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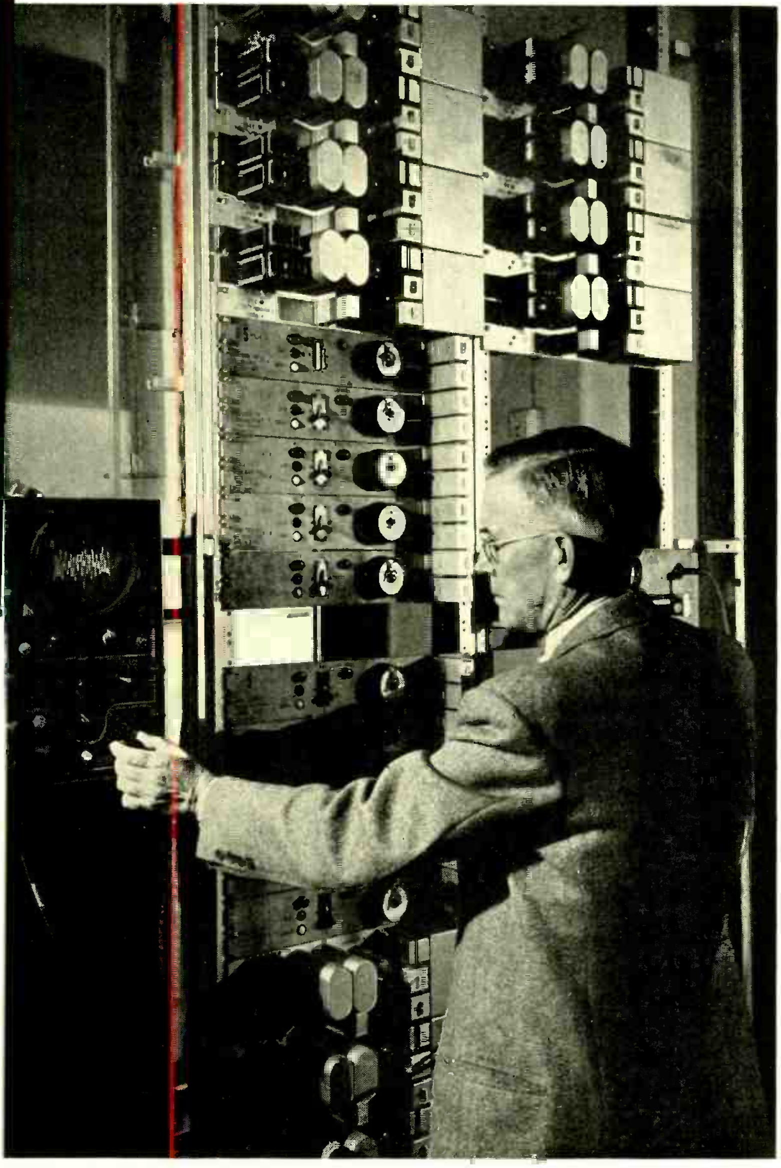

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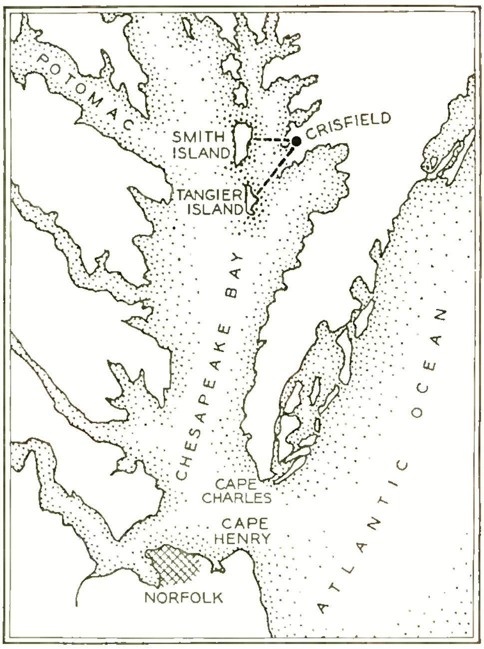
Observing the line current in a carrier telegraph system

Radio Telephone Service in Chesapeake Bay

By C. C. TAYLOR
Radio Research Department



SMITH and Tangier Islands in Chesapeake Bay have had small fishing populations since Revolutionary days. Their point of contact with the mainland is Crisfield, a small Maryland town on the eastern shore of the Chesapeake some ten miles east of the islands. Crisfield is a railroad terminal, and here the island fishermen bring their catches for shipment to the large centers of population. Except for the fishing boats, the only means of communication with the islands has been a mail boat, which makes one trip a day. During the winter of 1938 and 1939 a severe freeze stopped all water traffic for several weeks, and unfortunate results of the lack of communication at this time led to the installation of emergency radio telephone service late in 1939. The demands placed on this service indicated that permanent and more adequate facilities were needed. As a result, the Laboratories developed the 311A radio-transmitting and the 902A radio-receiving equipments, which were installed for the Chesapeake Bay service in February of this year.

This new radio telephone equipment is designed for operation at the ultra-high frequencies — either between 30 and 40 or 156 and 162 megacycles. At these latter frequencies, which were chosen for the Chesapeake installation, the waves are short, about two meters long, and they travel in approximately straight-line paths. There is little noise, and volume regulation is not required. The distances involved are short. From Crisfield to Smith and Tangier Islands, it is ten and thirteen miles respectively, and fifteen-watt transmitters are used. Since the volume of traffic expected is small, only a single channel to each island has been provided, and a single transmitter and receiver at Crisfield operates with either one of them. Tangier Island has a population of 1200 and Smith Island has a population of only 800, divided into three small communities. The present installation makes provision for a maximum of six telephones on each island. At Crisfield, the radio equipment connects with the local telephone switchboard, and connections to and from it may be established as desired.

Communication in the two directions of transmission, that is to and from Crisfield, is at different frequencies. Transmission from Crisfield is at 161,475 kc, and the two island receivers are tuned to this frequency. The Crisfield receiver, on the other hand, is tuned to 157,875 kc, and will receive from either island. At Tangier Island the transmitter operates at 157,875+6 kc, and at Smith Island the operating frequency is 157,875–6 kc. These two frequencies are near enough the same so that either is readily received and detected by the Crisfield receiver, and when both island transmitters are on, the beat note of the two carriers is 12 kc, which is not passed by the receiving circuits, and thus causes no interference. Although normal communication is between one or the other of the two islands and Crisfield, the two islands may communicate with each other by passing through the Crisfield radio equipment—each island being received at Crisfield and retransmitted to the other island through a by-pass connection.

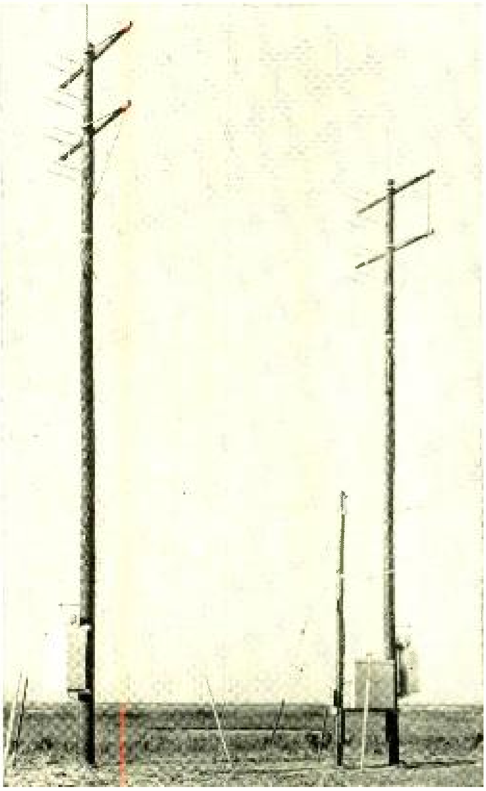


Fig. 1—At Crisfield the radio transmitter and receiver and the emergency power supply are mounted on the antenna poles

Fig. 2—Radio hut at Smith Island, with the transmitting and receiving antenna poles

At Crisfield the radio transmitter and receiver are each installed in weather-proof housings and mounted on 65-foot poles that carry antennas. A third unit includes a small gasoline-driven generator that is automatically brought into service on failure of the Crisfield commercial power supply.

This radio installation, shown in Figure 1, is at some distance from Crisfield on the edge of a salt marsh. At the islands, the radio receiver and transmitter, although essentially the same as those at Crisfield, are mounted in a small hut, Figure 2, which also houses the control terminal, the subscriber line equipment, and two gasoline engine generators. Privacy equipment is included, and is used on all radio calls. Since there is no commercial power on either of the islands, these generators form the sole power supply. They run alternately on six-hour shifts with automatic changeover; in addition, there is automatic operation on one engine in case of failure of the other.

A schematic of the general circuit arrangement is shown in Figure 3, where only one island is indicated since the arrangement is the same at both. Associated with each subscriber's telephone at the islands is a key that enables the subscriber to select either a local party line, which furnishes intercommunication between subscribers on the same island, or a radio telephone line running to the terminal hut. When the key is thrown to the radio position, the radio transmitter is started, and a lamp at the subscriber's station lights to indicate that the transmitter is on and operating at the proper frequency. Each subscriber has a bell which is rung individually from Crisfield by a selective signaling system.* One of the island subscriber stations is shown in Figure 4.

To place a call, an island subscriber lifts his handset, throws his key to the radio position, and listens. If the circuit is in use by the other island, he hears a busy tone, while if it is in use by his own island, he hears conversation and hangs up. If the circuit is not in use, he gets a green light, and will be answered by the Crisfield operator. She then takes his call, asks him to hang up, dials a code that locks up the radio transmitters at both of the islands so that if an island subscriber on either island should try to place a call he would get a busy signal, and proceeds to establish the land con-

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*Record, *April*, 1936, *p.* 255.

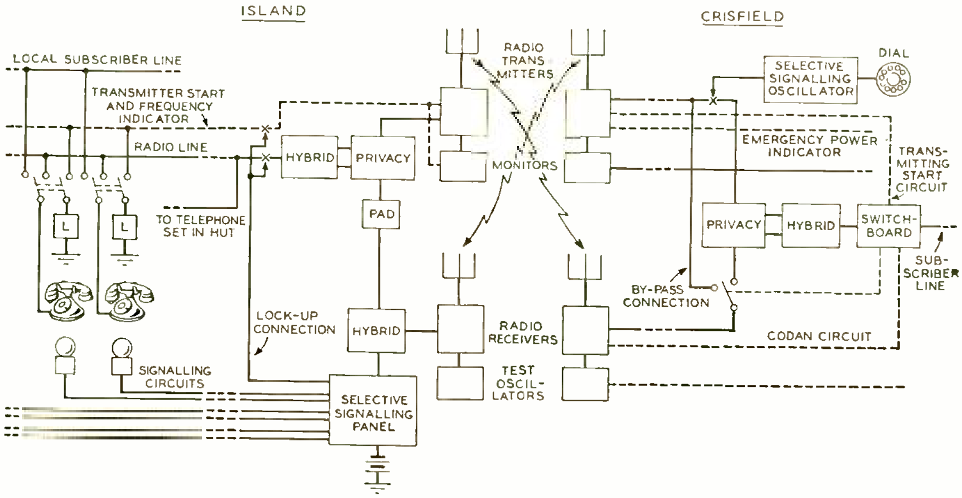

Fig. 3—Circuit schematic showing radio telephone equipment at Crisfield and at one of the islands. Dotted lines represent derived channels

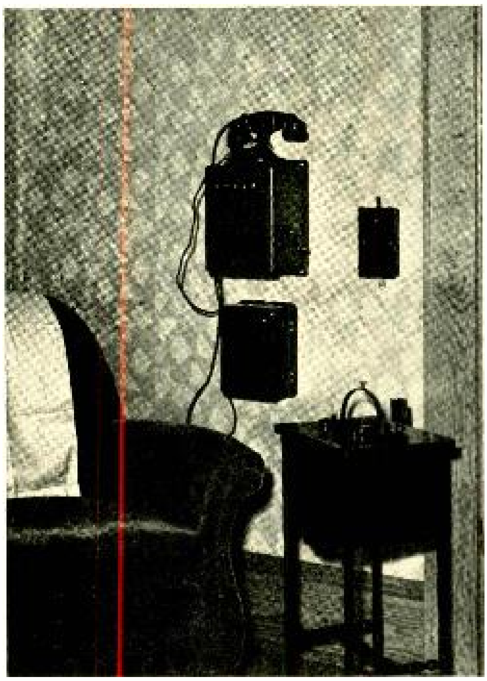

Fig. 4—Subscriber installation on one of the islands showing key box at the right

nection desired. After this connection has been secured, the operator rings the calling subscriber, which unlocks the transmitter at that island, and the conversation proceeds.

On a call from Crisfield, the operator plugs into a jack associated with the radio equipment, and when the transmitter is on and operating at the correct frequency, she gets a green light. She then connects a dial cord to a jack and dials a code that locks up the transmitters at both of the islands. She then dials the individual code for the called subscriber, which rings the bell of the called station and unlocks the transmitter at that island. At the completion of the call, the operator dials a code that unlocks the transmitter at the other island.

The green lamps that indicate when the transmitters are operating at the correct frequency are under the control of a monitor circuit that is part of each transmitter. Similarly, each receiver is equipped with a test oscillator to provide means for checking its operation. The receivers are also equipped with codans, and it is the operation of the Crisfield codan when one of the island transmitters is turned on that signals the operator.

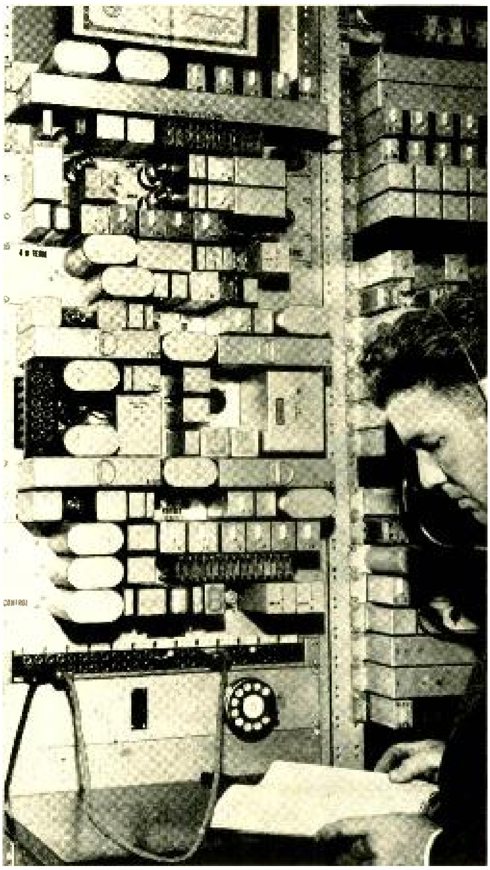

Fig. 5—Terminal bay at the Crisfield office

In radio circuits of this type, there is a four-wire circuit between the radio equipment and the voice terminals while the central-office trunks and subscriber lines are all two-wire circuits. It is necessary, therefore, to provide conversion equipment to connect the four-wire and two-wire circuits together. This function is performed by the hybrid coil indicated on Figure 3. There is also a considerable amount of additional equipment, such as the by-pass relays, the privacy equipment, and the selective signaling oscillator, that is needed for the proper operation of the circuit. All such equipment is mounted on a terminal panel, and one of these panels is required at the Crisfield office and on each of the islands. These terminal panels also include testing equipment to enable the maintenance force to check the operation of the system as occasion demands. The terminal bay that is located at the Crisfield office is shown in Figure 5.

On these short ultra-high-frequency circuits the noise is low, and the circuit stability and loss-frequency characteristics are equal to those of good land lines. It is planned that this radio equipment, including the 311A transmitting equipment, the 902A receiving equipment, the F1 control terminals, and the engine alternator plants will be made available through the Western Electric Company for other Bell System projects.

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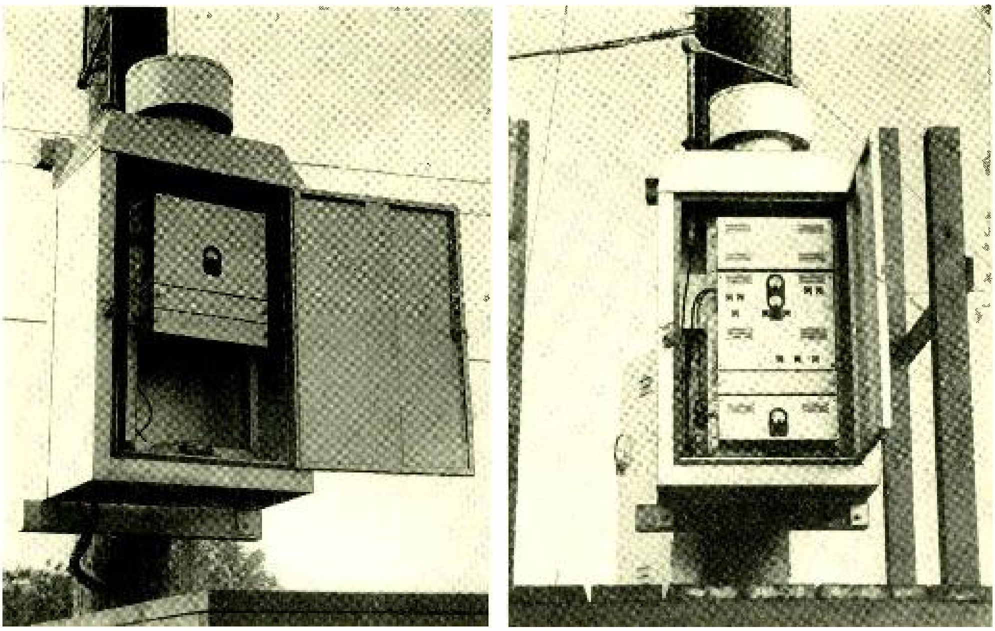

The 31A radio transmitter at the left, and the 31A radio receiver at the right, as installed for the Crisfield terminal. This radio equipment is described in some detail in the article beginning on the opposite page

Radio Equipment for the Crisfield Project

By A. B. BAILEY
Radio Development Department

THE waters of Chesapeake Bay surrounding Smith and Tangier Islands and extending some distance out from Crisfield on the Maryland shore are very shallow. For the most part the depth is under six feet except for a narrow channel running midway between the islands and the mainland. A submarine cable installation under such conditions is very undesirable, since the likelihood of its being damaged by ships' anchors or oyster dredges is great. Radio was therefore preferred in providing telephone service* to these isolated islands with their fishing population. Since the distance involved is short, under fifteen miles, transmission at the ultra-high frequencies was decided upon. For these frequencies, the antennas are small, and can readily be mounted at the top of tall poles to provide the height needed for satisfactory transmission. Besides the antennas, a new radio transmitter and receiver were developed—both completely automatic in operation. A new automatic gas-engine power supply and two new vacuum tubes for the radio equipment were required to round out a development that would meet the best modern standards and serve not only this particular installation but others of a similar nature that might be called for in the future.

The antenna developed, the 53A, is connected to the transmitter or receiver mounted on the lower part of the pole by a coaxial transmission line. It consists of four horizontal half-wave antennas spaced a half-wave apart in a vertical plane, and four half-wave parasitic reflectors placed approximately one-quarter wave behind each antenna. A schematic of the arrangement is given in Figure 1, and a photograph of the antennas installed on the poles is shown on page 359. Each antenna consists of two quarter-wave sections—one being

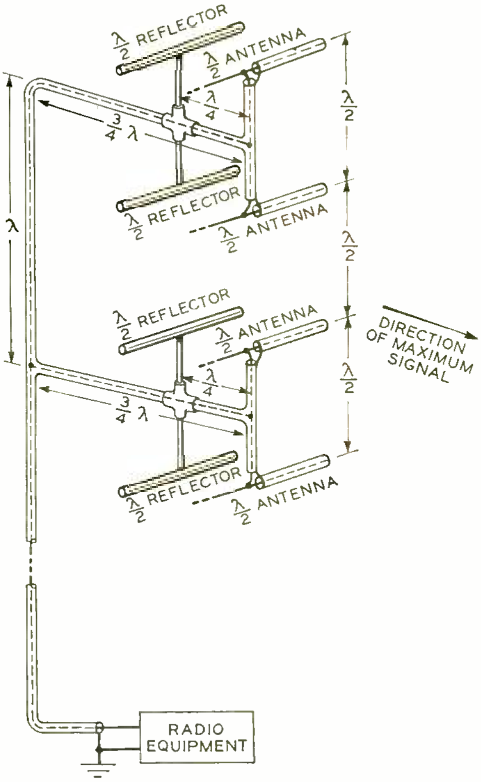

Fig. 1—Arrangement of antenna and transmission line for Chesapeake Bay ultra-high-frequency radio telephone

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*Page 358, this issue.

an extension of the sheath of the line, and the other, an extension of the inner conductor. In the actual assembly, this latter section is surrounded by an insulating sleeve. The antenna is made up for the most part of standard ⅞-inch coaxial transmission line and fittings, and is mechanically and electrically able to withstand heavy ice coatings with little or no effect on its radiating characteristics. The entire antenna structure and transmission line is gas tight. No end seal is required between the line and antenna, and thus the discontinuity usually caused by an end seal is avoided.

It is economical and very convenient to have the transmitting and receiving antennas close together to avoid having to secure two sites, and to permit both equipments to be reached by a single pole line. The amount of separation is commonly controlled by the power of the transmitter, the frequency separation, the selectivity of the receiver, and the directional characteristics of the receiving and transmitting antennas. Since for this installation the power radiated is relatively small and the directional characteristics of both the transmitting and receiving antennas have a minimum along a line perpendicular to the circuit direction, it was found practical to place the antennas only thirty feet apart. In the vertical plane these antennas are highly directive, but in the horizontal plane their directional characteristics are just broad enough to permit a single antenna directed midway between the two islands to cover the arc between the two islands, which subtends an angle of about sixty degrees at the Crisfield antenna site. The directional characteristics of the antennas are shown in Figure 2. The pickup between antennas is reduced to small values by placing the antennas so that the deep minima at right angles to the line of maximum radiation in the horizontal plane face each other.

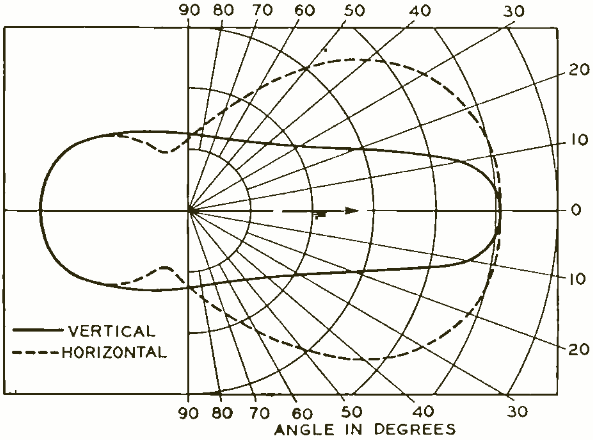


Fig. 2—Directional characteristics of the antennas

The fifteen-watt radio transmitter, called the 31A, is shown in its weather-proof housing at the left of the photograph at the bottom of page 362. The upper unit is the power supply, while the large central unit with the meters is the transmitter itself. The small panels beneath it include the control unit and the frequency monitor. A block schematic is shown in the upper part of Figure 3. The crystal oscillator circuit, operating at one twenty-fourth of the carrier frequency, holds its frequency constant to a thousandth of one per cent. It includes a frequency doubler and drives the two succeeding doubler stages and the one tripler stage. In the final, or output, stage a push-pull pentode is amplitude modulated on both plate and screen elements by audio-frequency delivered from the push-pull audio-amplifier. The transmitter is inductively coupled to the antenna circuit, and a small adjustable condenser permits the antenna circuit to be independently tuned to resonance, thus avoiding mistuning and loss of power output that might be of appreciable magnitude at the 160-megacycle frequency.

A frequency monitor is associated with each transmitter to give a continuous visual indication when the carrier frequency is well within the allowed tolerance limits while the transmitter is in operation, and thus to insure that the set will not be used "off frequency." A green lamp, controlled by the monitor oscillator, indicates to the telephone operator or island subscriber that the circuit is available. If the lamp fails to light due to a drift in the frequency beyond the limits, it is a warning to the operator not to use the circuit. This monitor samples a portion of the radio energy delivered to the antenna, and beats this signal with that from a harmonic generator circuit driven from a quartz-plate oscillator. The difference frequency passes through a band-pass filter with a very narrow pass band centered at 155 kc, and the output of this filter is detected. In the plate circuit of the detector is a d-c relay that operates to close the lamp circuit when the frequency is correct. If the carrier frequency is more than three thousandths of one per cent from its nominal value, the difference frequency will depart from 155 kc sufficiently to prevent enough energy from passing through the filter to operate the relay. For the successful operation of this circuit, the monitor oscillator must be extremely stable, and to insure satisfactory operation, a new type of quartz-plate assembly is used. This assembly, known as the 5M quartz plate, contains a thermostat and heater that maintain the temperature of the plate within one-half degree of sixty degrees Centigrade at all times.

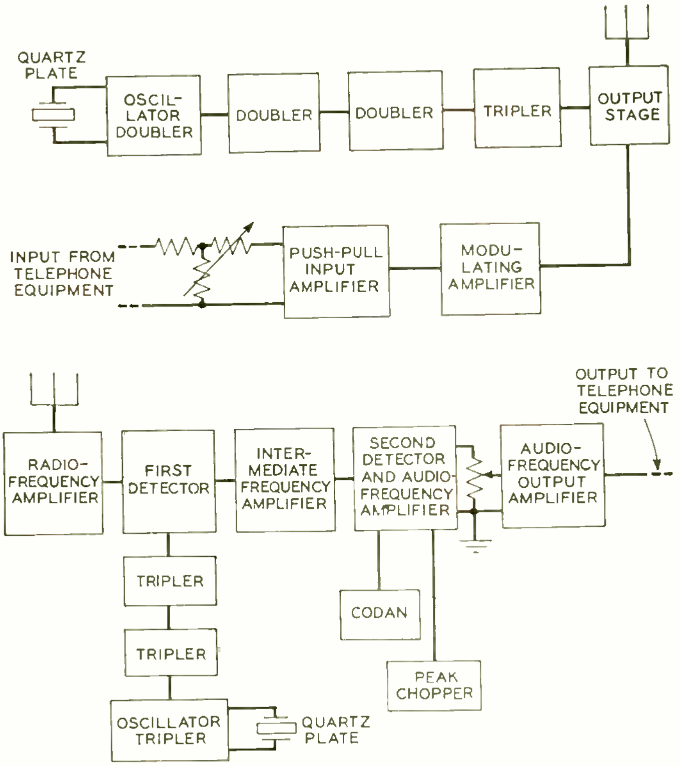


Fig. 3—Block schematic of radio transmitter, above, and radio receiver, below

The associated radio receiver, known as the 31A, is a superheterodyne with a quartz-plate oscillator that supplies the beating frequency through a harmonic generator circuit. It is shown in block schematic form in the lower part of Figure 3. A codan incorporated in the receiver operates a relay to short-circuit the audio output whenever the carrier is cut at the distant terminal. This codan relay also gives a signal to indicate when the distant station comes on, and thus at Crisfield notifies the operator when an island subscriber is calling. The receiver also includes a peak chopper, or noise-silencing stage, to reduce the effect of peak noise impulses if they are present. Two new vacuum tubes, the 383A and the 385A, are used in the receiver, and by virtue of their small size and short internal leads they are particularly useful in enabling the receiver to meet the specified sensitivity objectives.

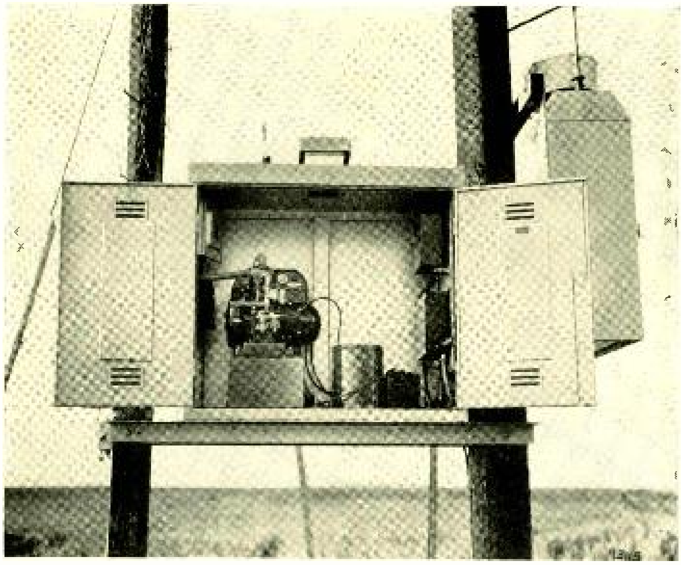


Fig. 4—A small gas-engine generator supplies emergency power for the Crisfield transmitter

Like the transmitter, the receiver is enclosed in a weather-proof housing for pole mounting as shown at the right of the photograph at the bottom of page 362. Associated with the receiver is a test oscillator used for checking the sensitivity and tuning. It includes a quartz-plate oscillator, the output of which may be modulated with an audio tone and adjusted to any input level to the receiver that is desired.

At Crisfield, power for operating the radio equipment is obtained from the commercial a-c supply, but a small emergency gas-driven generator, mounted in a weather-proof housing as shown in Figure 4, is provided adjacent to the transmitter. At each island, where no continuous commercial supply is available, two of these generators are installed in the radio hut. They operate alternately on six-hour shifts.

These islands are important sources of supply for the oyster and crab industry, and it is expected that this telephone service will facilitate the normal progress of these industries, besides providing the prompt communication essential in emergencies.

Peak Voltages in Carrier Telegraphy

By B. P. HAMILTON

Switching Engineering Development

MOST people think of a telegraph wire as carrying only a single message, but this is often very far from the fact. In modern telegraph systems twelve or more messages may be flashing back and forth over a single circuit. This is made possible by carrying each of the several messages on a current of different frequency and unscrambling those currents by electrical filters at the receiving end. Until recently the carrier currents have been drawn from a generator which delivered twelve different frequencies in the voice range starting at 425 cycles per second and progressing at 170-cycle intervals to 2295 cycles.

When experiments were made recently looking toward substituting a group of unrelated vacuum-tube oscillators for the generator, slight changes in phase between them produced high peak voltages in the circuit every two or three minutes. Those voltages overloaded repeaters and thus caused interchannel interference. To eliminate the phase changes, the apparatus was modified to control all of the carrier currents from a single 85-cycle oscillator. By connecting its amplified output to a harmonic-generating coil, odd multiples of 85 cycles were produced. That complex wave was applied to the carrier frequency oscillators and they selected the particular harmonic to which each was tuned. All the oscillators then remained in exact step but this failed to

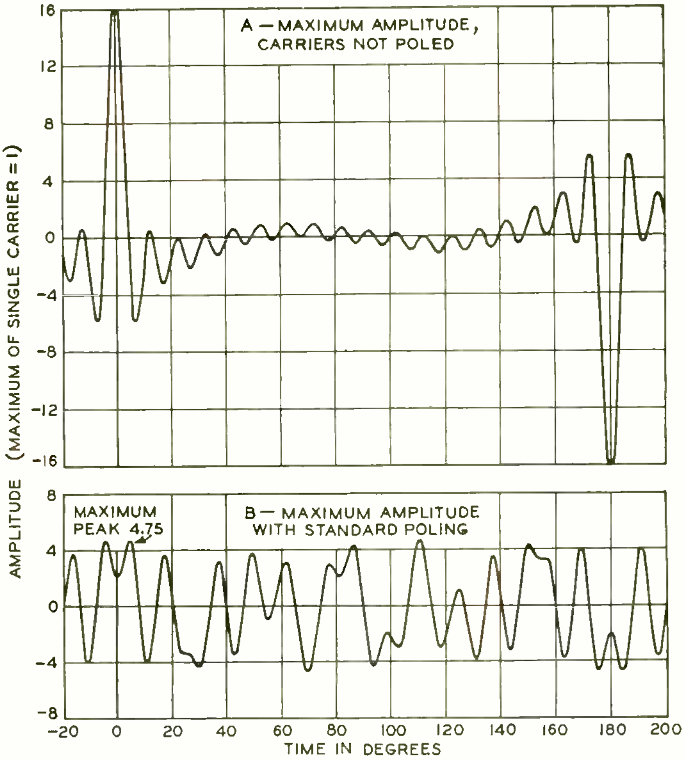


Fig. 1—(A) Voltage peaks obtained with sixteen carriers in phase. (B) By reversing channels 4, 6, 11, 12, 14, 15 *and* 16 *the maximum voltages are greatly reduced*

prevent peak voltages from occurring because the maximum values of all the carriers came at the same instant. The calculated resultant of sixteen frequencies thus combined is shown in

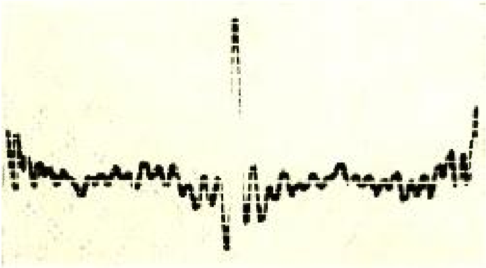


Fig. 2—Oscillogram of sixteen telegraph carrier currents combined in phase

Figure 1A and a cathode-ray oscillogram obtained from the oscillators is reproduced in Figure 2. The problem was then reduced to finding other definite phase positions to which the synchronized harmonic frequencies could be shifted to keep the peak values of the resultant wave as small as possible at the sending end of the telegraph line.

The simplest practical method of staggering phase positions is to change the phases of some of the oscillators 180 degrees by reversing their output leads. Studies indicate that this is also the simplest practical method of reducing the peaks and that it is theoretically very close to the best possible solution. For systems involving not more than six or eight channels, it is comparatively easy to determine which frequencies to reverse to obtain the lowest peaks by calculating the values for all possible combinations of reversed channels. With a larger number of channels, the available combinations are so numerous that it is impractical to try all of them. Thus eighteen channels can be combined in 131,072 ways.

The best combination which has been found, partly by calculation and partly by experiment, for sixteen channels, all marking, has channels 4, 6, 11, 12, 14, 15 and 16 reversed. This combination has been standardized. Peak values obtained with systems poled thus are shown in Figure 3 for different numbers of channels. Theoretical limits for maxi-

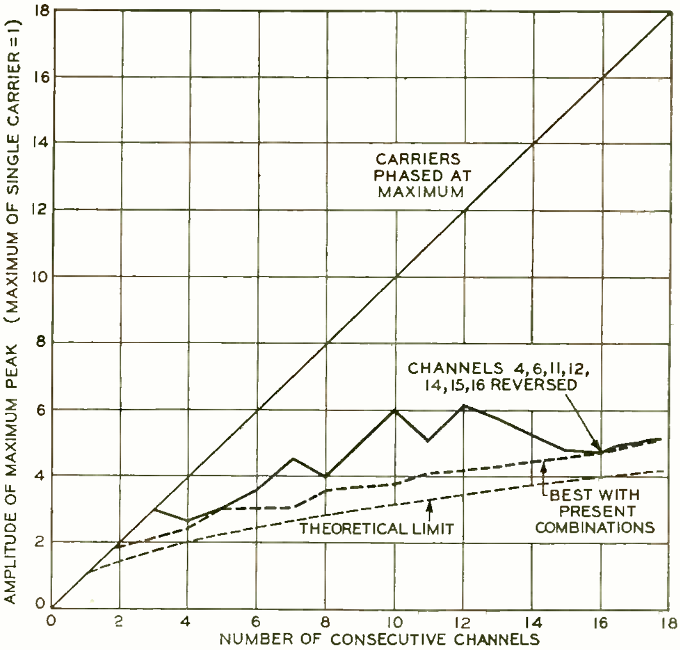


Fig. 3—Peak voltages on carrier telegraph circuits having different numbers of channels when the standard combination of channels is reversed. Theoretical maximum and minimum values are also given and the lowest peak values obtained with any combination thus far tried

mum and minimum peak values are also given there and the lowest peak values obtained with other combinations thus far tried. The curve for what has been assumed to be the minimum theoretical values gives the maximum voltages of a single sine wave current which has the same heating effect as the sum of the corresponding carrier currents. Calculated values of the voltages in a 16-channel system with the standard group of channels reversed are shown in Figure 1B and the corresponding oscillogram in Figure 4.

Even if the carriers are poled to obtain maximum reduction of the peaks at the sending end, this relation will not persist along the line because of phase shifts. This is particularly true for cable circuits. There are certain small phase shifts in the modulator circuits, the sending tuned circuits, and in the oscillator itself which make it impossible to predict the exact phase position of each carrier. Regardless of the phase shifts along the line, however, the carriers must be phased at the sending end to avoid the high peaks, otherwise the first few cable repeaters will be overloaded and produce modulation before the line changes the phases.

Tests made with the channels operated over cable systems have shown that the standard reversed channel combination reduces the interference considerably from that obtained with either the uncontrolled oscillators or controlled oscillators without poling. Since some channels are ordinarily spacing at a given moment the phase balance is affected to a certain extent and it is possible to obtain peaks somewhat higher than when all sixteen channels are marking. This upsetting of the phase relation is partially counterbalanced by the reduced energy when channels are spacing. Computation has indicated that there is a slight advantage in using a combination which reverses just half the number of channels, if account is taken of the channels which may be spacing. This is principally of theoretical interest since the carrier telegraph as now designed operates satisfactorily any number of channels up to eighteen.

Fig. 4—Oscillogram of sixteen telegraph carrier currents with channels 4, 6, 11, 12, 14, 15 *and* 16 *reversed*

When the number of channels is as high as sixteen or eighteen there are hundreds of combinations of reversed channels which would keep the peaks reasonably low at the sending end. If tests were made on a particular line some combinations might be found which would be better than others, from the standpoint of interference, although they might not cause the lowest peaks at the sending end. For another line of different length and with different repeater spacings an entirely different combination would probably be preferable. Considering operation over all lines and with different numbers of channels it appears that the present standard combination is satisfactory. To attempt a better solution would require a large number of field tests over many lines and these would not be warranted. Tests which have been made indicate that a reduction in the peaks below a value of roughly six times that of a single channel becomes relatively unimportant in reducing interference.

Order-Disorder Transformations in Alloy Crystals

IN SINGLE crystals of some alloys the atoms of one of the components are substituted in an orderly way in the lattice structure of the other component. With increase in temperature this orderliness gradually breaks down and finally ends in a completely disordered state. This change is accompanied by an extremely small increase in the volume of the crystals. In studying this effect a very sensitive device is required to detect the minute volume changes and the apparatus has to record the results automatically because these changes occur slowly.

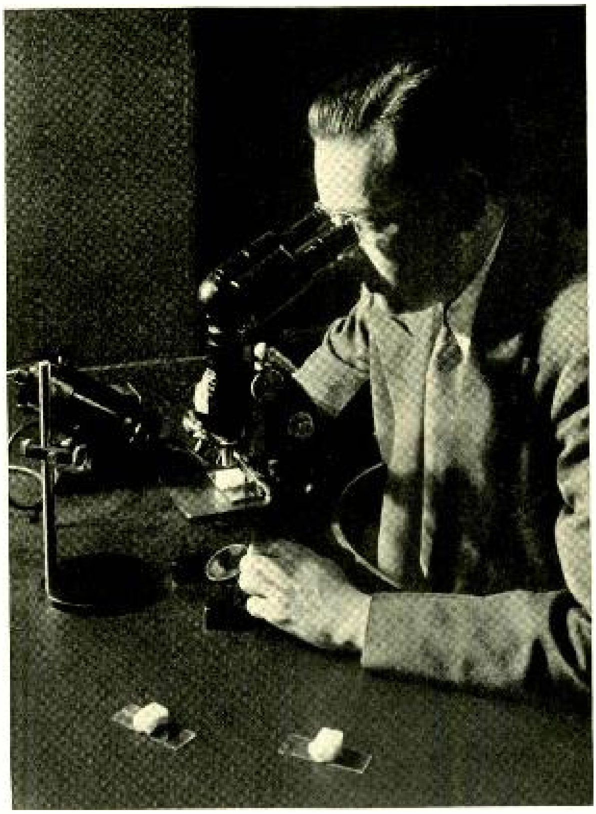
To meet these requirements three small pyramid-shaped specimens of the material whose expansion is to be measured are mounted between two optically polished discs of fused silica. Adjusting the specimens to produce a slight tilt between the lower surface of the upper disc and the upper surface of the lower one forms an optical interferometer which sets up interference fringes when monochromatic helium light is reflected from these surfaces. With temperature changes the fringes shift because the specimen expands or contracts; the rate of change is measured by recording the shifting of the fringes photographically on 16-mm. film at frequent intervals.

This dilatometer is operated in vacuum to prevent oxidation of the specimens and the temperatures are controlled automatically by an electric furnace or by cooling the interferometer in a thermos bottle with liquid nitrogen.

The apparatus is so extremely sensitive that it can detect expansions or contractions of a millionth of an inch.

Insulating Paper

By J. M. FINCH
Chemical Laboratories



INSULATING paper,* unlike that used for writing or printing, is relatively pure cellulose and contains no clay or sizing; but pure cellulose is one of the most hygroscopic of substances and very little moisture renders it conductive. Paper used for insulating, as in condensers, must therefore be dried and kept so by impregnation with waxes. Immersion in oils or potting in asphalts may also be necessary. Simple wax impregnation will not prevent paper from absorbing moisture. It retards the rate at which water is taken up but the total amount absorbed is as large as in unimpregnated paper. This is shown by the graph of Figure 1. Phenolic resin is also used to impregnate paper. It helps the paper to maintain a higher resistance largely because layers of pure resin on the surfaces of the material, which have high resistance, prevent direct contact of the paper fibres and the parts insulated.

Maintenance of dryness, moreover, is not alone sufficient to assure permanence of good insulating properties, because contamination with small amounts of certain chemical compounds cause electrical and physical deterioration and failure. Embrittlement results from the presence of small amounts of acidic compounds in the paper and freedom from them is important when paper has to be heated in processing or in apparatus manufacture. Chlorides have long been recognized as the cause of excessive conductance and objectionable corrosion, but more recently their presence in condenser paper has been shown to greatly shorten their life. A condenser made with paper purposely contaminated with 0.19 per cent chlorides failed under exaggerated voltage conditions in about 1.5 hours, while a condenser made with paper containing 0.03 per cent chlorides had a life of about 60 hours under the same conditions and one with paper containing only 0.01 per cent chlorides survived 280 hours. Chlorides are so harmful that it is considered good practice to avoid the use of bleached pulp in insulating papers for the more critical uses such as in condensers. Substitution of un-

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*Record, *Feb.*, 1937, *p.* 197.

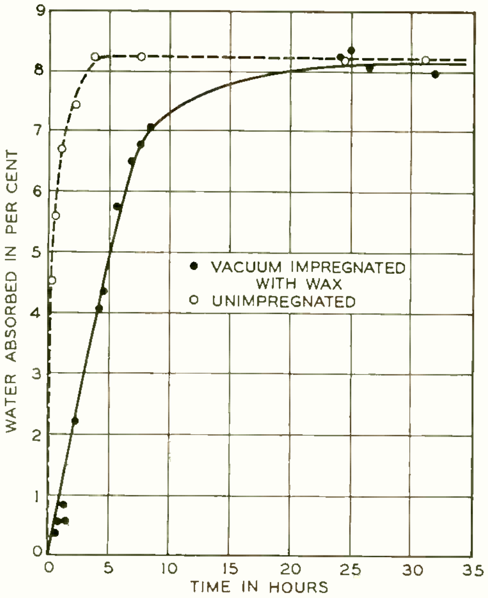

Fig. 1—Paper impregnated with wax absorbs water more slowly than untreated paper but the total amount absorbed is ultimately the same

bleached Kraft paper for bleached sulphite paper in phenol fibre has effected a definite improvement in the insulation resistance of this material.

Chemical contamination is not always introduced during the paper-making process, but may be added to the finished paper when it is wound into small rolls in manufacturing operations. The adhesive used for splicing accidental breaks during the slitting and rewinding of condenser paper is an example of a source of such contamination. Commercially available adhesives of this kind contain objectionable quantities of soluble conducting salts. If a splice, made with these adhesives, is wound into a condenser it causes rapid failure. The stains on the condenser paper shown in Figure 2 were caused by purposely using contaminated adhesive in a condenser, and then subjecting it to exaggerated voltage conditions. The stains indicate changes which will ultimately result in electrical breakdown and condenser failure. No deterioration of the paper occurs if an uncontaminated adhesive made of cellulose-acetate solution is used.

Soot, coal, metal dust and finely divided salts may settle from the air during the paper-making process or when the apparatus is manufactured, and purification of the air is advisable where very thin tissue insulation such

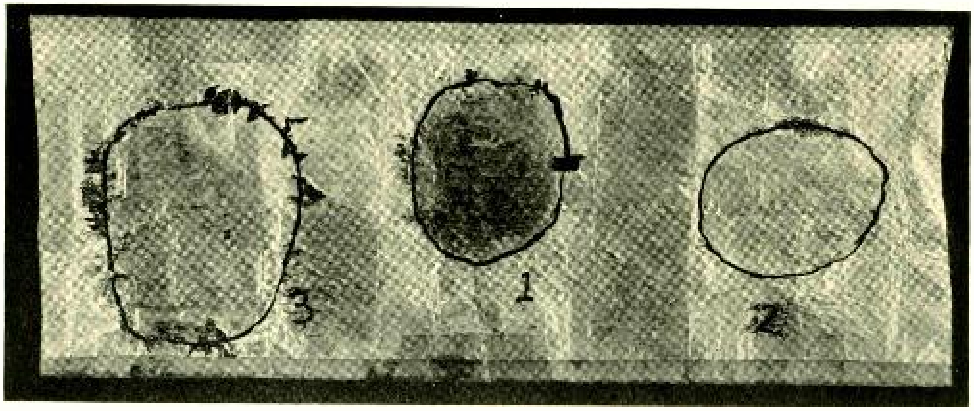

Fig. 2—Stains 1 and 3 were made by exposing to exaggerated voltage conditions condenser paper on which commercial adhesives had been daubed. These adhesives contain conducting salts which would cause condenser failure. No deterioration occurs with an adhesive made of pure cellulose acetate, 2

as condenser paper is made or used.

Paper is a mass of felted fibres or fibre particles combined with dried gelatinous cellulosic material which is produced by prolonged maceration of the fibres in water. Structurally, paper is not uniform because small areas may be composed largely of this gel which shrinks more than the fibres during the drying process in manufacture. Condenser paper contains comparatively large amounts of the gelatinized material and its thickness may vary from spot to spot by a factor of as much as 4 to 1. This is shown by the photomicrograph, Figure 4, left. Knowledge of this variation has made it possible to rationalize expressions relating condenser life to the intensity of the applied electrical stress. It also shows that the apparent density is higher than the accepted value of about 1.0, because the thickness, as now measured, includes the air space between the two paper surfaces and two planes contacting the high spots on these surfaces. In contrast with this non-uniform paper, Figure 4, right, shows a cross-section of very uniform sheet viscose 0.0004 inch thick. Although the structure of this material is practically ideal, there are economic and technical considerations which prevent its application to condenser insulation.

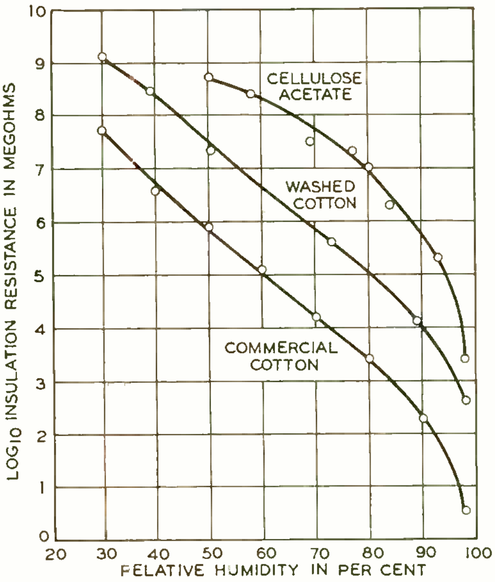

Fig. 3—Cellulose acetate is a better insulator than cotton in humid atmospheres

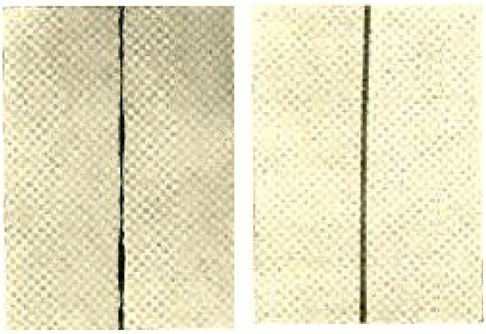

Fig. 4—Left, photomicrograph of a cross-section of a sheet of paper showing 4 to 1 variations in thickness; right, sheets of viscose are very uniform in thickness

Among the substitutes for insulating paper, thin sheet cellulose acetate has established itself as a superior material for interleaving fine coil windings, principally because it has better insulating properties than cotton in humid atmospheres as is shown in Figure 3. Its use has practically eliminated breakage of fine wire in coils from electrolytic corrosion. Other substitutes, such as ethyl cellulose and cellulose butyrate, are being scrutinized as they become available. Sheet material, like cellulose acetate, is sometimes laminated with paper to add toughness and resistance to abrasion and to increase the electrical resistance of the product. At present, however, pure cellulose paper provides the most satisfactory material for the commercial production of condensers and for most other uses involving thin sheets of insulation.

The Measurement of Modulation in Carrier Amplifiers

By J. P. KINZER
Transmission Development Department

BECAUSE of the non-linear characteristics of amplifiers, harmonics of a single-frequency input or combination products of two or more frequencies appear in the output. These modulation products are usually undesirable, and steps must be taken to hold them to values that will not seriously affect the quality or intelligibility of the transmitted signal. In voice-frequency amplifiers the modulation results chiefly in distortion, and since the ear is relatively tolerant of distortion, the requirements are not severe.

In carrier systems, however, where more than one band is carried through the same amplifier, modulation may be the source of a form of interference called cross-modulation. The harmonics produced are of a frequency that places them in one of the other channels of the same system. In a K carrier system, for example, the second harmonics of the frequencies of one channel may fall in the band of one of the higher-frequency channels, and after demodulation at the terminal will appear as voice frequencies to the listener. These frequencies, although not intelligible, have many of the characteristics of speech. They are thus distracting, and the requirements on modulation under these conditions must be more severe than with voice-frequency amplifiers.

Modulation-measuring equipment has been in use for a long time, but with the advent of broad-band carrier systems, where there is a wide scope for the appearance of cross-modulation, more precise and more extensive measurements have been wanted than could be obtained with existing equipment. As a result, a new apparatus has recently been designed for measuring modulation in carrier amplifiers. It incorporates a number of improvements, and limitations in the frequencies to be used have been removed. With this new apparatus, shown in the photograph at the head of this article, it is possible to measure any modulation product of one or two input frequencies in the C, K, or J carrier systems, which cover the range of 4 to 150 kc.

In long carrier systems with many

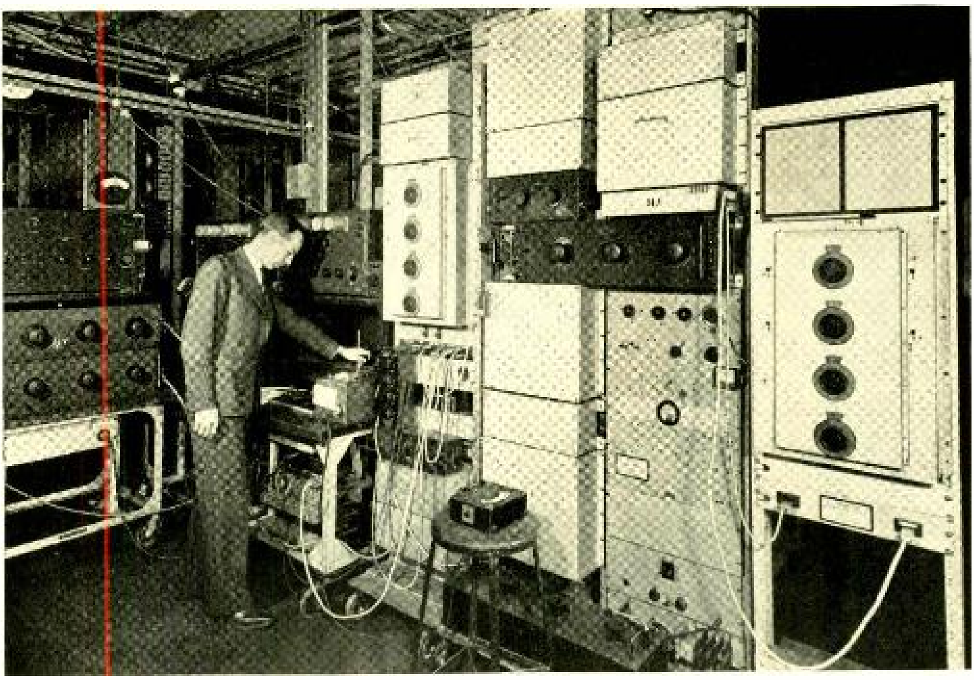

Fig. 1—Comparison of this early modulation-measuring set-up, comprising four relay racks and two tables, with that on the opposite page shows how the size has been reduced

amplifiers in tandem, most of the modulation products add up in such a way that the total modulation power is the sum of the modulation powers of all the amplifiers. The modulation product $2P - Q$, however, where P and Q are the two combining frequencies, is usually in phase for all the amplifiers. As a result the total power of the modulation product at this frequency is proportional to the square of the number of amplifiers, while for other modulation products the total is proportional to only the first power of the number of amplifiers. Modulation products of the $2P - Q$ type are thus of particular importance, and it is for measuring them that the new circuit has primarily been designed.

The procedure is to supply two frequencies to the apparatus under test, and then from the output of this apparatus to select and measure the desired modulation product. The value of the product is generally stated as so

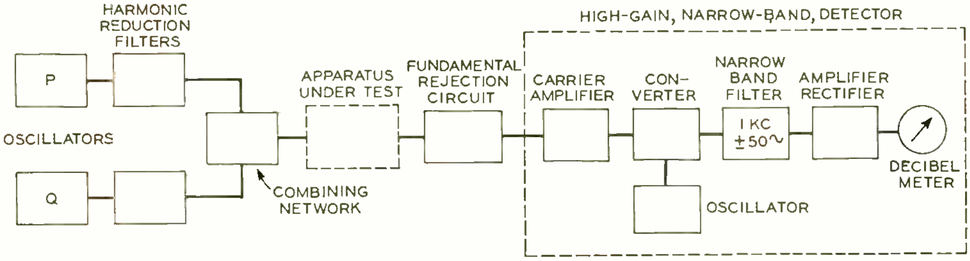

Fig. 2—Block schematic of the modulation-measuring equipment

many db below the fundamentals causing it, both measured at the output of the amplifier under test. A block schematic of the circuit employed is shown in Figure 2. Since the modulation product may be far weaker than the fundamentals, a high-gain detector is required ahead of the db meter which indicates the amount of the modulation product present. Since, moreover, most carrier amplifiers are provided with feedback circuits that reduce the modulation product to about or below the noise level, the noise level in the measuring circuit must be kept very low to permit a satisfactory measurement of the modulation product itself. Care must also be taken to insure that any extraneous frequencies arising in the measuring equipment itself are well below the level of the frequency which is being measured.

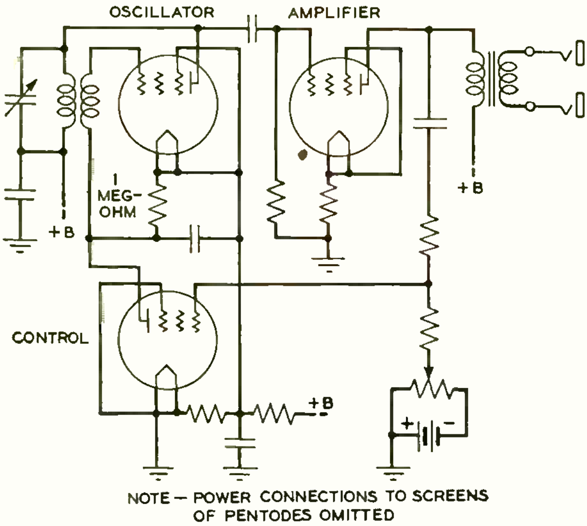

Fig. 3—Simplified schematic of the oscillator circuit that supplies the P *and* Q *frequencies*

Two adjustable oscillators are provided to give the P and Q frequencies. The output of each oscillator is passed through a filter to reduce any harmonics that may be present, and is then carried to the combining network that supplies the input to the apparatus under test. This network which is essentially a balanced hybrid coil serves primarily to decrease interaction between the two oscillators. Since the modulation products are usually smaller than the input frequencies, these latter frequencies are eliminated by a circuit immediately following the apparatus under test, so that only the modulation product is passed to the detector.

Although the P and Q frequencies are eliminated before the modulation product is passed to the measuring circuit, there is still the possibility that the noise level might be as great as or even greater than that of the frequency to be measured. The noise, however, is a function of the width of the frequency band. By employing a very narrow band filter in the measuring circuit the level of the noise can be drastically reduced without affecting the level of the frequency component to be measured. For this purpose, a pass band of only about 100 cycles is employed.

Measurements, of course, must be made over a wide range of frequencies, and to provide a convenient method of bringing any frequency down to the pass band of this filter, a converter and demodulating oscillator are supplied in the measuring circuit. An amplifier is used ahead of the converter so as to make the noise level of the latter low relative to that of the frequency being measured. A rectifier and db meter complete the measuring circuit.

To obtain P and Q frequencies as

free from harmonics as possible, automatic output control has been used for the oscillator circuit. The oscillator tube is followed by a power amplifier, and a portion of the voltage across the output transformer is rectified by a control tube and used to vary the bias on the oscillator tube. The circuit is shown in Figure 3. Feedback of this type tends to hold the output level and the frequency constant regardless of changes in the voltage of the power supply. It also results in considerable improvement of the wave shape. With the output controlled in this manner, the requirements placed on the following filters need not be so severe, and simpler circuits may be used to eliminate the P and Q frequencies later.

The circuit between the apparatus under test and the high-gain detector, although required to eliminate only two frequencies, P and Q, should be adjustable, since these frequencies may be at any values over a wide range. It has been possible to use a bridged-T structure, as shown in Figure 4, to eliminate each fundamental. With perfect adjustment such a structure can be made to have an infinite loss at a single frequency. At the resonant frequency, the transmission through such a T network has a phase shift of 180 degrees, while transmission through the shunting resistance R has a zero phase shift. By adjusting the value of R, the currents transmitted by the two branches may be made equal, and since they are opposite in phase, the net output is zero. Since the action of the rejection circuit is practically independent of its termination, two of them may be used in tandem—one to reject the P, and the other, the Q frequency. The loss through the rejector circuits is high only at a single frequency, and it is largely because of this that every precaution is taken to obtain good stability in the oscillator.

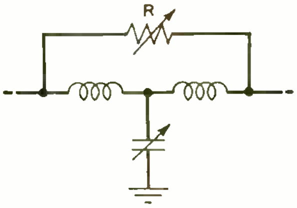

Fig. 4—Schematic of adjustable bridged-T rejector circuit

The circuit of the high-gain narrow-band detector is shown in Figure 5. The carrier oscillator for the converter, like those that provide the P and Q fundamental frequencies, has automatic output control. The band-pass filter is a standard filter from the voice-frequency carrier telegraph system.

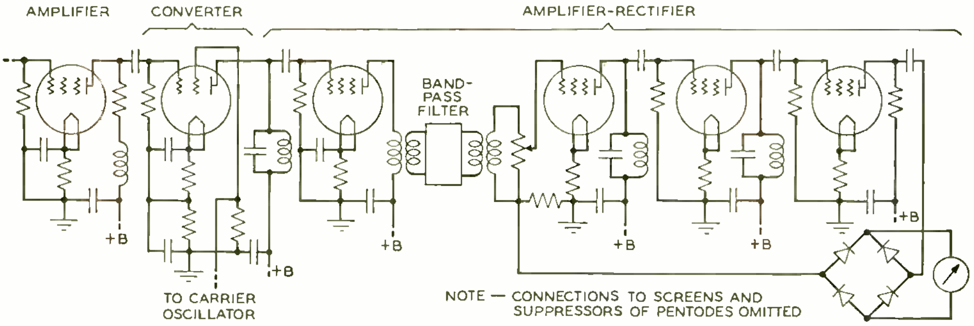

Fig. 5—Simplified schematic of high-gain narrow-band detector

Each stage of the low-frequency amplifier has cathode feedback and in addition overall feedback is used. The sensitivity of the circuit is such that an input level 130 db below one milliwatt will override thermal noise and other interference sufficiently to insure an error of less than 1 db in the measurement. The maximum modulation level that can be measured is approximately one milliwatt.

For an input level of one milliwatt modulation produced within the set itself is 120 db below the fundamental. Modulation products, therefore, as low as 100 db below one milliwatt may be satisfactorily measured. Although the equipment was designed primarily for the K carrier range from 12 to 60 kc, it may also be used in the C and J carrier ranges, or from 4 to 150 kc. So far it has been used principally to measure the modulation of new types of amplifiers for the C and K carrier telephone systems, and of thermistors for these amplifiers.

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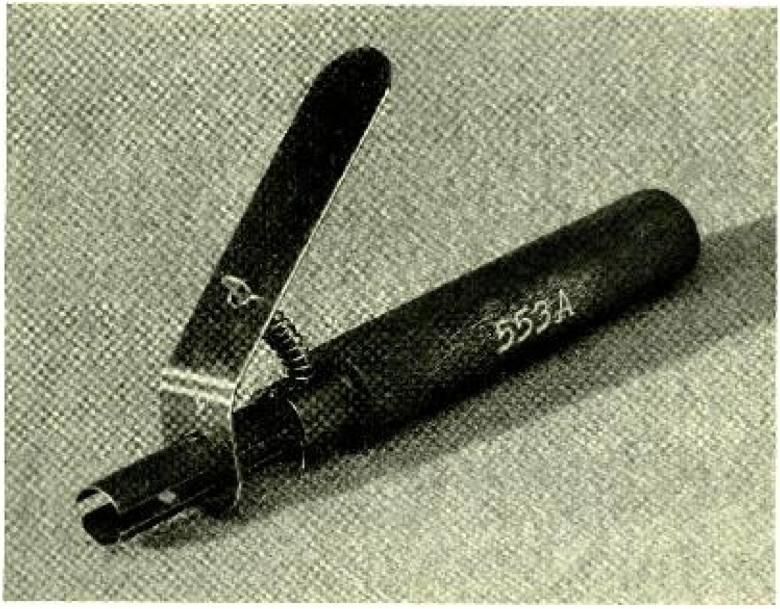
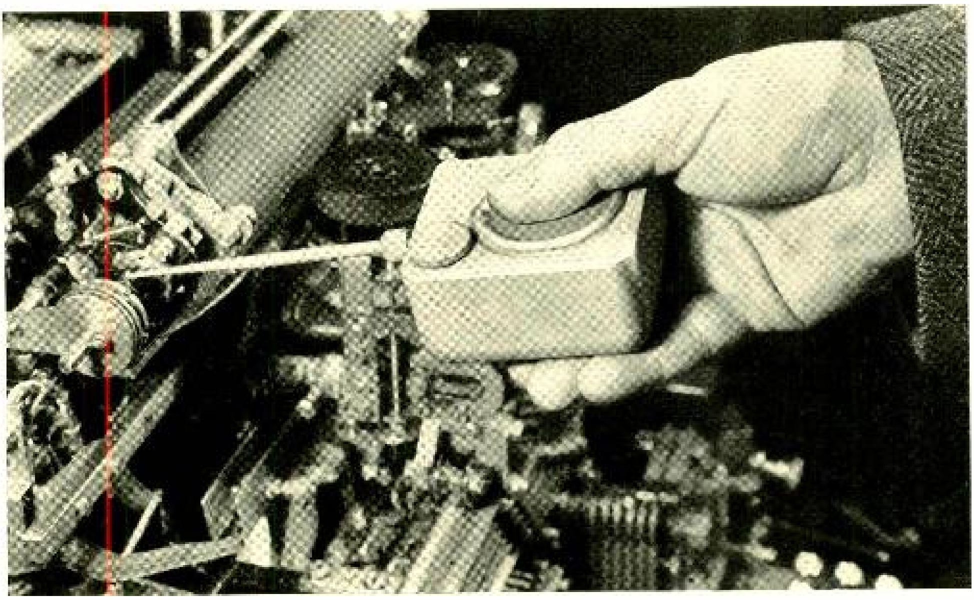


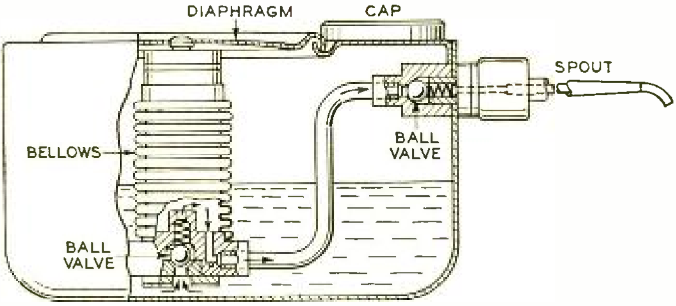
SWITCHBOARD LAMP EXTRACTOR

When switchboard lamps need to be removed for replacement, a special tool is required. Formerly this was a thin steel tube, split lengthwise, which was forced over the lamp. This tool sometimes broke a lamp, or itself was broken. The new tool shown above has two jaws and a spring controlled lever. When it is slipped over a lamp and the lever is depressed, the jaws clamp the lamp gently but firmly



Teletypewriter Oiler

An ORDINARY oil can is no friend to the teletypewriter maintenance man. It will spill if overturned, and mess up his tool kit; unless full, it will not feed "uphill"; and the quantity dropped is hard to control. With the importance of proper teletypewriter lubrication and these shortcomings in mind, the Laboratories have developed a teletypewriter oiler called the 512A Tool. Part of its top is a metallic diaphragm; to that is attached a metal bellows into which oil is drawn through a ball check valve. When the diaphragm is pressed oil is expelled through the spout; a drop at a time when pressed gently and a squirt of up to about fifteen drops when forced down far enough to bring the bellows into greater action. Another ball valve at the entrance of the spout keeps the oil from escaping except when the diaphragm is pressed.



Extended Use of Rubber Insulation in Telephone Cords

By R. T. STAPLES

Apparatus Development

FAVORABLE experience in the manufacture and use of rubber-insulated conductors in telephone cords* has indicated the desirability of extending the use of rubber insulation to other types of cords so that they may better withstand the most severe conditions of station and central-office service.

Standard cords with rubber-insulated conductors and a brown textile-braided outer covering are well adapted for normal station use. In places where usage is much more severe, however, such as at coin boxes, in business offices, restaurant kitchens, markets, laundries and in many industrial plants a much more rugged cord is needed. Cords are subjected in these services to abnormal wear and to kinking which detracts from their appearance. They may also have to withstand frequent wetting with water or other liquids as well as contamination with grease, dirt or chemicals.

For these situations rugged cords with rubber-insulated conductors and a tough rubber jacket have been developed. They are finding extensive use in the telephone plant, not only in the specific locations mentioned, but also for residence and general use in localities where long periods of high humidity or actual condensation of moisture are encountered. Their use may also be advisable in residences where cord kinking is troublesome.

In manufacture, the rubber-covered conductors are twisted together (Figure 2) with cotton filler threads, which lie in the interstices, and covered with a cotton binding to form a smooth core. The core is then covered with a thick extruded jacket of tough brown rubber. A cord structure of this type costs more than that used in the braided type of cord but the longer life of the rubber-jacketed cord justifies its use

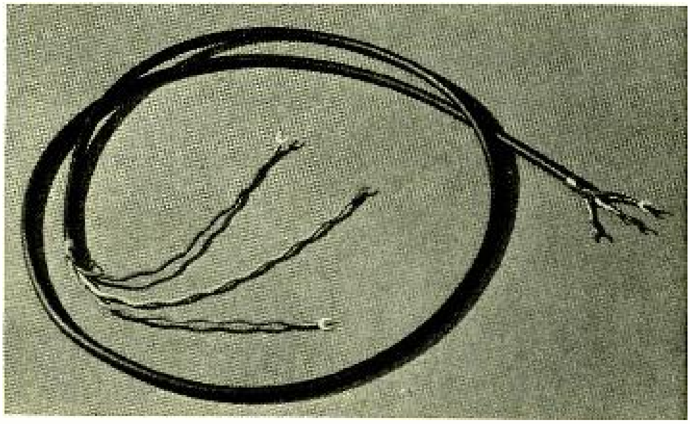


Fig. 1—Rubber-insulated station cords have rubber-insulated conductors with filler threads between them and a spaced serving of cotton to bind the conductors together

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*Record, *Nov.*, 1937, *p.* 85 and *Aug.*, 1938, *p.* 396.

where service conditions are severe. The rubber jacket has the further advantage that its stiffness and torsional resistance are greater and this minimizes the tendency of the cord to become twisted and kinked in service.

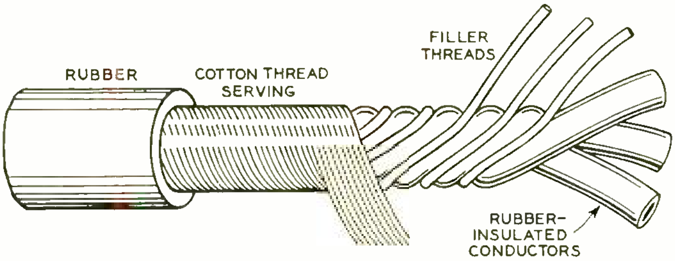

Fig. 2—Station cords with an outer covering of rubber are used where service conditions are unusually severe, as at coin boxes and in industrial plants

Experiments and field tests had been conducted previously to determine whether a rubber jacket could be employed advantageously instead of glazed cotton as a covering for switchboard cords. A rubber jacket was found unsuitable for this application because it was difficult to attach the cord securely to its associated plug; also, friction between the rubber jacket and the walls of the hole in the plug shelf prevented the cord from being restored readily.

Use of rubber insulation to replace silk and cotton on the individual conductors of the switchboard cords showed promise as a means of improving the electrical insulating properties of the cords and reducing substantially their manufacturing cost. That development, which would require changes in design of upwards of 150 standard cords, seemed warranted considering the probable future demand for the cords.

Although the majority of dial-system telephone calls do not involve the service of an operator or of switchboard cords, some of the calls will continue to require the use of manually operated switchboards. Toll systems are operated in general through manual switchboards and, in a large number of towns, local service is more economically given by manual boards. Added to these cord demands are those required for maintenance purposes in existing manual-system central offices, many of which are relatively new, and in the large number of manual private branch exchange boards. Both of these types of equipment may continue in service for a number of years.

Experimental cords of various designs were made up and were subjected to forced manual plugging tests simulating actual service conditions. On the basis of these tests, cords were given field service trials for a final check of their serviceability.

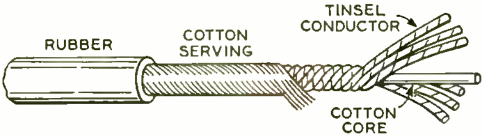

Fig. 3—The new rubber-insulated conductor for switchboard cords has a serving of cotton over the tinsel conductor and a thin outside layer of rubber applied by a continuous vulcanizing process

Rubber-insulated conductors developed for these cords had to be smaller than those used in station cords so that the completed cords could be held within the specified diameter limits. The new structure is shown in Figure 3. A thin wall

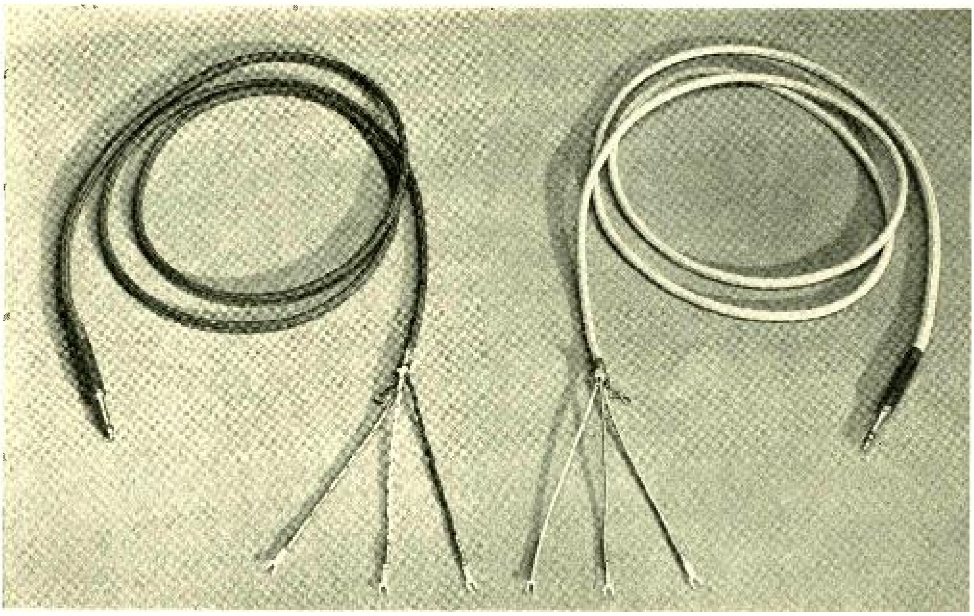

Fig. 4—Switchboard cord with rubber-insulated conductors (right) has better electrical characteristics and greater flexibility than cord with textile-insulated conductors (left)

of rubber is applied by the continuous vulcanizing process in the several different colors required. The twisted and filled-core construction, the glazed cotton reinforcements and the outer braiding used in former cords have been retained. New solderless tips were developed to match the smaller diameter of the insulated conductors.

Switchboard cords with rubber-insulated conductors are better adapted to economical methods of manufacture than those with textile insulation. They are more flexible and can be handled with greater ease by the operators at the switchboards. Their service life is relatively the same as that of the textile-insulated cords and they retain flexibility during prolonged periods of high relative humidity, such as occur along seacoast localities during the summer months. Their electrical insulation characteristics remain at a high level during severe climatic conditions.

Contributors to this Issue

C. C. Taylor received the B.S. degree in Electrical Engineering from Colorado College in 1917. After two years in the United States Navy he entered the Long Lines Department of the A T & T at Denver, serving in various capacities including that of District Plant Engineer until 1929. He then transferred to the Department of Development and Research, where his work was concerned with radio telephone control terminals and voice-operated equipment. Since the consolidation of this department with the Laboratories in 1934 his work has continued with radio telephone systems.

R. T. Staples joined the Western Electric Company in 1907. He spent six months in the student training course and was then assigned to testing models of central-office apparatus and inspecting tool-made samples. Later he became active in designing the paper and mica condensers used in the First World War radio receiving sets. For the past ten years Mr. Staples has been engaged in developing cords, wires and cables.

J. M. Finch began his association with the Western Electric Company in 1910 as a member of the Installation Department. A year later he was transferred to the chemical group at West Street to work on insulating materials including cable and condenser papers. Mr. Finch has since continued in that work with the Laboratories. He has made important improvements in methods of testing such papers and preparing specifications for them.

J. P. Kinzer graduated from Stevens Institute of Technology in 1925 with the degree of M.E. He at once joined the Research Department of these Laboratories, where he worked on the loud speakers for the first sound pictures. Some two years later, he went to the Systems Development Department, where he engaged in the development of voice repeaters for two-wire circuits. In 1930 he transferred to the carrier group and has since been concerned with the development of carrier systems for cables. During this period he studied at Brooklyn Polytechnic Institute, and in 1933 received the degree of B. in C.E.

C. C. Taylor

R. T. Staples

J. M. Finch

J. P. Kinzer

B. P. Hamilton

A. B. Bailey

B. P. Hamilton was graduated by Columbia University in 1913 with the E.E. degree. He taught there for two years and then joined the Engineering Department of the A T & T in 1915 to work on equipment design and later on field tests of high-frequency and voice-frequency carrier telegraph systems. Mr. Hamilton's work has also involved development problems in connection with the Key West-Havana submarine cable and transcontinental carrier telegraph systems. Since 1930 he has been engaged in developing voice-frequency carrier telegraph systems and applying them to carrier telephone channels.

Arnold B. Bailey received a B.S. degree in Engineering Administration from Massachusetts Institute of Technology in 1925 and then became a member of the instructing staff of the Department of Economics of the Institute. In 1926 he joined the Radio Development Department of the Laboratories and specialized in the design and installation of radio telephone and broadcast transmitters. He aided in the development of a universal radio beacon for aircraft and later made a series of technical studies on the location and selection of radio sites for broadcast stations, including Stations WABC, WSB and WHN. For the last two years Mr. Bailey has been engaged in the development of two-way mobile radio systems.

MATERIALS SAVED FOR DEFENSE

About 150 airplanes for defense will have aluminum this year thanks to savings made by Western Electric Company, producer of Bell telephones, in using substitutes. Enough zinc will be saved to make nearly twelve million three-inch cartridge cases. Western Electric's substitution program began several years ago when studies were instituted in this direction. The company has or will make substantial reduction in requirements of nickel steel, nickel, magnesium, tungsten, and other vital metals.

Iron Age. July 3, 1941.

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