# Bell Laboratories Record



Bell Telephone Laboratories, Incorporated
463 West Street, New York, N. Y.

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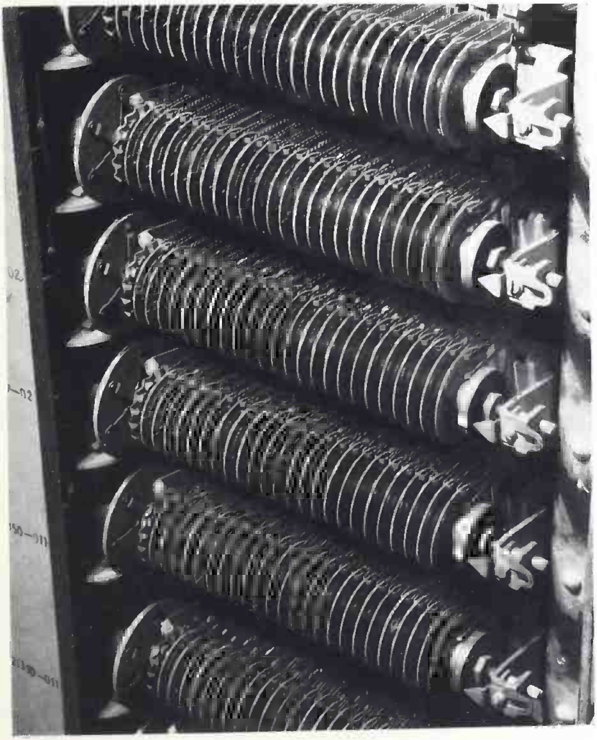
# BELL LABORATORIES RECORD



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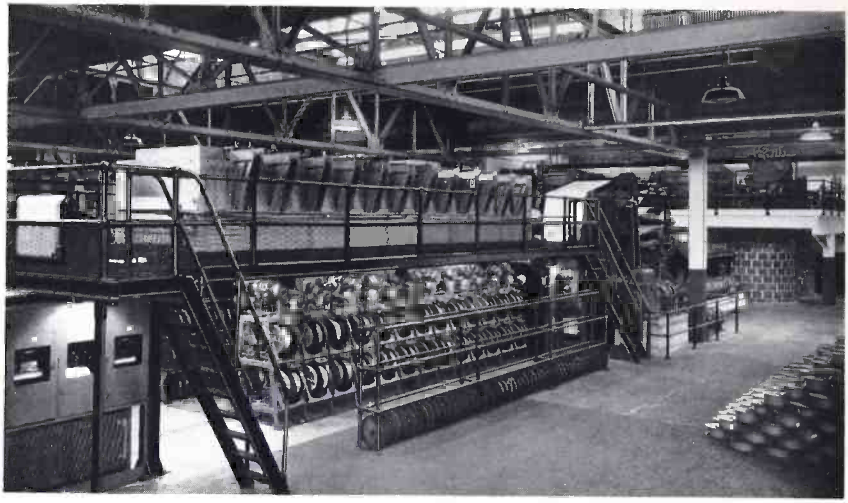


# Pulp—the New Cable Insulation

By L. S. FORD
*Outside Plant Development*

THE history of telephone cable is a living story woven into the vast intercommunicating network of the Bell System. Not the least fascinating of its chapters is the story of insulation development. That story is not completed; each paragraph written is indicative of continuous progress. The most recent of these paragraphs is concerned with the development of a new insulation, a development characterized by many and at times seemingly insurmountable manufacturing obstacles, which finally culminated in the introduction of pulp-insulated cable.

The satisfactory insulating of fine wires with wood fibres applied directly to the wire in the form of pulp was the objective of ten years of intensive study and experiment, originating in the Western Electric Company and subsequently prosecuted cöoperatively by Western Electric and Laboratories engineers. Narrow strips of paper ribbon which for the past forty years have served so remarkably well, find themselves suddenly displaced by pulp as a better standard for the insulation of No. 24 and No. 26 gauge wire for exchange area cables.

One of the main promotive ideas which initiated the development of pulp insulation was that of utilizing an inherently inexpensive fibre. Using nothing but wood-pulp, the contemplated procedure was to embed each wire in a ribbon of the pulp, and to turn this ribbon down into a cylindrical sheath while still wet. This general procedure has been embodied in a continuous manufacturing process,* which takes advantage where-

*Bell Telephone Quarterly, October, 1931;
*Bell System Technical Journal, July,* 1931.

ever possible of methods and equipment used in paper-making.

Pulp for use as insulation is prepared from jack pine or spruce by an outside supplier. He chips the wood, cooks it with a sulphate solution, and finally washes and dewaters it. In the works of the Western Electric Company the pulp is mechanically worked with water, which reduces it to its individual fibres and hydrates them to such a state that they will form a suitable covering. From tile storage tanks the pulp is taken as it is needed, diluted to about a twentieth of one per cent, and is then piped to a paper-making vat.

Also passing continuously to this vat are sixty wires, supplied by rotating fliers from stationary spools on a supply stand which accommodates two spools in each of the sixty positions. As each spool is emptied, an operator can braze the end of its wire to the outer end of the wire on a full spool without stopping the machine. An electrolytic cleaner then removes residual drawing compound, preparing clean copper surfaces to which the insulation will adhere.

Into the vat dips a cylindrical screen, continuously rotating about a horizontal axis. The pulp about the outside of the cylinder is filtered by passage through the screen, the water passing out through an outlet inside the cylinder. The deposition of pulp on the screen is confined to sixty narrow ribbons by lacquer dams. The wires are brought into contact with these ribbons when they are partially formed, and the remainder of the deposition then takes place, leaving each wire embedded in a ribbon.

Wires and ribbons are transferred intact from the screen by an endless travelling woolen blanket pressed against them by a couch roll. This blanket serves both as a driver for the cylinder and a carrier for the tender sheets. To protect the ribbons from rupture, a second felt is laid over them. Felts and ribbons then pass through two sets of press rolls to re-

*Fig. 1—Pulp is thrown into the beater, kneaded with water, and then dumped into the storage tanks beneath*

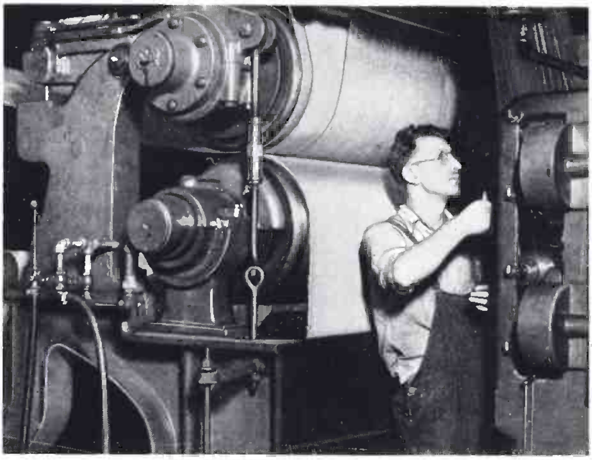


*Fig. 2—The wires embedded in ribbons of wet pulp leave the press rolls (center) and enter the polishing machine (right)*

move excess moisture and permit the ribbons to be separated from the felts. Still containing about seventy per cent moisture, the ribbons now pass to the polishing machine which turns the pulp down over the wire.

This machine contains sixty rapidly rotating heads, through whose axes the wires pass. Each head bears three blades of which one deflects the travelling wire from a straight line against the other two, with a pressure controlled by the tension on the wire. From these heads the wires emerge, each covered with a uniform wet sleeve of pulp.

To drive off the remaining moisture, the wire is passed through a box-type electric furnace, twenty-six feet long. By thermostats the entering zone is maintained at a red heat, the second zone at about nine hundred degrees Fahrenheit, and the tempering zone at about six hundred degrees. Drying at these high temperatures leaves the insulation porous and relatively unshrunk. On a stage at the far end of the furnace, a rotary pulling mechanism draws the wires through the polishing machine and drier, and delivers them to take-up reels arranged in pairs for continuous operation.

Pulp insulated wire is structurally different from wire insulated with air-spaced paper ribbons. The insulation is firm with no appreciable air space between it and the wire, bundles of

*Fig. 3—The finished insulated wire is spooled beneath the drier*

wires nestle together differently when grouped into a given space, and when pairs are stranded together in the usual manner the unit thus formed is considerably less flexible than with ribbon insulation. Sharp kinks form with even moderate cable bends. While this feature is less pronounced for small cables it is, of course, objectionable, and an improvement in the handling qualities is effected by stranding several layers in the same direction rather than reversing successive layers. For the large size cables, a design whereby the pairs are first grouped into units of fifty or one hundred and these in turn stranded together into a cable gives a construction which offers the most satisfactory arrangement. This is illustrated in Figure 4 which shows a full-size cable containing eighteen 101-pair groups of No. 26 gauge conductors.

Next to obtaining a continuity of insulation sufficient in amount to withstand the necessary dielectric stresses, the most important electrical characteristic is low mutual pair capacitance. The earlier pulp cables had a capacitance at 900 cycles 20 to 25 per cent higher than similar paper-ribbon cable. This impairment in transmission efficiency was considered prohibitive for cables to be used for interoffice trunks, and was definitely objectionable for any cable. The indicated savings in cable first cost, however, warranted continuing the development, and over a period of years marked progress has been made in reducing this excess of capacitance.

Many factors have brought about this reduction in capacitance. The treatment of the pulp itself has been improved. Refinement in machinery operation has enabled the use of a lower density covering. Improvement in the process has resulted in more nearly round and better centered insulation. The rapidity with which the radiant heat dryer expels the moisture from the pulp, results in less shrinkage of the insulation on the conductors and leaves the insulating medium light in weight for the volume occupied. Although a substantial improvement has been made in lowering the mutual capacitance to values much nearer those corresponding to ribbon-insulated cable as shown in Figure 5, efforts are being directed toward a further reduction in capacitance.

*Fig. 4—This 1800-pair No. 26-gauge cable illustrates the application of unit stranding to pulp-insulated cable*

No new practices are involved in installing pulp insulated cable except in the boiling out of the cable ends preparatory to the splicing of the conductors. Even the most flexible pulp insulation so far produced, when impregnated with straight paraffin wax, will not withstand satisfactorily the handling incident to splicing at low temperatures. A softer and more lubricating type of compound is required, and has been found by adding paraffin oil to the wax. Another problem requiring attention arose from the fact that the natural brownish color of the unbleached pulp results in less sharp color distinction for the different groupings than with ribbon insulation. By simplifying the color code, however, sufficient contrast in the shades is obtained for the satisfactory matching of colors in splicing.

Millions of feet of wire are now daily being insulated with pulp, fabricated into cables and put in service in the telephone plant. Thus pulp insulation, young as it is, has already reached a prominent place in cable history and because of the substantial economies which it promises, it must play a conspicuous part in the Bell System's engineering in the future.

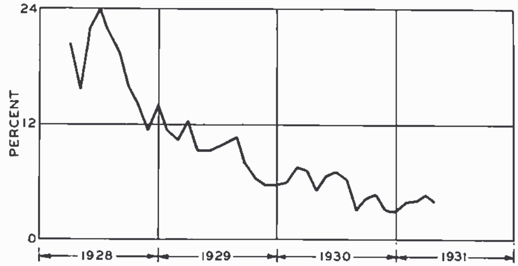


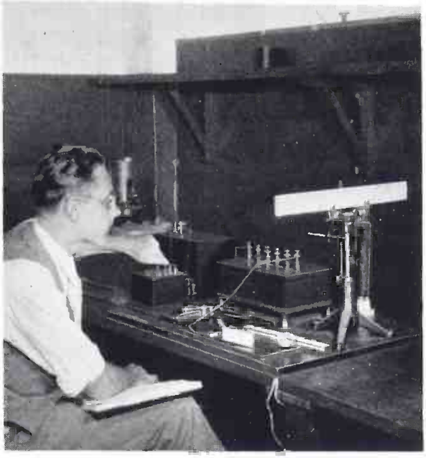

*Fig. 5—The improvement effected in the last four years of development is shown by the decrease in the percentage by which the capacitance of pulp-insulated cables has exceeded that of their ribbon-insulated predecessors*

## Calls to Europe

*That the establishing of an overseas connection to European countries is often a polyglot procedure was attested by Grace P. Kelly, Chief Operator of the American Telephone and Telegraph Company's foreign service department, in a recent radio interview.*

*When asked if a call to Roumania would have to be translated into Roumanian, she replied:*

*"More than that, we would have to pass it to London in English; London would pass it to Budapest in German; Budapest would pass it to Bucharest in German also and the Bucharest operator would speak with her subscriber in Roumanian. We have had calls which involved five languages before the call was announced to the called telephone."*



# Smaller and Better Condensers

By K. F. RODGERS
*Telephone Apparatus Development*

BECAUSE of their widespread employment in radio receivers during the last decade, condensers—formerly rather mysterious scientific toys to the man in the street—are now familiar pieces of apparatus. Long before the advent of radio broadcasting, however, they had lost all appearance of mystery to the telephone engineer, and had become commonplace elements of communication systems. They are, as a matter of fact, widely used in almost all electrical fields. From large power distribution systems, where they may be used for power factor improvement, to automobile ignition systems, their peculiar characteristics find useful application, but from the standpoint of quantity used the telephone industry probably ranks first. Not only are they required at all of the nineteen million subscribers' stations but in even greater quantity they find use in every central office of the country. Although for their varied uses they are made of a number of combinations of materials, condensers for most uses in the telephone plant consist of alternate layers of paper and metal foil rolled together.

In partial contrast to the American production slogan of "bigger and better," the objective of condenser development for telephone use has been "smaller and better." At subscribers' stations smallness is obviously desirable. The less bulky the subset, or bell-box as it is popularly called, the more readily can it be mounted in some inconspicuous location. In central offices, space—although perhaps not so obviously—is also of great importance. It is desirable to mount condensers along with relays and other apparatus, which places certain preferred limits to their length and width, and because of the very large

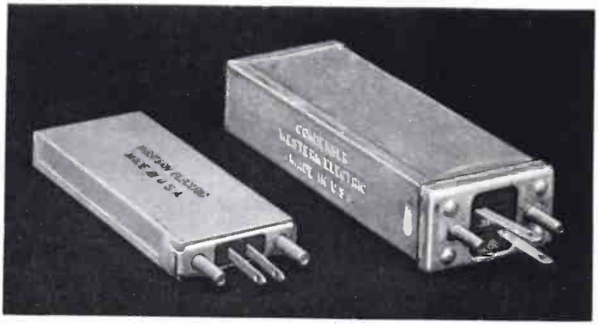


*Fig. 1—The 141-A condenser has less than 1/3 the volume of its predecessor of the same capacity*

one inch thick—which seemed a very satisfactory attainment. The urge of "smaller and better" continued, however, and recent development work, both by the Laboratories and by the Western Electric Company, has reduced the 1 microfarad condenser to less than ⅓ of its 1924 size. Fundamental studies of the materials used leading to progressive improvement in their characteristics, with improved manufacturing methods superimposed, have been responsible for the achievement.

numbers of them used, reductions in thickness also become of considerable value.

Size, however, is not the only consideration. Permanence of rating and reliability are of even greater importance. Although for all purposes it is desirable that there be no radical change in the capacity of a condenser with the passing of time, for certain purposes it is essential that it remain accurately constant. In addition to its ability to maintain a constant capacity, a condenser should not break down under possible abnormal voltages, nor lose its high resistance in the presence of unusual moisture. In efforts to obtain reduction in size these other characteristics, therefore, can never be entirely lost sight of.

Since the beginning of the telephone industry considerable reduction in size and improvement in quality has been obtained. By 1924 the commonly used 1 microfarad condenser was housed in a container only 4½ inches long by about 1⅝ inches wide and

Two sheets of conducting material, separated by an insulating medium, form the essential elements of a condenser. The common practice for telephone condensers has been to use paper for the insulating medium, which allows multiple layers of foil and insulation to be built up to give comparatively large capacity with small bulk. A metal container is used to protect the condenser unit from mechanical damage.

Capacity is a function of the area of the conducting sheets and of the

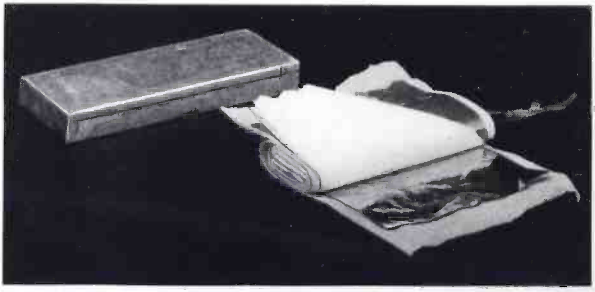


*Fig. 2—Two sheets of paper between adjacent layers of aluminum foil form the elements of a telephone condenser*

thickness and nature of the insulating material. This nature of the material is measured by its dielectric constant, and capacity varies directly with dielectric constant and area, and inversely with distance of separation. To decrease size, therefore, it is necessary either to decrease the thickness of the insulation or to increase its dielectric constant, or both.

If a condenser were built up solely of tin foil and paper, the actual insulating material would be partly paper and partly air since the paper itself includes air and in addition there are interstices between the layers of paper and foil which also contain air. The effective dielectric constant of the insulating medium of a wound paper condenser is small due to the large effect of the air present. To raise this constant it has been customary to impregnate the condenser unit with a substance having a higher dielectric constant than air. Until recently paraffin has been used for this purpose. The decrease in size has thus required a double development: an improvement in paper to permit thinner insulation, and an improvement of the impregnating substance to increase the effective dielectric constant.

The search for a thinner paper runs back over a number of years. The best paper obtainable in this country until the last few years has been .5 mil thick (1 mil = .001 inch). It was possible to obtain .4 mil paper abroad but a local source is desirable for an assured supply. To secure a satisfactory supply of .4 mil paper in this country has required sustained cooperation with the paper manufacturers. The procedure has been to authorize a definite number of condensers to be made up from some specified paper, and then to test the product under service conditions. As a result of a long sequence of such trials, interspersed with recommendations to the paper manufacturers, an assured and adequate source of paper of .4 mil thickness has finally been obtained. With the attainment of this objective one of the essential factors of reduction in size of the condenser was gained.

Efforts to obtain an impregnating compound which gives a higher effective dielectric constant in the finished condenser have also been carried on for a considerable period. Some years ago a material became available which seemed very promising. It was a chlorinated naphthalene known commercially as halowax. As then produced, however, it had certain undesirable ingredients, and only after many years of development have manufacturing methods been improved sufficiently to yield a product which warrants commercial use in condensers.

*Fig. 3—J. A. Kater making a capacity measurement on a 141-A condenser*

Even with a satisfactory .4 mil paper and an improved impregnating compound the entire gain would not have been possible without improved manufacturing methods. The actual process consists in rolling two sheets of tin foil and four of paper so that the completed unit will have two layers of paper between adjacent sheets of tin foil. After the winding step the unit is pressed into a compact shape, thoroughly dried in vacuum ovens, and then—while still in a high vacuum—is impregnated with the halowax. Following this the unit is pressed to the required size, which forces out all excess wax, and the soldering lugs are fastened to the metal contact strips that, at the beginning of winding, were laid in contact with the sheets of tin foil. The unit is then ready for potting in the rectangular tin plate containers. These are partially filled with a sealing compound which, when the condenser units are inserted, completely fills the container and seals the condenser against all entrance of moisture.

Manufacturing methods for all these steps have been improved by the Western Electric Company and have contributed no small share to the great overall improvement. Another change has been the substitution of aluminum foil for tin. This does not decrease the size—the tendency is slightly in the opposite direction—but it does reduce the cost.

These new designs and manufacturing methods have been approved only after thorough trials. From the results of an extensive field survey of atmospheric conditions in a number of cities, accelerated laboratory tests were devised which simulated from fifteen to twenty years of actual service. In carrying out these tests large numbers of condensers were subjected over considerable periods of time to severe conditions of continuously applied voltage, high humidity, high temperature, and of mechanical abuse. Also before final approval was given, several trial lots of many thousand condensers were made up by actual manufacturing methods and tried under operating conditions. The new condensers are now being placed in service, and are not only smaller than the old but are expected to bring about appreciable savings in initial cost.

*The Morris Liebmann Memorial Prize has been awarded by the Institute of Radio Engineers to*

Edwin Bruce

*"for his theoretical investigations and field developments in the domain of directive antennas."*

# The Mendham Laboratory

By F. M. RYAN
*Radio Development*

SOME of the development work for various telephone systems cannot be effectively carried on in the New York Laboratories. The outside-plant development work carried on at Chester, already described in the Record[1], is a typical example. Sooner or later a stage is reached in many developments when it is necessary to move to the field. For development work on radio transmitters, the Whippany[2] laboratory has provided the necessary facilities for such work as well as for certain other activities. Tests of radio receiving equipment, however, and of complete two-way radio systems, cannot be made in close proximity to high-power radio transmitters or even to the usual urban disturbances arising from the operation of electrical appliances. To carry on tests of this type of radio apparatus, therefore, and for a number of other developments requiring an isolated site, a need has been felt for some time for a field laboratory as remote as possible from all forms of electrical disturbances.

Increased development activity on two-way radio projects during 1929 involved special receiving equipment and made the establishment of a new field laboratory imperative. A survey of available sites made during the latter part of the year led to the purchase, in February 1930, of a plot of approximately 133 acres near Mendham, New Jersey. The tract is

[1]Bell Laboratories Record—*July* 1931, *p.* 529.
[2]Bell Laboratories Record—*October* 1926, *p.* 46.

located about a quarter of a mile south of the main road between Morristown and Chester: about six miles from Morristown and eleven from Whippany. On a portion of the tract, which at one time had been used for farming purposes, were a farmhouse and a barn. The farmhouse has been reconditioned and modernized, and part of it is now used as living quarters by G. P. Hodges, who is caretaker at the new Laboratory. The other part is used for laboratory purposes. The stone walls of the old barn have been utilized in the construction of a modern garage.

The main portion of the tract had been employed by the former owner as a private flying field and is reasonably level and well cleared. On this field a new laboratory building has been erected. As shown at the head of this article, it is of Colonial design

*Fig. 1—Building the road to the new garage at Mendham. This building utilizes the stone walls of the old barn*

*Fig. 2—J. M. Henry talking to one of the Laboratories' airplanes from the aeronautical ground station at Mendham*

and makes a pleasing addition to the surrounding landscape. Up to the present time it has been used primarily for the development of radiotelephone systems for commercial aviation. In it is now housed a complete Western Electric aeronautical radio ground-station, such as is used by the principal air lines of the United States, which will be used for further developmental studies. Figure 2 shows its radio equipment. The large unit to the right is a 400-watt Western Electric radio transmitter, and the similar size unit to the left, the rectifier for supplying plate and grid voltages to this transmitter. A small unit mounted on the wall above the rectifier is used for coupling the radio transmitter to the antenna system. The radio receiver may be seen on the table between the rectifier and transmitter units. Equipment is available for connecting the radio-telephone circuit to the wire telephone system. This latter equipment is used principally when it is desired to demonstrate airplane communication to people unable to visit the field laboratory.

This ground-station installation serves not only to provide experience in the operation of this type of equipment but also to maintain constant communication with the Laboratories' airplanes when in flight. As the operators of the ground station are able to communicate promptly over telephone lines with weather bureau stations and airports throughout this part of the country, the airplane radio-telephone circuit provides the same safeguard to the Laboratories' planes that commercial installations provide to air transport lines.

Electrical power for operating the ground-station equipment and for general use in the main laboratory building is brought from the power company's lines near the boundary of the Laboratories' tract through approximately 1600 feet of underground cable. This isolation of the power supply tends to remove from the laboratory itself certain disturbances which might otherwise be present, and thus permits full advantage to be taken of the isolated site. As a further precaution this supply, as well as that to the laboratory in the farmhouse, is fed through a special radio-frequency filter circuit to avoid any possible interference from any radio-frequency disturbances.

In aviation communication, as in broadcasting and other radio operation, it is essential that the transmitting stations be maintained accurately on their assigned frequencies; interference and confusion are otherwise likely to result. The Mendham

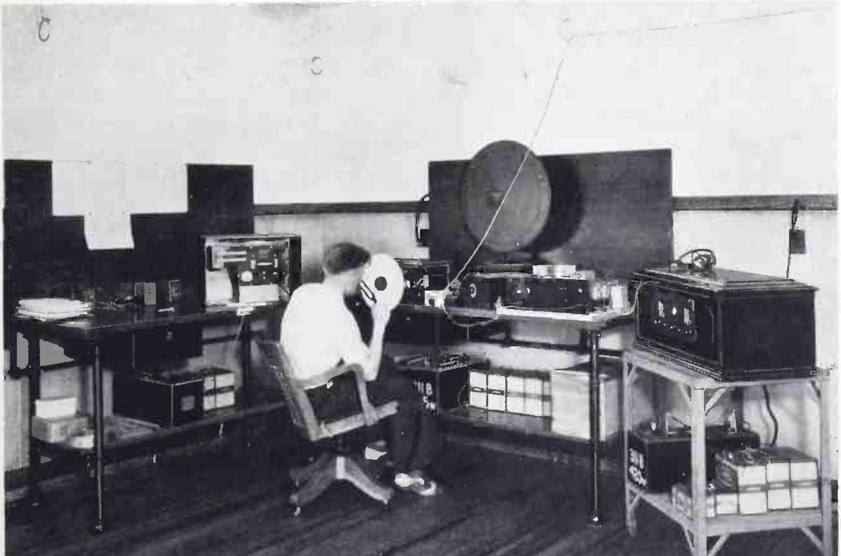


*Fig. 3—J. P. Dolbear at the Mendham Laboratories measuring the frequency of a distant airplane radio station*

*Fig. 4—N. M. Anderson and M. E. Krom of the Systems Department engaged at Mendham in a study of induction from dial telephone apparatus*

laboratory has been utilized in making observations of the actual performance, in this regard, of radio transmitters in airplanes and at ground stations on air-transport lines. Figure 3 shows measurements of this kind being made. Frequencies of aeronautical stations as far west as Chicago have been measured at Mendham.

The use of the Mendham laboratories has not been confined, however, to problems associated with the development of aviation communication. Tests, for example, have recently been completed there of the terminal arrangements to be employed in Bell System radio stations for communicating with harbor craft. The Mendham laboratory has also been frequently used in the checking and calibration of radio field-strength measuring sets. A room has been provided on the second floor of the main laboratory building for this purpose. Here no electric wires or other metal parts have been brought above the base board. This precaution makes possible accurate measurements of the field strength of the electromagnetic waves since it avoids local distortion of the field.

Another important activity which has been carried on at Mendham is the study of the radiation and induction effects of the operation of telephone and teletype apparatus. This work has been conducted in the laboratory section of the old farmhouse. Figure 4 shows such radio-interference studies under way on sub-station equipment.

The ample space, and freedom from all forms of interference that the Mendham laboratory provides, has made it very valuable in airplane and other radio studies, as well as for other work requiring quiet surroundings. It will undoubtedly play an important part in future developments carried on by the Laboratories.

# A Push-Button Key for Train Dispatching

By J. C. FIELD
*Special Products Development*

TO be able to call any one of seventy-eight stations on a single line without ringing any of the others was the problem placed before the designers of the telephone train-dispatching system. How this problem was first solved has already been described in the Record*. On the dispatcher's desk are a set of keys—one for each station on the line. To call a particular station the dispatcher gives the proper key a quarter turn to the right and allows it to return under its own spring action. In doing so it sends over the line three groups of pulses, alternately positive and negative. These groups of pulses are received by selectors at all the stations, but the selector at only one station will respond in a manner to ring the call bell.

Operated in this manner and with substantially the same equipment, telephone dispatching systems have been used by railroads to a steadily increasing extent ever since the first installation in 1910. It is the principal system of dispatching at the present time. The telegraph and telephone section of the American Railway Association recently reported that on January 1, 1931 sixty per cent of the railroad mileage of the country was dispatched by telephone.

In these days of rapid technical and scientific progress, however, no system, no piece of apparatus, is ever considered incapable of improvement.

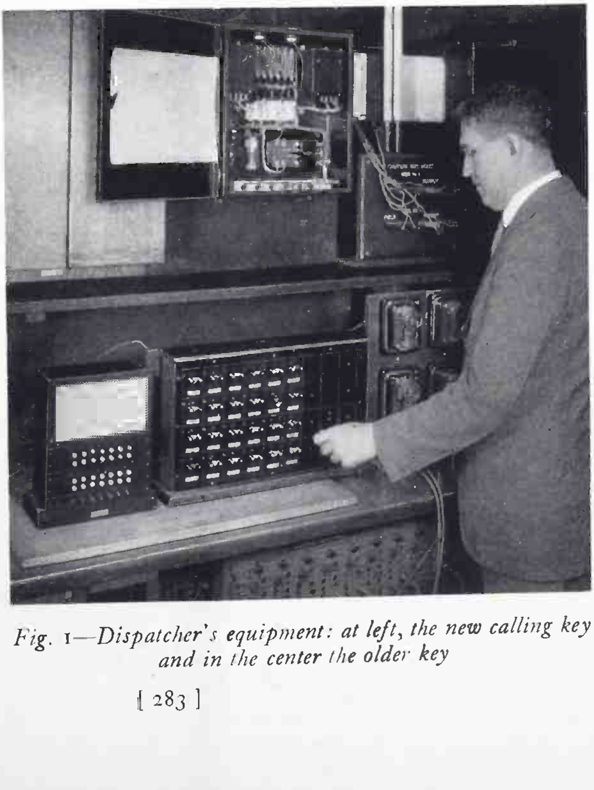


*Fig. 1—Dispatcher's equipment: at left, the new calling key and in the center the older key*

*Bell Laboratories Record, *December*, 1926, *p.* 108.

Satisfactory as the system has been, there did seem to be possibility of improvement—particularly in two respects. The first of these was the timing of the pulses. The cam of the keys, which sends out the pulses, is operated by a spring, and controlled by a fly-ball governor of the friction type. To one acquainted with this type of mechanism, it is evident that the accuracy of timing which can be secured in this manner is limited. In the second place the space required for the keys was large: the cabinet for mounting 60 keys was over 33 inches long. Although this was the largest size ordinarily furnished, the full capacity of the system—78 keys—would have required a cabinet well over a yard long.

These two objectionable features of the old system have now been removed by the development of a new calling unit. A synchronous motor instead of a spring is used to time the pulses, and because of the uniform speed obtained in this manner, all pulses are of the same duration. Then in place of a separate key for each station on the line, there are two sets of push keys on which any of the seventy-eight possible codes may be set up. With this arrangement the new calling unit, although of approximately the same height and depth as the older type, is only ten and one-quarter inches wide. This is less than a third as wide as the 60-key unit of the older type and thirty per cent narrower than the 24-key cabinet which was the smallest size supplied to railroads. A comparison of the new selector-key with a 36-key cabinet of the older type is shown in the photograph of Figure 1.

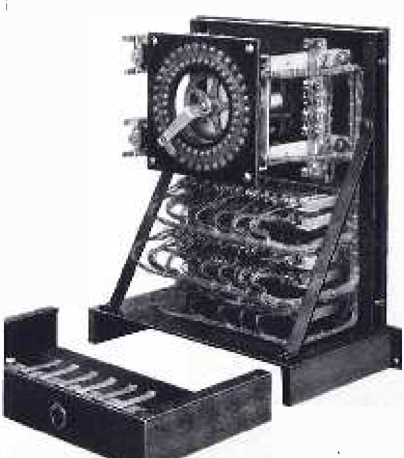


*Fig. 2—Pulses are sent out by a brush, driven by a synchronous motor, passing around a circle of seventy segments*

With the system of pulsing used, three groups of pulses are sent, but the sum of the three groups is always seventeen. Because of this fact, when the number of pulses in any two groups of a complete signal is known, the number in the third group is fixed, since it is seventeen minus the sum of the other two. It is necessary to set up only two numbers, therefore, to determine the three groups of pulses, and as a result only two sets of keys are provided for setting up the code wanted. Each set consists of two rows of buttons numbered 0 to 13, inclusive; the upper set, on which the first number of the code is recorded, is red, and the bottom, used for recording the last number of the code, is white. When 3 and 8 are set up on the red and white buttons respectively, the code sent out is of necessity 3–6–8 ($3+8=11$ and $17-11=6$).

The single row of lettered buttons at the bottom are employed for certain auxiliary functions such as repeating a call, stopping the progress of a call, or selecting any of four possible stations at the office called.

*Fig. 3—The 63-type selector key has 21 keys in each group instead of fourteen*

The number of pulses in any of the three groups of a code is never less than two so that buttons 0 and 1 are not used for regular codes but are reserved for special services. Setting up 0–0 sends out a single group of 17 pulses and calls all stations on the line simultaneously. Setting up 1–1 advances all selectors so as to permit time signals to be received by all stations along the line. Special services of this sort required additional keys with the old system.

Another feature made possible by the new equipment, which would have required extra keys with the old, is the calling of stations in groups. The selectors of all stations along the line, as described in the article already referred to, advance with each group of pulses, but at the end of each group, all selectors but those having pins in a position corresponding to the particular number of pulses in the group sent turn back to the initial position. There are two of these pins in the rotating wheel of each selector, and it is their positioning that determines the code to which the selector responds. This arrangement makes it a simple matter to call certain arbitrary groups of stations—all codes the sums of whose first or last two numbers are alike belonging to a group.

When a white key is pushed for the final number of a code, a contact is automatically made that starts the

*Fig. 4—On the upper part of the calling equipment, in front of the space occupied by the synchronous motor and the rotating brush, is a designation card for listing the various codes*

synchronous motor. This motor rotates a brush around a complete arc of seventy segments as shown in Figure 2. The operation of the two keys has previously arranged the connections from those segments so that the correct three groups of pulses are sent out. This will be accomplished in all cases by the time the 34th segment is reached, and from this to the 48th segment the bell is rung. Segments 49 to 58 inclusive are strapped together and send a single pulse to release the selector at the called station, and segment 59 stops the synchronous motor. Segments from 60 to 69 are also strapped, and are used to allow the motor time to accelerate at the beginning of a call.

Electrical connections to the selector key are made through a set of plug contacts in the base, as is also shown in Figure 2. This permits the mechanism itself to be readily removed for repair, replacement, or inspection, by simply removing two screws in the front plate and sliding the unit out from its base. Connections made and signals sent out are similar to those for the old type keys so that the new system is readily substituted for the old.

Although an ordinary dispatching line does not have more than 78 stations, it is sometimes desirable—at least for short periods of time—to have a single dispatcher operate several lines. This may be accomplished by connecting the calling equipment to a plug which can be inserted into jacks for the various lines: an arrangement permitting calls to be placed on each line separately.

Often, however, it is desirable to combine several dispatching lines and treat them as a unit. To make this possible a selector key is employed which is like the other except that each of the two groups of keys has three rows, with keys numbered up to 20 as shown in Figure 3. When this arrangement is used the total number of pulses per code is 27 instead of 17, and the number of possible codes is 341 instead of 78. With this arrangement each station on the group of lines that may be combined is assigned a different code; and any station on any of the lines may be called from a single location. All of the stations may also be called at the same time or groups of them may be called in a manner similar to that already described.

In addition to the desk-mounting form, known as the 62 type, selector keys are made in a form suitable for mounting between the stiles in the face equipment of a manual PBX of the No. 604 type*. When mounted in this manner they generally serve message lines, which parallel the dispatching lines, and which are used for general railroad business that does not need to go through the dispatcher's office. The selector key of Figure 3 is of this type while that of Figure 4 is of the desk mounting type.

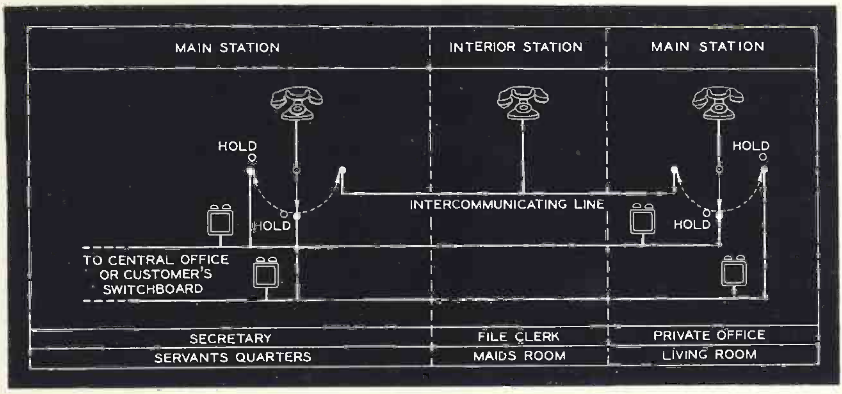
Besides securing a uniform length of pulse, made possible by employing the synchronous motor, the new unit has several other advantages. Not least of these is that the unit is entirely self-contained. All equipment required is mounted in the single housing. Also the keys lock in the operated position so that the last number called is always indicated by two depressed keys. On setting up a new number those last depressed are released.

Another advantage of the new arrangement is that the same sending equipment is used regardless of the number of stations on the line. As stations are added from time to time, no new equipment is needed at the dispatcher's desk. With the old system a key would be added to the dispatcher's equipment for each new station added to the line. When several new stations had been added a completely new cabinet might be needed to house the larger number of keys, while with the new selector-key only the addition of a code number to the designation card is required.

*RECORD—*February* 1929, *p.* 226.

# NEWS AND PICTURES

## *of the Month*




*Wiring plan No.* 202 *when there are two lines from the central office*

### WIRING PLANS OFFER UNUSUAL FACILITIES

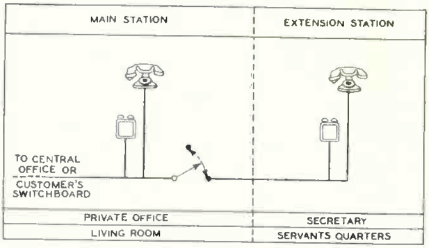
One of the most interesting fields in telephone sales work is that offered by wiring plans. It should appeal particularly to members of the Laboratories because of the opportunity for constructive analyses of the subscriber's needs and selecting a plan which will afford him the most effective service.

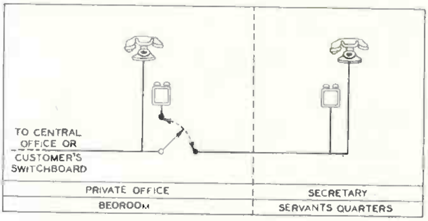
A wiring plan is an arrangement of telephones, keys, and bells at the subscriber's premises, to render certain services for which P.B.X. operation is not required. Wiring plans may however be used to supplement a P.B.X., where one is desirable for other reasons.

At least one and sometimes all of the following features are found in a wiring plan:

1. Intercommunication between all telephones, without the use of the central office line.
2. Transfer of incoming calls from one telephone to another.
3. Means of cutting off one or more extension telephones or bells.
4. Pick-up, or the use of two or more central office lines with one telephone instrument.
5. Means of holding a call on one or more central office lines, while making a call for information, answering a call on another line, or transferring the call.

Perhaps the best way to understand wiring plans is to watch a few of them in operation. As most of them are useful for both business and residential purposes, let us consider their use in both cases. Take plan 100, the simplest we have. It provides a switch at the main station which cuts off all extension stations and bells. This might be used by an executive and his secretary. The secretary would be on the extension, and receive all calls. If a call required the attention of the executive, the secretary would sound a buzzer in his office, and he would take up his receiver. If the call proved to be of a private nature, he would push down his




*Wiring plans for cutting off extension station and main station bell. No.* 100 *above; No.* 101 *below*

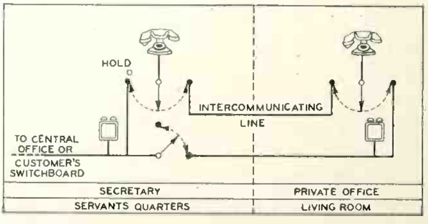
switch and cut off the secretary. At the conclusion of the call, he would raise the switch again, putting the secretary back on the line to receive the next incoming call. This plan, while practicable for business purposes, is more suitable for residential use. Here it is often desirable to cut off an extension. The extension may be in the servants' quarters, or there may be a situation similar to one recently reported. A young man with a 13-year old sister was in the habit of calling his fiancee every evening. The sister immediately went to an extension in another room and listened in on the conversation. The installation of plan 100 solved the difficulty.

Now consider another plan—number 102—which contains all the features possible in a wiring plan. Let's suppose it is being used by a small printing concern. In the plan there is one master telephone with two black keys, one red key, and one lever key. This is in the manager's office. In the composing room, press room, and binding and cutting room there are extension telephones. A call comes for the manager which he wishes to keep private. He lifts the lever key, cutting off all extension telephones. Suppose a call comes for the press room. The manager pushes the red key which holds the call, and buzzes the extension in the press room twice. This is the signal to pick up a call from the central office. Someone in the press room throws a lever key at the extension telephone and answers the call. Suppose a call comes for the manager on which he needs information from the composing room. He pushes the red key to hold the call, and buzzes the composing room telephone once. One buzz is the signal to come in on the intercommunicating circuit, and this is done by throwing the lever key at the extension down. The manager gets his information, and picks up the outside call again. While the outside call was being held, the person on the line could not overhear the inside call.

This illustration shows the remarkable flexibility of plan 102 which combines all four service features of the wiring plan. Plan 102 is useful also in residences. It may be desirable to get information from a person in a distant part of the house or grounds while holding an outside call, or the intercommunicating and other features of the plan may be useful.

Plan 202 brings in a new feature—two lines to the central office. The great advantage of this is that it reduces the likelihood of the calling party's receiving the busy signal. In other respects the plan is much the same as plan 102 except that it is arranged for a maximum of six extensions and has no cut-off feature.

Members of the Laboratories will find that there is a wiring plan for almost every customer need, each plan being a combi-




*Wiring plan No.* 102 *showing intercommunicating feature* nation of some or all of the five service features listed at the beginning of the article. The holding feature, for example, not only prevents disconnection on a call by means of a holding key, but offers a number of other conveniences. Once the

*Station fitted out with Wiring Plan No.* 102

holding key is pressed, the receiver may be immediately replaced, saving the somewhat annoying process of calling someone at an extension, and listening to make sure the call has been received before replacing the receiver. Also, as most people know who are without holding keys, the person at the main station sometimes forgets to replace the receiver. With the holding key, the "hold" is released as soon as anybody removes the receiver at another telephone, and also should the calling party meanwhile hang up and the operator take down the connection.

As the next step beyond ordinary "main and extension station" service, wiring plans offer many added conveniences to those business and residence users whose telephone needs will not quite justify a P.B.X. It is important, however, that the subscriber should not substitute wiring plans for a P.B.X. when a P.B.X. is necessary, since savings which might be made otherwise would be more than offset by the inconvenience and additional effort required for unsuitable equipment. Members of the Laboratories should therefore consult with the Employee Sales Bureau or the Business Office of the Telephone Company before recommending any particular form of service to a prospective user.

## RESEARCH

### Transmission Instruments

W. C. Jones and N. Blount at Washington conferred with naval engineers on communication equipment for the United States Navy.

Several problems relating to moving-coil microphones were taken up by L. W. Giles in a recent visit to Hawthorne.

A. F. Bennett at Hawthorne reviewed manufacturing problems on audiphones.

D. G. Blattner was in Washington with L. S. O'Roark where he set up the equipment and demonstrated vertical recording in conjunction with Mr. O'Roark's address before the American Concrete Institute.

### Chemical Laboratories

R. E. Waterman attended the meeting of the American Wood Preservers' Association held at St. Louis.

Accompanied by J. A. Becker of the Radio and Vacuum Tube Research group, S. O. Morgan visited the General Electric plant at Pittsfield. Messrs. Becker and Morgan also visited the plants of the Carborundum Company at Niagara Falls and the Horton Company at Chippewa, Canada.

H. Boving rounded out twenty years in the Bell System on March 28.

R. R. Williams describes functions of a laboratory organization in the February issue of Industrial and Engineering Chemistry.

### Electro-Optical Research

A paper, *The Depth of Origin of Photo-electrons* by Herbert E. Ives and H. B. Briggs was presented at the Cambridge meeting of the American Physical Society. K. K. Darrow also attended the meeting.

### Transmission Research

The third of a series of papers on plane waves of light by T. C. Fry was presented at the meeting of the American Physical Society at Cambridge. The title of Dr. Fry's paper is *Absorption of Metals*.

B. G. Bjornson has sailed for England where he will make a series of investigations on transatlantic radio-telephone transmission.

### Acoustical Research

H. Fletcher on a recent visit to Canada spoke at McGill University and before the Northern Electric Engineering Society and the employees of the Bell Telephone Company of Canada in Montreal on speech, hearing and the transmission of speech. He also spoke before the local section of the American Institute of Electrical Engineers in Toronto on physical characteristics of speech and music.

Acoustical measurements were made by W. B. Snow and A. R. Soffel at the Academy of Music in Philadelphia.

### Radio and Vacuum Tube

A report, on new investigations of the diffraction of electrons by metal surfaces, was made by C. J. Davisson and L. H. Germer at the Cambridge meeting of the American Physical Society.

J. A. Becker and R. W. Sears have a paper, *Phenomena in Oxide Coated Filaments*, in the Physical Review.

A paper, *Effect of Shore Station Location upon Signals* by R. A. Heising is published in the I.R.E. Proceedings for January.

### Special Research

Another paper in R. M. Bozorth's series on the Barkhausen effect has been published in the January 15 Physical Review. The title is, *Orientation of Magnetization in Elementary Domains*. A paper on *Hydrogenized Iron*, by P. P. Cioffi, a more detailed account on the subject than that published in the January Record, is also published in the January 15 Physical Review.

A technical description of the rapid-record oscillograph by A. M. Curtis in collaboration with T. E. Shea and C. H. Rumpel of the Apparatus Development Department is published in the January issue of the Journal of the Society of Motion Picture Engineers.

### Radio Research

C. E. Forsberg, of the Radio Research Department, celebrated the fortieth anniversary of his Bell System service on March 9.

For eight years he worked in the Clinton Street shop of the Western Electric on the manufacture of electrical apparatus. From this work he was transferred to what was known as the Experimental Shop. In this department, a forerunner of our present Development Shop, he constructed models of telephone apparatus for engineers' designs. He moved with his department to New York and until 1926 was associated with the old Model Shop. Since that time he has performed the mechanical work on models of various apparatus built for engineers of the Radio Research Department. On March 9 about twenty of Mr. Forsberg's associates in the Radio Research Department, including W. Wilson and R. A. Heising and J. W. Upton and A. H. Sass of the Plant Shops, and O. F. Forsberg of the Apparatus Development Department, tendered him a luncheon in Charles Restaurant.

*C. E. Forsberg*

## SYSTEMS DEVELOPMENT

On march 3, E. B. Smith was twenty-five years a member of the Bell System. For fourteen years Mr. Smith worked on central office installation for the Southern

New England Telephone Company and the Western Electric Company. In 1917 he became a member of the U. S. Navy and served on the U. S. S. *Arkansas* while it was associated with the British Grand Fleet in the North Sea.

Mr. Smith came to the Engineering Department of the Western Electric Company in 1920 and worked on test circuits for manual offices. In 1928 he transferred to test circuit design for dial central offices on which he is at present engaged.

### Equipment Development

V. W. Langborgh visited the exchange at Tuxedo Park to investigate ringing conditions.

Panel Equipment problems were discussed by F. W. Treptow at Hawthorne.

V. T. Callahan visited the Buffalo Gasolene Motor Company relative to shielding of engine alternator sets to be used on radio installations.

W. L. Heard completed twenty years in the Bell System on March 4.

### PERSONNEL

G. B. Thomas attended the Personnel Conference of the American Management Association held at Pittsburgh.

### PUBLICATION

L. S. O'Roark at a dinner of the Junior Executives Club at Boston gave an address *Some Stories of Telephone Research*. Mr. O'Roark was also a speaker at the annual meeting of the American Concrete Institute in Washington. He spoke on *Experiments in Speech and Music* and following his remarks a demonstration of vertical recording was given by D. G. Blattner of the Research Department.

### PATENT

G. F. Heuerman was in Washington to attend a hearing before the Board of Appeals.

Routine patent matters required the presence of S. B. Kent in Washington and J. F. McEneany in Rochester.

The annual dinner of the New York Patent Law Association at the Waldorf-Astoria on March 2 was attended by J. G. Roberts, E. V. Griggs, H. P. Franz, G. M. Campbell, W. C. Kiesel, O. D. M. Guthe, F. Mohr, N. W. Lamb and F. M. Nolan.

### INSPECTION ENGINEERING

W. A. Shewhart gave a paper, *Economic Control of Quality in Manufacture*, before a meeting of the Society of Industrial Engineers held in Philadelphia.

A. F. Gilson visited the Westinghouse Electric and Manufacturing Company's plant at East Pittsburgh in connection with a quality survey on rectifiers and engines.

T. C. Rice's twenty-fifth service anniversary occurred on March 19. He is in charge of technical reviews and reports in the Inspection Engineering Department and is a former vice-president of Bell Laboratories Club.

*T. C. Rice*

Mr. Rice gained much practical experience in telephone work in Nebraska where he worked on toll testing and was wire chief for the Nebraska Bell Telephone Company. From this company he went to the Lincoln Telephone Company of Nebraska and was state wire chief in charge of toll lines and later traffic engineer.

In 1916 he came to the Inspection Engineering Department of the Western Electric Company in Hawthorne. He transferred to New York in 1923 and for a while worked on the design of panel link circuits. Shortly after the organization of the present Inspection Engineering Department he was placed in charge of Engineering Complaint work which was transferred from Hawthorne. Mr. Rice has been in charge of his present work on technical reviews and reports since 1928.

E. J. Bonnesen, Field Engineer, St. Louis, visited Dallas and Sweetwater, Texas, and Oklahoma City, Oklahoma, on field engineering work in his territory.

R. C. Koernig, Field Engineer, Omaha, made a similar trip to Denver, Colorado, while C. K. Milner, Assistant Field Engineer, Cleveland, visited Dayton, Ohio.

## OUTSIDE PLANT

R. H. Colley discussed timber products in communication in an address before the colloquium held by the Department of Electrical Engineering at Massachusetts Institute of Technology.

W. K. Oser and W. T. Jervey visited Phoenixville, Pennsylvania, to observe the insulator testing facilities of the American Telephone and Telegraph Company at that place.

Measurements by dynamotor readings of the force required to pull in cable when different types of cable lubricant are used were made by J. M. Hardesty, C. C. Lawson and S. M. Sutton at New Haven.

C. R. Moore made several addresses in a recent trip to the West. At Omaha he addressed the Nebraska State Telephone Association on outside plant development work. He also spoke before the Omaha Engineers Club on submarine detection. In a talk before the Omaha Inter-Professional Club he described engineering work and its application to various safety features in industry.

At Madison, Wisconsin, Mr. Moore spoke before the student branch of the A.I.E.E. at the University of Wisconsin. He dwelt on various phases of engineering work which, although not concerned directly with electricity, have electrical engineering as their basis.

## PLANT SHOPS

The eighth star, signifying forty years of service, was added to Luigi Barbieri's service button on March 3.

Mr. Barbieri is an accomplished wood finisher. He started working for the

*L. Barbieri*

Western Electric Company in 1892 as a cabinet maker. From 1897 to 1900 he worked on the assembly of transmitters. From this work he transferred to wood finishing on central office switchboards. Of late years he has performed the wood finishing of the work turned out by the Cabinet Shop.

## STAFF

Thomas Donovan, watchman at the court gate on West Street, retired March 1. His service with the Western Electric Company extends to nearly twenty-seven years.

## APPARATUS DEVELOPMENT

A group luncheon of one hundred sixty-seven supervisors of the Apparatus Development Department was held at the Fifth Avenue Hotel on Tuesday, March 8.

This was the first of a series of occasional informal luncheons which are being arranged by a committee of supervisors in accordance with generally expressed interest in wider acquaintanceship at the Laboratories. The plan is to present information regarding some of the current activities of the Bell System.

The speaker, W. H. Harrison, Plant Engineer of the American Telephone and Telegraph Company and a former member of the Laboratories' staff, was introduced by R. L. Jones. Mr. Harrison gave an interesting résumé of past and present Bell System performance and of business conditions in the telephone industry.

The thanks of the committee and the appreciation of the audience were conveyed to Mr. Harrison by Vice-president Charlesworth at the conclusion of the luncheon.

The committee of arrangements consisted of O. A. Shann, Chairman; R. A. Devereux, Secretary-Treasurer; F. W. Cunningham; R. V. Terry; P. S. Darnell; H. O. Siegmund; R. J. Nossaman; J. A. St. Clair; and W. H. Sellew.

### Special Products Design

L. B. Cooke supervised the installation of the public address system for the Legislative Press Association dinner in Albany and operated the equipment during the dinner.

Naval communication systems were discussed by W. L. Betts and H. C. Curl with engineers of the U. S. Navy at Washington.

R. Nordenswan has been at Hawthorne where he reviewed the production of the new line of audiphones.

W. R. Goehner attended the spring meeting of the Optical Society of America held at Cambridge.

### Radio Development

F. W. Cunningham and W. L. Tierney accompanied representatives of the Western Electric and Graybar Companies on a trip to the West and Southwest where they visited numerous radio broadcasting stations.

Radio stations KFXD (Nampa, Idaho), KIT (Yakima, Washington), KJBS (San Francisco, California), KXL (Portland, Oregon) and KXRO (Aberdeen, Washington) were visited by O. W. Towner during an inspection tour of Western Electric equipped broadcasting stations in the Western States.

H. Vadersen completed twenty years of service on March 11.

### Transmission Apparatus

Accompanied by E. W. Niles of the American Telephone and Telegraph Company, E. B. Wheeler and J. H. Bower attended a conference at the Bureau of Standards at Washington for contemplated revisions of ASA specifications on dry cells and batteries.

Problems of equipment for use in radio transmitters were considered by R. W. DeMonte in a visit to the Pittsfield works of the General Electric Company.

J. R. Bardsley, accompanied by C. C. Hipkins of the Chemical Laboratories and R. I. Crisfield of the American Telephone and Telegraph Company, inspected the finish on underground loading-coil cases in several cities and towns in Connecticut.

### Manual Apparatus

H. T. Martin visited Hawthorne for discussion of problems on the manufacture of new combined telephone sets for desk and wall use. While in Chicago, he also visited the plant of the Teletype Corporation.

C. F. Swasey with F. E. Fairchild of the American Telephone and Telegraph Company visited the plant of the Weston Electrical Instrument Company at Newark in connection with meter problems.

### Dial Apparatus

P. T. Higgins visited Geneva, New York, in connection with a study of wear on step-by-step switch bank contacts.

### Materials

F. F. Lucas described his new high power metallographic equipment before a joint meeting of the American Physical Society and the Optical Society of America at Massachusetts Institute of Technology. Dr. Lucas was guest of honor at a dinner sponsored by the Metallurgical groups of Harvard, Massachusetts Institute of Technology, and the Watertown Arsenal at which he spoke briefly on the results possible with his new metallographic apparatus.

J. R. TOWNSEND attended a meeting of Committee E-1 of the American Society for Testing Materials held at Philadelphia. C. H. Marshall was also in Philadelphia for A.S.T.M. committee work.

T. S. HUXHAM visited Hawthorne to observe the molding of housings for combined telephone sets.

A SPECIAL meeting of the sub-committee on Electrical Tests of the A.S.T.M. held at the Engineering Societies Building was attended by J. M. Wilson, W. A. Evans, R. Burns, and K. G. Coutlee.

H. N. VAN DEUSEN and J. M. WILSON accompanied by Dr. I. G. Barber of the Western Electric Company witnessed the installation at Chester of special toll cables on the experimental pole line.

## DRAFTING AND SPECIFICATIONS

The death of Herbert Waller, which occurred on February 8 after an illness of several months, severed many close personal ties formed during his quarter-century in the Laboratories and Western Electric Company.

*Herbert Waller*

Mr. Waller was engaged in preparing manufacturing specifications on several kinds of manual apparatus. He had previously worked on apparatus drafting. Active in social affairs of his Department, Mr. Waller was for many years a regular member of the Bowling Club.

## REPORT OF EMPLOYEES' BENEFIT COMMITTEE

A total of $129,225 was expended for all purposes under the Employees' Benefit Plan in 1931. This was the best health year in the history of the Laboratories in spite of a severe outbreak of respiratory diseases in the early months. Accident frequency in proportion to the number of employees decreased 42% and lost time approximately 24% as compared with 1930. The months of November and December 1931 were the first in the history of the Laboratories in which there were no "lost time" accidents. Five members of the Laboratories were retired with pensions. Eighteen deaths occurred during the year and where eligibility to death benefits existed, such cases were administered in accordance with the provisions of the Plan.

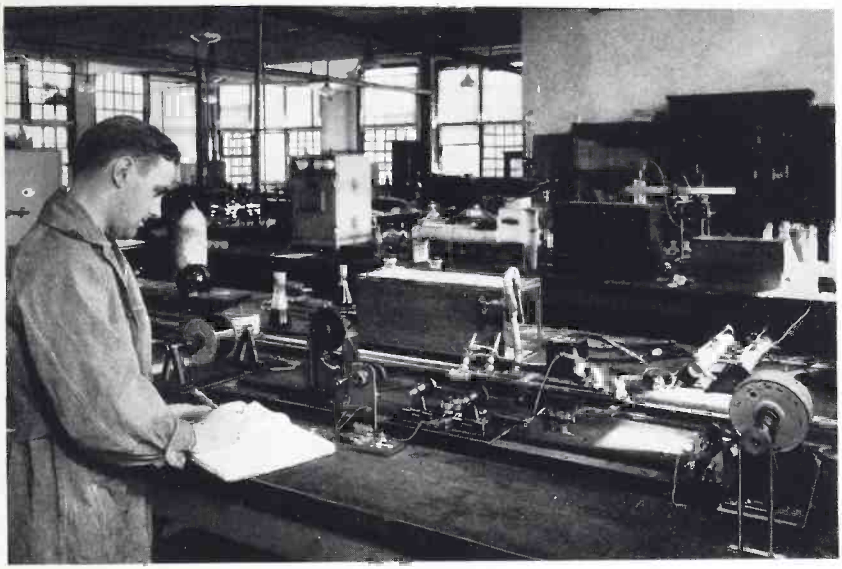
A report of payments under the Plan, during 1931, as prescribed in paragraph 30 of Section 8 of the Plan for Employees' Pensions, Disability Benefits and Death Benefits follows:

| | |
|---|---|
| Pensions | $ 12,416.82 |
| Accident Disability and Death Benefits | 5,423.58 |
| Sickness Disability Payments | 88,984.12 |
| Sickness Death Payments | 22,400.39 |
| Total | $129,224.91 |

A. F. WEBER, *Secretary,*
*Employees' Benefit Committee.*

*The above statement of payments audited and found correct.*

E. J. SANTRY,
*General Auditor.*



# Improved Continuity Test for Enamel Insulation on Wires

By C. L. ERICKSON
*Chemical Laboratories*

SOME twenty billion feet of enameled wire is used annually by the Bell System. In the smaller sizes large quantities of it are used for winding numerous pieces of apparatus such as relays, ringers, transformers, and retardation and repeating coils. For this purpose enamel is considerably cheaper than textiles and takes up much less space. The reduction in space secured is particularly important with the smaller sizes of wire so that for certain windings, such as transformers, enamel insulation is practically indispensable. It is applied by passing bare wire through a varnish solution and then through an oven to bake it on. The process is repeated until an insulating coat of the desired thickness—ranging from a few ten thousandths of an inch for the smaller sizes to a few thousandths for the larger—has been built up on the wire.

Any discontinuity in the enamel coating is, of course, a potential source of trouble. Should two breaks in the insulation be in contact in a coil, one or more turns would be short-circuited. To test for continuity of the film it has been customary to pass the wire through a mercury bath with a potential maintained between the mercury and the wire so that any defects may be detected electrically. A relay and message register serve to record the number of defects in a given length of wire.

These defects have commonly been believed to be small holes, some of them perhaps microscopic, in the enamel coating. It has been realized, however, that perhaps some of the defects were minute irregularities in the copper wire which projected through the thin insulating film. It has also been thought that perhaps certain small projections might not quite pierce the film but that under the pressure of a wound coil they would break through and give trouble. With a mercury bath it is impossible to distinguish between the first two types of defects, and projections not quite through the surface would not be detected at all.

Microscopic examination shows that such projections undoubtedly exist and that they may be fins running lengthwise along the wire, small slivers of metal projecting out from one point, or particles of copper detached from the wire and suspended in the enameling bath. The latter, even if not originally in contact with the wire, may be forced into contact by the winding pressure. To gauge the relative number of slivers or fins, and pinholes, is practically impossible by visual examination through a microscope because of the extremely small number of them in any reasonable length of wire. Work was therefore started on a new laboratory testing method which would detect metal projections.

As finally developed for laboratory use the new testing machine is shown in the photograph at the head of this article. At the extreme left is the supply spool of wire to be tested. From it the wire passes over a wheel for measuring its length, and then under an idler pulley which is weighted to maintain a uniform tension on the wire. It then passes through the testing apparatus and from that over a spacing pulley and onto the take-up spool at the extreme right. The testing apparatus consists of two ball bearings mounted on vertical posts of hard rubber, and two guiding wheels—one on each side of the two rollers. The front roller is fixed while the other is attached to a movable lever. Weights, suspended beneath the table, act on this lever to establish a pressure between the rolls, which may be adjusted as desired.

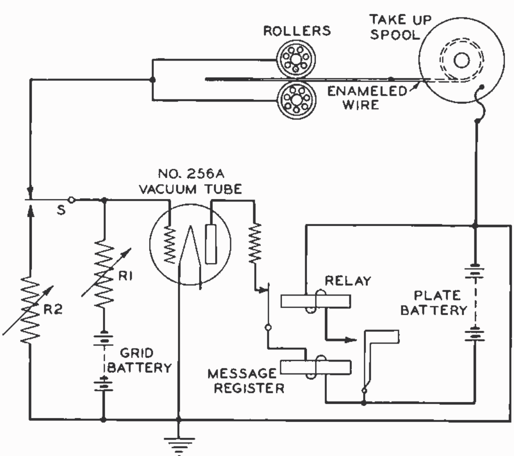



*Fig. 1—Schematic arrangement of the testing equipment*

The rollers and the wire under test form part of an electrical circuit which counts the defects found. The arrangement of the equipment is shown schematically in Figure 1. It resembles that used with the mercury bath in employing a message register for counting the defects, but differs in using a grid-controlled discharge tube, suggested by D. S. Bond. This permits much higher speeds of the wire since a very brief electrical impulse through the defect will start a discharge of the tube which will continue until the message register has operated—at perhaps quite a considerable interval after the defect has passed beyond the rollers. Operation of the register actuates a relay which opens the discharge circuit of the tube and reinstates the circuit in its normal condition ready for another impulse.

Sensitivity, or the amount of resistance at the defect through which the equipment will operate, is controlled through the grid biasing resistance R1. For adjusting, the switch S is moved into contact with R2 which is set at the desired contact resistance. R1 is then moved until the tube discharges. With this setting of R1, S is moved back to contact with the rollers, when the test may proceed. Curves showing typical results are given in Figure 2. The specimen of the upper graph had a comparatively large number of defects while that in the lower had very few.

Although the rollers make contact with only two sides of the wire, the number of defects found will be proportional to the total number over any appreciable length of wire. By adjusting the pressure between the rolls it is also possible to discover some potential defects, developed by the winding pressure, which would not be detected in a mercury bath.

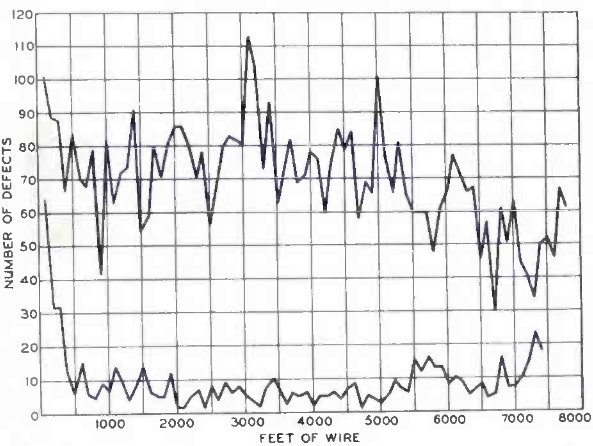
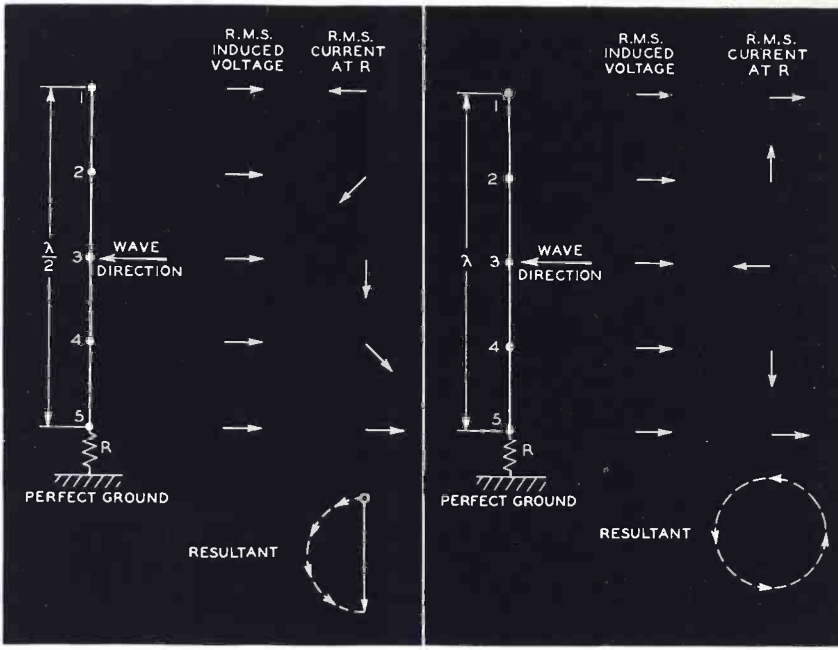
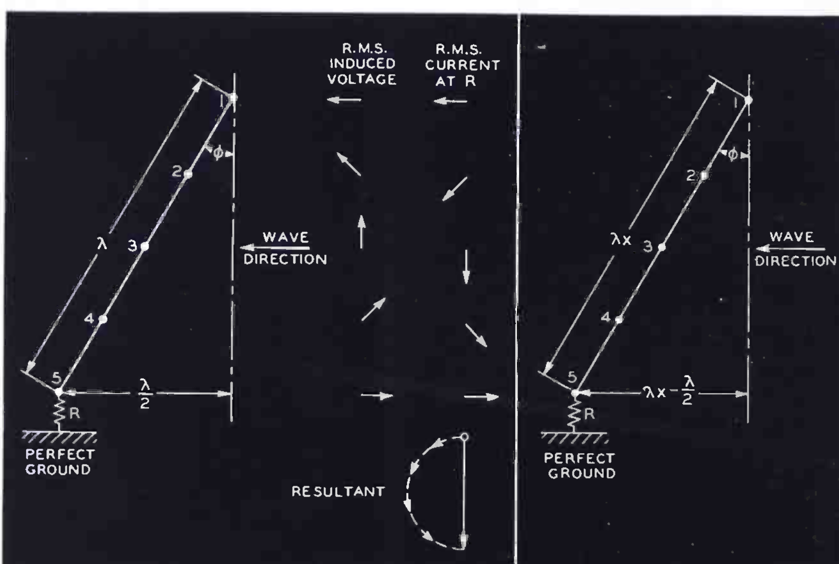



*Fig. 2—Plots can be made of the number of defects found; and samples from various sources differ widely*

Another advantage of the new equipment is that it does not damage the wire run through it, which—after the test—may be used for the production of coils or other products. Mercury, with the former method, would adhere to the wire and make it unfit for further use. The new method has been thoroughly tested and is expected to prove valuable in further Laboratory studies.




*Figs.* 1 *and* 2—*The voltages induced by a horizontally propagated wave in a vertical half-wave antenna (above, left) are all in phase. On reaching the receiver, the resulting currents are out of phase: the vector resultant is the diameter of a half-traced circle. For a full-wavelength antenna (above, right), summing the vectors traces a complete circle, and the resultant is zero. But this antenna also will give optimum reception if properly tilted (below, left). There is a proper tilt for an antenna of any length (below, right)*



# The Horizontal Diamond-Shaped Antenna

By E. BRUCE
*Radio Research*

IN use on the Bell System's short-wave transoceanic circuits, directive antennas have amply proven their value. As was anticipated, their selectivity of direction has effected economies in the power output of transmitters[1], and has increased the ratio of the signal in receivers[2] to the noise coming from static, from neighboring electrical equipment, and from sources inherent in receiver circuits. Justified by these successes, the continued development of directive antenna systems has now brought forth a new system having many definite advantages over its predecessors.

Most prominent among these advantages, perhaps, is the preservation of directional selectivity over a far greater range of frequencies. Thus to transmit and receive the daylight, dusk, and night frequencies used on a transoceanic channel, one transmitting and one receiving antenna can replace the three transmitting and three receiving antennas required heretofore. The much simpler mechanical structure of the new antenna further reduces the antenna cost per channel. For these and other reasons, antennas of the new type have been installed for use on the Bell System's new radio-telephone links with Bermuda, Rio de Janeiro, and Honolulu[3].

For reception the new antenna employs wires of such lengths, and at such angles to the favored direction of reception, as to cause a maximum current in the receiver from voltages induced by a wave advancing from that favored direction. For transmission the antenna is basically similar. The principles by which the lengths and angles are determined can best be explained by regarding the voltages induced in a receiving wire as lumped along the wire, producing elementary currents which separately traverse the wire to the receiver where they add vectorially.

By increasing the length of a vertical wire exposed to horizontally propagated waves, and matching its

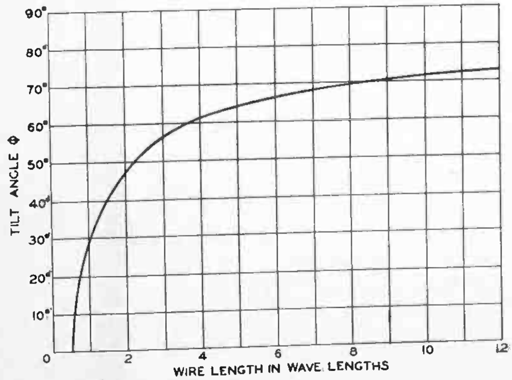



*Fig. 3—The optimum tilt of an antenna approaches ninety degrees as the antenna is lengthened*

[1] Record, *August*, 1929, *p.* 502.
[2] Record, *August*, 1929, *p.* 514.
[3] Record, *November*, 1931, *p.* 66.

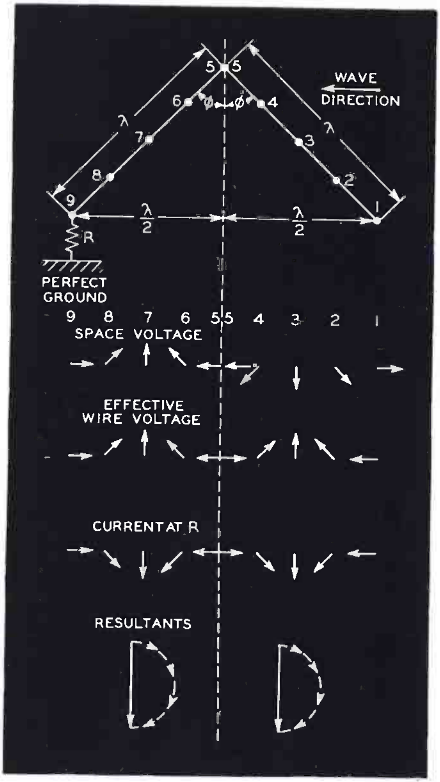



*Fig. 4—The V-shaped antenna provides an array of two tilted wires which not only reenforce each other but leave the optimum direction of response unaltered over a considerable range of frequencies*

impedance by the load at its base, the load power increases until the length of the wire reaches one-half the length of the approaching wave. When this point is reached, the current in the receiver can be represented vectorially (Figure 1-A) by the diameter of the circle whose semicircumference is traced in summing the elementary vectors. If the length of the wire is further increased, this circle is more nearly closed and the resultant becomes smaller. When the wire reaches a full wavelength, the circle is completely closed, and no current flows in the receiver (Figure 1-B).

This example illustrates a fact true of a single-wire antenna not only when upright but when inclined at any angle to the direction of a wave. The current at the receiver end of any wire

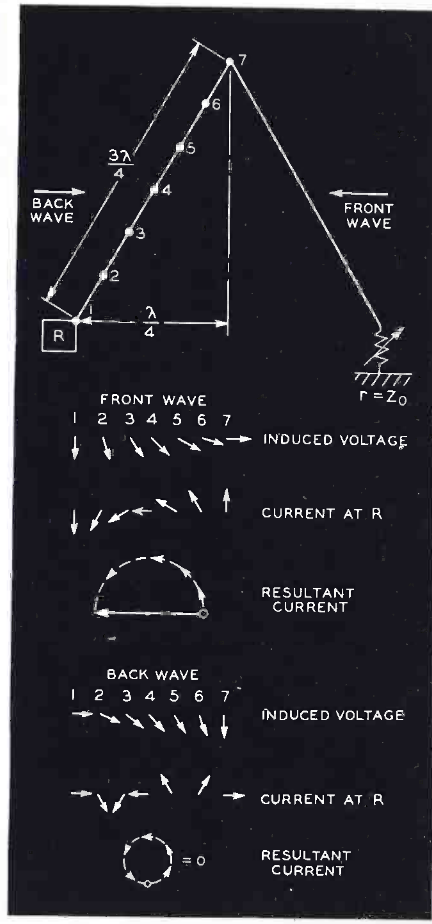



*Fig. 5—A wave coming from the back of a V-shaped antenna whose legs are three-quarters of a wavelength long produces elementary currents whose phase at the receiver changes twice as rapidly as when the wave comes from the front, and which thus cancel there*

will be a maximum when summation of the elementary current vectors in it traces a semicircumference, or in other words when only the elementary currents originating at its two ends are opposite in phase at the receiver.

To achieve this condition, a wire longer than a half wavelength can be tilted at such a vertical angle to the direction of the wave that the phase difference in the voltages, induced at the ends of the wire, compensates for the increase in the length of the path which the more distantly produced current must travel. Figure 2-A shows how this takes place for a wire one full wavelength long. It can be shown that the optimum tilt of any wire will be that at which the wire is one-half wavelength longer than its projection on the direction of motion of the wave (Figure 2-B). This principle permits increasing the length of the antenna to any desired value, and achieving thereby the increased output and directivity which always attend increased dimensions.

Furthermore, as the antenna is lengthened, the necessary readjustment of the tilt angle diminishes, as shown in Figure 3. It is this fact which permits the use of longer tilted-wire antennas over larger frequency ranges. Thus if an antenna, whose length was ten times the wavelength for which it was designed, were used to receive another frequency such that the antenna was only eight wavelengths long, the inaccuracy of tilt would be merely two degrees. This error would take effect only as a nearly inappreciable alteration in the direction of optimum response.

Like other antenna elements, tilted wires can be combined into arrays of the most various sorts. The effectiveness of tilted wires over broad frequency ranges is of such practical

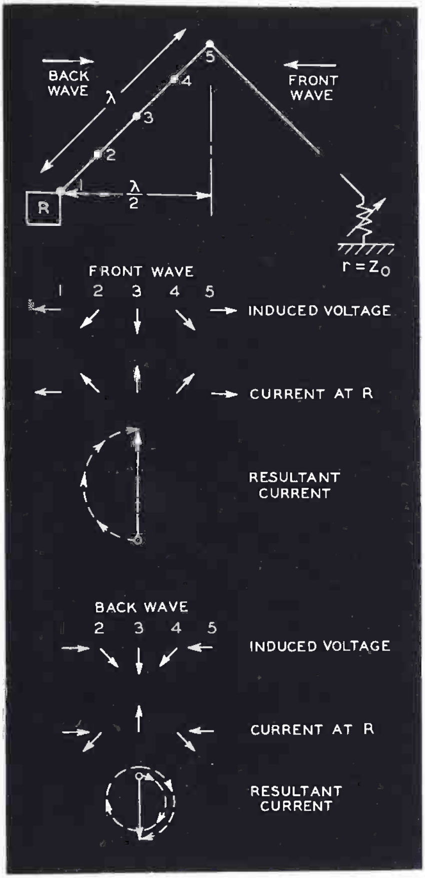



*Fig. 6—A V-shaped antenna whose legs are a full wavelength long responds to waves from the back one-third as strongly as to waves from the front*

value that only those arrays which do not restrict the frequency range have been extensively developed by these Laboratories.

One such is the V-shaped combination of two wires shown in Figure 4, whose added exposure of wire appreciably improves its directional characteristics and thus its signal output. Another advantage is its further extension of the breadth of the frequency

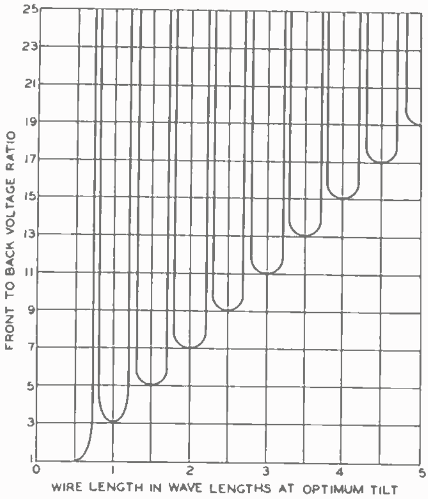



*Fig. 7—V-shaped antennas the lengths of whose legs are even integral multiples of one-quarter wavelength have the lowest front-to-back ratios, but these minima become larger as the wire lengthens*

range to which it is applicable. The tilt-angle errors, when the antenna is used at frequencies other than the optimum, are opposite for the two legs of the V, and thus cancel in the combination, leaving the optimum direction of response unaltered.

If the far end of any of these antennas were left open, there would have to be considered, in summing the elementary currents, not only those directly propagated to the receiver but also those propagated in the other direction and reflected back to the receiver from the open end. In practice, however, the far end of a tilted-wire antenna is terminated to ground through an impedance, equal to the characteristic impedance of the antenna, which absorbs all currents reaching that end.

It is this termination which achieves directional asymmetry, establishing a front and a back to the antenna so that it will respond strongly to signals from the front and inappreciably to signals from the back. Figure 5 shows that such an antenna can theoretically have an infinite front-to-back ratio, and indeed it is an experimental fact that the ratio is limited only by the physical rigidity of the antenna in space. It can be shown that an optimally tilted wire will have an infinite front-to-back ratio if its length is an odd integral multiple of one-quarter wavelength.

It might appear that this prescription of length would restrict the fre-

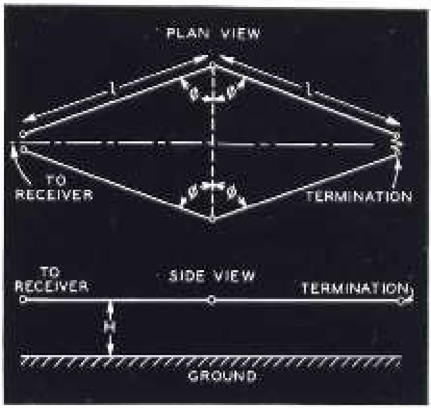



*Fig. 8—When one V balances another in a diamond-shaped array, the terminating impedance need not be grounded but can be connected between the far ends of the two V's*

quency range within which any particular antenna would exhibit an adequate front-to-back ratio. The frequencies for which the ratio is lowest are those for which the wire length is an even integral multiple of one-quarter wavelength. For a wire one wavelength long, for example, the resultant when the wave approaches from the back is found in Figure 6 to be as much as one-third the value of the resultant when the wave approaches from the front. The values of the ratio for optimally tilted wires of all lengths up to five wavelengths are shown in Figure 7, whence another advantage of long wires appears in the increase in the minimum ratio as the wire lengthens.

But even when a wave arriving from the back has one of these unfavorable frequencies, the signal it produces in an antenna can be cancelled by permitting an equal and opposite signal to be reflected from the antenna's far end. This can be accomplished by adjusting the terminating impedance so that it differs from the characteristic impedance of the antenna. It can be shown that the desired cancellation will occur for the most unfavorable frequencies when the termination equals the antenna's characteristic impedance times the cosine of the angle between wave direction and wire. Since this cosine approaches unity as the wire lengthens (Figure 3), the necessary adjustment of the terminating impedance for long wires is quite small. By making the terminating impedance a compromise between the ideals for the most favorable and the most unfavorable frequencies, large front-to-back ratios can be secured for a long optimally tilted wire over its entire useful range of frequencies.

The instability of the resistance of a ground contact with varying weather conditions, and the not inappreciable signal-pick-up of its connecting leads, has dictated the combination of two V-shaped antennas into a diamond-shaped array (Figure 8). Here the balancing effect of the two V's removes the necessity for a ground connection. Mounted in the horizontal plane, its supporting structure is less costly, and it is responsive to the horizontally polarized components of the arriving waves, which are less affected by variation in ground reflection with weather.

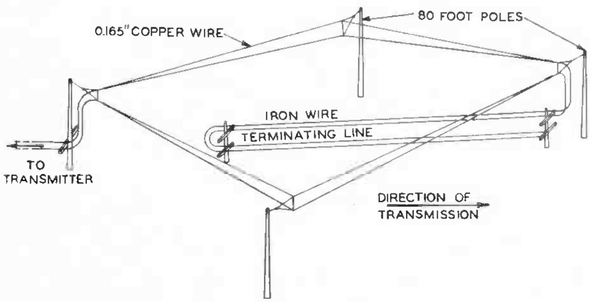
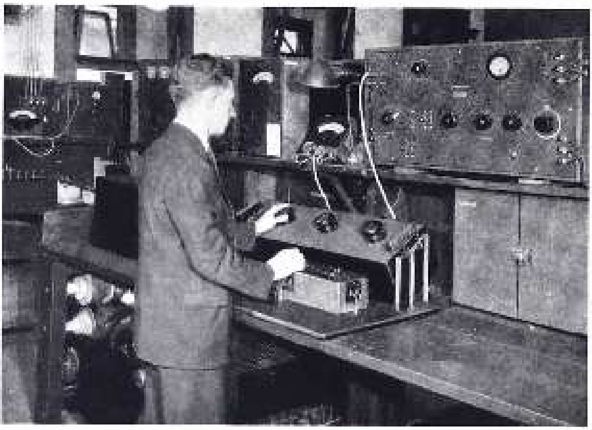



*Fig. 9—For transmitting antennas, a terminating impedance of the required dissipating ability has been found in a long two-wire iron transmission line shorted at the far end*

Of such an antenna the optimum direction of response in the horizontal plane remains the same over a frequency range of two to one, although the directivity becomes somewhat less sharp as the frequency becomes less favorable. The vertical-plane directivity in the optimum horizontal direction is dependent on the length of each leg, the tilt angle of the component wires, and the height of the whole antenna above ground. Undesirable characteristics can to some extent be reduced by changing these factors. The low response to horizontally propagated waves discriminates against man-made interference originating near the ground.



# Transmission Networks and Their Measurement

By H. W. AUGUSTADT
*Telephone Apparatus Development*

MULTIPLEX communication systems, such as carrier telephone, carrier telegraph, and radio systems in general, are made possible by networks that segregate the energy in various signals on the basis of their frequency range. Networks employed for this work are known as electric wave filters, or more commonly, as filters, and are designed to pass a desired frequency range very efficiently and to attenuate all frequencies outside this range. The attenuation or loss of power caused by the insertion of a filter or any other piece of apparatus in a circuit is known as its insertion loss and is usually expressed in decibels.* Filters thus have a low insertion loss over the band of frequencies they are designed to transmit and a high loss for all frequencies outside this band.

In addition, filters are required to provide and to maintain their loss characteristics to a high degree of precision. In the type "C" carrier telephone system, for example, the insertion loss characteristic of a filter must not depart from that specified by more than 125 cycles. This is necessary, in part, to prevent the signal in one channel from appearing as noise in another channel. Since band filters operate at frequencies as high as 27,000 cycles, this requirement means that the filter must hold its insertion loss characteristic to an accuracy of 125 cycles in 27,000, or less than one-half of one per cent. The characteristics of two filters for adjacent channels in this system are shown in Figure 1, and the schematics of their circuits are shown in

**A unit equal to one-tenth of the common logarithm of the ratio of the power in the circuit before inserting the apparatus to that after.*

the upper part of the same illustration.

A second network playing an important role in the operation of communication systems is the attenuation equalizer. This network enables one to construct a telephone system that is free from frequency distortion and thus assists in obtaining natural reproduction, at the receiving end, of the signals entering the system. It must provide an insertion loss that is complementary, throughout the useful frequency band, to the loss of the system or circuit in which it is to be used. The sum of the losses of the system and the equalizer, therefore, is the same for all frequencies within the specified frequency range and thus faithful reproduction is secured. The relationship between these various losses over the useful frequency band for the type "C" carrier telephone system is shown in Figure 2. Here are given the loss characteristic of the system between repeaters, that of the equalizer, and the sum of these losses, which is very nearly constant over the useful frequency band. The schematic of the equalizer is shown in the upper part of the illustration.

In systems employing large numbers of equalizers, such as long cable circuits, the precision to which the insertion losses must be held is much greater than for shorter circuits since the overall loss must be maintained within close limits and the systematic variations in individual equalizers are cumulative. If a long circuit contained as many as 160 repeaters, which may happen sometime in the future for example, the total variation from their required characteristic allotted to 160 equalizers connected in tandem would be 1 decibel. One-half of this variation would be assigned as the total departure of the 160 equalizers from their requirement due to manufacturing variations of the elements of the equalizers. This would leave only one-half decibel variation for the total departure of the theoretical design performance of the equalizers from their required performance. Thus the theoretical design characteristic of any individual equalizer would have to be within .003 decibel (one thirtieth of one per cent) of the required characteristic. Theoretically, of course, an equalizer can be designed in which even this small departure is eliminated. Practically, however, the cost and size of such a network would prove prohibitive and even with the present design some individual corrections have to be made in the over-all circuit.

The actual loss characteristic of a

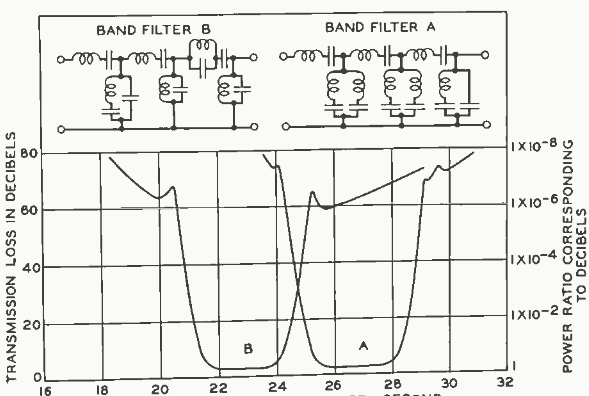



*Fig. 1—Insertion loss characteristics of two adjacent band filters employed in the type "C" carrier telephone system, below, and the configuration of filter elements giving insertion loss characteristics, above*

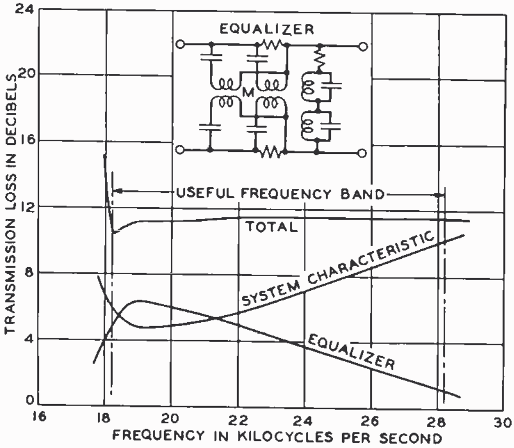



*Fig. 2—Typical insertion loss characteristics of apparatus entering the type "C" carrier telephone system are shown below, and the configuration of elements furnishing the insertion loss characteristic of the equalizer is shown above*

network departs from its theoretical characteristic as a result of numerous causes, and to obtain a network with a precise characteristic, these causes must be evaluated and considered in the design of the network. Some of the factors giving rise to these discrepancies are: mutual impedances between the elements, impedances introduced by the wiring, distributed impedance effects in the elements themselves, changes in the elements with current variations, or with temperature and humidity changes, aging of materials, and admittances from elements to ground. To evaluate the effect of these factors, high precision measuring equipment is indispensable for testing the models designed.

To measure the design characteristics of filter and equalizer models, a circuit is employed similar in its general arrangement to that shown in the simplified schematic in Figure 3. It is arranged to compare the insertion loss of the network under investigation with the insertion loss of a standard network at any frequency. A vacuum tube oscillator impresses the same test voltage on both the standard and the apparatus under test, and by means of the four-pole, double-throw switch, the output of the standard is compared with that of the apparatus. The operation of the circuit consists in setting the oscillator and the detector to the test frequency, and adjusting the loss in the standard until the same detector reading is obtained with the switch thrown either to the apparatus or standard position. The

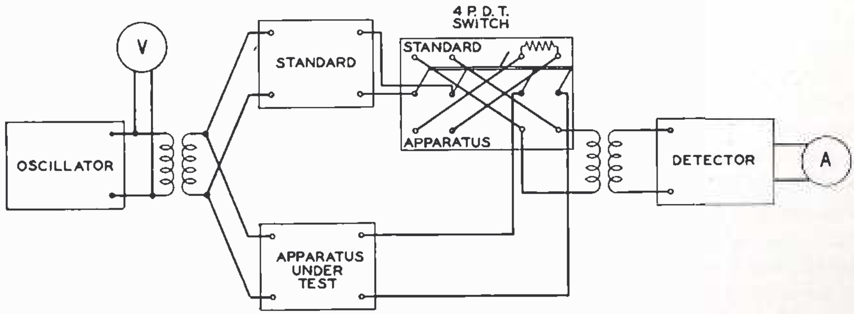



*Fig. 3—Simplified schematic of circuit used for measuring insertion loss*

insertion loss of the network is then read from the standard. A photograph of the external appearance of a circuit capable of making this type of measurement is shown at the head of this article.

Equipment for this purpose in the Transmission Networks Laboratory, must have a frequency range of from 10 to 4,000,000 cycles and be able to measure, with precisions of from ±.001 to ±1 decibel, losses varying approximately from 0 to 140 decibels. It is not economical to cover these wide ranges of frequency, loss, and precision with one circuit, and so separate circuits are provided each adapted to a single specific range. For general measuring purposes the frequency range is covered by four circuits capable of measuring losses up to 80 decibels with precisions ranging from ±.05 decibel for the low losses to ±.5 decibel for the higher losses. Some filters employed in carrier telegraph and telephone systems, however, because they must introduce sufficient loss outside of their pass band to prevent interference from adjacent channels which may be at a much higher level, require for their measurement a circuit capable of measuring losses as high as 140 decibels. This is accomplished with a circuit that covers a frequency range of from 3,000 to 50,000 cycles and measures losses with a precision varying from ±.1 to ±1 decibel. This circuit, so as to be able to measure these high losses, must be carefully shielded and wired to avoid errors due to stray coupling either with outside sources or between its own parts. Networks furnishing a prescribed loss characteristic with a high degree of precision, such as the equalizer described above, must be tested on a high precision circuit. A circuit developed for this purpose measures losses to a precision of ±.001 decibel but is limited in its range to losses varying from no loss to 30 decibels.

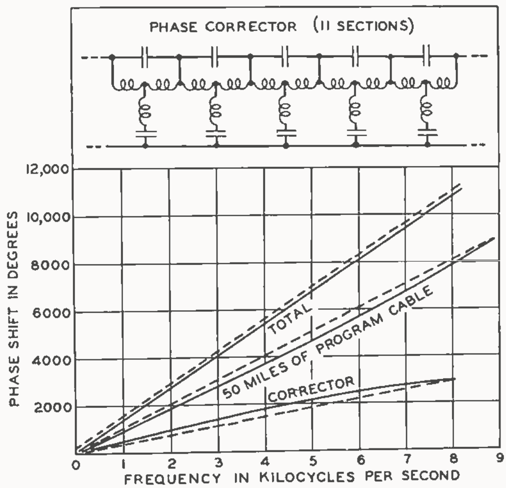



*Fig. 4—Typical phase characteristics of apparatus entering program transmission circuits. (The dotted straight lines are drawn to illustrate the curvature of the characteristics.) The configuration of delay equalizer elements furnishing the phase characteristic of the corrector is shown above*

In telephone and telegraph systems a network is called upon not only to provide prescribed loss characteristics, but to have other specified characteristics as well. One of these is that its impedance shall be nearly constant over a given frequency range. This requirement is important especially in carrier systems where the network is associated with a long open wire line, which is practically a constant resistance. A mismatch between the impedance of the line and of the network will cause part of the current to be reflected back along the line. The reflected currents produce undesirable effects on the transmission-frequency characteristics of the circuits in which they originate and, where the lines for two or more carrier systems are strung on the same poles, may possibly cause serious interference through near-end cross-talk in other systems.

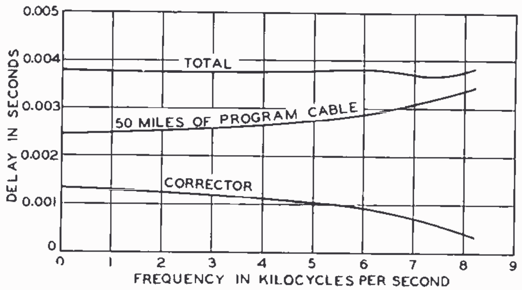



*Fig. 5—Delay characteristics corresponding to phase characteristics shown in Fig. 4*

To check the impedance characteristics of networks, bridges—accurate to ±.1%—are provided in the Transmission Networks Laboratory for the frequency range of from 10 to 4,000,000 cycles. These bridges are an adaptation of the Wheatstone bridge in two arms of which are equal fixed resistances, and in the other arms are switching arrangements to allow variable condensers or variable inductances to be thrown in series with the variable resistance in the third arm, or with the terminals for the unknown in the fourth arm. These bridges are necessary not only for checking the impedance characteristic of the network, but also for measuring the impedance of the elements of the network.

In addition to meeting insertion loss and impedance requirements, networks operating in long distance telephone systems, such as transcontinental systems, or in program transmission circuits interconnecting various broadcasting stations, must meet phase shift requirements. These latter are necessary because a system with a phase shift characteristic which is not directly proportional to frequency, introduces a distortion to the signal known as delay distortion. The measure of delay at a given frequency is the ratio of the increment of phase shift expressed in radians to the increment of $2\pi$ times the frequency in cycles, generally denoted $\frac{dB}{d\omega}$ where B is the symbol for phase shift and $\omega$ for $2\pi f$. The distortion caused by not having a constant delay to all the frequencies comprising the signal manifests itself as noise, apparently extraneous, in the system, and in unnaturalness of reproduction.

The correction of the non-linear phase characteristic of a system is effected with a network known as a delay equalizer. This network is designed to have such a phase characteristic that the sum of the phase shift of the corrector and of the system is very closely a linear function of the frequency. The characteristics of a program circuit, its delay equalizer, and their combination are illustrated in Figure 4, which shows the phase shift characteristics of apparatus employed in a newly developed high quality program transmission circuit. The delay corresponding to the phase characteristics of Figure 4 is shown on Figure 5, and the schematic of the delay equalizer employed in this system, in the upper part of Figure 4. It can be seen from the delay curves that a circuit of this type 3,000 miles long would delay a signal .225 second, and that the delay distortion—the maximum deviation of the curve from the mean value—is about .006 second over the useful frequency range. Without employing correction, the delay distortion amounts to .055 second or approximately nine times as much as that of the corrected system.

The phase shift characteristic of a network is measured on a circuit with a frequency range of from 10 to 75,000 cycles, to an accuracy of ±10 minutes. A simplified schematic of this circuit, which measures insertion loss as well as phase shift, is shown on Figure 6. Two distinct operations are required for a phase measurement. The first consists of adjusting the standard $A_1$ until it has the same insertion loss as the apparatus under test. This is done by throwing the switches to the side marked "Attenuation" and obtaining a balance as described in connection with insertion loss measurements. When this operation has been completed, the currents from the standard and from the apparatus under test are equal in magnitude but differ in phase, and the insertion loss of the apparatus may be read at the test frequency.

The second operation attenuates the vector sum of these currents until it is equal to their vector difference. This is accomplished by throwing the switches to the side marked "Phase" and adjusting the attenuator $A_2$, on which either the sum or difference may be impressed through operating the switch $S_4$, until the vector sum and difference of the currents are equal. The ratio of the vector sum to the vector difference of the currents, as determined by the setting of the attenuator $A_2$, is a trigonometric function of the phase angle between the current from the standard and that from the network.

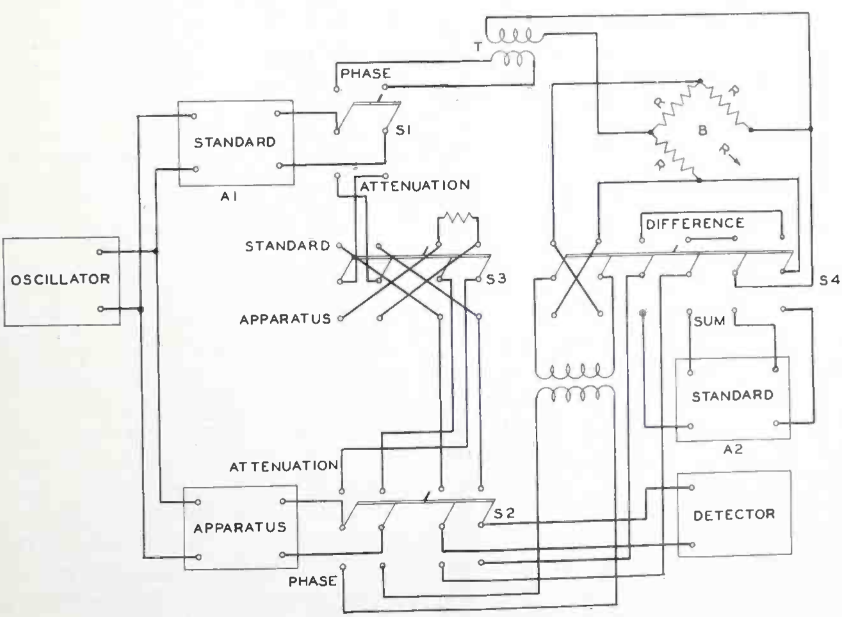



*Fig. 6—Schematic of circuit employed in measuring phase shift*

In addition to requirements already discussed, networks may also have longitudinal unbalance, phantom-to-side cross-talk, modulation, and break-down requirements to meet. Space limitations do not allow a discussion of the methods employed to check networks for these requirements, but to meet them is often as difficult as to meet the loss, impedance, or phase requirements.

The increasing complexity of communication systems resulting from transmission over greater distances, increased multiplexing, and an increasing variety of systems makes it imperative to provide transmission networks that, by meeting increasingly stringent requirements, will allow a more efficient use of the transmission facilities. The art of network development must consequently advance both in improved designs, and in better methods of controlling the effect of manufacturing variations. This involves theoretical study and experimental investigation of all of the factors that cause the final product to depart in performance from its design characteristic.

## *Hydrogen Isotope and Time Are Colloquium Topics*

*Professor H. C. Urey of Columbia University spoke at the meeting of the Colloquium, February 15, on "The Hydrogen Isotope of Mass 2." Systems of atomic nuclei, he said, suggest that isotopes of hydrogen and helium might be expected. He referred to work carried out by Dr. Murphy and himself that has shown that the hydrogen isotope of mass 2 is present in concentrated samples and in ordinary hydrogen, using the atomic spectrum to detect the isotope. Professor Urey described research work by means of which its presence has been definitely established.*

*At the meeting on February 29 W. A. Marrison was the speaker. His subject was "Time and Frequency Measurements."*

*Mr. Marrison described methods of generating current of constant frequency and for making precise comparisons over a wide frequency range. He also described some of the proposed uses of a central frequency standard for synchronization, and also for time and frequency services.*

## *Kearny Works Staff Visits Laboratories*

*S. S. Holmes, Works Manager of the Western Electric Company at Kearny, and his staff, visited the Laboratories on March 9. They were guests of the Executive Staff at luncheon and visits were made to several of the Laboratories departments under the escort of R. L. Jones and A. F. Dixon. Arrangements for the visit were in charge of G. F. Fowler of the Bureau of Publication. Other members of the visiting party in addition to Mr. Holmes were: F. W. Bierwirth, R. L. Hart, F. J. Feeley, J. R. Shea, C. W. Gates, N. M. Argo, J. W. Dietz, D. B. Peckham and T. M. Erickson.*

# Contributors to This Issue

H. W. Augustadt received the degree of B.S. in Electrical Engineering from the University of North Dakota in 1928. He joined the Apparatus Development Department of the Laboratories the same year and became engaged in the design of filters and equalizers. The major portion of his work has been on problems connected with the testing of the electrical characteristics of experimental models of such networks.

C. L. Erickson received a B.S. degree in Industrial Chemistry from Kansas State College in 1927, and in September of the same year joined the Technical Staff of the Laboratories. Since that time he has been associated with the Chemical group of the Research Department. For the most part his work has consisted in studies of the enamelling process, and in the development of tests for enamelled wire.

K. F. Rodgers interrupted his studies at the Massachusetts Institute of Technology to take part in war activities. After two years' service in the Chemical Warfare Service he returned to the Institute and received an M.E. degree in 1921. He then joined the Technical Staff of the Laboratories where he has been engaged in the development and design of condensers and loading-coil cases.

After receiving a C.E. degree at Princeton in 1903 and the degree of S.B. from M. I. T. in 1905, J. C. Field joined the Western Electric Company. Following a student course, he worked in the shop on switchboard assembly and testing, and in equipment engineering on preparation of specifications for switchboards and associated equipment. Transferring to the laboratory, he engaged in general circuit work and in the development of semi-automatic switching of the panel type. In the old "physical laboratory" he worked on the development of equipment for train dispatching with which he has been associated most of the time since. During the war period, Mr. Field was employed on deep-sea submarine detection work both in New York and at the naval laboratory at Nahant, Massachusetts. He also worked on methods of selective control of mine systems for the Coast Artillery. At the present time he

*H. W. Augustadt*

*C. L. Erickson*

*K. F. Rodgers*

*J. C. Field*

*F. M. Ryan*

*E. Bruce*

is in charge of the development of train-dispatching apparatus.

F. M. Ryan graduated from the University of Washington in Seattle in 1919 with the degree of B.S. in E.E., and joined the Technical Staff of the Laboratories, then the engineering department of the Western Electric Company, in January 1920. Having acquired a varied radio experience before graduating from college, including service as marine operator, radio laboratory assistant, radio inspector and radio instructor, it was but natural that he should be assigned to radio development work with the Research Department of the Laboratories. During his first year with the Laboratories, he was associated with the development of the radio telephone link connecting Catalina Island with the California mainland. He also has had an important part in the development of radio broadcasting equipment. At the present time, he is in charge of groups responsible for the development of radio apparatus for mobile applications, and has directed much of the work of developing radio equipment for commercial aviation service.

After three years with the United States Navy, E. Bruce entered Massachusetts Institute of Technology in 1920, and joined the Engineering Staff of the Clapp-Eastham Company in 1922. In 1924 he received the B.S. degree in electrical communications and came to the Research Department of these Laboratories. Mr. Bruce has been principally concerned here with the development of short-wave field-strength measuring equipment and directive receiving-antenna systems. In recognition of his work in this latter field, Mr. Bruce has just been awarded the Morris Liebmann Memorial Prize by the Institute of Radio Engineers.

*L. S. Ford*

L. S. Ford received from Worcester Polytechnic Institute the B.S. degree in 1905 and the E.E. degree the following year. After three years in electric railway engineering, he joined these Laboratories. Mr. Ford has since been associated almost continuously with cable development, most of the time as a representative of the Laboratories at Hawthorne and then at Kearny. He is now supervising work on general engineering problems in connection with lead-covered cable designs.

# The peace that pennies buy

EACH DAY, after breakfast, you bid good-bye to your husband and he is gone. Miles of distance and hours of traveling may separate him from you, yet you do not fear. You have no feeling of his being far away—no sense of loneliness or isolation. For there, within reach of your hand, is your contact with all the world—the guardian of your home . . . your telephone.

All you see is the telephone instrument itself and a few feet of wire. Through the familiarity of use, you are likely to take it for granted in much the same manner as air and water and sunshine.

Rarely do you think of the complicated exchanges, the almost endless stretches of wire and the hundreds of thousands of trained employees that are needed to interconnect, through the Bell System, nearly twenty million telephones in this country and twelve million in foreign lands. No matter where you are you can command the full use of the telephone. It knows no class or creed. There is no distinction of position. All may share it equally.

Every time you lift the receiver you employ some part of the nation-wide Bell System. Yet the charge for residential use is but a few cents a day. For this small sum you receive a service that is almost limitless in convenience and achievement —so indispensable in emergencies that its value cannot be measured in terms of money.

Thinking of the peace and security it brings each home—of hurried calls to doctors and hospitals—of priceless, necessary talks with relatives and friends—of the many ways it saves you steps and time and trouble throughout the month, you will know why so many millions of people look on the telephone as a member of the family.

AMERICAN TELEPHONE AND TELEGRAPH COMPANY