BELL LABORATORIES RECORD

INDEX

VOLUME 19

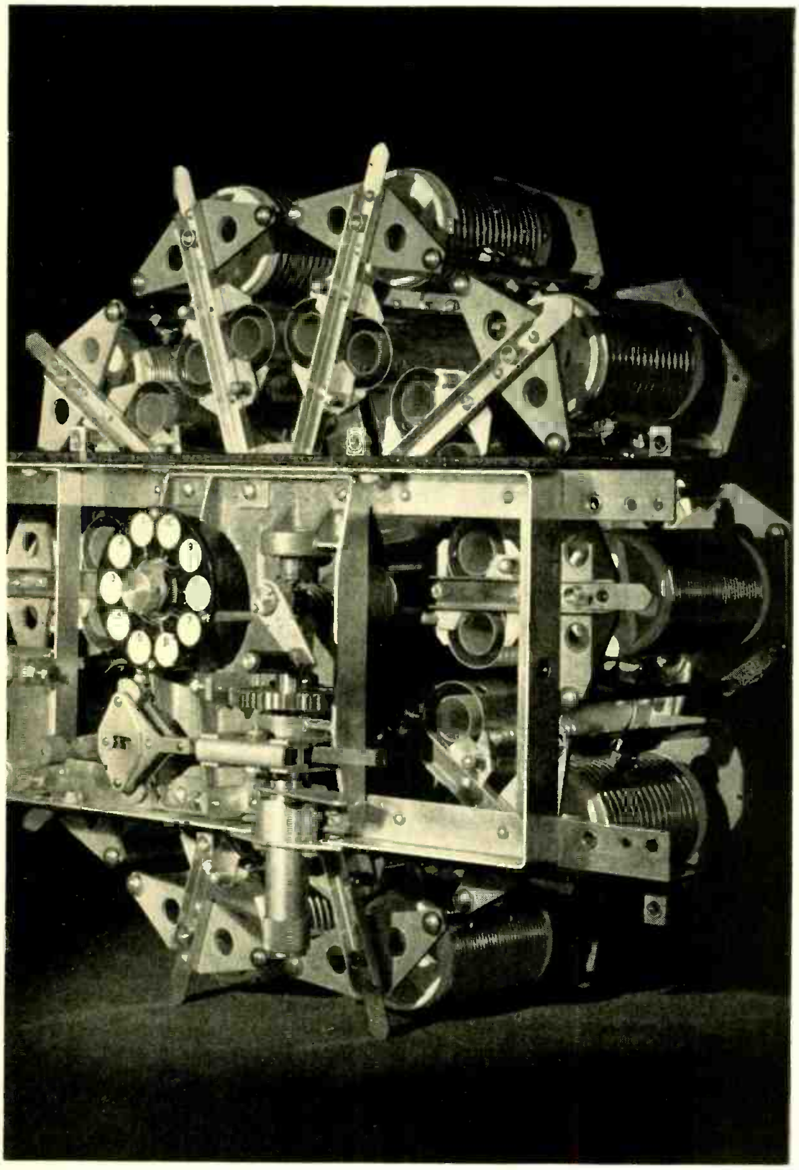
from September 1940 to August 1941

BELL LABORATORIES RECORD

Bell Telephone Laboratories, Incorporated
463 West Street, New York, N. Y.

LIST OF ISSUES IN VOLUME XIX

BELL LABORATORIES RECORD



SEPTEMBER
1940

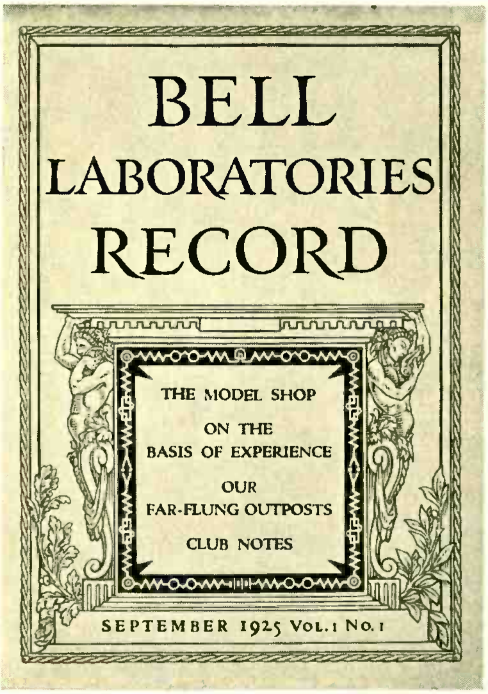
VOLUME XIX

NUMBER 1

Turret carrying crystals and tuning coils for a ten-frequency aviation-type radio transmitter

Fifteen Years

IN SEPTEMBER, 1925, appeared the first issue of BELL LABORATORIES RECORD. Eight months earlier Bell Telephone Laboratories had been formed from the Engineering Department of the Western Electric Company. Acquaintance with the new organization and its work needed to be fostered; hence the new magazine.



Volume one, number one. The familiar cover design, by Thomas M. Cleland, was used for thirteen years. It was printed in dark ink on yellow paper stock

As their typical reader the editors visualized an engineer or scientist who followed the professional journals for detailed information regarding his chosen field, but whose general interest in related fields would lead him to read articles attractively presented and of not-too-great difficulty. Non-technical readers, it was hoped, would find in the opening paragraph of each article something worth remembering about current advances in the art. Literary style was to be consistent with the excellence of the Laboratories' scientific and technical work.

The first issue of the RECORD found the Laboratories' activities in Manhattan confined to the original West Street building. That issue carried an account of the permanent groups stationed at Cliffwood and Deal, New Jersey, at Hawthorne, and of the inspection engineers at Telephone Companies' headquarters. From time to time the RECORD has carried news of changes in our outposts—the transfer of activities from Cliffwood to Holmdel, and the establishment of laboratories at four other New Jersey points—Whippany, Mendham, Summit, and Chester. Cable engineers are stationed now at the Kearny and Point Breeze works instead of at Hawthorne.

"On the Basis of Experience" captioned a biographical article on the Laboratories' Board of Directors. They were John J. Carty, Bancroft Gherardi, and Frank B. Jewett, representing the American Telephone and Telegraph Company; Charles G. DuBois, James L. Kilpatrick and Jay B. Odell, representing the Western Electric Company, and Edward B. Craft, Executive Vice President of the Laboratories. Of these, only

Messrs. Jewett and Kilpatrick are now in active service

A picture of Dr. Buckley appeared in Vol. 1, No. 1, with a specimen of the permalloy-loaded cable for transoceanic telegraphy which was an outstanding contribution to the communication art. Letters-per-minute were increased from 500 to 1900 by the new cable and its terminal apparatus. In the RECORD for September, 1933, appeared the news that Dr. Buckley had become Director of Research, following the death of H. D. Arnold. The January, 1937, issue marked, by a portrait and biographical note, that he then became Executive Vice President.

Beginning a long record of central-office developments, the first issue carried an article on the semi-remote control power board, then beginning to come into use. Many other power-plant developments through the years have been traced: commercial-type generators, emergency gasoline engines, noise filters, rectifier plants for vacuum tubes, regulating circuits, down to the constant-current system for coaxial-cable repeaters and the wind-driven generators that are used for the type-J carrier.

Appearance of members of the Laboratories before professional and other audiences was in 1925 as now a recognized way of telling our story to the public. Picture transmission was then the Bell System's latest announcement, and Dr. Ives was recorded as having described it to some ten engineering and scientific bodies. K. K. Darrow delivered a series of lectures in Pittsburgh on "Atoms and Radiation." Dr. Jewett spoke at the American Institute of Electrical Engineers convention in St. Louis, and elsewhere. L. H. Germer presented a paper, "Initial Velocity Distribution of Thermionic Electrons," before the American Physical Society.

So the RECORD set out on its career with stories of things close at hand, and so month by month it has continued with factual accounts of the Laboratories' work. Seldom is a ro-

This picture of O. E. Buckley appeared in the first issue, in connection with a résumé of his Bell System Technical Journal paper on permalloy-loaded cables. Dr. Buckley was then in charge of submarine cable development, in the Research Department

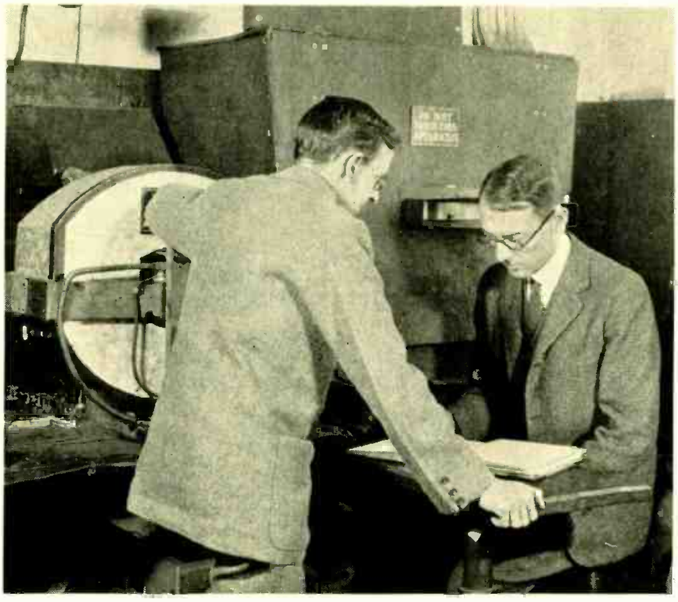
mantic phrase found in its columns. But the saga of communication is there. Two-way transatlantic radiotelephony was chronicled in 1926, the first link in what is now a world-wide network of speech channels. The same year brought an account of sound motion pictures, for the first time offered on a commercial basis. America's preëminence in this field rests on developments subsequently reported in the RECORD. In 1927 was described the achievement of television by wire and radio over substantial distances; television of out-door scenes in 1928; television in color in 1929; a year later the demonstration of two-way television as an adjunct to telephony.

The Fall of 1928 saw the announcement of the Laboratories' program for aircraft radio development. Through subsequent years descriptions have appeared of transmitters and receivers which have become standard equipment on American airways.

At the present time more than two thousand yachts and coastwise craft can be connected by radio with Bell System telephones. This system was described in the RECORD for November, 1932. It supplements the ship-to-shore system for passenger steamers whose initial installation on the *Leviathan* was described in January, 1930.

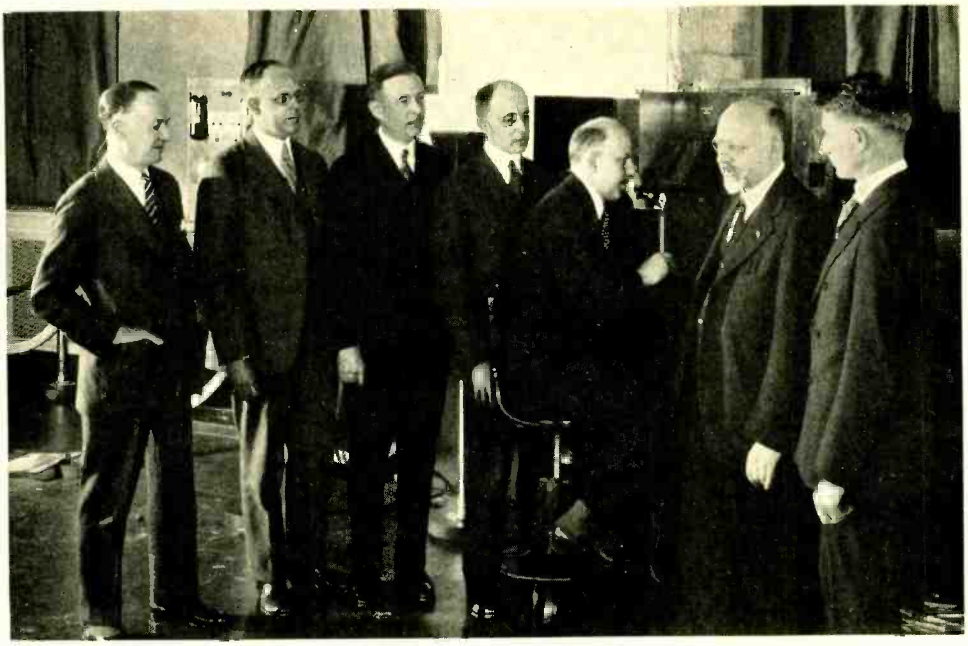
Less dramatic but of even wider usefulness have been the carrier-telephone systems. The then new type-C system was described in the December, 1925, issue; subsequent articles carry the development down through single-channel systems to the latest three-channel system, the two twelve-channel systems for open wire and cable circuits, and the 480-channel coaxial system.

Another sequence of informatory articles began with "A Mechanical Brain" in November, 1926. That was the first non-technical explanation of the panel dial system. Its reception was encouraging; and a description of the then new decoder was published. From time to time other articles have presented a comprehensive exposition of the panel system. With the standardization of the crossbar system, a set of articles was published during 1938 and 1939. Later collected into a booklet, 5,000 copies of these articles were distributed in the Bell System.



In April, 1927, *appeared a paper by C. J. Davisson (left) entitled "Are Electrons Waves?"; it was the first description for readers of the* RECORD *of an electronic research program carried on by Dr. Davisson and L. H. Germer (right) which earned the Nobel Prize in physics in* 1938

Measurement is basic to research and engineering; in their pioneering work the Laboratories have, as might be expected, produced many new measuring techniques and the instruments to effect them. New units, even, have been created: the decibel and its cousin the VU. A glance over the heading "Measurements and Testing" in any index to the RECORD brings to light such entries as "Electrical Reflections and Their Measurement"; "Measuring One

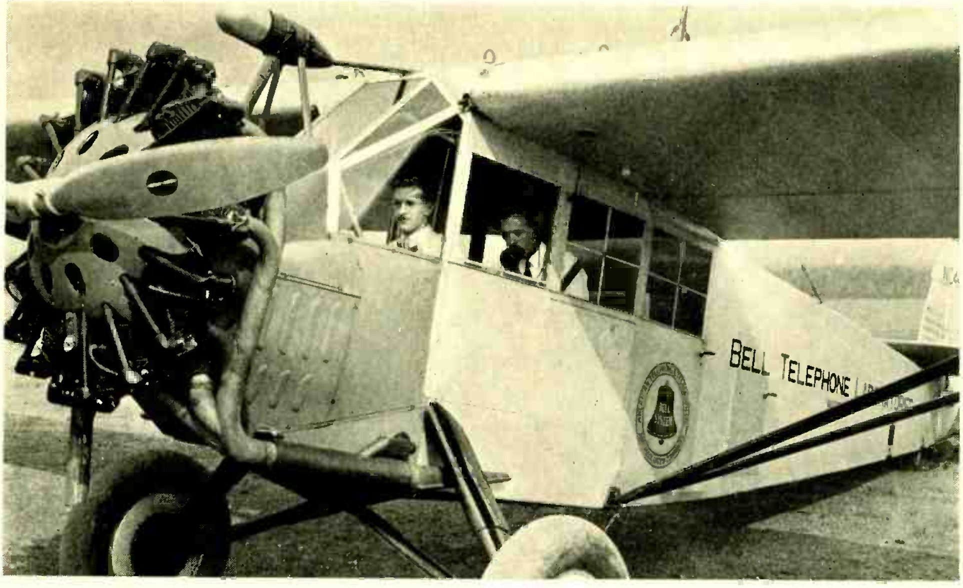


The entire issue of May, 1927, was devoted to television. This photograph, taken at the time of the first public demonstration, shows W. S. Gifford in the Laboratories auditorium talking with Secretary of Commerce Hoover in Washington. With Mr. Gifford are E. P. Clifford, H. D. Arnold, E. B. Craft, F. B. Jewett, H. E. Ives, and Frank Gray

Trillionth of an Atmosphere"; "Portable Sound Meter"; "Impedance Bridges"; "Master Reference System for Transmission"; "Permeameters for Wide Temperature Ranges"; "Measurements of Articulation"; "Strength of Earth Anchors"; "Recording Humidity." Particularly in the measurement of electrical quantities such as impedance, reflection, attenuation and frequency, the Laboratories' contributions have been outstanding. The quality of manufactured products has been given a precise significance; in the statistical theory which connects the quality of a sample with that of the entire lot, Laboratories' mathematicians have achieved recognition.

Honors have come to men of the Laboratories; the citations recall earlier articles in which the discoveries were reported. C. J. Davisson, Nobel prizeman of 1937, had described electron waves in April, 1927. Elliott Cresson medallists, six in number, have been authors of RECORD articles. So have been the seven Morris Liebmann Memorial prizemen, and the two John Price Wetherill medallists.

Several entirely new Bell System services have had their inception within the lifetime of the RECORD. There is the teletypewriter network, as furnished to police and aeronautical authorities. There is the teletypewriter switching system, described in January, 1932, and now serving 14,000 stations. There are the radio-broadcasting networks, carrying programs to hundreds of stations. There are unattended central offices, bringing dial service to places formerly served by magneto boards. There are secretarial, time-of-day, and weather services. To all of these the Labora-



An article in October, 1928, *by E. B. Craft, Executive Vice President of the Laboratories until his death in* 1930, *described our development work on airways communication equipment. Mr. Craft is shown at the right, with A. R. Brooks in the Laboratories' first plane, a single-motored Fairchild*

tories have contributed circuits and apparatus; and those contributions have been recorded in their magazine.

Initially the RECORD was distributed to all members of the Laboratories, and to the Department of Development and Research of the American Telephone and Telegraph Company. Gradually requests extended the distribution to management and technical personnel of the Bell System. Libraries and heads of appropriate departments of universities were added, as well as writers in the popular science field of magazines and newspapers. There are also about seven hundred paid subscribers. All in all, the circulation is now between eleven and twelve thousand.

Fifteen years have passed; the Bell System serves directly fifty per cent more telephones and handles more than double the number of long-distance calls than in 1925. For this expansion, the Laboratories have contributed ideas, methods, circuits and equipment. The RECORD is proud to have been a chronicler of that epoch.

The Nature of Organic Insulating Materials

By C. S. FULLER
Chemical Laboratories

OF THE great variety of insulating materials used in the telephone plant, by far the major part consists of organic compounds. The engineer recognizes among these insulations paper, cotton, silk, rubber, gutta-percha, shellac, insulating varnishes, phenol-formaldehyde both as phenol-fiber and as plastic moldings, cellulose acetate, and a growing host of new synthetic resins and plastics.

Although an apparently heterogeneous and unrelated group of substances, these materials really have much in common. They all belong to the class of compounds known to the chemist as high-molecular substances because they are composed of very large molecules. In the ideal case these molecules may be considered as long threads consisting of hundreds, often thousands, of atoms joined together. Along these threads one finds an orderly repetition of atom groups so that the molecule may be reproduced by connecting with chemical bonds a large number of identical units, each consisting of the same group of atoms. This arrangement is illustrated in Figure 1 where are shown a few of the many hundred identical units in rubber and cellulose molecules. All of the molecules in any given substance do not have the same number of units; there is a "spread" or distribution of molecule sizes.

Although the arrangement of long, thread-like molecules is closely approached in many instances, a cross-bridging or cross-linking commonly occurs at intervals between the long chains. These bridges may be composed of the same atoms as those in the molecules themselves or of an entirely different chemical element. Thus sulfur probably acts as such a bridge between the molecules in vulcanized rubber. The number of cross-linkages between chains varies widely. In cellulose they are absent or relatively few but occur so frequently in phenol-formaldehyde resin that the conception of the chain molecule is entirely lost and the structure may be regarded as a particularly compact three-dimensional molecular network.

The conception of these high-molecular substances as myriads of thread-like molecules explains many of their properties and why they have been selected so often as insulating materials in the electrical industry. Great strength and flexibility are provided by the felted, thread-like molecules or molecular networks. These properties are essential in insulating materials, particularly those on wires and cables where they often have to withstand severe mechanical strains. The specific properties of each substance vary with the chemical nature of the repeating unit, or group, as well as with the size of the molecules, their size distribution and the number of cross-linkages between them. Certain units, such as those in cellulose, favor the formation of minute crystals which further strengthen the chain structure as a whole. On the other hand, the units show little tendency to crystallize under ordinary conditions in natural and synthetic rubber and the chain molecules are thus free to glide past one another—a condition essential for rubber-like behavior.

The nature of the repeating unit likewise is important in determining the insulating qualities of a given material. If the unit contains polar groups like the −OH in cellulose, water is attracted into the insulation from the surrounding atmosphere and the conductivity of the material increases with the relative humidity. On the other hand, if the repeating unit is non-polar, which is essentially the case when only carbon and hydrogen atoms are involved as in rubber, the insulation resistance is high even under humid conditions and the power factor and dielectric constant attain particularly desirable values.

Recent progress in the synthesis of high-molecular substances has made possible combinations of electrical and mechanical properties heretofore unattainable. Development is proceeding along two lines: Defects in natural insulating materials are being corrected by forming chemical derivatives from them, and high-molec-

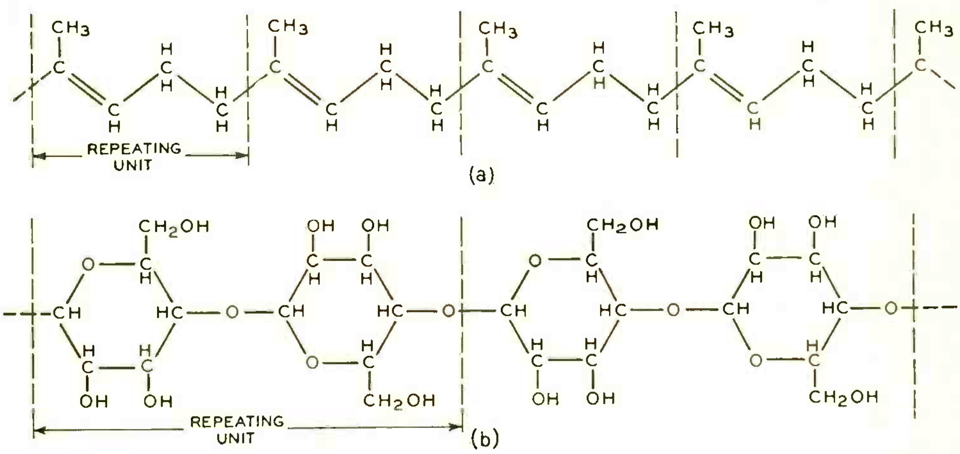


Fig. 1—*The molecules of rubber* (a) *and cellulose* (b) *consist of chains of many identical units, each composed of the same group of atoms*

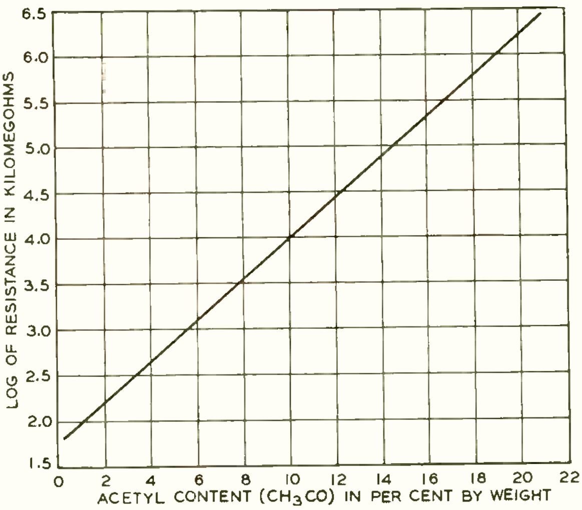


Fig. 2—The insulation resistance of cotton yarn increases when hydroxyl groups are replaced by acetate groups. The results are for a single size 60 thread which is three-quarters of an inch long

ular compounds are being synthesized directly from cheap raw materials. The acetylation of cellulose is an example of the first development. Cotton cellulose may be esterified with acetic acid and acetic anhydride with the result that some of its water-attracting —OH groups (Figure 1) are replaced with acetate or other groups which are much less hydrophilic. This may be done directly on the cotton yarn itself or by using raw cellulosic materials and subsequently reforming the fiber as cellulose-acetate rayon. In either case a decided improvement in electrical characteristics results. Figure 2 shows the change of insulation resistance at 38 degrees C. and 85 per cent relative humidity of cotton yarn for various degrees of acetylation. The results are for a single size 60 thread ¾ inch long; they show that the resistance increases logarithmically with the percentage of acetate. Parallel with this increased resistance there is also a decrease in moisture absorption as shown by the curve of Figure 3 for the equilibrium amount of water held under the above temperature and humidity conditions.

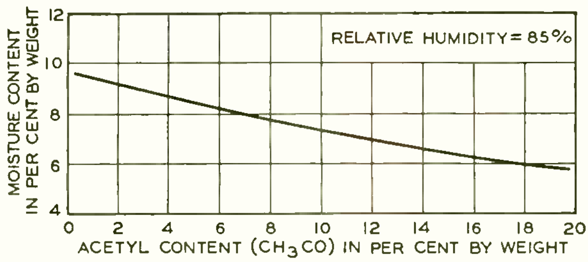
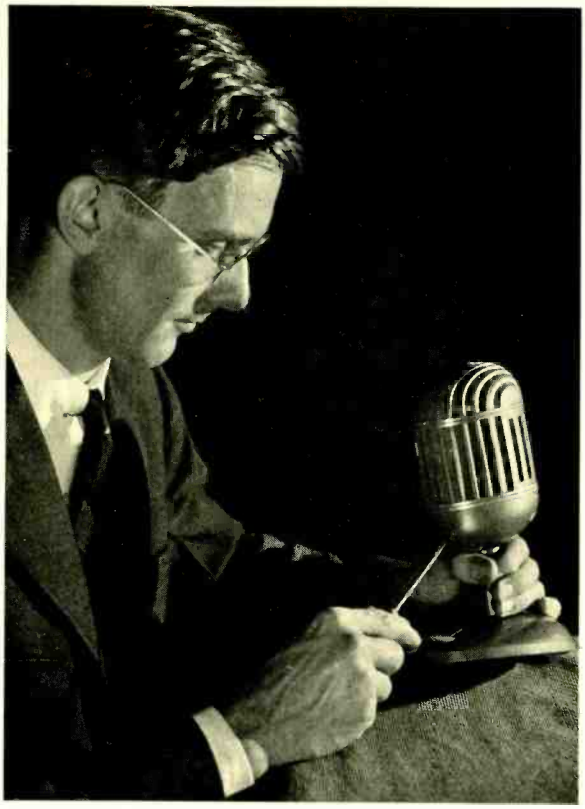


Fig. 3—The moisture absorbed by cotton fiber decreases as its acetate content rises

In the second field of activity the long molecules themselves must be created and not simply transformed. These substances have not made great headway thus far in the insulation field, except in a few instances, because of higher costs and other considerations. The situation is rapidly changing, however, and the time is probably not far off when a number of valuable combinations of useful properties may be expected from this purely synthetic approach.



Six-Way Directional Microphone

By W. R. HARRY
Transmission Instrument Development

SINCE its introduction a year ago, the Western Electric 639A microphone has found a wide range of usefulness. Its directivity pattern is heart-shaped, with a broad area of uniform sensitivity in front and an area of zero sensitivity behind. This "cardioid" pattern, which has given a name to the microphone, is only one of a family of directivity characteristics which can be obtained with a microphone of the same general construction. Other patterns have dead regions in other directions; and since a problem in sound pick-up is to eliminate the noise which our senses disregard in binaural hearing, a new microphone was developed to suppress these unwanted sounds more effectively. This Western Electric 639B microphone has three patterns in addition to the cardioid and those obtained when the ribbon and moving coil elements are used separately, thus providing a microphone with six entirely different directional patterns.

The new directional characteristics are obtained, as were those of the 639A microphone,* by combining in series the outputs of a moving coil and ribbon microphone element. When sound strikes this combination from the front, the output voltages of the two elements are in phase and add. When it arrives from the rear, the phase of the ribbon element reverses while that of the moving coil element remains unchanged and the outputs of the two tend to cancel each other. The operation of this combination gives the equation $E = a + b \cos \theta$ for the output voltage, where a is the output of the moving coil element, which is independent of the angle, and $b \cos \theta$ that of the ribbon element for sound approaching at an angle θ to a line drawn perpendicular to the plane of the ribbon. This is the equation of a family of polar curves which change with the values assigned to a and b. Actually the directional characteristics are represented by surfaces of revolution in three-dimensional space. One of these surfaces is illustrated in

*RECORD, *July*, 1939, *p.* 338.

Figure 1 and shows that the microphone characteristics are the same in vertical and horizontal planes as well as intermediate ones.

For many applications the most useful characteristics are obtained when a is equal to or less than b, that is, when the pressure element (moving coil) output is less than that of the pressure gradient (ribbon) element. Where $a = b$ the two elements are equal; and they are out of phase for sound incident at 180 degrees, so that cancellation occurs at this angle. This is the condition in the 639A cardioid microphone. Where the value of a is decreased the two outputs are equal and opposed at two angles symmetrically disposed around 180 degrees so that cancellation results at these two angles. The exact manner in which the directional patterns of the two elements combine to yield new patterns with two dead zones symmetrically disposed about the 180-degree axis is shown in Figure 2. By adjusting the output of the pressure element with respect to the pressure gradient element the zones of minimum sensitivity may be shifted to

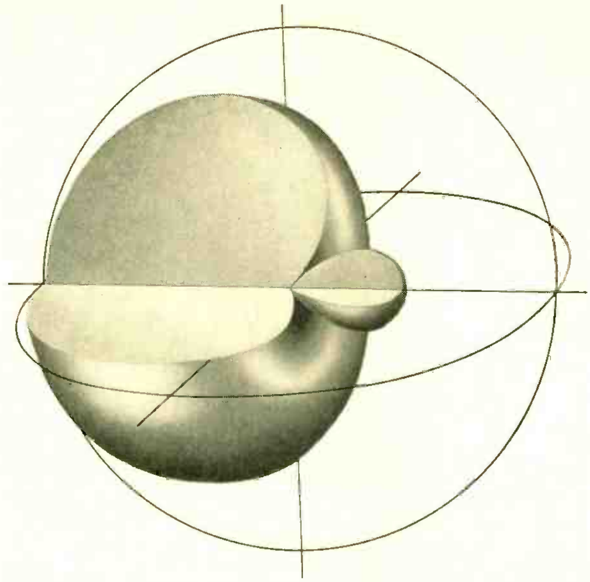


Fig. 1—Three-dimensional diagram of No. 2 directivity pattern of the 639B microphone. A quarter section has been removed to show more clearly the form of the surface. At any angle, the sensitivity is proportional to the length of the radius drawn to the surface of the solid

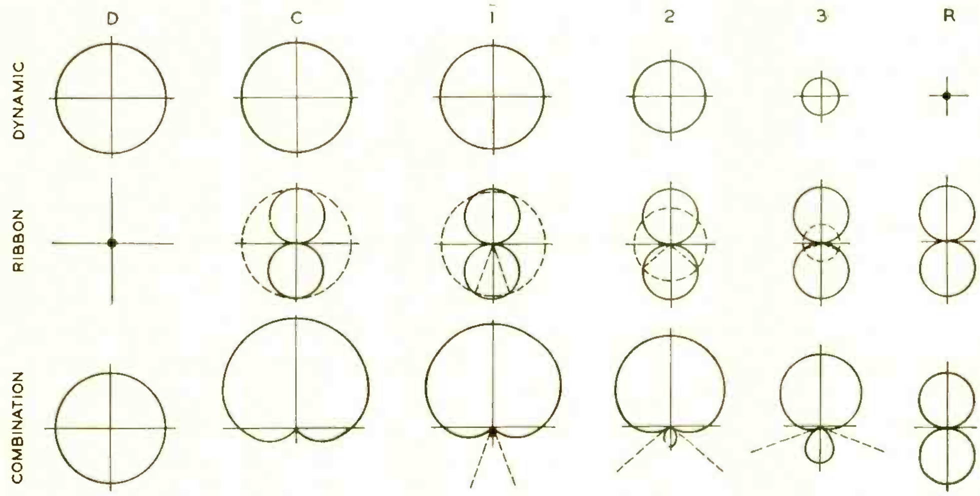


Fig. 2—Directivity patterns of the 639B six-way microphone

any point between 90 and 180 degrees, and this feature is used in the six-way directional microphone. Three definite patterns were chosen for the new microphone because an arrangement to continuously vary the combination would introduce serious contact and noise problems in the low-level microphone circuit, whereas fixed switch positions provide reliable operation and sufficient choice of pattern for all practical purposes. The main structural details of the 639B microphone are identical with those of the 639A. In the 639B provision has been made for reducing the output of the pressure element so that all of the directional patterns shown in Figure 2 may be obtained. This is accomplished by connecting different values of shunt resistance across the pressure element without breaking the main microphone circuit. A six-position switch permits the selection of either the moving coil or the ribbon elements, the cardioid combination and the three new directional patterns.

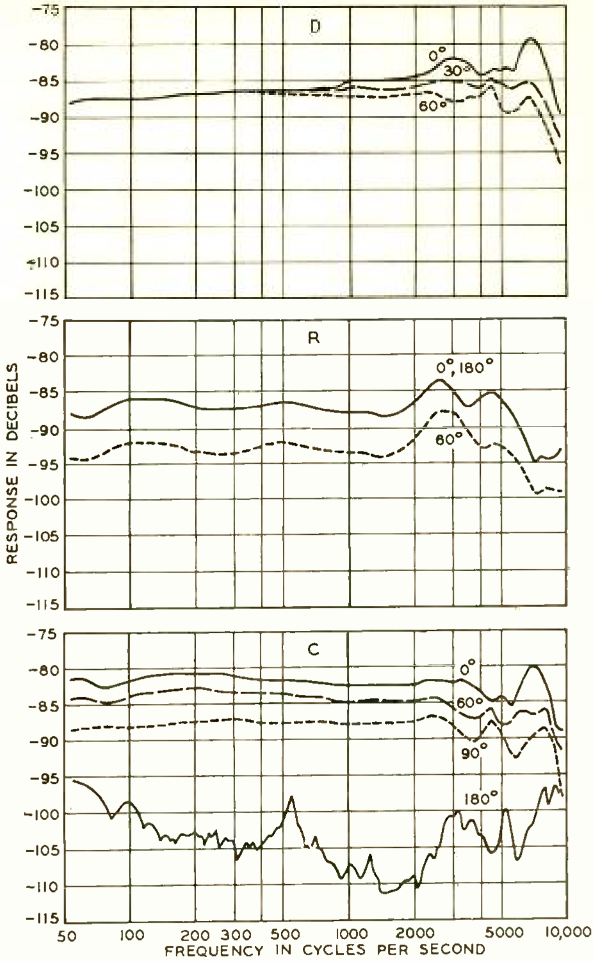
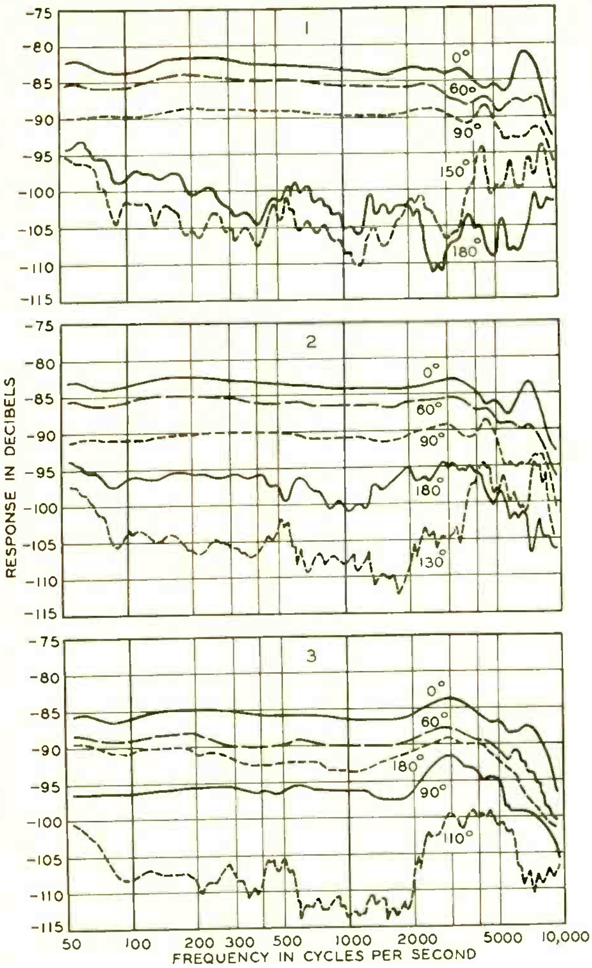


Fig. 3—Field responses of a typical 639B microphone for the six switch positions. The lower curves in each group contribute negligible amounts to the

Shunting the output of the moving-coil element to reduce its output is all that would be necessary to obtain the new directional patterns in an ideal theoretical microphone, but the problem is more complicated in practice. Phase equalization in the 639A was largely responsible for the excellent agreement of the directional characteristic with the theoretical cardioid over a wide range of frequencies. This equalization was used partly to compensate phase differences arising within the elements themselves but also to correct the phase difference caused by the different distance which sound had to travel to reach the two elements. The selection of new angles of minimum sensitivity changes the amount of this correction and the constants of the phase-corrective network were therefore changed accordingly. The result is shown in Figure 3 where the response with respect to frequency for several angles of each directional pattern is given. The curves are nearly



total pick-up because of the unusually high discrimination against sound arriving at these angles. (Response is shown relative to 1 volt/dyne/cm²)

factory service in this location the additional improvement obtained in this trial encouraged extensive probing into the action of these pick-up patterns under other conditions encountered in the field.

A sound-reinforcement system was installed in the U. S. House of Representatives in January, 1939. The highly reflecting marble walls and the shape of the auditorium made feedback conditions so severe that serviceable reinforcement could not be used with a non-directional or bi-directional microphone without developing "sing." To relieve this situation, a 639B was employed. Figure 4 shows the approximate position of the microphones and loud speakers. The No. 3 pattern proved to be the best and permitted an 8-db increase in sound output. This was 3 db more or twice the power obtained with the cardioid, which in itself was quite an improvement over other microphones.

At the huge Madison Square Garden, indoor sports arena in New York, the sound-reinforcement problem is difficult because the loud speakers are arranged so as to radiate sound equally in all directions and may be moved up and down or from one end of the arena to the other for different performances. A typical set-up has been with the microphone position at one side of the arena. This condition gave a feedback which was best controlled by pattern 2. The improvement was 6 db over the cardioid pattern which in turn was 6 db over that of the moving-coil setting—a

parallel except in those cases where the sensitivity is so low as to pick up little if any sound.

A 639B microphone was used in the public-address installation when Anthony Eden, British War Secretary, talked at the Waldorf-Astoria Hotel in New York, December 9, 1938. Pattern 2 in Figure 2 permitted a 2-db increase in the sound output over that obtainable with the 639A cardioid before singing occurred. Although the 639A gave quite satistotal increase in power of 16 times that previously used. There was also an improvement in naturalness because the microphone gave more prominence to direct over reverberant sound. The different pick-up pat-

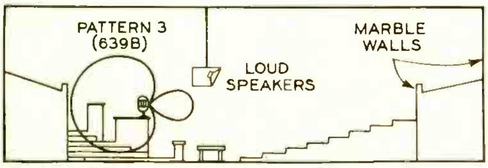


Fig. 4—Sound-reinforcement system installed in the House of Representatives

terns of the 639B microphone make it unusually well adapted to the changing requirements of the Garden program.

These public-address demonstrations showed that reverberation effects in studio pick-up could be controlled to a greater degree than heretofore. This was corroborated in practice through the coöperation of WOR, with a small symphonic orchestra arranged as shown in Figure 5. Pattern 3 gave as much improvement in quality over the normal cardioid as the latter gave over the bi-directional ribbon-type microphone. A curious subjective effect noted in these trials was that the bass, cleared of excess low-frequency reverberation, permitted the ear to give more attention to other sounds, thus aiding the impression of definition between all the instruments.

At times, an illusion of sounds different from those observed at the microphone is wanted and elaborate synthetic reverberation machines have been constructed to create these effects. Additional reverberation may be used to give an impression of space and distance and the 639B microphone may be employed for this purpose where studio characteristics permit. Direct sounds can be eliminated entirely from the pick-up by properly directing the microphone and selecting the desired zone of minimum sensitivity. This extreme may be modified by actually using the microphone backwards; that is, by pointing the smaller lobe, as in pattern 3, toward the source of sound. Thus, the various pick-up patterns in the 639B microphone allow reverberation effects to be enhanced or suppressed at will. This new control may be useful in studios which are operated under crowded conditions.

There is no simple way of expressing completely and quantitatively the value of a given directivity pattern but analysis has shown that pattern 2 or 3 of the cardioid family is the optimum one for many pick-up conditions. Choice of the pattern best suited to a particular acoustical condition is made very easily with the 639B by turning a switch. Moreover, the performance of this microphone follows the ideal directivity patterns to an unusual degree for the entire frequency range from low bass to high treble. Consequently, a program may be picked up in proper balance while annoying problems of reverberation echoes and feedback are effectively handled at the same time.

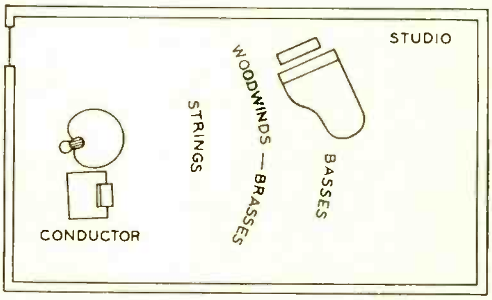


Fig. 5—Studio arrangement for the pick-up of a small symphony orchestra. One 639B microphone placed at one end leaves the studio free for action and very considerably reduces the pick-up of room reverberation

New Voice-Frequency Electrical Delay Network

By H. M. THOMSON
Transmission Networks Development

STRANGE as it may seem, delay in certain kinds of telephone service has been found very advantageous. Artificial delay in the form of "delay networks" makes possible the simultaneous operation of highly directional radio receiving antennas in the Musa* radio receiving system; it facilitates economy in operation of the automatic recording oscillograph†; and it improves the operation of transatlantic radiotelephone service when used in connection with the vodas‡ in the control terminal. Sometimes extra delay is inserted in the form of "delay equalizers" to compensate for the occurrence of undesirable delay distortion, which is introduced by filters and loaded cable circuits. Delay equalizers and delay networks differ only in the relative amount of delay provided at different frequencies within the operating range. Delay equalizers, such as those used on long toll circuits, provide more delay at low frequencies than at high frequencies, whereas delay networks generally provide approximately constant delay over the operating range of frequencies.

A delay network, or equalizer, is composed of resistances, inductances, and capacitances arranged to give a specific delay to the current passing through it, with as little attenuation as possible. The telephone current, which rises and falls with the sounds at the subscriber's telephone, supplies energy to the electromagnetic and electrostatic fields of the coils and condensers. In these fields the energy

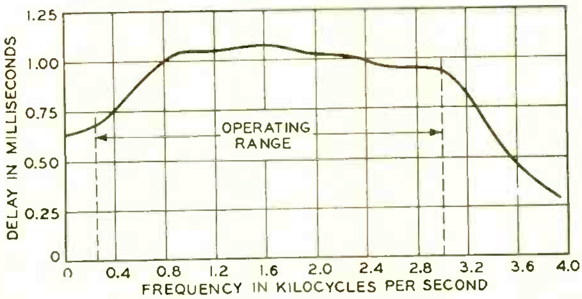


Fig. 1—Overall delay characteristics of four sections of the new delay network

may be stored for an appreciable time before it is delivered to the output terminals. In this way, a delay occurs between the receipt of the energy at the input and its delivery at the other end.

When the development of a new radiotelephone control terminal was undertaken, a new voice-frequency delay network was desired which would be much smaller and cheaper than the previously existing network. Large economies were promised by the availability of new materials and methods of manufacture. Further

*Record, *January*, 1938, *p.* 148.
†Record, *January*, 1940, *p.* 140.
‡Record, *November*, 1927, *p.* 80.

economy in the design of the delay network was to be secured by tapering off the low-frequency delay about thirty-five per cent, and the high-frequency delay about ten per cent of the nominal, as shown in Figure 1. This also is a desirable characteristic from a transmission standpoint since it tends to offset the greater delay at low and high frequencies, relative to the middle frequencies, in wire lines that may be associated with or connected to the radio circuit.

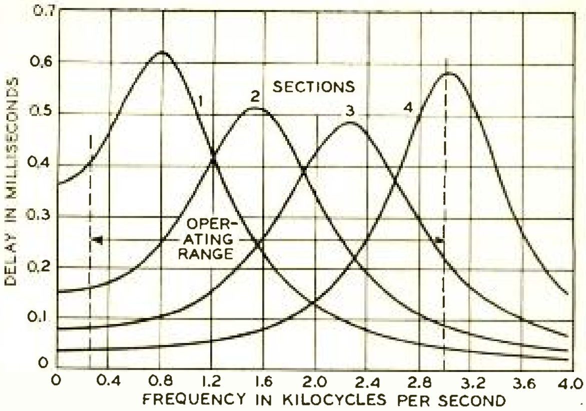


Fig. 3—Delay characteristics of each of the four sections used in the delay network

The network could have been arranged in any of several ways, because all configurations of inductances and capacitances have delay characteristics. The lattice type of configuration was selected, however, because it permits resistance elements to be placed in the network in such a way as to give a flat insertion loss with frequency, thus obviating the need for a separate loss equalizer. The essential elements of a lattice delay network of the all-pass constant-resistance type (one that passes all frequencies and has the same output and input impedances to all frequencies) are shown in the upper diagram of Figure 2. To obtain a flat loss characteristic, resistances are added to both series and shunt arms, giving the configuration of the lower diagram.

Such a configuration, or section, gives a delay that is greatest over a small band of frequencies and falls off rapidly for higher and lower frequencies. To secure the desired delay characteristic, four sections are connected in tandem. Each section provides some delay at all frequencies within the voice band, but the maximum delay for each section occurs over a different region, as shown in Figure 3. At each frequency the sum of the delay of the four sections gives the total delay for the group, shown in Figure 1. Each network section has

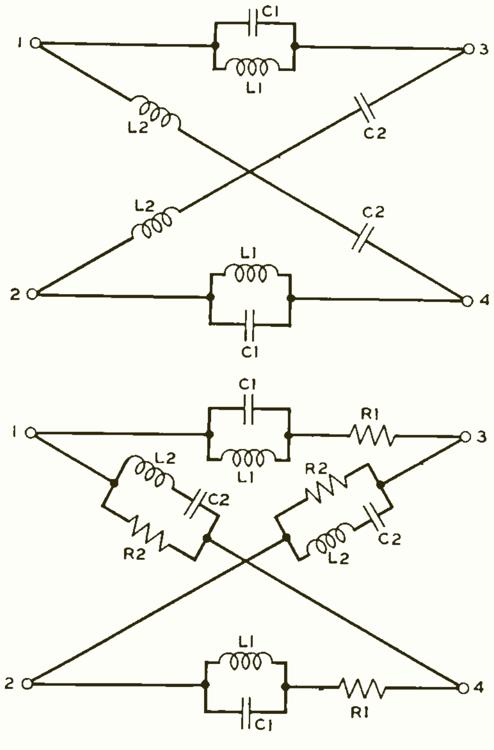


Fig. 2—Typical all-pass constant-resistance lattice section, above, and the same section with resistances added to both series and shunt arms to secure flat loss, below

the same configuration but different values of inductance and capacitance.

This group of four sections, connected in tandem, gives a delay of about one millisecond. Four identical groups are assembled in tandem in a single container to form a complete delay network, thus providing a total delay of about four milliseconds.

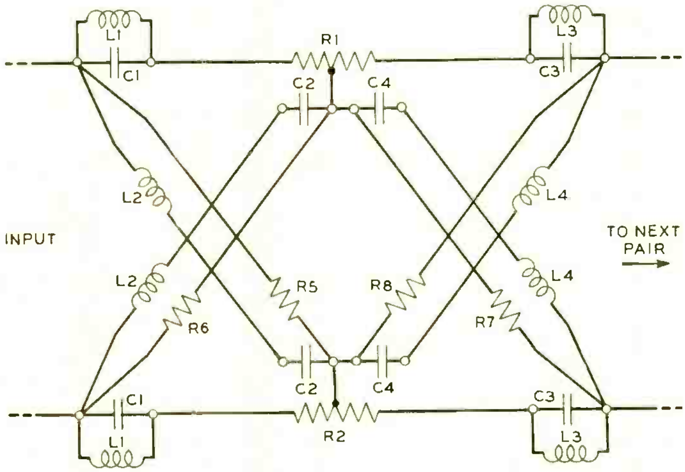


Fig. 4—Two sections are assembled, and the elements arranged so that all connections are made to condenser terminals

To simplify the network assembly and reduce the number of connections, two sections are assembled as a unit. The resistances R1 of Figure 2 for two adjacent sections are wound as a tapped unit. The pair of sections could thus be represented schematically as shown in Figure 4.

To avoid having to make splices between the wire leads of the coils and resistances, the elements in the configuration have been so arranged that all connections may be made at the terminals of the condensers, as may be seen in Figure 4. Moreover, the like-numbered condenser elements have the same capacitance, and are mounted together in the same container with separate terminals. The like-numbered inductance elements are also equal and are wound on the same core. Although the series resistances in each side are made two in a unit as already noted, the R5 to R8 resistances are made as separate units because of their higher resistance values.

The arrangement of the units within the container is indicated in Figure 5. The units of one pair of sections are assembled in a paper casing, so that any pair of the eight in the complete network may be removed for repair without disturbing the other section pairs. This removal is simplified by the fact that between pairs only two leads have to be provided. This is clearly illustrated in Figure 4.

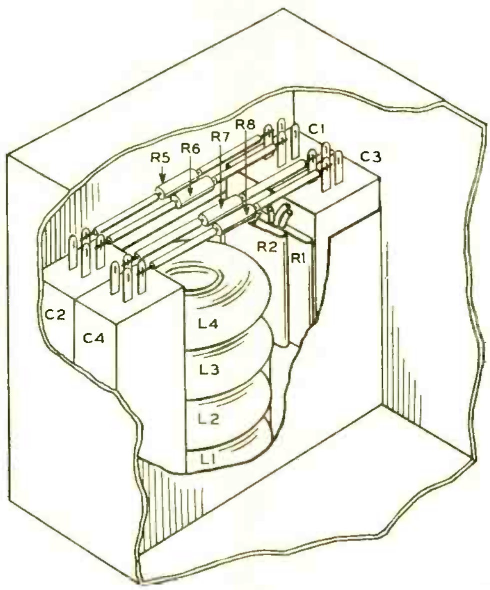


Fig. 5—Arrangement of a pair of sections in the container. Eight such pairs form a complete network

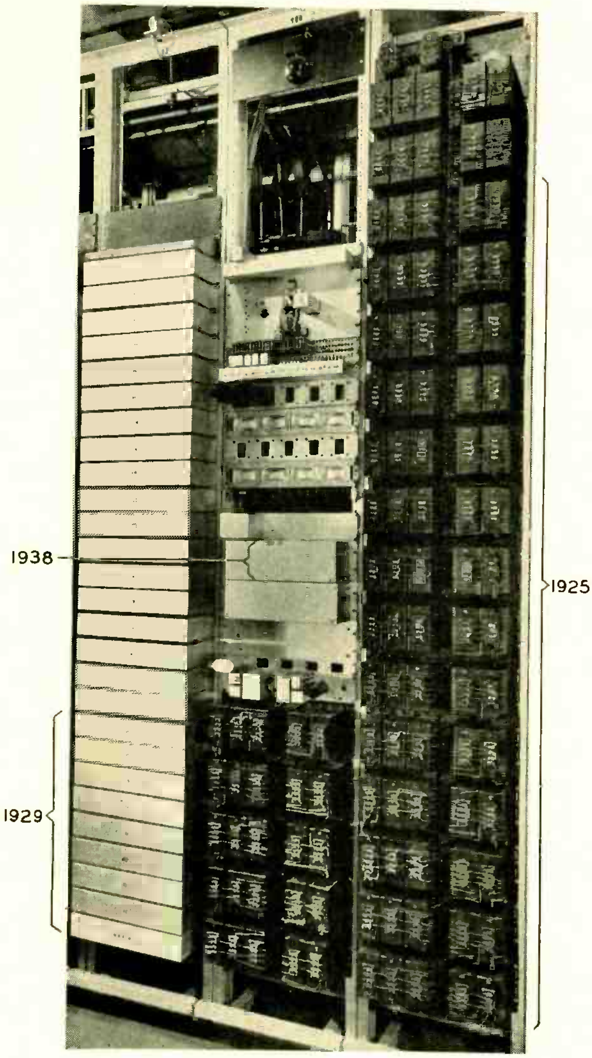


Fig. 6—The small size of the new network, 1938, *compared with the networks of* 1925 *and* 1929

This is the most compact and inexpensive voice-frequency electrical delay network we have yet developed. The achievement was made possible, in spite of an increase in the total number of elements, by taking advantage of a number of new developments and techniques. Chief among these are: the use of twin paper condensers and small toroidal coils with cores of powdered molybdenum permalloy, the assembling of sixteen delay sections in one container, an arrangement of section elements in a schematic circuit that permits a simple mechanical and electrical arrangement of units, and by the departure from a constant delay characteristic that was permitted by the requirements. The great reduction in space required is indicated in Figure 6, which shows an installation of the new type of network adjacent to installations of the two older types. Compared to the network of 1925, there is a reduction in the space required of sixteen to one, and there is even a four to one reduction in space compared to that of 1929.

Unit Ventilator

By O. C. ELIASON
Apparatus Development

IN PROVIDING for the ventilation of telephone operating rooms and offices, the exclusion of excessive outside noise and dust, which are frequently encountered in industrial locations, is an important consideration. Buildings equipped with central ventilating systems with duct distribution of filtered air present no particular noise problem beyond keeping the windows closed. In buildings not equipped with central ventilating systems, unit ventilators are frequently used to draw air directly through a window or wall opening into the space to be ventilated. This type of ventilator is usually provided with dust filters but may admit almost as much street noise as an open window. To correct this condition and also meet certain mechanical and size requirements a new unit ventilator has been developed by the Laboratories.

This ventilator is housed in an attractive metal cabinet and mounted on wall brackets directly in front of a window. To install it, a section of glass is cut away from the lower part of the window and a metal intake duct, equipped with weather louvers, is fastened to the outside of the sash over the opening. Another metal duct is attached to the inside of the sash and coupled to the air intake of the ventilator by a slip joint which allows the window to be raised for cleaning.

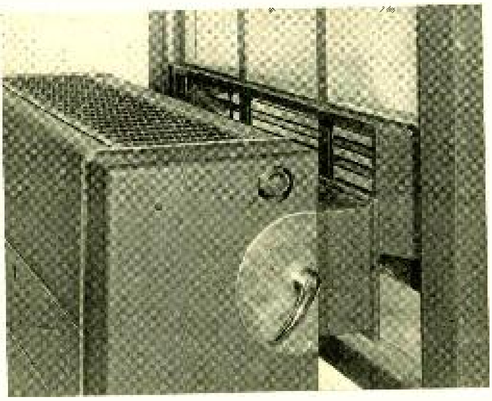


Fig. 1—Unit ventilator for telephone operating rooms and offices. Air is drawn in through a metal duct in a window frame, and then it is filtered and delivered to the room through a grill at the top of the ventilator

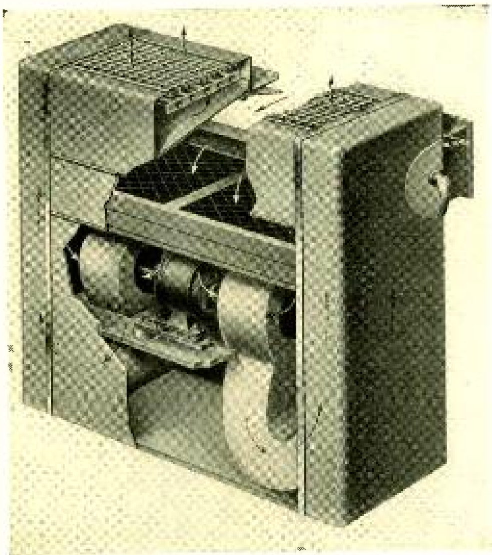


Fig. 2—Two fans attached to a slow-speed motor draw air in through a dust filter and discharge it vertically into the room. A radiator is installed below the outlet grill if heated air is required

Provision is made for installing a fin-type steam radiator directly underneath the grill of the ventilator, where it is desired to heat the incoming air. Eight hundred cubic feet of air per minute are delivered with a radiator and nine hundred cubic feet without it.

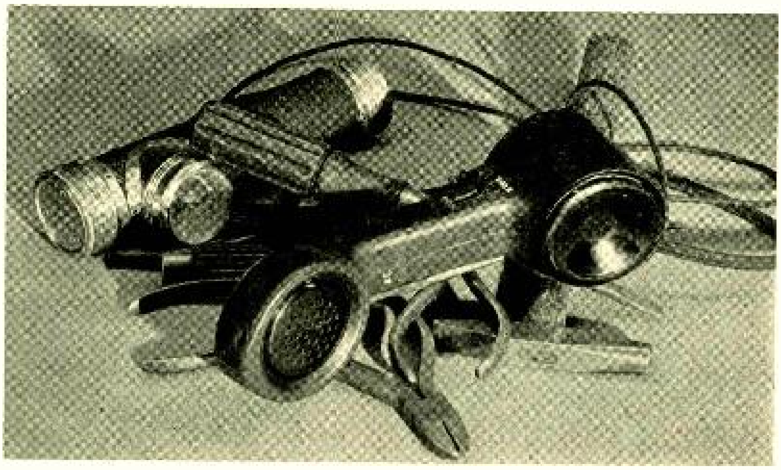
To absorb outside noise the walls of the cabinet and the ducts are made of two thicknesses of metal with soft asbestos between them. This construction, in conjunction with relatively long air passages, deadens the sound enough to make the ventilators about as effective against noise as a closed window.

A slow-speed motor with a fan mounted on each end of the shaft supplies the power. Rubber feet support the motor and effectively absorb motor noise and vibration. An automatic fire damper and motor shut-off actuated by a fusible link are provided in the intake duct to prevent flames from being drawn into the building in case of fire in a nearby structure. The damper may also be closed or set at any desired degree of opening, while the ventilator is running, by the external handle shown in the illustrations.

The ventilator is regularly equipped with a renewable air filter which has to be replaced usually at intervals of from four to six weeks depending on atmospheric dust conditions. A door in the front provides easy access to the air filters and to the motor for oiling. The inner air passages can be reached for cleaning and inspection by removing the large front panel.

Air is drawn in through the damper openings and the filter. It then divides and passes through the fans, thence through the ducts at the ends of the ventilator housing, and upward through the outlet grill.

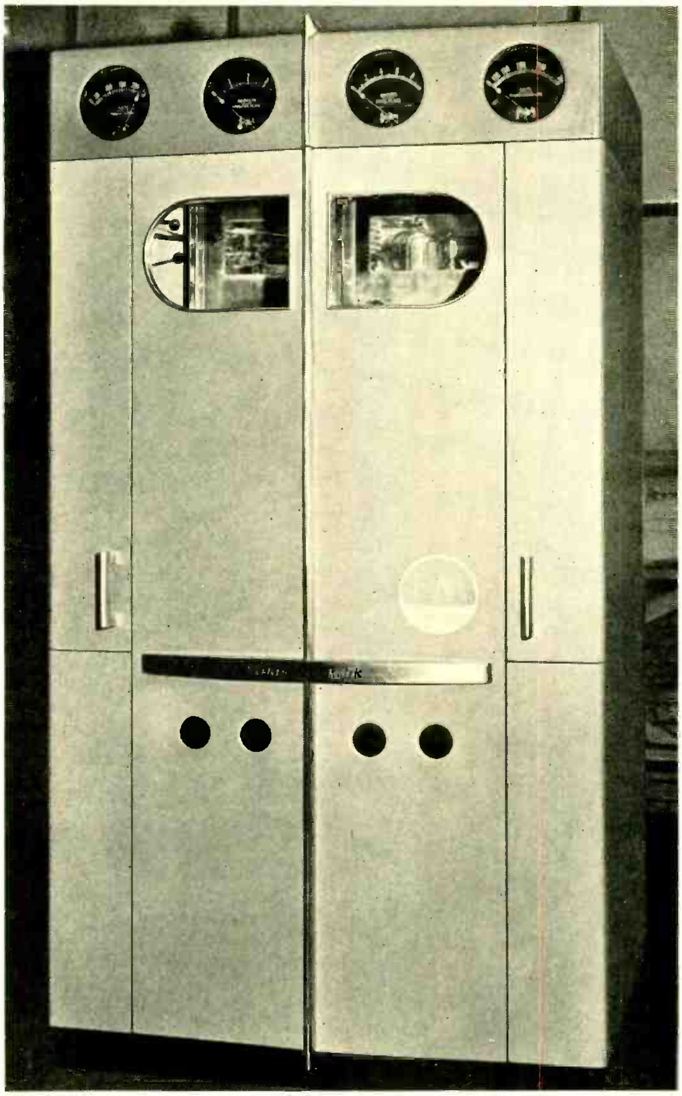
Because it is unusually narrow, the ventilator is especially suitable where aisle space is at a premium, as behind telephone switchboards.



To provide a repairman's hand test set which would be small and light but strong enough for the conditions of use, a new set has been developed. It weighs only a little over one pound as compared with somewhat over two pounds for the present set. A rubber handle substantially reduces the possibility of damage to the set when dropped

Synchronized FM Transmitter

By W. H. DOHERTY
Radio Development



THE first of a line of Western Electric broadcast transmitters employing wide-band frequency modulation is now in production. Known as the 503A-1 radio transmitting equipment, it is designed to meet the forward-looking requirements of this mode of transmission, for which high standards of performance are being set up, and it embodies a number of new and interesting technical developments which have emanated from various departments of the Laboratories.

Frequency modulation presents a new fundamental problem in that any source of oscillations stable enough to hold the mean or carrier frequency within the desired limits will be too stable to permit the wide variations in frequency necessary for modulation. It follows that the crystal oscillator or other fixed-frequency standard cannot be used directly as the source of the oscillations, but must be associated with the system indirectly in a monitoring rôle, through some mechanism which will ignore the rapid frequency changes accompanying modulation, and respond only to variations in the mean frequency. This is done in the new transmitter by a method known as Synchronized Frequency Modulation.

In this system the carrier wave is generated and frequency-modulated at one-eighth of the final output frequency (at 5 megacycles, for example, for a 40-megacycle carrier) and the final frequency is obtained through frequency doublers. A portion of the modulated 5-megacycle signal is applied to a series of frequency divider stages which shrink the spectrum by a factor of 2^{10}, or 1024, giving a frequency of about 5,000 cycles with variations of only a few cycles as compared to variations of many kilocycles in the transmitted wave. This low-frequency wave is then compared with a precise low-frequency crystal standard in a modulator that produces a rotating magnetic field whose speed and direction of rotation correspond to the amount and sense of the frequency difference. Due to the dividing process, the rotation is slow enough so that a small armature, geared to the tuning condenser of the 5-megacycle modulated oscillator, readily follows the field and comes to rest when exact synchronism is attained. The variations due to frequency modulation occur at an audio rate, and result only in a slight oscillation of the field, which is not followed by the armature because of its inertia; even the slightest change in mean frequency, however, produces a continuous rotation of the field and is corrected at once. So effective and immediate is the control that if the output frequency of the transmitter were to depart by as much as four hundred kilocycles from its assigned value, it would be returned to exact synchronism in a few seconds, even in the presence of continuous frequency modulation by an applied audio signal.

There is thus provided a method of frequency control that amounts essentially to a cycle-counting scheme, wherein the mean frequency, or total number of cycles occurring in a second, is maintained constant even though wide variations occur in the distribution of cycles over the interval.

The frequency divider which makes this method of control possible is a comparatively new communication tool employing the principle of regenerative modulation, whereby an exact submultiple is derived directly from the original frequency, with its variations reduced in proportion.

The frequency-modulation circuit employs a balanced oscillator and balanced reactance control tubes, with several circuit refinements that give extremely low distortion and wide frequency response.

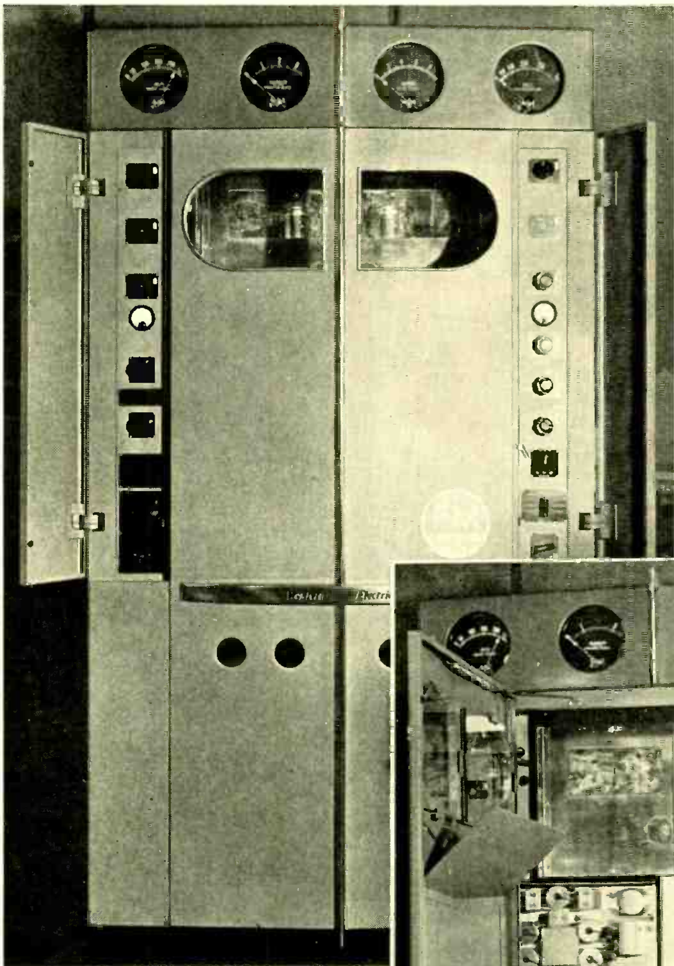
The low-frequency crystal oscillator is of a newly developed type having the same per cent stability as is obtained in the best low-temperature coefficient crystals used in the standard broadcast band. Since the per cent stability afforded by this method of frequency control is identically that of the crystal oscillator itself, unaffected by changes in gain of vacuum tubes or the frequency characteristics of associated circuits, the transmitter requires no temperature control of any kind.

The control motor itself has been in successful use for some years with frequency-synchronization equipment* designed for other purposes.

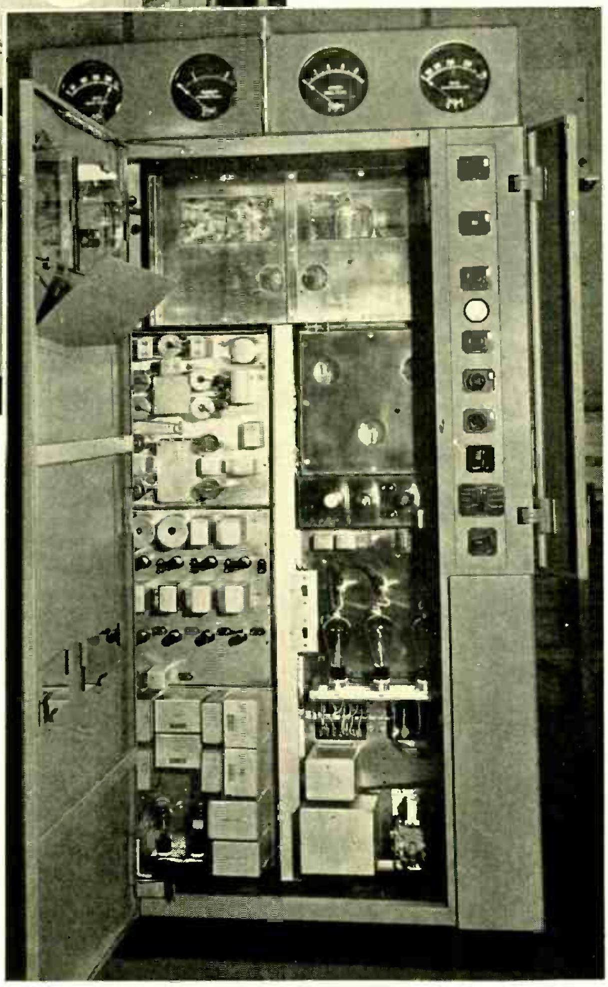
The 503A-1 is a 1000-watt transmitter housed in a single cabinet of modern design, similar to that used for the recently developed 1000-watt standard broadcast transmitter.† The photographs on these pages, taken of the advance model built at the Whippany Laboratory, illustrate many of the important details of its construction. The approaching expansion in FM broadcasting is expected to find 503A-1 equipments located in a large number of stations where the utmost is desired in mechanical design, appearance, and performance.

*Record, *July*, 1938.

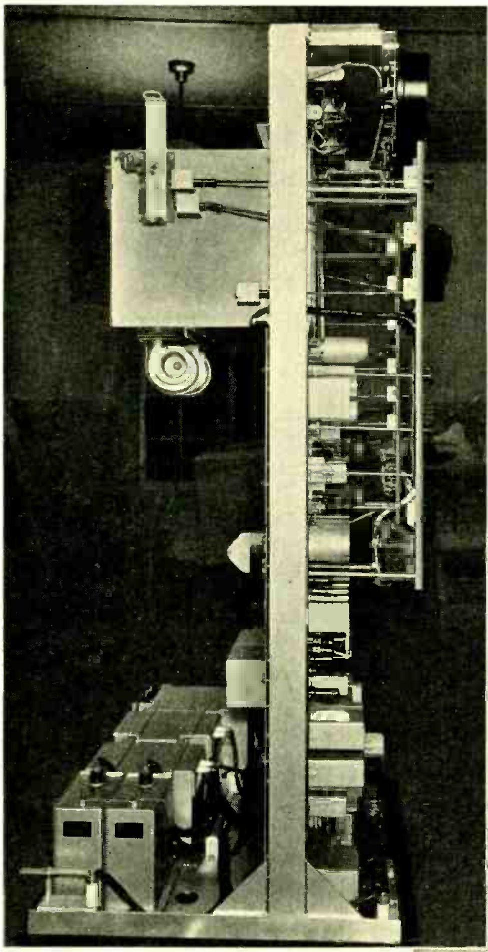
†Record, *September*, 1939.



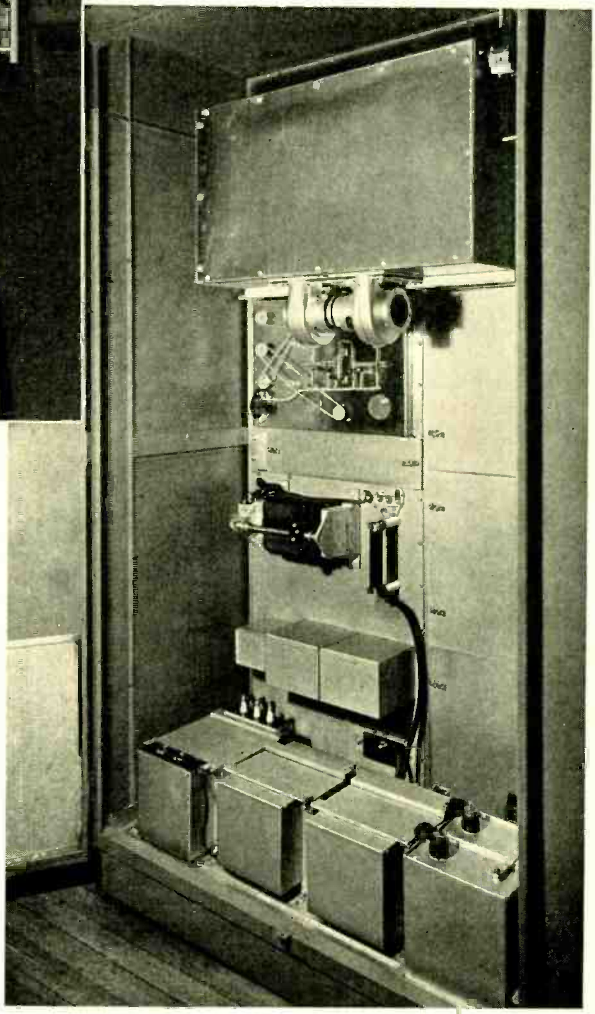
All the operating and tuning controls on this equipment are protected from accidental handling and dust by the two side doors, which may be opened at any time. The cabinet exemplifies the trend of contemporary styling



When the main front door is opened, automatically removing all dangerous voltages, the vacuum tubes and numerous other components are available for inspection or maintenance

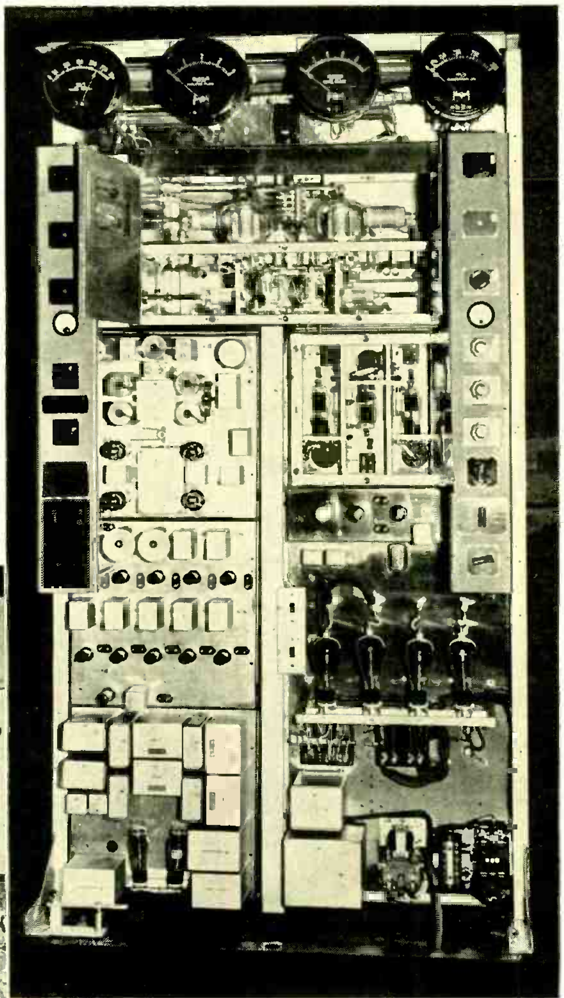


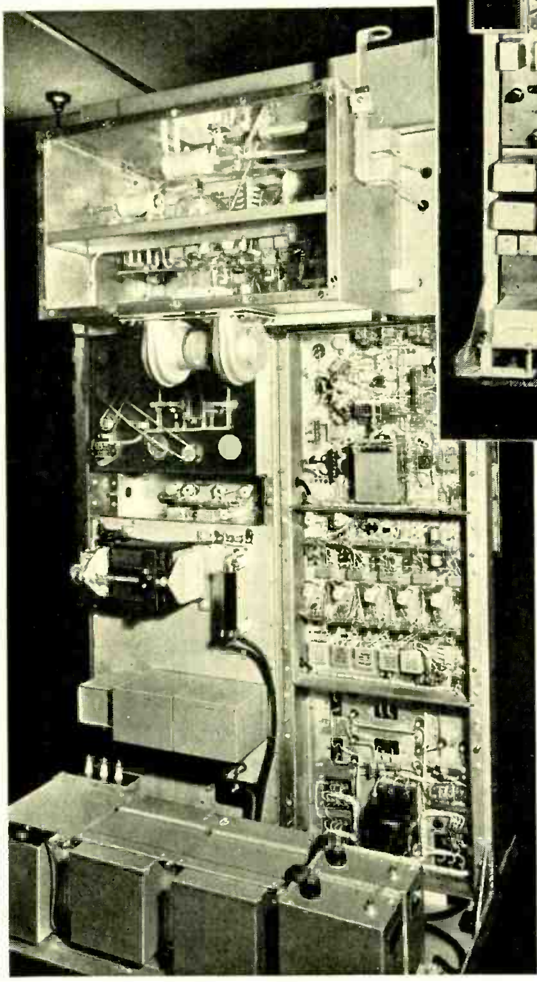
The side view with cabinet removed illustrates the method of construction; nearly all apparatus, including control panels and meters, is mounted on a central structure over which the cabinet may be slipped



View of the interior with rear doors open. Note the location of bulky apparatus on the heavy bottom plate. A spun-glass filter in one of the rear doors prevents the entrance of dust. A small blower provides forced-air cooling of the top compartment where the power amplifier equipment is located

Front view with cabinet removed and all apparatus exposed. Just below the meters, the two 357A tubes in the 1000-watt amplifier are seen, with the roller-type variable coils used in tuning. Note two small test meters on the side panels, for checking plate currents on the various individual tubes





From the rear, details of the frequency modulation panel and frequency divider panel may be seen at the right with covers removed. On the left side is mounted a voltage regulator, operated manually from the front of the transmitter, for accommodating power line voltages from 190 to 250 volts

Toll Crossbar Call-Distributing System

By J. MESZAR
Toll Switching Development

AT CERTAIN high-speed manual tandem switchboards, such as the 3B toll switchboard recently described,* incoming trunks have, in the past, been permanently wired to single-ended cords. The operators are connected automatically to their respective cord circuits to answer a call, and they establish the connections simply by lifting the single plug of the cord circuit and inserting it in the jack of the line that has been requested.

The permanent association between the trunk and cord circuits meant, of course, that to give service on all the trunks originating in various distant offices, every position at the switchboard had to be continuously attended by an operator. Except during a few busy hours, there is not enough traffic to justify this, and various methods have been used to effect adjustment. These included the restriction of the use of certain trunks by the originating operators to periods when the associated switchboard position was covered; or the grouping of several switchboard positions together so that one operator could establish connections at any one of them. The first method requires considerable coördination between operating groups of the various originating offices and the switching toll office; the second necessitates the patrolling by one operator of a number of positions.

Both of these difficulties are completely eliminated by the new call-distributing system. This is a mechanical switching arrangement fitted between the incoming trunks and the cord circuits to associate, automatically, any trunk on which a call arrives with an available cord circuit of any idle operator. This association is maintained only for the duration of the call. It is obvious that with such a system all the trunks are always usable at the originating offices, and still only enough positions need be

*Record, *Dec.*, 1939, *p.* 104, and *Feb.*, 1940, *p.* 167.

operated at the switching toll office to take care of the combined call-load at a given time. Furthermore, if any cord circuit can be associated with any trunk for the duration of a call, only enough cords need be installed to take care of the maximum simultaneous call load of the office. In general, this efficient use of the cord circuits results in substantial economies by reducing the number of cord circuits and switchboard positions. In some actual installations 100 cord circuits suffice for as many as 600 trunks. Finally, call distributing effects an improvement in the speed of service, because each incoming call is automatically steered to an operator who can serve it immediately.

This new distributing system uses the crossbar switch as its basic apparatus. The operating speed and reliability of this switch, together with its precious-metal relay-like contacts, make it eminently adaptable for switching on toll circuits, where—because of the frequent presence of sensitive voice amplifiers — contact variations are extremely objectionable. The switch used is of the ten-vertical type, like that used with the 755 PBX,* but the switches are mounted in bays each with ten primary and ten secondary switches, like the line-link bay† of the crossbar central-office system. Supplementary primary switches may also be used, as in some central offices. The incoming trunks are connected to the verticals of the primary switches, and the cords to the horizontals of the secondaries, so that each bay can accommodate 100 cords and 100 or 200 trunks depending whether or not supplementary bays are used. The arrangement of the links between primary and secondary switches differs slightly from that of the central-office line-link bays* in that they run from horizontals of the primary switches to verticals of the secondaries, but is like that of the line-link frames in that each primary switch has one link to each secondary switch. The arrangement is shown in Figure 1.

Since there are 100 horizontals on the ten secondary switches of one bay, each bay will accommodate 100 cords. Where more cords are needed, additional switching frames will be required. The arrangements and size of each installation are very flexible, but practical considerations have led to limiting the maximum size of a system to twenty operators' positions, each of fifty cords. Where more than twenty positions are needed, a second system will be installed. The horizontals of the secondary switches of each frame are distributed over all the positions, and thus with twenty positions, each frame will connect to five cords at each position. Ten frames are thus required to accommodate the 1000 cords of a full twenty-position system. Ten frames, however, will accommodate only 1000 trunks—or 2000 if supplementary primaries are used—while to keep the cords loaded, many more trunks may be required. Provisions are made therefore for multipling each cord to two or three different frames.

For convenience of control the system is divided into "groups," each of 100 cords, and each group may serve from 100 to 600 trunks, depending on whether supplementary primaries are used and whether the cords run to only one frame or are multipled to two or three. The possible arrangements of a system are indicated in Figure 2. The basic unit is the group

*Record, *June*, 1938, *p.* 337.
†Record, *May*, 1939, *p.* 266.

*Record, *March*, 1939, *p.* 217.

of 100 cords. Calling the number of switchboard positions N, where N is not greater than 20, each group of cords will be distributed over the switchboard to give 100 ÷ N to each position. Since each position has 50 cords, there will thus be required 50 ÷ 100/N, or N ÷ 2, groups for the complete system. At the trunk end each group of 100 cords is connected to one, two or three frames, and each frame may or may not have supplementary primary bays. Since each group of 100 cords may serve from 100 to 600 trunks, a fully equipped system of twenty switchboard positions, with a total of 1000 cords, will take care of from 1000 to 6000 trunks.

The control equipment for this crossbar call-distributing system, like that for the central-office system, is designed to work on a unit basis. Only one call is handled at a time, but the handling time is only a very small fraction of a second so that the calls are handled just about as fast as they come in, and in approximately the same order. The control equipment consists of three major units: a group allotter, a position allotter, and a link allotter. There is only one group and one position allotter for an entire system, but there is one link allotter for each group, which as may be seen from Figure 2 may include one, two or three frames.

When calls come in, they operate relays in the group allotter which indicate which group of frames is entitled to the next operator assignment, and lock out all further calls until this one has been handled. The group allotter then starts the position allotter, which selects a position that has an idle operator. The position allotter then sends a signal to the link allotter serving the group indicated by the group allotter to establish the connec-

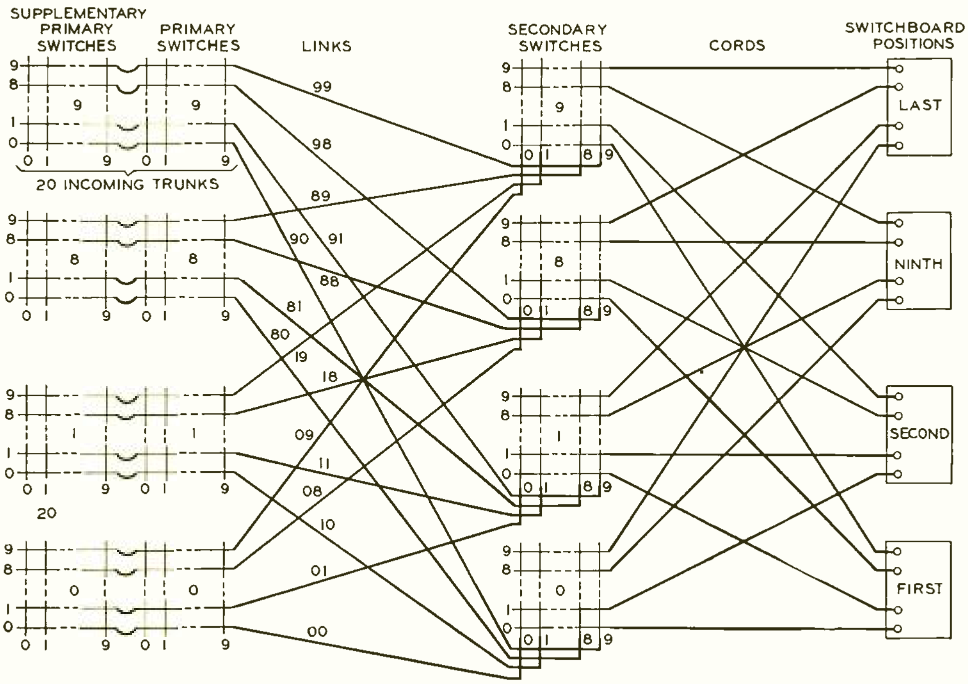


Fig. 1—Connections of links and cords for the crossbar call-distributing system

tion. Both group and position allotters are then released to serve the next call. The link allotter performs a function much like that of the marker* in the central-office system. It selects an idle cord at the position selected by the position allotter which can be reached by the calling trunk through an idle link on the crossbar frame. Having found such an idle path it operates the required select and hold magnets to cut the connection through. This link allotter is then available to handle another call.

The group allotter, besides indicating the group to be served at any one moment, also determines the order in which the groups will be served. After a call from one group has been handled, the allotter locks out that group until one waiting call on each of the other groups has been served. Only after this will it return to handle another call in the first group. Had there been no waiting calls on some of the groups, these groups would be passed over until their next turn. The position allotter performs very similar functions for the positions, and its circuit in its broad features is similar to that of the group allotter. It thus serves to distribute the calls among the operators so that no one receives an excessive load.

The manner in which this allotting is accomplished is indicated in Figure 3, which shows part of the circuit of the group allotter in simplified form. Each group has a set of three relays—AG, MG, and HG—and an incoming call in any group places a ground on the "A" lead for that group. If there is at least one idle operator who has idle cords, this ground will be extended to the windings of the AG and HG relays of that group. If this call comes in on an intermediate group, for example, and none of the HG relays to the left of

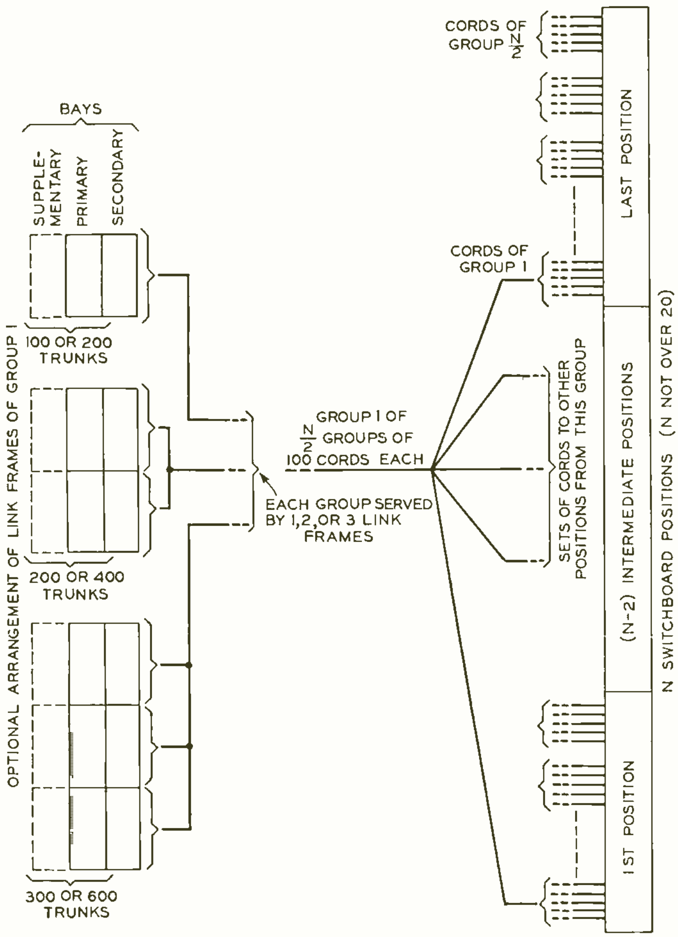


Fig. 2—Schematic indication of possible arrangements of crossbar call distribution

*RECORD, *June*, 1939, *p.* 327.

this group is operated, the ground will be extended, through the winding of HG and back contacts on the HG relays to the left of it and on the common GH and GR relays, to the winding of HM, and HG and HM will both operate. In opening its lower back contact, HG opens the operating circuit of all HG relays to the right of it. Through its upper front contact, it holds itself in series with AG and GH, which also operate, and in opening its upper back contact, it opens the holding circuit of all HG relays to the left of it. The operation of AG brings in MG, which holds itself in through a front contact of HM, and at the same time operates GR. Operation of MG also opens the circuit to the operate winding of HG, which is held in by its hold winding in series with AG, GH, and HM.

It will be noticed that while several calls may have come in at the same time, the first HG relay to operate would block the operation of all HG relays to the right of it, and while an HG relay to the left of it could operate, its holding circuit would be open at the upper back contact of the first operated HG relay, and the operating circuit of the HG relays to the left would be opened when GH operated. Thus only one HG relay will remain operated, and those that operate momentarily—to the left of the first operated HG—will not operate their AG relay. Thus HG selects and AG indicates the particular group to be served next in the system.

When AG operated, it placed a ground obtained from the front contact of GH onto the B lead, and this ground acts on the position allotter much as the ground on the A lead does on the group allotter. After the position allotter has selected an available position for the group, it opens the ground on the A lead to the group

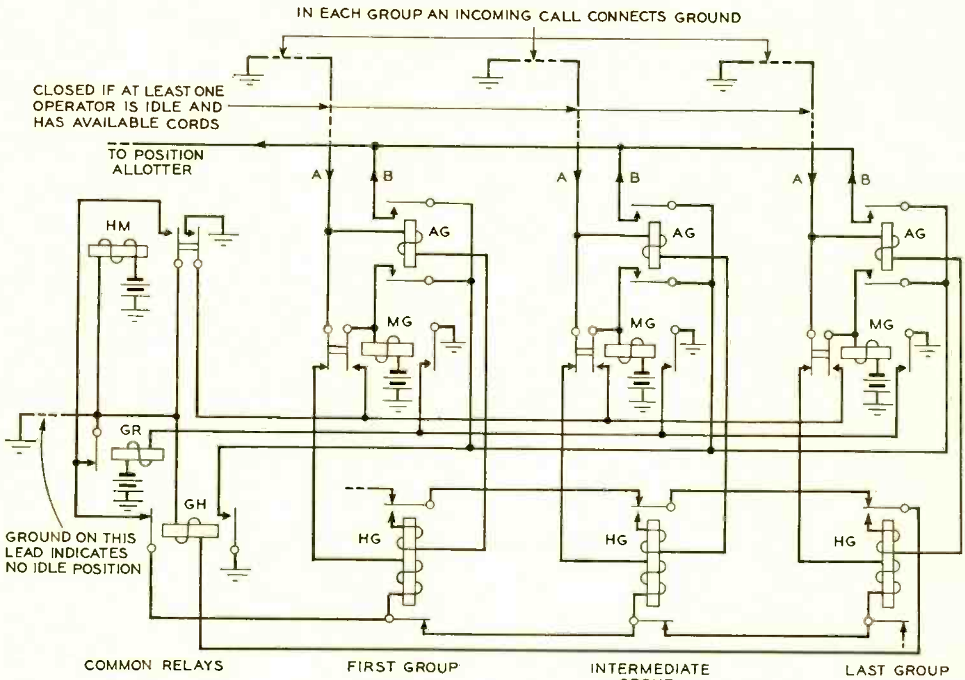


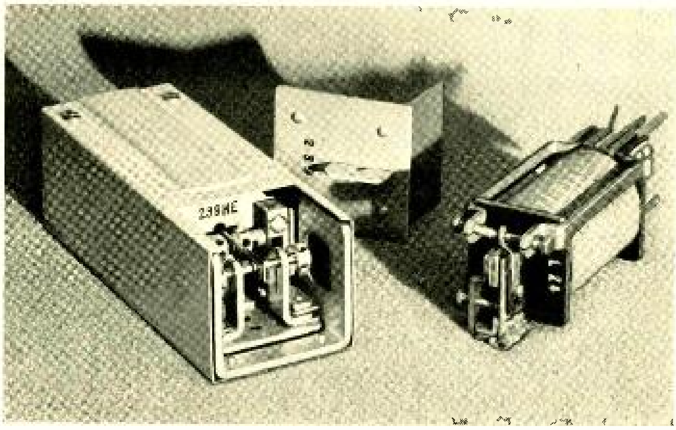
Fig. 3—Simplified schematic of the group allotter

allotter, signals the link allotter of the group to establish the connection to this position, and then releases itself. The group and position allotters can then proceed with the next call.

When the ground is removed from the A lead of the group allotter, the series circuit including the windings of AG, HG, GH, and HM is opened, and AG, HG, and GH release at once. HM is a slow-release relay, however, and if other calls are waiting allotment, some other HG relay will operate and hold HM before it has opened. So long as HM remains closed, moreover, none of the MG relays that have operated will release, and with the MG relay of a group operated, the HG and AG relays of that group cannot be operated by a ground on the A lead. Once a group has been served, therefore, it cannot be served again as long as there are calls waiting in other groups, or until all the other groups have been served. After all groups have been served, or after there are no calls waiting in the other groups, HM will release, and release all the MG relays that have been operated. When the last MG relay has released, GR will release and restore the circuit to normal.

As soon as the position allotter has allotted a position for a call, it turns the connection of the call over to the link allotter for the group concerned, and with the group allotter is then ready for the next call. A link allotter may be completing a call, therefore, while the group and position allotters are indicating the group and operator for the next call. The rate of handling calls is not determined, therefore, by the combined operating time of all three allotters, but by the operating time of the group and position allotters. While the total time for handling a call is about a quarter of a second, the operating time of the group and position allotters is only around five-hundredths of a second each. Since there is a link allotter for each group, their somewhat slower operation does not affect the rate of handling calls for the system as a whole, which is thus determined by the operating time of the group and position allotters. The theoretical average rate is thus ten calls a second.

Bound copies of Volume 18 *of the* RECORD (*September*, 1939, *to August*, 1940) *will be available shortly*—$2.75, *foreign postage* 25 *cents additional. Remittances should be addressed to Bell Laboratories Record*, 463 *West Street*, *New York. A separate index to Volume* 18 *is now available and may be obtained upon request*



A Dialing Circuit of Increased Range

By F. K. LOW
Central-Office Switching Development

THE correct counting and recording in the central office of a train of dial pulses depends largely on the action of the pulsing relay. This relay responds to the momentary openings and closures of the subscriber loop caused by the dial as it returns to normal, and gives out corresponding openings and closures of its contacts to the circuit or mechanism that counts and records these pulses. In addition to variations in the time intervals of the dial pulses, there are a number of electrical effects imposed on the pulsing relay which may interfere with its correct operation. Some of these tend to hold the relay when it should release; long loops reduce the current needed for operating the relay when it is supposed to operate; and other effects tend to cause the relay to operate or release falsely. The degree of fidelity with which the relay follows legitimate dial pulses, and the margin by which it withstands various impulses to operate or release falsely, are measures of its efficiency. In these respects the relay developed for the subscriber sender of the new crossbar dial system, and recently adapted to the more widely used of the panel system senders, represents important improvements as compared to relays previously used for this service. Outstanding among these improvements are an extended loop range and a greater permissible variation in the speed of operation of the dial.

The new relay will respond satisfactorily to either ten or twenty pulses per second over 1500-ohm loops, while the former relay would respond to ten pulses per second only over loops not exceeding 1000 ohms, and to twenty pulses per second only over loops not exceeding 350 ohms. Strictly speaking, however, the new development should not be referred to as a relay but rather as a pulsing or dialing circuit, since the circuit features immediately associated with the relay account for its efficient operation certainly as much as do the characteristics of the relay structure itself.

A different relay is employed as well as a new circuit, however. Former pulsing circuits have employed an L-type relay, while for the new circuit, a 239-type relay is employed. These two relays are shown in the photograph at the head of this article, where the 239 type is at the left. The structure of this latter relay is of low inductance, and is thus conducive to fast response. In addition, by using a biasing winding, it lends itself better to the securing of a high "percentage release," which expresses the relationship between the release and operate currents of a relay. The higher this ratio the larger the variations in operate and release conditions the relay can tolerate. The reasons for this are indicated in Figure 1, which shows the current conditions existing during two extreme pulsing conditions. The upper graph of this figure represents the worst conditions for the release of the pulse relay on a short subscriber's line, i.e., maximum ringing bridge capacity and maximum leak. The lower graph represents the worst conditions for the operation of the relay on a long PBX trunk with which is associated a high-speed operator's-type dial. With operate and release currents such as those of the older L-type relay, as represented by the lines *a-a* and *b-b* respectively, the percentage release is comparatively low and consequently the interval of time during which the relay may be in the released position under the first set of extremes or in the operated position under the second set of extremes is short in either case. These intervals are indicated by the distance on the time scale between points R and O. With operate and release currents as represented by *c-c* and *d-d*, however, which apply to the new 239-type relay and illustrate a high-percentage release, the releasing and operating intervals are considerably longer as indicated by the points R′ and O′.

The arrangement of the new pulsing circuit as it appears in the crossbar sender, together with the elements of the subscriber telephone set involved in dialing, are shown in Figure 2. The pulsing relay is of the polarized type, and employs no retractile spring against which the operate winding must act. Release is secured by a separate biasing winding. The current through this winding is adjusted so that at nominal voltage and with 18.5 milliamperes in the operate winding, there will be zero flux in the core—

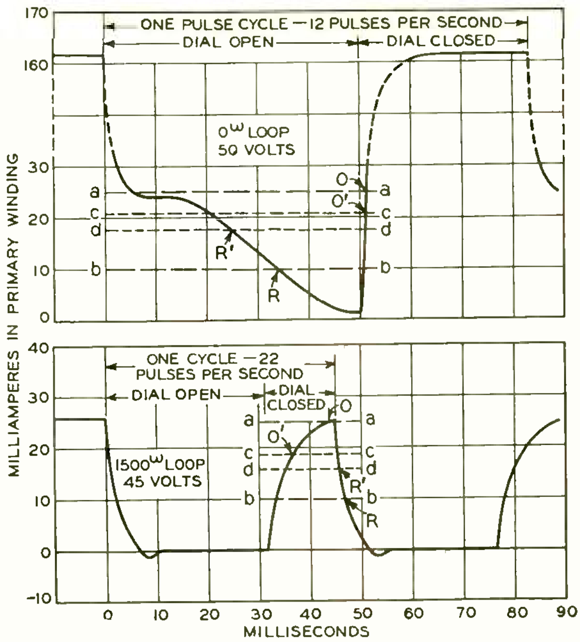


Fig. 1—Representation of dial pulses, showing high and low percentage releases

and thus no tendency for the armature to move in either direction. When the relay is properly adjusted, it will then operate on 20 milliamperes and release on 17, a change of only 1.5 milliamperes on each side of the zero-flux current. These values of current will vary with the battery voltage, but since both windings are supplied by the same battery, there is a natural compensation. As the current in the operate winding rises or falls with changes in voltage, the current in the compensating winding will also rise or fall, so that their differential effect tends to remain constant.

With this sensitivity, and the high-percentage release, the pulsing relay has ample margin for releasing and operating in response to regular dial openings and closures. Under some conditions, however, transients occur that might cause false operation or release if additional precautions were not taken. In the dialing circuits of PBX boards and order turrets, for example, the loop is held closed through a retard coil of moderately high inductance. When the dial is operated, this coil is short-circuited, but shortly after the dial returns to normal, the retard coil is reinserted in the loop. This causes a sudden lowering of the line current, momentarily dropping it to a point appreciably below the steady-state value, and thus tending to cause the release of the pulsing relay.

To counteract this tendency, the condenser and resistance marked R in Figure 2 are connected between the line side of the operate winding and ground. When the retard coil is connected back into the circuit, the voltage across the line, and thus across the condenser, rises, and a momentary charging current flows through the relay winding to the condenser. This current is sufficient to counteract the decrease in line current, and thus holds the relay operated. The action is indicated in Figure 3. Without the condenser, the current would follow the dotted curve when the retard coil was reinserted, dipping below the release value. With the condenser in the circuit, however, the current follows the solid curve, and remains well above the release value. There is a similar charging current to the condenser

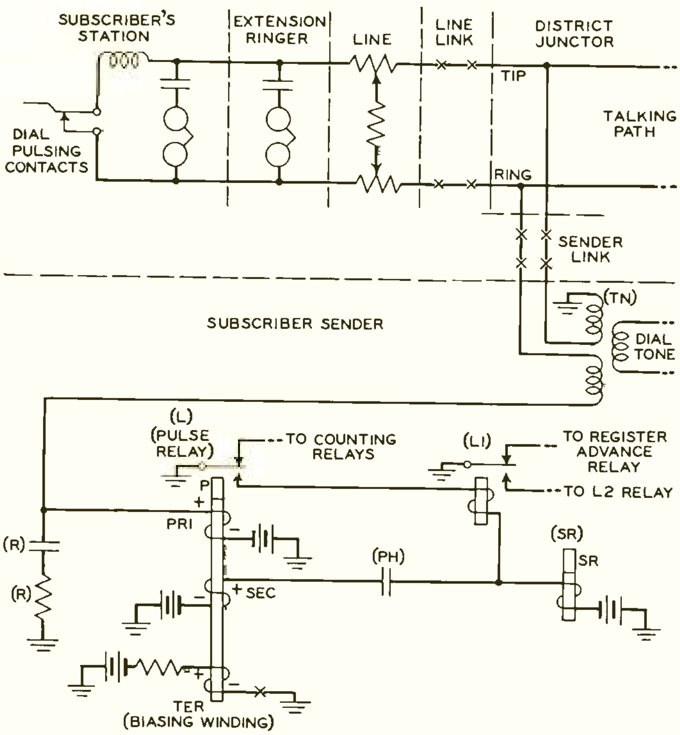


Fig. 2—Simplified schematic of new dialing circuit

tending to hold the relay operated when the pulsing contacts of the dial open and the relay is supposed to release. In this case, however, the

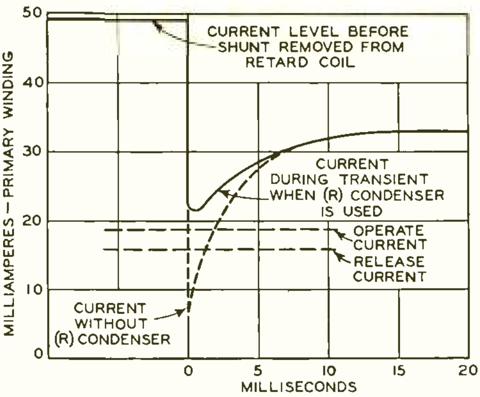


Fig. 3—Effect of condenser R *on the operation of the pulsing relay*

effect is spent in the early part of the pulse and is therefore negligible.

Difficulties may also occur because of the condensers in series with the ringers, which are permanently connected across the line. Closure of the dial contact provides a discharge path for these condensers, and when the contact opens, the condensers will recharge. Because of the high inductance of the ringer circuit, the charging current increases slowly at first, and then reaches a peak about twelve or fifteen milliseconds after the dial contact has opened. Under certain intermediate line conditions, which—except for this—would cause no dialing difficulties, the pulsing relay may release within the first twelve milliseconds, and then be reoperated by the charging surge, and released again with its cessation, thus causing a false pulse. Figure 4 illustrates the characteristics of such a transient.

To make the new circuit completely insensitive to this form of transient, a circuit arrangement is provided that electrically locks the relay in the released position for a short period of time. If the relay does release before this charging surge it will be held released until the surge has passed.

This locking action is secured by a secondary winding connected through the PH condenser as shown in Figure 2. With the pulsing relay in the released position, this condenser is discharged because of the presence of the same battery potential on both sides of it. When the pulsing relay operates, however, it grounds one side of the condenser through the low-resistance LI relay, and so the condenser charges. The time for the charge and discharge of the condenser is determined by the constants of this secondary winding circuit, and is adjusted to secure the desired time interval. The charging current is in a direction tending to operate the relay, and the discharging current in a direction to release it.

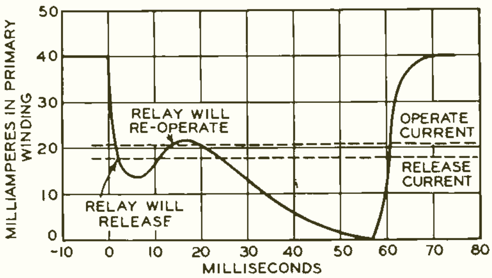


Fig. 4—Severe conditions sometimes encountered due to ringer condensers

When the relay releases on the opening of the dial contact, therefore, the discharge current that flows holds it released until the charging surge of the ringer condensers has passed.

This secondary winding is also useful on long loops with short dial closures, such as occur with the operator's dial giving twenty pulses per second. The long loop tends to shorten the length of the operating pulse, but the charging current to the

PH condenser when the pulsing relay operates increases the operated period and insures a closure of satisfactory length. This winding thus tends to equalize the difference between long and short pulses, since it lengthens the short pulses and has no effect on the long ones because the charging surge has died out before the dial contact has opened.

The slow-release relay SR operates when the hand set is lifted and should not release unless the call is deliberately abandoned. It is given a slow-release characteristic so that it will not release on the dial openings. Its proper action is considerably helped by placing the relay in the circuit of the secondary winding of the pulsing relay. In this position, its winding receives not only the full dial closure pulse, but the discharging surge of the PH condenser when the pulsing relay opens its front contact.

Besides the increased range and ample operating margins of this new dialing circuit, special contact wear and adjustment stability tests indicate that it will require less maintenance than the previous circuits.

An Important New Magnetic Alloy

"Vicalloy," a new magnetic alloy of remarkable qualities, was announced on June 20, 1940, to the American Physical Society by E. A. Nesbitt and G. A. Kelsall of Bell Telephone Laboratories, New York, N. Y. Composed of cobalt, vanadium and iron, the alloy can be made to hold more permanent magnetism than any other commercial material. In addition, it can be drawn and rolled—a property of decided advantage in many applications, and not possessed by other permanent magnet materials of importance in the art. For example, it has been rolled into tape 1/500 inch thick and 1/20 inch wide; several thousand feet of this tape are used for sound recording at the New York World's Fair, while shorter lengths are running constantly as endless loops in the Bell Telephone weather-announcing systems.

E. A. Nesbitt holds up two iron bars by the magnetism stored in the little semicircular magnet made from "Vicalloy"

Taking its name from the initial letters of its three components, the new material is composed of 6 to 16 per cent vanadium, 30 to 52 per cent iron, and 36 to 62 per cent cobalt. From the molten state it is cast into an ingot, which is hot-swaged to ¼ inch diameter. It is then drawn into wire or rolled into tape, as desired. When in final form, it is heat-treated to develop its magnetic qualities. It is permissible to use a heat treatment that will not be harmful to most high-permeability materials. Thus it is possible to weld such pieces to the magnet and heat-treat them both together.

Magnetic Ultra-Micrometer

By W. B. ELLWOOD
Circuit Research

MEASURING the thickness of a thin deposit of metal or paint on a backing material without damaging the deposit is a difficult problem when the junction surface is not accessible. The Laboratories has devised a method of doing this where the backing is a sheet of iron or other magnetic material. The measurements are made by comparing two magnetic circuits which have the test specimen between them as a common part of both circuits. The non-magnetic film on one side of the specimen introduces a gap in one of these otherwise identical circuits and unbalances them. The amount of unbalance is a measure of the thickness of the film on the specimen.

The test specimen is clamped between the ends of two magnetic probes as shown in Figure 1. Probes P1 and P2 have exciting coils C1 and C2 and exploring coils S1 and S2. The exciting coils are connected in series to a constant source of alternating current at 110 volts. The exploring coils form a bridge with the resistances R3 and R4, and the output of the transformer T2 measures the unbalance of the bridge. This output may be rectified mechanically with a commutator, or electrically with a thermocouple or copper-oxide rectifier. It is read on a d-c galvanometer or microammeter.

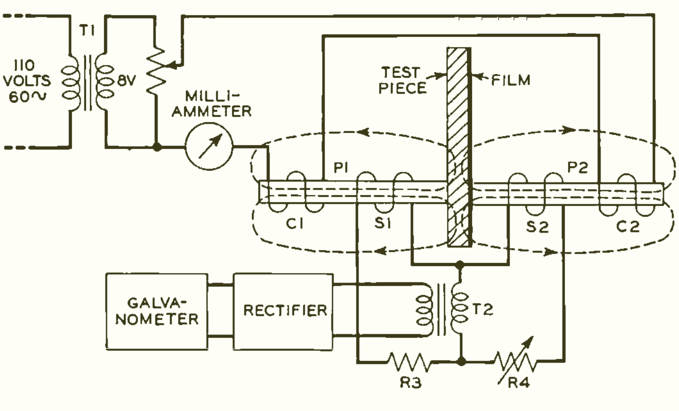


Fig. 1—The test specimen is clamped between the ends of two magnetic probes which are excited by alternating current

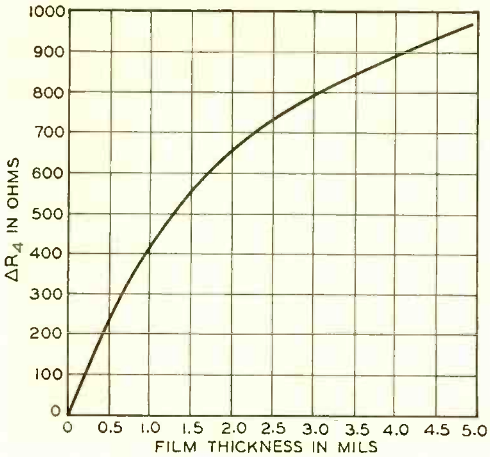


Fig. 2—The change of resistance R4 *required to balance the bridge for coatings of different thicknesses is determined by calibrating the apparatus with coatings of known thickness*

In making the measurements a strip of iron whose thickness is that of the test specimen with its non-magnetic surface deposit is inserted between the probes. The bridge is then balanced by adjusting the resistance R4. The test specimen with its non-magnetic surface on one side is substituted for the iron strip and the unbalance of the bridge is read on a galvanometer, which has been calibrated with strips having surface deposits of known thickness. An alternate method is to reduce the output voltage of the transformer T2 to zero by adjusting the resistance R4 to balance the bridge with the test specimen and note the change in resistance.

The relation between this resistance change and the thickness of the surface film is indicated by the curve in Figure 2. If the permeability of the test piece is large, the change in resistance R4 is only slightly dependent on the thickness of the magnetic base. One scale division of the galvanometer corresponds to 10^{-5} or less inches of film thickness. The accuracy of the device depends largely on the smoothness of the contact surfaces.

This new method of measurement is a rapid and accurate means of determining the average thickness of a given area of non-magnetic films of metal, paint, paper or weathering on a magnetic base material. It also has been used to measure the thickness of contact metal on relay springs.

Contributors to this Issue

W. R. HARRY graduated from Cornell University in 1936 with the degree of E.E. in Communications and joined the Technical Staff of the Bell Laboratories in the fall of 1936. His first work was product engineering on microphones used for radio and sound pictures. Following this he did much of the development work on the 639A cardioid directional microphone and on the more recent 639B six-way directional microphone described in his article in this issue of the RECORD.

W. B. ELLWOOD received the A.B. degree from the University of Missouri in 1924. He did graduate work at Columbia University and received there an M.A. in 1926 and Ph.D. in 1933. Dr. Ellwood joined the Laboratories in 1930 to carry on investigations on the magnetic properties of materials at very low and very high field strengths. Recently he has turned his attention particularly to applications of magnetic materials in telephone apparatus.

W. H. DOHERTY received the B.S. degree in electrical communication engineering from Harvard University in 1927, and the M.S. degree in engineering in 1928. He spent a few months in 1928 with the Long Lines Department in Boston as a technical employee and then became a research associate with the radio section

W. R. Harry

W. B. Ellwood

W. H. Doherty

of the Bureau of Standards, where he engaged in a study of radio wave phenomena. In June, 1929, he joined the radio development group at the Whippany laboratory where he has since been engaged in the development of transmitters for transoceanic radio-telephony and broadcasting. In 1937 Mr. Doherty was awarded the Morris Liebmann Memorial Prize of the Institute of Radio Engineers for his improvement in the efficiency of radio-frequency power amplifiers.

O. C. Eliason joined the Laboratories in 1921 on graduating from Iowa State College. He worked at first on electrolytic condensers and later transferred to the Telephone Apparatus Development Department where he was concerned with inside wires and switchboard cables. Recently he has been interested in the design of apparatus for humidity studies and the investigation of central-office ventilation. It is in this connection that the unit ventilator discussed in this issue of the Record was designed and developed.

H. M. Thomson received the degree of B.S. in E.E. from the University of Washington in 1930, and at once joined the Radio Research Department of the Laboratories. Almost immediately, however, he went to the Department of Development and Research of the American Telephone and Telegraph Company to conduct field tests on an experimental wave antenna. At the termination of his tests of the wave antenna, he took part in other long-wave radio transmission studies. In 1937 he transferred to the Apparatus Development Department, where he has since been engaged in the design and development of electric filters, equalizers, and networks for voice-frequency and coaxial-cable circuits.

O. C. Eliason

H. M. Thomson

J. Meszar

F. K. Low

C. S. Fuller

J. Meszar joined the toll circuit laboratory group in 1922, and for a number of years was engaged in tests of a wide variety of toll circuits. In 1927 he transferred to the toll circuit design group, and since 1935 has been in charge of a group designing toll switchboard and toll testboard circuits. During this period he has been connected with most of the major toll circuit developments, including crossbar call distribution.

F. K. Low joined the Western Electric Company at Hawthorne in 1921 after having studied electrical engineering at the University of Oklahoma and the Milwaukee School of Engineering. The following year he transferred to the Installation Department; and two years later to West Street where, in the local systems circuit laboratory, he became engaged with problems relating to subscriber's dialing and revertive and call-indicator pulsing circuits of the panel system, later being placed in charge of this work. He participated in the development of the call-announcer machine and associated circuits, and more recently, he has been concerned with the development of pulsing circuits for the crossbar system, and with the extension of dialing ranges of the panel system.

C. S. Fuller graduated from the University of Chicago in 1926 with the degree of B.S. in Chemistry and he received the Ph.D. from the same University in 1929. He joined the Research Department of the Laboratories in 1930 where he was initially concerned with investigations relating to the improvement of enamel insulations for wire. Later he undertook work on synthetic insulations for wire. This work led to studies on the molecular nature of these synthetic materials which have occupied his time during the last few years. Recently he has assumed direction of work on plastic molding materials.