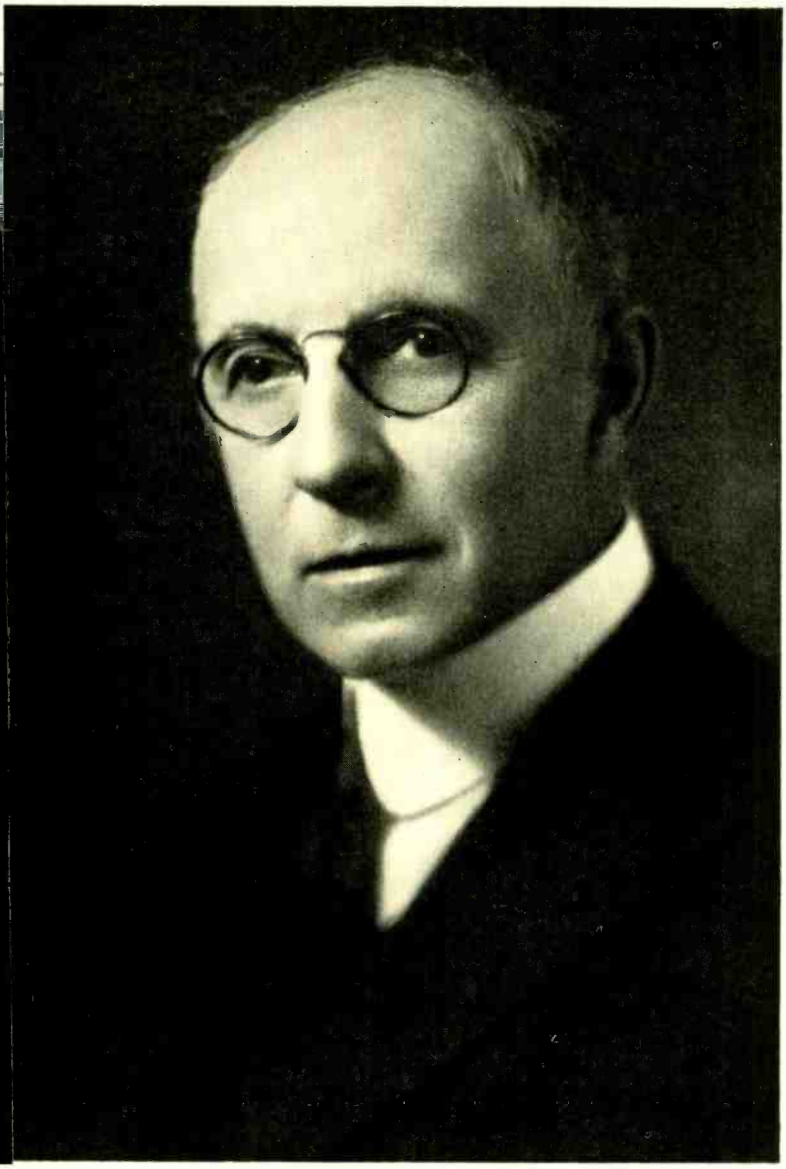
ELL LABORATORIES RECORD



NOVEMBER
1938

VOLUME XVII

NUMBER III

The John Fritz Medal for 1939 has been awarded to Franklin Baldwin Jewett, President of Bell Telephone Laboratories

Drying Cable Splices by Desiccants

By C. D. HOCKER
Outside Plant Development

FOR many years the drying of cable splices has been done by "boiling out"—that is, repeatedly pouring hot melted paraffin over the paper insulation. This method is effective but has the disadvantages of involving some fire hazard, of being a cause of burns to workmen, and of generating fumes which are often objectionable in buildings.

In a new method recently placed on general field trial, splices in lead-covered cable are dried by a granular desiccant which is put in among the conductors after the wire splicing work is completed. The bundle of spliced conductors and the desiccant are then compacted by a spiral wrapping of muslin, and covered in the usual manner by a lead sleeve. The new method involves no boiling out of conductor insulation with hot paraffin no matter how long the splice is unsheathed for wire joining work.

Only a few of the many desiccating materials available could be hopefully considered for trial in cable splices. Silica gel, anhydrous aluminum, and anhydrous calcium sulphate or gypsum are about the only readily available desiccants which are practically insoluble, nonacid, and nonalkaline so that they could be expected to have no deleterious effect on the insulation of the cable.

The matter of how to evaluate desiccants as splice driers could be most satisfactorily determined by trying the materials in actual splices. Accordingly, trial splices as shown in

Figure 1 were made between short pieces of cable in the laboratory, the work being done under the direction of D. T. Sharpe in humidified rooms where the cable insulation could readily absorb moisture. In each experiment, when the wire splicing work was done, desiccant was put into the splice, a lead sleeve wiped on, and measurements were then made at intervals to chart the rise of insulation resistance between cable conductors as the desiccant absorbed the moisture that was given up by the insulation.

The early exploratory experiments with splices in the laboratory showed that it was possible to dry splices with desiccants as completely as by paraffin boiling, but the time required was much longer. Laboratory tests on actual splices showed that silica gel and anhydrous calcium sulphate were more effective than anhydrous alumina. Calcium sulphate is less expensive than silica gel and was therefore selected, in a specially prepared form based on many trials, as the desiccant most advantageous for drying cable splices.

This desiccant will absorb a little over 6 per cent of its weight of water and still have a zero vapor pressure. This means that if a pound of desiccant is sealed in a splice containing an ounce of water, all of this water will gradually evaporate and pass over to the desiccant where it will be held. If the splice contains more than an ounce of water, the pound of desiccant will absorb some of the additional water but not all of it.

Much of the work on desiccants was directed toward finding a technique for using them which would make them dry splices as effectively and rapidly as possible in practical use. A desiccant in a splice can dry the insulation only by absorbing the water vapor which has evaporated from the paper and diffused to the surface of the desiccant. The opportunity for rapid diffusion of the water vapor through a tightly bound mass of cable conductors is inherently not very good. Accordingly, to achieve rapid drying it is necessary to use an adequate quantity of the material, and to distribute it properly in the cable splice.

The first field trials used a method of distributing the desiccant which was selected from among several studied in the laboratory. Sausage shaped bags of the desiccant were placed lengthwise among the conductors of the splice and also wrapped around the ends near the wiped joint locations. The bags, which were made of cheesecloth, were ¾ inch in diameter and 12 inches long. Desiccant bagged in this manner effectively dried the splices in all cases tried. However, the use of the bags of desiccant was discontinued because it involved the trouble of filling the bags in the field or of packaging the prefilled bags in too many sizes of sealed containers.

The method recommended for introducing the desiccant is illustrated in Figure 2. About half the granular desiccant is trickled into the spaces among the conductors made by spreading them apart and the rest is placed in the ends of the cradle of muslin near the sheath butts. The total quantity of desiccant recommended is sufficient to take up completely all the moisture present even if the insulation contains the extreme amount that the paper and paraffined sleeves can absorb when exposed for a three-day splicing period in a highly humid manhole. The small size of the desiccant granules makes it easy to trickle them into the spaces among the conductors. The granules are relatively soft—about as easily crushable as a chalk crayon; consequently they do not harm the paper insulation when the splice is compacted by spiralling on a wrapping of muslin preparatory to putting on the lead sleeve.

To facilitate its use in the field and to avoid waste of material, the desiccant is packaged in only three sizes of cans with screw-tops and seals: capacity one-eighth pint, one-half pint, and one quart. After a can has been opened, any material left in it at the end of a day is thrown away to make sure that no desiccant spoiled by moisture absorption is used in splices.

Some splices treated with desiccant quickly attain very high insulation resistance between conductors. Others require days or even three or four weeks to reach the high values. Typical variations in the time required for desiccated splices to attain high insulation resistances are illustrated by measurements made on the eight splices comprising an underground installation of 1800-pair cable. The resistance measurements were made between individual 100-pair groups and all the other wires plus cable sheath. In the fastest drying splice, made in a dry atmosphere, all 100-pair groups tested above 1000 megohms immediately after completion of sleeve wiping. In the slowest drying splice, made in a deep, highly humid manhole, the different 100-pair groups tested 6 to 250 megohms immediately after completion of the sleeve wiping, but all had attained 1000 megohms in twenty-one days. In the completed installation of cable the different 100-pair groups tested fourteen to 1000 megohms eighteen hours after completion of the final splice, and all showed resistances of more than 1000 megohms after thirty days.

A lagging recovery is not particularly serious for cable telephone circuits because they will operate as long as the insulation resistance between the conductors of a pair is only a fraction of a megohm. Even when splices are exposed to 100 per cent humidity for two or three days while being worked on, the insulation resistance between wires of pairs does not drop to values low enough to preclude circuit operation. Presumably inoperative circuits might result if a cable installation contained a sufficient number of highly humidified splices, but this could hardly happen when the desiccant drying scheme is used. The splices could not all be made at one time, and the ones first completed would have reached high insulation-resistance before the last splice was made.

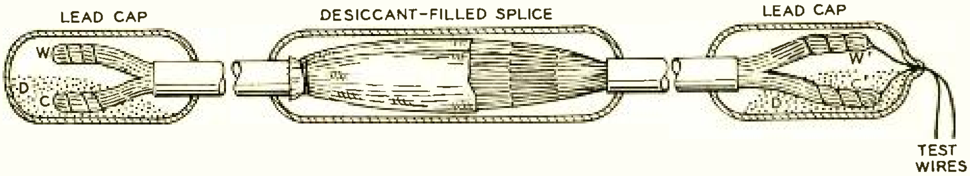


Fig. 1—In the laboratory method of testing desiccants the cable ends are prepared first. The white wires are separated from the colored wires of each pair and grouped (W, W', C, C') after which lead caps containing desiccant (D) are wiped on. The cable is then cut at the mid-point and spliced in an atmosphere of high humidity. Desiccant is introduced into the splice and a lead sleeve wiped on. The insulation resistance is then measured periodically as the desiccant dries the splice

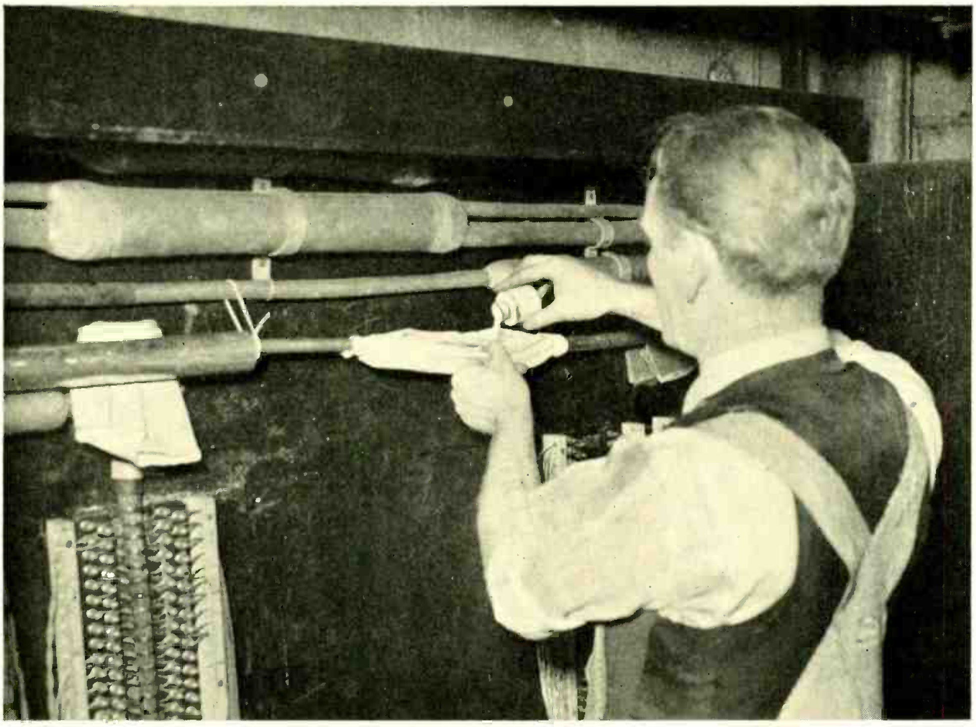


Fig. 2—Using desiccant in a cable splice. After the wires are joined a cradle of muslin is tied over the splice; part of the desiccant is then trickled into the spaces among the conductors and the rest placed near the sheath butts

Tardy recoveries of insulation resistance are of some import in determining methods of testing desiccant dried splices. If splices which are disposed to lag in recovery are tested when newly completed, they will not pass the standard insulation resistance requirement of 500 megohms per mile measured between any wire and all the other wires of the cable plus the sheath. However, in all field trials made to date this required insulation resistance has been attained or exceeded after a period of time.

The rapidity with which a desiccant can dry a splice depends not only on the amount of moisture present but on several other conditions which affect the ease of diffusion of the moisture from the insulation to the desiccant. Thus, small splices usually dry more quickly than large ones. Tight binding of splices, which usually cannot be obviated, tends to show up the drying rate. Paraffined insulation of sleeves give up their moisture more slowly than unwaxed ones. In fact, there is some evidence that the drying period of two or three weeks observed for certain large splices has been required because of the time needed to dry the paraffined sleeves.

Conventional technique in cable splicing includes the impregnation of the paper insulation with hot paraffin or a mixture of paraffin and splicing oil. This serves the double purpose of affording some protection against moisture and of stiffening the insulation so that it will break at the sharp bend where the two wires are first brought together. There is little

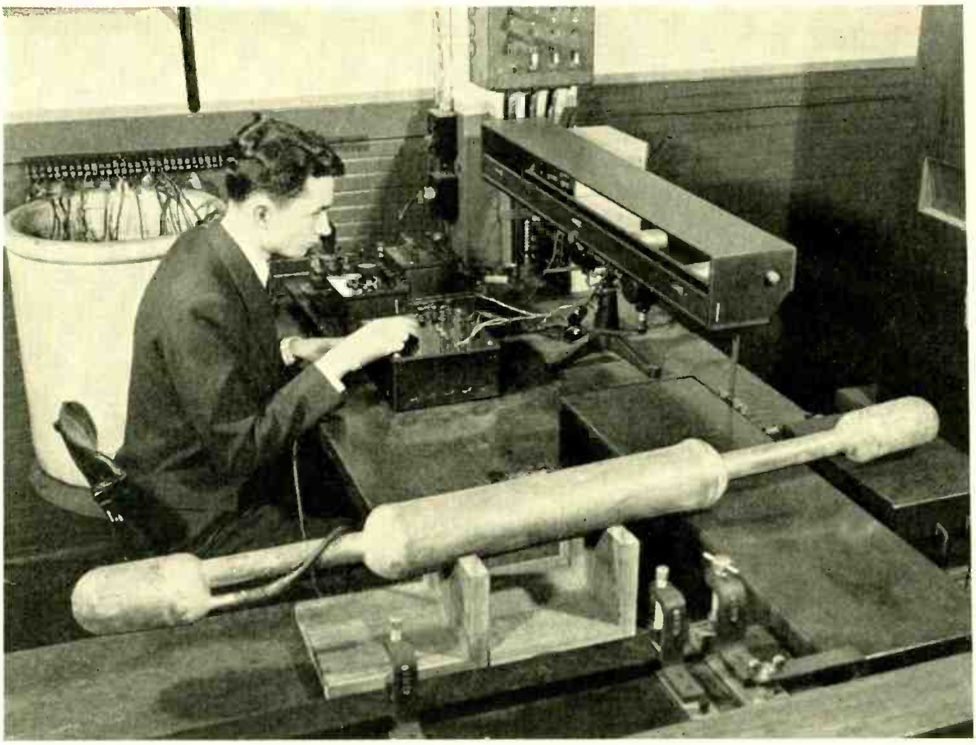


Fig. 3—Making a laboratory test of a completed splice filled with desiccant. The insulation resistance between conductors was measured at intervals while the desiccant absorbed the moisture given up by the insulation

doubt that much of the pulp insulation can be satisfactorily or at least reasonably easily stripped in splicing work without any oil or wax treatment. Some splicers, after a little practice, like to handle the insulation dry but others prefer it treated. However, there is a tendency for pulp insulation to toughen and become less easy to strip after exposure for several hours in a humid atmosphere.

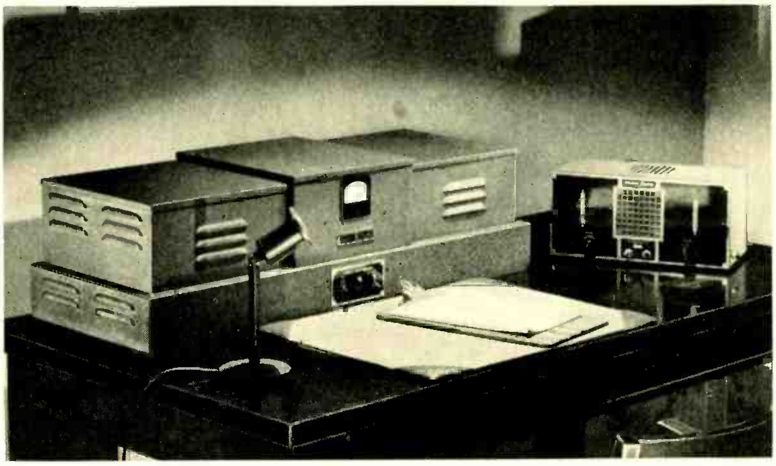
After trial of several materials, the one selected to aid insulation stripping was a light mineral oil a little heavier than kerosene, which has been denominated as "cold stripping" oil. A light oil of this type is quickly absorbed by and penetrates this paper insulation when applied cold and it is also less of a deterrent to rapid drying of the insulation than paraffin or heavy oil.

The method finally developed for applying the oil comprises application of the material with a paint brush if, when, where, and in the amount needed. The splicer starts the wire work with the insulation unoiled and unwaxed. If any group of wires on which he is working seems to need a stripping aid, he oils them by touching the oil filled brush to the wires at the point where he is crossing the wires to break the insulation for skinning. This scheme, which enables the splicer to control the time and quantity of oil application, has seemingly worked well in limited field trials. The headpiece of this article illustrates the method of applying the oil.

Apprehension was felt that the selected desiccant, being plaster of Paris in chemical nature, might harden into a rock-like mass in a splice if water got into it and a repair would become impossible. Reassurance on this point was provided by several laboratory experiments in which water was allowed to seep into desiccated splices slowly—at a rate such as would occur as a result of a defective wiped joint or the development of a small crack in the sleeve. Water admitted at such a rate began after 1 to 3 hours to lower the insulation resistance of some of the cable pairs to the point that trouble conditions would be indicated in a central office. Continued admission of water at the same rate would bring half or more of the conductor pairs to a troubled condition in another two hours. Ordinarily in plant maintenance during this additional two-hour period some attention would have been directed toward stopping the influx of water at the affected splice. In every experiment when the splices were opened at the end of the additional two hours, the desiccant could be shaken out without damaging the insulation and in every case the splice was restored to high insulation values by putting in fresh desiccant.

One associated telephone company in its work in urban sections has made fairly extensive trials of the desiccant drying method during and since its transition from the laboratory development stage. The method has been found to be so advantageous for work in buildings that it has already come into extensive use. It is also finding favorable applications in aerial and underground work, particularly in the case of old splices which have been boiled out so often that the insulation has become brittle. It has also been used successfully to dry out wet spots which have been caused by defective sheath.

A general field trial now in progress will largely determine the extent to which desiccant drying will find advantageous application. It is expected that the new method will be very helpful in indoor splicing work. In the telephone plant as a whole, the method will likely find more ready utilization in new cable installations than in maintenance work; and easier application to pulp insulated cables than to strip paper ones. There is no evidence of possible impairment of the quality of the cable plant by the proposed use of desiccant nor reason to expect any long-time change in the condition of dryness of splices. The degree of extension of desiccant drying to the aerial and underground cables would seem to depend largely on what experience teaches concerning its economics and its reception by the people who work with it.



22A Radio Transmitter

By W. K. CAUGHEY
Radio Development

THE use of radio communication by police has been steadily increasing since the entrance of the Western Electric Company into this field in 1930. The first transmitters were designed for the high frequencies just above the broadcast range, but more recently the use of ultra-high frequencies has proven particularly effective. In this very high frequency range there is available a five-watt car transmitter, and station-house transmitters of five, fifty, and 500 watts power, which were described in the RECORD for June, September, and November of 1935. The effectiveness of the car transmitter is generally acknowledged, and is indicated by the increasing use of this unit by police. The five-watt station transmitter is also popular, particularly in towns of small area. The fifty-watt transmitter and 500-watt amplifier are of more elaborate design, and meet the transmission requirements for installations in the larger communities. Lately, however, a demand has arisen for a headquarters medium-power station transmitter that will be low enough in cost to meet the economic restrictions imposed by conditions in many medium-size towns, and yet will incorporate many of the recent advances in radio-transmitter design.

A new transmitter, known as the 22A, has been developed for this purpose. It delivers twenty-five watts of carrier power into a coaxial transmission line throughout the frequency band 30-42 megacycles. Besides its power-output rating, the transmitter differs from other existing Western Electric police transmitters in many respects. A new mechanical design is used, which attains certain economies in manufacture and at the same time gives the transmitter a modern appearance. A high-gain audio amplifier is incorporated to permit the use of a low-level high-quality dynamic type of microphone. In the amplifier an automatic gain-control circuit reduces over-modulation, and provides other advantages that are inherent in such circuits.

The transmitter consists of a single chassis, on the upper surface of which all the equipment is mounted in three well-ventilated compartments with removable covers. Besides providing the necessary shielding, these compartments group the apparatus according to its function in the circuit. The left-hand compartment contains the power-supply apparatus; the center compartment, the radio-frequency equipment; and the right-hand compartment, the audio-frequency equipment. The operating controls are on the front of the chassis, and consist of a filament on-off switch with signal light, and a carrier-control key which turns on the carrier when operated downward, and provides a tone-signal for an "attention call" when operated upward. The radio-frequency output meter, located on the front of the center compartment, indicates the current at the input of the transmission line.

All connections to the transmitter are made through the bottom of the chassis. The power-supply and control conduits are run through the table top, and terminate beneath the transmitter, and the wires are provided with sufficient slack to allow the chassis to be readily tilted back so that the equipment on the under side may be inspected.

The antenna transmission-line connection presented an interesting problem because of the inflexibility of the seven-eighths-inch diameter transmission line and the requirement that this line must terminate very close to the output current meter, which is located near the top of the transmitter. Any appreciable length of

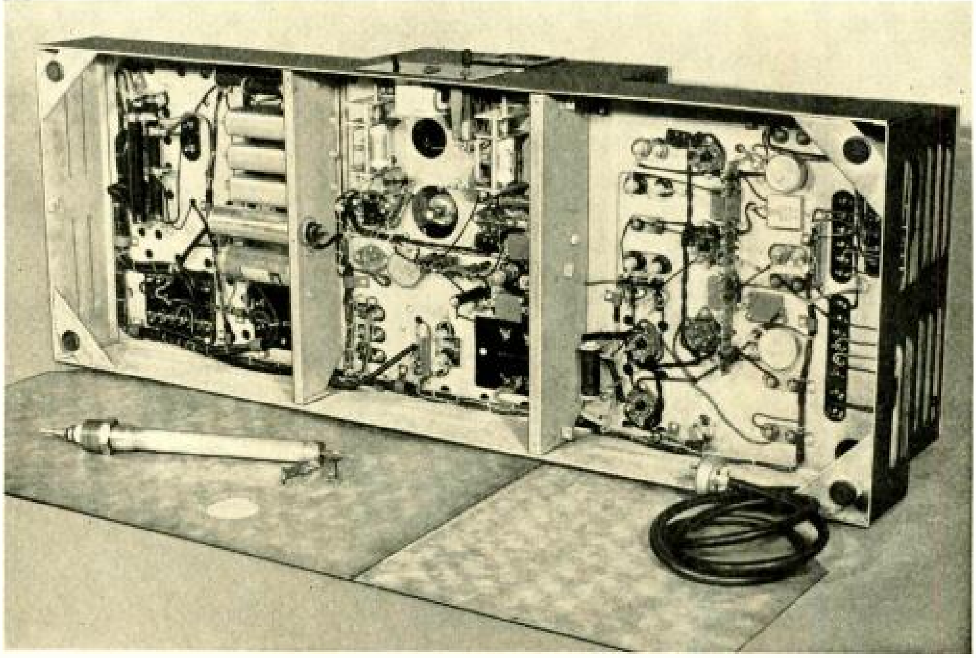


Fig. 1—The use of a short removable section of transmission line permits the transmitter to be tipped back for inspection

open lead to the meter would prevent it from indicating actual transmission-line current. A satisfactory solution was obtained by terminating the transmission line from the antenna in a junction box on the under side of the table top directly below the meter, and installing a short removable section of transmission line between the box and the output current meter. This short section of transmission line and the 22A Radio Transmitter, tilted back for inspection of the apparatus beneath the chassis, is shown in Figure 1.

The audio-amplifier section of the transmitter has a gain of approximately 100 db. Although this is considerably more gain than is used in the other existing police transmitters, it was obtained without undue expense by the use of resistance-coupled voltage amplifier stages employing high-gain receiver type tubes, and an audio-frequency power amplifier using tubes of the beam type. The gain is sufficient to give close-talking operation with a dynamic microphone such as the No. 633A.* A d-c microphone supply is incorporated in the unit so that either a double-button low-level or a single-button high-level carbon microphone can be used. Provision is also made for an input connection from a telephone line.

Although automatic gain-control has been applied to radio receivers for many years, the 22A is the first commercial transmitter to take advantage of it. In this transmitter, the control is effected automatically in the audio amplifier, and reduces the gain of the amplifier when the applied signal level exceeds a certain amount. Its action is analogous to that of the 110A amplifier already described in the Record.† The circuit compensates to a large extent for excessive variations in level of the speech input, reduces distortion due to over-modulation, and allows an increase in the average percentage of modulation. For police application, where a monitoring operator is not ordinarily employed, this feature is a distinct advantage, since it automatically controls the irregularities and differences in speech characteristics of car dispatchers, who may talk

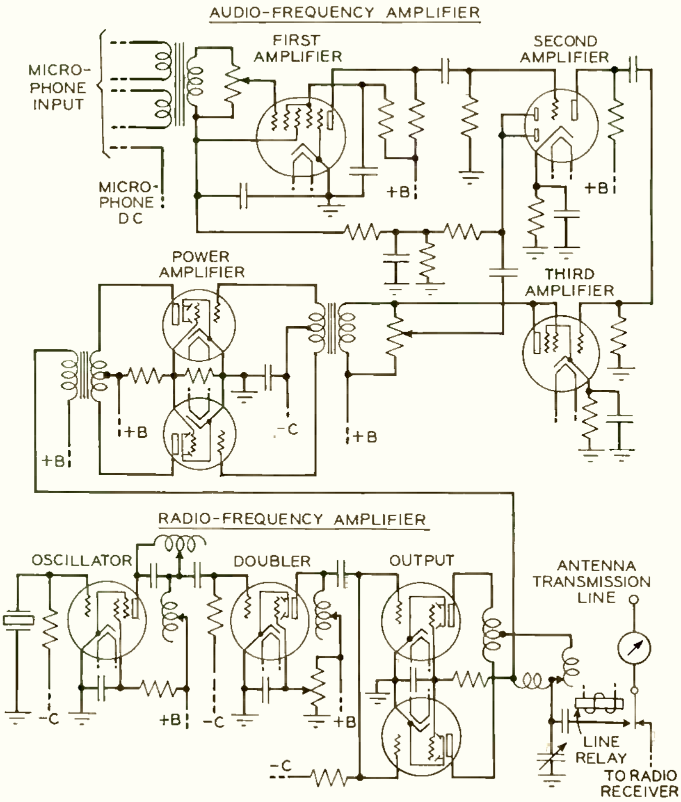


Fig. 2—Simplified schematic of the 22A radio transmitter

---

*Record, *November*, 1937, *p.* 80.

†Record, *January*, 1938, *p.* 179.

at various loudness levels and at different distances from the microphone.

A simplified schematic of the transmitter is shown in Figure 2. The audio-frequency amplifier, shown in the upper part of the diagram, supplies the audio power necessary to completely modulate the carrier. It consists of four stages of amplification, two resistance-coupled and two transformer-coupled. The automatic gain control is effected by feeding back a portion of the audio-frequency voltage in the plate circuit of the third amplifier, rectifying it in the diode section of the second amplifier and applying the resultant d-c voltage as a bias voltage to grids 1 and 3 of the first amplifier. The characteristics of this latter tube are such that the amplification can be varied over a large range without introducing excessive distortion, simply by varying the bias voltage applied to the first and third grids. Figure 3 shows the static characteristics of the automatic gain control of the transmitter as measured with a tone signal. The diode rectifier in the second audio-amplifier tube is biased by the voltage drop across the cathode resistor, so that rectification occurs only for signals having a peak amplitude in excess of this voltage. This produces the change in slope in the characteristic curve. The amplifier operates normally and at full gain until the signal applied exceeds a certain value, −70 db in Figure 3; beyond this point the gain is automatically reduced.

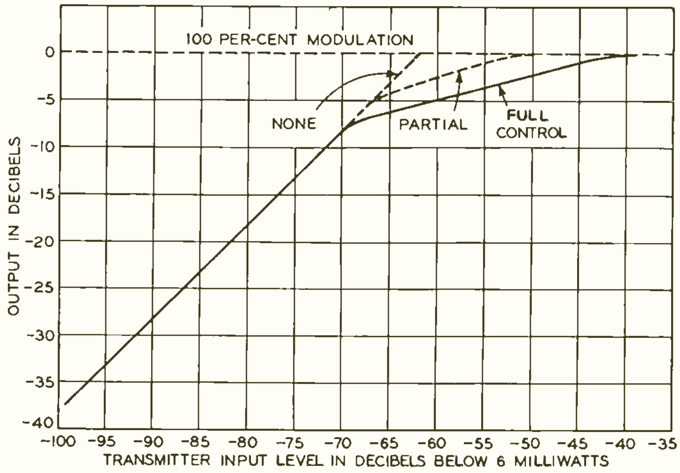


Fig. 3—Automatic gain-control characteristics

The audio amplifier in this transmitter may be converted into an audio oscillator to transmit a distinctive tone-signal for the attention call when the circuit is changed by the operation of a relay. This relay may be contolled either by the manual tone-carrier key located on the front of the transmitter, or by a semi-remote control switch. When the relay is energized, a series-resonant tuned circuit is connected between the cathode circuit of the second amplifier stage and the plate circuit of the fourth, or audio-frequency, power amplifier stage.

The radio-frequency equipment consists of a crystal-controlled oscillator employing a pentode tube operating at one-fourth the carrier frequency, a doubler stage using a beam-type power tube, and a radio-frequency output stage employing two beam-type tubes connected in parallel. Continuously variable inductors are used for tuning the various radio-frequency circuits, thus maintaining high efficiency over the frequency range of the transmitter without the use of plug-in coils. These inductors are adjusted by a screw-driver from the front of the panel. The potentiometer connected in the screen-grid supply circuit of the doubler tube provides a radio-frequency gain control to compensate for output variations of the oscillator. Of particular interest is the use of a center-tapped inductor between the plates of the parallel-connected tubes of the radio-frequency output stage, to prevent parallel singing without introducing appreciable inductance or loss at the operating frequency.

The power-supply equipment is of conventional design employing two separate rectifiers, one for the plate supply and one for the grid-bias, microphone, and control circuits. The use of the grid-bias supply for energizing the control circuit of the plate-supply rectifier provides a simple safety method to insure grid-bias voltage when the plate-supply rectifier is operating.

One of the interesting features is the method of measuring tube currents for tuning the transmitter. Instead of incorporating milliammeters, three pairs of pin jacks that accommodate the test prods of a voltohmmeter are mounted in the center compartment. The pin jacks are connected to meter resistors in the essential circuits of the transmitter, and are of such value that only the zero-to-three volt range of the voltohmmeter is used, and multiplication factors are employed to obtain actual current measurements. This arrangement is a definite saving to the customer since a voltohmmeter is usually on hand for servicing radio equipment.

◆

Demonstration of Clearance Indicator for Airplanes

An airplane's clearance above the terrain has heretofore been determined by subtracting the terrain altitude above sea leavel, as read from a map, from the plane's altitude as read from an aneroid barometer. Should the pilot be ignorant of his location, his estimate of his clearance may be widely in error; barometric irregularities are a further source of inaccuracy.

A terrain clearance indicator which reads directly and continuously in feet, from 50 to 5000, has been developed in Bell Telephone Laboratories. Public demonstrations were recently made in a plane of United Air Lines. It operates on the principle of a radio echo from the terrain. Frequency of the outgoing wave is varied according to a straight-line curve. The return wave, being delayed by transit to the terrain and back, has the frequency of an earlier epoch; how much earlier is determined at every instant by the difference in frequency of the outgoing and the returning wave. This difference is then proportional to the length of path. It is determined by generating a "difference frequency" by modulation and measuring that frequency with a meter.

Time Intervals in Telephone Conversation

By O. J. MURPHY
Circuit Research

IN A telephone conversation one party normally speaks for a short time, pauses and the other party replies. In many instances, however, the process is not so orderly; one speaker may pause and then resume speaking or the listener may begin to reply without waiting for the end of the talker's speech. In any case the time-pattern of the conversation may be described in terms of three elements: "talkspurts" during which there is speech by one party or the other, pauses within talkspurts, and pauses between talkspurts by alternate parties. These latter two elements have been called resumption times and response times. The magnitude of these time intervals is of importance to the telephone engineer, particularly in toll circuits equipped with automatic voice-operated devices which restrict conversation to one direction at a time.

By making oscillographic records of telephone conversations these factors have recently been studied at the Laboratories. The conversations took place on a circuit between Chicago and New York which was used only for Bell System business. Recordings were made with a six-string rapid-record oscillograph* whose strings were energized by speech power from the two talkers and by control cir-

---

*Record, *Aug.*, 1930, *p.* 580; *Jan.*, 1935, *p.* 145.

cuits. This arrangement is indicated in Figure 1, the particular circuit configuration shown having been set up for other tests which were going on at the same time. The machine was started at the beginning of each call and run continuously at a speed of about twenty feet of film per minute. This arrangement gave a complete pictorial record of the conversational interchanges.

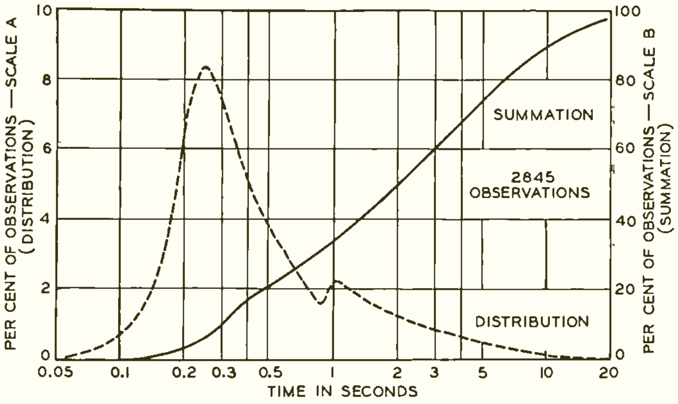


Fig. 2—The talkspurt which occurs most frequently lasts 0.25 *second. The average value is approximately four seconds*

Sample oscillograms are shown in Figure 3. The speech energy is given on traces three and four counting from the top down, the upper being from Chicago and the lower from New York. The cyclic waves on string two indicate lockout, which is the simultaneous blocking of transmission in both directions by voice-operated devices. Traces five and six show when control of the circuit, i.e. operation of both echo-suppressors, was held by the talker at Chicago and New York, respectively. These traces were made by an oscillator which was used concurrently to drive an escapement-type electric clock for measuring the total duration of the call.

The oscillogram at the top was selected to show the simplest type of conversational interchange. New York had been talking but had reached the end of his talkspurt. Approximately 0.4 second later Chicago responded. His talkspurt apparently consisted of three syllables, and then after about 0.3 second New York responded and continued to talk. The second film was selected to show a less simple type of

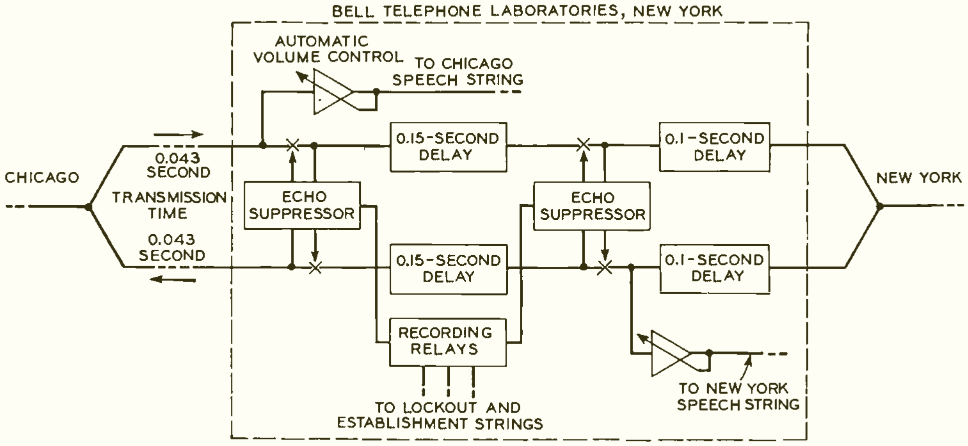


Fig. 1—Schematic of the circuit used in recording with an oscillograph the time intervals occurring in telephone conversations

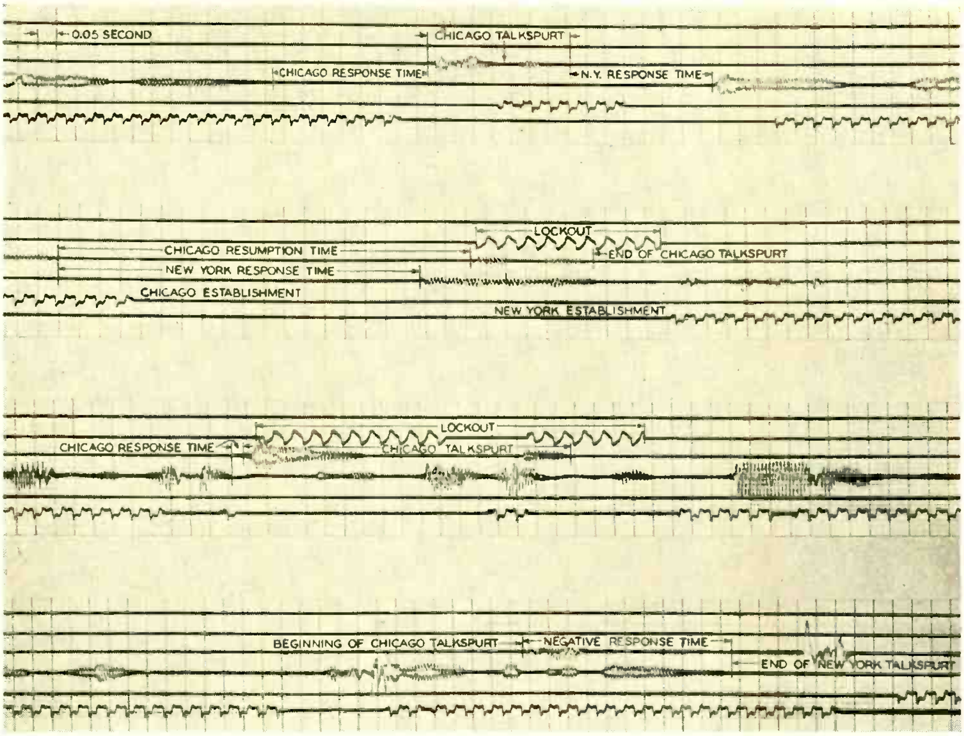


Fig. 3—Oscillograms of talkspurts are shown on traces 3 and 4. Trace 2 indicates when lockout occurred. Traces 5 and 6 show when the control of this circuit was held by the talker at Chicago and New York, respectively

interchange wherein a long pause within the talkspurt prompted the listener to reply. In this instance the time intervals were such that a lockout resulted. Since the remainder of the talkspurt by the original talker, Chicago, was short and the responding party, New York, continued talking, the circuit was established in New York's direction after the lockout. In the third oscillographic strip a response was again induced by a long pause, but the interrupting party did not gain control of the circuit. This is an example of concurrent talkspurts. The fourth example was chosen to illustrate a negative response time. In this case Chicago began to reply before the end of New York's talkspurt; no lockout occurred, but the first part of the reply was lost be-

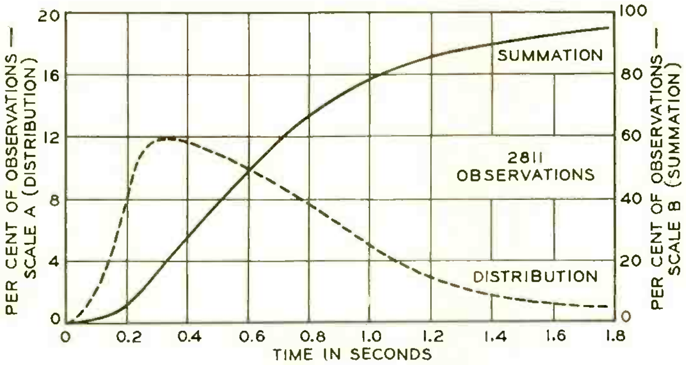


Fig. 4—Duration of pauses during talkspurts. Most frequent occurrence .35 second; average time about 0.7 second

cause the circuit continued to be established in the opposite direction.

The speech traces shown in Figure 3 were recorded at New York. The party responding at Chicago heard the previous talker not at the time shown on the film but two-tenths of a second later, because the circuit introduced that delay in transmission. Likewise his response from Chicago did not begin at the time recorded but about four-hundredths of a second earlier. The apparent response times were corrected for these delays when the results were computed.

Observations were made on fifty-one calls which totaled a little over 13,000 seconds. At the recording speed of 20 feet per minute this gave about 4,400 feet of oscillograms. In all cases recording began at the start of the call but in some instances the film ran out before the termination of the call. The oscillograms, which ranged in length from 29.6 to 660.8 seconds, represented calls whose mean duration was 430.5 seconds. The speed of recording was such that the time intervals of the talkspurts and pauses could readily be measured with a precision of 0.01 second. These data from each of the calls were tabulated by grouping together values which fell within each of a regular progression of time intervals. The results were plotted as time-distribution curves and are shown in Figures 2, 4, and 5.

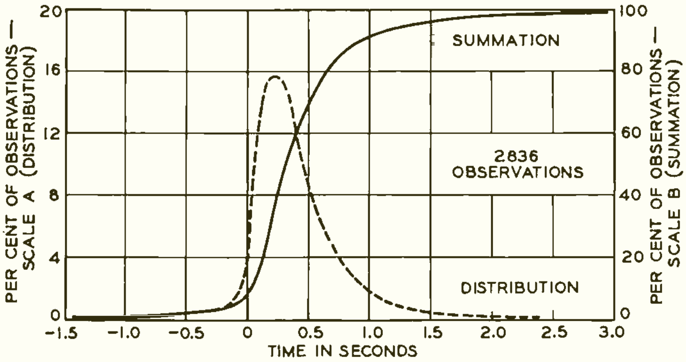
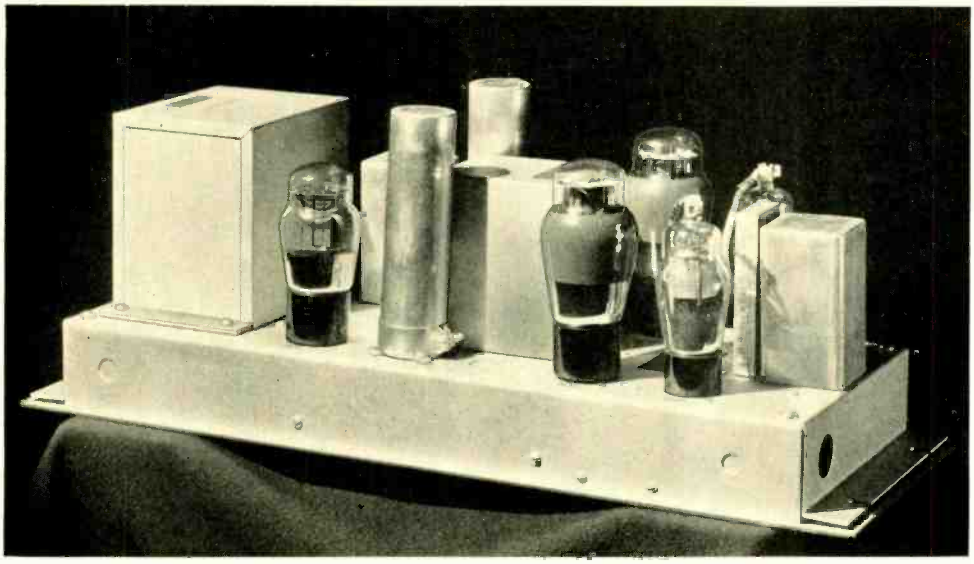


Fig. 5—Duration of the pause between a talkspurt and the reply. Most frequent occurrence 0.25 second; average time about 0.4 second. About 7% of the pauses are negative and represent a reply before the end of speech by the first party

Talkspurts only 0.25 second long occurred most frequently which indicates that monosyllabic replies are by far the most numerous. The summation curve of Figure 2 shows that these monosyllables, together with terse replies or questions under one second in duration, constitute about a third of the talkspurts. There were a few very long talkspurts: 27 exceeded 30 seconds, and of these 2 were over 120 seconds long. During the longest talkspurt, which lasted 143.82 seconds, there were 62 resumptions of conversation following silent intervals ranging from 0.34 to 4.04 seconds. About 60 per cent of the talkspurts contain no pauses; these comprise all the monosyllabic replies and about half the longer talkspurts. When talkspurts with a given number of resumptions are sorted according to length, almost all talkspurts which have no resumptions are under 6 seconds. In the longer talkspurts resumptions occur about every 3⅓ seconds. The total time taken by resumptions amounts to about 17 per cent of the total talkspurt time.

A preliminary study under different conditions gave results that agreed with these data. This suggests that the time intervals found here are characteristic of American telephonic speech.



The New 94-Type Bridging Amplifier

By J. B. HARLEY
Commercial Products Development

WITH the widespread practice of providing additional facilities in radio broadcast studios for simultaneous rehearsal and audition purposes,* loudspeaker monitoring systems rose to greater prominence. These systems have become in effect complex loudspeaker distributing systems for executives, sponsors, and remote studio audiences. Amplifiers, which naturally form an essential part of such systems, required more careful consideration; and switching requirements became more rigid—distribution at telephone levels becoming mandatory to avoid possible cross-talk between program and monitoring systems. To provide more satisfactory apparatus to meet these changed conditions, the Laboratories developed the 94A and 94B amplifiers, which have found extensive use. Experience over the last few years has indicated certain desirable changes, however, and to provide them the 94C and 94D amplifiers have now been made available. In all essential features these new amplifiers are the same as the two previous ones; the major modifications are the use of more efficient tubes, which may be either of the glass or metal type, more effective shielding, and the increase in output power from 8 to 12 watts, or with modifications to 20 watts.

It is essential that such amplifiers be adapted for bridging across low-level high-quality program circuits without affecting the transmission over these circuits. They are thus designed with a high input-impedance, and to make them independent of the impedance of the program circuit, the input transformer is so designed that

---

*Record, *September*, 1934, *p.* 2.

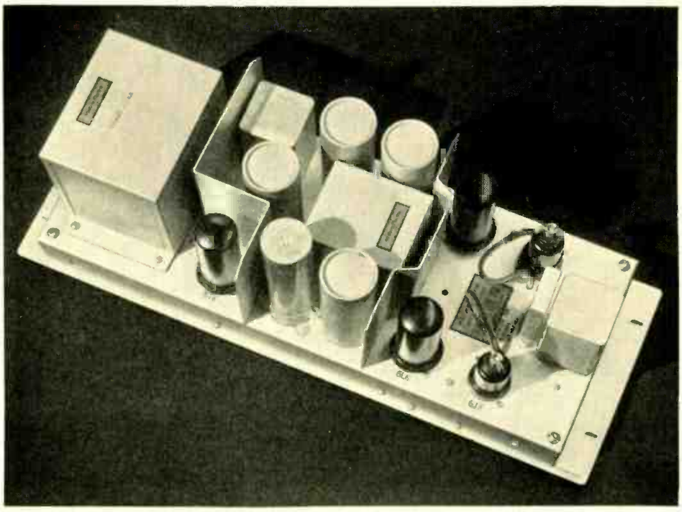


Fig. 2—The 94C amplifier arranged for a 20-watt output

the maximum deviation of the amplifier in either direction from a flat frequency characteristic is less than 2 db at any frequency from 35 to 10,000 cycles, when working from impedances ranging between 0 and 12,000 ohms. This gives them a wide application, since they may be connected across almost any circuit without the use of special input transformers. It is essential also that the amplifiers be capable of use with loudspeakers in rooms varying in size from a small monitoring booth to a medium size auditorium, and their gain, noise level, and output should be adequate for this range of service. Besides their application to radio broadcasting studios, they are suitable as monitoring amplifiers for telephone or sound-recording systems, and they may be used in conjunction with a carbon microphone to form announcing or paging systems. In such service the 94-type amplifier could drive loudspeakers in from twenty to thirty school rooms or in from 100 to 150 hotel rooms.

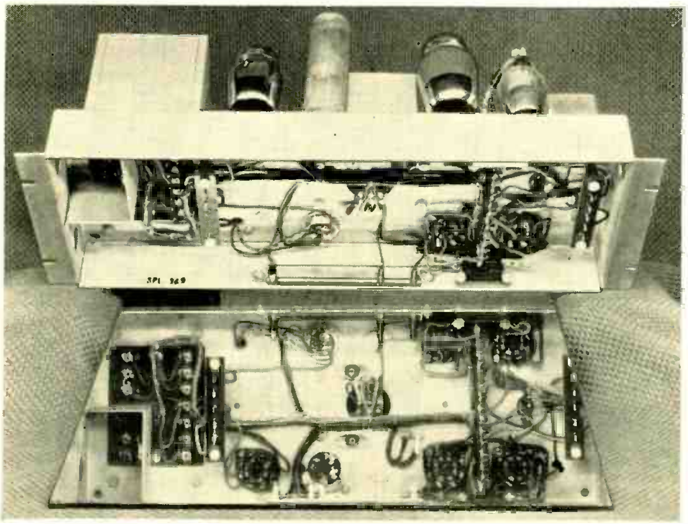


Fig. 1—Although occupying but seven inches on a relay rack, the chassis of the 94C amplifier is not crowded, as is evident from this photograph of the underside of the chassis

The 94-type amplifier is intended for relay-rack mounting, but its recessed panel construction* adapts it also for mounting in a carrying case or cabinet with the mat side down, as shown in the photograph at the head of this article. Although it occupies but seven inches on a relay rack, the apparatus is not crowded as may be seen in the view of the underside of the chassis shown in Figure 1, where the mat that forms the front of the amplifier when it is

---

*Record, *July*, 1938, *p.* 383.

mounted on a relay rack has been removed. These photographs are actually of the 94C amplifier, but the 94D differs only in incorporating a power switch, and a gain control in the form of a potentiometer connected ahead of the input transformer. When the amplifier is mounted on a relay rack, these are arranged to project through the front mat, but for carrying-case mounting they may be installed in the side of the chassis in knock-outs provided.

The circuit arrangement of the amplifier is shown in Figure 3, where the gain-control potentiometer and power switch are shown in dotted lines. Two stages of amplification are employed, using pentode tubes in a push-pull arrangement. Those in the second stage are of the "beam" type, as indicated by the unusual symbol employed for their suppressor grid. Either metal tubes or their glass equivalents may be used throughout. The resistance of the gain-control potentiometer is 25,000 ohms, which is high enough not to interfere with the use of the 94D as a bridging amplifier.

The two-stage push-pull arrangement makes for a balanced circuit, which minimizes interference, and gives stability and increased freedom from harmonic distortion. The balanced structure is carried over into the input circuit where a balanced transformer that is electrostatically shielded connects to the input terminals through two 5000-ohm resistances, which with the unterminated secondary of the transformer provides the high input impedance essential in a bridging-type amplifier. Stabilized feedback* is employed not

---

*Record, *June*, 1934, *p.* 290.

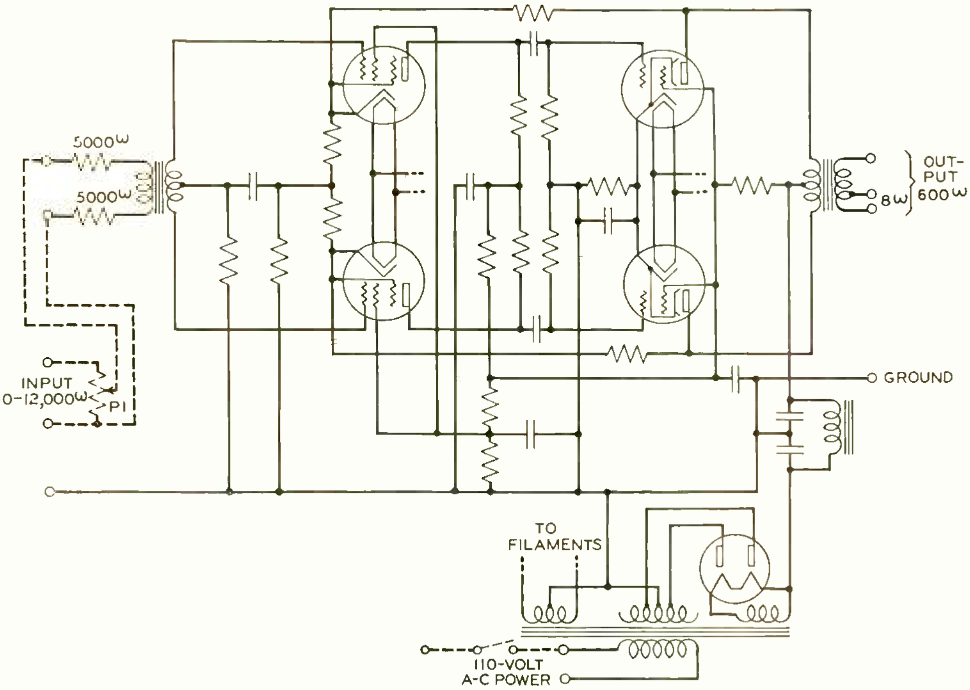


Fig. 3—Circuit arrangement of the 94C amplifier. The addition of an input potentiometer and a power switch, shown in dotted lines, converts it to a 94D

only to reduce harmonic distortion generated within the amplifier, but to correct to some extent for variations in the load impedance arising from the many mechanical resonance peaks of the loudspeakers.

Measurements on the 94C and D amplifiers made over a range of fundamental frequencies of 50-3000 cycles show that they will deliver twelve watts to a nominal load impedance of either eight or 600 ohms with less than five per cent total harmonic distortion arising from any of these fundamental frequencies. At lower output levels, the harmonic distortion decreases, and at six watts is about one per cent. The output noise level, unweighted, is better than 40 db below six milliwatts, and is 60 db below when measured with a program noise meter,* which is based on the audibility characteristic of the ear. By a careful selection of tubes it is possible to drop the unweighted noise level to 60 db below reference. Although nominally rated at twelve watts, the output of the new amplifier may be increased to twenty watts by a few minor changes, including a rearrangement of the condensers and the addition of two heat shields. Figure 2 shows the amplifier arranged for this larger output.

Neither input nor output impedances are critical. The variation in gain of the amplifier as the impedance across which it is bridged is varied from two to 12,000 ohms is shown in Figure 4. The output transformer has taps for connection to load impedances of approximately eight or 600 ohms; the former connection is used for direct connection to moving-coil loudspeakers, and the latter for connection to program circuits or high-impedance loudspeakers. There is very little variation in the power delivered to loads between four and sixteen ohms on the low-impedance tap or to loads between 250 and 1000 ohms on the high-impedance tap. This ability of the amplifier to be used over wide ranges of circuit impedance, together with its liberal gain and output, makes it suitable for many applications other than the broadcast monitoring for which it was primarily designed.

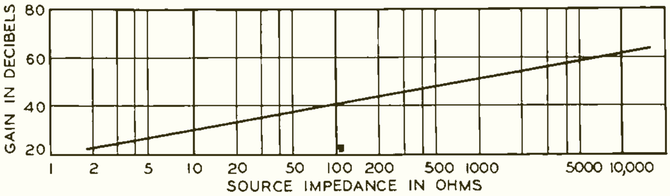
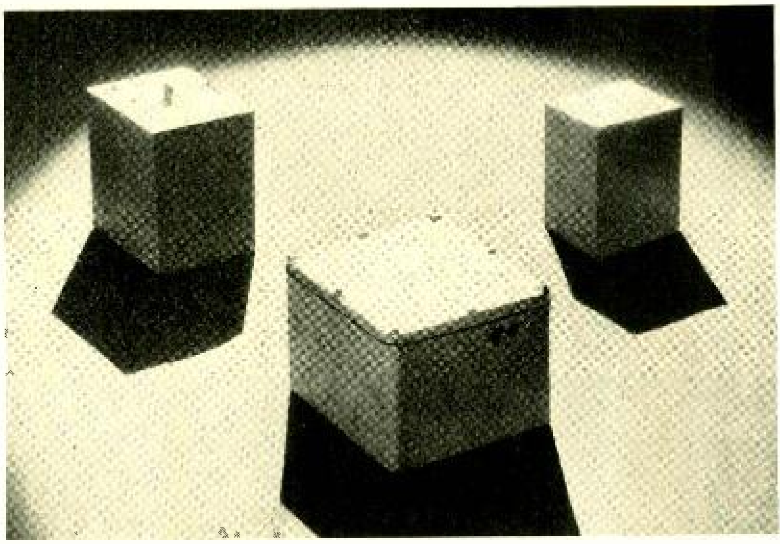


Fig. 4—Variation in gain of 94C amplifier as the input impedance changes from 2 to 12,000 ohms

---

*Record, *March,* 1936, *p.* 233.



Magnetic Shields

By W. B. ELLWOOD
Physical Research

SHIELDS are often used to protect electric and magnetic apparatus from stray magnetic fields which come from neighboring equipment, or even from the earth's field. Iron boxes have served this purpose for over a century and many investigations have been carried out to determine their shielding characteristics. The results are not well known, however; and since new magnetic alloys far superior to iron for shielding have recently been developed the subject justifies reviewing.

The mechanism of shielding may be illustrated by the line-of-force diagram of Figure 1, where a cylindrical shield is shown at right angles to a uniform horizontal field in the plane of the diagram. The lines of force are diverted at the boundaries of the shield from the space within because the shield offers a path of less magnetic resistance. Not all of the lines are eliminated but by careful design the residual field inside can be made very small. In the attempt to obtain effective shielding heavy cast iron or permalloy boxes have often been used, but thin shields are actually more effective per unit weight than thick ones and the shielding can be increased considerably by using several concentric shields with air space between adjacent units. Multiple shields are better because they have more boundary surfaces to deflect the field.

The theory of shielding design involves an equation which expresses the ratio of the original field at any point to the field at the same point when protected by the shield. This ratio, usually designated as "G," is a function of the magnetic properties and geometrical distribution of the material employed to form the box or boxes which constitute the shield. The equation can be solved for only a very few practical cases, and the problem of shield design thus reduces to the proper choice and fabrication of materials to fulfill as nearly as possible the requirements of the mathematical theory within the economic and space limitations prescribed.

The simplest practical case amenable to theoretical treatment is that of a single spherical shell surrounding the device to be shielded. An approximate formula for the shielding ratio is $G = \frac{2\mu}{9}(1 - \beta^3)$. In this formula μ is the reversible permeability of the material as measured ballistically in a ring specimen and is assumed very much larger than unity. The ratio of the internal to the external radii of the spherical shell is β. For an infinitely long cylindrical shield magnetized perpendicularly to its axis the ratio is $G = \frac{\mu}{4}(1 - \beta^2)$. Experiment has shown that G is reduced only by a factor of two in some cases, as for instance when the field is parallel to the axis.

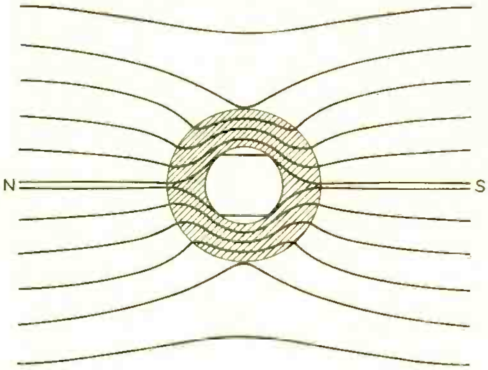


Fig. 1—A magnetic shield diverts most of the lines of force from the space inside the shield because it offers a path of less magnetic resistance. The lines of force are refracted at the boundaries of the shield

The values of G versus $1/\beta$ for silicon steel shields in these two forms are shown in Figure 2, curves A and B. Shells which are geometrically similar though of different size have the same shielding ratio. Curves A′ and B′ give the relative shielding per unit weight of material. For a value of $1/\beta$ equal to 1.15 the shielding ratio is twenty; beyond that point the shielding per unit weight falls off so rapidly that thicker shields are uneconomical.

The curves of Figure 2 are for a silicon steel for which the initial permeability is about 400. By using 3.8 per cent molybdenum permalloy, which has an initial permeability of approximately 20,000, a shielding ratio fifty times greater can be attained. Thus a shielding ratio of more than 1,000 is now obtainable with a single permalloy shield of economical dimensions.

The cylindrical shields just discussed were assumed to be infinitely long to eliminate end effects, but it has been found experimentally that a cylinder with a ratio of length to mean diameter of 1.25 gave about sixty per cent of the shielding of the infinitely long cylinder. Closing the ends of the shield with plates of the same material increased this to eighty per cent.

Shields are ordinarily employed to protect against stray external fields, but they may also be used to prevent neighboring parts from being affected by the apparatus inside the shield. Thus the magnetic field set up by relays, inductance coils, transformers and permanent magnet structures may be practically restricted to a definite region by surrounding them with a shield. Equal and opposite magnetic poles, however, must be included within the same shield, since there is no shielding effect if only one pole is enclosed. A pair of straight parallel wires which carry and return a current, for example, may be shielded by enclosing the wires in a cylindrical tube of magnetic material. If such a pair, occupying a space 1/10 centimeter in radius, is provided with a shield with walls 0.015 centimeters thick and $\mu = 500$, the shielding ratio will be approximately 30.

If greater shielding is desired than can be provided by a single shield and if the ratio of the external to the internal diameters of the shield may be greater than 1.5, multiple concentric shields may be employed. With them almost any amount of shielding can be attained except for the limitations of space and cost. The design of multiple concentric shields is very complicated. In general the shielding factor of a system of two concentric shields is roughly equal to the products of their individual shielding ratios multiplied by the ratio of the volume of the air space between them to the volume occupied by the shield system. This relation does not apply where the clearance space between shields is small. No great advantage is gained by multiple shielding unless the volume occupied by the shielding system is more than four times the volume to be shielded. For example, if the shield shown in Figure 1 were made of silicon steel ($\mu = 400$), the shielding ratio, G, would be approximately eighty since the ratio of the internal to the external radii is two. The shielding ratio could be increased to more than 500 by using two concentric shields of silicon steel separated by an air space, if the ratio of successive radii were 1.26, i.e. 1:1.26::1.6:2. This would require about thirty per cent less material. If instead of two shields separated by a single air space we divided the steel into four shields separated by three air spaces, with successive radii in the ratio of 1 to 1.1, the shielding ratio would become 2000. The shielding obtainable by using one of the shells of the double shielding system of silicon steel would be about thirty-eight; for the quadruple system a single shell would give about eighteen.

In a single shell the shielding is proportional to the permeability of the material. For multiple shields, however, the shielding varies roughly as μ^n where n is the number of shields. This shows the advantage of using a high-permeability material such as 3.8 molybdenum permalloy with its initial permeability of 20,000.

Remanent magnetization of the shield material will cause it to produce a steady field in the absence of an external field but this field may be

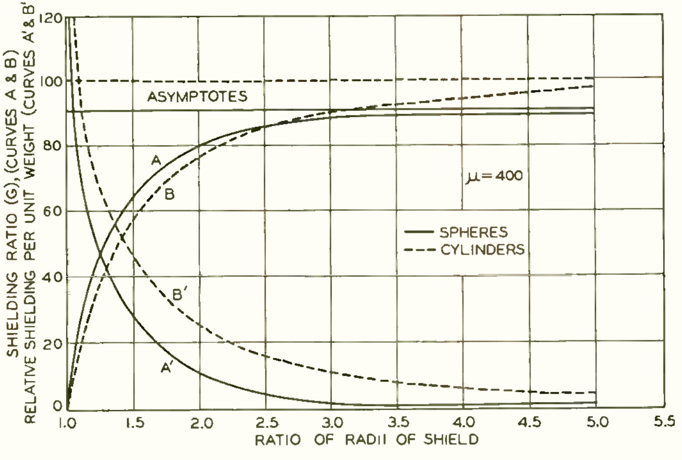


Fig. 2—The effectiveness of a magnetic shield depends not only on its permeability but also on the thickness of its walls. These curves show, however, that it is not economical to use very thick shields. Multiple shields are preferable when space permits

compensated by that of another permanent magnet.

The theoretical considerations presented here have assumed constant fields but they can also be applied with caution to alternating or transient fields provided the material is sufficiently laminated. Shielding against transient or alternating fields is sometimes impaired by having the material as a thick unlaminated wall. Eddy currents are then induced and may prevent the instantaneous change in magnetization of the shell walls which is needed to compensate for the changing field. Under those conditions it is desirable to laminate the material in a direction to eliminate the eddy currents. In practice, shields have been made of piles of ring stampings separated by insulation or of a long spiral of material with insulation between turns. For a sufficiently short cylinder the effect of eddy currents in a ferro-magnetic shield is to decrease its efficiency as the frequency increases. On the other hand for a non-ferromagnetic cylinder the efficiency increases with increase in frequency. The two effects may be superimposed in any practical case. A combination of a copper shell inside a ferromagnetic shield will produce a shield good for all frequencies as well as for steady fields.

Magnetic shields should have high permeability in the range of field intensities to which they are subjected and for this reason several of the new magnetic alloys are especially useful as shield materials. If the field to be shielded out is very small, 3.8 molybdenum permalloy may be used because of its high permeability, high resistivity, and the fact that it can be obtained in sheet form. One heat treatment will produce the desired properties. A single shield having a shielding ratio of 1000 may be made of this material and where multiple shields are used, ratios of more than 1,000,000 can be obtained. For intermediate fields up to five gauss the perminvars are suitable, especially where the effects of residual magnetization must be minimized and the field must be uniform, because these alloys have low remanence and constant permeability. If shielding is used at high fields, 50:50 iron-cobalt alloy is preferable since it has high permeability at high flux densities.

◆

The John Fritz Medal for 1939

has been awarded to Dr. Jewett for "vision and leadership in science and for notable achievement in the furtherance of industrial research and development in communication." This medal is awarded annually by a board composed of four representatives of each of four national engineering societies. Among previous recipients of the medal were Alexander Graham Bell, Thomas A. Edison, Guglielmo Marconi, John J. Carty and Michael I. Pupin.

Magnetic Shields for Transformers

By W. G. GUSTAFSON
Apparatus Development

TRANSFORMERS and coils used in telephone repeaters, and in the amplifiers of sound-picture and public-address systems, are frequently designed with magnetic shields. Otherwise, disturbing fields caused by neighboring power equipment or by other amplifiers in the vicinity would induce voltages in the windings of the transformers and coils which would introduce noise and deteriorate the quality of the amplified sound. As the gain of amplifiers has been increased, and also the demand for good quality, shielding has become increasingly important to protect against such fields.

A transformer may be shielded by a case of high permeability. The shielding effect can be calculated with the aid of general theory; but the calculation assumes theoretically ideal conditions and is only an approximation for any actual design. The factors which determine the shielding efficiency are the mechanical construction of the case and of the core inside. Experience and theory, however, taken together enable the design engineer to make estimates satisfactory for practical purposes.

The effectiveness of a shield at any point is measured by the ratio between the original magnetic field to the field at the same point when protected by the shield. With transformers, however, where the primary interest is the disturbing voltages produced in the windings, it is convenient to define the shielding efficiency in

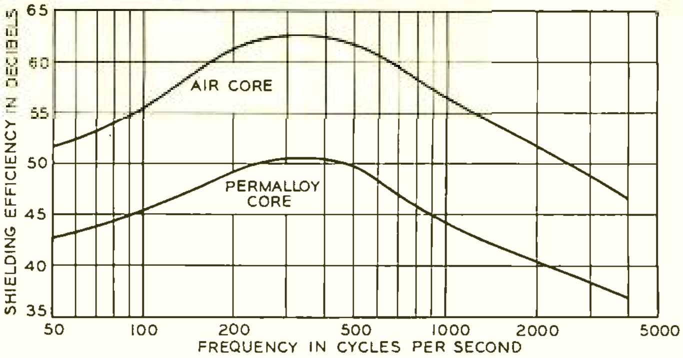


Fig. 1—Shielding efficiency of a rectangular case of five contiguous layers of sheet permalloy .014″ thick

terms of voltages induced with the shield and without. The shielding efficiency in decibels will then be 20 log E_e/E_i where E_e is the terminal voltage due to the disturbing magnetic field with the shield removed and E_i the corresponding voltage with the transformer inside the shield. In addition, for the sake of definiteness, the transformer is assumed to be in the angular position with respect to the direction of the magnetic field, which gives the maximum terminal voltage. In the case of an unshielded shell-type transformer, for example, this angular position would be that in which the axis of the winding coincides with the direction of the disturbing field.

The shielding efficiency versus frequency of a rectangular permalloy case, consisting of five successive layers of permalloy sheet 0.014 inch thick, is shown in Figure 1. These curves illustrate the effect of the core material on the shielding efficiency. In both cases the shielding at low frequencies is due mainly to the permeance of the shield, but at higher frequencies also to eddy currents. At approximately 300 cycles a maximum is reached and beyond that the shielding efficiency decreases because the effective permeability of the walls of the shield decreases faster than the shielding efficiency due to eddy current increases.

The curves of Figure 2 show shielding efficiency versus frequency for cylindrical cases, of permalloy and of silicon steel, with walls 1/32 inch thick. Comparison between the curves shows the great advantage of permalloy over silicon steel and also the increase in shielding that is gained by adding a cover.

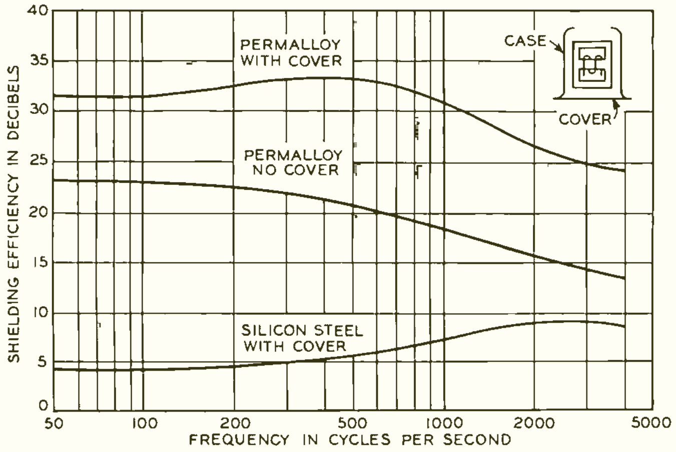


Fig. 2—A permalloy case $\frac{1}{32}''$ *thick even without a cover is a much better shield than is a case of silicon steel*

Figure 3 gives the shielding efficiency versus frequency for a copper cylinder 1/16 inch thick. The shielding efficiency in this case is due entirely to

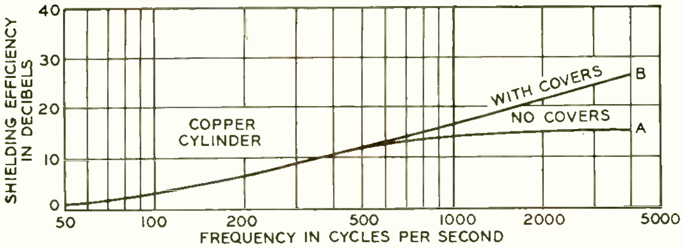


Fig. 3—Shielding effect of a copper cylinder is due to eddy currents and is approximately proportional to the frequency

eddy currents and curve B shows that it is approximately proportional to frequency, after the effect due to the open ends of the cylinder is eliminated by adding covers. Although copper gives a very low shielding efficiency at low frequencies when used alone, it is very effective under certain conditions as will be noted later in connection with Figure 4.

A shielding efficiency of 20 to 50 db is generally sufficient for transformers but occasions arise when much greater shielding is desired. To accomplish this by a single layer is impracticable with magnetic materials commercially available, and recourse is, therefore, to multiple shields as illustrated by Figure 4. Curve B in this figure gives the shielding efficiency of a permalloy cylinder which has an effective alternating-current permeability of approximately 5000 at low frequencies and flux densities. This cylinder has a wall thickness of 0.07 inch and the efficiency would be only slightly greater if the thickness of the wall were increased. However, by adding another cylinder, a substantial improvement is obtained, as shown by curve C. Still greater shielding is given by three cylinders as shown by curve D. The dimensions of the second and third cylinders were such that the ratios between the outside and inside radii of the three cylinders and of the air-gaps between them were approximately in geometric progression.

The effect of the copper cylinder between two permalloy cylinders, as shown by curve E, is an increase of from 15 to 20 db for frequencies between 50 and 500 cycles per second. A further gain in shielding can be attained by using three concentric permalloy cylinders with copper cylinders placed between them. This arrangement will give a shielding efficiency that is of the order of 100 db from 50 to 4000 cycles per second.

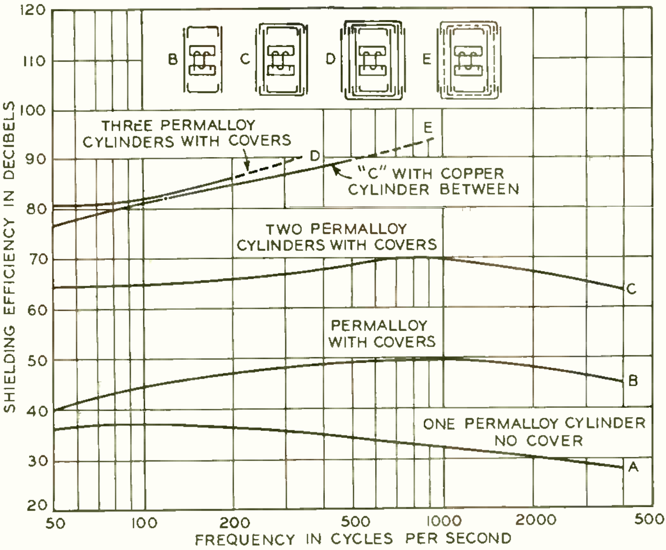


Fig. 4—Very much higher shielding can be obtained by using multiple concentric shields

The No. 4 Order Turret

By W. M. BEAUMONT
Circuit Development

WHENEVER large numbers of calls of a similar nature are made to a single establishment, the usual PBX facilities are frequently not suitable for providing some of the special features desired. For this type of service the order turret was especially designed. It is employed in brokerage houses, telegraph offices, department stores, taxicab offices and a large number of similar establishments. The needs vary somewhat with the type of business, and several types of order turret are available—two of them, the No. 2 and the No. 3, have already been described in the RECORD.* The size of these turrets and the features provided vary, but in the two larger ones the incoming lines appear at many or all of the turrets, and are answered by any idle attendant.

This feature has many advantages, especially when there are two groups of trunks to the establishment: one to the regular PBX and one to the order-turret positions. Under these conditions each group must be large enough to handle the busy load for its own class of calls, and since the busy periods may not coincide, a loss of efficiency, compared to that of a common group, is possible. For this

---

*RECORD, *March*, 1929, *p.* 270; *Sept.*, 1932, *p.* 2.

re it may be preferable in some cases to have all trunks terminate at a single PBX, and then to distribute the calls to the order-turret or other positions as required. Such an arrangement not only gives a more efficient trunk group, but simplifies changes in the number of order-turret positions in use, which in many establishments must be varied from time to time to meet their seasonal loads.

To provide flexible equipment reached through the regular PBX, a new turret known as the No. 4 has recently been developed. It differs from the 2 and 3 types not only in this feature but also in that each regular order line from the PBX runs to only one turret and the distribution of incoming calls is handled at the PBX switchboard. This gives assurance that the call is routed to an idle attendant, and also provides a ready means of determining the order-turret load from time to time. The use of the No. 4 order turret will vary, of course, with the type of application. In general any call may be handled by any order-turret attendant, but in some establishments, such as a very large department store, certain order clerks may be assigned to handle particular kinds of merchandise; one group for groceries, another for men's furnishings, and so on.

Each order clerk will be provided with an operator's telephone set and a small turret as shown in Figure 1. The turret is equipped with four three-position keys, three of them used for talking, and one for making the position busy. When a key is up, in the "normal" position, that line is not in use. Moving the key to the "talk" position connects the attendant's telephone set to the line, and if the key is moved further down to the "hold" position, the call on the line is held, and the telephone set is disconnected so that it may be used on some other line.

Key 1 controls the regular order-turret line, which appears with the other order-turret lines at the PBX board. Here the jacks may be grouped so that those for lines to clerks handling the same type of merchandise appear side by side, and above each jack is an availability lamp, which lights when the turret position is occupied and the line is not in use. When a call comes in, the operator connects it to a jack of the proper group, selecting a line whose availability lamp is lighted.

Key 3 controls an "overflow" line, which appears at each of a group of from five to ten turrets. A lamp is associated with this line at each turret, and lights when a connection is made to it at the PBX. Should a call

Fig. 1—One corner of the No. 4 order-turret installation at Macy's. A more complete view of this installation is shown in the photograph at the head of this article

come in to the PBX when all the regular lines to a given group of turrets were busy, the call would be connected to this overflow line. The overflow lamps would light at all turrets in the group, and the first order clerk to become idle would pick up the call. When any clerk moves the key of the overflow line to the "talk" position, the overflow lamp at all of the turrets is extinguished.

Key 2 at the turret controls a regular PBX extension over which the order clerk may place outgoing calls. A dial is provided for setting up the call where dial service is employed. This line permits the order clerk to call the various departments in the store to obtain more detailed information. While placing such a call, the call on her regular line is held by moving the key to the hold position. After the desired information is obtained the key on line 2 may be restored to normal, permitting conversation with the customer; or a conference connection may set up between customer, the store department, and the attendant by operating the keys on both the lines to the talk position. Line 2 may also be used for calling the customer when necessary.

Key 4 at the turret is a "busy" key and is associated with a "busy" lamp. It frequently happens that for a few minutes after taking an order, the clerk may be occupied in making out order forms, and the purpose of the busy key is to prevent incoming calls during this interval. Depressing the busy key puts out the availability lamp for the line to this turret at the PBX, and lights the busy lamp at the turret. It does not, of course, put out the availability lamp for the overflow line, and thus a clerk whose turret has been made busy would be able to answer a call on the overflow line.

One of the unusual features of this turret is the arrangement for signaling the attendant. Instead of using bells, buzzers, or lamp signals, ringing tone is heard over the headset. This arrangement not only avoids the noise of bells or buzzers, but eliminates the close attention of the attendant, which is required when a lamp must be watched.

The order clerk's telephone set is connected to the turret equipment through a plug and jack. Plugging in the telephone set lights the availability lamp for that turret at the PBX, thus notifying the PBX operator that the clerk is available to take orders. When the clerk leaves and pulls out the plug, the availability lamp at the PBX goes out.

One of the great advantages of this new order turret is the flexibility resulting from its being based on an operating unit of one order clerk. The size of the installation may thus readily be extended or decreased to any desired extent. Although there is a secondary unit of turrets, because of the overflow line, which is common to a group of turrets, there is no need to expand or reduce the installation in units of five, since the overflow line may serve a group of any desired size up to a maximum of ten.

Contributors to this Issue

W. K. **Caughey** received an M.E. degree from Stevens Institute of Technology in 1928 and joined the Apparatus Development Department of the Laboratories that autumn. Part of his time has been spent at Whippany where he worked on the development of radio apparatus for aeronautical stations. For the past few years he has been located at the radio laboratories in the Graybar-Varick building in connection with the development of ultra-high-frequency radio equipment.

C. D. **Hocker** graduated from Wabash College in 1912 with the A.B. degree and three years later received the Ph.D. from the University of Michigan. He joined the Laboratories that year as a member of the Chemical Research Department where he carried on investigations on vacuum tube filaments, enameled wire, metal finishes and corrosion. Later he supervised work in metallurgy, chemical analysis and transmitter carbon studies. In 1927 he transferred to the Outside Plant Development Department as Ceramics Engineer. He is now Plant Material Engineer in which capacity he has charge of groups investigating paints, wood preservation and miscellaneous products.

W. K. Caughey

W. G. **Gustafson** received the B.S. degree in electrical engineering at Union College in 1927 and joined the Technical Staff of the Laboratories in June of that year. Since that time he has been engaged in the development of audio and carrier frequency transformers and repeating coils. Some of his time has been devoted to special studies in connection with the development of transformers.

W. B. **Ellwood** graduated from the University of Missouri in 1924 with the A.B. degree and continued studies at Columbia University. There he re-

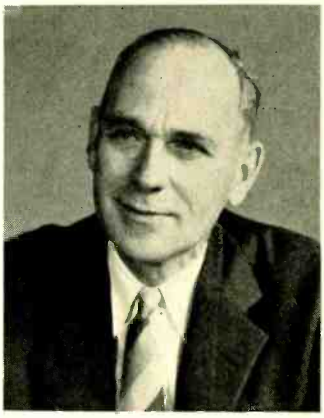
C. D. Hocker

W. G. Gustafson

W. B. Ellwood

O. J. Murphy

J. B. Harley



W. M. Beaumont

ceived the M.A. degree in 1926 and the Ph.D. degree in 1933. Meanwhile in 1930 he joined the Laboratories to undertake studies on the magnetic properties of materials at both very low and very high field strengths. More recently he has also been concerned with the applications of magnetic materials in apparatus.

O. J. Murphy received a B.S. degree in Electrical Engineering from the University of Texas in 1927. He joined the Technical Staff of the Laboratories that year and has since been engaged in the study of voice-operated devices and their effect on telephone transmission.

J. B. Harley joined the Research Department of the Laboratories in 1924, and for two years engaged in work connected with carrier broadcasting systems. During this period he took the technical assistant's engineering course. In 1926 he left the Laboratories, and for two years was concerned with the design and manufacture of radio receivers for F. A. D. Andrea, Inc. Returning to the Laboratories in 1928, he became a member of the Technical Staff with the Commercial Products Department. He also studied at the Polytechnic Institute of Brooklyn, and in 1936 received its E.E. degree. Since then he has been chiefly engaged in amplifier design.

W. M. Beaumont entered the Bell System as substation installer with The Bell Telephone Company of Pennsylvania early in 1911. After a short time he transferred to the Maintenance Department and remained in that department until 1919, when he joined the engineering department of the Western Electric Company. With the Circuit Laboratory he has participated in the development of manual central offices and private branch exchanges. At present he is engaged in the development of both manual and dial private branch exchanges. He is a graduate of the night school of the Drexel Institute of Philadelphia.