BELL LABORATORIES RECORD

WOOD PRESERVATIVES
R. E. Waterman

RADIO TELEPHONE FOR HARBOR CRAFT
W. K. St. Clair
F. B. Woodworth

PROTECTOR BLOCKS
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In this Issue

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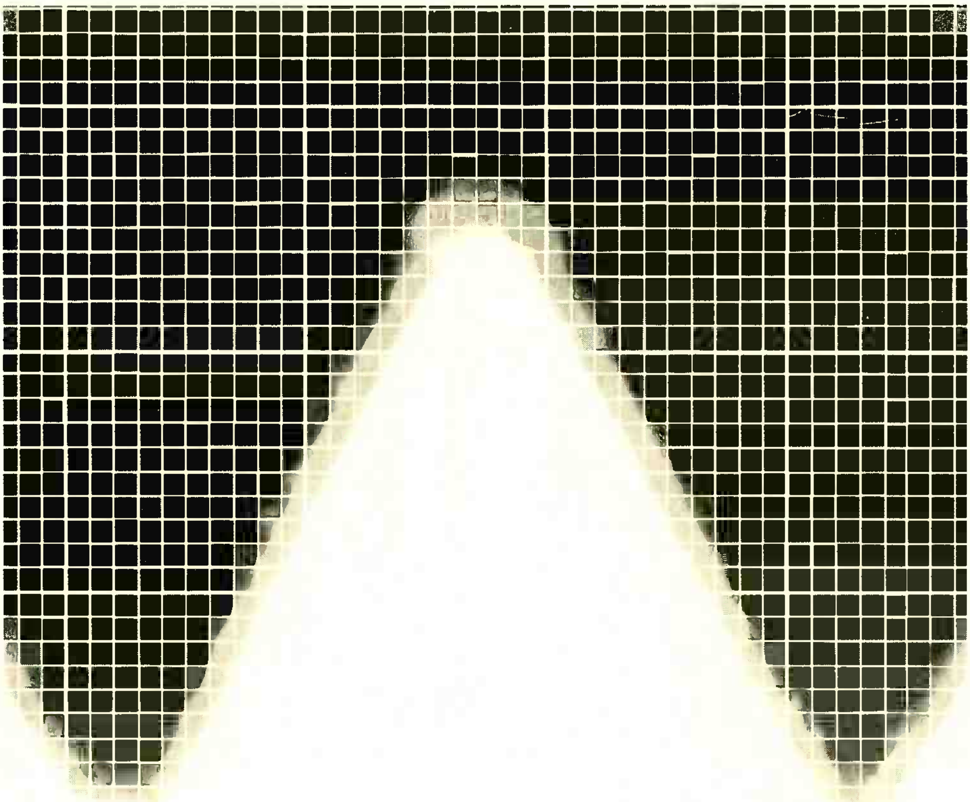

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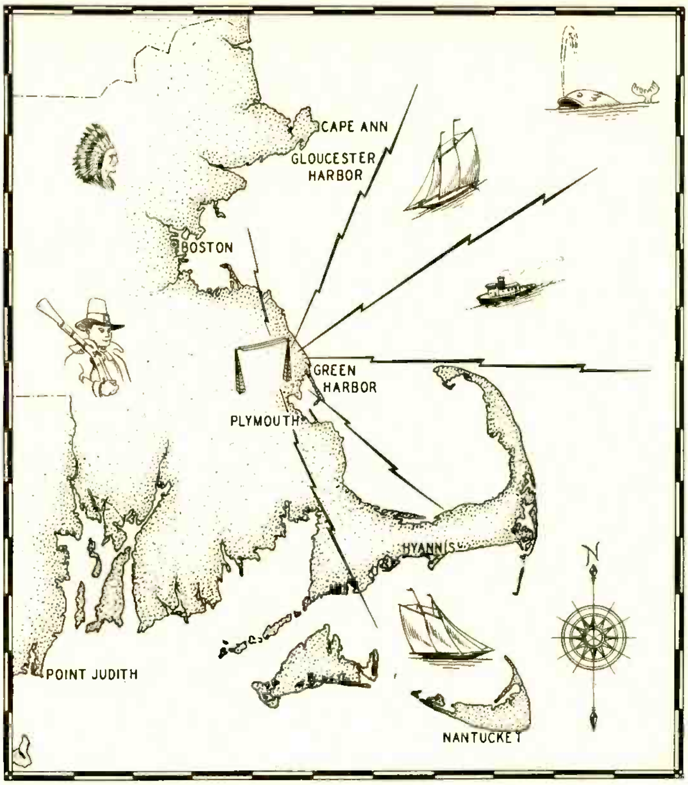


A Telephone System for Harbor Craft

By W. K. ST. CLAIR
Equipment Development

IN the past when a captain of a tug boat or other small craft left his dock to proceed on an assignment, he immediately severed communication with shore, and might proceed on a long trip which changing conditions made useless or be ignorant of the need for his presence in an emergency occurring at another place. It is, of course, possible to equip such small boats with radiotelephone to permit conversation between harbor craft and shore or from craft to craft. Whether or not this is desirable is a matter of economics. Several of the Telephone Companies are contemplating the inauguration of shore-to-ship radiotelephone service in some of the large harbors of both the Atlantic and Pacific Coasts. At Boston the New England Telephone and Telegraph Company has opened its station on a trial basis, largely for the benefit of the fishing fleets which operate in nearby waters. It is expected that the fishing fleets through this service will be able to concentrate where the fish are running and that the companies may keep in touch with the boats, advising them when to run in to port to take advantage of favorable price conditions.

The equipment aboard ship is described in an accompanying article. At the shore station is equipment similar to the ground-station transmitter and receiver used for airplane communication*, but modified somewhat to meet the special requirements of harbor service, and to provide for connecting the radio circuit to the land lines of the Bell System. A photograph of the transmitter with its associated rectifier for power supply, the antenna tuning unit, and the antenna switch is shown in Figure 1. The receiver, grouped for operating convenience with the voice-frequency control equipment, is shown in Figure 2. This control equipment has the same general functions as that employed for the transatlantic telephone service†, but is much simpler. Through land lines to the toll office, the radio link is connected to the local and long-distance telephone system.

A simplified schematic of the shore station is given in Figure 3. Speech to be transmitted to a boat passes from the land circuits through a volume control for regulating the input to the radio transmitter, through an amplifier, and then through a hybrid coil. Here the main speech channel passes through the front contact of a relay to a transformer, which couples the circuit to the radio transmitter. When the relay is unoperated, the transmitter is blocked through a back contact, but part of the voice current passes from the hybrid coil to the transmitting amplifier-detector which operates the transmitting relay so that transmission may take place. This amplifier-detector is a vacuum tube and relay device arranged to be more sensitive to pulsating currents, like speech, than to disturbances like line noise which have a comparatively unvarying envelope. At the same time that the transmitting amplifier-detector operates the transmitting relay, and so permits transmission, it also operates another relay which blocks the receiving circuit.

Incoming speech, from the radio receiver, passes through a repeating coil combination and then through a volume control for adjusting the speech to the land lines. Part of the incoming speech, however, is shunted from the repeating coil combination to a receiving amplifier-detector. This is a voltage operated trigger device, using a gas-filled detector tube, and designed to be fast and positive in its operation. At the first impulse of incoming speech this apparatus operates a relay which opens the circuit to the two relays already mentioned, so that the transmitter remains blocked and the incoming circuit clear. When speech is not being transmitted, the transmitting circuit remains blocked, to prevent re-radiation, and the receiving relay is closed so that incoming signals may be heard.

The receiver is equipped with an automatic gain control which adjusts the amplification according to the level of the incoming carrier. When no carrier is being received this control raises the gain to its maximum value, thus greatly magnifying all incoming noise. To avoid transmitting this noise over the land lines a piece of apparatus known as the "codan"—made from the initial letters of the words indicating its function "carrier operated device, anti-noise"—is used to insert a large loss in the receiver circuit when no carrier is being received. By the use of this device, practically no radio noise is received at the amplifier detector or at the subscriber's station when the distant

*Record, *October*, 1930, *pp.* 65 and 71.
†Record, *September*, 1929, *p.* 15.

carrier is not being received.

Provision is made to enable a ship to talk with another ship as well as with the land station. Such communications must pass through the shore station, however, because two frequencies are employed for harbor communication; one for transmitting from shore to ship, and one, from ship to shore. All ship transmitters are tuned to one frequency and all ship receivers to the other. To make ship to ship communication possible, a key-operated transfer circuit is provided at the shore station, which permits the incoming voice currents to be by-passed directly to the radio transmitter. This connection is under the control of the technical operator.

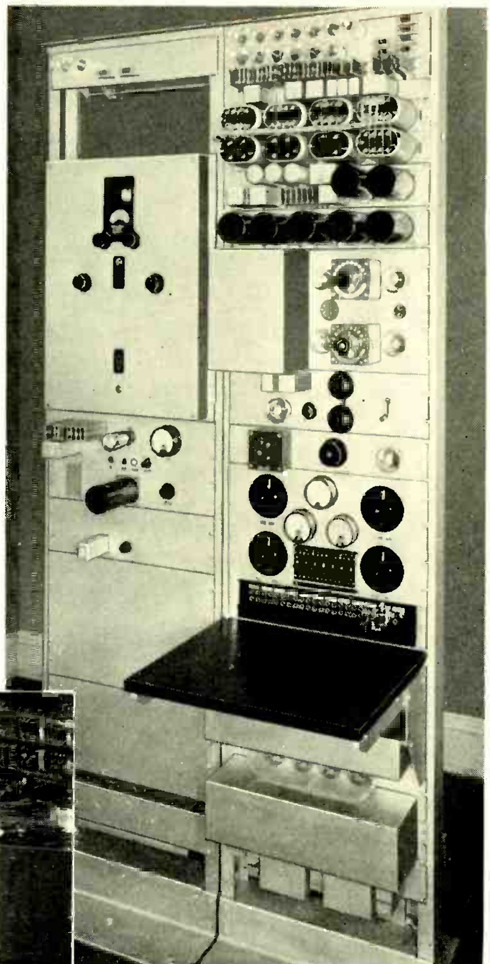


Fig. 2—Connections between shore and ship are made by a technical operator who sits at the voice-frequency control panel

Fig. 1—Shore station at Green Harbor with J. M. Henry, who supervised the installation, at the voice-frequency control equipment

The control apparatus, mounted on a panel in front of the technical operator, includes attenuators for regulating the transmitted and received volumes and the sensitivity of the amplifier detectors, a direction indicating meter to show whether speech is being transmitted or received, a volume indicator available for either received or transmitted speech, as well as a meter for plate voltage, and keys for starting the transmitter and for talking and monitoring on various parts of the circuit.

The shore transmitter, known as the 9-C, is designed to deliver 400 watts of carrier power at any frequency between 1500 and 6000 kc, and will maintain its frequency to better than .025 per cent. This equipment may be located at some distance from the control and receiving station, or it may be in the same building. If in a separate building, a short-wave radio receiver at the control station is used for monitoring the output of the transmitter.

Power for the radio transmitter is furnished by the rectifier associated with it, and both the transmitter-rectifier and the radio receiver are arranged for operation from the usual alternating current mains. A motor generator set, with the necessary filter equipment located on the same mounting, furnishes filament and plate supply for the voice-frequency control equipment, the monitoring receiver, and for the codan as well.

The service at Boston, operated by the New England Telephone and Telegraph Co., makes use of the site and buildings at Green Harbor formerly owned by the Laboratories. From this point, on the shore of Massachusetts Bay some thirty miles southeast of Boston, it is expected that it will be possible to communicate with ships from Point Judith, on the coast of Rhode Island, to beyond Cape Ann on the northern Massachusetts coast, and from these points some two or three hundred miles easterly over the ocean. Within this area are located most of the important fishing banks.

Two "beam trawlers" cast off from their wharves in Boston early in June for their first trip with the new radio equipment. This service should be helpful to other craft than those engaged in the fishing business. Pilot boats, tow boats, oil tankers, coastal steamers, private yachts, coast guard boats, and similar small craft are all potential candidates for this service.

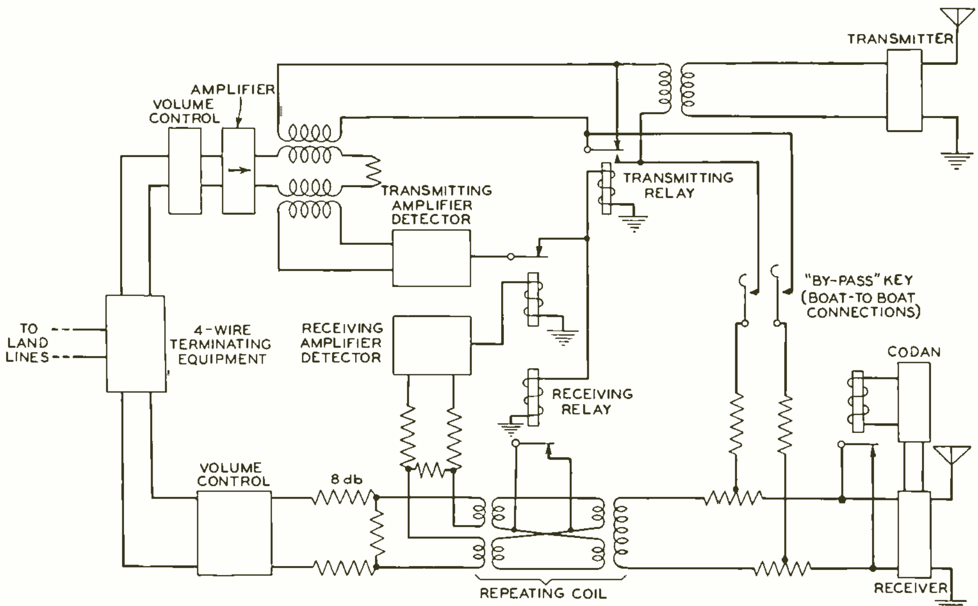
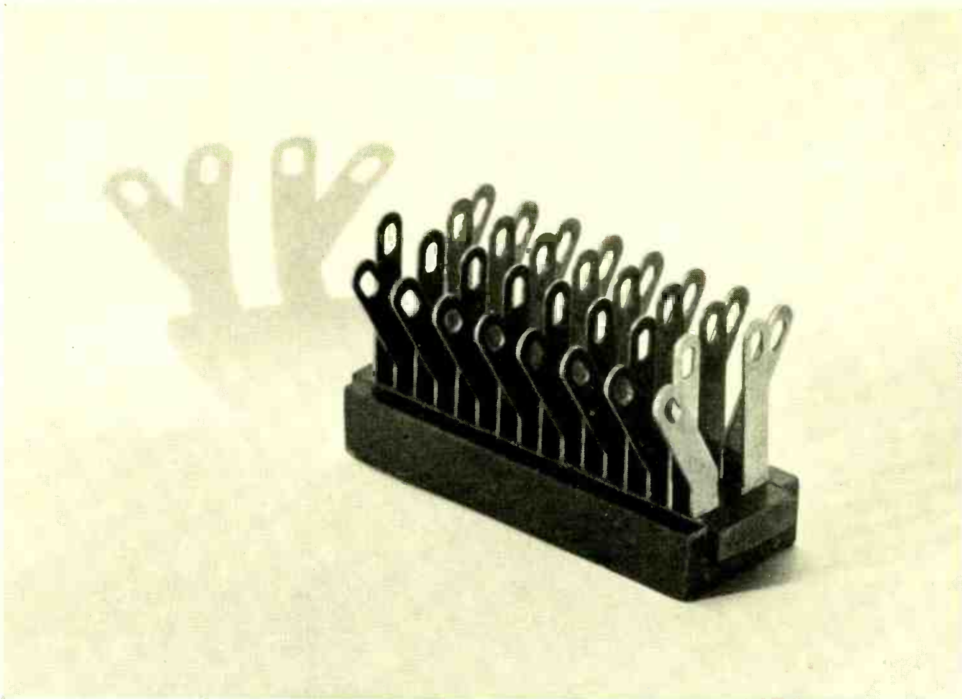
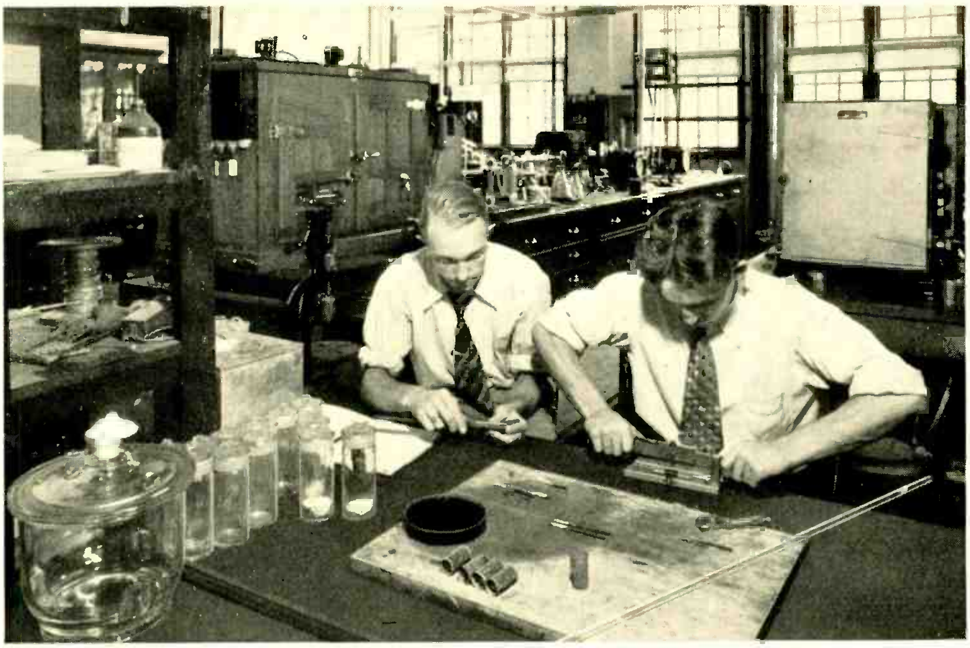


Fig. 3—Simplified schematic of shore station circuits



A new terminal strip, of novel design and small size, has recently been developed by the Laboratories, and will, it is expected, have extended use with shop wired units requiring only a small number of connections. Applied to such units, it closely resembles the terminals of a relay. This new strip consists of sets of rectangular U-shaped punchings moulded in a phenol plastic base. Such an assembly permits the unit local cable to be connected to one side of the strip and the outside wiring to the other. Projections on the ends of the phenol fibre base allow the strip to be slipped into or out of a small punched metal supporting bracket, one type of which is shown below.



Forecasting the Behavior of Wood Preservatives

By ROBERT E. WATERMAN
Chemical Laboratory

FEW people realize that the rotting of wood, although promoted by moisture and warmth, is caused exclusively by the actions of organisms of the fungus type which use the wood as food. Yet it is this fact which determines the means of wood preservation. There must be introduced into the wood a fungicide which will remain there for decades in spite of exposure to sun, wind, rain and soil moisture. This must be done at a cost so moderate that the extension of the life of the wood is economically profitable.

Creosoted timber has acquired an excellent reputation and is often accepted by construction engineers as the last word in durability. At the beginning of the creosoting industry, creosote was so cheap and abundant, and the possible extension of life of wood under favorable circumstances was so great, that few questioned what kind of creosote should be used and how much. Today not only are new wood preservatives constantly coming on the market but creosote itself is changing in character. Creosote is a by-product of the carbonization of coal, and the kind of coal tar which is available depends on the changes in practice from year to year which are found to improve the yield, quality, or cost of coke. Also the tar distiller has found it necessary to change his processes either for economies in operation or to meet market conditions. For example pitches were formerly in greater demand and creosote in less demand than at present. Thus new types of creosote have come into existence and have tended to displace the older types upon which much of the experience of the wood-preserver is based.

The interest of the Bell System in extending as much as is practicable the useful life of its telephone poles has led these Laboratories to search for means of determining how these new types of creosote and other new preservatives compare with those of the past. To use untried preservatives would be foolhardy, and to await the results of trial in the field would lead to costly delay, or even perhaps to the choice of a preservative which changing conditions had made unavailable. It is necessary to learn within a few years the relative value of proposed protective agents, and to develop some reasonably exact measure of their costs.

One of the first methods used in the wood preserving industry to forecast the value of any new preserving agent was the fungus pit. This was a damp warm cellar, well infested with various wood-destroying fungi. The compound to be tested was injected into several pieces of wood in varying amounts, and the samples were placed in the pit together with other test blocks and untreated specimens and examined from time to time. With good fortune, some pieces would gradually rot while others would remain as hard and strong as the day they went into test.

Often, however, a series of specimens which had been treated alike did not behave alike, or perhaps even untreated wood would not decay. This confusion resulted from the transfer of preservatives from one specimen to another by diffusion of their solutions or their vapors due to the proximity

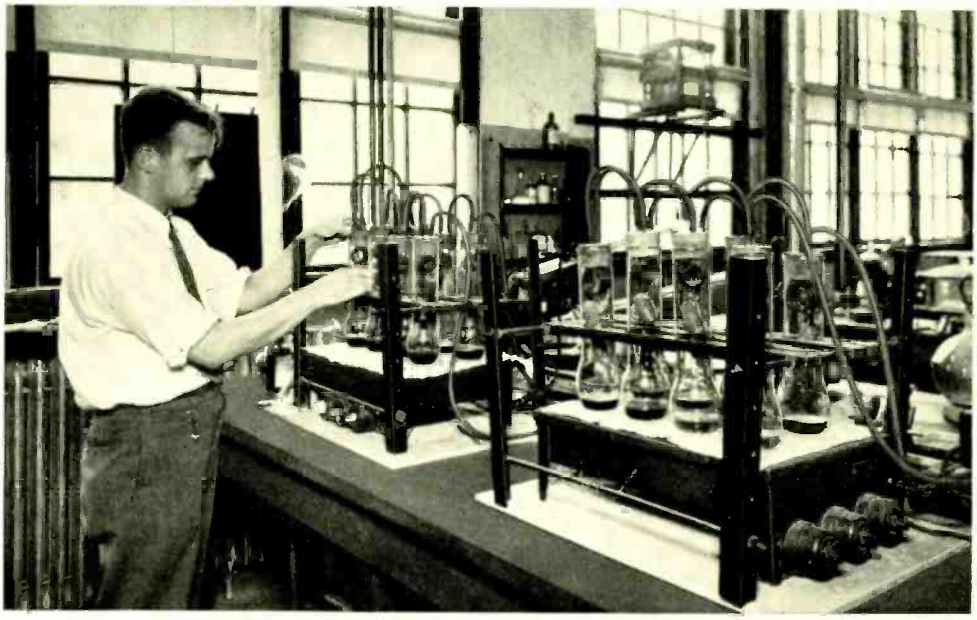


Fig. 1—Oil-type preservatives are extracted from the pole samples by a suitable solvent

of samples and the necessarily limited ventilation. Indeed a single specimen might sterilize the whole cellar.

The fungus pit had the further disadvantage of telling nothing about the permanence of the material in the weather. Benzene for instance is very toxic to wood-destroying fungi but it will not last long in a pole because of its high volatility at moderate temperatures. Several highly fungicidal salts are known, but they are so soluble that they are soon washed out of the wood. The fungus pit has fallen into disrepute, therefore, and it is doubtful whether there is one left in the United States today.

Laboratory tests likewise have definite handicaps. In dealing with such a complicated chemical, physical and biological process as that which takes place during the time that a treated pole is losing its toxicity and starting to rot, it is always possible that some vital factor has been missed in the laboratory. Careful attention to this danger, however, and continual checking of the results of tests with experience in the field, are beginning to bring to light reliable methods of test which employ both laboratory and field conditions.

Wood preservatives may be divided into two general classes—oils, and water-soluble materials, the latter being usually inorganic salts. The mechanisms by which a pole loses these two types of materials differ widely. An oil, such as creosote, is lost mainly by evaporation, from that part of the pole which is exposed to the air. Salts, which are subject to leaching, leave the underground section of the pole faster than the upper part. Both of these types of loss may progress very rapidly. Since losses of toxic agents allow subsequent rot to take place, it is important to follow the rates with considerable exactness.

Fig. 2—*The toxicity of a preservative is determined by observing the rate of growth of different fungi in cultures containing different concentrations of the preservative*

In case of salts or a single organic compound, the problem is relatively simple. Data on the toxicity of the compound to wood-destroying fungi give in a general way what concentration is needed to keep the wood sterile. Extrapolating the curve of the rate of loss to the danger point gives the probable life of the preservative without waiting for actual rot to take place.

With mixtures the problem is more difficult. Creosote, for instance, contains several hundred different chemical compounds which evaporate at different rates and have different toxic values. Thus the total loss in weight no longer measures the loss in toxicity. Two creosotes may have the same initial toxicity, but after a twenty per cent loss in weight one may have diminished only slightly in toxicity while the other may have become almost neutral. Since it is obviously impossible to analyze repeatedly for each constituent, biological tests must be used to tell how the loss is progressing.

At present two principal methods are used by these Laboratories to procure the data for curves of toxic loss. In one case the preservative under test is injected into eight foot posts of the diameter of a small telephone pole under carefully controlled conditions. Samples are then taken from the treated pole in a way which does not render the pole section unfit for further studies on the permanence of the preservative but procures enough of the specimen to find out the initial concentration of the material under test. The sampling tool is the increment borer, an instrument used by foresters to determine the age of standing trees. It cuts out a small cylindrical core when introduced into a piece of timber. Eight of these cores, a fifth of an inch in diameter and extending to the center of the post, are taken in a two-foot band at the longitudinal mid-point of each post and equally spaced circumferentially around the pole. Each of these cores fairly well represents the content and distribution of the preservative in that sector of the post from which it is taken, but contains a disproportionate volume of the inner layers of wood as compared with the outer ones. Each of these cores is accordingly split in a small machine developed for the purpose, the line of cleavage running diagonally across the cylindrical core and tangential to the circular cross sections at its two ends. The piece thus obtained, which tapers toward the heartwood, approximates as nearly as is necessary the pie shape of the mathematically correct sample. A composite of eight such pieces makes up the final sample of the post.

If the material under test is a salt or a simple mixture, the concentration of the different constituents in the borings is determined analytically. Although in some cases it has been necessary to resort to more unusual means, in most cases the familiar methods of analytical chemistry have sufficed.

For oily mixtures such as creosotes where the changes of the material both in quantity and in quality are important, a biological test of toxicity is used. The borings from the treated posts are cut into small pieces, dried of water over calcium chloride, and then extracted with ether. The loss of weight of the borings during extraction represents the quantity of oil present, and the extracted oil is in a condition convenient for the determination of the toxicity. This determination is carried out mainly according to methods developed by the Forest Products Laboratory at Madison, Wisconsin.

The poles are then placed in outdoor test plots and are again sampled with an increment borer in the same way from time to time. In the salt-type treatments sampling is done in a band below the ground-line, and in the oil-type above ground, the regions where maximum loss of preservative takes place in each case. These cores are subjected to the same routine as were the original samples and the results so obtained are plotted against time to form the basis for forecasts.

About 500 posts are now under test by this method. They represent about twenty varieties of treatment. Data covering periods of exposure up to five years have been obtained. During this time as much as 50 per cent by weight of a variety of creosotes have evaporated and their toxicities

Fig. 3—The sapling plantation affords an accelerated testing ground for wood preservatives

have declined by a larger factor. Preservatives of the salt type have generally been found to lose ninety per cent or more of their activity after exposure for ten to thirty months. In the case of creosote the validity of these results has been confirmed by the examination of scores of poles from telephone lines which have been in service for known periods of time up to thirty years. For this purpose the existing careful records of origin, method of application, and analysis of creosote in poles installed many years ago have been invaluable in correlating the rates of toxic loss and the occurrence of decay with specific factors involved. In general these studies confirm the prevailing opinion that a well chosen creosote is the best available preservative for the purpose, but they also reveal many opportunities for further perfecting creosoting practices.

Forecasting new treatments by the boring method, however, is accomplished only by an extrapolation usually far beyond the experimental period, and its reliability depends critically on the accuracy with which the experimental points are known, since extrapolation will greatly exaggerate any errors. Another method eliminates this danger by accelerating the depletion of preservative and subsequent onset of decay so that a complete life observation can be made.

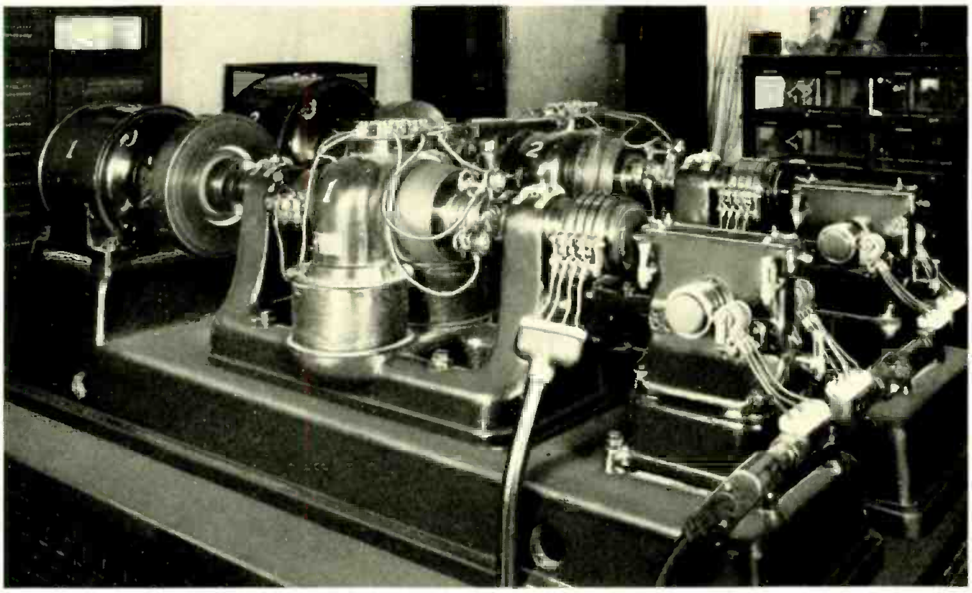
This method makes use of small saplings of southern yellow pine about one-half inch to three-quarters inch in diameter. The ratio of surface in square inches to volume in cubic inches in the average pole in use in the Bell System is 0.467. In a sapling of 0.75-inch diameter this ratio is 5.33. Hence for a given unit of volume, the sapling has a surface available for evaporation or leaching 11.42 times as large as the pole with a diameter of 8.56 inches. Roughly speaking these saplings will decay some ten times faster than equally well treated poles.

Three dozen saplings are injected with the preservative to be tested in a miniature treating plant at the Summit Laboratories of the Chemical Research Department. A six-inch section of each sapling is cut off for analysis, or for extraction and toximetry, and a dozen of the saplings are then set out at each of three test plots located in various parts of the United States, representing distinct types of climate.

These specimens are examined for rot or insect attack once a year. If no great amount of failure has taken place, one or more of each group is removed for laboratory examination. Chemical or biological assay of these saplings affords evidence of the rate of depletion. Within the first year it is usually possible to tell by analytical means whether or not the material will be worthy of further study, and by the second year the less successful materials will have failed either by rotting or insect attack.

The application of this method to known preservative treatments has yielded results in harmony with those of the boring method and with general commercial experience. The method has the advantage of carrying the test to actual destruction, thus including insect as well as fungus attack and eliminating some uncertainties of inferences drawn from chemical analysis. For example, in one case a preservative became ineffective with time not by leaving the wood but by conversion to an inert insoluble form.

Doubtless both of these methods are capable of improvement, especially in the precision of the forecasts which they permit. They are, however, of great immediate value in promptly eliminating from consideration inferior wood preservatives, and are gradually furnishing a basis for writing more exact specifications for the selected kinds of treatment.



Commercial Construction Adopted for Ringing-and-Coin-Control Generators

By J. R. STONE
Equipment Development

IN the larger central offices, ringing-and-coin-control motor-generator sets supply the twenty-cycle alternating current required for ringing, and both positive and negative direct current for collecting and returning coins at pay stations. For many years the type P machine, designed particularly for the special duties required of it, has been standard in the Bell System. A set of this type, shown in the photograph at the head of this article, includes a standard motor as the driving power, at one end; a ringing-and-coin-control generator, in the center; and a low-speed interrupter employed to secure certain operating signals at the other end. Mounted beyond the right hand bearing of the generator is a group of commutators which supply low and high frequency tones. This group has now been replaced by the tone alternator as already described in the RECORD.*

The type P generator, and its predecessors the G and H, were designed to give the peak voltages and low interference required for telephone service, and are special throughout. Dating from the last decade of the nineteenth century, they are of the general external form of the machines of that era, and have spool-type field windings, and cast steel pole pieces, with faces shaped to give approximately a sine wave form to the a-c voltage output. At one end, the left in the photograph, is a commutator for

*RECORD, *September*, 1932, *p.* 6.

supplying the positive and negative coin-control current, and at the other end are two collector rings, from which the a-c ringing supply is taken. Both commutator and collector rings are connected to a single armature winding, which is placed on a core built up of special steel punchings with partially closed slots. Although the voltage characteristics of both a-c and d-c outputs are better than obtained from standard machines, filters are always employed in the a-c output circuit, and in the negative d-c output for panel offices, to reduce the harmonic content.

Because of the relatively small number of them produced, the manufacturing cost of the type P generators has been high. That lower cost could be obtained by employing commercial parts produced in large quantities has, of course, been recognized, but until recently, the steps taken in this direction have not led to successful accomplishments. The outputs of machines built of commercial parts several years ago on trial did not prove satisfactory for telephone power plants, and studies made at the time indicated that the cost of a more complete filtering of the output, or of modifying the design of the commercial parts to obtain satisfactory results, would be great enough to offset the advantages secured.

Recent improvements in the construction of commercial generators and advances in the design of power filters, however, have changed this situation. Ringing-and-coin-control generators, made from commercial parts and employing new filters, are now available in place of the special type P machine. The new generator, shown in Figure 1, has a rolled steel frame, laminated pole pieces, flat field coils, and a conduit terminal box, as have commercial generators for general use. Ball bearings are provided to hold the end play of the shaft within the limits required by the tone alternator, which is mounted outside the bearing at the collector ring end as may be seen in the photograph. Output ratings of the new machines duplicate those of the older type. Full load characteristics for the two types of machines, both filtered and unfiltered, are shown by the four accompanying oscillograms. In the unfiltered d-c outputs from a combined ringing-and-coin-control generator, a forty-cycle ripple ap-

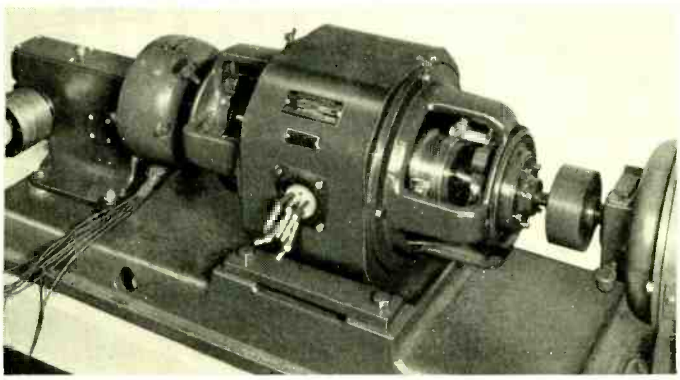


Fig. 1—The new generator follows modern design in its construction throughout

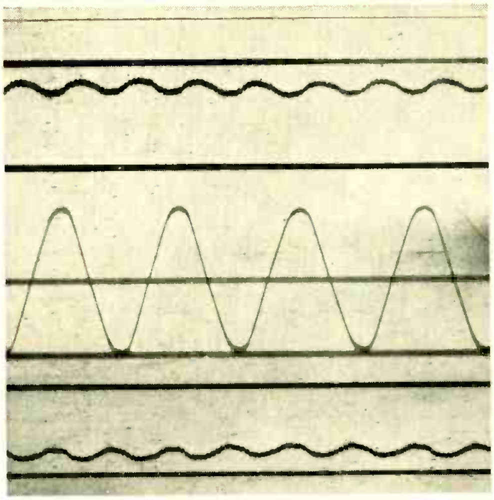


Fig. 2—Unfiltered output of type P machine

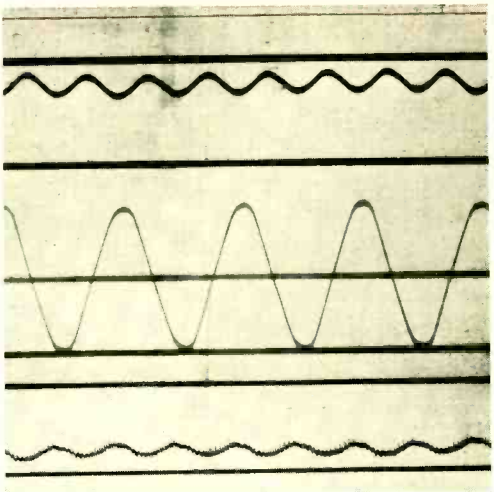


Fig. 3—Negative d-c filtered output of type P machine

pears, which is caused by the variation in voltage drop within the machine. When the twenty-cycle current is at its peak, the voltage drop is a maximum, and when it crosses the zero axis, the drop falls to a minimum, with the result that the ripple is of twice the frequency of the a-c voltage. Superimposed on this forty-cycle ripple is a ripple of much higher frequency but of smaller amplitude caused by the armature slots and commutator. Figure 2 shows this unfiltered condition of the type P generator outputs, and Figure 3, the filtered condition. From the latter illustration it will be noticed that the high frequency slot ripple has disappeared although the forty-cycle ripple remains.

With the commercial machine both forty-cycle and slot ripples are much

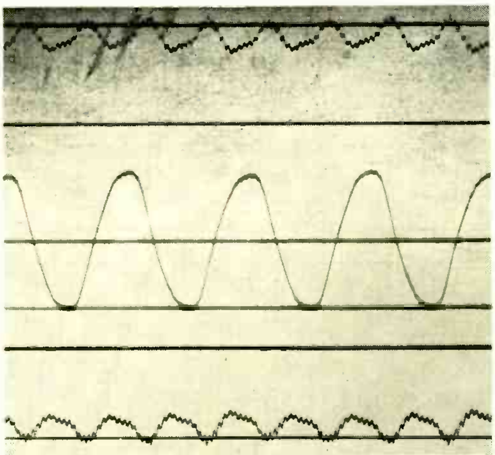


Fig. 4—Unfiltered output of commercial machine

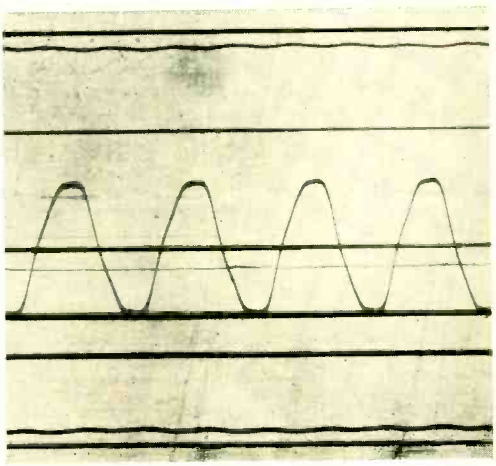
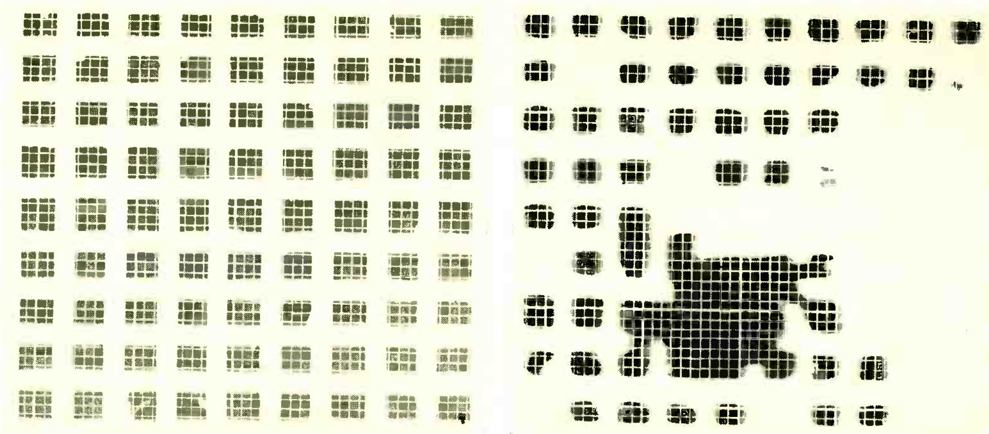
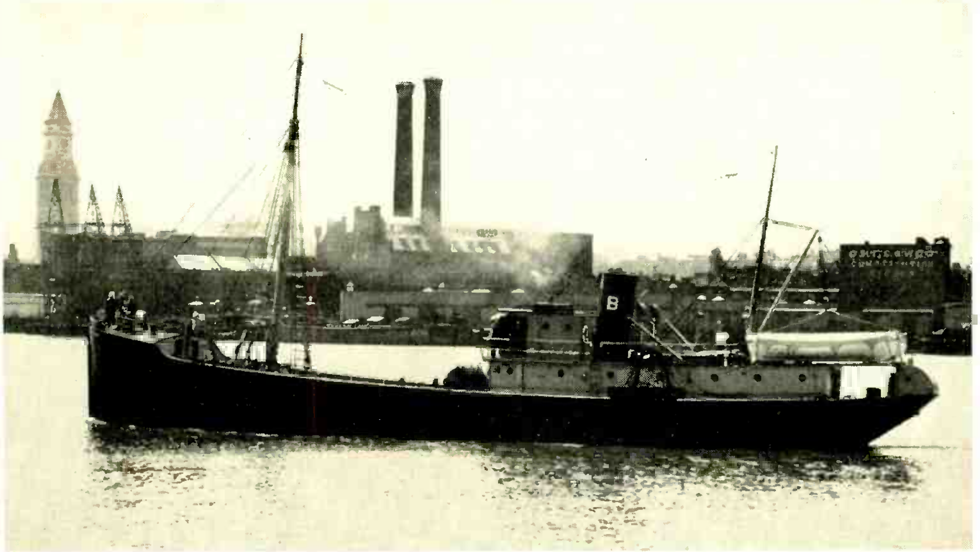


Fig. 5—Positive and negative d-c filtered output of commercial machine

more pronounced in the unfiltered output, as may be seen in Figure 4. When this output is passed through the larger and improved filters used with the commercial machines, however, not only is the slot ripple eliminated, but the forty-cycle ripple is reduced to a very small amount as shown in Figure 5. As a result the filtered output is actually an improvement over that from the type P machines.



Breaks in the wires of a sieve used for abrasives will let oversize particles through to cause scratches on the work. When the screen is passed through a contour projectograph, such as that of the Materials Laboratory, gaps and blocked holes are easily seen, and a photograph can be made for reference. A perfect screen is seen at the left for comparison. Each small square of the reference grid is .001 *on a side*



Fishing Industry Adopts Marine Telephony

By F. B. WOODWORTH
Radio Development

EIGHT bells had just struck the end of the morning watch on the trawler "Flow," which was steaming over the Georges Bank some 200 miles east by south from Boston. The wheelsman glanced at the compass, gave the wheel a couple of spokes to correct his course, and as he lifted his eyes to the vessel's bow, a shrill thousand-cycle tone came from a loudspeaker mounted above his head in the front of the pilot house. Immediately after a voice came from the loudspeaker saying "Marine Service, Boston calling the 'Flow'."

Captain Ness stepped into his cabin, and removed a handset from a hook projecting from a small metal box fastened to the bulkhead just inside the door. In a moment a red light showed that his transmitter was ready for use. He pressed a switch in the handle of the handset and replied,

"This is Flow answering."

"Just a moment, please," came the voice—now from the handset receiver—"Mr. Malcolm of the Bay State Fishing Company is calling you."

A moment's pause and a new voice from the receiver—"Good morning, Captain Ness, how much fish have you?"

"Good morning, Mr. Malcolm. The fish are running fine. We took in 75,000 lbs. of haddock last night."

"That's fine," replies Mr. Malcolm, "We expect the price for haddock to be very good tomorrow. You had better come in."

"All right," replies the Captain, "We will head for Boston in a couple of hours. Goodbye."

This is a typical application of one of the latest services of the Bell System. Radio telephone equipment similar to that designed by the Laboratories for aviation has been employed in this new field. The equipment now available is suitable for tugs in the harbors or pleasure yachts not more than a few hundred miles from shore. At Boston, trial installations have demonstrated that fishing boats over 200 miles at sea may have very satisfactory communication with their home office or with any Bell System telephone. Such communication can be given through shore stations located at important harbors on both coasts. The design of these stations is described in another article.

The equipment for the boats has been made as reliable and as simple to operate as possible. The necessary control units, which include a telephone handset, will, in general, be located in the pilot house or captain's cabin. The installation on the "Flow" is shown in Figure 1. A loudspeaker, placed where it may always be heard, receives all incoming calls. A single master control switch in the upper section of the control unit starts or stops the operation of the entire system. With the master switch in the "ON" position, the radio receiver runs continuously and any call for the boat is heard from the loudspeaker. A volume control for the incoming speech and a small meter to indicate when the transmitter is working are also included in the control unit.

Fig. 1—Captain Ness at the radio telephone equipment on the Trawler "Flow"

Removing the handset from the hook at the side of the control unit automatically starts the radio transmitter. This handset is similar to the standard type with the exception of a finger plate switch located in the handle, which is pressed while talking and released while listening.

The remaining radio and power apparatus, shown in Figure 2, may be installed in any convenient place elsewhere in the boat, and requires little space. The radio transmitter is the standard Western Electric 50 watt aviation unit, and has been described in previous articles.* It is very small and light in weight, and provides crystal control of the carrier frequency and high-percentage modulation. The radio receiver is a compact superheterodyne with automatic gain control. The tuning is adjusted to the particular shore station frequency and locked.

An antenna tuning unit, flexible enough to adjust the radio transmitter to antennas which can be constructed on a small boat, is shown at the left of Figure 2. In it is a relay which switches the antenna from the receiver to the transmitter when the finger

*Record, *October*, 1930, *pp.* 59-76.

plate switch on the handset is pressed. A relay set is also provided so that the radio equipment may be located a considerable distance from the control apparatus without incurring loss of power due to long supply wires.

Fig. 2—An installation of harborcraft radio on a trawler out of Boston

The power equipment may be any one of four types depending upon the kind of boat on which this radio apparatus is to be used. On a steamboat, for example, it is convenient to use a small steam turbine generator. This machine will run continuously so that power is always available for the radio equipment. The B supply for the radio receiver is obtained from a small dynamotor which is run from this turbine generator set. On a boat with a large capacity electrical supply, motor generators may be used for both transmitter and receiver power. For use on Diesel or gasoline engined boats there has been developed a small automatic gasoline engine generator set, which starts automatically when the handset is removed from the hook in the pilot house. The fourth arrangement provides for the use of storage batteries and dynamotors for both transmitter and receiver power. The main advantages of this latter system are the compactness of the power machinery and ability to operate in emergency without any other source of power than the storage battery.

In view of the compactness of the equipment and of its adaptability to different types of power supply, it is expected to find application on a wide variety of craft operating in coastal waters, and a widespread use of the new system is anticipated as its many advantages become fully appreciated.

The Development of the Protector Block

By D. T. MAY
Telephone Apparatus Development

WITH the installation of the first commercial telephone circuits there arose the need of protecting the equipment against high extraneous voltages. To produce a protector is easy: a pair of conducting parts separated by a small air-gap will divert the high voltage to ground. But to produce a protector which is not likely to remain short-circuited as a result of a single discharge of relatively low current is more difficult. A tendency to permanently short-circuit is very troublesome, occasioning interruptions of service and the expense, often considerable at subscribers' stations, of removing and replacing the damaged protectors. It is the problem of their maintenance that has dictated most of the work on high-voltage protectors since the early days of the telephone.

One of the earliest protectors, in use about 1877, consisted merely of two pieces of silk-insulated wire twisted together, of which one was connected to the line and the other to ground. An excessive voltage punctured the insulation and thus formed for itself a by-pass to ground. Wire was soon displaced by variously formed metallic plates; in 1879 protectors were composed of two brass plates separated by a dielectric such as mica. In the following decade numerous minor changes were made in this general form, especially to the use of carbon instead of metal. Using this material a wider electrode spacing met the same breakdown voltage requirement. About 1890 the carbon-block protector with mica separator was standardized (Figure 1-A).

Thereafter occasional efforts were made to improve the maintenance characteristics of the protector. Various methods were devised for impregnation and cleaning the carbon faces to reduce the surface dust. A metal-block protector, for use where a higher breakdown voltage could be tolerated, also appeared (Figure 1-B). The essential features of the protector, however, remained the same: two parts, of conducting material, forming the electrodes, and a third part, of insulating material, separating the electrodes by the desired amount.

About 1913 an essentially different block appeared in experimental form, assembled of both insulating and conducting materials. In it the ends of one of the copper blocks then standard were equipped with insulating plugs (Figures 1-C and 1-D). This construction permitted the use of a metallic separator, or, by suitably depressing the parts of the conductors between the insulating plugs, the elimination of the separator entirely. Though it never advanced beyond the experimental stage, this block is interesting as one of the earliest embodiments of the basic principle of the present protector block.

By 1914 the telephone system had expanded to such proportions that

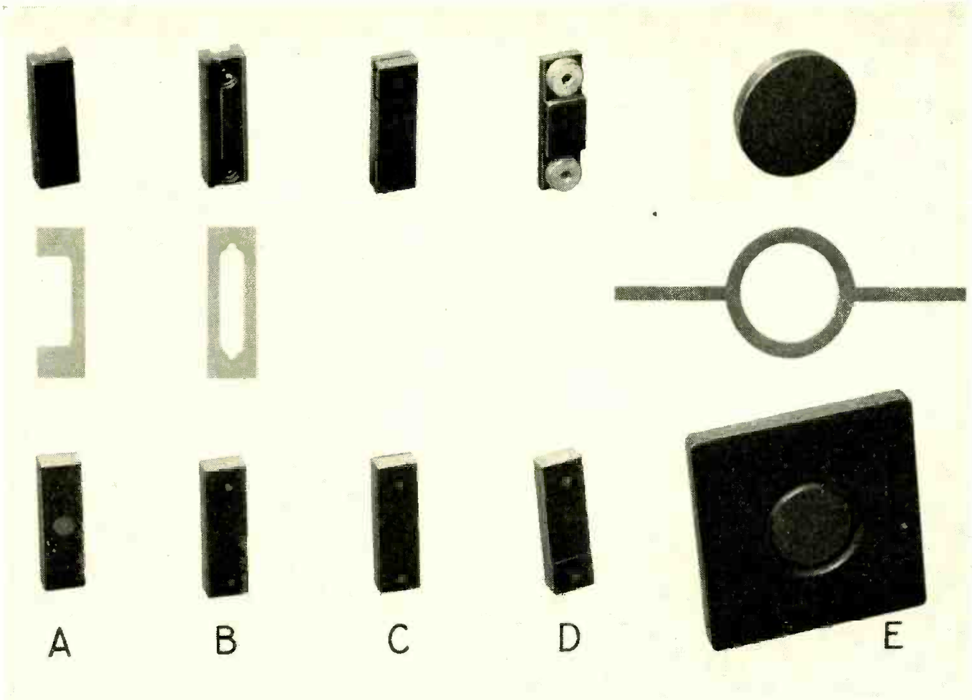


Fig. 1—Important steps in the development of the porcelain protector block. A—The formerly standard combination of the No. 1 and No. 2 protector blocks and the No. 3 mica. This was used for central office and sub-station protection. B—The formerly standard copper block protector, consisting of the No. 19 and No. 20 protector blocks and the No. 10 mica. C & D—The original bi-material protector blocks. In the type shown at C phenol plastic inserts were used; in the type shown at D lavite studs were employed. These blocks were associated with a block having the central portion depressed to give the desired separation. E—An early block wherein a conducting insert was used in an insulating frame. At the time this block was made, studies were in progress to determine whether increasing the size of the sparking surfaces would materially affect the breakdown voltage. This explains the large size of this protector. Separation was obtained by a gasket-like separator of metal

the high maintenance of protectors had become a serious concern. A vacuum arrestor was tried; but its high cost and excessive maintenance characteristics, due to breakage and loss of vacuum, made its use impracticable. Intensive work began, therefore, toward the development of an open-space cut-out with low maintenance.

From the outset of this work it appeared desirable to avoid the use of the dielectric separator, which was not only inconvenient to manufacture but also, at least in the forms previously employed, contributive to high maintenance. Attention naturally focussed on the part-insulating, part-conducting block of 1913. The first step was to reverse the two materials: to make an insulating block with a conducting insert forming the electrode, instead of a conducting block with insulating inserts. Various forms, and many materials such as glass and phenol plastic (Figure 2-F), were embodied

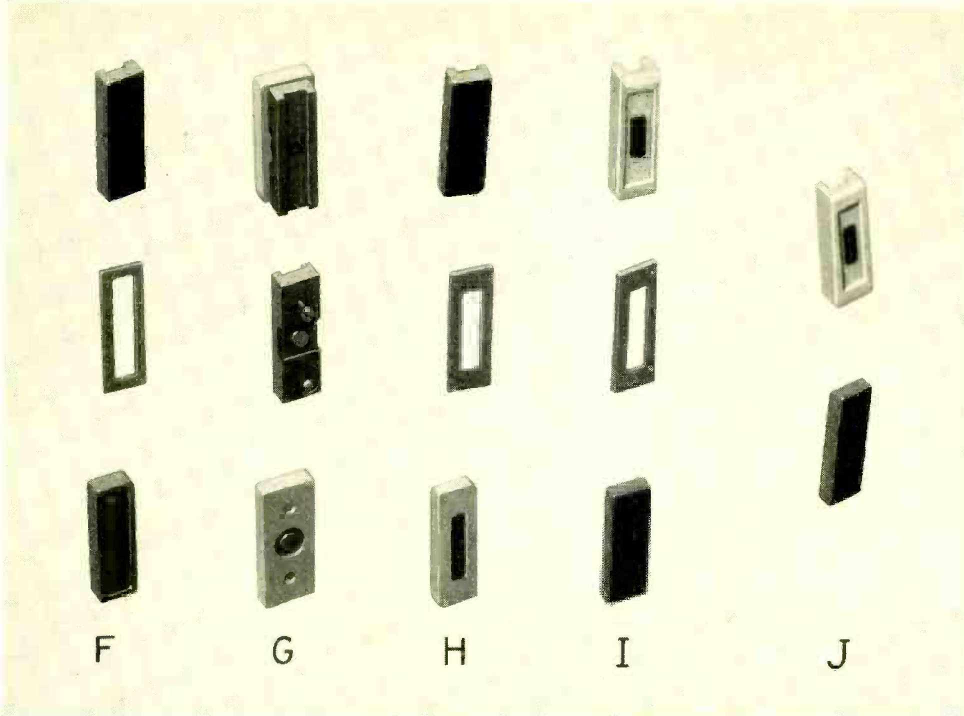


Fig. 2—Further steps in the development of the porcelain protector block. F—The first experimental protector submitted to trial installation. This consists of a phenol plastic frame carrying a copper electrode and separated from another copper electrode by means of a metallic separator. G—A construction employing tungsten-faced electrodes. A porcelain frame carries a small tungsten-faced tack. The two are assembled as a unit, opposed to a metal block carrying another tungsten-faced tack. Separation is secured in assembly, without the use of an individual separator. H—An early hard-carbon porcelain-frame combination. This employs a plane carbon block as a line electrode and the carbon-equipped porcelain frame as a ground block. A metal separator is used. I—A combination similar to C except that the carbon-equipped porcelain frame is used as the line block. J—The final step in development, wherein the separator is omitted and proper separation is secured by depressing the carbon insert

in experimental insulating blocks. The most satisfactory proved to be a porcelain frame, resembling in shape the No. 2 carbon block, and carrying at its center a rectangular block of conducting material.

Work on the electrode material started with metals, since these seemed most likely to free the protector from the dust troubles theretofore experienced. Many metals, variously combined, were tested in the laboratory, and the more promising were given trial installation to determine their behavior toward lightning (Figure 2-G). The results were discouraging; nine of these protectors showed less tendency to ground than did the carbon blocks standard at that time. Lightning discharges produced eruptions of metal sufficiently high to bridge the small gap between the electrodes. Fortunately during the latter part of the work on metals further work was done on carbon—not the former soft carbon, but a hard dense material with but little free surface dust. Promising results in the laboratory led to trial installations, which confirmed the conclusion that the long sought reduction in maintenance could, in a measure at least, be obtained with dense carbon.

Need had early been recognized for a means of short-circuiting the protector blocks when an arc persisted longer than a few seconds. Overheated blocks and mountings would otherwise constitute a fire hazard. In the protector formerly standard, with No. 1 and No. 2 carbon blocks, this need was filled by inserting in one of the blocks a plug of metal with a low melting point which would melt to bridge the gap between the blocks. This construction was not feasible for the new combination of hard carbon and porcelain. Several low-melting cements for attaching the carbon insert to the porcelain frame were tried, therefore, and a lead borate glass was finally selected. This does not cold-flow, but softens at a comparatively low temperature and allows the pressure of the clamping spring in the protector mounting to move the insert into contact with the ground-block.

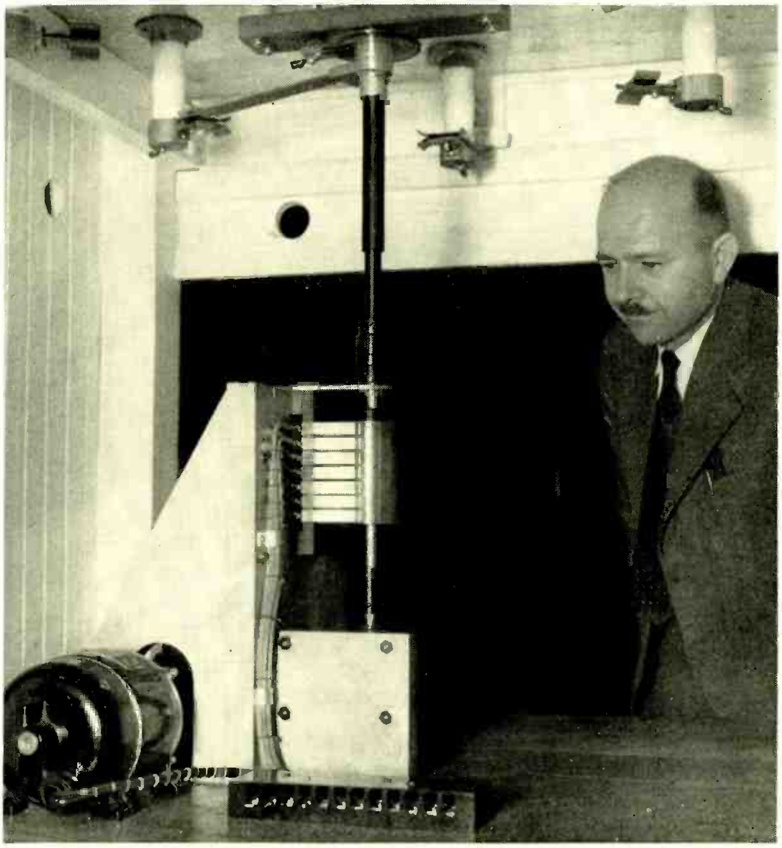
In most of the trials, the operating surface of the electrode was ground flush with the insulating frame, and the separation was secured by a metallic separator (Figure 2-H and 2-I). In considering commercial manufacture of the new protector, it developed that this construction imposed very close dimensional limits, not only on the separator but also on the porcelain block, for insurance against accidental short-circuit of the electrodes. This difficulty was avoided by omitting the separator and depressing the sparking surface of the carbon electrode the proper distance below the plane surface of the porcelain frame as in the block shown in Figure 2-J.

Starting production of the new piece of apparatus required thousands of tests to establish the various limits necessary to its proper operation and cooperation with associated apparatus. The protector block, consisting of but two piece-parts, is one of the System's smallest pieces of coded apparatus. Nevertheless, in the assembly and piece-part drawings, eleven dimensions have plus-and-minus tolerances. Some of these requirements are very exacting; their insurance demands one hundred per cent check of the product. Especially precise must be the depression of the sparking surface of the electrode below the plane of the porcelain block. The normal depression of the No. 27 block is twenty-eight ten-thousandths inch and variations of but four ten-thousandths inch above and below this value are allowed. To gauge to such dimensions the several million protectors manufactured annually, required the development by the Western Electric Company of elaborate means of automatic gauging.*

Because of its superior maintenance characteristics, the porcelain block soon outgrew the original restriction of this use to station protection and thenceforth provided central-office protection as well. That the porcelain type of block might be associated with all types of main-frame protectors, some of which require their blocks to be mounted on three-eighths inch centers, there was developed the No. 29 block, electrically identical with the No. 27 and differing only in the dimensions of the porcelain frame. For cable protection, to replace the old copper blocks, the No. 30 block was developed, mechanically identical with the No. 27 and differing only in

Bell System Technical Journal, October, 1928.

a greater depression of the insert, and in the dark blue color of the porcelain frame, distinguishing it from the lower-breakdown blocks. The decreased maintenance of these three porcelain blocks is saving the Bell System hundreds of thousands of dollars annually.



A final inspection of an antenna switch before it is shipped to Miami. The switch, housed outdoors and remotely controlled from the transmitter room, will connect a two-wire line from a short-wave transmitter to the lines to any one of six directive antennas. Contacts for one side of the lines can be seen fastened to the ceiling. Those to the other side are in the compartment above. It will be used in radiotelephone links between the United States and points bordering the Caribbean Sea. The inspection is being made on the Laboratories' shipping platform by J. L. Mathison, of the Radio Research group.

Cellulose Acetate Treatment of Textile Insulation

By E. B. WOOD
Telephone Apparatus Development

SILK and cotton have been the standard materials employed for wire insulation in telephone central offices for many years. These materials in the form of wrappings or braidings used either singly or in combination, and supplemented for some purposes by enamel and impregnating waxes, provide sufficient insulation to withstand the comparatively low voltages required to operate telephone apparatus. Also this type of insulation occupies small space, can be applied in a large number of color combinations, and is not easily damaged by handling. Silk and cotton, however, absorb moisture from the air and may exhibit very undesirable variations in electrical characteristics under variable conditions of humidity.

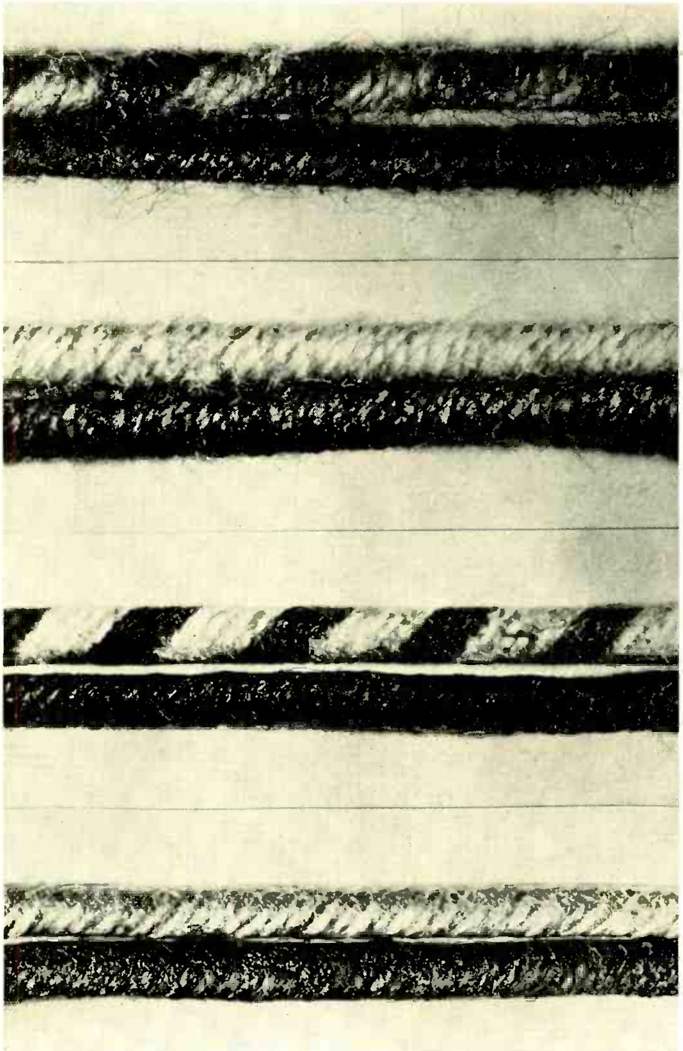


Fig. 1—Enlarged photograph of treated and untreated wire showing how the cellulose acetate film smooths down and covers the textile fibres

Development work to improve textile insulations has had two

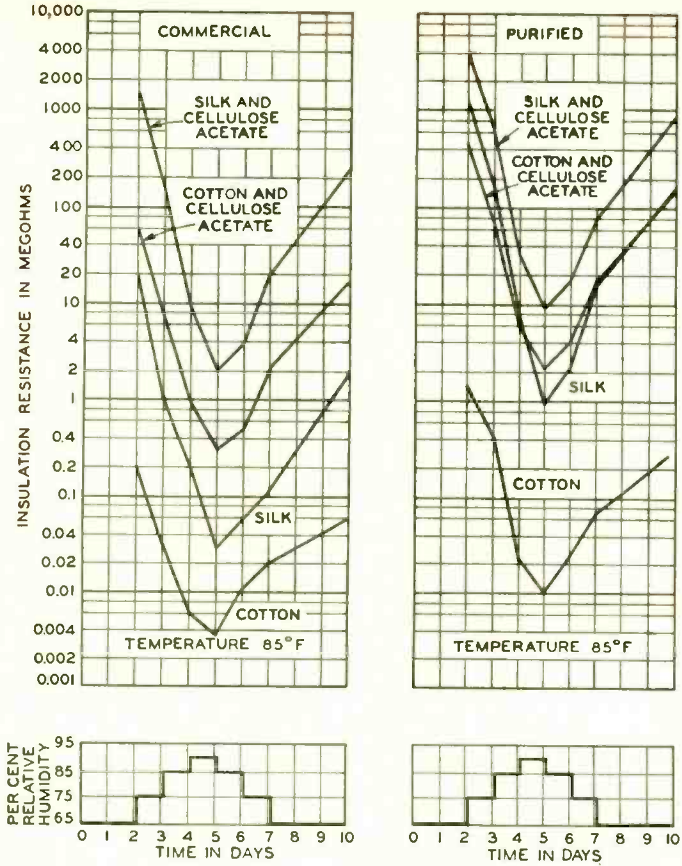


Fig. 2—D-c insulation resistance of 50 *feet of twisted pair* 22-*gauge wire insulated with double servings of equal thickness. These data show that commercial cotton may be improved from* 100 *to* 300 *fold by acetate treatment alone and from* 500 *to* 2000 *fold by purification plus acetate treatment*

objectives: to provide at moderate cost a super quality insulation for use where it is important to have the best electrical characteristics obtainable, such as in toll circuits; and to improve the characteristics of cotton sufficiently to permit its use to replace silk as far as possible for general purposes. Within the past few years, two methods of improving the electrical characteristics of textile insulation have been brought into commercial use. The first, already described in the RECORD*, is the purification of silk and cotton whereby electrolytic impurities, such as sodium and potassium salts, which are inherent in the commercial materials, are removed by a simple and inexpensive washing process. The second is the treatment of textile-insulated wire with cellulose acetate.

Several years ago cellulose acetate in the form of artificial silk was investigated as a possible substitute for natural silk in wire and cable insulation. Although its electrical characteristics were found to be excellent, the application of the material in the form of a lacquer to cotton or silk insulation appeared more promising because, at that time, commercial means of handling the acetate silk on high speed insulating machinery had not been developed.

Cellulose acetate is made by treating cellulose fibres, usually cotton, with glacial acetic acid and acetic anhydride, together with a catalyst such as sulphuric acid. This process is followed by precipitation, purification, and drying, which yields a product in the form of a white flaky mass that, when dissolved in acetone, produces a clear transparent lacquer. The insulated conductor to be treated is passed through this solution and then through a wiping die to remove the excess lacquer, and following this to a heated drying chamber where the solvent is evaporated. This process is

*RECORD, *April*, 1929, *p.* 311.

repeated several times, to build up a film of satisfactory thickness and smoothness.

The film so formed has a high dielectric strength, low conductivity, and low a-c capacities and conductance. Also it absorbs much less moisture than silk or cotton so that its characteristics vary less with changes in humidity. It does not, however, prevent the entrance of moisture to any appreciable extent into the textile over which it is placed. From this fact and from extensive laboratory tests, it was concluded that the improvement in electrical characteristics brought about is due mainly to the lacquer film acting as a barrier in the leakage paths between two pieces of insulated wire.

Its effect may be seen in Figure 1, which shows enlarged photographs of sections of both treated and untreated wire. With untreated cotton insulation, fibres project in all directions and form connecting leakage paths between the two conductors when moisture is present. With the fibres smoothed down and covered with several layers of lacquer film, these leakage paths are largely eliminated and any current leakage must pass through this relatively high resistance film. Repeated tests have shown that the improvement obtained in a treated wire may be gauged by observing the extent to which the fibres have been laid and covered by the lacquer film. Even cracking of the film, which may occur during manufacture or subsequent handling, does not affect the electrical characteristics appreciably so long as it is not severe enough to permit interlinkage of the textile fibres.

Increasing the thickness of the lacquer film beyond that required to cover the fibres and provide a smooth

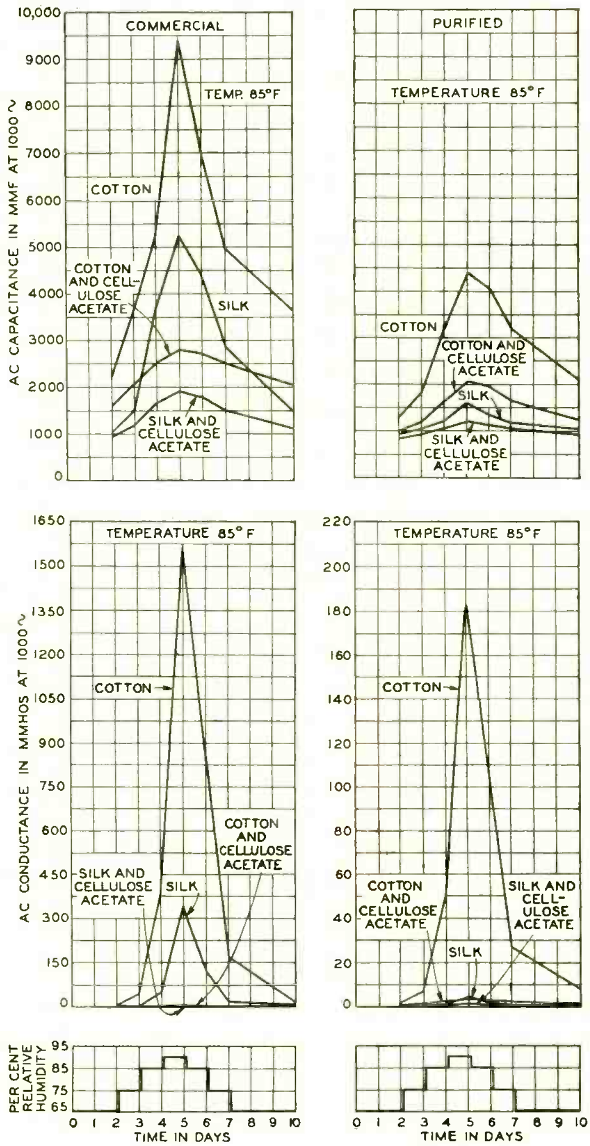


Fig. 3—A-c capacitance and conductance of 50 feet of twisted pair 22-gauge wire insulated with double servings of equal thickness. Curves on the left are for commercial textile insulation, and those on the right purified

surface results in little additional improvement in the insulation. This is of considerable economic advantage since, with proper methods of application, a relatively thin film may be practically as effective as a thick one requiring a considerably greater quantity of material. It also permits a rapid check on the quality of the product by a visual inspection of the surface condition of the treated insulation.

The effectiveness of cellulose acetate treatment in improving the electrical characteristics of silk or cotton used as wire insulation is shown by the accompanying illustrations for a constant temperature of 85° F., and for relative humidities varied from 65% to 90% over a seven-day cycle. As a matter of general interest the comparison is given for both commercial and purified materials although purified textiles are now employed exclusively in wire insulation for central offices of the Bell System. The data shown illustrate the improvement brought about by the treatment of the respective materials as insulation, but do not apply quantitatively to any standard type of central office wire.

Data on insulation resistance, given on Figure 2, show that purified cotton, when treated with cellulose acetate, becomes a comparatively high grade insulation, suitable for many purposes that would have required expensive combinations of silk and cotton heretofore. For telephone transmission purposes, the a-c characteristics of conductance and capacitance are of particular importance because they determine the transmission loss at voice and carrier frequencies, which must be kept at a minimum to maintain high quality communication. Data for these two characteristics at 1000 cycles are given on Figure 3. The data of these two graphs, converted into transmission loss, are represented on Figure 4. Of particular significance is the reduction of capacitance and conductance at the higher humidities, since it is very important for good telephone transmission that these characteristics do not vary greatly with changes in weather conditions.

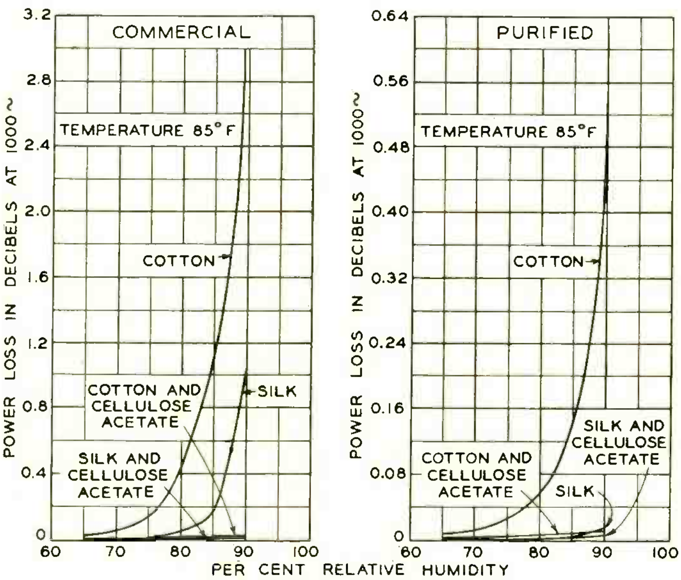


Fig. 4—The data of Figure 3 converted to transmission loss, shows how cellulose acetate treatment reduces the loss at the higher humidities

One example of how treatment with cellulose acetate improves telephone transmission is given by Figure 5 which shows the capacitance unbalance at 1000 cycles between phantom and side circuits in a four conductor wire for toll use. Capacitance unbalance is the main cause of electrical interference between two associated circuits and should therefore be kept low. As shown here, treatment with cellulose acetate not only materially reduces the unbalance but makes it less dependent on humidity. Although there was some difference in design of the two types of wire tested, practically all of the improvement was due to the treatment.

The improvement in characteristics obtained by cellulose acetate treatment is sufficient in many cases to permit the substitution of cotton for silk, which results in a substantial reduction in cost. In other cases silk is retained and the cellulose acetate treatment results in a cable of much higher quality, which is desirable for many toll circuits. This treatment has also made possible the elimination of enamel in a large amount of cable where it has formerly been required to prevent excessive leakage under high humidity. The economic importance of this arises from the ease with which the textile insulation may be removed for soldering. Enamel is difficult to remove and the precautions necessary to prevent faulty soldered connections increase the cost of installation and maintenance of apparatus.

Wire treated with cellulose acetate has been found particularly advantageous for use on distributing frames. Here the wire cannot be used in cable form, and to guard against the fire hazard from a large mass of loose wire, it has been standard practice heretofore to cover the wire with a cotton braid impregnated with flameproofing salts. These salts, because of their hygroscopic and electrolytic nature, have a deleterious effect on the electrical characteristics of the insulation under humid conditions. Exhaustive tests have proved, however, that cellulose acetate treated wire, without the addition of flameproofing salts, is as safe as the old type, and the elimination of the salts has made it possible to provide a wire

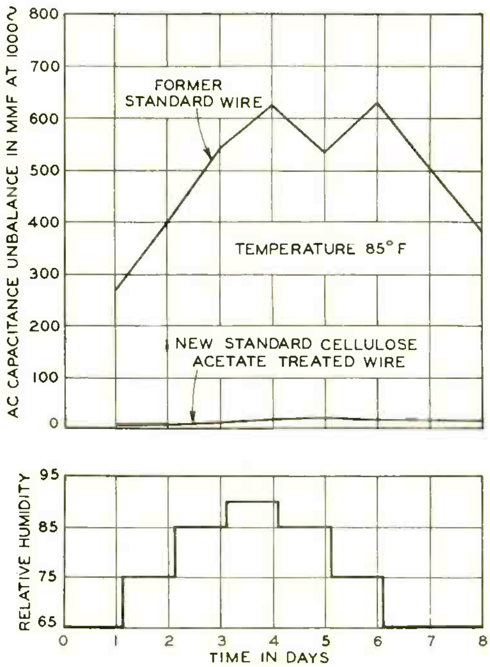


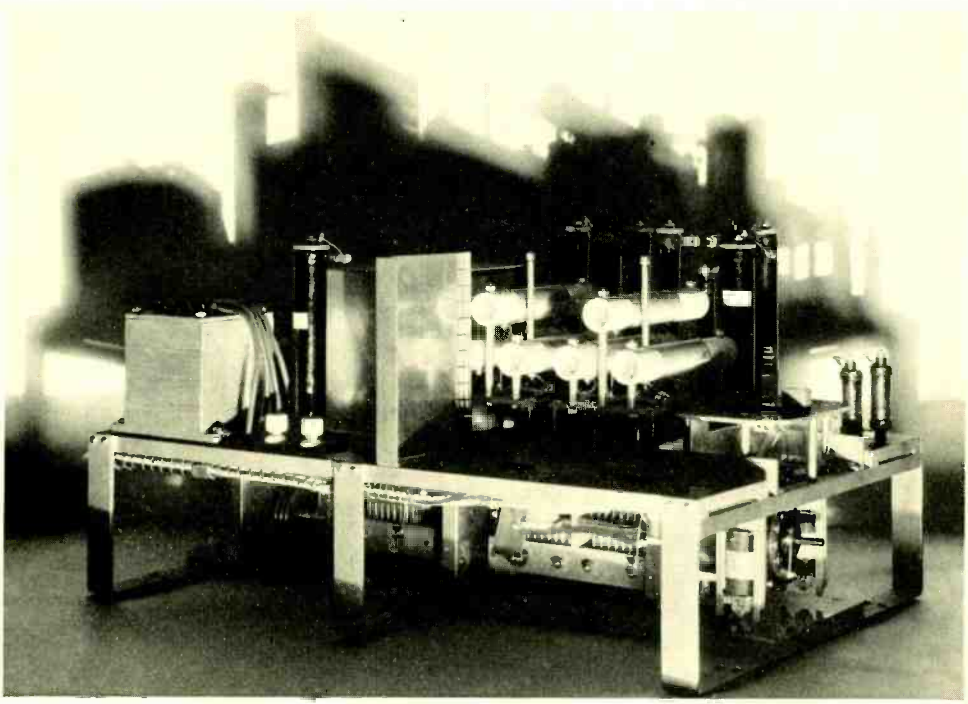
Fig. 5—A-c capacitance unbalance between the phantom and side circuits of 50 feet of quadded 22-gauge wire

greatly superior to the old electrically, considerably less expensive to manufacture, and smaller in size.

Another advantage in cellulose acetate treatment is its effectiveness in preventing unwrapping and fraying of the textile at terminals. With untreated wire, fraying has been diminished by impregnating the insulation at the ends of the wire with wax, but this adds to the flammability, tends to obscure the color markings, and collects dust. Acetate treatment holds the insulation together, and at the same time provides a glossy surface that does not readily collect dust.

Cellulose acetate is very stable both under normal use and when exposed to artificial aging tests. Tests in the Laboratories running over a period of years have shown that high humidities and temperatures produce very little deterioration in either physical or electrical characteristics.

The application of cellulose acetate treated wire to regular production was made early in 1930, although considerable quantities were installed for service trials in commercial apparatus in 1927. Cables and wires used in the toll plant, where the improved characteristics are of greatest value, are being changed first to employ the new insulation. Supplementing this program, consideration is being given to extending the use of cellulose acetate treated wire to the local plant where the annual requirements are of the order of three billion feet. Application of the new wire is being made gradually so that manufacturing and installation methods and technique may be further developed as conditions seem to warrant.



Gang tuning unit, with coil shields removed, used with one of the five radio transmitters built by the Western Electric Company for the Tropical Radio Telegraph Company. This transmitter will be installed in Panama City for communication with the Bell System station at Miami, Florida.

Contributors to This Issue

For slightly more than a year in 1923-1924 F. B. WOODWORTH was a member of the Research Department. He left in September, 1924, for Schenectady and started on the Electrical Engineering course at Union College. For three summers while at college he worked with the New York Telephone Company. Following his graduation in 1928 he became a member of the Radio Development group and worked on radio-beacon and aircraft radio-telephone development at Hadley Field. At present he is engaged on the development of radio-telephone apparatus for harbor craft. Mr. Woodworth's trip to Alaska in connection with a trial installation of the radio telephone on the fishing boats of Libby, McNeil and Libby, described in this issue, took place during the past summer from May 9 to August 5.

After receiving the B. S. degree in Mechanical Engineering from the University of Illinois in 1905, D. T. May spent four years as an engineering student with various departments of the Western Electric Company in Chicago. He then came to West Street to participate in the routine testing activities of the physical laboratory, and a year later he became head of the group devoted to this work. It was in 1911 that he first became engaged in the design and testing of electrical protection apparatus and systems which he describes in this issue of the RECORD. Later he became concerned also with transmission tests on long telephone cables, reducing inductive interference from electrified railways, and designing special testing apparatus. Since 1917 he has had charge of the electrical analysis of apparatus and the design and test of special protective systems. In 1926 the general electrical protection and mechanical analysis of apparatus was added to his charge, and very recently he has taken supervision over materials investigation.

After two years at Williams College, ROBERT E. WATERMAN transferred to Massachusetts Institute of Technology, where he received the B.S. degree in chemical engineering in 1921. Joining the Chemical Department of these Laboratories a year later, he worked first on rubber and then for a short while on japans. In 1926 he started work on the

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chemical and biological phases of wood preservation, and now heads a group devoted to these investigations at the Summit laboratory.

After receiving a B.S. degree from Montana State College in 1922, W. K. St. Clair joined the Inspection Engineering Department of the Western Electric Company at Hawthorne. Later in the same year, however, he transferred to the Inspection Department of these Laboratories and worked on panel installations in New York City. In 1925 he went to Philadelphia as Field Engineer, but three years later returned to West Street and joined the Equipment Development Department. Here he has been concerned with equipment for carrier telephone and telegraph systems. At the present time he is associated with the radio equipment group.

J. R. Stone received an E.E. degree from Cornell University in 1923 and immediately joined the Installation Department of the Western Electric Company, in New York City. The following year he transferred to the power development group of the Laboratories, where he has since been engaged in the development of power machines. He has been particularly concerned with the design of charging machines, ringing machines and centrifugal exhaustors for telephone power plants, and with rotary converters, dynamotors, and motor-generator sets for radio transmitters and receivers.

E. B. Wood received a B.S. degree from Princeton University in 1915 and an A.M. degree the following year. After teaching mathematics for one season, he joined the Reserve Officers Training Camp and was commissioned captain in the coast artillery. Following a year spent in training recruits, he went overseas in command of a battery of coast artillery where he served until the end of the war. He then taught physics at Pratt Institute for a year and joined the Technical Staff of the Laboratories—at that time the Engineering Department of the Western Electric Company—in 1920. With the Apparatus Development Department, his field has been chiefly central-office wire, cable, and cords; in connection with which he has been active in the development and application of purified textile insulation and cellulose acetate treatment. He has also been concerned with the development of methods and apparatus for the precise control and measurement of humidity in electrical testing.