the outer edge of the glass stand out effectively as though made of self-luminous material. Most of the light not used in illuminating the dial from within escapes from the edge and makes an effective luminous border. The effect of this lighting method is enhanced by the use of crystal-clear optical glass having only a small fraction of the absorption of ordinary plate.

Although the chief scientific interest centers on the large clock because of its unique accuracy, considerable attention has been drawn to a set of eight smaller clocks adjusted to indicate the time in various places throughout the world. These eight clocks are structurally all alike, and all operate from the previously mentioned commercial power supply. They differ only in the setting which permits them to indicate the hour, the day of the week, and if it is morning or afternoon in any selected locality.

The new clock is continuing a tradition of public time service that has grown up about the block on which the headquarters building stands. It was in this block that the famous "Time Ball," on top of the old Western Union building, by its noonday fall regulated the watches of a generation of Harbor navigators and Manhattan office workers. After the Time Ball was discontinued in 1914—by that time it was practically hidden by surrounding skyscrapers—a chronometer in Benedict Brothers' window on Fulton Street served for many years as the local time standard. In 1938 the jewelry firm gave up its business, but now, after the lapse of a year, the Telephone Clock is ready to carry on the tradition.

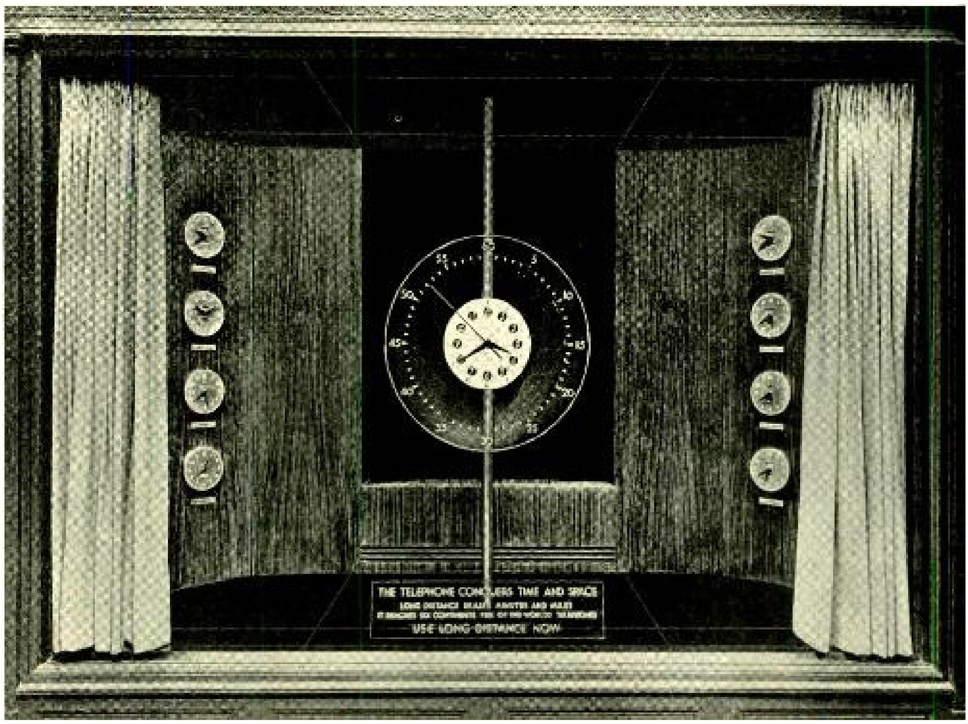
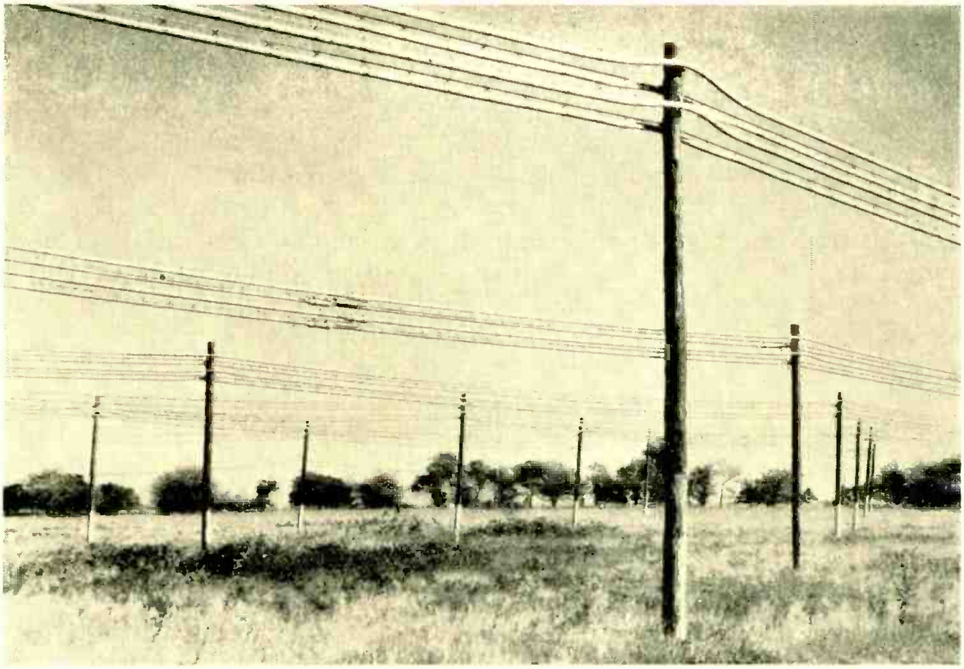


Fig. 5—The "Telephone Clock" and its eight companion clocks in the front window of the American Telephone and Telegraph Company's building at 195 Broadway



Outside Plant Field Laboratory

By C. A. CHASE
Outside Plant Development

DEVELOPMENT problems in the outside plant of the Bell System often raise questions which cannot be answered satisfactorily on the drafting board, inside a laboratory, or around a conference table. Until 1930 those questions were handled by field trials, in coöperation with the personnel and by using the equipment of the Associated Companies. This arrangement permitted development and plant engineers to observe installation methods, maintenance practices, the effects of weather, and the coördinating of new developments with the existing plant. Field trials are still an essential part in the work which precedes the adoption of most of the new outside plant standards but it has been found that much of the preliminary outdoor work can be done with less interference with the plant and more convenience for the development engineers at a field laboratory.

For a number of years a field laboratory has been maintained by the Laboratories at Chester, New Jersey. A varied terrain of some one hundred acres makes it possible to provide for a considerable range of ground conditions. Standard methods and equipment are used and a small general machine shop is provided. A wide range of work is undertaken including development problems on aerial plant in the form of cables, open wire, drop wire, insulators and poles. Underground work is represented by manholes, conduits and cables. Tests of hardware and tools are made for both aerial and underground plant.

Close association of the old with the new is an important factor in making a field laboratory an effective proving ground for outside plant apparatus where things undergoing development can be subjected to conditions closely approximating actual service in the telephone plant. Wind and weather, dry or wet soil, rocks, vegetation, insects, fungi and other efforts of nature to reduce artificial things to unusable forms must be available for measuring the success of attempts that are made to combat them.

Perhaps the most typical characteristic of an isolated laboratory is its dependence on its own resources as though it were on an island or a ship. Since a substantial part of the work at such a laboratory consists of extemporized solutions for the details of the various projects and since external sources of supplies require a trip of at least an hour by truck, expensive delays can only be avoided by careful advance preparation and the maximum use of the equipment and material on hand.

One of the advantages of the field laboratory is the speed with which projects can be undertaken because only one department is involved. The development engineer usually discusses the proposed work with the resident engineer at the field laboratory either by a visit or by telephone. After reaching an agreement on such points as location, materials required and approximate cost, the materials are ordered and the work scheduled. Small jobs are often ready within twenty-four hours and even the larger ones are usually well in hand within a week.

Scarcely less necessary than adequate equipment and materials is a varied experience and versatility on the part of the laboratories' personnel. Several jacks of all trades and at least one sailor work to advantage at Chester in carrying out the ideas of the development engineers.

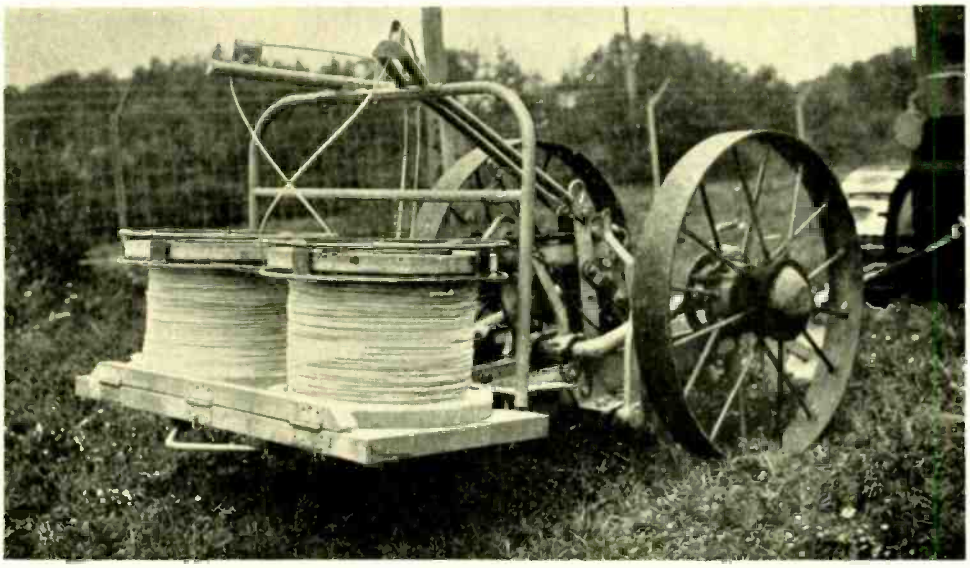


Fig. 1—Plow for laying telephone wire underground in rural districts. The wire is fed into a furrow made by a narrow plowshare

Occasionally, the necessity for making things do more than they were originally designed to do, leads to some curious operations. For example, when it became necessary to string considerable quantities of drop wire through brush, a shotgun was converted into a line-throwing gun and the wire was pulled through by a cord which had been shot through first.

Another problem which was dealt with by adaptation was devising means for repeatedly releasing a 1000-pound deadweight from a point some distance above a manhole cover. It was solved by hanging the weight from a vertical piece of drill rod which was gripped by a large strand puller on the end of the hoisting line. Release was accomplished by hooking a light tackle into a shackle through one jar of the puller and by using the tackle to exert a small force to break the grip of the puller.

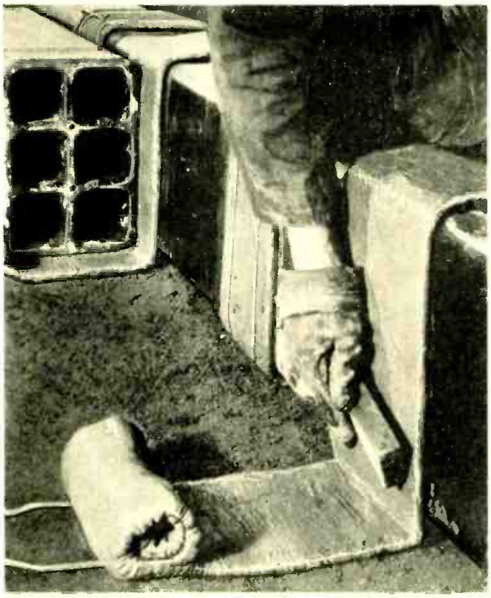


Fig. 2—Experimental conduit joints are made with a bandage that has been saturated with plastic cement mortar

Fig. 3—Bricks hung on open wires to simulate ice load in line-wire tie tests

Some years ago in connection with the development program on lead-covered cable, tests of the relative merits of the present lead-antimony alloy for cable sheaths and a new lead-calcium alloy were proposed. It was decided to make a comparative field trial and to locate the test cables at a field laboratory rather than in the plant of an Associated Company. Consequently six 1600-foot cable lines, each of which carried four cables, were erected at Chester. The large number of cables made it possible to obtain data simultaneously on several different sheath thicknesses of the new alloy as well as on the control cables of the present standard antimony alloy. These cables were gas filled and equipped with alarm circuits which terminated in a test house. In addition to the detection, study and repair of sheath failures, valuable data on bowing, ring cutting, and grade-clamp slippage have been obtained from the cables.

The majority of the tests required in the design or modification of Bell System hardware can be carried out either in the testing machines at New York or in field trials by Associated Companies, but occasionally it is desirable to use the facilities of a field laboratory for this work. Examples of field laboratory work on hardware are: impact tests on manhole frames and covers; a slippage test of a new corner clamp for suspension strand; installation and appearance tests of metal pole gains; life and performance tests of cable rings and other cable supports; holding power tests of rock guy-anchors and other expanding anchors; and tests of the effectiveness of malleable-steel pole reënforcements.

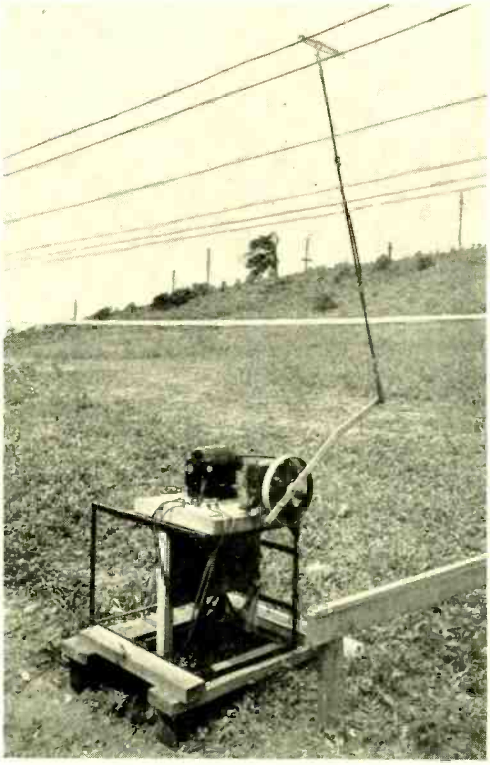


Fig. 4—Copper wires separated by an insulating spreader being swung in a tie test to simulate the action of the wind

Insulator tests at Chester are at present limited to exposure tests with periodic removal and shipment to New York for electrical tests. Insulators are involved incidentally, however, in the line-wire tie tests; and insulator design changes may result from this test. Various forms of outside terminals are brought to the field laboratory for installation trials and tests of their weather tightness.

Tests of various tools form an important part of the work at Chester. Such things as kerosene furnaces, hand lanterns, rock-drill holders, cable-treating torches, and vibratory tools for placing concrete and pipe pushers have been subjected to field laboratory test. By far the most extensive tool project was the develop-

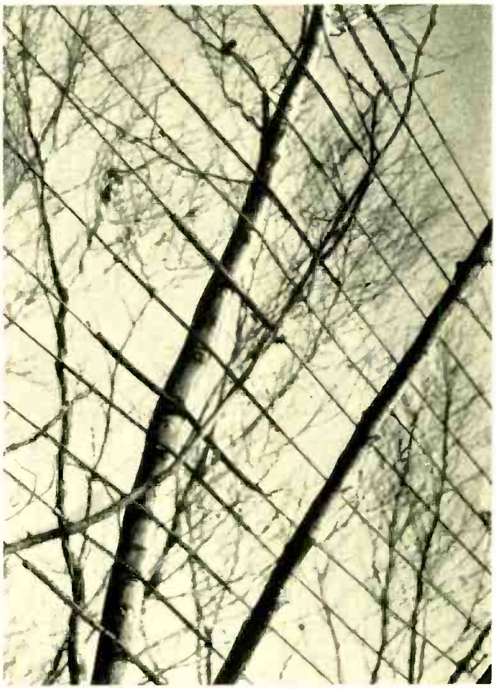


Fig. 5—Tests of drop-wire tree guards

ment of a tractor-drawn plow, in co-operation with engineers of A. T. & T., for burying rubber-covered wire for exchange and rural distribution.

Tests of bare and insulated wire are always in progress. Numerous kinds of bare wire are being subjected to exposure tests with periodic examinations to determine their condition. Tests to determine the rate of change of resistance in rolled-sleeve joints and other types of line-wire connectors are now in progress. A sleet-accumulation test on bare wire was in operation for several years.

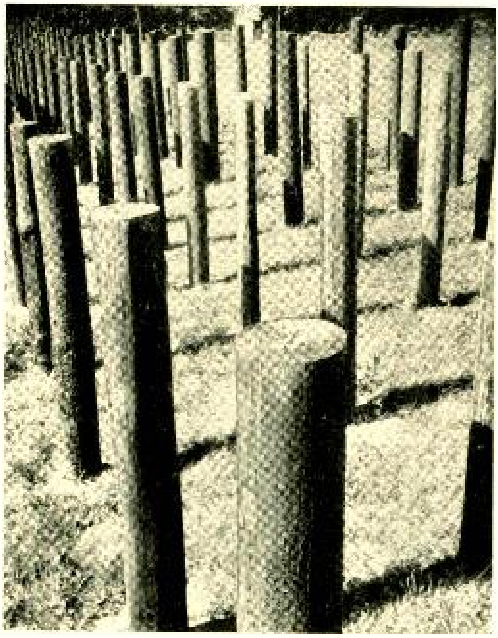


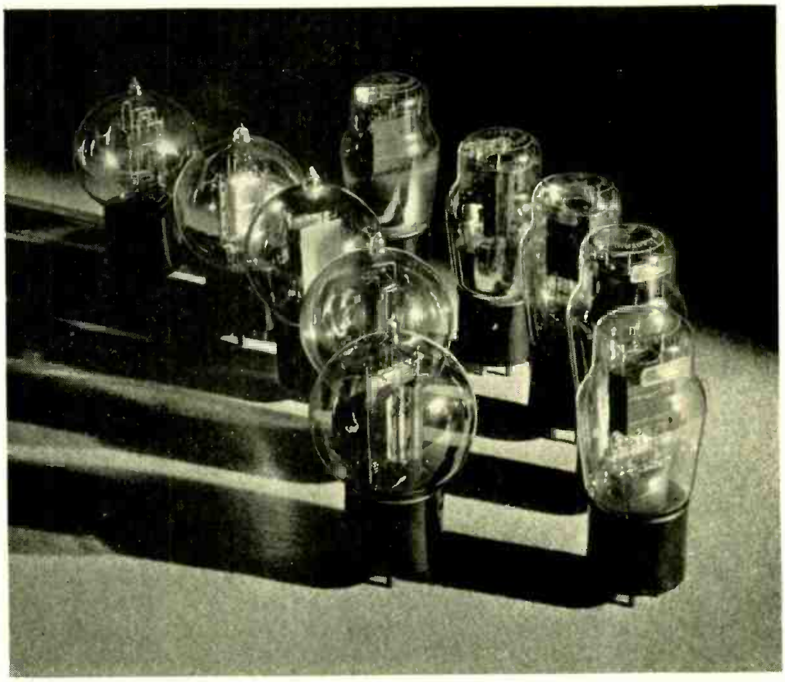
Fig. 6—Life tests of telephone poles

Considerable quantities of insulated wire of various types are under observation for the effects of weathering and tree abrasion. Underground wire has been buried in different locations to study the effects of moisture and aging; and long lengths of this wire were subjected to artificial lightning to develop a means for protecting it from lightning when in service. Various kinds of joints in insulated conductors are under observation. Crotch joints in parallel drop wire are maintained under approximately 250 volts of direct current while exposed to the weather in the course of developing a joint which will be free from electrolytic corrosion.

Timber products are an important factor in the work of an outside-plant field laboratory. Large numbers of pole stubs, representing a variety of woods and kinds of preservative treatments, are set under conditions typical of this part of the country. A supplement to this test involves using small saplings instead of full-sized stubs to give an accelerated rate of decay. All of these specimens are subject to frequent inspection to insure a practically continuous knowledge of their condition. Other stubs which have been creosoted are used for experiments with means for controlling creosote bleeding, either by the use of sealing paints or by the removal of the excess creosote on and near the surface. Several beds of earth have been fenced off and planted with specimens of wood for the study of fungus growths, and colonies of native termites are being studied.

Experiments with reduced spacings and new configurations for the wires of open-wire lines have been in progress over a period of years. This work is done on a six-span open-wire line running over the top of the highest part of the property. Equipment for the recording of swinging contacts, wind velocity and direction, and temperature is located in the test house.

As experience with the outside plant field laboratory accumulates, the advantages gained by maintaining a laboratory of this character become increasingly evident.



Improved Repeater Tubes

By G. E. MOORE
Vacuum Tube Development

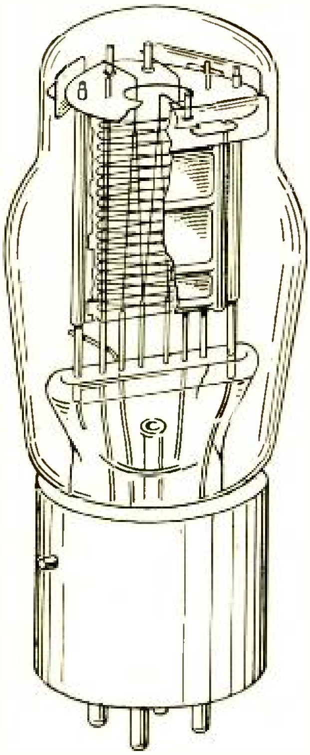
NEW methods of constructing repeater tubes have recently been developed which permit lower manufacturing costs, more uniform electrical characteristics, lower noise outputs, and longer life. These newer methods have been utilized in tubes recently standardized to replace the older designs of repeater tubes. The new tubes are shown in the headpiece at the right, together with samples of the corresponding older designs at the left. The electrical characteristics of the new tubes are identical with those of the old, thus permitting replacement of the old tubes by the new without circuit readjustment.

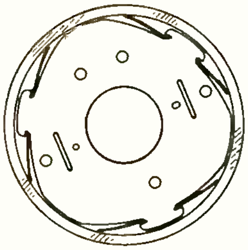
The characteristics of a vacuum tube are determined by its electrode geometry and they are very sensitive to small variations in spacings. The manufacturing deviations in these spacings are held within narrower limits in the new tubes, with consequent improvement in the uniformity of the product. This improvement results principally from the use of a mica insulator to support the electrodes at the top, as shown in Figure 1. The grid and plate are aligned by holes drilled in the mica. The filament hooks are welded to small studs inserted in the mica and the tungsten springs which support the filament are welded to the studs with sufficient deflection to keep the filament under the correct tension when hot. Mica can be machined to dimension more accurately than any other insulator readily available and the spacings between elements are thus controlled almost as accurately as the mica is machined.

Although the older tubes were quite satisfactory from the standpoint of microphonic noise at the time they were developed, the severe requirements of program and other circuits which have since become increasingly important have made improvement desirable. Figure 2 shows the statistical distribution of the microphonic noise output found in new and old 101F tubes. This improvement is typical of all tubes of this type and is largely due to firmer support of the electrodes at the top.

In the older tubes with spherical bulbs, the electrodes were supported entirely from the glass stem on which they were assembled. In the new tubes the cylindrical structure or "dome" at the top of the bulb permits support of the electrodes at top as well as bottom. The bottom support is obtained from the wires in the glass press, somewhat as in the older designs. The mica disc which forms the top support is fastened securely to the electrodes and contact is made with the glass of the dome by the three transverse members mounted around the circumference of the disc. These transverse members spring sufficiently to hold the top structure firmly in position with all manufacturing variations likely to occur in the interior diameter of the dome. The mica support also keeps the electrodes at the center of the bulb as well as accurately spaced with respect to each other.

Very high insulation is required between the grid and other electrodes of repeater tubes. It can be impaired by gas ions, thermionic emission of electrons from the grid, and the formation of conducting paths across the insulating surfaces. Gaseous ions are practically eliminated by thorough removal of the gas during carefully controlled exhaust processes. Thermionic emission from the grid can occur when it becomes coated with material evaporated from the filament, if the operating temperature of the grid is sufficiently high. Similarly, electrical leaks can develop across insulating surfaces if they become coated with evaporated material and are operated at high temperatures. In the new tubes, evaporation of the coating is reduced to almost negligible values by keeping the operating temperature of the filament low. Furthermore, the grid and insulating surfaces are maintained at low temperatures by





DETAILS OF MICA SUPPORT AT TOP

Fig. 1—The electrode structure of the new tubes is supported at both top and bottom. A mica disc at the top is fastened to the electrical structure and held firmly against the side of the dome by three transverse members

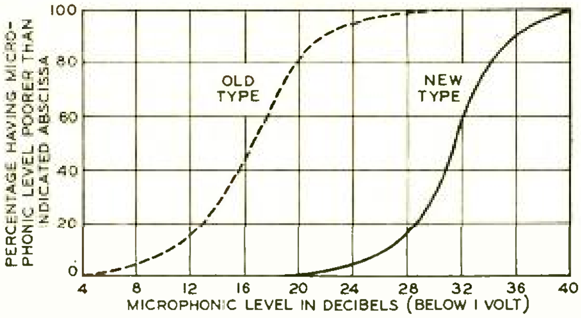


Fig. 2—The improved repeater tubes are quieter than those of previous designs

blackening the plates which then radiate more readily the relatively small amounts of energy dissipated in these tubes. Since the grids and insulating surfaces are surrounded by the plate, they also tend to operate at the same low temperature. The insulation is improved still further by coating the surfaces of the mica insulators which face the filament with a fluffy layer of insulating material. This presents an extended surface to the evaporating atoms and makes any conducting path across the mica very long. The wires in the press are also spaced well apart by a special tool developed for this purpose. These changes have improved the insulation in the new tubes by a factor of approximately ten compared with tubes that are of older design.

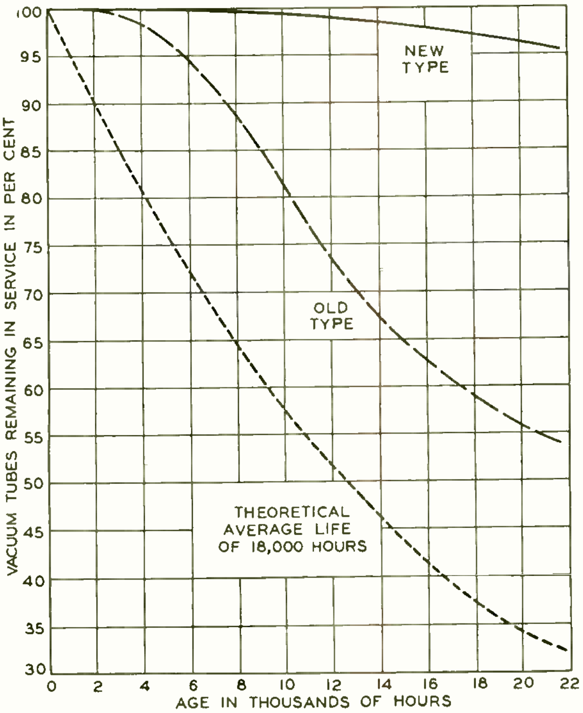


Fig. 3—The new repeater tubes have longer life than earlier ones, as shown by the upper curve which gives the results of a typical field life test

The older tubes were exhausted through a tubulation at the top of the bulb and thus had exposed seal-off tips which were unsightly and a breakage hazard. The exhaust tubulation in the new tubes is located in the press and the seal-off tip is protected by the base.

The new design permits the use of a number of common parts in the five different tube types. Only two types of press, plate, and mica are required and these differ only in minor details. The presses are alike except for the number of anchor wires and the plates differ only in length, so that both types can be made with the same tools. Similarly the two mica discs are alike except for the number of holes for the studs to which the hooks supporting the filament are attached.

Substantial improvement has been made in the filaments. They require considerably less power per unit area to heat them to the operating temperature than the older types because their whiter surface radiates heat less readily. The filaments in the new tubes were designed to consume the same total heating power as in the old so that the corresponding types would be interchangeable without readjusting circuit resistances. As a result, the electron-emitting surfaces of the new filaments are much larger. Thus the filament area in the new 101F tube is about one square centimeter while it was only about 0.35 square centimeter in the older tube. This nearly threefold increase in emitting area gives considerably longer and more uniform tube life.

One of the most important advantages of the new tubes is their longer life. The changes in the filament have made it practical to impose more severe manufacturing acceptance tests and this eliminates almost all early life failures. It is still too early to make definite predictions of the ultimate life of the new tubes but it is safe to expect that it will be several times that of the corresponding older types. This is illustrated in Figure 3, where the results of typical life tests are shown. The abscissae represent hours in service and the ordinates, the percentage of the tubes started on the life test which are in operation at any later time. At the bottom is a theoretical curve for an average life of 18,000 hours, the nominal average life of the older 101F tubes. The next curve above it represents the experimental results obtained in an actual life test of the older type of 101F tubes. The upper curve shows the behavior of a typical field trial of the new tubes. The improvement in life will lower both the routine testing costs in repeater stations, and annual tube replacement expense. The lower manufacturing cost represents additional economy.

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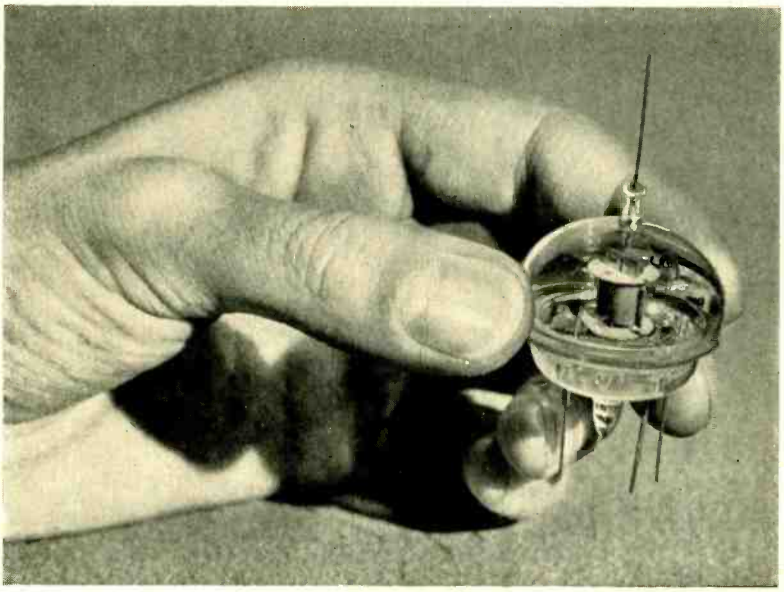

One of the new vacuum tubes developed especially for amplifiers in the coaxial system. It is a pentode and involves such small parts and accurate assembly that microscopes are used in the manufacturing process. The tube is wired directly in the circuit without the usual base in order to minimize the capacitances between the various lead-in wires

Contributors to this Issue

C. A. Chase received the B.S. degree in Naval Architecture and Marine Engineering from Massachusetts Institute of Technology in 1922. After five years of mechanical and marine engineering experience he joined the Laboratories in 1927, where he was engaged until 1932 in a variety of staff work in the Outside Plant Development Department. He was next assigned to the Chester Field Laboratory as Resident Engineer and remained there until the fall of 1939. At present he is concerned with the construction of the Murray Hill Laboratory as Field Representative.

D. W. Farnsworth was graduated from Lehigh University with the B.A. degree in 1929, following which he spent a year with the Radio Corporation of America. He has been a member of the Acoustical Research Department since joining the Laboratories in 1930. He was at first concerned with hearing studies, including investigations of the acoustical properties of telephone bells and other signalling devices, and studies of telephone noise. More recently he has been concerned with fundamental speech investigations, especially measurement of the distribution of speech power around the talker's head, and most recently, studies of the mechanism of speech production.

After receiving the degree of B.S. from Queens University, Canada, and a master's degree from Harvard, W. A. Marrison joined these Laboratories in 1921. He was soon engaged in the study of constant-frequency sources of alternating current and of methods for the precise measurement of frequency and time. His chief contribution in this field was the development of the quartz crystal clock, which with later modifications is now used for precise time and frequency measurements in industrial and national physical laboratories throughout the world.

Benjamin Slade received the degree of S.B. in Electric Communication Engineering from The Harvard Engineering School in 1927, and in the same year joined the Laboratories. For the next two years he was engaged in the design of re-

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tardation coils for filters and equalizers. In 1929 he transferred to the radio development group and until 1936 was concerned with the development and calibration of quartz plates for radio frequency control. Since that time he has been engaged in the development of crosstalk balancing coils and retardation coils.

G. E. Moore came to the Laboratories in 1927 immediately after graduating with the B.S. degree in Physics from California Institute of Technology. In 1930 he received the degree of M.A. in Physics from Columbia University. He has worked on vacuum-tube development problems including research concerning the properties of oxide-coated cathodes and their development for commercial use.

Benjamin Slade

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