BELL LABORATORIES RECORD

SPEECH INPUT EQUIPMENT
W. L. BLACK

IRON-COBALT ALLOYS
G. A. KELSALL

SWITCHBOARD CORDS
R. T. STAPLES

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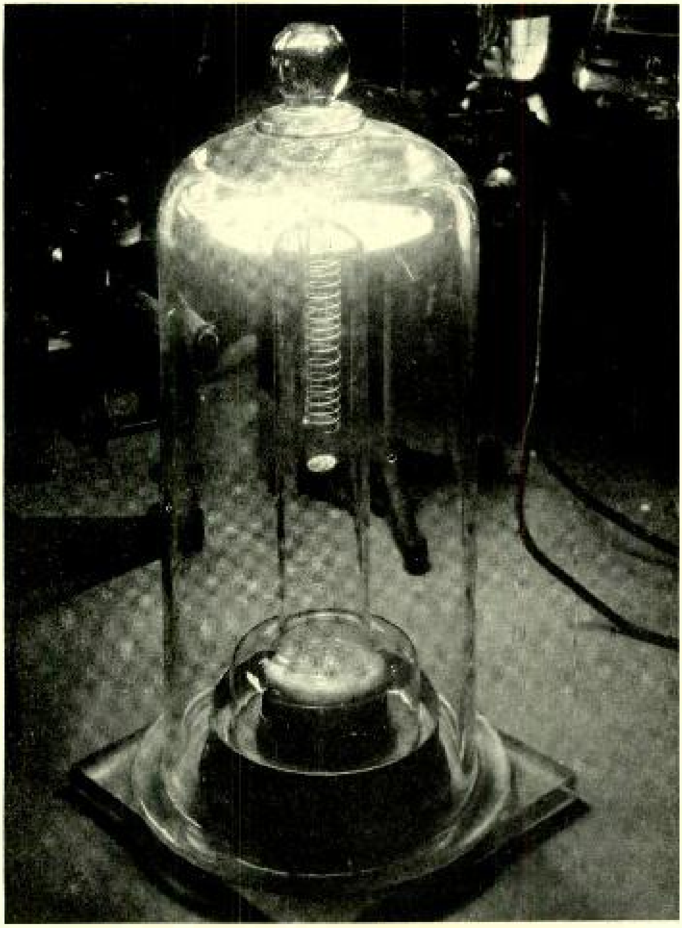

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Speech Input Equipment for Radio Broadcasting

By W. L. BLACK
Radio Development

As the radio listener enjoys orchestral harmonies or thrills to an adventure story, he is happily unconscious of the minute care that has been given to every piece of equipment in the broadcasting system from its earliest design to its ultimate operation during the program. Communication engineers, however, are "within the family", and it is likely that no small part of their satisfaction in listening to a program is due to the thought that its smoothness and tone quality are to a very considerable extent the achievement of some of their professional associates.

The circuits and apparatus through which a broadcast program passes on its way from studio to radio transmitter are collectively known as speech input equipment.

As in public address systems and sound recording systems, high quality microphones and amplifiers are utilized; as in the telephone exchange, incoming telephone lines are selected and routed; and, as in telephone repeater stations, amplifiers are associated with outgoing telephone lines. However, unlike a sound recording system, the program once presented on the air cannot be replaced by a repetition even though errors of omission or commission are made. Unlike a public address system, the program material is amplified many times in the associated radio transmitter and by the listener's radio receiver after leaving the studio and the program source is entirely isolated from the listener in the event of apparatus failure. In the event that it is a network program it is further amplified, both by telephone repeaters and by the

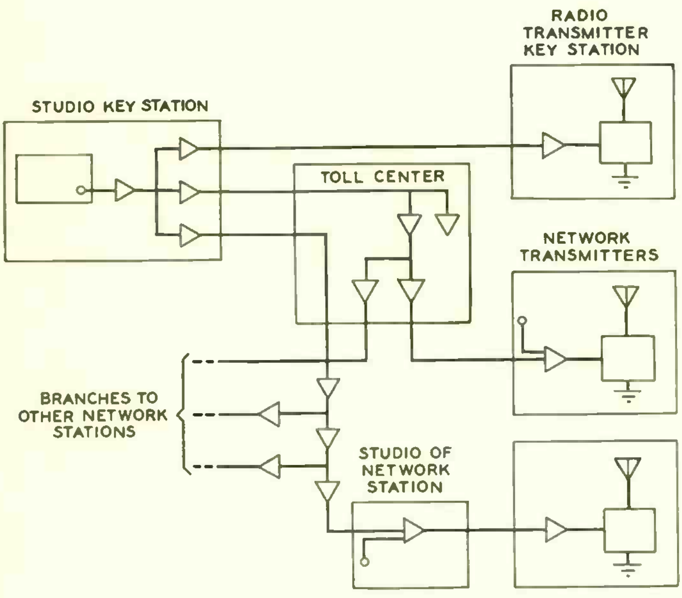


Fig. 1—Elements of a typical broadcast network. Actual networks may have several key stations and as many as seventy or more transmitters radiating the same program

speech input amplifiers of other stations, as well as by the radio transmitter and receiver.

On account of the very low output of any of the high quality microphones—double-button carbon, condenser, and moving coil—considerable amplification is immediately necessary and the noise level in the first amplifier stage must be extremely low. In the earliest speech input systems, the amplifiers used for this purpose had resistance and impedance coupled stages. The subsequent availability of high quality audio frequency transformers with permalloy cores has made possible the use of transformer coupled stages throughout the amplifiers. The early amplifiers obtained their filament and plate supplies and grid bias potentials from batteries. Later, it became feasible to use alternating current rectified and filtered for the plate supply, and the voltage drop in a resistance in the plate return circuit for grid potential. Even more recently, with the availability of exceedingly quiet equipotential type vacuum tubes such as the Western Electric 262A, it has become possible to employ alternating current for heating the filaments without any material decrease in the amplifier signal-to-noise ratio. These uses of alternating current have resulted in considerably simpler installations occupying less space, capable of being put in service in considerably less time and at greatly reduced expense, and requiring far less maintenance. The elimination of batteries at program pick-up points has been completed by the introduction of the Western Electric No. 618A (moving coil) microphone, which requires no direct current supply.

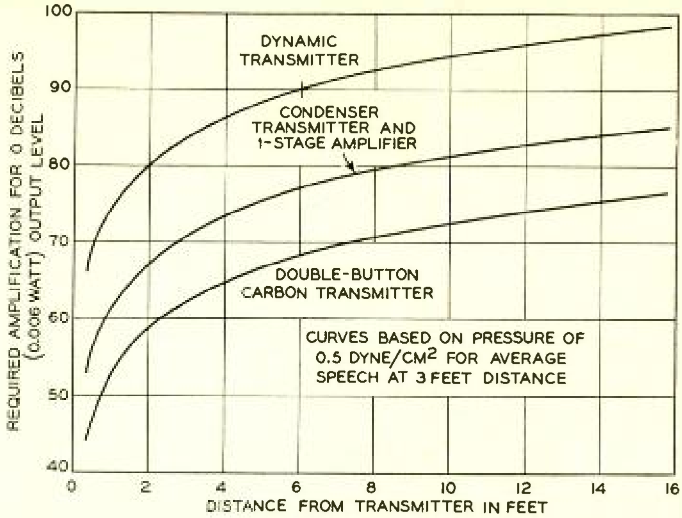


Fig. 2—Amplification required to give a "zero" output level (0.006 watt) with average speech at various distances from the transmitter

The microphone in the studio and the amplifier required to supply an immediately associated radio transmitter, together with the power supply for the amplifier, are of course the fundamental essentials of a speech input equipment. However, it was found that satisfactory control of the program necessitated a loud speaker for indication to the operator of the quality and continuity at the output of the system. To provide adequate energy to operate one or more loud speakers at comfortable volume and to isolate them electrically from the main program circuit, a monitoring amplifier is bridged at the output of the main amplifier system, through a high impedance so that it may be removed or connected without changing the program level.

It was also found that satisfactory

control of the program energy level necessitated a visual indication to the operator of the energy level at the output of the system. For this purpose, a volume indicator is used. This ordinarily consists of a rectifier associated with a direct current meter. The input to the rectifier is ordinarily bridged on the main program circuit through a coupling circuit of high impedance and consequently low bridging loss. Since no meter has a sufficiently long scale to indicate directly the wide range of energy values encountered, there is ordinarily a calibrated attenuation circuit ahead of the rectifier which can be set by a key or dial switch or both. In practice, the settings of the attenuation circuit, once made, are left undisturbed and the volume control is used to hold the swings of the meter within a definite range.

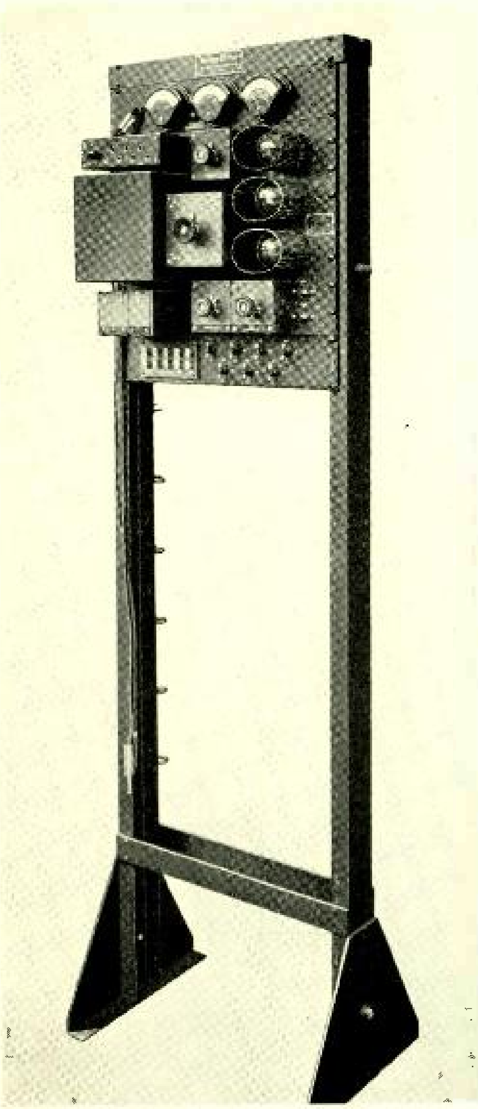


Fig. 3—The Western Electric No. 1A Speech Input Equipment

As the programs became more complex, it was found that a single microphone in a studio was not adequate for all programs. This requirement of several microphones in a studio, for example, one for the announcer exclusively, one for musical accompaniment and one or more for the several speakers of a dramatic production, together with the necessity of providing for programs from other sources, necessitated means of quiet, precise and, in some instances, remote or multiple-control microphone switching. This switching is accomplished by lever unit keys or, if the switching must be controlled from more than one point or controlled remotely, by means of telephone type relays usually operated by momentary contact push-button or lever keys. With the use of several program microphones it also became desirable to control the output level of each separately from that of the others as, for example, when an announcement is made with a background of music. In such a case the level of the music is gradually reduced while the announcement is being made and then gradually increased. This requirement is met by the use of potentiometers, the input of each associated with a microphone or program source and the outputs connected together and to the input of the main amplifier. Such an arrangement is known as a mixer. Ordinarily, the mixing potentiometers are located immediately at the outputs of the microphones so that the required apparatus investment may be as small as possible. However, this location necessitates not only that the output impedance of any potentiometer be substantially constant regardless of setting so that a change in the setting of one does not affect transmission efficiency through the others, but also requires, particularly with more recent types of microphones, extremely quiet operation. This is necessary because all of the amplification in the system follows the potentiometers.

Pickup of programs at points outside the regular studios—an early step in the evolution of broadcasting—brought about the development of portable speech input equipment. All the essential facilities of the studio equipment are incorporated but in the mechanical design emphasis is naturally laid on lightness and compactness. For example, the convenience of loud speaker monitoring must be sacrificed for the light weight of a headset. Programs are transmitted over wire lines at levels comparable with those of telephone conversations. Sufficient attenuation is introduced at the studio to reduce the level to that of the local microphone output, so that the incoming program can be handled substantially as though it originated in the studio.

When one studio program immediately follows another, it is desirable for smooth transition from one to the other that two studios be available so that the performers may be preparing in one for the subsequent program during the presentation of the earlier. Furthermore, rehearsals under conditions simulating those of actual broadcasting are conducted for the more elaborate programs. The rehearsal time may be from six to ten times as great as the time required for final presentation to the radio audience. In addition, most stations depend upon commercial advertising for their continued existence. This necessitates auditions of typical programs for prospective advertising clients. Such auditions are most effective when presented in a studio and observed by means of a loud speaker, and so are auditions for selecting new broadcasting talent. Consequently it is not uncommon in the larger stations for

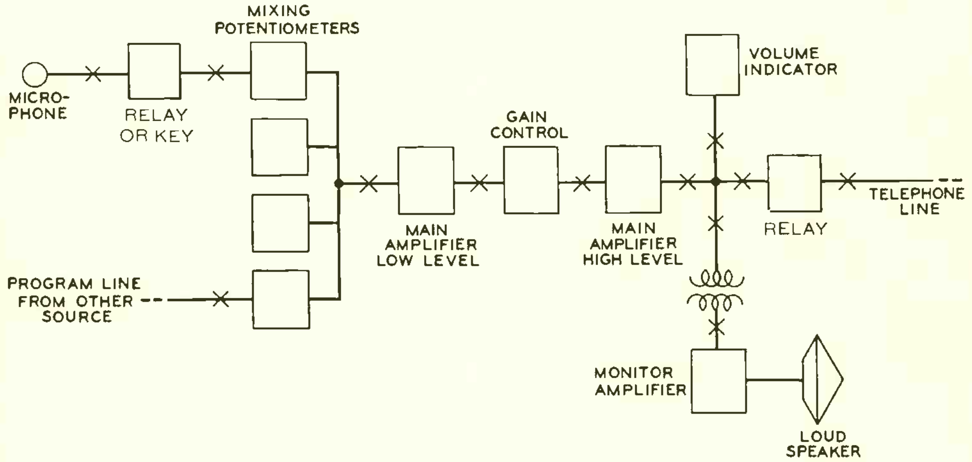


Fig. 4—A typical studio channel

as many as fifteen or twenty studios to be available and for all to be in practically constant use.

When a number of studios are employed, it is of course difficult, if not impossible, to observe the several different programs originating simultaneously in them by means of loud speakers unless the speakers are located in separate rooms. Further, the satisfactory control of the program by the operator practically necessitates his location away from extraneous distractions. These requirements, together with the fact that the more comprehensive programs such as dramatizations, especially those with musical background, can be controlled better when the operator can observe what is occurring in the studio, has led to the use of individual control rooms adjacent to each of the several studios. The operator in one of these rooms has a full view of the associated studio through a large plate glass window and is ordinarily responsible only for the program originating in that studio.

Fig. 6—The five lower knobs on the 10A Cabinet control the output of five microphones or program lines, while the upper knobs have a similar function for the main and monitoring amplifiers

Directly in front of him is a control cabinet which houses keys for switching programs, mixing potentiometers, controls for the main and monitoring amplifier, and indicating lamps. In the back of the room is a speech input bay in which are the amplifiers, a volume indicator, and jacks for testing. Space is also available to mount the panel of the control cabinet if desired.

During rehearsals the control operator can talk to those in the studio by throwing a key which connects his microphone to the amplifier in place of the

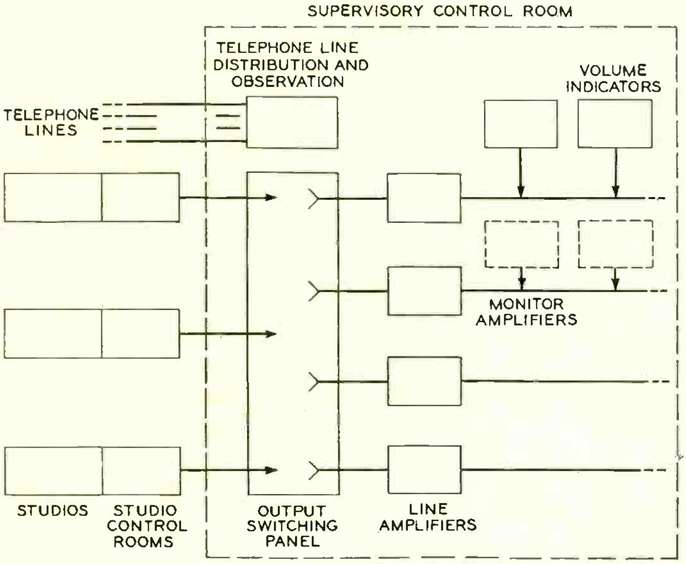


Fig. 5—While each of several studios has its own control room, a supervisory control room is necessary for the group

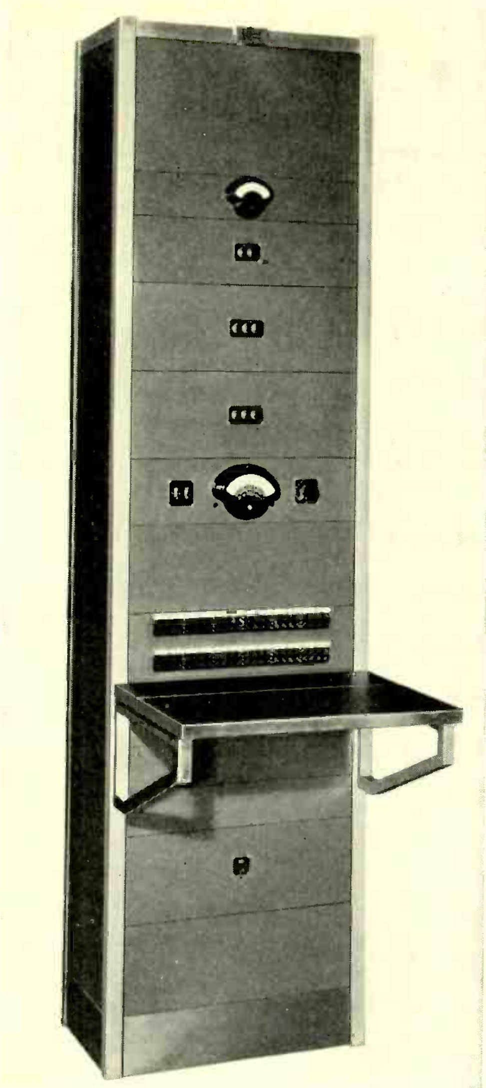


Fig. 7—The Western Electric 701A Speech Input Bay is installed in the studio control room

studio microphones and connects a loud-speaker in the studio in place of the monitoring loud-speaker in the control room.

The use of more than one studio further complicates the technical problem as it is necessary for each studio to be entirely independent of all others both acoustically and electrically so that a program originating in one studio will not be superimposed on another. At the same time it is essential that the outputs of all of the individual amplifier systems be brought together at some point for supervision and switching. This supervisory activity, together with the testing, distribution and observation of program circuits extending outside of the studio

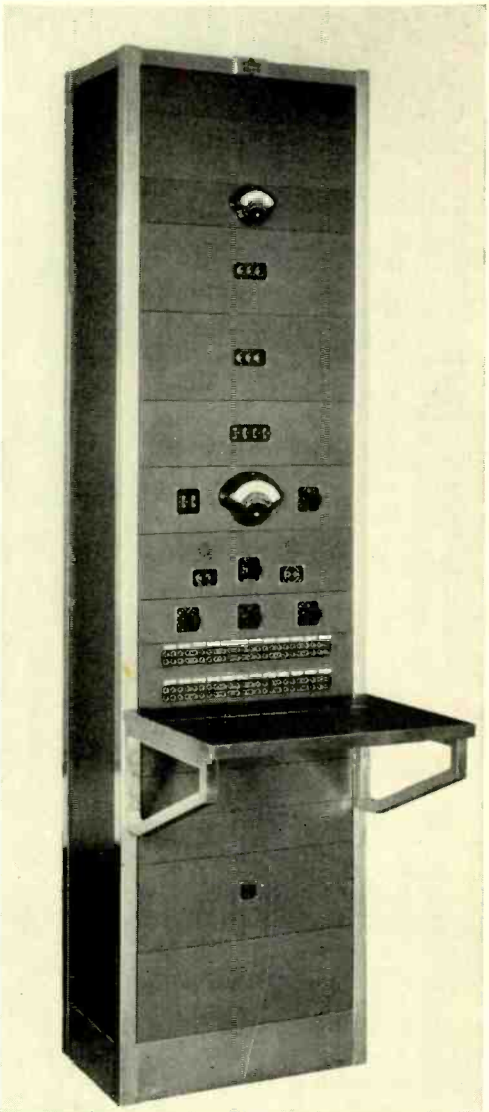


Fig. 8—A program enters the radio-transmitting station through this Western Electric 700A Bay

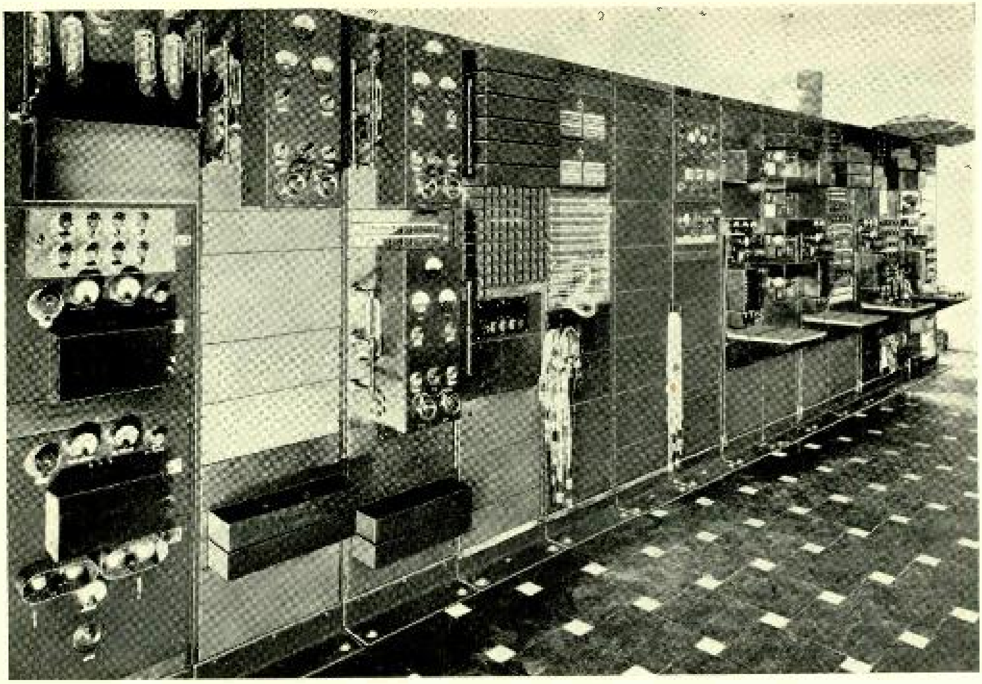


Fig. 9—Supervisory control equipment in the studios of Station WMAQ, Chicago

is ordinarily exercised in a central control room. Here are also ordinarily located amplifiers for each of several outgoing lines when it is necessary to send the same program to several destinations simultaneously. These amplifiers isolate each line from the others and also make possible the use of varying amounts of amplification for each outgoing circuit as desired.

When it is considered that during one broadcasting period a large station may, for example, be supplying a program to its own transmitter and to separate branches of the network and during the next broadcasting period may be required to supply one program to its own station and two entirely different programs to each of the two branches of the network simultaneously, it is appreciated that the precise changeover from one condition to the other imposes severe operating requirements on both the equipment and the operating personnel.

In the interest of speed, accuracy and quietness, these circuit changes are made by keys rather than by cords and plugs. When the cue is given for the switch, only one key need be thrown to put in effect a circuit combination previously set up by other keys*. Provision must also be made for the optional selection of one or more of a number of incoming telephone lines, for the selection of the various spare microphone outlets in the studios, for the interchange of the various amplifier circuits for testing and other purposes, and for the setting up of special circuit arrangements for auditions and rehearsals. This type of switching, which does not impose as severe time limitations, is ordinarily accomplished by the use of jacks and patching cords similar to those used in toll test boards.

So far, it has been assumed that the

*"*A Switching Unit for Program Circuits.*" RECORD, *August* 1932, *p.* 430.

radio transmitter is immediately adjacent to the studio location with which it is associated. However, the use of higher power has necessitated the location of the transmitter in a sparsely populated section while the studio remains in the city where it is readily accessible to artists and advertising clients. Under these conditions, the program is transmitted from the studio to the transmitter over a telephone line. This ordinarily necessitates an amplifier which is in effect a telephone repeater at the transmitter. It is also necessary to provide both a volume indicator and a monitoring loud speaker at the radio transmitter so that the attending operators may observe the quality, volume level and continuity of the program. Furthermore, a microphone is ordinarily provided at the transmitter location so that in the event that emergency announcements are necessary they may be made with a minimum of delay.

These facilities are available in the new Western Electric No. 15A speech input equipment. Except for a three-cell dry battery in the operator's telephone circuit, power is supplied entirely from the commercial alternating current service. The receiving end of the telephone line is bridged by an equalizing network designed to make the frequency characteristic of the circuit suitable for program transmission, and an attenuation network is provided to bring the level of the incoming program at the broadcast transmitter down to that of the local announcing microphone. Testing jacks give access to the circuit at all important points.

In addition to the basic requirements for speech input equipment, namely, high gain, high quality amplifiers having an extremely high signal-to-noise ratio, it may be seen that the precise and accurate control of programs, both studio and remote, the satisfactory conduct of rehearsals and the impressive presentation of auditions for advertising clients necessitates an elaborate installation of supplementary technical apparatus. Further, it should be noted that advances in communication, superficially as remote from one another as the development of permalloy on one hand and of the moving coil microphone on the other hand, are all taken into account in the design of a modern speech input equipment, and that such diverse techniques as toll test board operation and the proper use of loud speakers are involved in this highly specialized branch of radio engineering.

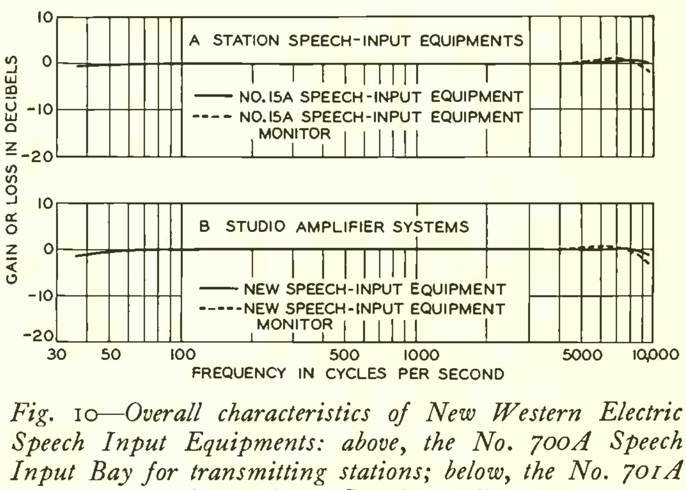


Fig. 10—Overall characteristics of New Western Electric Speech Input Equipments: above, the No. 700A Speech Input Bay for transmitting stations; below, the No. 701A Speech Input Bay for studios

Iron-Cobalt Alloys

By G. A. KELSALL
Magnetics Research

In many magnetic circuits, it is desirable to have at some points the highest practicable flux density. For example, the pull on a relay armature is proportional to the square of the flux density in the air gap. Flux density, in turn, is related to the magnetic permeability of the core and to the ampere-turns in the relay winding in such a way that an improvement in the core material in this respect makes possible a reduction in ampere turns, with resultant saving in power and copper. Or, with the same ampere turns a better core material will give a stronger pull on the armature.

While densities satisfactory for many purposes can be secured at reasonable cost in ampere turns with a commercially-pure soft iron such as Armco, an improved material would show economies in size and in power cost and would make practicable certain designs which otherwise could not be made up. For these reasons, the "fifty-fifty" iron-cobalt alloy developed in these Laboratories a few years ago is of particular interest. The unique property of this alloy is its high permeability at high flux density.

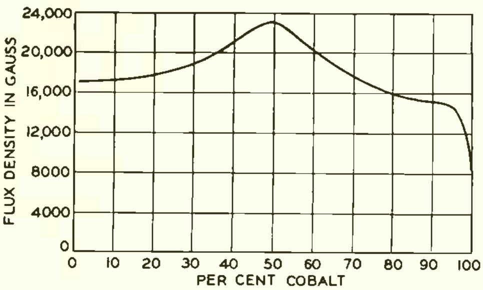


Fig. 1—How composition affects the flux density of iron-cobalt alloy at 50 oersteds

As a graphic illustration of what happens when cobalt is alloyed with iron, consider the curve of Figure 1. In plotting this curve the magnetizing force has been held constant at 50 oersteds, while the composition has been varied from all iron to all cobalt. The maximum value of flux density, a little over 23,000, occurs at half iron, half cobalt. This is almost saturation value for this alloy. Iron, however, is far from its saturation value of 22,000 at this value of magnetizing force.

The comparison between this iron-cobalt alloy and iron alone is further brought out by Figure 2, showing "B-H" curves for the two materials. Above a density of 13,000 the alloy has a higher permeability than has iron. This property suggests the use of the alloy in heavy duty relays or other apparatus requiring high flux densities.

As a practical demonstration, an

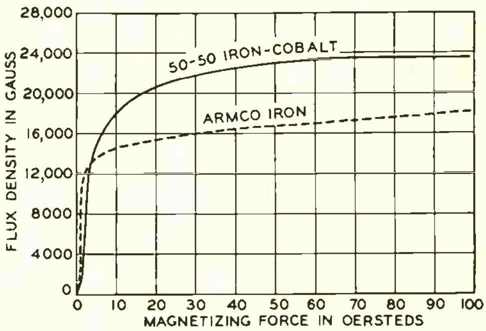


Fig. 2—Magnetization curves of iron-cobalt alloy and of iron alone

electromagnet was made up on a core ⅝ in. square of "fifty-fifty" iron-cobalt alloy. Windings were provided which could conveniently produce a magnetizing force of about fifty oersteds. With this value of magnetizing force, the magnet supported about 210 pounds just before the armature was pulled off, while an iron electromagnet of similar dimensions and with the same ampere turns would support about 110 pounds. It is possible to make the iron magnet exert nearly the same force as the iron-cobalt magnet, but it would require about 16 times as many ampere turns.

In working with this "fifty-fifty" iron-cobalt alloy it was found that it could be used commercially in thick pieces, but its brittleness made difficult the cold rolling necessary to reduce it to thin sheets. The difficulty of cold working was overcome by adding a third element. A method of alloying with vanadium and subsequent working was invented by J. H. White and C. V. Wahl*. Below 2 per cent vanadium, the magnetic properties were practically unaffected. At the same time the resistivity was increased more than three-fold—a desirable factor in reducing the losses due to eddy currents from an alternating field.

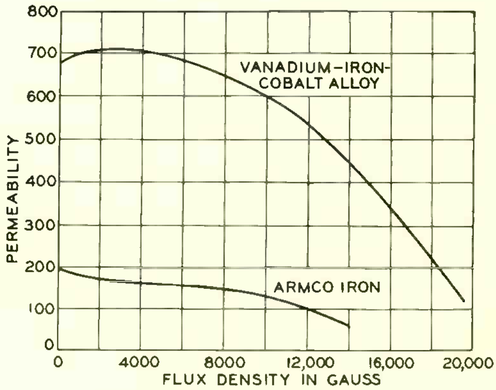
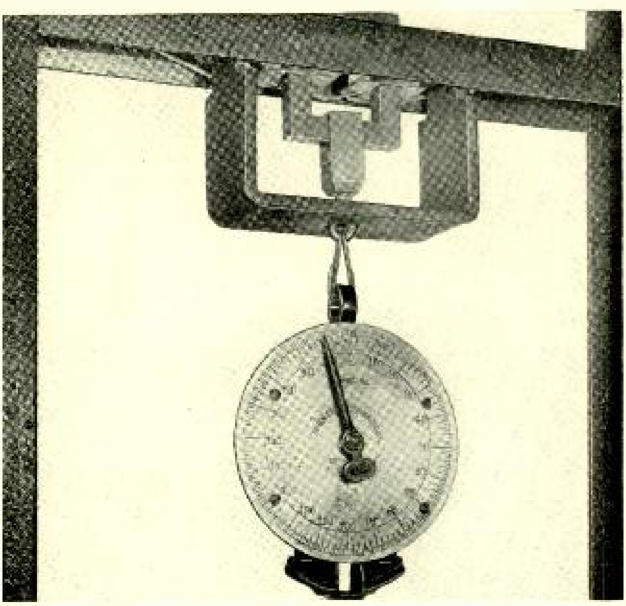


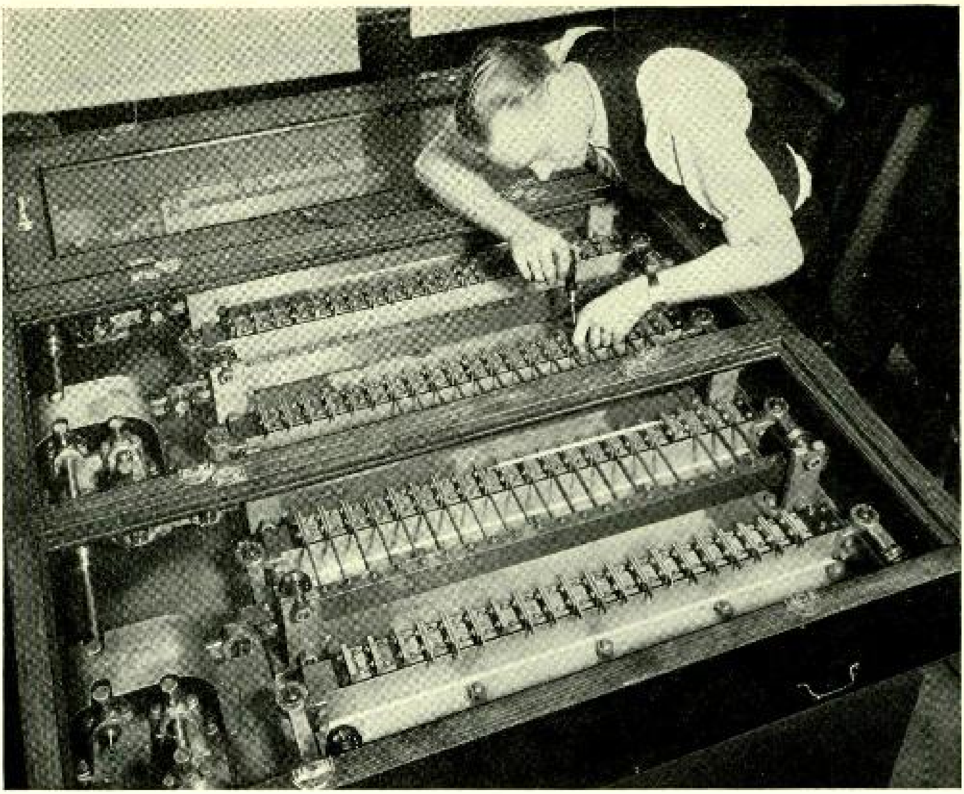
Fig. 3—Permeability for small alternating fields in the presence of a steady polarizing field

In many magnetic structures, a part of the magnetic path is required to carry not only a steady polarizing flux but an alternating flux due to the speech-frequency currents. For this reason an important characteristic of magnetic materials is their permeability to alternating flux in the presence of superposed steady flux. The curves of Figure 3 show that "fifty-fifty" iron-cobalt alloy is superior to iron in this regard, since the permeability to alternating flux is much higher at all the superposed flux densities shown.



Before the armature (smaller U-piece) pulled off, a force of 210 pounds was indicated.

**U. S. Patent* #1862559.



Testing Cable Sheath for Fatigue

By C. H. GREENALL
Telephone Apparatus Development

As a result of extensive engineering and manufacturing development work, lead-alloy sheathed cables have reached the stage where they provide one of the most dependable forms of communication channels. Their average life is now in excess of fifteen years which has only been obtained by a thorough scientific study along metallurgical and mechanical lines. After they have been in service for a considerable length of time, however, irregular cracks sometimes develop in the sheaths. Through these cracks, moisture, of course, can enter, and since the insulation of the conductors is dry paper, a small amount of moisture is sufficient to impair the transmission characteristics of the cable. These cracks differ from those that might result from a single application of a large stress, in that no deformation of the material is evident, and for the sheath alloys in general use—lead, lead-tin, and lead-antimony—the cracks follow the crystal boundaries. A failure of this kind is due to a condition called "fatigue", which results from repeated stressing of the cable sheath over long periods of time. Stresses causing this type of failure in cable sheath arise from the swaying of the cable in the wind, from variations in air temperature—causing the cable to contract or expand—or from various types of vibration to which the cable may be subject. The cumulative effect of the long sequence of such stresses if they reach certain critical values ultimately results in intercrystalline fatigue failure of the sheath, although none of the individual stresses to which the sheath is subjected is, as a rule, great enough to cause immediate failure.

Considerable expense may result from such failures of cable sheath. The fault has first to be located and then repairs made which may result in considerable maintenance expense. It has been desirable therefore, to devise laboratory methods of measuring the resistance of various cable sheathing alloys to fatigue, so that the life of cables may be prolonged by improvement in the sheathing materials.

Fatigue failure in cable sheath, as in all other metals, frequently starts from a region of highly localized stress, such as is produced by a sharp bend or surface injury, and from these localized points may spread progressively through the sheath, resulting in ultimate failure. If, however, the stresses to which the sheath is subjected are below a certain limiting value, failure of the sheath either will not occur or will be much delayed. This value is called the "fatigue endurance limit" and represents the maximum repeated stress to which the material may be indefinitely subjected without failure.

The development of laboratory testing methods to simulate service fatigue failures has been the subject of much study. The first investigations were made by bending full sections of the cable around a rather large radius, as shown in Figure 1. Sample lengths of cable, 9 feet long, were subjected to fatiguing action wherein one end of the cable was moved back and forth through a deflection of 2 inches, at a constant rate of approximately 96 bends per minute. This movement ultimately caused failure of the sheath at the bend due to fatigue. In order to record the time of failure of the sheath, the specimens of cable were sealed at each end and a slight vacuum was maintained in them. At the stationary end a connection was made to

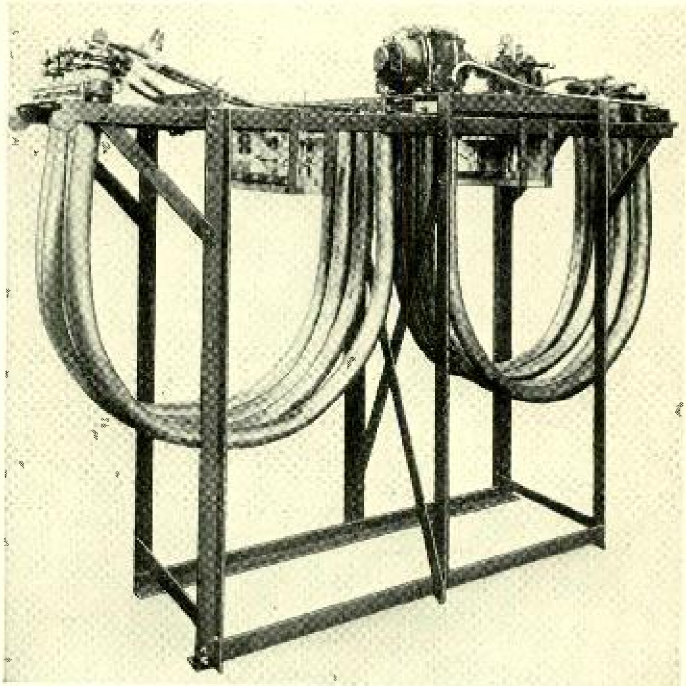


Fig. 1—One of the first types of fatigue testing machines which subjected full-sized cable to fatiguing action until failure occurred

a mercury manometer. Failure of the sheath permitted air to enter and destroy the vacuum, causing the manometer to register the failure through an electrical connection. Failure in this test showed the same intercrystalline breakdown that is obtained in the field.

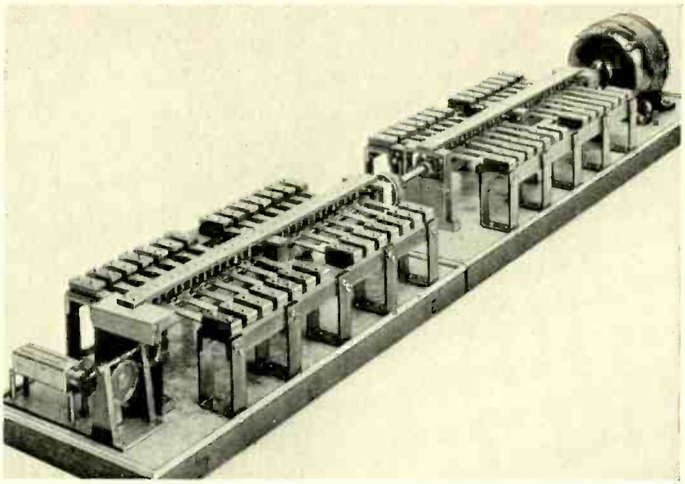


Fig. 3—An early type of fatigue test flexed sections of cable sheath back and forth till failure occurred

A subsequent test was then developed which would not require as long a length of cable for the test, which resulted in considerable economy. In this test longitudinal sections of cable were held firmly at one end, while the other end was vibrated transversely ⅛ inch 1700 times per minute, thereby subjecting the sheath to alternate periods of tension and compression stress. This machine is shown in Figure 2. Here, again, the same method of determining sheath failure by means of a vacuum was used. An examination of the failures obtained compared to those being experienced in the field again indicated a similarity of type, namely, failure along the crystal boundaries, and showed the same appearance when examined microscopically.

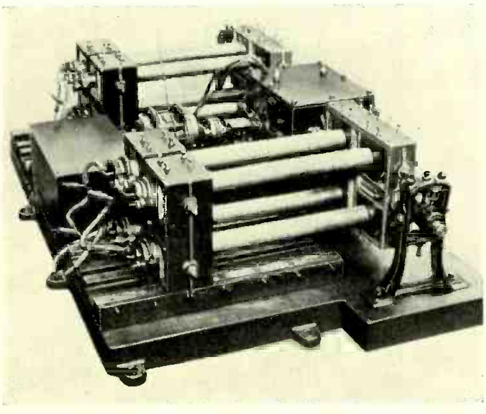


Fig. 2—Another type of fatigue testing machine which subjected sections of full-sized cable to fatiguing actions

A further development in fatigue testing is illustrated by Figure 3. Here flat cantilever beam specimens are actuated by a rotating cam to varying degrees of deflection. The specimens for test are cross-milled from sheath which has been flattened prior to the machine operation, with considerable economy in the amount of material necessarily used for the test. Using this type of machine, more precise engineering data relative to the actual stresses in the material were obtained for the first time. Likewise, comparison of new alloys extruded in the laboratory in the form of tape, which were under consideration as possible sheath substitutes, could also be compared directly to the standard sheathing alloys. This also permitted correlation of the fatigue data being obtained during the test with the other physical properties of the sheathing alloys, such as tensile strength, hardness, and ductility.

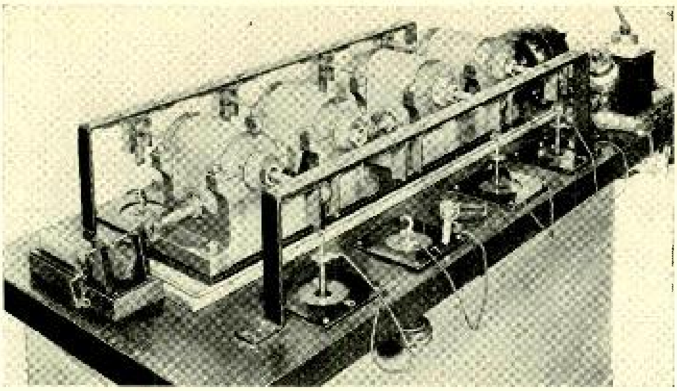


Fig. 4—A later type used rod form specimens which were rotated while sustaining a cantilever load

Laboratory studies of the data which have been obtained on the three machines indicated the desirability of determining the fatigue characteristics of sheathing alloys throughout the entire range of stress to which the sheath might be subjected in the field. In the next machine designed, of the rotating contilever beam type shown in Figure 4, alloy rods extruded in the laboratory could be loaded to any stress desired—the specimen being rotated under that stress until fracture occurred. Corresponding studies on the rod alloys for tensile strength, hardness, and ductility were then correlated to the fatigue data obtained on the rotating beam machine. A counting device on the machine permitted accurate determination of the number of reversals of stress to which each specimen was subjected until failure. In this type of test each of the outer fibres of the specimens was subjected to successive cycles of tension and compressive stress.

The laboratory experiments had now reached the point where it was felt that various thicknesses and sizes of cable sheath should be extruded for experimental field installations. At the same time, it was realized that it would be desirable to be able to conduct laboratory tests on these various samples of sheath which were to be extruded for experimental test in the field. Accordingly, the latest type of fatigue testing machine, shown in the headpiece to this article, was developed. Studies are now in progress of the fatigue characteristics of many alloys which have been under consideration for possible use as a cable sheathing material, all of which are being evaluated by using this type of machine. This machine has been found to be advantageous from the standpoint of economy of operation and the speed with which complete engineering data relative to the fatigue characteristics of the alloy may be obtained. One loading of the machine will supply sufficient data for the determination of the endurance limit and fatigue characteristics of the sheath at stresses comparable to those which occur in the field. The machine has a capacity of 126 fatigue specimens. Six reciprocating arms each having twenty-one specimen positions availa-

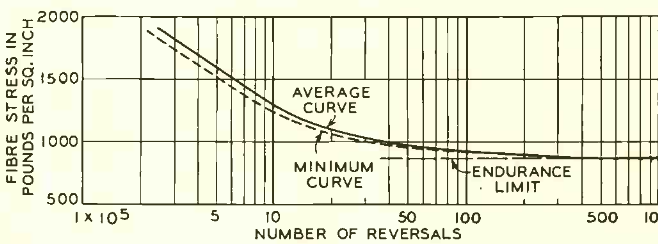


Fig. 5—Typical fatigue endurance curve of extruded 1% antimony lead alloy

ble, are adjusted so as to provide six different deflections. The deflections of each of the arms are chosen in such a manner that the fatigue endurance limit of the alloys, as a rule, will lie between the two smallest deflections used. In general, three specimens per alloy are used, which permit studies of seven alloys to be made on the fatigue testing machine at one time. The machine is designed so that the point of application of the bending force does not change as the reciprocating arms move back and forth. This avoids small changes in the free length of the specimen, which in previous designs have resulted in extraneous stresses being imposed upon the specimen, the value of which could not be definitely determined.

Early in the investigation of fatigue characteristics of cable sheathing materials, it was realized that temperature had considerable effect on the fatigue characteristics of cable sheath. Temperature control has, therefore, been installed on the latest type of fatigue testing machines, the variations of the temperature being held to within ± 2 degrees Fahrenheit the average temperature being 85 degrees. Although this temperature is somewhat higher than standard room temperatures — 68 degrees — the higher temperature is more economical and easier to control from an inspection standpoint. Variations in temperature from below zero to as high as 140 degrees are frequently encountered at locations where aerial cables are installed. For this reason, a temperature of 85 degrees was not considered seriously out of line with the average temperature to which sheath is subjected when exposed to the greatest fatigue conditions found in the field.

The latest machine was also developed primarily to permit the evaluation and testing of specimens at various thicknesses of cable sheath, as well as to permit allowance to be made for the fluctuation in sheath thickness or eccentricity which is noticeable around the circumference of cable sheath. Results which have been obtained have been correlated to the physical properties of the sheath and it is anticipated that ultimately these data will likewise be correlated with data obtained from the field trials. This correlation, however, will only be possible following compilation of complete field data such as is now being obtained on cables of various types and thicknesses of sheath at the Outside Plant Laboratories at Chester. A typical fatigue curve obtained from the latest type of machine is shown in Figure 5. This curve shows that as the fibre stress is decreased the number of reversals required for failure increases rapidly. At a certain stress (the endurance limit), which is represented in the figure by the approximately horizontal portion of the curve, the number of reversals of stress required for failure becomes indefinitely great. In other words, for any lower stress the material can endure an unlimited number of reversals without failure.

A special room at the Laboratories is devoted to these fatigue studies of metals. Although a very considerable amount of data has been gathered by the use of these machines in testing for the fatigue characteristics of cable sheathing material, the field of fatigue testing is still felt to be in its infancy.

A Portable Oscilloscope

By R. F. MALLINA
Acoustical Research

VISITORS to the Bell System exhibit at the Century of Progress Exposition in 1933 had the opportunity of talking into a transmitter and seeing the wave form of the words they spoke on a screen before them. This was made possible by a large oscilloscope developed at Bell Laboratories which amplified the current from the telephone transmitter, converted it to a moving light beam by an electrodynamic vibrating element, and projected the beam onto a reflecting screen. This apparatus which has already been described in the RECORD*, created a great deal of interest. As it seemed to have a wide field of usefulness, a portable model has been developed and was recently demonstrated before the Society of Motion Picture Engineers and the Acoustical Society of America. It is shown in use in the photograph at the head of this article.

The principle of operation is the same as for the larger oscilloscope already described. The vibrating element consists of a spherical mirror connected to the diaphragm of a moving-coil microphone. A narrow beam of light of high brightness, obtained from a small automobile lamp, is thrown onto this mirror from which it is reflected to a rotating mirror, and thence to a three-foot screen. The spherical vibrating mirror gives the

*RECORD, *August* 1933, *p.* 361.

up and down motion to the beam, and the rotating mirror, made in the form of a regular polygon of twenty sides, gives motion across the screen. The layout of the apparatus is indicated in Figure 1.

All of the apparatus except the screen and the amplifier is mounted in a small portable case about 19 by 12 by 6 inches. The screen, together with the hood which shields it from external illumination, folds into a thin case 3 feet by 2 feet by 2 inches. The amplifier and loud speaker form a third unit, which has already been described in the Record*. Tripods are provided for supporting both the reproducer unit and the amplifier with the screen on top of it.

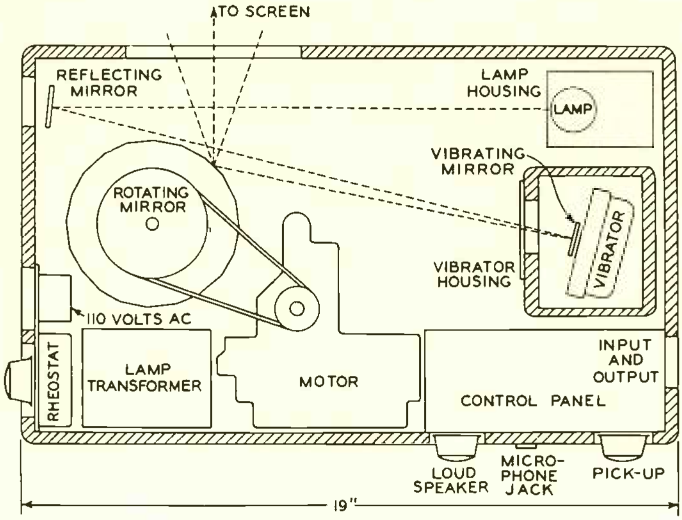


Fig. 1—Plan view of portable oscilloscope

Either a microphone or a phonograph pick-up may be connected to the input circuit. A single phonograph motor drives the rotating mirror and also the record when one is used. The same amplifier is employed for both microphone and phonograph pick-up, and is switched from one to the other by a small rotating switch on the front of the case, as shown in Figure 2. Separate potentiometers are provided for the microphone and for the pick-up, while a third is located in the input to the loud speaker. By means of these volume controls, the amplitude of the wave shown on the screen may be adjusted to the desired height, and the volume of the loud speaker controlled independently.

To reduce the size of the apparatus so that it could be assembled in a readily portable form, several changes have been made. The rotating mirror has been reduced in diameter from the eight inches used for the Century of Progress machine to about five inches. The distance from the lamp to the rotating mirror could not be changed appreciably but it was brought within a smaller overall compass by employing a reflecting mirror between the lamp and the vibrator. Thus the lamp and vibrator are placed side by side, but the light beam travels across the length of the case to the reflecting mirror and back to the vibrator. Advantage is taken of this arrangement to make it possible to place the screen at a considerable distance from the oscilloscope, such as at the farther end of a hall. Under these conditions a brighter light source is needed which may be an arc lamp placed outside the case. An opening is left in the case behind the reflecting mirror, and when the mirror is slid out of its support, light from the arc will fall directly on the vibrator. Space economy was further secured

*Record, *August* 1932, *p.* 417.

by employing only one phonograph motor and driving the rotating mirror from it by a belt.

Besides these changes to increase the portability of the oscilloscope others were made to increase the flexibility of its employment. The lamp housing is movable and can be moved nearer to or farther from the reflecting mirror by a knob on the top of the case. This permits accurate focussing for different positions of the screen. Using the lamp in the case, the screen may be mounted at any distance from five to ten feet from the rotating mirror, but by using an external source of light, this distance may be increased up to any desired value.

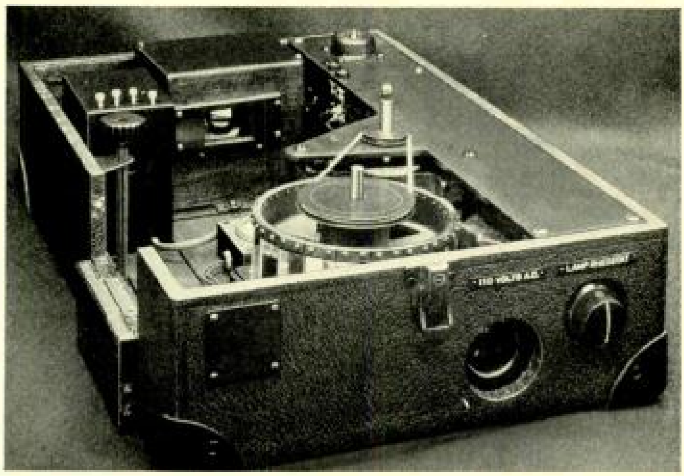


Fig. 3—Power input and lamp rheostat are on one end of the case, and the other controls on the front

Adjustment of the size of the light spot is provided by four screws at the front of the light housing. This permits a very fine line, when high frequencies are to be shown in a darkened room, or by enlarging the aperture allows more light to fall on the screen when the oscilloscope is used in a lighted room. Provision is also made for tilting the rotating mirror so that the screen may be mounted above the level at which the oscilloscope stands.

The arrangement of the oscilloscope in the case is shown in Figure 3. The rectangular black container at the left houses the lamp, and the four small knobs projecting above it are for adjusting the size of the aperture. The larger knob just in front of the lamp container is the focussing adjustment. In the center back is the vibrating-mirror and microphone unit, and in the front center is the rotating mirror. The drive motor is under the central spindle at the right, on which is mounted a record when the phonograph attachment is used. The square plate on the outside of the case at the left covers an opening behind the reflecting mirror. Through this opening light passes to the vibrating mirror when an external source is employed. Figure 4 shows the appearance of the oscilloscope when a phonograph record is being used, and also shows how the screen is shielded when the oscilloscope is used in a lighted room. Both this photograph and that at the head of this article show

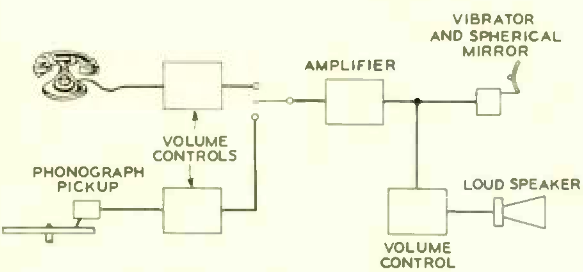


Fig. 2—Schematic arrangement of oscilloscope circuit

the last portion of the sound "er" in "fathers" being reproduced. The section appearing on the screen lasts about 0.02 second, and represents about one-fourth of the complete sound.

The convenient and portable arrangement of this new oscilloscope, combined with its many adjustable features should make it very valuable for a variety of uses. Besides its obvious advantages for instruction in schools and colleges, it is also suitable for lectures and demonstrations as well as for actual acoustic studies.

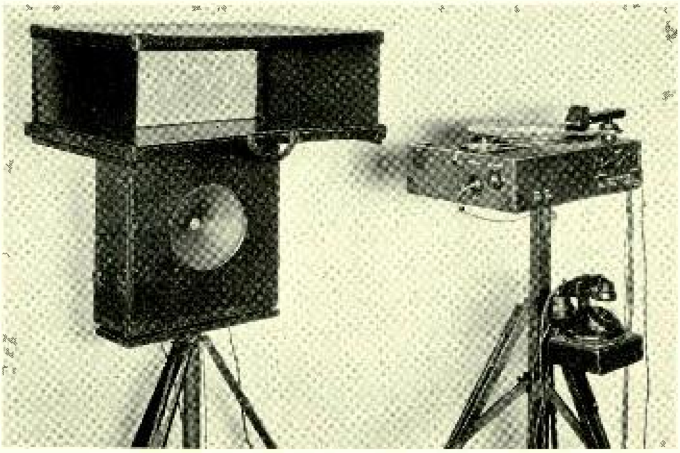


Fig. 4—A shielding hood for the screen permits the oscilloscope to be used under normal illumination

The Trunk Group Busy Register

By W. C. OAKES
Local Systems Development

TRUNKS and toll lines of the Bell System represent a very large investment. There is not only the cost of the outside plant, wires, poles, cables, underground duct systems, loading coils, and a variety of associated equipment, but there is also the expensive office apparatus such as repeaters, composite sets, repeating coils, and switchboard facilities. If high grade communication service is to be provided at the lowest consistent cost, therefore, the number of trunks and toll lines must be carefully regulated so as to be adequate to render rapid service, but not great enough to result in burdensome overhead charges on unused equipment.

To determine to what extent the trunks and toll lines are being used, it was at one time customary to obtain records manually of the number of circuits in use. The methods of doing this varied somewhat, depending on the type of groups being considered. Local call-circuit trunks for instance, which prior to the extension of machine switching and straightforward operation made up a large part of the local trunk groups in cities and large suburban districts, ended in plugs at the "B" position. Each trunk group appeared either in one position or adjacent positions, and it was common practice, prior to busy hour periods, to turn down a certain portion of the trunks in a group; that is, put the tip end of the plug into the hole used as a plug seat. These turned down trunks were assigned only when all the other trunks were in use. It was therefore a simple matter, by noting the number of trunks which remained turned down, to determine whether the group was large enough or whether it was approaching a state of congestion in which some relief would be required. These records have been quite generally referred to as "turn down" or "plug count" records.

With toll lines, however, the circuits for the most part are jack ended. Associated with the outgoing jack of these circuits is a visual busy signal which indicates when the toll line is in use. For some time, it was the practice for an observer to determine the number of toll lines of a particular group in use by reference to the visual signals. By frequent count in the busy hour, it was possible to secure an approximation of the number of circuit minutes used during the hour and an indication of the extent to which

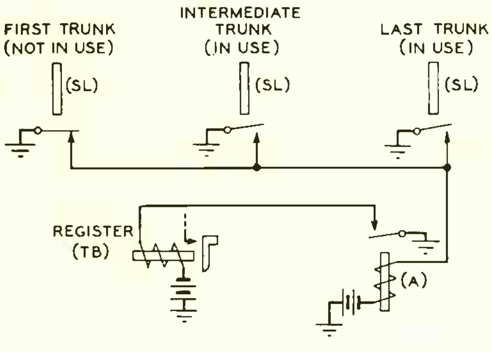


Fig. 1—Group register circuit employed for local trunks

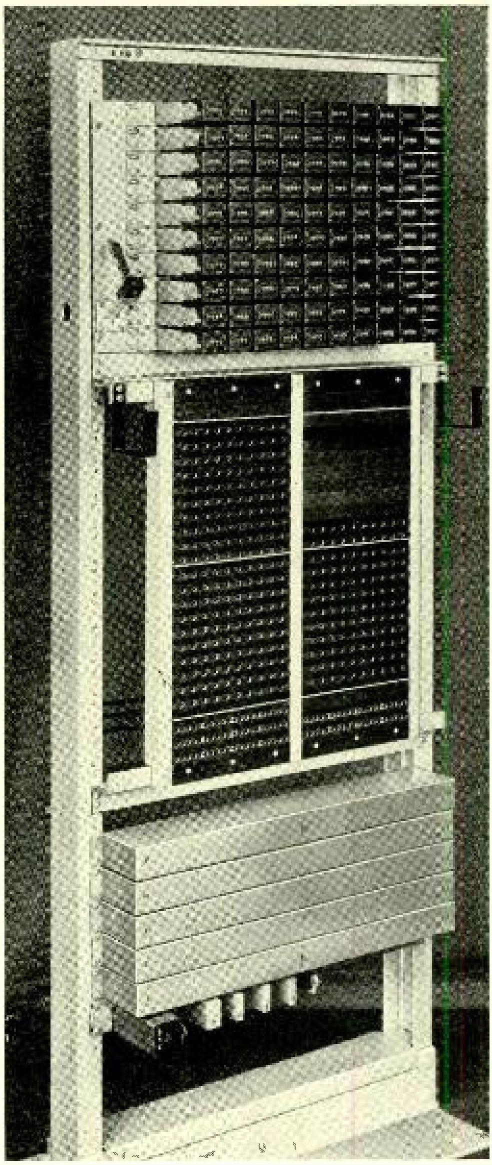


Fig. 2—A group-busy time register rack showing registers, above, jack field, and relays, below

"no circuit" conditions were being encountered. These data were referred to as "jack count" records. These manual "plug count" and "jack count" records served as a reliable basis for the engineering studies as to the adequacy of the circuit facilities, and also as a forecast for seasonal trend of the traffic.

With the extension of machine switching and straightforward operation, it was not possible to apply the "plug count" method to determine the circuit usage, and group-busy register equipment similar to that shown at the head of this article was developed.

The main elements of the circuit employed are shown in Figure 1. One end of the winding of a relay, A in the diagram, is connected to battery and the other end is connected to the back contacts of the SL relays of all the trunks in the group to be studied. When anyone of the trunks is not in use, the back contact of its SL relay will be closed, and the A relay is operated. When all the trunks are in use, the circuit of the A relay will be opened, and when the relay releases, a circuit will be established through its back contact to operate the register TB. Each operation of the register moves the number wheels one digit ahead and thus the number of times all trunks are busy is counted.

It was unnecessary to arrange this circuit to take account of the length of time that all the trunks remain in use. Local trunk provision generally contemplates a very small proportion of failures to secure a trunk. Hence a simple measurement of the number of times all trunks in a group are busy, indicating the potential delays to service, is sufficient for local trunk engineering and administrative purposes.

Because of the greater distances involved, toll lines differ from local trunks in that the investment per toll line is higher and the average volume

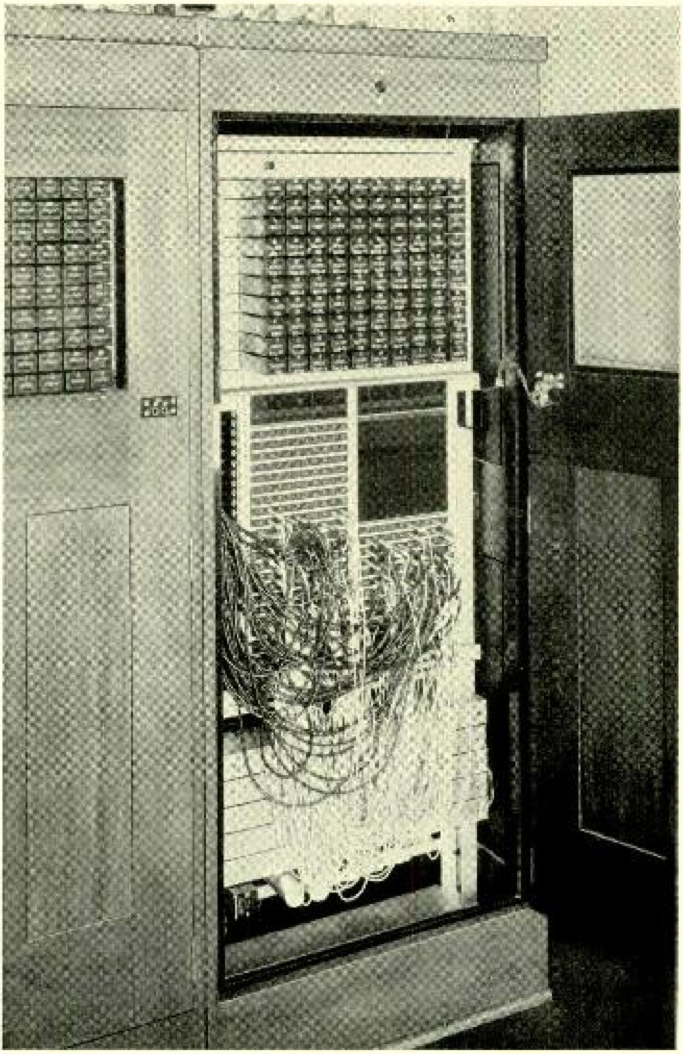


Fig. 3—The group-busy time register rack is mounted in an enclosing cabinet which allows the register to be read without opening the doors

of traffic between pairs of points is much lower requiring smaller circuit groups. In addition, the circuit holding time per call is greater on toll than on local trunk calls. For these reasons, somewhat different data are desirable as an aid in engineering a toll plant that will be adequate and yet not be overbuilt when both cost and service aspects are considered. With such a plant, "no circuit" conditions will be encountered more frequently and be of longer duration than is the case with a local trunk plant. It was considered essential, therefore, that the register circuit for toll lines take into account both the number and duration of the "no circuit" conditions. As a result, a circuit was developed similar to that of Figure 1 except for an additional contact in the operating circuit of the register. This contact is in a master clock in the toll office and is closed by the clock mechanism every 6 seconds. With this arrangement and all trunks busy, the register will be operated every 6 seconds. When one of the trunks in the group is idle, the operation of the contact in the master clock will not, of course, operate the register.

For this latter system, equipment units for 100 registers are built as shown in Figure 2, the registers are mounted at the top of the frame, and the A relays under the covers at the bottom. The middle of the frame is filled with a jack field. Each register circuit is brought to a jack in the lower part of the field and each toll line group to a jack in the upper. The register circuits can be connected with the various toll groups by means of patching cords between the upper and lower jacks. Provision is made for 400 toll line groups, one quarter of which may be under observation at a time.

The frame of Figure 2 is mounted in a cabinet as shown in Figure 3. A glass panel permits the register to be read without opening the door. This equipment is widely used for studies of toll line groups. The photograph of Figure 3 and that at the head of this article show an installation in the Long Lines building in New York.

The Switchboard Cord

By R. T. STAPLES
Telephone Apparatus Development

FROM the early days of the first crude telephone switchboard down to those of the great modern central office, the talking connection between subscribers has been completed by an indispensable piece of apparatus—the switchboard cord. Because of the important part which the switchboard cord has always played in the telephone plant, it has been subject to continual modifications of structure to improve its serviceability, ever since its humble beginning as a pair of twisted lamp cord conductors. To the casual observer, the switchboard cord is merely a flexible cotton-braided conductor having a plug attached to one end, and having the other end arranged for attachment to terminal punchings in the switchboard as shown on Figure 1. It is not so well appreciated, however, that this structure of textiles and conductors is composed of materials that are inherently variable in their character, size, and durability, and that it must not only meet close dimensional limits for attachment to the plugs and for satisfactory operation in the switchboard, but must be smooth and flexible, and able to withstand thousands of operations in service without breakage of the conductors or fraying of the outer covering.

The evolution of the switchboard cord is illustrated in Figure 2, which is a photograph of specially prepared samples including the more prominent types that have been developed for use during the past thirty years. Figure 3 is an X-ray photograph of these same samples, and illustrates clearly the various structures of these cords.

An early type, shown in the illustration as No. 2, had stranded copper wire conductors with rubber insulation. The extremely short service life of such conductors soon led to the investigation of other types of flexible conductors that might better withstand the conditions of use in a switchboard. As a matter of course, the use of tinsel, which for many centuries has been employed for decorative purposes, was proposed. It possessed the desired flexibility for use in cords, but the thin metal ribbon lacked the toughness required to produce long

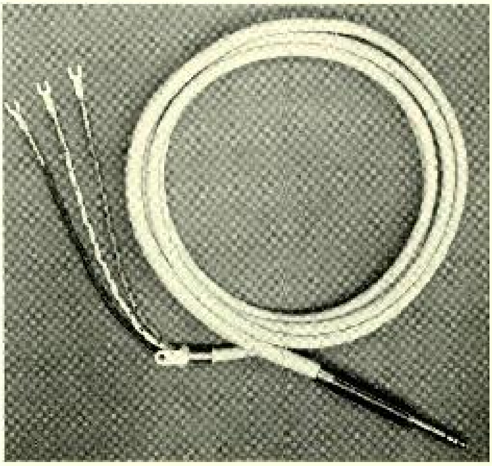


Fig. 1—The equipment end of the cord has a metal band with eyelet clamped around the braid which is used to suspend the switchboard end of the cord. On the band are stamped the cord identification marks

lived electrical conductors. Consequently, a special tinsel, more durable than any commercially available, was developed, and its production was controlled by specification. This tinsel was used in the structure of switchboard cords of the brass helix types shown as Nos. 1 and 4 in the photograph. These cords possessed the desired flexibility, and, because the brass helix reinforcement which surrounded the tinsel conductors prevented the cord from being bent sharply, better cord life was obtained. The cord illustrated as No. 4, which used the same tinsel ribbon as No. 1 and an improved conductor structure, continued in service because of the low conductor resistance required in toll connections until about 1909, when it was displaced by a further improved type having low conductor resistance and employing a rope-core cord structure.

While the tinsel cords thus far produced met the operating conditions satisfactorily, and had the low conductor resistance required for use in toll boards, they had relatively short life when subjected to the severe service in local switchboards. Breakage of the tinsel ribbons resulted in "noise" caused by the variable resistance at the broken spot in the conductor. Simultaneously with the early development work looking toward improving the service life of tinsel cord conductor, other materials and structures were investigated.

These efforts were rewarded by the development of the steel-conductor switchboard cord, which was introduced in 1905 and continued as a standard for use in local boards for nearly 10 years. The structure of the steel cord, as may be observed from No. 3 of the photographs, was radically different from the previous types. The conductors in this case were made from No. 26 tinned-steel wire rolled flat and spiralled around the axis of the cord; the tip conductor being in the center, spiralled around a twine core; the ring conductor spiralled in the reverse direction over it; and the sleeve conductor on the outside. Layers of tussah silk supplemented by a linen braid formed the insulation between the spirals. The steel conductor cord had exceptionally satisfactory conductor life but was not so satisfactory in some other re-

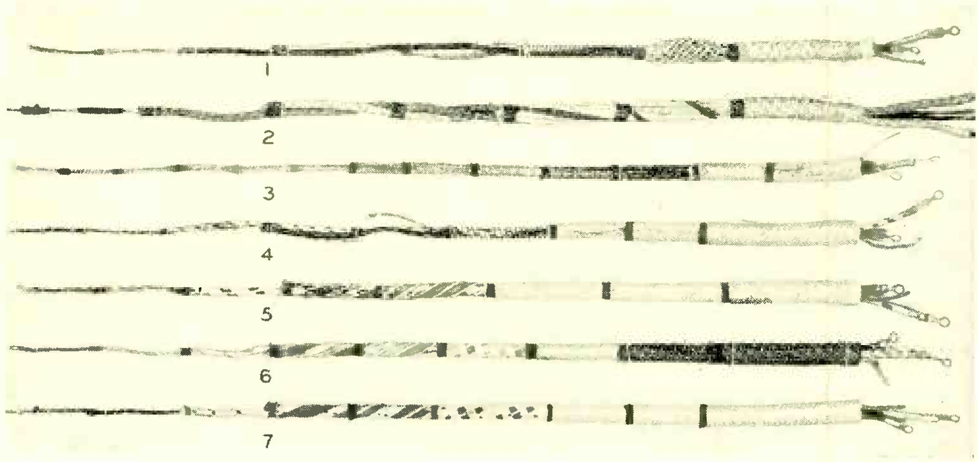


Fig. 2—Various types of switchboard cords developed during the last thirty years

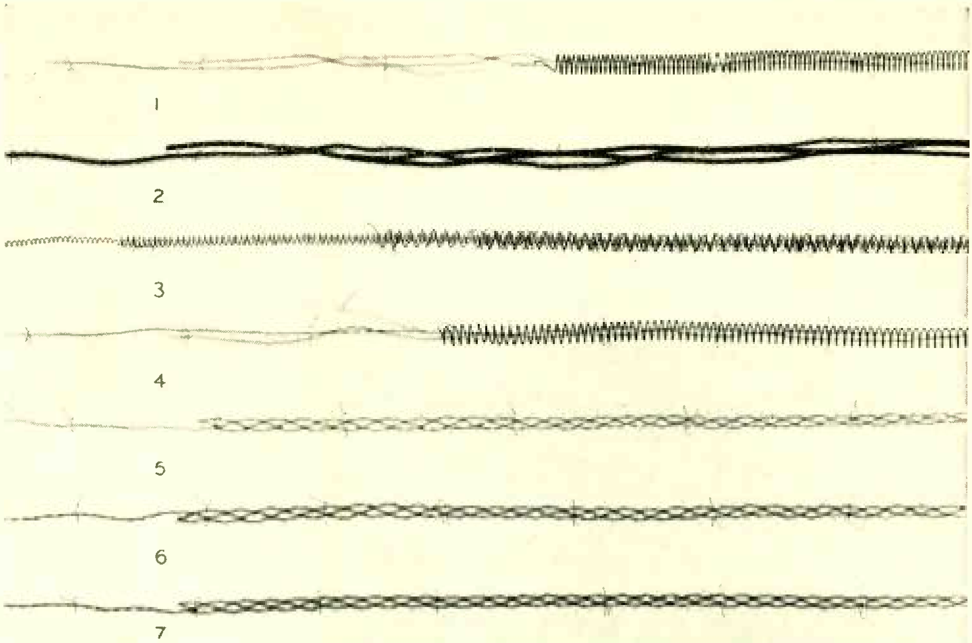


Fig. 3—An X-ray photograph reveals the arrangements of the conductors in the cords shown in Figure 2

spects as the tinsel cord because of its stiffness and higher resistance. Consequently, further consideration was given to the possibilities of tinsel for cord conductors.

This work on the tinsel conductor resulted first in the development of an entirely new type of cord structure having the so-called "rope core" construction as illustrated by No. 5 in the photographs. In service trials cords using this new construction compared favorably in life with the efficient steel conductor cord, but further improvement in the tinsel conductor was found to be needed. The final development of the modern long-life tinsel conductor for use in station and switchboard cords is described in a previous issue of the RECORD* and need not be discussed in detail here. It should be noted, however, that the fundamental improvements in the tinsel consisted in the replacement of the copper ribbon by one of tough bronze alloy which was better able to withstand the repeated bending which the conductors received in service; the later use of two tinsel ribbons of larger size on each thread; and the reduction in the number of tinsel threads to six from the eighteen formerly used. Also, to render the cords suitable for use throughout the country, a moisture-proofing treatment was applied, so that a satisfactory insulation level would be obtained when the cords were subjected to the extremely humid climatic conditions which are encountered frequently during the summer months along the seaboard localities.

This new cord came into general use in 1925. While it completely fulfilled all expectations in serviceability, other improvements were still to follow. The first of these was the adop-

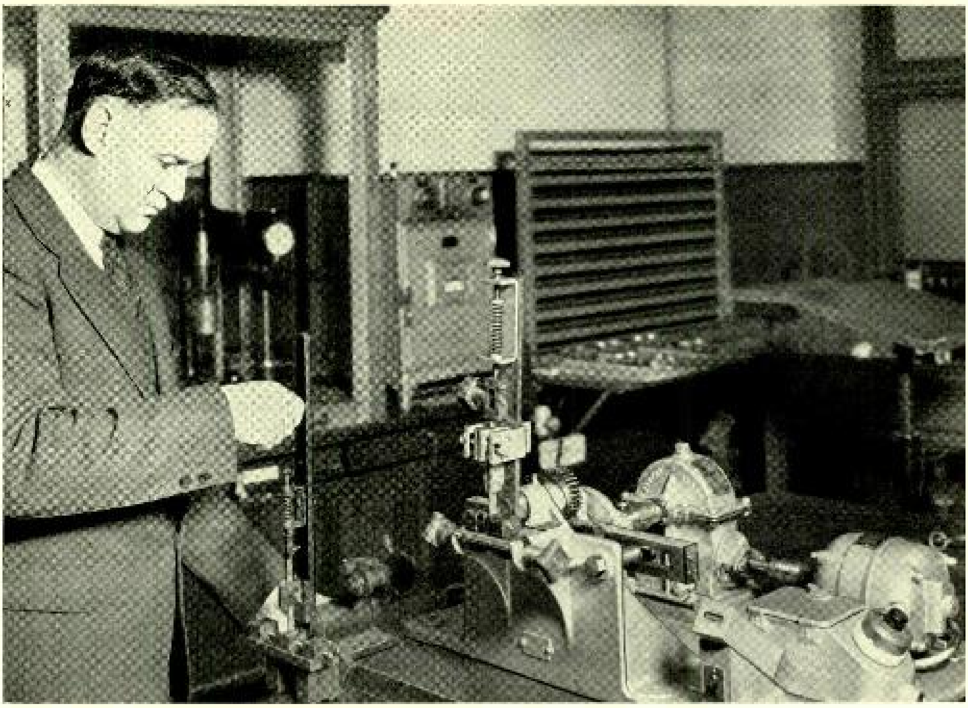
*RECORD, *July*, 1926, *p.* 196.

tion of solderless cord tips for the conductors, which reduced the contact resistance between the tip and the tinsel, and virtually eliminated troubles in service from variable resistance at the tips, and from tips pulling off the conductors.

Since the adoption of the rope-twisted conductor, with two tinsel ribbons on each core thread, practically eliminated the failure of the conductor before the braid began to fray, it was evident that the life of the cord could be further increased by making improvements in the braid. Braid-life improvement was brought about through the development of better glazed cotton and its more uniform application through the use of automatic braiding machines developed by the Western Electric Company. These improvements were accompanied by other structural changes in the design of the cords and these final improvements have recently been embodied in the commercial product and thus are now coming into use in the telephone plant. Their useful service life is approximately ten times the life of the earlier types of tinsel switchboard cords used in toll switchboards, and two to three times the life of the steel cords formerly standard for local central offices.

General studies of the materials and manufacturing processes involved are being continued with the expectation that this work will be productive of further improvements in switchboard cords in the future.

Experimental circuits for 60 cm. radio waves take some unusual forms. Four tuned circuits are present in this detector circuit being tested by J. G. Chaffee of the Research Department.



An Improved Bend Tester

THE ability to withstand bending is one of the characteristics of metals that plays an important part in apparatus design. Bending tests are carried on in Bell Telephone Laboratories as part of its study of materials. One phase of this subject, which has recently been discussed in the RECORD*, is the determination of the minimum radius to which a metal may be bent.

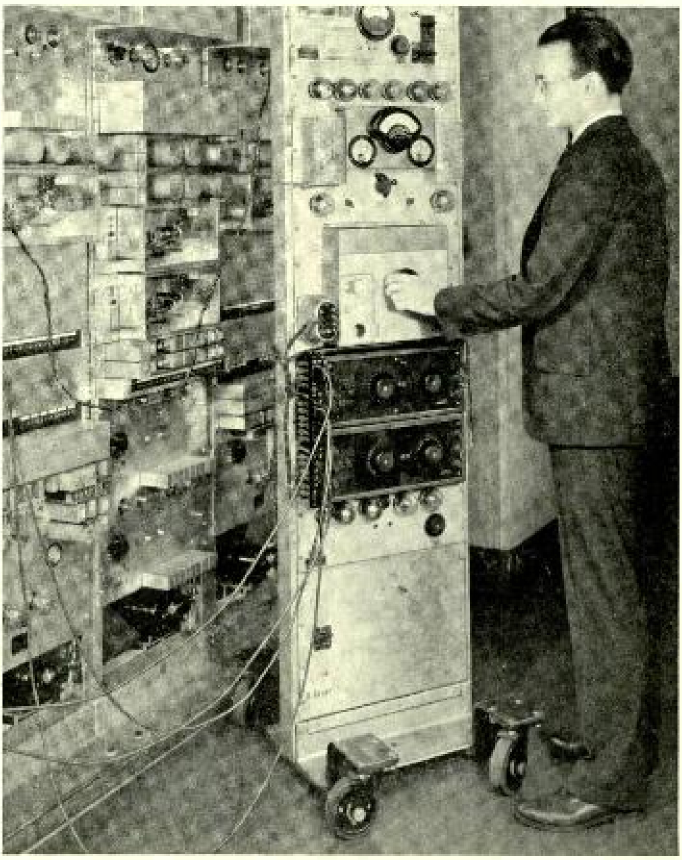
When bending tests first began to be made, the only machine available consisted of a hand operated lever, to which was clamped the upper end of the test strip. The lower end was clamped between two moveable blocks, which could be ground to any radius of bend. A counter was provided to record the number of complete bends before failure. The bending was done by moving the lever back and forth by hand as illustrated by W. S. Hayford at the left of the above photograph.

Results obtained from this machine were not entirely satisfactory for our work because of many uncontrollable factors. It was difficult to control the arc of swing very accurately, and the speed of motion—which also might vary—was found to affect the results. Moreover, the necessity of hand operation made the process slow and tiresome. As a result, Mr. Hayford, at that time with the Materials group of the Apparatus Development Department, undertook the development of an improved machine, on which he has recently been granted a patent.

The new machine, shown at the right of the photograph, has lower

*RECORD, *April*, 1934, *p*. 230.

clamping blocks and an oscillating arm as did the earlier machine, but many of the details are greatly improved, the angle of bend is constant, the clamping blocks are more accurately ground, and the machine is motor-driven. The two lower clamping blocks are controlled by a single rod with right-hand and left-hand threads, which insures that the specimen is always held directly beneath the center of the lever when the latter is in a vertical position. Turning the handle on the end of the rod in one direction unclamps the specimen, and turning it in the other direction, clamps it. The arrangement of the moving arm has also been improved by a better clamping and tensioning device, and by greater flexibility in the adjustable guides which lie closely against the sides of the specimen to within a short distance of the lower blocks. The provision of a motor drive eliminates the manual operation, and provides a constant number of bends per minute, thus insuring that more dependable results will be secured.



This portable transmission measuring set, being manipulated by E. W. Waters of the Research Department, operates very quickly and accurately over a wide range of transmission equivalents and frequencies, and is especially useful for voice operated circuits. The oscillator output is equalized so that the frequency response characteristic is flat from 50 cycles to 9,500 cycles. Measurements can be made between losses of 80 db and gains of 75 db without additional apparatus with an accuracy of 0.1 db. By merely twisting the oscillator dial and reading the meter, complete frequency response measurements can be made.

Contributors to this Issue

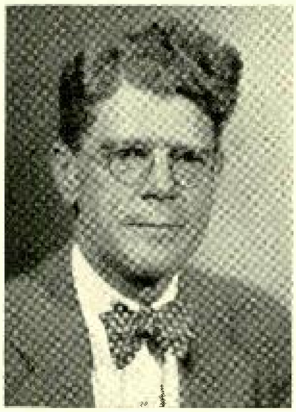
Entering these Laboratories in 1918 as a technical assistant, W. L. Black took part in the testing of a number of special systems, notably the terminal equipment for the Key West-Havana cable, and the first public address system for commercial installation. In 1922 he went to Rio de Janeiro to install a public address system at the Centennial Exhibition and remained to install a carrier telephone system between Rio de Janeiro and Sao Paulo. After his return, he worked for a time on power line carrier systems and then on radio transmitters for government service. In 1926 he entered a group concerned with speech input systems for broadcasting stations and in 1929 was placed in charge of it.

R. T. Staples joined the Western Electric Company in 1907 and after spending six months in the Students' Training Course was assigned the duties of testing models of miscellaneous central office apparatus and inspecting tool-made samples. Several years later he became actively engaged in the development of paper and mica condensers. During the early period of the World War he designed the condensers used in the receiving sets, which were supplied to the government, and supervised their manufacture in the Laboratories until the Western Electric Company obtained the necessary manufacturing facilities. His past five years have been spent in the development of cords, wire, and cables.

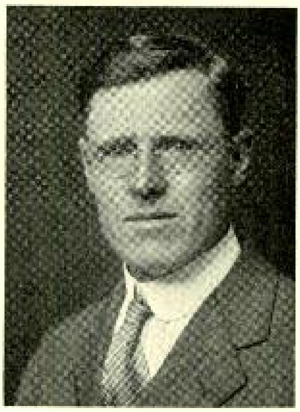
G. A. Kelsall graduated from Rose Polytechnic Institute in 1906 with the degree of B.S. in Electrical Engineering. The following three years he spent with the General Electric Company at Schenectady and with the Indiana Steel Company at Gary, and in 1909 went to Michigan State College as Instructor in Electrical Engineering. Since 1912 he has been with Bell Telephone Laboratories. For five years he worked on loading coils in the physical laboratory, during which time he developed the permeameter and permeameter furnace. From 1917 to the present time he has been with the Research Department employed in the investigation of magnetic materials.

After receiving a B.S. degree in M.E. from Brown University in 1910, W. C. Oakes joined the Bell System with the

W. L. Black



R. T. Staples



G. A. Kelsall

W. C. Oakes

R. F. Mallina

C. H. Greenall

Toll Traffic Engineering Department of the A. T. & T. Company. His early work was in connection with studies seeking a speedier toll service between New York and Philadelphia, a forerunner of the present station-to-station long distance service. In 1914 ill health forced Mr. Oakes' temporary retirement from active work, but in 1917 he joined the Outside Plant Department of the New Jersey division of the New York Telephone Company, his activities covering the territory of Staten Island and the shore near Asbury Park. In 1920 he transferred to the Engineering Department of the Western Electric Company at West Street where he has remained since. His work here, for the most part, has been on local manual telephone circuit development covering straightforward trunking and interconnection between dial and manual offices.

R. F. Mallina received an M.E. degree from the Vienna Technical College in 1912 and then studied textile engineering for two years at the Textile Engineering College in Austria and at the London Institute in England. He came to this country in 1922 and was engaged as designer and engineer by several concerns, spending over two years with the Victor Talking Machine Company. In 1929 he joined the technical staff of Bell Telephone Laboratories where with the Apparatus Development Department he worked on disk recording and call announcers. At the present time he is with the Acoustical Research Department.

C. H. Greenall's college course was interrupted by his service overseas in the United States Field Artillery. After the war he resumed his studies at Lehigh University, and was graduated in 1922 with an M.E. degree. He then became associated with the Laboratories and worked on apparatus analysis and protection. In 1927 he transferred to the Materials group where he engaged in the development of specifications for non-ferrous materials and in the design of equipment and application of methods for fatigue tests on these materials. Since 1931 he has been in charge of metallic materials and materials testing. His work is mainly directed toward the proper use of, and the development of engineering requirements for materials used in Bell System apparatus.