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OPERATORS' TRANSMITTER
A. F. Bennett

POWER-DRIVEN MAINTENANCE TOOLS
W. T. Pritchard

QUARTZ CRYSTAL RESONATORS
W. A. Marrison

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Articles in this Issue

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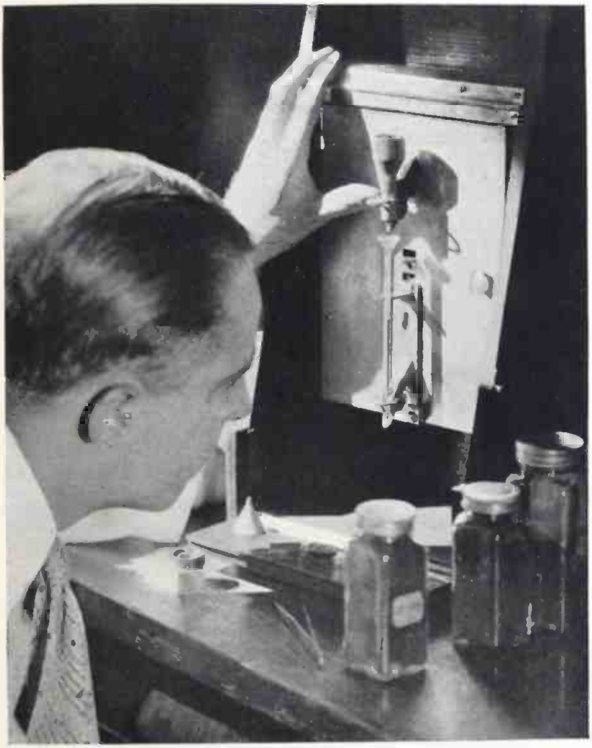

Obtaining a measured volume of carbon granules is one of the first steps in testing transmitter carbon in the Transmission Instruments Engineering Department

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An Improved Transmitter for Operators' Use

By A. F. BENNETT
Transmission Instruments Engineering

SOME of the operators' transmitters used in the past have already been described in the RECORD.* To this group of progressive developments a transmitter of improved type has been added by the Laboratories. It differs considerably in construction from the earlier forms due to new features introduced as a result of development studies undertaken during the past few years. Among the advantages provided are a materially improved quality of reproduction, and a slightly higher output level. Carbon noise has been practically eliminated, and the amount of room noise picked up by the transmitter has been noticeably reduced. Variations in performance due to thermal effects have also been minimized, while the useful life of the transmitter has been increased, and its construction made more rugged. The appearance of the new transmitter is shown in the illustration at the head of this article.

Every effort has been made in the design of the granular carbon element, which is built as a separate unit, to obtain good quality of reproduction. The moving parts have been designed to respond to a broad range in frequency. This requires both that the mass of the moving parts and the stiffness of the vibrating system as a whole be kept low. These conditions have been met by making the diaphragm of thin sheet aluminum, and

*BELL LABORATORIES RECORD, *January*, 1929, *p.* 203.

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by supporting its periphery between paper rings in a recess in the front of the unit to obtain the required resiliency. The dimensions are such that the rings occupy a space about fifty per cent greater than the combined thickness of the paper material. This combination provides a light, stiff moving structure capable of vibrating as a piston. The paper rings act as low stiffness springs and add a certain amount of damping. They are punched from stock only four ten-thousandths of an inch thick, and are impregnated to reduce the effect of moisture.

Such a vibrating system differs radically from those of the operators' transmitters previously used, one of which is shown in the accompanying illustration. The effective mass of the moving parts of the new transmitter is approximately half a gram, as contrasted with five grams for the earlier transmitter.

All granular carbon devices operate by the change in resistance of the carbon contacts which occurs when the movable member is displaced in accordance with the sound pressures acting on the diaphragm. The form of carbon chamber used with previous operators' transmitters consists of an essentially cylindrical cavity with a flat conducting electrode at each end, one of which is stationary and the other movable. It has several distinct limitations not present in the carbon chamber of the new transmitter, which is of the "barrier" type.

With the new chamber the electrodes are the inner surfaces of two gold-plated brass cylinders insulated from each other by a ring or barrier of ceramic material. The diaphragm itself serves as the movable front wall of the carbon chamber and its surface is insulated with phenol varnish so that it does not conduct current to the carbon. The movable surface thus merely changes the force on the carbon contacts and does not itself act as an electrode—an arrangement which has been found to improve the useful life of the transmitter. The back wall of the chamber is provided with a capped opening through which the chamber is filled with carbon. The entire microphone element is assembled in a brass shell somewhat larger than one inch in diameter.

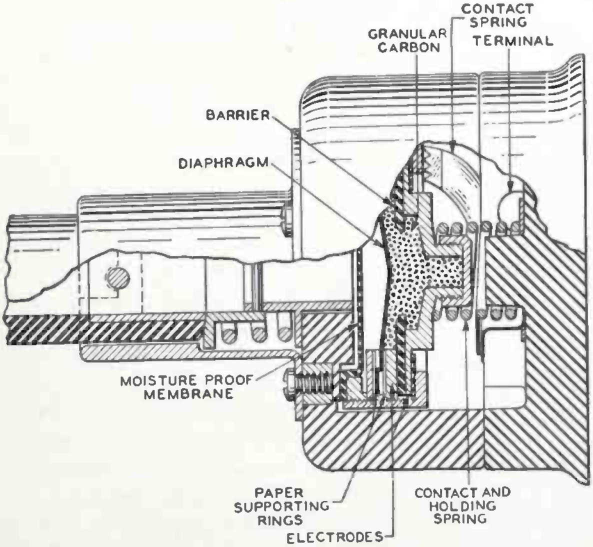

Fig. 1—Cross section of the new transmitter (396A) showing the barrier construction, the moisture proof membrane, and other major structural details

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Because the granular carbon contact is sensitive to forces acting on it, the expansion and contraction of the component parts of the chamber —produced by the temperature increase when power is dissipated in the carbon—influence it to a rather exceptional degree. These thermal effects cause relatively slow changes in resistance and sensitivity, which with many of the older types of instrument are erratic and a source of trouble. In operators' service the transmitter is connected in the circuit for relatively long intervals of time and it is desirable that over most of this period the resistance should remain steady. In the new transmitter the expansion of the walls of the chamber causes a steady increase in resistance during the first few minutes in which temperature equilibrium is being established. Thereafter, variations due to thermal effects are inappreciable. The diaphragm itself has little effect, because its temperature is fairly uniform and it is free to expand radially without displacing the center.

When a potential in excess of about a volt is impressed on a granular carbon contact, under forces ordinarily employed in transmitters, a "frying" noise is apt to be introduced in the electrical output. The barrier type of chamber has an inherent advantage over the older form in that the applied voltage is quite uniformly distributed over the chain of granules between the electrodes, whereas with the earlier type the potential is likely to become concentrated at the vibrating electrode because of its motion. The noise caused by excessive potentials has been practically eliminated in the new transmitter because of this inherent advantage of the barrier type of construction.

An excessive potential is also likely to cause overheating of the minute contact areas of the carbon granules. If maintained on a transmitter for a considerable period of time, this injures the surface of the granules and raises its resistance—an effect that increases the carbon noise. Because of the more uniform distribution of potential among the granules of the barrier type transmitter these effects

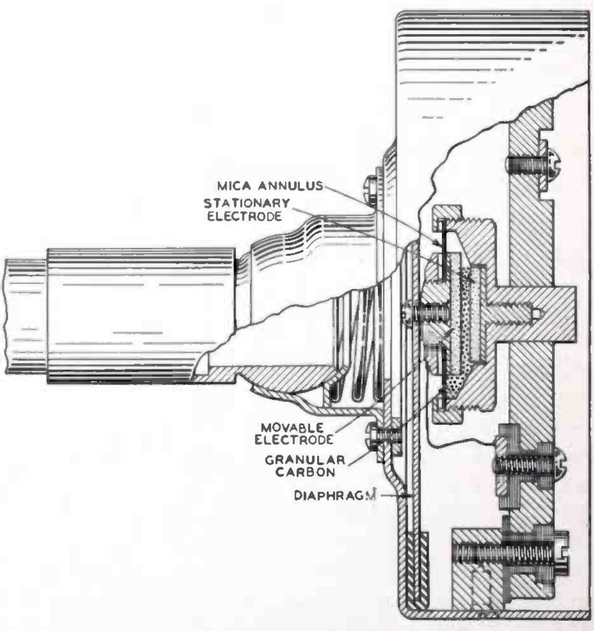

Fig. 2—The greater mass of the moving parts of the older transmitter (234) *is evident in this cross-section*

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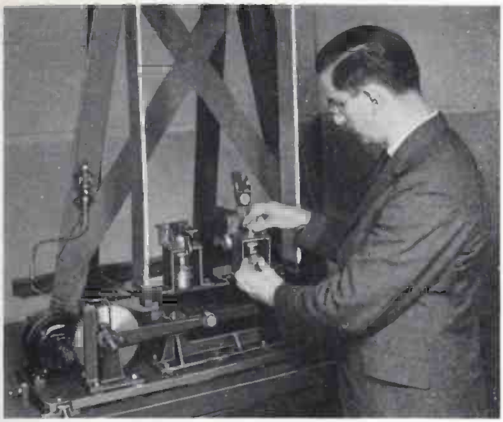

Fig. 3—G. F. Schmidt filling one of the new transmitters with granular carbon. The machine vibrates the transmitter while it is being filled. This settles the carbon and leaves very little free space in the chamber so that movement of the carbon granules, and consequently aging, is reduced

also are minimized and the useful life of the transmitter is substantially lengthened.

Should the chamber containing the granular carbon be subjected to mechanical shock such as jarring or rolling, the surfaces of the granules receive an abrasive treatment which alters their microphonic properties. Resistance is increased and sensitivity is usually lowered. Studies of the carbon transmitter have shown that this tendency for the carbon to "age" with use is greatly reduced by filling the transmitter practically full of carbon instead of partially filling it as in the past. A machine process is employed which leaves very little free space in which the carbon may move when the transmitter is handled, and the abrasive action is thereby reduced.

For protection against moisture and against water condensed from the breath, a membrane of thin molded rubber is placed in front of the diaphragm. The material employed for this membrane was developed by the Chemical Laboratory and has a long life. Its periphery, which is attached to the front of the unit with a special adhesive, is thicker than the rest of the membrane and serves as a sealing gasket to prevent moisture from entering the housing of the transmitter. The introduction of this membrane does not materially affect the operation of the instrument.

The unit is assembled in a housing of molded phenol plastic, and the electrical connections are made by springs, one of which is of helical form and holds the unit in position. The transmitter is equipped with a horn type mouthpiece which is secured by a quickly detachable mechanism. Dimensions of the transmitter, such as the distance between the breastplate and the end of the horn, the angle of the horn opening, and the length of the neck band, are based on an analysis of measurements made on a large number of operators. The dimensions chosen, with the aid of the adjustable features provided, will accommodate the maximum number of operators equally well.

The small microphone element of this transmitter is capable of excellent sound reproduction. In fact, this portion of the transmitter, without the rubber membrane, is used as a high quality microphone in a new public address equipment already described in the Record.* Its frequency response characteristic is comparable to that of the stretched-diaphragm

*Bell Laboratories Record, *January*, 1932.

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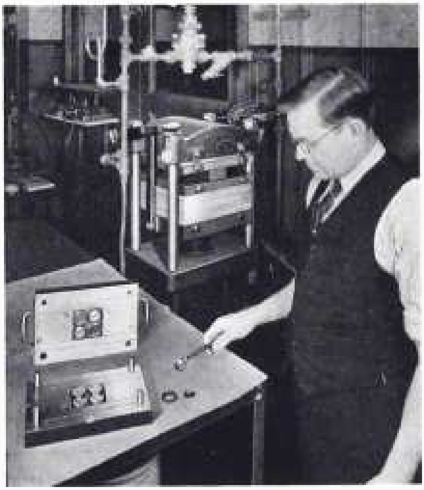

Fig. 4—E. L. Dias of the Chemical Laboratory removing one of the rubber membranes of the new transmitter from the mold

carbon microphone employed in broadcasting. Its output level, however, is not sufficiently high to permit it to be used as a telephone transmitter without the use of a sound collector such as a horn. The horn introduces a certain amount of distortion, but the quality of the transmitter is still materially better than that of previous operators' transmitters, and a substantial gain in intelligibility is effected. One of the methods of measuring the reaction on telephone service which a change in instruments or line condition has brought about, is to observe the number of times it is necessary to repeat a statement or, in the case of the operator, a station number. Observations of repetitions in service show that their rate is greatly reduced when the new transmitter is used.

The housing of the new transmitter is much stiffer than that of the old, and the microphone element, therefore, does not respond as readily to the acoustic pressure of room noise acting on the housing. A background of noise may seriously interfere with the interpretation of speech, so that it is a distinct advantage in the new transmitter that it does not as readily pick up sounds at a distance as the earlier instrument did.

It is anticipated that the longer life and more rugged construction of this transmitter, together with the ease of replacement and repair, will affect material economy in service, quite aside from the substantial improvement in performance which it offers.

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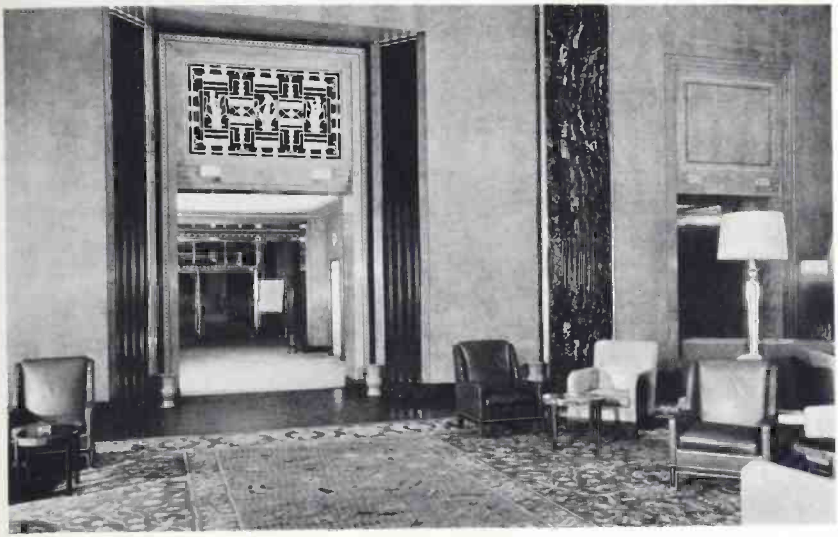

Distributing Programs in the Waldorf Astoria

By J. J. KUHN
Special Products Development

THE largest program distribution system yet brought under one roof was placed in service in the new Waldorf Astoria on October 1, 1931. The system represents the latest step in size and flexibility beyond the apparatus installed in the Atlantic City Convention Hall.* Amplifying and distributing equipment permits an instant choice of six programs to guests in each of the Hotel's 1,940 guest rooms. The same equipment provides program distribution and voice reenforcement in the Hotel's many public rooms. Independently, two radio-frequency distributing systems afford the residents in each of 138 tower apartments access to all radio programs which their own radio receivers are able to detect.

The system for distribution to the Hotel's guest rooms and public rooms comprises equipment for pickup, and for amplification and distribution over six channels. For any of these channels the programs may be picked up in any of the public rooms, may be reproduced from records or may come from distant sources by wire or through the aid of radio receivers.

A program taking place in one of the Hotel's public rooms is picked up by portable condenser microphones appropriately located and connected through flexible shielded cords to outlets in the baseboard of the room. These outlets have been provided in considerable number, so that microphones can be located anywhere in a room without the necessity of using

*Bell Laboratories Record, *December*, 1931, *p.* 111.

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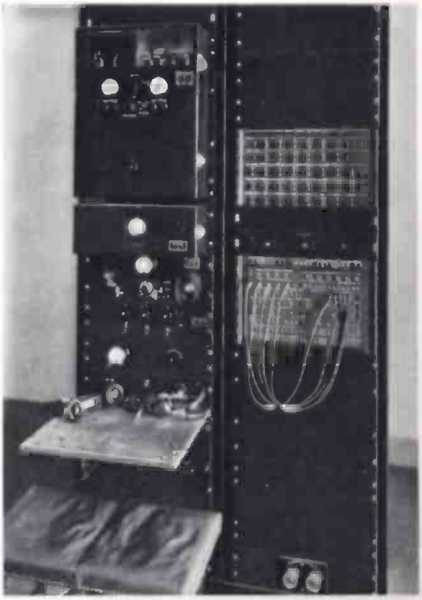
are so arranged that the operation of each receiver is independent of the operation of the others. Thus they can be used without mutual interference to detect different programs for their respective channels.

The control rack for each main channel contains mixing equipment permitting the inputs from as many as three microphones to be blended, and a preliminary amplifier to raise the level of the microphone currents. The rack also contains a main channel amplifier of the Western Electric 59-B type, whose input may

The control room contains twenty-two racks of equipment. The six Western Electric 10-*A Radio Receivers are shown on the two racks at the right*



The control rack (left) for each channel contains mixing equipment, a preliminary amplifier, and a main amplifier. Adjacent to the first control rack there is a rack (right) of patching and intercommunicating equipment for all channels

unduly long cords to connect them.

Shielded cable connects the speech circuits from all the base outlets to a connection box in the control room on the sixth floor. The filament and plate circuits of the amplifiers* directly associated with the microphones also receive their power over this cable. Each speech input circuit terminates in a jack in a switching panel, whence it can be connected by a patching cord to the input of any of the six main channels.

Radio programs to be placed on the channels are picked up by an antenna hung between the Hotel's two towers, and thence are led down to the control room. There the antenna circuit is multipled to six Western Electric 10-A Radio Receivers, one associated with each main channel. The input circuits of the receivers

*Bell Laboratories Record, *June*, 1928, *p*. 329.

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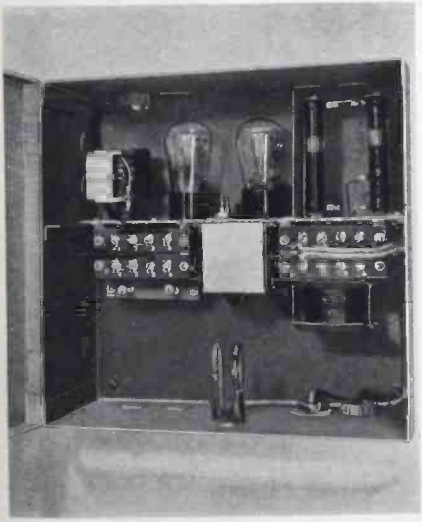
come from the preliminary amplifier, the radio receiver, a wire line, or a reproducer. Each channel is provided with a volume indicator, and the necessary controls; monitoring can be accomplished either by headphones or by the monitoring loud speaker in the control room. Communication with observers in the public rooms over separate communication circuits is also provided.

Power amplification is finally accomplished by Western Electric 57-A Amplifiers, of which thirty-one are available. Twenty-four of these are normally associated with guest-room circuits, six with public-room circuits, and one with the outgoing wire-line circuits over which events of public interest can be transmitted to distant broadcast stations. Thus normally each of the six main channels has four power amplifiers associated with it for guest-room amplification, and one for public-room amplification.

Thirty-one power amplifiers raise the level of the program for transmission to guest rooms, public rooms and distant broadcast stations. At the right is the remote control rack for the alternating current power equipment



Each private radio receiver is coupled to the antenna circuit through a balanced, neutralized amplifier

For distribution to guest rooms, the output of each power-amplifier is connected through matching and switching apparatus to a strip of jacks from each of which a conducting pair passes through lead-covered cable up a riser in the building to an electrical closet serving the rooms in its neighborhood on its floor. Here the pair is cross-connected to four terminal strips from which several circuits run, each to about twenty guest rooms. To bring to each guest room a pair representative of each channel requires three 152-pair cables and one 101-pair cable. The use of terminal strips hav-

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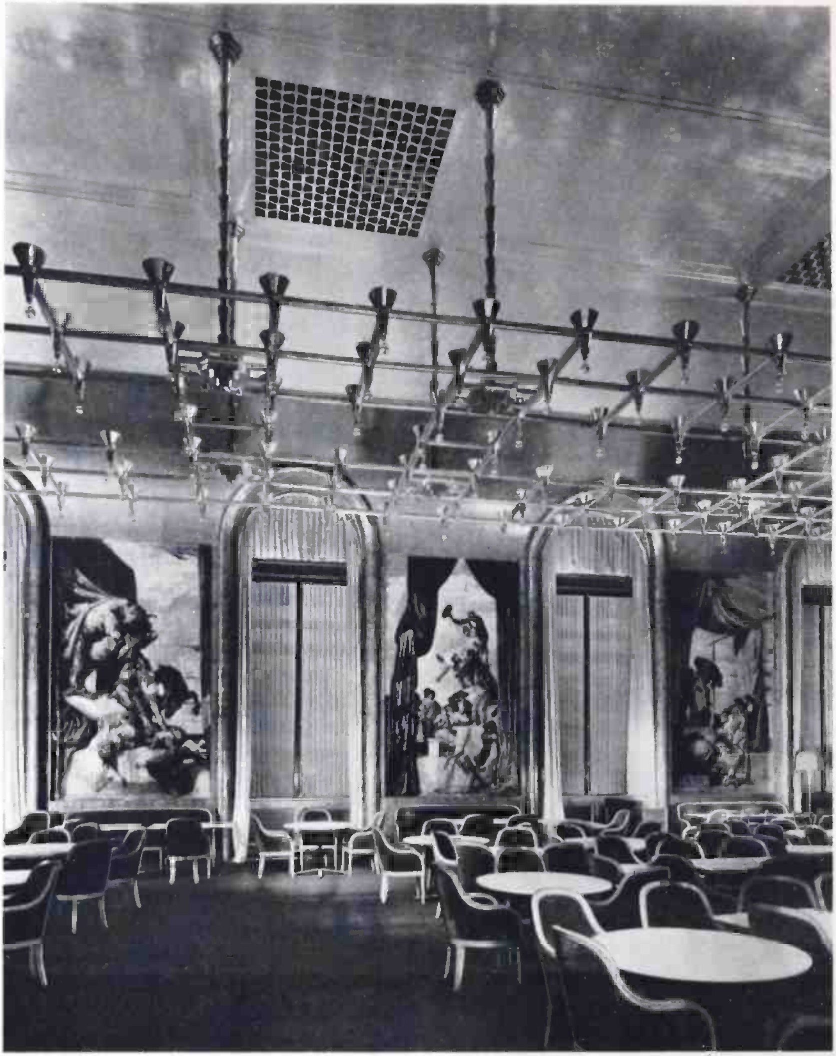

In the famous Sert Room dinner music is provided by a loud speaker back of a grille in the ceiling

ing a sealed chamber for the cable end prevents the moisture prevalent in closed shafts and cabinets from reaching the insulation on the conductors.

The system is designed so as to reduce maintenance to a minimum. Two brief testing operations will segregate trouble to a group of twenty guest rooms. To locate the particular guest room in which the trouble exists, a maximum of only half that

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group need be disturbed. Furthermore, the major items of equipment in the control room are interchangeable, and can be patched from channel to channel to meet any unusual need.

Six pairs of wires are connected to each of the guest rooms and to several rooms in each of the apartments of the Hotel. To avail himself of the programs they offer, a guest requests that a loud-speaker be brought him, and the page who delivers it inserts the twelve-conductor plug at the end of its cord into the base outlet. By rotating to the proper position the knob of a six-position switch in the loud-speaker, any of the six programs available can be selected. The volume of the program can be adjusted by a control knob on the speaker. The master volume control in the control room is so set that no guest can raise the volume to a point where it would annoy the occupants of an adjoining room.

To the public rooms the sound currents pass over cable from the power amplifiers in the control room. The sounds are reproduced by loud-speakers, the type and location of which are chosen to suit the rooms which they serve. In most of the public rooms loud-speakers are permanently installed behind concealing grilles, chosen to suit the decorative schemes of the rooms. Such a grille, in the main lobby, is shown at the head of this article. Both in these rooms and in the public rooms not so equipped, portable loud-speakers can be connected to base outlets when speech reenforcement is required.

Since the Hotel is supplied only with direct current, and the radio receivers and the preliminary, main-channel and power amplifiers are designed to operate on alternating current, it was necessary to provide converter equipment. Located in a power room on the seventh floor, a 240-volt motor operates on direct current to drive an alternator capable of producing 15 kilowatts of power at 115 volts 60 cycles. To guard against interruption of programs, a duplicate set is provided and duplicate control and regu-

Occupants of guest rooms can order loud speakers which, when connected with the twelve-conductor base-outlet, will provide them with a choice of six programs

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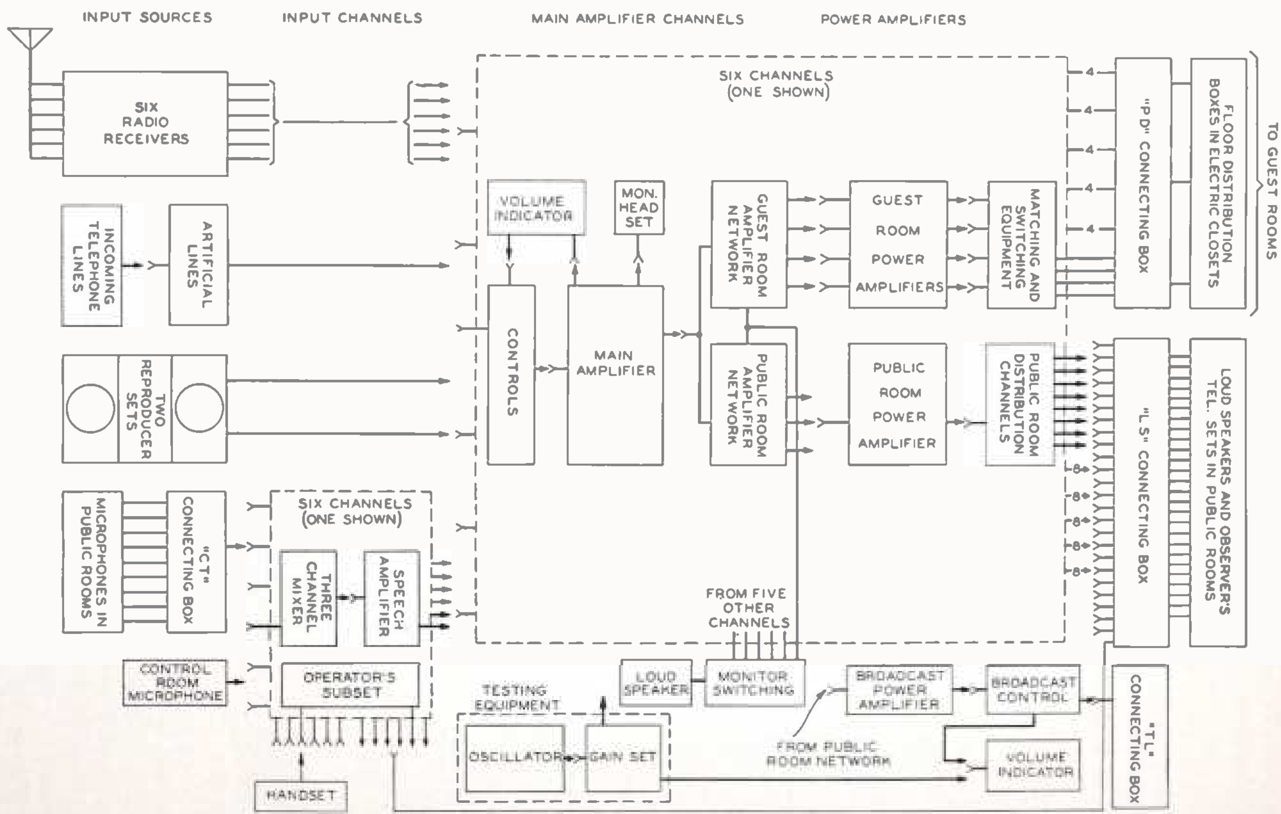

The public address system in the Waldorf-Astoria has been provided with a maximum of flexibility by patching equipment

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lating equipment is associated with each set. For convenience of operation the control facilities in the power room are extended to a remote-control panel in the control room.

Apart entirely from the system distributing to guest and public rooms is the antenna service for residents of the tower apartments. It was thought that these residents might wish to use their own radio sets as well as the Hotel's loud-speaker service. For their accommodation two additional antennas have been hung between the towers, one to serve each tower. Each antenna is coupled to a radio-frequency transmission line of low impedance through a protector, a wave trap for suppressing strong local stations which might overload the system, and a repeating coil. On reaching the highest floor on which apartments are located, the line is coupled to a loaded line of high impedance. To this line in turn are coupled low-impedance lines, sometimes as long as 250 feet, running to the individual apartments, where the impedance is again finally stepped up.

The coupling of the individual lines is accomplished through single-stage amplifiers, balanced and neutralized. These insure against the feed-back of energy from improperly designed receivers, and against the modulation of one frequency in the signal by another. The filament of each amplifier burns only when it is needed; its 110-volt supply is trunked through the outlet in its apartment, and current flows only when the set is operating.

Through the care taken in designing these systems, and the hearty cooperation of the building contractors and Hotel authorities, the systems were installed, tested and ready for operation *before* the Hotel was opened last October 1. Since that time they have been in practically continuous operation and have given entire satisfaction. They form indispensable parts of the Hotel's facilities for entertaining its guests.

The system forms an unparalleled example of what can be accomplished in designing and installing public-address equipment when owners, architects and builders cooperate with the communication engineers from the time when the first plans are drawn. To adapt standard methods to particular needs, to provide many convenient microphone outlets, to fit loud-speakers into decorative schemes and retain acoustic effectiveness, to bring cable for the required number of channels to each of several hundred rooms and suites, can only be efficiently done by carefully planning the electrical installation in advance of the actual construction of the building.

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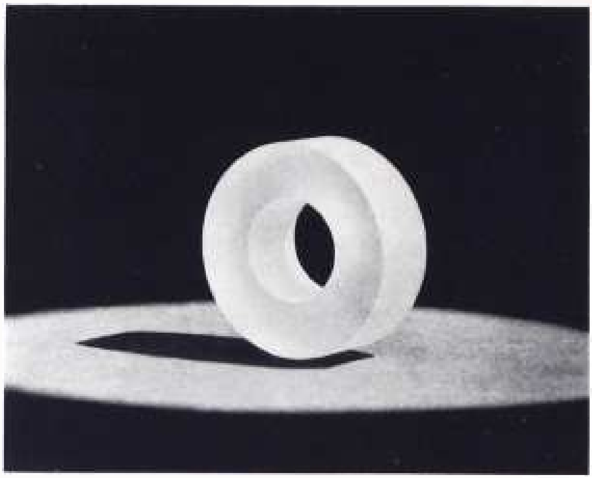

Quartz Crystal Resonators

By W. A. MARRISON
Transmission Research

THE properties of quartz crystals which make them useful in many electrical circuits are due largely to the piezo-electric effect. If a piece of crystalline quartz is strained mechanically, it sets up an electric field in its neighborhood, inducing charges or electric potentials on conductors in the field. Hence the derivation of the term piezo-electric from the Greek expression "piezein" which means "to press." Conversely, when a piece of crystal is placed in an electric field, it changes its shape slightly. The deformation thus produced is very minute; it is in extreme cases only a few thousandths of a millimeter for a rod one centimeter long.

Many other crystals have these same properties in varying degree. Rochelle salt crystals are many times more "active" than quartz. Even ordinary cane sugar has marked electrical properties, as indicated by the flashes obtained when lumps of sugar are broken apart or rubbed together in the dark. Quartz, however, has other desirable properties in addition to piezo-electric effects, chiefly due to its low internal friction and consequent low damping, and due to its hardness and chemical stability.

It is the low damping in quartz that makes this material especially suitable for resonators. The damping is so low that an oscillation when once started may continue through 6,000 vibrations before it is reduced to half of the original amplitude. The resonator illustrated symbolically on the cover of this magazine, in the form of a conch shell, is a poor resonator in comparison to quartz, but illustrates one point they have in common. The air in the shell resonates

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at certain audible frequencies from the great variety of sounds always present under natural conditions, and gives that characteristic sound reminiscent of the sea. A quartz crystal will select certain vibrations in a much higher frequency range and give a corresponding response under suitable conditions.

Quartz is the familiar "crystal" that is used so much in jewelry. Amethyst, rose quartz, agate and flint all have the same composition except for very small amounts of coloring matter in some of the forms. They are all harder than glass and will scratch it easily. The hardness of quartz is important in the use of resonators, as it prevents wear and consequent change of dimensions which would change the frequency of response. Because it is harder than most metals and alloys, quartz cannot be scratched by the metal electrodes or clamping devices. It can be scratched by topaz, ruby or diamond which are all still harder. It is usually cut or ground to required shapes by diamond dust or powdered carborundum used as abrasives.

The chemical stability of quartz is also of great importance. It cannot oxidize because it is already silicon dioxide (SiO_2). The only chemical substances that affect it to any extent at ordinary temperatures are hydrofluoric acid and a few related minerals which do not occur free in nature. Quartz is not appreciably soluble in water except at very high temperatures and pressures. The fact that clear crystals of quartz are often found among rocks that are disintegrating with age is a fair guarantee of the permanence of this material.

If electrodes are arranged about a suitable piece of quartz crystal so that an electric field between them will cause a deformation, the combination will behave in many respects like an electrical network containing a highly-resonant circuit element. This is due to the piezo-electric influence, which effectively couples some of the mechanical properties of the quartz crystal into the electrical circuit of which the electrodes of the crystal are the terminals. The piezo-electric resonator thus formed can be used in many ways for the measurement, control, or separation of frequencies over a considerable frequency range.

Perhaps the best known use of quartz crystals is for the control of frequency in radio transmitters.* The high constancy of crystal control also makes it especially adaptable for use as a frequency standard. A standard of frequency employing quartz crystal oscillators is now in use in the Laboratories and gives an accuracy of approximately one part in ten million.†

*Bell Laboratories Record, *September*, 1928.

†*"A High Precision Standard of Frequency," I. R. E. Proc., July*, 1929.

Fig. 1—Slab for thickness vibration cut from large crystal

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Crystals for the broadcast and high-frequency range are obtained from slabs cut parallel to one of the six natural faces of the original quartz crystal. Resonators of the desired shape, either round or square, as is most convenient for cutting and mounting, are cut from these slabs. The most important dimension from the standpoint of frequency is the thickness, as the principal response depends most on this dimension.

The frequency of such crystals may be determined approximately by dividing the constant 2,100,000 by the thickness in millimeters. Crystals cut in the manner illustrated in Figures 1 and 2 are mounted between pairs of parallel plate conductors, often, though not necessarily, in contact with them. The direction of the applied electrical field is perpendicular to one of the three electrical axes of the crystal.

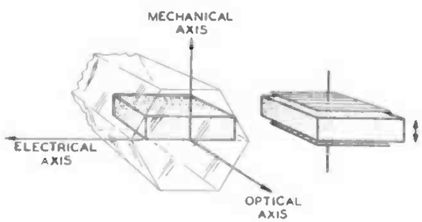

Fig. 2—Method of cutting crystals to obtain thickness vibration

The different axes of a quartz crystal are referred to as the optical, electrical and mechanical axes. The optical axis is the axis of symmetry of the hexagonal quartz prism and may be defined as a direction parallel to the length. The electrical axis is parallel to opposite faces of the prism and perpendicular to the optic axis. The mechanical axis is also perpendicular to the optic axis, but is perpendicular instead of parallel to opposite faces of the prism.

Crystals for operating at relatively lower frequencies are usually cut so that the long dimension is parallel to a mechanical axis, that is, perpendicular to the electric and optic axes. The electric field is applied by electrodes which are in the plane of the mechanical and optic axes as indicated in Figure 3. An electric field applied in this way produces the greatest response along the length of the crystal. The resonant frequency of long rods or plates of this type may be determined approximately by dividing 2,850,000 by the length in millimeters.

It is difficult by this method to obtain really low frequencies. A rod giving a frequency of 1,000 vibrations per second, for example, would have to be nearly 3 meters long. This of course is impracticable because it is impossible to obtain large enough pieces of quartz crystal. A frequency of 25,000 cycles, requiring a crystal about 10 centimeters long, is about as low as can be obtained readily by this means. An appreciable lowering of frequency can be obtained by making a crystal dumbbell-shaped, so that a greater part of the mass is concentrated toward the ends of the rod. This is sometimes useful in the final adjustment of frequency.

A method that can be used to obtain much lower frequencies is to set

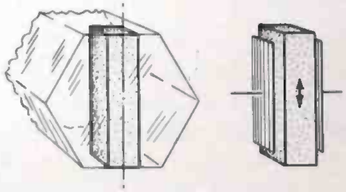

Fig. 3—Method of cutting crystals to obtain length or flexural vibration

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the resonator in flexural or bending vibration. An ordinary long rod cut from the crystal as indicated in Figure 4 will vibrate in this way, provided the dimension parallel to the optic axis, the width in this case, is not too great. If the electrodes cover the crystal for the whole length but only half of the width as illustrated in Figure 5-a, one side only of the crystal is lengthened and shortened alternately, resulting in flexural vibration in the plane of the mechanical and optic axes. If additional electrodes are arranged about the remaining half of the crystal in reverse polarity, the coupling with the electrical circuit for this mode of vibration is increased considerably. Crystals vibrated in this way can be made to have frequencies as low as 1,000 cycles.

A convenient way of employing flexural vibration to obtain low frequencies is to make the crystal in the shape of a tuning fork, arranging the electrodes as shown in Figure 5-b. In this way each prong of the fork is driven independently, as in the case of the long rod just described, which results in the usual tuning-fork mode of vibration.

The frequency of an oscillator controlled directly by a crystal is usually above the audible range and may have any value, depending on the size of the crystal and the circuit conditions, up to several million cycles. The frequency of the primary standard now in use in the Bell System is 100,000 cycles per second.

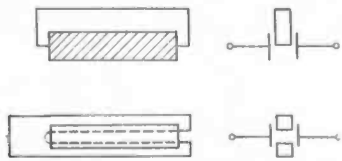

Fig. 5-a (Above)—Arrangement whereby half the width of quartz rod is covered by electrode to obtain flexural vibration Fig. 5-b (Below)—The same arrangement on a crystal cut in the shape of a tuning fork

When it is desired to obtain a low frequency controlled by a quartz crystal it is usually done by the use of a submultiple generator. This is a circuit that will control a current at a frequency that is an exact submultiple of the input or controlling frequency. Any simple reduction from a half to a tenth can be obtained readily by this means in a single stage. When higher frequency-reduction ratios are required they can be obtained by the use of two or more stages in cascade. Thus to obtain 1,000 cycles from a 100,000 cycle standard, two stages, each having a ratio of ten to one, may be used.

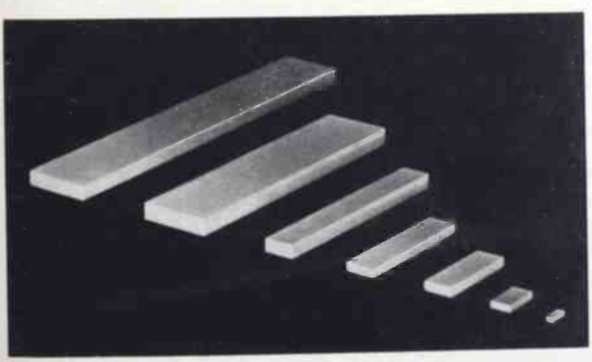

Fig. 4—Resonators suitable for length or flexural vibration

For frequency control work of high precision, the usual types of resonator require very accurate control of temperature. To simplify the problem of

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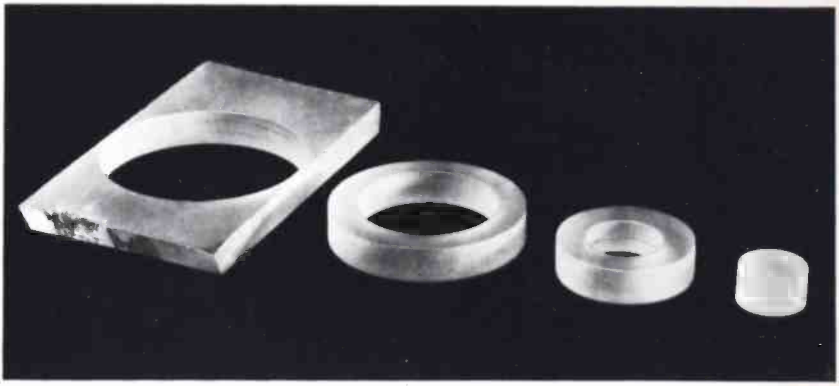

Fig. 6—Some crystals used in temperature-coefficient studies

temperature control in certain cases it has been found possible to make crystals, within a limited range of frequencies, that have a very low temperature coefficient. This is accomplished by adjusting the crystal so that it vibrates at the same time, and at the same frequency, in different modes having temperature coefficients of opposite sign. In this way the coefficients can be made to annul each other over a considerable range of operating temperatures.

One of the shapes that provide low temperature coefficients over a wide range of temperature is a ring cut in the plane of the optic and electric axes. The manner of cutting, and the first experimental low coefficient rings that were made for this study, are shown in Figure 6. The reduction of the outside diameter or increase in the hole diameter will in general lower the positive value, or increase the negative value, of the temperature coefficient of the ring. When the difference between the radii is approximately equal to the thickness of the ring, the temperature coefficient becomes zero. A ring crystal adjusted to have a frequency of 100,000 cycles and a temperature coefficient of less than one part in a million per degree centigrade is shown in the headpiece. This is the type of crystal used in the Bell System frequency standard.

A sphere of quartz crystal will vibrate and control the frequency of an oscillating circuit. Some tests have been made using spheres of different diameters and it has been found that they make very good resonators, although not so good for most purposes as some other shapes now in use. One advantage in the use of a sphere is that it has the smallest possible surface area for a given volume of material and, accordingly, would be least affected by surface contamination or erosion. The frequency of the fundamental mode (lowest frequency) is about inversely proportional to the diameter. The frequency of one of the spheres tested, which is about 3½ inches in diameter, is 33,212 cycles. A sphere 10 inches or more in diameter would vibrate at an audible frequency. The 13-inch crystal sphere in the United States National Museum at Washington would have a funda-

*"A High Precision Standard of Frequency," I. R. E. Proc., July, 1929.

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mental tone about one octave above the highest note on a piano.

The chief uses of quartz resonators up to now have been for the measurement and control of frequency. The first important application was in accurate single point wave meters. Then came frequency control and the application to radio broadcasting, short-wave transatlantic radio-telephony and airplane radio. The use in a primary standard of frequency has already been mentioned.

A good frequency standard, with the addition of a phonic wheel motor and a few gears, may be made into a clock capable of keeping accurate time and of accurately controlling time impulses. A clock of this sort controlled by a quartz resonator has an accuracy comparable to that of the highest precision pendulum clocks.

The use of quartz resonators in electrical circuits is of increasing importance and the above applications are not by any means all that could be stated. Some functions are performed by the use of crystals that could be achieved only with great difficulty or perhaps not at all by other means. The fact that a small piece of rock can be substituted for a highly resonant electric circuit element, and in many cases give an improved performance makes the use of quartz unique in the electrical art.

Progress Through Research

When a life insurance company is considering an applicant for life insurance, there are certain things which it would like to know about the applicant. Among these are his past history as to health and disease, and his present health. In addition, it wishes to know certain facts which will give some indication of his expectancy of future life. Is not the same true of any business? Does not the future health of a business depend not only upon what it has done and what it is doing today but what it is planning to do to meet the future? What is its vision for the future and what plans is it making to adapt itself to that vision? We all know that the general conditions and the surroundings under which business will be done will change; the habits of the people will change; their tastes and desires will change. Will the business in question change and adapt itself to these new conditions? Will it do its part in the creating of new conditions under which it can survive?

More and more as time goes on the answer to these questions will, I believe, depend upon the intelligence and vigor with which research is carried on and the intelligence with which the general management of a business or industry directs this research along the proper lines.

As with peoples so with industry—"Where there is no vision the people perish."

—From a paper presented by Bancroft Gherardi at the Silver Anniversary Convention of the Association of Life Insurance Presidents.

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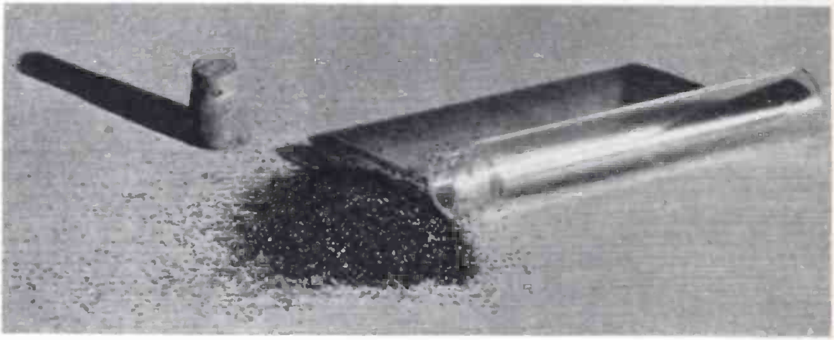

Coal Talks

By W. E. ORVIS
Transmission Instruments Engineering

IN the communications field as in the power industries, Coal is King. Granular carbon made from coal gives to the telephone its voice. Each of the twenty million telephones in this country depends upon granular carbon in the transmitter to change the air pressure waves of the calling subscriber's voice to electrical waves which may be transmitted by wire to the receiver of the called subscriber. This it does by virtue of the change in the electrical resistance of a contact between two adjacent carbon granules with change in pressure at the contact. Under the operating conditions in the telephone transmitter the resistance-pressure characteristic of carbon made from anthracite coal is more satisfactory than that of any other known material.

This resistance-pressure characteristic, as well as other operational characteristics of the carbon, is a function of the nature of the surface of the granule and of the amount and kind of gas adhering to this surface. Control of these factors starts with the selection of the proper coal at the mines and is accomplishd only by rigid control of every step in the manufacturing process.

Naturally, the early manufacture of carbon was conducted on a more or less empirical basis. The degree of control now possible is the result of many years of research into the problems of microphonic action, to determine what variables were involved and what could be done to control them. In order to adapt laboratory methods and equipment to commercial practice before recommendation to the Manufacturing Department of the Western Electric Company, the Laboratories has set up a semi-commercial unit covering every step in the process of manufacturing carbon from the lump coal. The coal is crushed, ground and screened, washed and dried, then roasted under carefully controlled conditions.

Since the shape of the carbon granule, as well as the nature of the surface, controls its behavior in the transmitter, the methods used to reduce

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the lump coal to the proper size must be studied. Because of the structure of the coal it cannot be cut into pieces of a definite shape and size but must be broken by some sort of crushing action. Jaw crusher, saw-tooth or gyratory crusher, attrition mill, ball, rodor pebble mill, swing hammer or burr mill, each influences the way in which the coal fractures, and leaves its imprint on the granule.

Whatever type of mill is used, the division of a lump of coal into a great number of small granules is not an exact operation. The crushed product must be carefully sieved to yield granules of a definite size distribution. The carbon of most importance at present, and of which the greatest quantity is used, is that for the handset transmitter. This carbon is shown approximately life size in the headpiece. It is made from raw material of 60-80 mesh: passing through a No. 60 screen having openings .0098 inch square and failing to pass through a No. 80 screen having openings .0070 inch square. After screening, the coal is washed by agitation in a cylinder of running water to remove the dust which adheres to the granules. When dried it is ready for roasting.

The roasting of the coal to carbon is conducted in two steps, the first a crucible pre-roast, the second a continuous final roast. For the pre-roast, the coal is placed in a steel crucible and brought slowly up to the proper temperature, held at that temperature for several hours, and allowed to cool. As the temperature increases, large amounts of volatile matter in gaseous form are driven from the coal. If the temperature were increased too rapidly these gases would be released more or less violently and so produce pores in the structure of the coal in their effort to escape from the inside to the surface of the granules. As the carbon cools, these pores would absorb gas which would be released when current in the transmitter causes an increase in the temperature of the carbon. Gas escaping from the pores into the contact area between granules would give rise to resistance fluctuation due to change in pressure at the contact and introduce noise in the transmitter.

The gases driven from the coal as the temperature increases would be partially reabsorbed when the material cools after being carbonized unless some provision were made to remove them from the crucible. This is done by carrying them away in a stream of a gas which does not react with carbon, such as nitrogen, hydrogen or helium, passed through the crucible during the temperature cycle.

The second step in the roasting

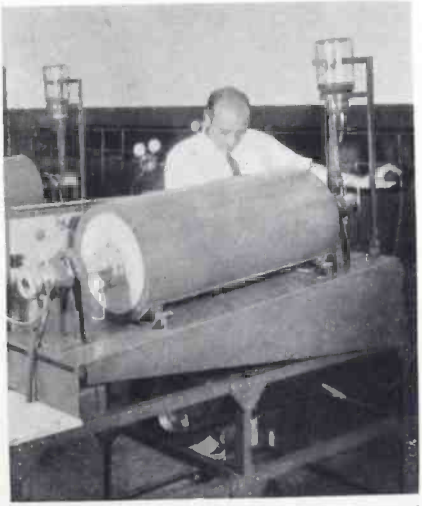

Fig. 1—J. M. Rogie adjusts the rate of flow of gas through one of the furnaces which accomplish the final roasting of coal to transmitter carbon

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process, the final roast, serves two purposes. By passing the pre-roasted carbon through a small rotating tube, the central portion of which is electrically heated to a temperature greater than that used in the pre-roast operation, each granule of carbon is put through exactly the same temperature cycle. By regulating the temperature and the rates of flow of carbon and of gas through the tube, the nature of the surfaces of the granules is influenced so that all the carbon has the same desired characteristics when used in the transmitter.

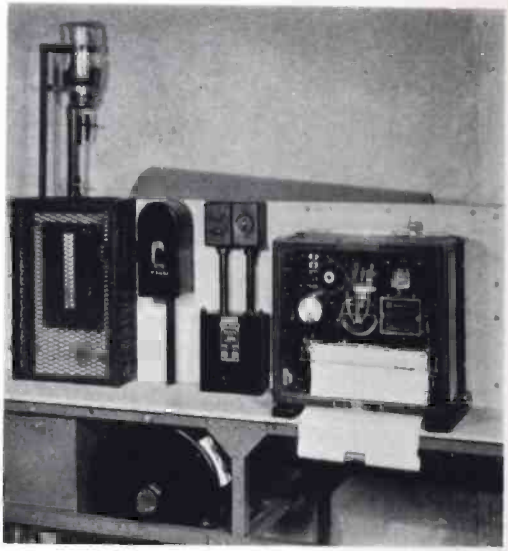

Fig. 2—Control side of a final roasting furnace

The type of continuous electric furnace used to roast the coal is shown in Figures 1 and 2. Meters indicate the current in the resistance winding and the rate of flow of the gas used to supply the proper atmosphere to the roast. The furnace winding is of platinum-rhodium wire. Rheostats permit control of the current in this winding and adjustment of the temperature of the furnace within wide limits. A recorder-controller holds the temperature constant at any desired value, and plots a continuous record of it.

Coal is supplied to the furnace from a bottle and is advanced through the furnace by the rotation of the tube, the inclination and speed of which regulate the rate of flow of raw material. The double-end drive of the furnace tube reduces the strain in the tube at the hot portion.

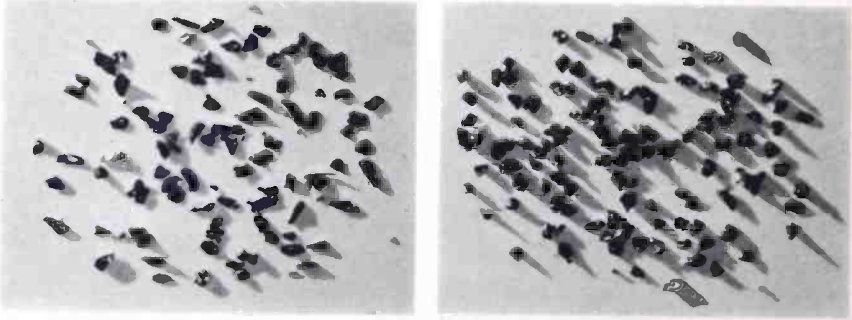

Fig. 3—The cubical granules (pictured at the right about ten times their actual size) are separated from the undesired flat granules. The lengths of their shadows show their relative thicknesses

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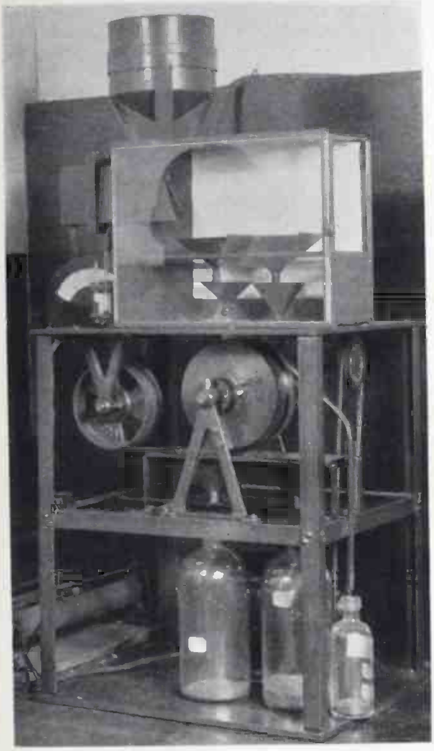

Fig. 4—This separator removes the flat and the magnetic granules from transmitter carbon

A visual examination of the resulting granular carbon shows the granules to be of innumerable shapes, some more or less cubical, others wedge-shaped or flaked (Figure 3). It has been found desirable to remove the latter. Since sharp edges are formed by the intersection of plane surfaces of comparatively large areas, a method of separating these granules from those of a more cubical shape is to utilize the greater air resistance offered by granules having a large ratio of surface to mass.

This is done in the air elutriator shown at the top of Figure 4. The carbon is allowed to fall from a hopper into an air stream blown from the left through a series of nozzles. The more a granule departs from a cubical or spherical shape, the farther it will be carried by the air stream. Two hoppers sliding on guide rails permit the removal from a lot of carbon of the thinnest granules up to any desired percentage of the total.

The roasting process not only carbonizes the coal but reduces the iron compounds contained in the coal to metallic iron. The distribution of these iron compounds in the coal is not uniform and when it is broken down to small granules some of these contain a much higher proportion of iron than others. The carbon product can be improved if the granules of highest iron content are removed by passing the roasted carbon through

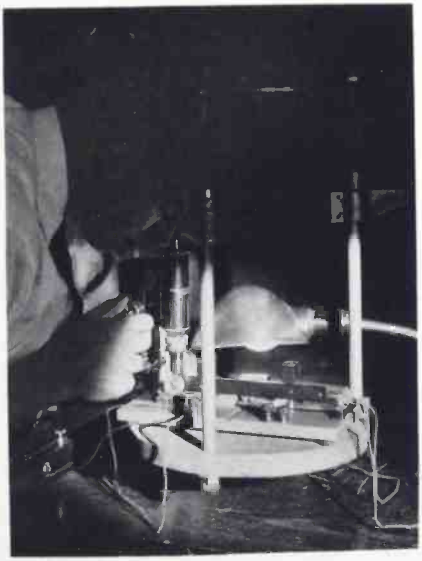

Fig. 5—M. L. Martin observes through a microscope the progress of a life test on finished transmitter carbon

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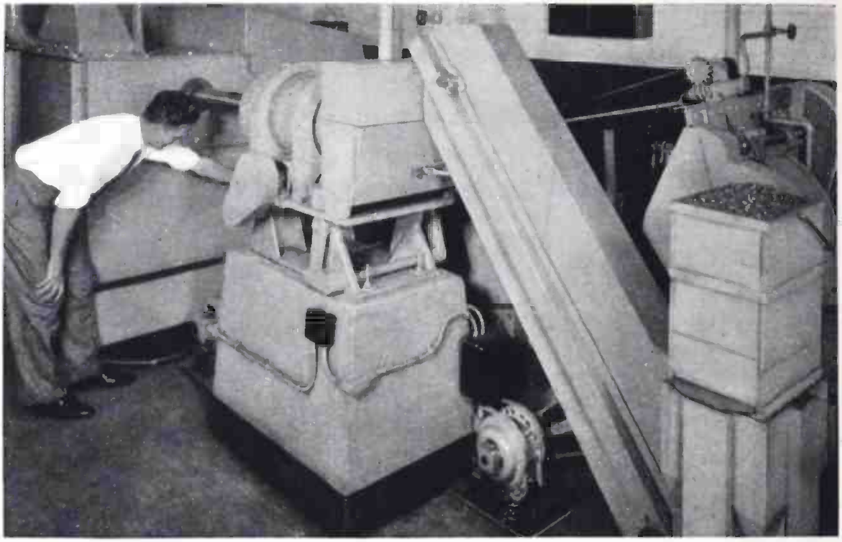

Fig. 6—C. E. Mitchell operates the machine which grinds and screens anthracite coal for preparation of transmitter carbon. Supplied from the hopper at the right, the crushed coal is ground in the ball mill at the center and sifted through screens whose housing appears at the left

a magnetic separator, and it is to this that the thicker granules now pass.

The magnetic pulley shown below the elutriator in Figure 4 is made up of two cup-like shells with a coil completely filling the space enclosed by them when assembled end to end on the shaft. Current is supplied to the coil through rings and brushes. A spacer, a narrow brass ring, separates the two halves of the pulley at the crown of the belt surface, and it is the flux across this gap which holds the magnetizable granules of carbon to the pulley. The belt is of phosphor bronze. Carbon is fed to a guide which confines it to that section of the belt which is directly over the gap in the pulley, the motion of the belt carrying the carbon out of the open end of the guide. The undesired magnetic material is held to the belt by the flux at the gap until the belt leaves the pulley at the bottom where it falls into a hopper and a suitable container. Granules which are non-magnetic fall directly into another hopper and container, whence they can be taken for use or test.

This process of manufacture of granular carbon for handsets is the result of a continuous study of the microphonic properties of carbon contacts and the relation of these to the physico-chemical characteristics of the carbon.

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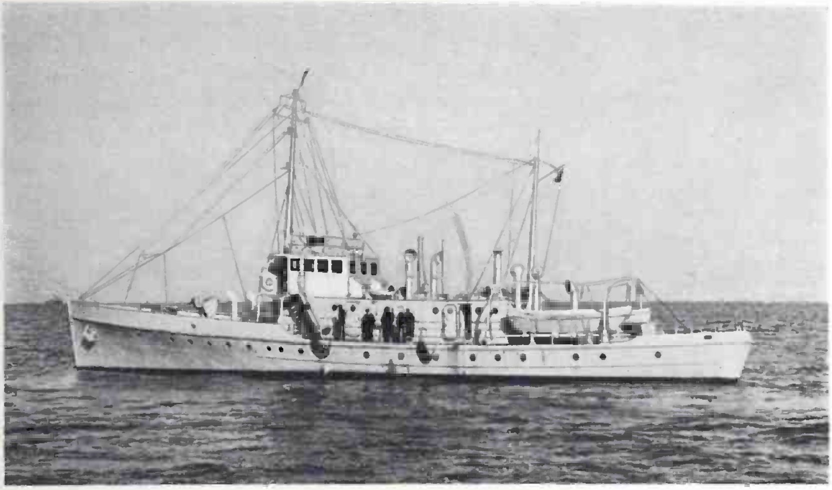

A Transmitter for the Coast Guard

By O. M. HOVGAARD
Radio Development

DAY and night, in all kinds of weather, the fast boats of the Coast Guard patrol the extensive coast line of our country. These boats operate from bases strategically situated along the seaboard. Communication between the bases and vessels, so vital to the operations of the Coast Guard, are carried on by radio. Recently there has been placed into service for this purpose new Western Electric transmitting equipment developed by the Laboratories which embodies several new and unusual features designed especially to meet the severe requirements of Coast Guard work.

The essential requirements for this equipment are simplicity of operation, ruggedness and compactness. The entire system with the exception of the dynamotor and certain accessories is contained in a single unit of less than 15 cubic feet. The transmitter is rated at 35 watts output on any frequency in the range of 2307 kc. to 3333 kc. (120 to 90 meters) and either telegraph or telephone operation is available. Telephone operation is for the use of the smaller patrol boats which, as a rule, do not include a telegraph operator in their crews.

The transmitter, which is designed to operate from a 32-volt d-c supply, consists of an oscillator followed by a radio-frequency amplifier which supplies power to the grid of a modulating amplifier. The microphone output passes through a speech amplifier to a push-pull power amplifier whose output is applied to the plate of the modulating amplifier. A modified Heising modulating system is used. Plate power is obtained from the 32-volt supply by means of a dynamotor.

The radio-frequency oscillator is

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crystal controlled. Five quartz plates are furnished and are mounted in a thermally-insulated chamber in which the temperature is maintained constant to one-tenth of a degree by a mercury-in-glass thermostat. A selector switch enables the operator to adjust the oscillator to operate at any one of five specified frequencies. A sixth setting of this selector switch is arranged to convert the crystal oscillator to an electric oscillator continuously adjustable through the frequency range of the transmitter. This makes possible the operation of the transmitter at frequencies for which crystals may not be available and provides an emergency oscillator in the event of crystal failure.

To obtain satisfactory frequency stability the emergency oscillator is operated at one-half the carrier frequency. The radio-frequency amplifier in this case automatically functions as a frequency doubler, its output circuits being tuned to the carrier frequency. By noting the dial settings of the emergency oscillator, corresponding to the frequencies of the five crystals furnished, a calibration chart may be made from which can be obtained the settings for any frequency within the range of the transmitter.

Fig. 1—Coast Guard operator using T-6 Radio Transmitter

The output circuits are sufficiently flexible to assure full power output with a wide range of antenna impedance. By means of a single switch the circuits may be changed to permit the output of the transmitter to be modulated by voice or tone, or to be keyed without modulation. When operating as a tone-modulated telegraph transmitter, the microphone circuit is opened and the speech amplifier is converted to an 800-cycle oscillator whose amplified output is applied to the plate of the modulating amplifier. Keying for either form of telegraph transmission is effected by a relay which controls the grid biasing voltage on the radio-frequency amplifier and on the modulating and audio-power amplifiers so that when the telegraph key is open, the vacuum tubes in these stages are biased to cut-off. In addition, when the key is opened the relay transfers the antenna from the transmitter to the receiver. A press-to-talk button on the microphone handset also operates this relay when the transmitter is used for telephony. This system is advantageous since its permits break-in operation even when transmitting and receiving on the same frequency. The transmitter is well shielded, precluding interference from the crystal oscillator.

Mechanically, the transmitter is divided into four major sections. In the bottom section are located the terminal strip for connections to the transmitter, rheostats and resistors for controlling and regulating the filament, biasing and plate potentials

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and the heavier retard transformers and condensers. The second section from the bottom is unique since it is constructed like a drawer and is removable. It contains the entire oscillator and a radio-frequency amplifier together with the temperature-controlled chamber and five crystals. On the front of this compartment are mounted the crystal selector switch, the tuning controls for the emergency oscillator and the radio-frequency amplifier as well as meters to enable the operator to adjust these circuits.

The third compartment is divided, the front section containing the speech-frequency apparatus and filament circuits, and the back section housing the output circuits of the modulating amplifier. Means for tuning the output circuit and adjusting the coupling to the antenna are brought to the front panel.

The top section is also divided into two compartments. The speech-frequency tubes and the modulating amplifier are in the front section and the antenna tuning apparatus in the back. The antenna tuning control is brought to the front panel on which are also mounted the filament and plate voltmeters and the antenna current meter. A door in this panel gives access to the transmitter so that tubes may be easily replaced, the send-receiver relay being reached through a second door in the dividing shield.

The tuning controls are new developments first used with this equipment. They consist of an all-metal fixed dial with a movable pointer attached to the control shaft. This pointer, which is sufficiently large to permit its being used as a handle for rough tuning, is associated with a vernier for accurate adjustments. Inside the scale are five concentric movable rings containing depressions for receiving detents. Clamping screws are furnished so the rings may be locked in any desired position. When the transmitter is first tuned, the set screws on the dial rings are released and detents on the underside of the pointer are dropped into the depressions on the dial rings by sweeping the dial with the pointer. The transmitter is then adjusted for the lowest crystal frequency and when the adjustment is complete, the inside ring on each dial is locked. The selector switch is then set to the emergency position and the electric oscillator tuned until maximum antenna current is obtained; the inside ring of this tuning control is then locked. The same procedure is followed for each

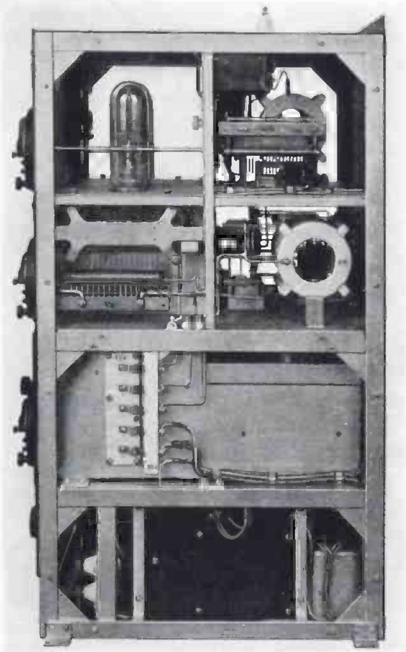

Fig. 2—Right side view of Coast Guard transmitter with shielding removed

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of the five crystal frequencies. The settings of the detent systems on all controls will then be arranged in the same sequence and to adjust the transmitter to any of the crystal frequencies, it is merely necessary to slip the pointer of all controls to the corresponding detents without reference to the dial reading. It is obvious that very rapid changes in frequency may be made even by inexperienced personnel.

All indicating instruments and controls being available from the front panel, the equipment may be installed in inaccessible locations. A remote control start-stop position is furnished and, if for long periods only one type of transmission and one frequency are to be used, the transmitter may be removed any reasonable distance from the microphone handset, telegraph key and start-stop control. To prevent corrosion, non-ferrous metals are used wherever possible, and, except for such openings as are required for ventilation, the equipment is completely enclosed.

To date 110 of these transmitting equipments have been delivered to the U. S. Coast Guard and thirty-five additional equipments have been delivered which are designed to operate from 110 volts d-c. These transmitters have exhibited excellent reliability and speech quality and have already proved of great service in the many activities of vigilance and rescue work carried on by the Coast Guard.

Radio and Wire Communications

"Wireless telegraphy, now that we understand it, is really the simplest kind of communication. We make a disturbance in the ether at one place, leave it to spread out in all directions, as it inevitably must, and as all radiation does, with the speed of light; and then, at any number of distant stations, we arrange a wire or a coil to pick up these ether waves.

"The acoustic analogy of wireless signalling may be likened to shouting to a multitude of listeners at once. When we want to speak to a particular person at a distance, we employ a speaking-tube, the walls of which prevent the sound from spreading, and convey it to anyone who puts his ear to the far end of the tube. This kind of process can be applied to etheric signalling too. The plan is to lay a wire between sender and receiver; the wire will then react to the etheric waves somewhat like a speaking-tube acts with respect to sound waves. The theory of wired signalling is not so simple as that of etheric signalling. Historically it came first, but if it had come later it would have been regarded as an improvement, because it enables privacy to be obtained: it is not broadcast, but concentrated."

—From an address by Sir Oliver Lodge before the Institution of Electrical Engineers, published in the Journal for November, 1931.

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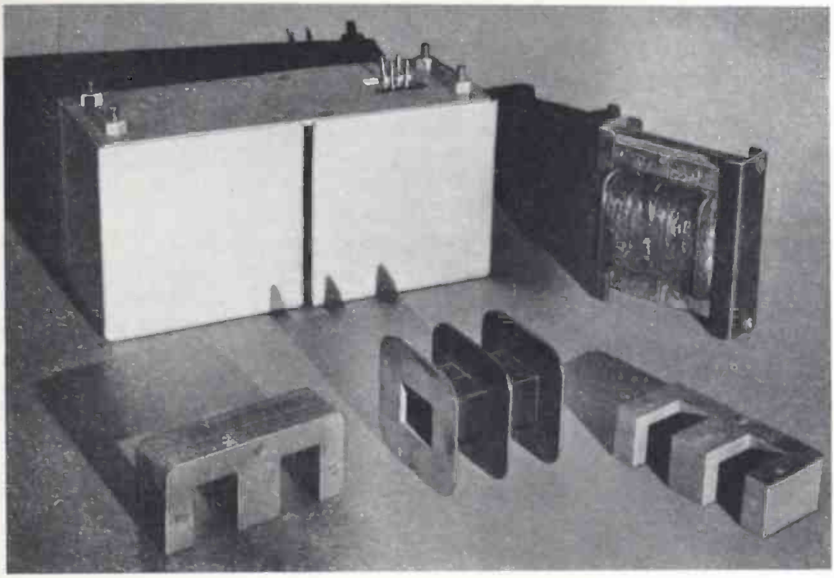

A New Retardation Coil for Composite Sets

By N. BOTSFORD
Telephone Apparatus Development

FOR twenty years the 5-AA retardation coil, with its flattened dome cover, has remained as almost the only relic of an older telephone civilization. Since 1910 practically every piece of apparatus employed in long-distance telephony has undergone a redesign that changed not only its characteristics but its appearance; the 5-AA coil alone, precocious in its early acquirements of refined characteristics, seemed to need no improvement. The advent of the vacuum tube repeater and the general use of the carrier placed more severe requirements on every element of the toll system, and during the last score of years a new generation of apparatus has come into existence educated to meet the more exacting demands of the day. Although not needing rehabilitation in its operating characteristics to any great degree, the old retardation coil has seemed to require some improvement in recent years—particularly a change of form to adapt it better to present layouts. A new coil, known as the 158-A, has been developed by the Laboratories as a result. The long familiar round form has been superseded by a rectangular outline which fits more compactly with other apparatus on the racks.

A retardation coil, together with a group of condensers, make up a composite set—a circuit which enables both telegraph and telephone communication to be held over the same pair of conductors. A diagrammatic representation of such an arrange-

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ment is shown is Figure 1. Practically all the direct-current telegraph facilities of the Bell System are derived from telephone circuits, and the composite set is the generally-used terminal equipment that, by acting as a combination of low- and high-pass filters, permits the separation of the telegraph currents from the higher frequency voice currents. Telegraph currents, consisting in general of frequencies below 100 cycles, are blocked by the condensers but readily pass through the retardation coil to the telegraph apparatus. Voice currents, on the other hand, including frequencies above about 200 cycles, are offered a high impedance by the retardation coils but easily pass through the condensers to the telephone equipment.

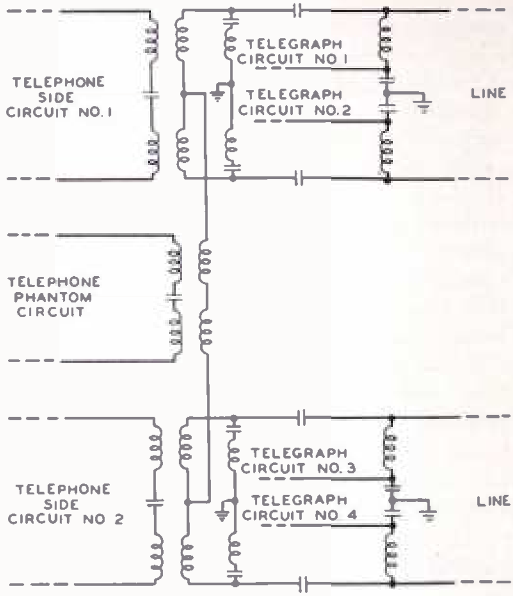

Fig. 2—By phantoming, three telephone channels may be obtained from two pair of conductors. The arrangement shown is for an open-wire line and provides four telegraph channels as well

If only a single telephone circuit were involved, unexposed to fields from other electrical circuits, the requirements placed on retardation coils would not be severe since exacting balance requirements could be waived. Two separate coils could be employed, shielded so that there would be no mutual inductance between them, and thus no interference between the two telegraph channels. The only requirements would then be that they, in conjunction with condensers, provide a satisfactory low-pass filter. Most of the lines used for both telephone and telegraph facilities, however, are phantomed. On two-wire circuits this gives three telephone channels and four grounded telegraph channels for each two pairs of conductors as shown in Figure 2. Voice currents in the side circuits pass over the two pairs of conductors in the usual manner. For the voice currents of the phantom circuit, however, each pair of

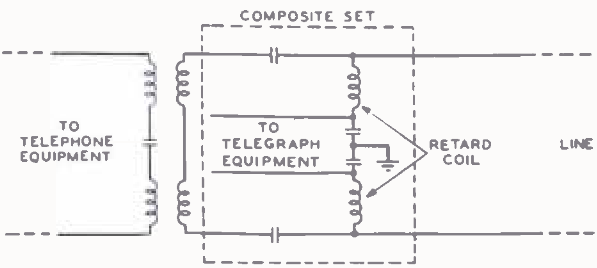

Fig. 1—A composite set acts as a low- and high-pass filter to separate the telegraph and voice frequencies

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conductors forming one of the side circuits acts as a single conductor, and if there is to be no cross-talk between phantom and side circuits the phantom current must divide equally between the two conductors of a pair. If there is not this equal division, unequal voltage drops, due to the phantom current will occur in the two conductors of a side circuit, and cross-talk will result. In addition, power lines or other electrical circuits induce voltages between the conductors of a telephone circuit and ground. If the resulting currents do not divide equally between the conductors of the telephone circuit, undesired noise currents will exist at its terminals.

The impedance to ground of each conductor of a line is affected by the impedance of the retardation coil. To obtain equal impedance to ground for each wire of a pair, and therefore electrical balance, the impedance of the two windings of the retardation coil must be alike. Thus the requirements for a retardation coil, in addition to those relative to its action as a filter, are that there be very low mutual inductance between the two windings of the coil, so that there will be no appreciable interference between the two telegraph circuits, and that the impedance to ground of the windings be alike so that there will not be excessive cross-talk or noise. Likewise the telegraph branch coil of the composite set on one side of a phantom circuit must balance that used on the other side to prevent unbalancing the phantom circuit. Should this balance not be attained excessive noise from induction currents would result, as explained above for the side circuits. This balance must be maintained under all conditions.

These requirements seemed almost impossible of attainment. If each of the windings is placed on a separate core so as to have no interference between the two telegraph channels, the impedance to ground of the two coils would not be alike at all times. Current flowing in one telegraph circuit and not in the other would result in different permeabilities in the two

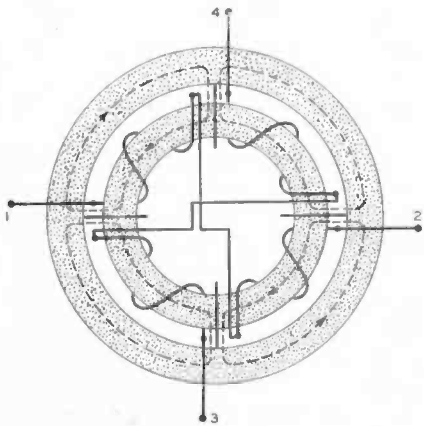

Fig. 3—Retardation coils for composite sets have in the past been toroidal in form with iron-wire cores and four windings: one on each quadrant of the core

cores and thus in different impedances in the two sides of the line. If, on the other hand, the two coils were wound on the same core so as to have a common magnetic path and thus equal impedances, it would be difficult to avoid mutual inductance, and thus interference between the two telegraph circuits.

The problem was successfully solved in a design patented by E. H. Colpitts. The construction of this 5-AA coil is shown in Figures 3 and 4. A core of iron wire is supplied with a winding on each quadrant, and those on diametrically opposite quadrants are connected to the same telegraph

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channel. Over these windings is wound another annular core—also of iron wire. Considering, for the moment, one telegraph channel only—say circuit 1 to 2—it will be noticed that since the windings oppose each other there will be no mutual flux: no flux, that is, that circulates around the entire core and thus links the turns of circuit 3 to 4 as well. The flux path, as indicated by the dotted lines, links each winding separately, passing through the inner quadrant, across the air gap to the outer, and through the corresponding outer quadrant. The other channel, passing through terminals 3 and 4, acts in a similar manner so that the two telegraph channels, although passing through windings wound on the same core, do not interfere with each other.

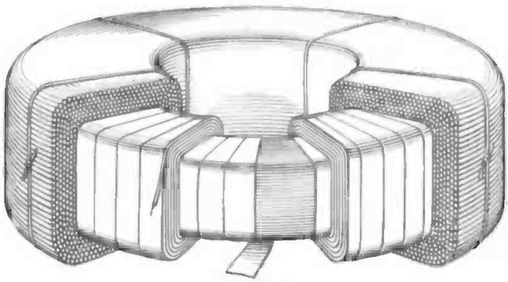

Fig. 4—Once a 5-AA coil was made, adjustment of the number of turns was practically impossible

The fact that the flux from both windings travels in one way or another in the same core causes the magnetization always to be practically the same for both windings so that the impedance to ground of each remains constant. The effective air gap in the magnetic path is relatively large, as is the amount of material in the core. This tends to make the cores quite stable, and results in keeping the impedance of the coils on the side circuits of a phantom group substantially the same under normal circuit conditions. Thus the requirements both for low cross-talk and noise, and for low interference between telegraph channels were so ingeniously met by the 5-AA coil that for twenty years they have met the requirements of the Bell System.

The size and shape of the coil, however, are not suited to present equipment layouts and certain inherent difficulties are met in its manufacture. The outer core, being wound directly on the windings, made adjustment of the number of turns in the winding of the completed coil practically impossible, so that rejections, which an adjustment of the turns would have made unnecessary, were numerous. Largely to rectify this manufacturing difficulty and to obtain a coil more adaptable to present equipment assemblies, a new design has been developed. It employs a construction patented by E. L. Schwartz.

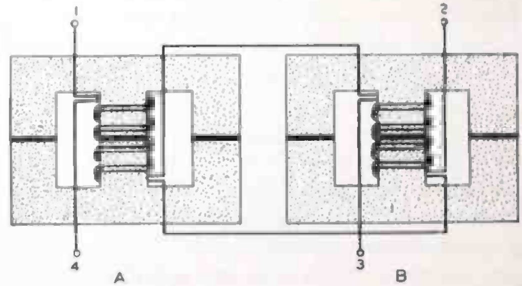

Fig. 5—Employing two separate cores, the new retardation coil meets the two chief requirements more satisfactorily than did the older coil

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The four windings for this new retardation coil, instead of being placed on a single core as formerly, are wound on two separate cores as shown in Figure 5. Between the two windings on one core there is a mutual inductance, but the connections to one of the windings on one core are reversed so that the mutual inductance of one pair of windings opposes that of the other pair, and as a result there is substantially no mutual inductance,

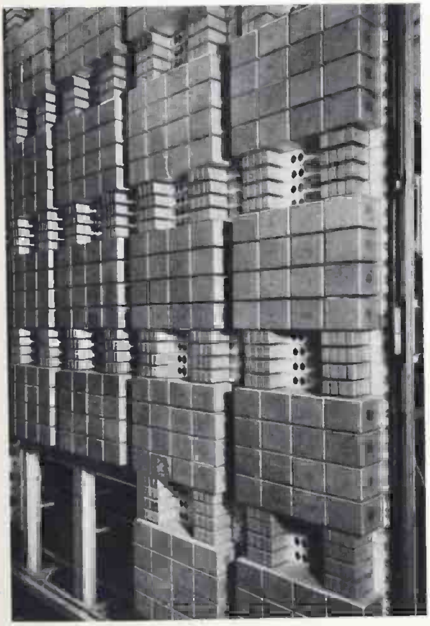

Fig. 6—Coils and condensers of the new type for four phantom groups are mounted together as a unit and several such units are mounted on a single bay

and thus no interference between channels, for the retardation coil as a whole. A current flowing in coil 1-2 would induce a certain potential in the turns of the 3-4 circuit on the A core and an equal and opposite potential in its turns on the B core.

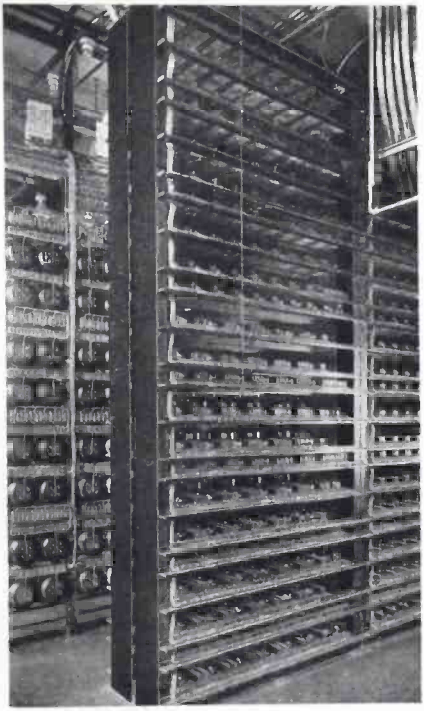

Fig. 7—Two forms of mounting were used for the older coils: on horizontal shelves and on vertical panels

The net induced potential in 3-4 would thus be zero. The requirement of practically no mutual inductance between the two telegraph circuits is thus satisfactorily met.

Moreover, since the windings of both circuits are identical and have the same magnetic circuits, the impedance is always the same for both. The effect of telegraph current in circuit 1-2, for example, is to change the inductance equally for circuits 1-2 and 3-4 since the magnetic circuits are common to both. As a result the inductance of the two coils remains alike under all conditions. The inductances need be balanced only once before the

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coil leaves the factory and henceforward they will remain balanced under all operating conditions. The requirement of equal inductance is thus more satisfactorily met than it was for the earlier coils where the magnetic path although to a large extent common to both, was not entirely so. Due to the use of 45 per cent permalloy and relatively large air gaps in the magnetic circuit of these coils, they are very stable—more so in fact than the replaced coils. As previously stated this is of great importance in maintaining the balance of the phantom circuit.

These new coils thus have somewhat better electrical characteristics in addition to being much easier to construct. The wound wire core is eliminated and changes or adjustments in the coils are more readily made with the new type of construction than with the older, where a second core was wound over the winding. The new cores are of permalloy and are thus much smaller and require less central-office space than the older ones. The type of construction and appearance of the coil is shown in the picture heading this article.

This new development has resulted in a retardation coil for composite sets which weighs only half as much as the former coil, occupies less than half as much space, and at the same time is the electrical equivalent of and in some respects electrically superior to the old coil. Its type of construction is more suitable to modern manufacturing methods, thus giving appreciable economies in its production.

The new construction also lends itself to a more convenient arrangement of the equipment on the relay racks, which permits the wiring to be considerably simplified. The front appearance of a group of the new coils, with their associated condensers above, is shown in Figure 6. This may be compared with the arrangement of the older coils and condensers shown in Figure 7. The new design has resulted in circuit improvements from the standpoints of noise and cross-talk, and although undertaken primarily to obtain a reduction of size, has like so many development projects, yielded collateral savings in the cost of apparatus.

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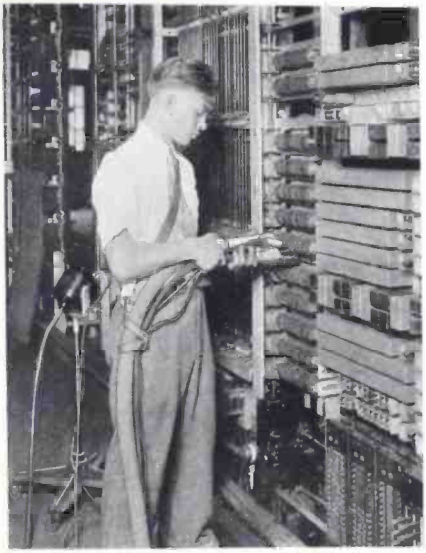

Power-Driven Maintenance Tools

By W. T. PRITCHARD
Telephone Apparatus Development

IN dial central offices the large number of moving contacts require occasional cleaning to maintain them in first-class condition. Hand cleaning methods have been used largely in the past, but to meet more thoroughly and expeditiously the needs of a constantly growing system, power-driven cleaning tools seemed desirable. One of the larger classes of contacts requiring cleaning are the cams of sequence switches, already described in the RECORD,* and to maintain them in good condition power-driven equipment has recently been developed by the Laboratories.

Three elements are desirable for a complete cleaning outfit: a brush or grinding wheel to perform the actual cleaning, a vacuum cleaner connection for removing the dislodged matter, and illumination to enable the surface to be watched during the cleaning process. These are all incorporated in the light and compact tool designed for sequence switches shown in Figure 1. The method of use is shown in the photograph at the head of the article.

The cleaning element consists of two galvanized iron wires twisted together so as to grip a layer of hog bristles. It is a little larger than a lead pencil in diameter and the bristle section is about 1¾ inches long. One end is slightly flattened and is inserted in the driving chuck of the tool, and the other rests in a bearing of hardened steel mounted in a vulcanized-fibre bearing post. To allow the brush to be readily removed or

*BELL LABORATORIES RECORD, *Dec.*, 1931, *p.* 119.

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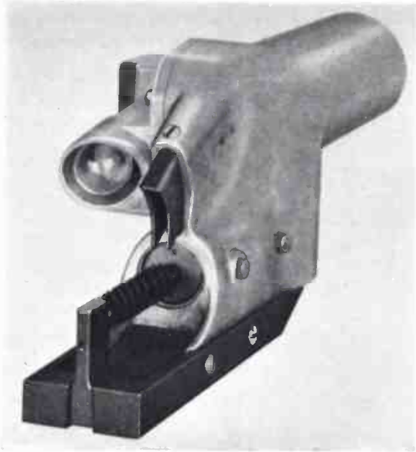

Fig. 1—The new cleaning tool incorporates a power-driven brush, a vacuum cleaner connection, and an electric lamp in a cast aluminum housing

inserted, the drive spindle is fitted with a spring and pin at the bottom of the drilled hole which can be pushed back by the brush shaft as shown in Figure 2. As a further assistance in replacing a brush the outer bearing is latched in place and may be tipped back.

The hardened steel sleeve of the bearing is not fastened in the fibre bearing support but is free to turn and grease is supplied around the periphery for lubrication. The steel sleeve turning in the greased fibre housing makes a better bearing than the wires turning in the steel sleeve, and in ordinary use it is expected to be acting a large part of the time. This arrangement was provided both because of the good bearing qualities of the fibre, and because the iron wires of the brush may become bent or expanded and stick in the steel sleeve, which would cause trouble if the sleeve itself were not free to move.

Two intakes are provided for the air suction; one above and the other below the brush. The upper orifice has a fibre extension designed to fit between two cams of the sequence switch. It is held in place by one screw and may be readily replaced. The lower one is built in the form of a tray, forming the lower part of the cleaning tool, and projects under the cams to catch the heavier particles. The outer end of it supports the outer bearing for the brush.

So that the cleaning operation may be watched, a small automobile lamp is mounted on one side of the upper part of the aluminum casting that houses the cleaning tool. The cord connection to it and the position of the tool while cleaning are shown in Figure 3. The aluminum housing around the lamp is shaped to form a reflector that directs the light on to the working surface.

Three connections are made to the

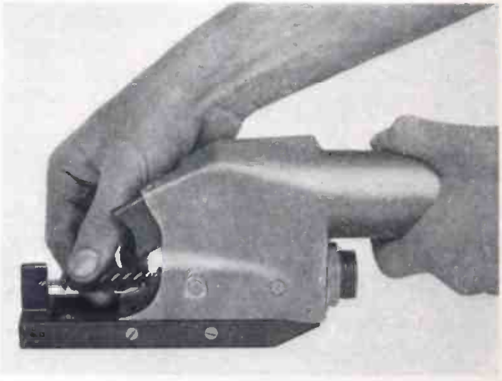

Fig. 2—Insertion or removal of the brush is simplified by a movable outer bearing and a push spring socket in the chuck

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cleaning tool. One is a flexible suction hose which may be connected to any of the vacuum cleaner equipments with which panel central offices are always equipped. Another is a flexible cord for the lamp which may be connected to the central office battery at the connecting block on the switch frames. The third is the flexible drive for the shaft. This is a commercial drive built up of layers of music wire wound in opposite directions to form a hollow cylinder about a quarter inch in diameter. The containing casing is of flat steel spring with a zinc plated outer covering. It is made oil tight with rubber reenforcement. At each end are swivel couplings. One of these couplings fastens to the cleaning tool and the other to the driving motor.

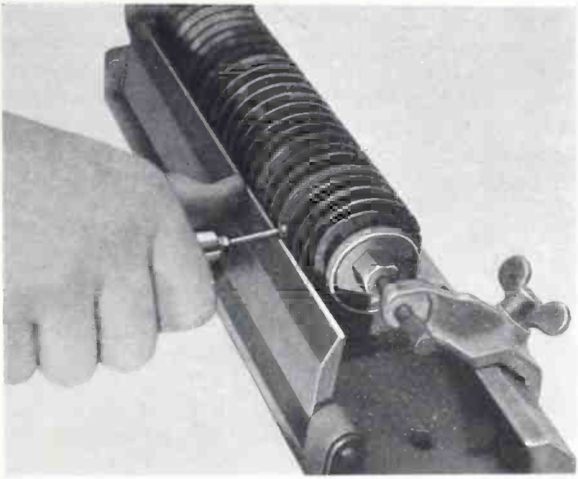

Fig. 4—A small grinding wheel permits burnt spots to be readily removed from the cams

The latter is a specially designed ⅛ horse power motor running at 3,400 r.p.m., and wound for 110 volts either a-c or d-c as desired. A portable stand has been designed to carry it. A pivoted mounting is provided which allows the motor to tilt up or down, or to swing around in a horizontal plane. A bracket has also been designed, as an alternative arrangement, for fastening the motor to the under side of a rolling ladder. The bracket carries the pivoted motor yoke so that the motor is as free to move with one mounting as with the other. This mounting equipment is evident in the photograph at the head of this article,

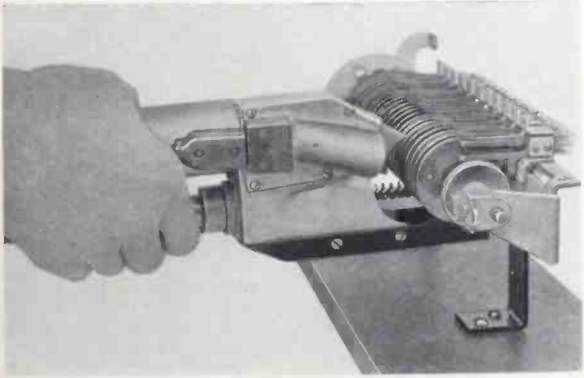

Fig. 3—A flexible cord for the lamp, the drive shaft, and the suction connection serve as a handle where they fasten to the cleaning tool. A cord terminating in a switch for controlling the motor is run along with the three connections

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which also shows a shoulder strap that allows the operator to carry the weight of the cleaning tool and the near end of the connections from his shoulders, thus making the control of the tool easier.

Another tool that has been developed for maintaining sequence switches is a small grinder that may be fastened to the end of the drive shaft in place of the cleaning tool. It consists of a ball bearing chuck and the grinding tool proper, and its use is shown in Figure 4. The overheating commonly found with this type of apparatus was overcome by the use of ball bearings, but even with this obstacle surmounted there remained the difficult design problem of securing a grinding stone that would not "fill up" with the material ground off, and thus make further grinding impossible. Also the ordinary method of mounting the wheels would not withstand the rigorous treatment involved in the grinding operation.

The latter difficulty was overcome by the combination of a special cement which expanded while setting and a fluted steel mandril on which the wheel was mounted. Difficulty with "filling up" was made negligible by a method of cleaning with an oiled pad which eliminated the necessity of stopping the machine for the purpose. The tool is used for removing carbonized spots or pits from the contact paths of the cams.

These new tools make the cleaning of sequence switches a much easier and quicker operation. The light weight of the equipment and the effectiveness of the cleaning and grinding tools make it possible for a single operator to clean a large number of switches with a minimum effort. It is expected that the use of the new equipment will greatly reduce the amount of cam replacement due to pitting. The employment of additional power-driven cleaning equipment is now being considered for apparatus in all types of offices.

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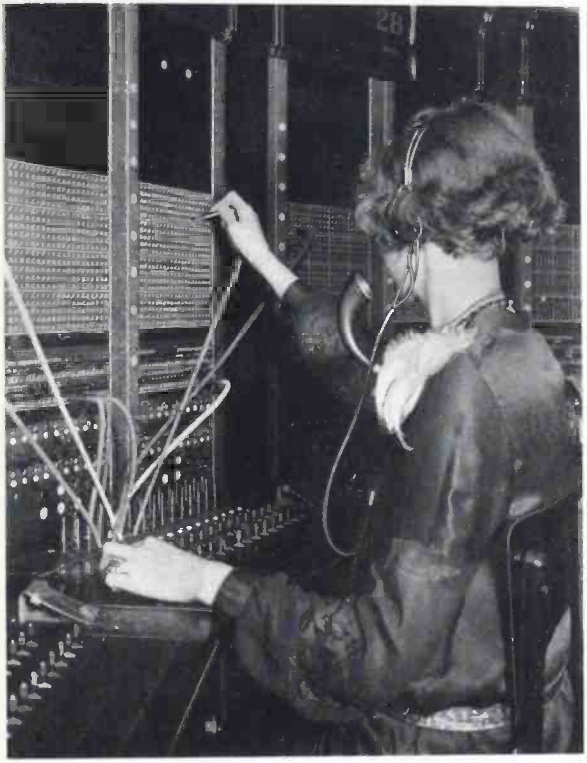

Busy Indications in the Manual System

By O. H. WILLIFORD
Local Systems Development

IN any telephone system a connection once established between two subscribers must be protected from interference by other subscribers who may be attempting to obtain a connection to lines already in use. This was a simple matter in the very early forms of manual boards because each line was connected to only one jack. Should an operator attempt to make a connection to a line in use, therefore, she would at once see that a plug was already inserted in the jack of the desired line, and would inform the calling subscriber that the line was busy. With the growth of the system, however, and the necessary development of the multiple board, incorporating a large number of jacks all connected to the same line, this positive busy signal no longer existed. Other methods had to be developed to indicate when a line was in use.

The first busy indicating system for multiple switchboards was built for a Chicago office about 1880. It took the form of a target board, separate from the main board, but within sight

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of all the operators, on which the lines that were busy could be indicated. Hooks were provided for each line and an attendant placed targets on them when the operators completed a connection, and took them off when disconnection was made. The arrangement had many rather obvious disadvantages, not the least of which was a more or less inherent delay in placing the targets. Since the line would be considered busy only when a target was on the hook, there could be short intervals between the actual making of a connection and the hanging of a target, when other operators might complete a connection to a busy line.

Fig. 1—Three connections are provided by the manual plug which, because of their locations, are known as the tip, ring, and sleeve

An improvement over the target board was the Scribner pneumatic signal: a method of automatically setting a busy signal similar to that of the target board and of releasing it when disconnection took place. For large offices the signal was displayed in several places so as to be easily visible to all the operators. The pneumatic signals were actuated by electrically controlled valves which operated whenever a plug was inserted in a jack. This was the forerunner of the more modern systems which provide an indication, available to all the operators at the board, whenever a plug is inserted in any jack of a line or trunk.

Fig. 2—Jacks are manufactured in strips of twenty and provide contacts for the tip, ring and sleeve of the plugs

In general, lines to subscribers, and trunks outgoing to other central offices consist of only two conductors in the outside plant but within the central office another conductor is added which is used for various switching and signaling purposes, one of which is to provide a busy indication in case the line or trunk to which a connection is to be completed is already in use. The construction and appearance of the plug used in completing connections is shown in Figure 1. One of the three conductors is connected to the metal tip of the plug, one to the outer sleeve that forms the main bearing surface, and one to an inner sleeve which appears, on the outside of the plug, only as a ring insulated from both the tip and outer sleeve. In addition there is a narrow metal ring between the tip and the ring formed by the inner sleeve, which is insulated from both and serves as a spacing strip only, having no electrical connection to any of the wires of the circuit. These parts of the plug have been employed as designations of the three wires of the intra-office circuit

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which are thus known as the tip, ring, and sleeve conductors. The tip and ring are the conductors that carry the telephone conversation and the sleeve is this third wire used for signaling purposes within the central office.

The jacks into which the plugs are inserted have three corresponding connections which are similarly named. They are manufactured in strips of ten and twenty and their appearance and construction is shown in Figure 2. The sleeve of the jack is flush with the front of the strip while the tip and ring are necessarily farther within.

Audible busy signals, which are the most commonly used form in the present manual system, are clicks or tones heard by the operator as she touches the tip of the plug with which she is about to complete a connection to the sleeve of the jack to which she wishes to connect. The method is shown at the head of this article. A click indicates that the line or trunk connected to the jack is busy and the absence of a click, that it is idle. Tones are used largely to reduce the amount of testing necessary by indicating groups of trunks which are busy.

The circuit arrangements by which clicks are produced vary with the type of switchboard. For the ordinary subscriber's "A" board the arrangement is shown in Figure 3. At these boards the operator's cords terminate in plugs at each end, and one plug is inserted in the jack of the subscriber's line that is placing a call and the other in that of a trunk leading to the office called. Before plugging into the trunk, however, the operator tests it for a busy determination by touching the tip of the plug to the sleeve of the jack.

To each trunk a number of jacks are connected which appear at regular intervals along the board so as to be accessible to all the operators. In Figure 3 a particular trunk (T-2) is shown in use, a connection having been made to it by the plug of cord circuit C-1 at some one position of the board. With the plug of C-1 in-

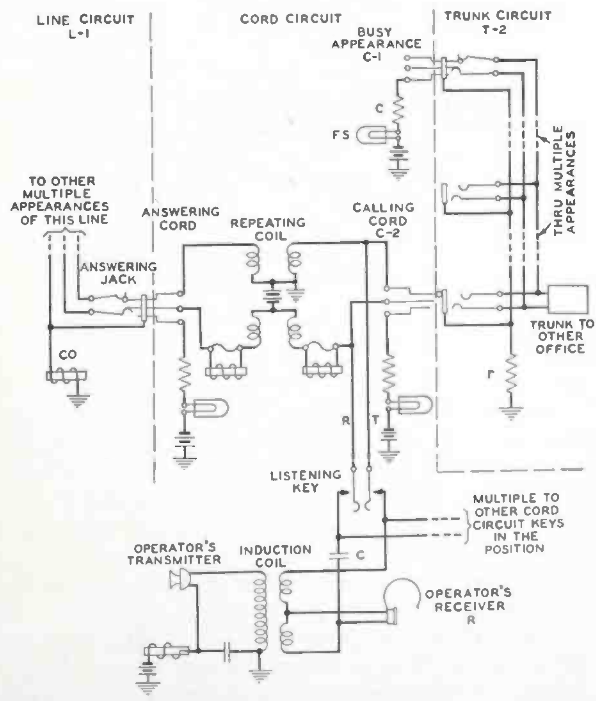

Fig. 3—Simplified schematic arrangement of circuit by which busy signals are produced at a subscriber's board

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serted in a jack, current flows through the sleeve conductor from battery on the (FS) lamp in the cord circuit, through the sleeve of the cord and trunk circuit, and through a resistance (r) to ground. This makes the

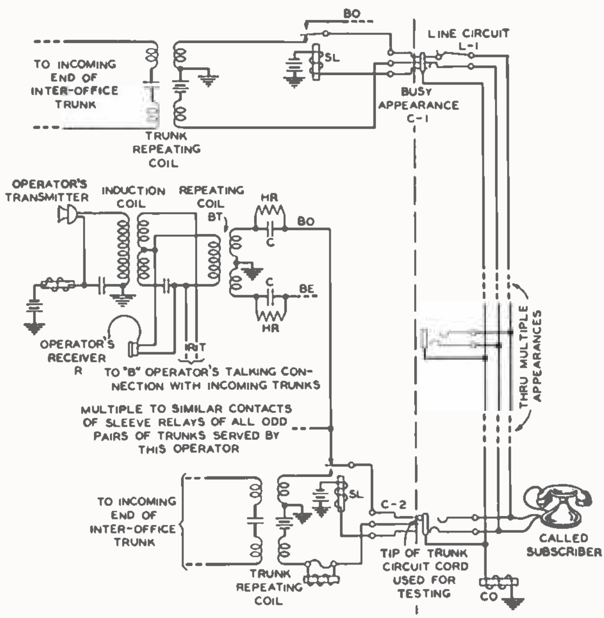

Fig. 4—Simplified schematic arrangement of circuit for producing busy signals at trunk boards

sleeves of all multiple jacks of this trunk circuit negative in potential.

Central office battery potential is connected across the tip and ring conductors at the repeating coil of the cord circuits as shown at C-2. When the operator closes her listening key, the tip and ring conductors of the cord are connected to her headset, and a condenser (c) in the circuit is charged to full battery voltage with the tip side at ground potential. When the tip of this plug is touched to the sleeve of the busy trunk, which as has already been noted is negative in potential, the condenser partially discharges and in doing so induces a click in her receiver. She will take this as an indication that that trunk is busy and proceed to test the next trunk to the same office.

Should the A board have been one at which calls to other subscribers are completed directly in the subscriber's multiple, the arrangement would be the same as described above, except that the resistance (r) would have been replaced by a cut-off relay. In either case, if no busy click is heard when a jack is tested, the operator completes the connection by inserting the plug, which immediately makes that line or trunk busy by putting a negative potential on the sleeve conductor.

At "B" or trunk-completing boards conditions are different and require a somewhat modified arrangement. The cords at these boards have plugs only at the completing end; the other end is directly connected to an incoming trunk. For some forms of service, also, the talking circuit of the cords is not connected to the operator's headset, and for other forms the talking connection to the operator's circuit may be disconnected before the lines are tested for the busy condition. The sleeve conductor of the line is made busy by the application of a negative potential as at subscriber's boards, but an additional link must be provided between the operator's headset and the

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trunk cords for test purposes. This is accomplished in all types of "B" boards by connecting the tip of the plug to a transfer spring of a sleeve relay, which forms part of the cord circuit. The arrangement is shown in Figure 4. When the plug is inserted, the sleeve relay operates and moves this transfer spring to a front contact which connects it to the tip conductor of the incoming trunk. While the plug is not inserted the sleeve relay remains unoperated and the transfer spring rests against a back contact which is connected to one side of the operator's telephone circuit. Under these conditions, the operator will receive a click whenever the tip is touched to the sleeve of a busy line. The click produced is similar in nature to that given at the "A" board, but it is caused by partially charging a condenser (C) in the operator's telephone circuit rather than by discharging it. The resistance (HR) dissipates this charge when the test is completed, in preparation for the next test.

The back contacts of the sleeve relays of all trunks handled by one operator are divided into two groups: one consisting of those of the odd numbered trunks and the other of the even. The back contacts of each group are multipled together. This grouping arrangement permits the balancing out of currents which otherwise might be picked up by the system of multiple tip leads and cause noise in the operator's circuit.

The net work of resistance (HR) and capacity (C), shown in Figure 4, are provided to maintain a "high resistance" tip lead for trunk cords after the operator releases them upon disconnection. In some "B" boards this high resistance tip is not necessary, and in these cases this network is omitted. The busy test click is then created in the operator's receiver

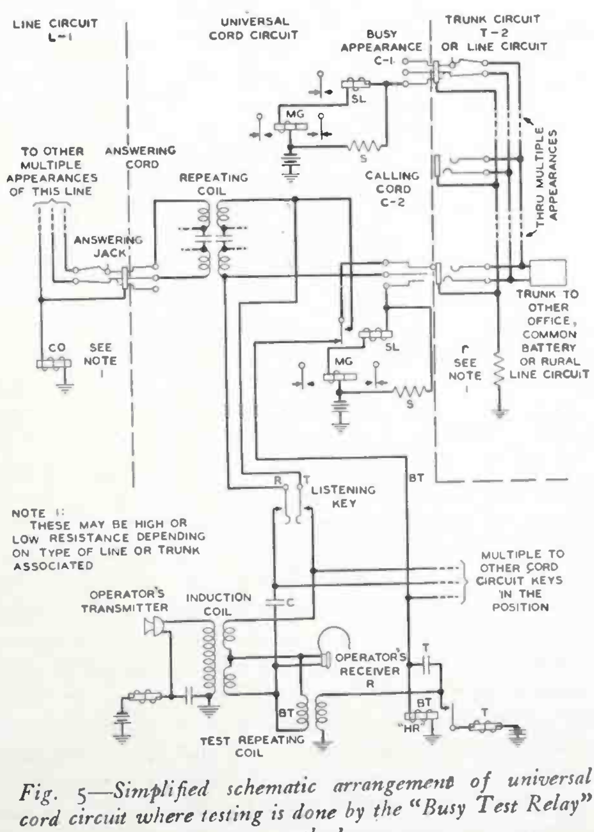

Fig. 5—Simplified schematic arrangement of universal cord circuit where testing is done by the "Busy Test Relay" method

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by a direct current being set up in the (BT) repeat coil from the potential of the busy jack under test.

There are some "A" switchboards where the busy testing arrangement shown in Figure 3 can not be used because the cord circuits employ marginal sleeve relays to determine the type of line or trunk to which the operator connects them. These are called universal cord circuits and, in general, are of three different classes: first, those which serve both toll lines and trunks to local offices; second, those which serve magneto and common battery subscribers' lines; and third, the operator's cords of dial-system "A" boards which connect to trunks to both dial and manual offices. The testing circuit of the local cords shown in Figure 3 has such a low resistance to ground in the tip lead that marginal relays in the universal cords would be falsely operated when the busy test was made.

Some of the universal positions employ a high resistance busy test very similar to that described for the "B" boards above. The (HR) resistance is sufficiently high not to disturb the marginal relays. In other universal "A" boards, a high resistance relay arrangement is employed as shown in Figure 5. Here, the resistance of the (BT) relay is sufficiently high not to disturb marginal sleeve relays. However, this relay will operate to the busy sleeve potential and by closing its contacts closes a path from the (BT) repeat coil to battery through the (T) retard coil. This causes a surge in the operator's receiver, which results in her receiving the busy test click. The condenser (T) is employed to permit the passage of "Out-of-Service" and other tones to the operator through the testing circuit.

Tones are used as busy indications at times where there are large groups of trunks running to the same office. Such large groups of trunks are divided into subgroups and when all the trunks in any one subgroup are busy a tone will be superimposed on the sleeve lead of the first jack of the subgroup. An operator, by testing the first jack of each subgroup, will know that all the trunks of the subgroup are busy if she hears the tone superimposed on the click and may proceed to the next subgroup without further testing within that subgroup. If she hears only a click on testing the first jack of a subgroup, she will then test within that subgroup until an idle trunk is found.

In addition to these audible busy signals there are two types of visual busy signals. One is a white shutter directly above the jack which may be seen in the headpiece opposite the designation TO on the lower part of the left-hand stile strip. These signals are magnetically operated and show white over busy jacks and black over idle ones. A similar method is a small electric lamp that illuminates a circular translucent spot behind the designation strip above the jacks. These visual signals require a continuous current drain but they require no effort on the part of the operator and so are conducive to fast operating. They are used principally for toll lines and large groups of trunks, and on PBX boards where their cost is justified by the large saving in operating effort. This latter method has already been described in the RECORD.*

In the present manual plant of the Bell System there are thus two types of busy signals, both of which repre-

*BELL LABORATORIES RECORD, *February, 1930, p. 267.*

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sent an enormous advance over the crude targets of the early days. For subscribers' lines and small trunk groups the audible signal will probably continue to be employed, as it is a highly satisfactory and inexpensive method. For large groups of trunks and toll lines, the visual signal provides an automatic indication that requires no effort on the operator's part and thus allows her to devote her entire time to completing calls.

Common Sense and the Common Cold

A few fortunate people never have colds, some people have as many as six colds a year, while the large majority of us average at least one cold annually. Colds cause more discomfort and loss of time and money among office and factory workers than any other disease.

The so-called Common Cold is caused by a virus or parasite that is spread from one person to another. Although this parasite is still unknown, it acts apparently by "pepping up" or making more poisonous the ordinary bacteria that exist in the nose and throat, thus giving rise to inflammation of the membranes of the upper respiratory tract.

While colds may be the direct or indirect result of such an infectious or "catching" organism, the resistance of the individual is of prime importance, as in most other diseases of this nature. While the resistance of the average individual against a cold is not high, all of us may do certain things that will tend to increase our chances for avoiding this troublesome malady.

The chief thing you can do to help prevent a cold is to develop good health habits. Remember that as yet there is no substance—solid, liquid, vapor or gas—that may honestly be called a "cold cure," in spite of the fact that some of these may give temporary relief. Favorite home remedies chiefly are of value for the other members of the family rather than for the one who is ill. Temporary relief and comfort for the patient naturally makes others happy and contented.

Vaccines apparently are of value in upwards of half the cases in which they are given, particularly in preventing the chronic complications of a cold. They may be worth a trial by those who suffer from repeated colds.

The cold fact about the common cold is that at the present time there is no drug store or medicine cabinet "magic" that will prevent or cure it. Common sense, which is only another way of saying Good Health Habits, is the best preventive and the best treatment of the Common Cold. This prescription of Common Sense should be taken in large doses day and night, especially from November to May!

—Leverett D. Bristol, M.D., Dr. P.H., Health Director, American Telephone and Telegraph Company, New York City.

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Contributors to this Issue

A. F. Bennett joined the instrument standards group of the Laboratories in 1914, and during the war took part in the development of submarine detection apparatus. After the armistice he turned to studies of the granular carbon transmitter, and took a leading part in the development of the handset transmitter, the barrier-type operator's transmitter, and the instruments for the portable audiphone. At the present time he has charge of the development of transmitters for use in the telephone plant and elsewhere.

In 1909 J. J. Kuhn joined these Laboratories as a member of the drafting division of the Apparatus Design Department. Two years later he transferred to the special order division. When the Western Union Company became affiliated with the American Telephone and Telegraph Company, he undertook the design of telegraph apparatus. The advent of the World War supplanted this activity with the mechanical design of communication and signalling equipment for the United States Government. He retained supervision of this work after the Armistice, and also took charge of the mechanical design of repeaters, rack-mounted apparatus, telegraph equipment, ticket distributing systems, and the like. When the Special Products Department was organized in 1927, he was placed in charge of several groups responsible for the mechanical design of amplifiers, audiphones, and government apparatus. In 1929 his organization was enlarged to include the development of mechanisms employed in recording and reproducing sound pictures.

Two years in the Royal Air Force interrupted W. A. Marrison's attendance at Queens University, but eventually he received the B.Sc. degree from his alma mater as of the Class of 1918, and a master's degree from Harvard in 1921. Then entering the Laboratories, his early work was on frequency-analysis. This led into studies of methods and apparatus for production of constant-frequency current, and in particular to the study of piezo-electric crystals. An outgrowth of this was methods of synchronizing distant devices by accurate speed control: methods of great value in picture-transmission and television.

A. F. Bennett

J. J. Kuhn

W. A. Marrison

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O. M. Hovgaard

O. H. Williford

N. Botsford

O. M. Hovgaard brought to the Laboratories a varied radio experience when he joined the Radio Apparatus Development group in 1928. After leaving Massachusetts Institute of Technology in 1919 after his freshman year, he had worked as a radio-telegraph operator for the Radio Corporation and the Tropical Radio Telegraph Company, first on ships plying the Gulf of Mexico and the Caribbean Sea and later at shore stations at New Orleans and Burrwood, Louisiana. Returning to the Institute, he received the B.S. degree in electrical engineering in 1926, then worked for various manufacturers on the design of transformers and chokes and on power-supply apparatus for radio receivers.

During his first year with the Laboratories, he worked on broadcasting antenna problems and the development of frequency controls for use in aircraft transmitters. Since 1929 he has been supervising the development and manufacture of frequency controls for radio apparatus and the design of antennas for broadcast stations, as well as conducting radio transmission studies.

O. H. Williford joined the Laboratories, then the engineering department of the Western Electric Company, in 1920. His first work was in the drafting room of the Apparatus Development Department, but he later transferred to the Systems Laboratory. In 1922 he transferred to the Installation Department of the Western Electric and worked in the Academy central office during the test period just preceding the cut-over. Following this, he returned to the Laboratories and

W. T. Pritchard

W. Orvis

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worked on manual systems. He was associated with the development of straightforward trunking, idle trunk and position indicating, and with the call-distributing switchboards used for handling information calls and for receiving orders to send telegrams. While at the Laboratories he completed the course for high-school graduates and continued his studies at Brooklyn Polytechnic Institute and at New York University. He recently transferred to the panel-system laboratory group and at present is engaged in development work on a new type of sender test circuit.

N. Botsford received a B.S. degree in electrical engineering from Union College in 1925 and immediately joined the Technical Staff of the Laboratories. Since that time he has been engaged in development work on various types of transformers and coils, among them the new retard coil described in this issue of the Record.

After completing an engineering course at Lewis Institute, Mr. Pritchard was engaged in the production of electrical apparatus and small tools. He came to the Western Electric Company at Hawthorne in 1921 and moved with the Installation Department to New York when this branch was separated from the Manufacturing Department. Transferring to the Laboratories in March, 1926, he has since been responsible for the design of maintenance apparatus, tools, and gauges for panel and step-by-step systems.

W. Orvis received the A.B. degree from Ripon College in 1916. After a year as instructor in the Physics Department of the University of Wisconsin he joined the Receiver Development group of these Laboratories. During 1918 he worked at Camp Merritt on the development of instruments for the detection of sapping operations. In 1920 he transferred his activities to carbon research. Save for two years of submarine cable development, a part of which was spent in London supervising measurements during the manufacture of the Fanning Island-Suva cable, Mr. Orvis has been associated with carbon research ever since. He is now in charge of the Transmitter Carbon Development group.

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