BELL LABORATORIES RECORD

PRIMARY TOLL TEST BOARDS

L. C. KRAZINSKI

DIRECTIVE ANTENNA FOR BROADCASTING

J. F. MORRISON

HIGH VOLTAGE RELAY

V. L. RONCI

APRIL 1935 Vol. XIII No. 8

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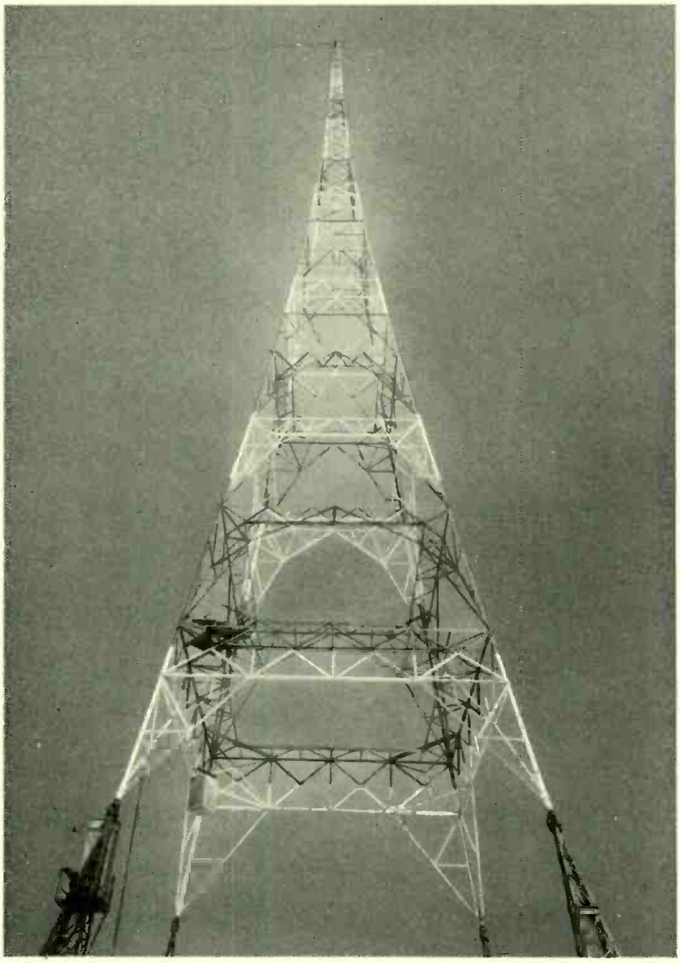

One of the antenna towers of broadcasting station WOR

VOLUME THIRTEEN—NUMBER EIGHT

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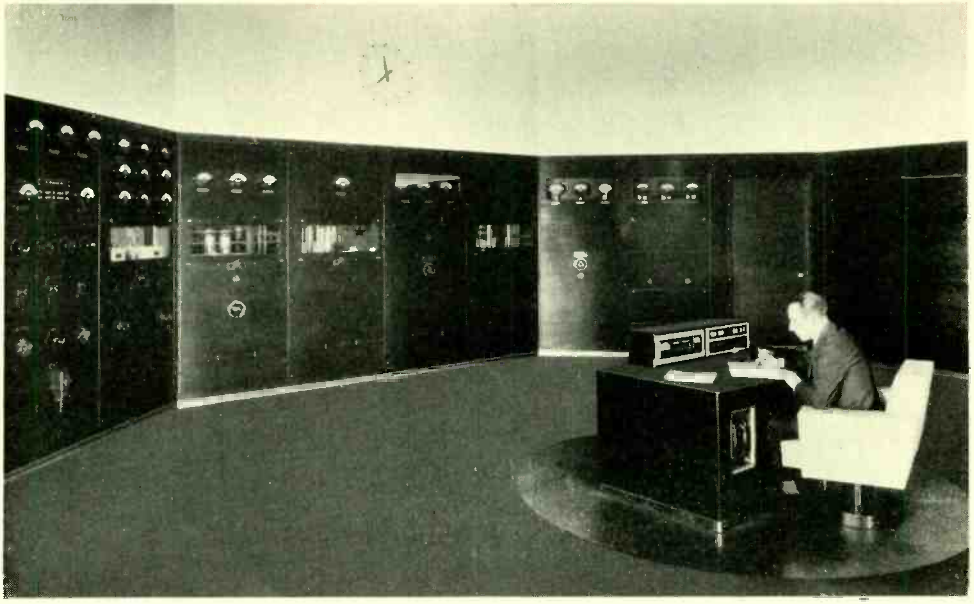
1935



A 50-KW Radio Transmitter of High Fidelity

By J. C. HERBER
Radio Development Department

A NEW high-power radio transmitter has recently been developed by the Bell Laboratories. The first transmitter of this type to be manufactured by the Western Electric Company is now in use at the new broadcasting station of the Bamberger Broadcasting Service, at Carteret, New Jersey. This new station marks a distinct advance both in the design of building and in the arrangement of apparatus. No effort or expense has been spared by the customer to secure the most dependable and effective broadcasting station that careful planning and modern engineering technique can produce. The building lies on the meadows between the towns of Rahway and Carteret, where the low level ground, some of it partially under water at high tide, offers a favorable site for a radio transmitter. With the directive antenna, described in an accompanying article in this issue, and the increased power of the station, a better signal will be transmitted in all directions, and toward Philadelphia and New York its coverage is considerably extended.

In the design of the building, the architects—Voorhees, Gmelin and Walker—have harmonized the structure to its function, and blended the interior decoration to the external appearance of the transmitter that it contains. Both in design and structure the building centers around the transmitter room shown in the photograph at the head of this article. A floor plan of the entire building, showing the various rooms surrounding the transmitter room, is given at the end of this article.

This transmitter room is semi-octagonal in shape with a control desk in the center directly beneath a large indirect lighting unit. The eight panels comprising the front of the 50-kw. transmitter form the lower part of the walls of the three sides facing the operator, who thus has a clear view of all the meters, indicating lamps, and most of the tubes. Certain of the more important controls and indicating lamps are extended to the two control units on the operator's desk where they can be under his more immediate supervision.

The wall behind the transmitter operator has a large plate-glass window; just beneath this, but on the other side of the wall, is the main control desk shown in Figure 1. This is the speech input room, and behind the control operator, who sits at the desk, are the speech input and audio control panels. Certain of the transmitter controls, as well as the speech input controls, are extended to this desk, so that the control operator has an indication of the operation of the entire station directly before him.

Behind the panels of the 50-kw. transmitter is the main apparatus room, shown in Figure 2. At the left are the various amplifiers and coupling units directly behind the panels, and on the right is the high-voltage power supply and filtering equipment. A notable feature of this installation is the absence of all overhead bus structures. All connections except to immediately adjacent apparatus are carried through the floor and run along the ceiling of the basement. The layout of power transformers and motor generators in the basement was planned with this arrangement in view, so that each piece of apparatus is directly beneath the apparatus it serves on the floor above.

The radio-frequency current from the final amplifier is carried by two concentric conductors through the floor and up again to the coupling apparatus in a small room in the corner of the building behind and to the right of the position of the camera in Figure 2. This coupling unit in turn connects to the concentric conductor running to the antenna array. A view of part of the coupling equipment is shown in Figure 3 where the outgoing concentric conductor may be seen at the extreme lower left. An electrically

Fig. 1—Charles Singer, Chief Operator of WOR, at the control desk at Carteret

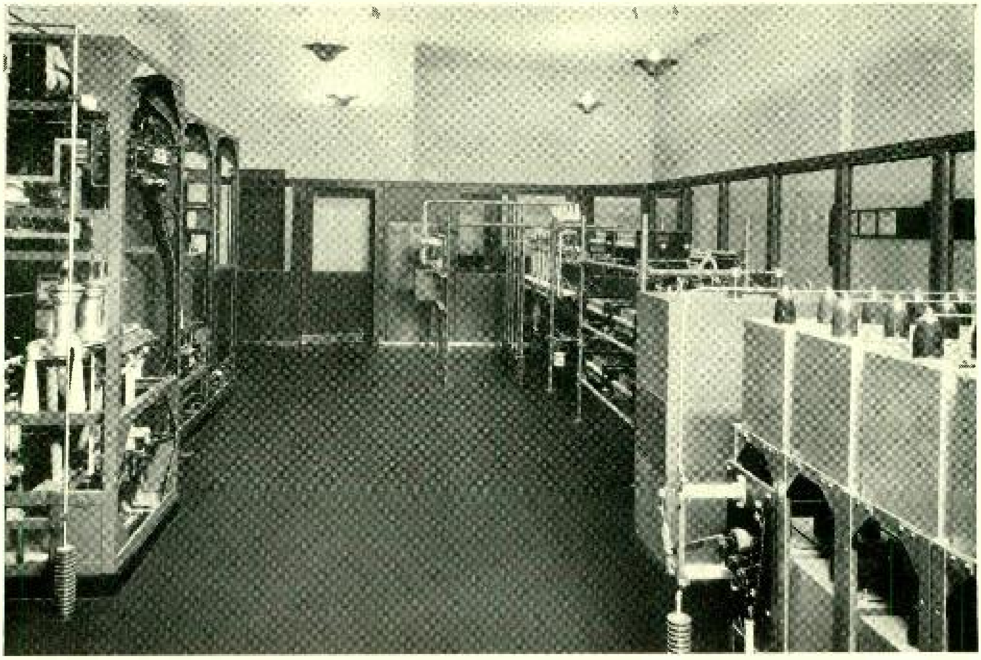


Fig. 2—The apparatus room is surrounded by a seven-foot metal and glass partition with doors interlocked with the power switches so that all power is off when any door is opened

operated double-throw switch allows the operator to connect the antenna system to the 50-kw. transmitter or to a stand-by 5-kw. transmitter.

Power for the station is brought in over two 4150-volt lines to provide a double source of supply. Remote-controlled switches permit the station apparatus to be switched to either of these circuits at will, and indicating lamps on the control desk show which switch is operated and whether the incoming circuits are alive or dead. By three banks of transformers, this primary supply is stepped down to 480, 240, and 120 volts. The 480-volt supply is used as the primary source of power for the 50-kw. transmitter. From it are operated the pump motors, the motor-generators supplying filament and grid potentials, and the 13,000-volt step-up transformers, shown in Figure 4, which supply the high-voltage rectifier furnishing plate potential for the radio-frequency amplifiers.

Just beyond the wall carrying these busses are the grid and filament motor-generator sets, Figure 5, where, above them can be seen the various conduit lines serving the transmitter directly above. Cooling-water lines come through openings in the floor from the power amplifiers above and run to the pump room shown in Figure 6. Distilled water is used for cooling, and during the winter is diverted through radiators in the ventilating ducts to heat the building. More than enough heat is obtained to warm the building during the coldest weather, and excess heat is transferred, through the heat interchanger shown at the right of Figure 6, to city water which is pumped to a spray pond for cooling. In summer all the heat is dissipated in this manner, while in winter the heat is divided between the ventilating system and the spray pond as required.

After the new 50-kw. transmitter was placed in service, the 5-kw. transmitter from the former station was installed at Carteret to serve as a stand-by. This transmitter, also of Western Electric manufacture, was installed where the blank panels now appear at the extreme right of the photograph at the head of this article. On the wall opposite the 5-kw. transmitter will be installed a Western Electric radio beacon transmitter to warn aviators flying the

Fig. 4—13,000-volt transformers and busses supplying the high-voltage rectifier. The upper bus is the 17,000-volt direct-current supply

Newark-Philadelphia airway of the proximity of the Carteret antenna towers. Planes flying this route follow the Newark Airport radio beacon, and the Carteret beacon transmits a five-dash signal 1200 cycles below the frequency of the Newark Airport beacon. As flyers approach Carteret, therefore, they hear the five-dash signal superimposed on the beacon they are following and can increase their altitude, if necessary, to be sure of clearing the antennas.

Besides the rooms already

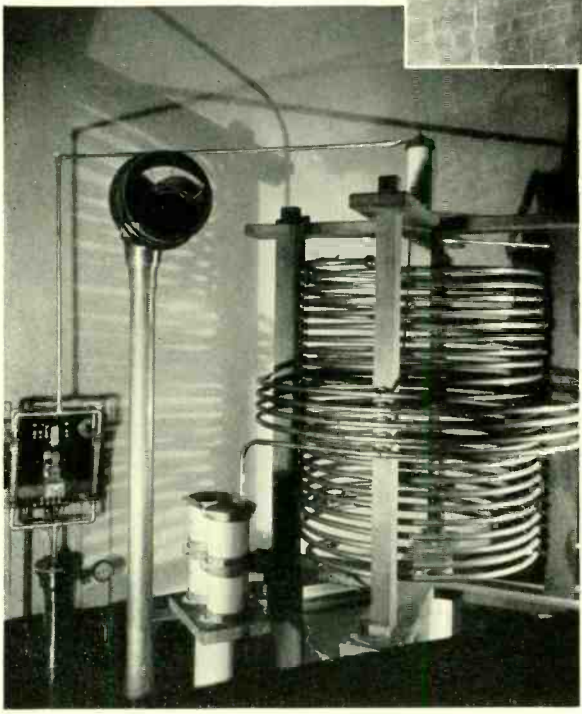


Fig. 3—Coupling unit connecting radio transmitter to concentric transmission line. Transmitter transfer switch and concentric line at lower left

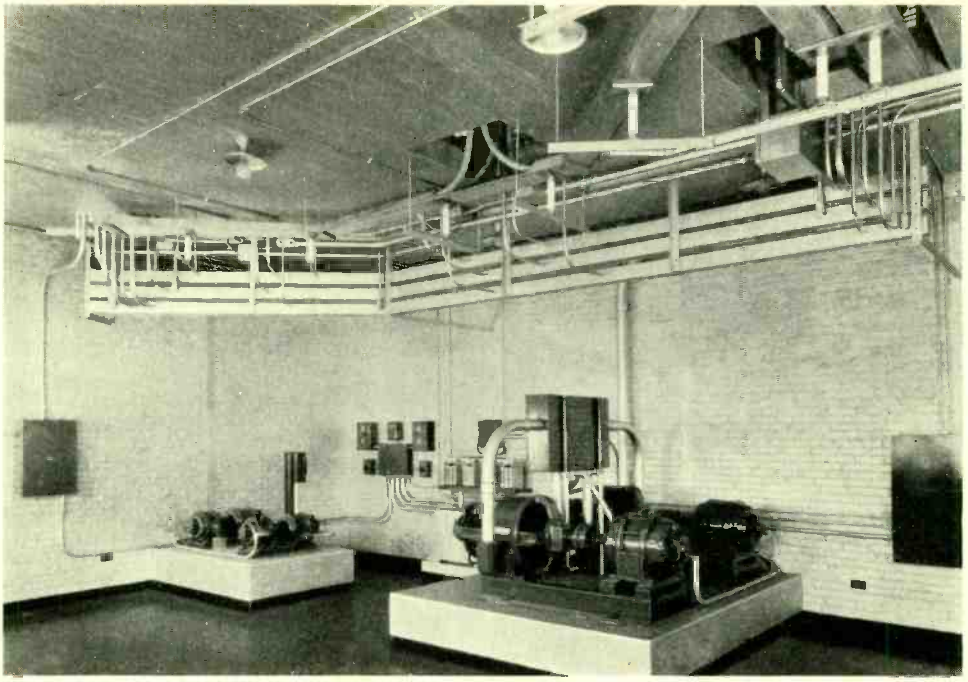


Fig. 5—A corner of the basement beneath the 50-kw. transmitter panels. Hose connections for the water-cooled amplifiers are carried in wooden troughs to the pump room on the other side of the basement

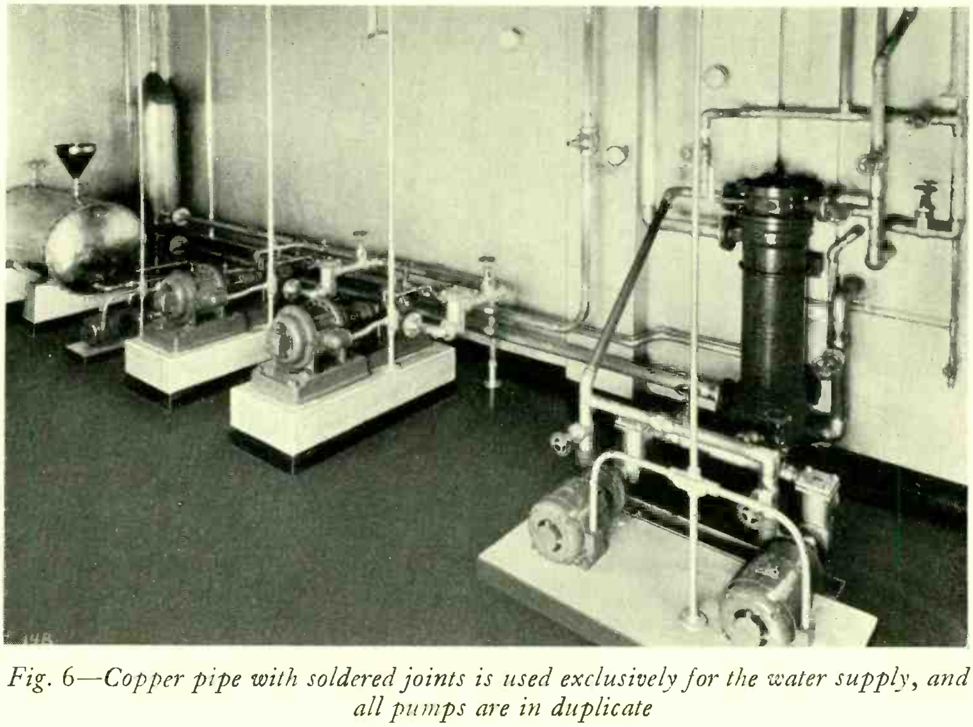


Fig. 6—Copper pipe with soldered joints is used exclusively for the water supply, and all pumps are in duplicate

described, WOR's new station has an emergency studio and office with doors to the speech input room and to the vestibule. This is an acoustically treated room, and programs may be broadcast from it when necessary. On the other side of the vestibule is a kitchenette with electric refrigerator, electric stove, sink, cupboard space, and a table, where the operating staff—on duty 24 hours a day—may prepare their meals. The vestibule itself has a glass front and the emergency studio and kitchenette on either side have windows, but except for these, the building is windowless. Indirect artificial lighting is supplied throughout the day and night, and warmed and filtered air is supplied through ducts run from the basement. A five-car garage adjoining the rear of the building is heated by exhaust air from the main building.

The brick walls of the building are painted white on the outside and their severe lines, unrelieved by windows or ornament, lend emphasis by contrast to the complexity of the intricate equipment within. In the design of the equipment details, dependability has been stressed and no facility has been omitted that would decrease the hazard of interruptions to service. The long experience of the Western Electric Company in building radio transmitters provides ample assurance of continuous and successful operation.

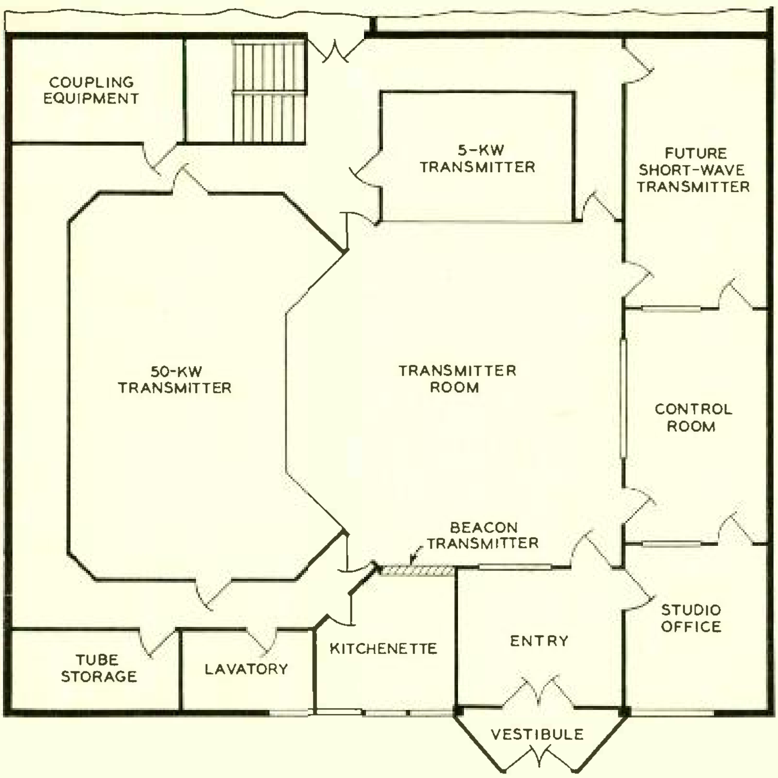
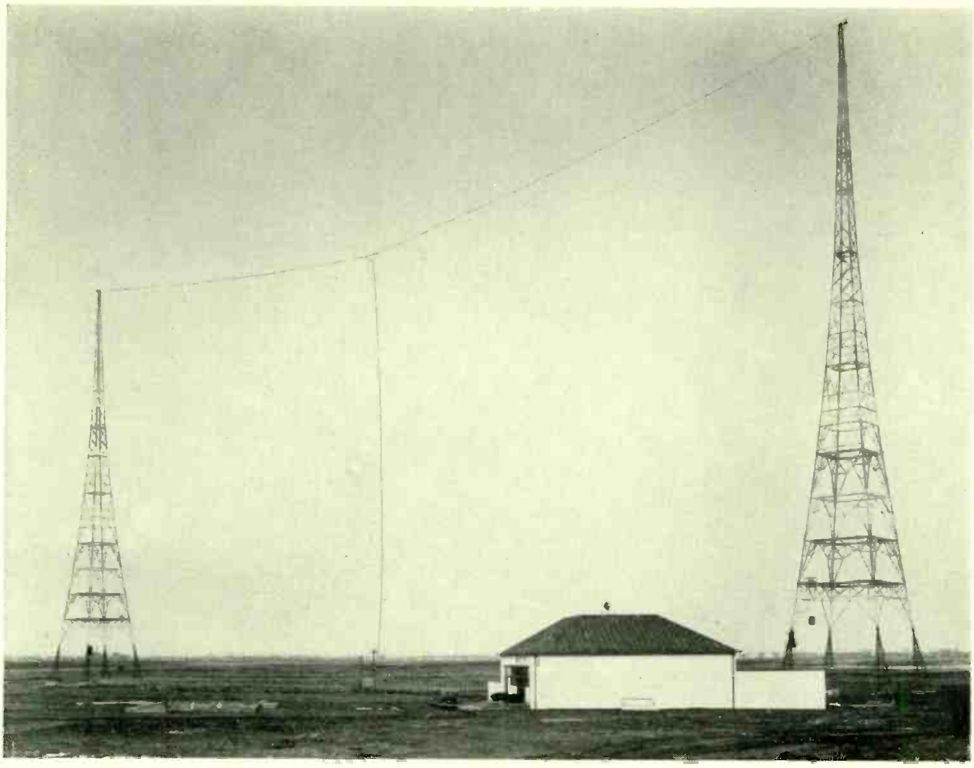


Fig. 7—Floor plan of WOR, Carteret



Controlled Radiation for Broadcasting

By J. F. MORRISON
Radio Development Department

IN the design of radio antennas, the primary objective is to radiate the allotted power in such a way that the greatest effective signal strength reaches the point or areas where reception is desired. For the various transoceanic services of the Bell System this has led to the design of antennas that radiate most of their power in one direction. A variety of antennas of this type have been successfully built and operated. They vary in design to accommodate best the wavelengths of the various systems.

Antennas for broadcasting stations, on the other hand, have usually been designed to radiate equally in all directions. This is desirable when the population to be served surrounds the station uniformly, but with WOR's new 50-kw. Western Electric transmitter at Carteret, N. J., the situation is different. The population it serves has centres of greatest density at Newark and New York, lying in a northwesterly direction from the station, and at Trenton and Philadelphia, lying in a southwesterly direction. To the southeast, only a few miles distant, lies the Atlantic Ocean, while to the northwest lies the sparsely populated mountainous territory of northern Jersey and Pennsylvania.

Bell Laboratories were asked to design an antenna that would have the desirable direction characteristics and meet the limitation on the height of the antenna system required by the proximity of Newark Airport.

It seemed desirable to provide an energy-distribution pattern of hour-glass shape, with its major axis along the line from New York to Philadelphia. The calculated distribution is shown in Figure 1. The curve drawn on this map gives the calculated shape of the field intensity pattern of the antenna array but is not to scale. Good reception depends not only on the field intensity but on the local noise level, which to a large extent is proportional to the population density.

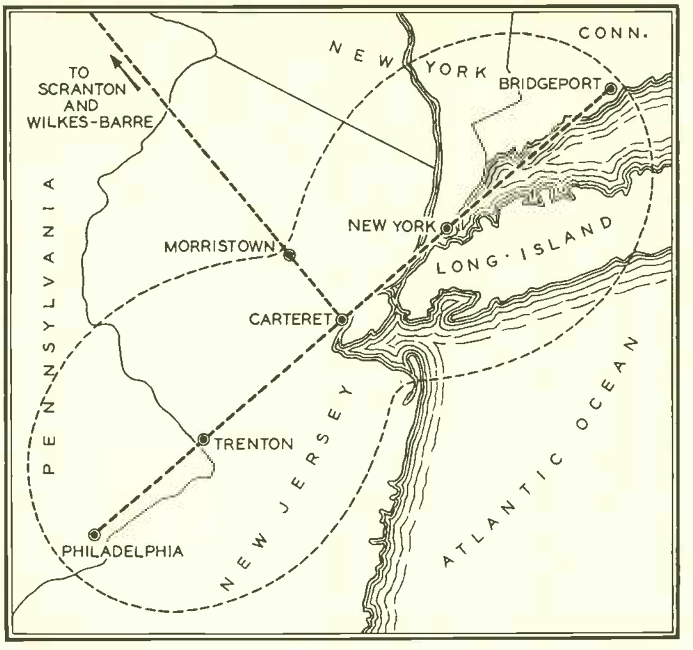


Fig. 1—Main coverage area of the new 50-kw WOR station

The curve shown on the map gives the field intensity pattern along a horizontal plane. The radiation above the horizontal, however, is also of considerable importance. At broadcast frequencies, radiation at high angles is refracted back to the earth during the night, and—depending on its strength relative to the horizontal field—may either extend the service range of the station, or decrease it by causing areas of interference where reception is poor. The best antenna design, therefore, takes into account these effects and minimizes the extent and severity of interference in those areas where possible listeners are most numerous. The sky-wave radiation obtained from the new antenna along the major and minor axes of the ground waves is given in Figures 2 and 3.

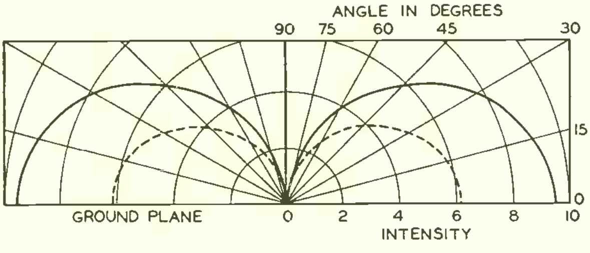


Fig. 2—Radiation from the new antenna in a vertical plane along the major axis of transmission. Dotted curve gives the characteristics of an equivalent non-directional antenna

A comparison of the curves of Figures 1, 2, and 3 shows the suitability of the design in covering the desired area.The intensity of the ground wave in the northeasterly direction is adequate to give good reception in all of greater New York and northeast as far as Bridgeport, while in a southwesterly direction it is adequate as far as Philadelphia. In a southeasterly direction, the comparatively small field strength is sufficient to serve the shore points, only a few miles distant. In a northwesterly direction, a fairly populous suburban area extends about to Morristown. Although the distances relative to the field strength are somewhat greater in this direction than along the major broadcasting axis, the noise level is lower so that adequate coverage can be obtained with lower signal strength. Because of the lower noise level, six millivolts of signal strength in Morristown may be as effective as thirty-five or more in some parts of New York City.

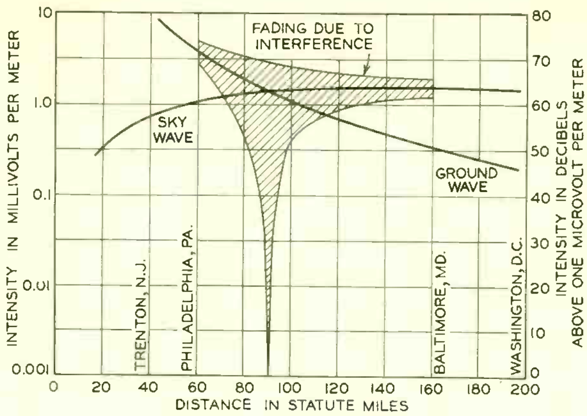


Fig. 4—Ground and sky waves along the major axis of transmission. This area of interference is indicated approximately in position and magnitude by the shaded area

The effects of the sky wave, along and across the major axis of the ground wave, and its interaction with the ground wave, are indicated by Figures 4 and 5. Southwesterly the sky wave has no appreciable effect

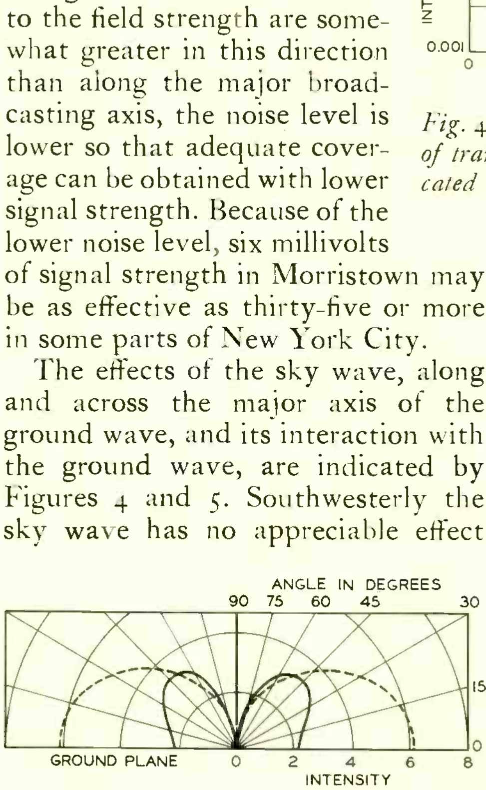


Fig. 3—Vertical plane radiation in a direction at right angles to the major axis. Dotted curve gives the characteristics of an equivalent non-directional antenna

until just beyond Philadelphia, while at Baltimore and Washington it is sufficiently greater than the ground wave to dominate the reception. The area of interference lies between Philadelphia and Baltimore, reaching its maximum some forty miles beyond Philadelphia, as indicated by the greatest height of the cross-hatched area of the curve. These distances are not fixed but vary appreciably with changes in the height of the ionosphere, but the average conditions are as shown.

In the northwesterly direction, Figure 5, the area of greatest interference between ground and sky wave is made to fall in the mountainous districts of north Jersey and Pennsylvania. At Scranton and Wilkes-Barre the sky wave predominates, and good nighttime reception will be obtained.

Such a distribution pattern is obtained by an array of three vertical antennas with their plane in the direction of minimum radiation. Each antenna radiates uniformly in all directions, giving a wave pattern as indicated in Figure 6. The radiation from the three antennas is alike in magnitude and phase, so that at right angles to the plane of the array the three waves reinforce each other, while along the array they tend to cancel out because of the relationship between the wavelength of the signal and the spacing of the antennas. The use of three rather than two or some

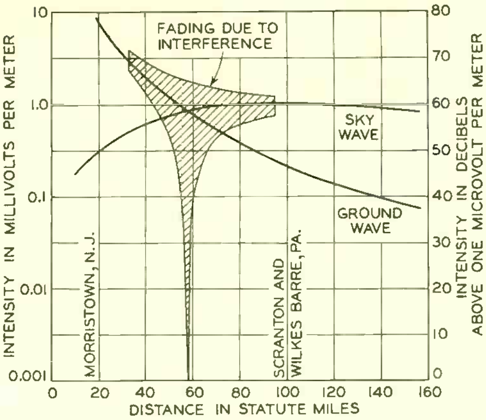


Fig. 5—Ground and sky waves at right angles to major axis, and their area of interference

larger number of antennas was decided upon only after considering the distribution pattern of both sky and ground waves and the relative costs of various combinations—all limited by the requirement of keeping the maximum height under the limiting figure.

The physical arrangement of the antennas is indicated in Figure 7. The antennas at the two ends of the array are 350-foot steel towers manufactured by the Blaw-Knox Company of Pittsburgh, and spaced 790 feet apart. The center antenna is a copper cable suspended vertically from the middle of a steel cable supported by the two towers. Insulators, spaced about twenty-six feet apart, sectionalize the messenger cable. The end antenna towers are sixty feet square at the base, and each of the four legs is mounted on a single porcelain insulator supported thirty-five feet above the ground by a separate structure. This arrangement reduces the capacitance between the lower part of the tower and the ground, and results in a more desirable distribution of current along the vertical elements.

A ground grid is formed by No. 8 bare copper wires, each 600 feet long, spaced about every three feet and buried at the depth of a plow furrow. These wires are laid at right angles to, and centered on, the axis of the array. Wires of the same size and buried in a similar manner on 6-degree radii extend 300 feet outward from the end antennas. Nearly forty miles of wire is used in this ground system.

The antenna is connected to the transmitter, several hundred feet away, by a concentric-tube transmission line. While comparatively new in connection with broadcast transmitters, the concentric conductor offers certain advantages over the more commonly used balanced open-wire line. This is particularly true of the WOR installation where radiation from the more usual form of line might distort the directional characteristics of the array. Both inner and outer conductors are of copper tubing, the latter being 2⅝ inches and the former 0.7 inch in outside diameter. Insulators between the two tubes are

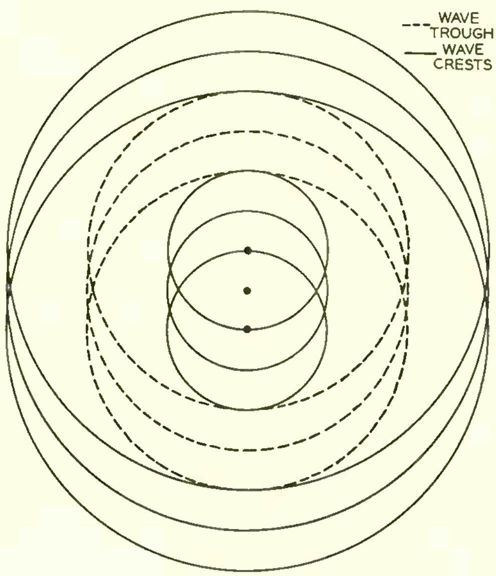


Fig. 6—Wave pattern of three-antenna array

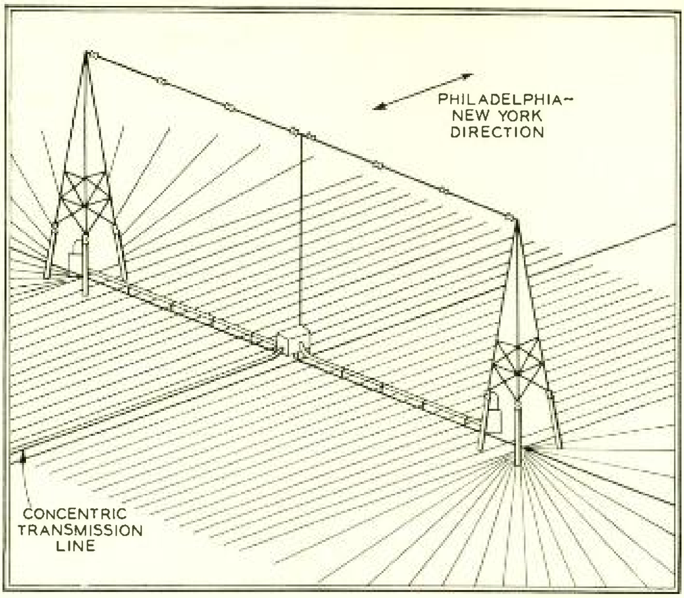


Fig. 7—Perspective diagram of the new WOR antenna array

spaced about thirty inches apart, and support the inner conductor concentrically with the outer. The tubes are hermetically sealed and filled with dry nitrogen at about ten pounds pressure. With the aid of pressure gauges, this gas filling gives warning of any openings which might admit moisture.

To secure the desired directional characteristics of the antenna, the currents in all three—as already noted — must be alike in magnitude and phase. This is made possible by the coupling and phase shifting units shown in the schematic of the antenna feed system, Figure 8. There is first a transmission-line coupling unit connecting the transmitter output circuit to the underground concentric-tube transmission line. The transmission line runs to a large box midway between the two towers and under the central antenna. Here is housed a line-branching and amplitude-adjusting unit, a phase-shifting unit, and an antenna coupling unit for the middle antenna. The line-branching transformer, Figure 9, serves to match the impedances of the three branches of the circuit, and also to provide an adjustment for equalizing the current in each. The phases of the currents in the two end antennas are the same because each passes over the same length of line. The phase-

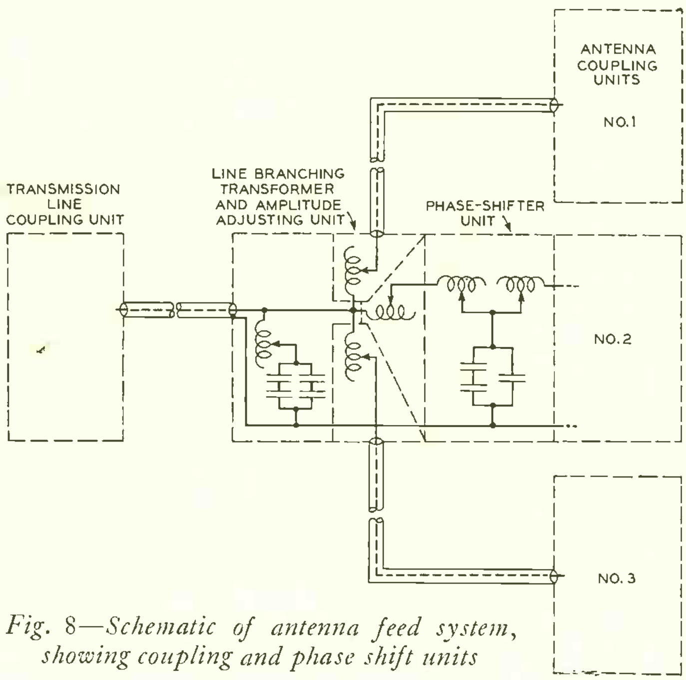


Fig. 8—Schematic of antenna feed system, showing coupling and phase shift units

shifting unit in the central circuit is employed to make the phase of the current in the center antenna the same as that in the other two. Each antenna has its coupling unit, those for the two end antennas being in similar but smaller boxes at each tower.

The new site of WOR at Carteret is twelve miles southwest of the site of their present 5-kw. station. With the increase in power to 50 kw., and the desirable directive characteristics of the new antenna, the apparent power radiated in the minimum direction (NW and SE) will be 20% greater than with the old station, while radiation along the New York and Philadelphia line will be twenty-four times greater. Since by far the greatest number of their listeners lie along this direction, it is obvious that the increase in service to the average listener will be much more than is represented by the tenfold increase in the power of the transmitter.

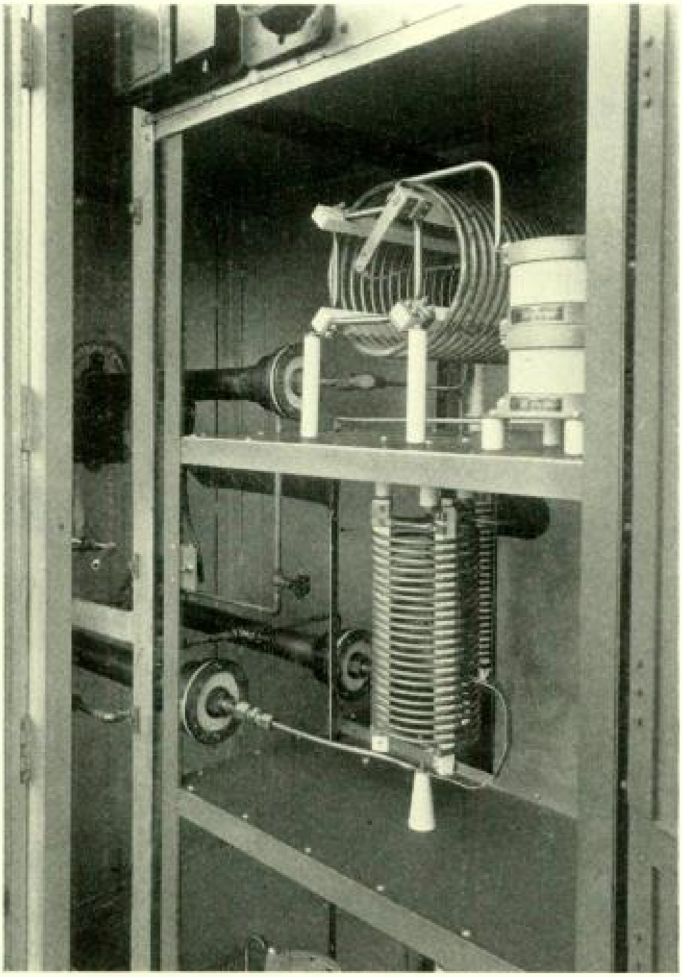


Fig. 9—Line-branching unit showing incoming concentric conductor, above at the left, and the two outgoing concentric conductors, below

Calling by Whistle

By M. L. ALMQUIST
Toll Line Facilities

LINEMEN who maintain open-wire toll lines frequently call the testboard both for instructions regarding troubles to be cleared and to report when troubles have been cleared. They also call in for tests when difficulty is encountered in finding a fault. To make this communication possible, the lineman is equipped with a telephone set mounted in a portable case fitted with a strap so it can be slung over his shoulder. When he wishes to call the testboard, he clips this set to a pair of wires, listens to make sure the circuit is not in use, and then turns a handle on the side of the set, which is geared to a magneto. This method has been in use for years, but changes in systems have brought new requirements for signalling, and if some day you see a lineman sitting on a crossarm and blowing a metal whistle, don't be surprised; he is only using the new method of calling an operator.

Originally all toll circuits employed a low frequency current for ringing, nominally either 16⅔ or 20 cycles, and many circuits still do. For such circuits the lineman's telephone set has a hand-driven magneto, geared so that at usual turning speeds its frequency is of the right order. Low-frequency ringing, however, cannot be used on pairs which carry d-c telegraph in addition to speech. As a result 135-cycle ringing current came into use early in the development of the toll plant. To provide for these circuits, the lineman's set was equipped with an interrupter mounted on the shaft of the magneto which interrupted the output of the magneto at a 135-cycle rate.

More recently, voice-frequency ringing has come into extensive use, particularly on the longer circuits which require telephone repeaters at intermediate points. This method is advantageous in that the signals are amplified by the repeater in the same manner as the speech currents, so that ringers to re-

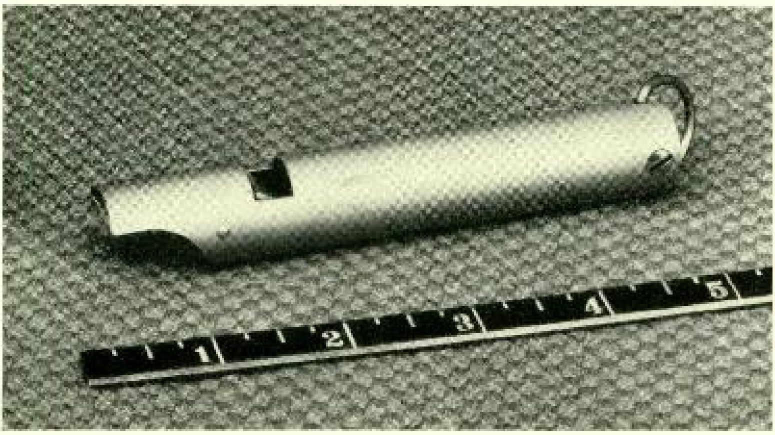


Fig. 1—The lineman's whistle, which gives a thousand-cycle interrupted tone for signalling over toll lines

peat the signals are not required at intermediate points. The voice-frequency systems use 1000-cycle current interrupted nominally twenty times a second. These interruptions, which are accurately timed, provide a type of signal that cannot readily be reproduced by the voice. The ringers, which are particularly discriminating with respect to the frequency of interruption, thus do not operate on the voice currents.

At central offices this thousand-cycle interrupted current is obtained from motor-generator sets equipped with speed regulators to insure the proper frequency of interruption. What to provide for the lineman to enable him to ring over such circuits was a difficult question. Inexpensive equipment of small weight was essential, while accuracy in the rate of interruption is difficult to obtain with hand-driven apparatus. It was known, however, that a sound resembling the thousand-cycle interrupted ringing tone could be obtained vocally by producing a steady tone of about a thousand cycles with the voice, and then trilling the tongue. In fact, with the early type of ringer, which was

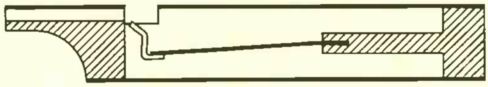


Fig. 2—Cross section of lineman's whistle showing reed that interrupts the thousand-cycle tone twenty times a second

less sharply tuned than the present design, it was possible with a little practice to operate the ringer in this manner. Difficulty in producing and maintaining the exact frequency of interruption required made this method impracticable, but it suggested a very satisfactory solution which was finally embodied in the small whistle shown in Figure 1.

This whistle is of the closed-end type, and of such a length that it produces a thousand-cycle tone when blown. To obtain the interruptions, a reed is mounted within the whistle, so

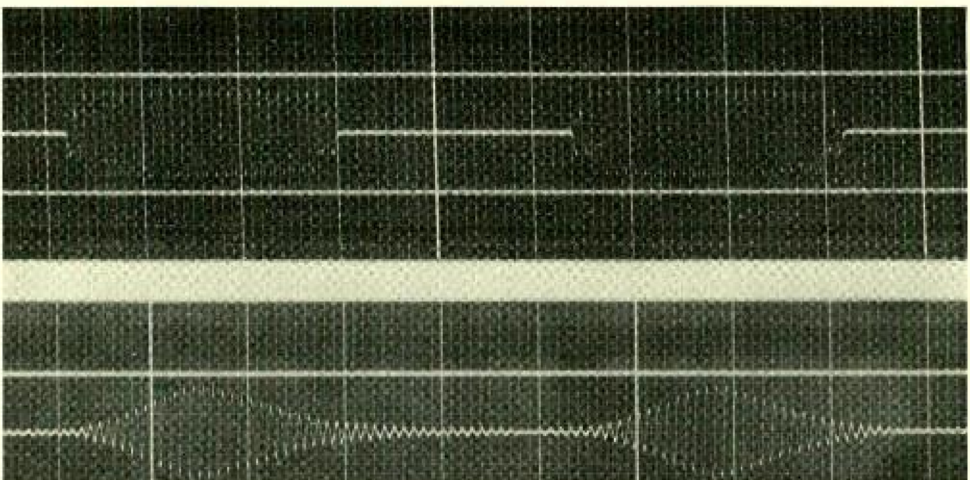
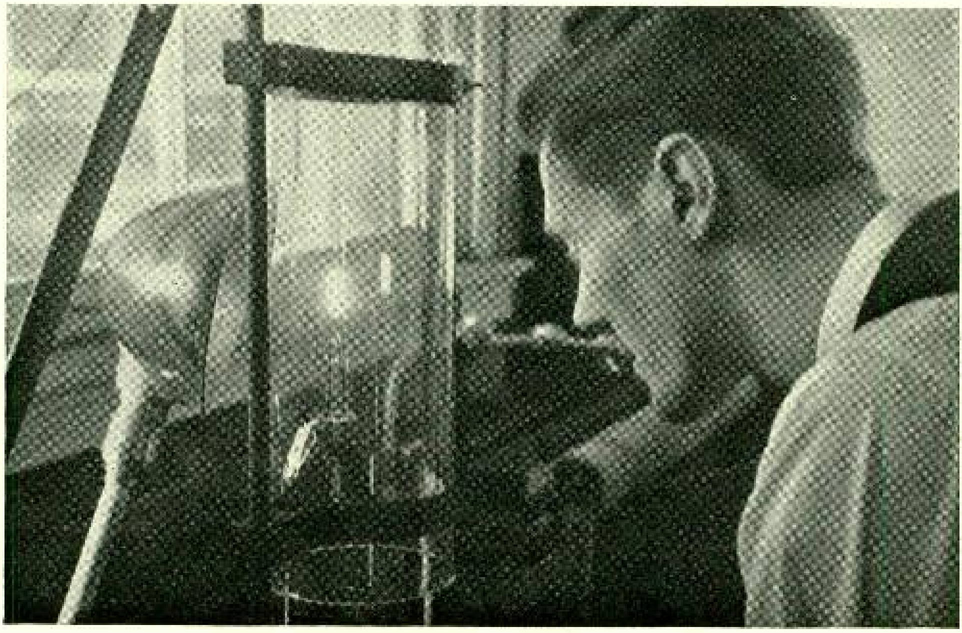


Fig. 3—Oscillogram of interrupted 1000-cycle ringing current: from motor-generator set, above; and from whistle, below

arranged that it cuts off the air supply, and thus interrupts the thousand-cycle tone at the required frequency. The arrangement is shown in Figure 2. The small piece on the end of the reed serves both as a weight to secure the proper frequency of vibration, and as a shutter to interrupt the steady flow of air once every cycle.

To ring on a circuit with this whistle, the lineman connects his telephone set to the proper pair of wires, and blows his whistle in front of the transmitter. The sound of the whistle is converted by the transmitter into an electrical current, which passes on to the line and operates the ringer at the end of the circuit. An oscillogram of the current obtained by blowing the whistle in front of a transmitter is shown by the lower part of Figure 3, while an oscillogram of the current from the motor-generator set is shown in the upper part of the illustration. Both waves consist of a thousand-cycle fundamental frequency which varies in amplitude at the required rate. Although the envelopes of the two waves differ somewhat, the differences are not of such a nature as to affect the operation of the ringer.

The whistle, which is three-quarters inch in diameter and four and one-half inches long, is light in weight and may be carried in the lineman's pocket or in a carrying case which may be slipped on the carrying strap of the telephone set. In addition to its use by linemen, it also affords a means for test room attendants at intermediate repeater stations to ring on circuits employing this type of signalling. A number of such stations have no thousand-cycle ringing supply, and for stations of this type the whistle affords a most convenient and inexpensive method of ringing.



Under the keen scrutiny of H. F. Winters a vacuum-tube filament is "flashed" in a hydrogen atmosphere to relieve possible mechanical strains

A High-Voltage Relay

By V. L. RONCI
Vacuum Tube Development

IN airplane radio communication it is desirable to remove the plate voltage from the tubes of the radio transmitter when listening to a ground station or another airplane so as to avoid the possibility of interference from the local carrier. Plate potential for these transmitters, however, is of the order of a thousand volts or more, and it was found early in the development of high power transmitters that none of the standard switches or circuit breakers would meet all the requirements for this class of service. As a result a vacuum type remote controlled switch was developed in these Laboratories. Besides being small and light in weight—two essential requirements for airplane equipment—it will interrupt a half ampere direct current at 1250 volts throughout a long life without the least evidence of arcing or deterioration.

For the ordinary type of high voltage switch, large size is essential to provide a long path of break with ample distance to ground. Such a switch for airplane use would have to be even larger because of the greater tendency for the arc to hold over at the reduced pressures of the higher altitudes. While the tendency to arc increases at pressures slightly below atmospheric, it decreases at higher vacuums, and at very high vacuums arc formation occurs only at extreme voltages. Advantage is taken of this fact in the new switch by breaking the circuit in a high vacuum. In an evacuated tube are mounted a fixed electrode and a moving electrode that slides on two polished rods. The moving electrode has an iron casing, and a coil placed around the vacuum chamber draws the moving element to close the circuit when an auxiliary low-voltage battery circuit is closed through the coil. When the current through the coil is interrupted, a spring opens the contact.

A simplified diagrammatic sketch of the arrangement is shown in Figure 1. It is essential that the moving element be light, and that it slide on its support rods with a minimum of friction. There are three major reasons for this, besides the general requirement that all airplane apparatus should be as light as possible. In the first place the operating current should be very small so as not to place more drain on the battery than necessary. Also the switch must be able to operate satisfactorily in any position, and this requires that the effect of gravity on the sliding element should be small in comparison to the other forces. Finally a large mass in the sliding element would tend to make it sluggish in action—slower both to open and close—and would also necessitate a heavier construction throughout.

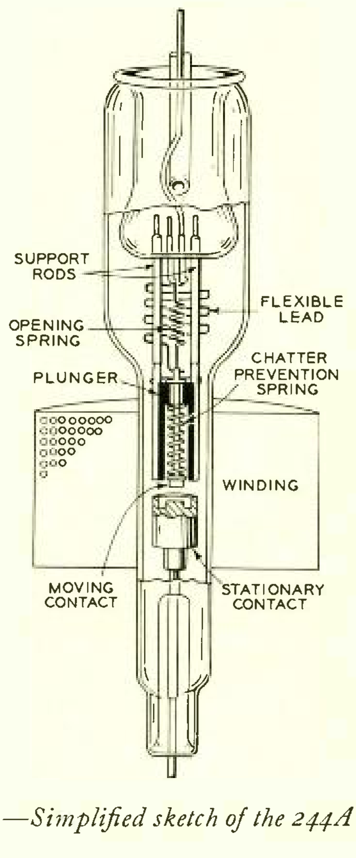


Fig. 1—Simplified sketch of the 244A relay

On the other hand it is desirable to have the moving element large so as to include as much magnetic flux as possible. To reconcile these conflicting requirements of large size and light weight, the moving element is made in the form of a hollow cylinder with the contact fastened to a rod running through the center. This gives a relatively large shell for gathering the magnetic flux and utilizes the space at the center for the contact rod and a chatter-preventing spring. The effectiveness of the magnetic pull was further enhanced by a design which brought the moving element as close as possible to the inner surface of the operating coil.

One of the most difficult parts of the design was to minimize the sliding friction and to insure that it would remain constant during the life of the switch. It is impracticable to use any lubricant, because even if it were applied during manufacture, there would be no way of renewing it during the life of the switch. The problem was satisfactorily solved by using dissimilar hard metals for the sliding surfaces, and by making them very smooth. Since the sliding element is iron, which is comparatively soft, it was given a thin plating of chromium to provide the desired surface, and the two rods on which it slides were made of polished molybdenum. Since low friction at rest is desirable, the area of sliding contact was lowered to a minimum by using cylindrical supports for the moving element to slide on.

Another difficulty of design was the avoidance of chattering at the contact. If the moving element were a single piece, it would tend to rebound after striking the fixed contact, and

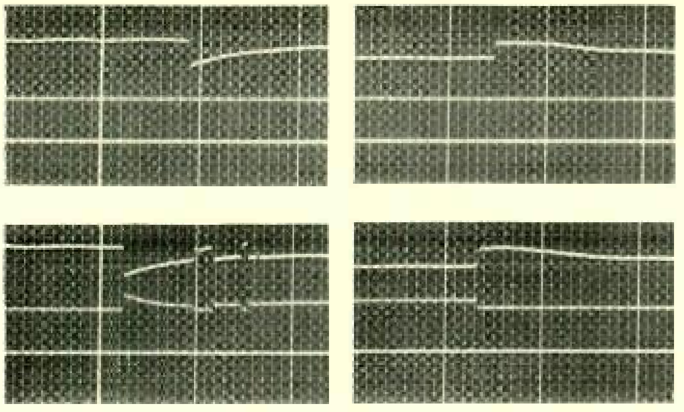


Fig. 2—Oscillograms showing voltage across contacts when the switch is operated. Below: switch without suitable anti-chattering device; Above: switch as finally designed

would perhaps open and close the circuit several times before equilibrium was obtained. This is avoided by making the moving contact a separate member free to slide within the moving element. A small spring, surrounding the contact rod within the iron plunger, holds the tip of the contact rod a short distance beyond the front of the plunger. When the control magnet is energized, the entire moving element is drawn over, but the central rod hits the stationary contact and compresses the chatter-preventing spring, which prevents the contact from rebounding. Should the plunger itself strike the fixed contact, it may rebound somewhat, but the force of the chatter-preventing spring will hold the contact rod against the fixed contact in spite of the vibrating motion of the plunger. The effectiveness of the arrangement is shown by the two oscillograms of Figure 2. The lower shows a contact being made when adequate provisions have not been made to avoid chattering. It is evident here that the contact opened three times before finally remaining closed. The upper oscillogram shows the operation of the actual switch where the contact closes rapidly and remains closed.

The electrical connection from the moving contact is carried through a flat current lead, which like the opening spring acts as a resilient member. Another of the design difficulties was in avoiding variations in the combined action of these two members. By an adjustment provided, the opening spring was made to cancel both variations and actuate the switch between very narrow limits.

An enlarged photograph of the moving element and its supporting structure is shown in Figure 3. The cylindrical plunger has V-shaped grooves in which rest the two rods on which it slides. The restoring spring is the coiled spring in the center between

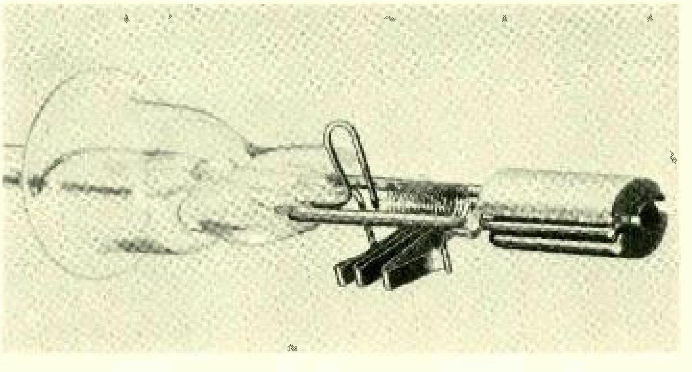


Fig. 3—Moving element of 244A relay with its supporting structure. Magnification 1.5

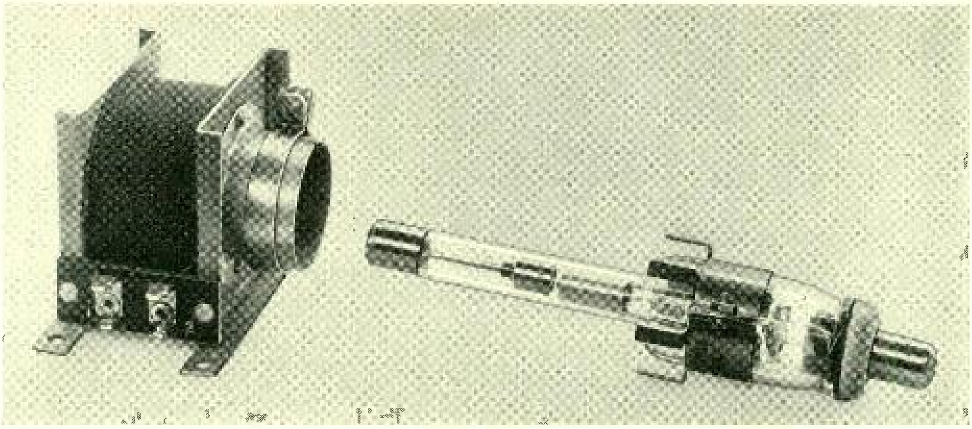
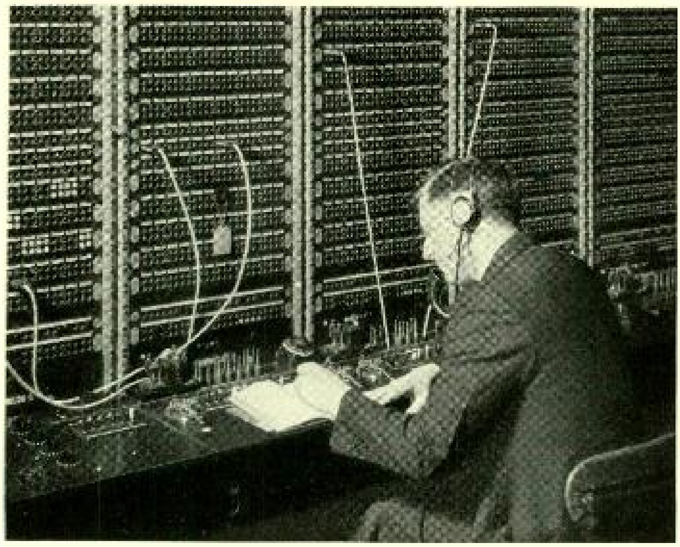


Fig. 4—The switch element of the 244A relay may be removed for replacement

the plunger and the glass support, while the flat ribbon below carries the current to the moving contact.

The operating coil has an indefinite life, while the switch element with its glass casing may have to be replaced. For this reason the complete relay switch is made in two separable parts as shown in Figure 4. The switch element, at the right, may be slid in or out of the operating coil and is fastened to it by the clamping ring. To obtain the maximum possible pull on the plunger, it is necessary that the electrodes should always be in a position relative to the coil where the maximum pull will be obtained. This is insured by securing the metal band on the switch element in such a position that when the switch is inserted in the coil, the plunger will be in the position to give maximum magnetic pull. The completely assembled switch is shown in the photograph at the head of this article.

The effectiveness of the switch in opening high-voltage circuits has shown up well in life tests. At over 7.5 million operations, the switch still passes all requirements, and even seems to have improved somewhat, probably because the slight vaporization of the contacts tends to absorb residual gas, and thus to improve the vacuum. It is felt that the initial application of this switch to radio transmitters is only one of many uses to which such a relay may be adapted.



Primary Toll Test Boards

By L. C. KRAZINSKI
Equipment Development

THE quality of service rendered by a telephone system depends to a large extent on how efficiently both the inside and outside plant are maintained. Maintenance of the outside plant consists essentially of detecting, locating, and repairing troubles in cable or open-wire conductors. Primary test boards are the means provided for quickly locating faults as they occur in the outside toll plant. Their use results in considerable economies by reducing out-of-service periods and by permitting repairs to be made when their cost is slight, since minor faults may be located and corrected before they develop into serious troubles. Primary boards, however, serve not only to facilitate testing operations by determining the nature and location of faults, but also permit the substitution of spare outside plant conductors for those in trouble. This substitution, commonly called patching, is accomplished by the use of cords of the two-conductor type with double-pronged plugs at both ends.

Figure 1 shows a toll line wired through the primary test board at an intermediate toll office. The line is first wired through the protector frame for the purpose of draining off high-voltage surges caused by lightning and power-line disturbances. Protectors are not required, however, where the line is in underground cable.

From this frame the line continues to the test board where it is looped through two pairs of jacks, designated "Line" and "Equipment." These jacks enable the attendant to pick up either the line or equipment for testing or patching purposes. The jacks are mounted in the face of the board as shown in Figure 2, while the testing cords are located in the keyshelf below the jack field. From the equipment jacks the line is cabled to the composite and repeating-coil equipments where telegraph and phantom circuits are derived.

The telephone leads are cabled from the repeating-coil equipment to the telephone repeater. The telegraph leads, however, are wired from the composite equipment to the telegraph line position of the telegraph test board, and from there to a telegraph repeater, or by-pass set. From the repeaters both telephone and telegraph branches of the toll line go, again through duplicate composite and repeating-coil equipment, jacks, and protectors, to the outgoing toll line. Such an office is called a repeater station.

In a terminal office the toll circuit, as shown in Figure 3, can be traced in a similar manner to the circuit of the intermediate office; namely, through protectors, jacks in the primary test board, and repeating coil and composite equipments, where the telephone and telegraph circuits branch off. The telephone circuit in a great number of cases goes through a terminal repeater, and the telegraph circuit passes through a telegraph line position and telegraph repeater. From these points the similarity ceases. The telephone branch proceeds through signaling, patching, and relay equipments, and finally terminates in the toll switchboard and in the test and control board,* while the telegraph

*Record, *July* 1934, *p.* 337.

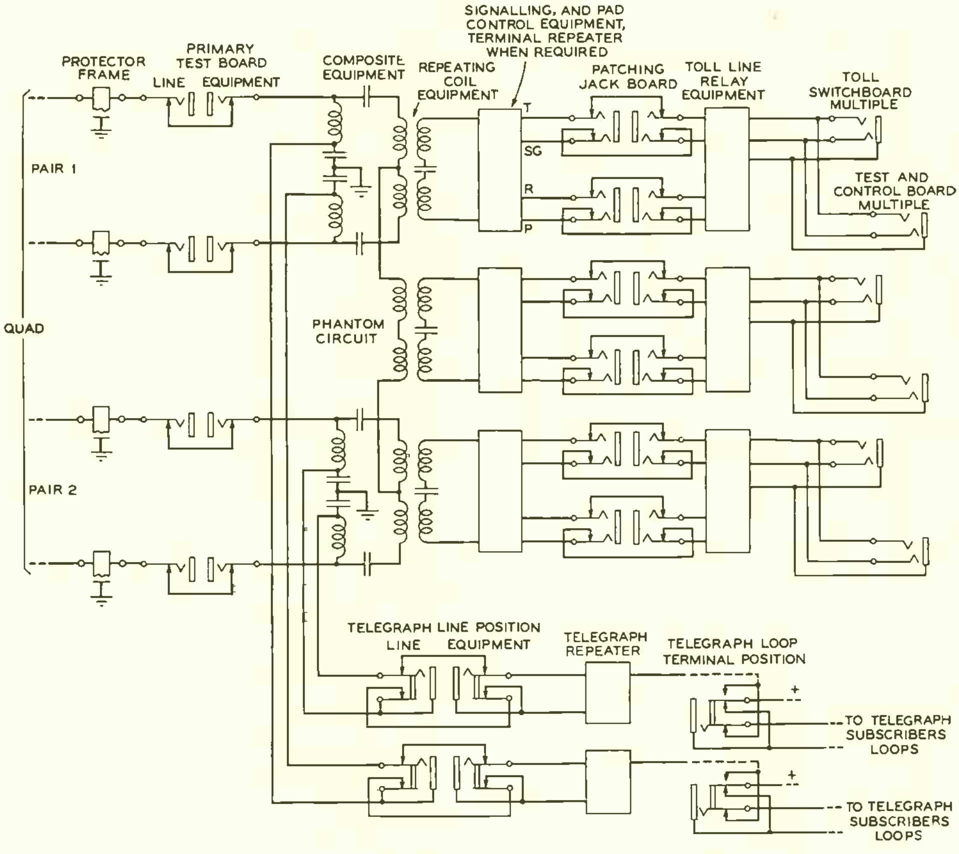


Fig. 1—Simplified schematic of a through line in an intermediate toll office

branch terminates in a telegraph loop terminal position of the telegraph test board.

The testing equipment is located in the lower half of the board, and consists in general of a voltmeter or Wheatstone bridge testing arrangement, as already described in the RECORD*, the testing apparatus being terminated in cords and plugs in the keyshelf to facilitate the testing procedure. The voltmeter testing arrangement is generally used for determining the nature of the trouble on the toll line such as grounds, crosses, opens, and foreign currents, while the Wheatstone bridge is employed for the location of faults; the voltmeter, in other words, is concerned with qualitative tests and the Wheatstone bridge arrangement with quantitative tests.

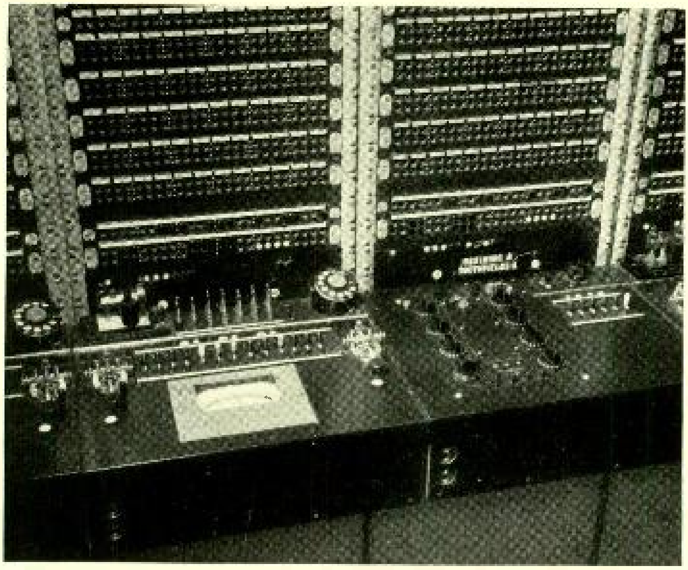


Fig. 2—In the No. 5 toll test board the line and equipment jacks occupy the vertical section and the horizontal shelves carry the testing equipment

When trouble in the outside plant is referred to the primary-test-board attendant, he at once proceeds to determine the nature and location of the fault. For these tests he uses the voltmeter and Wheatstone bridge, respectively. After the fault has been localized, linemen are dispatched to remedy the trouble and report back after the fault has been cleared. Further tests are then made to see that the fault has been removed and the circuit is restored to service. If the trouble is of such nature as to require a long period for making repairs or if the circuit is needed immediately by the Traffic Department, the test board man may "patch" the equipment side of the defective toll circuit to a good pair of outside plant conductors in order to restore service at once.

To facilitate tests with distant stations, telephone or telegraph order wires or both are employed. These order wires† usually join several stations in a district, so that the men in any one station may communicate with men in any of the other connected stations. Talking trunks are also provided for the convenience of the test-board man in reaching the operators at the toll switchboard and other positions.

The general construction of the present toll test board No. 5 is shown in Figure 2. The earlier test board assemblies were of the switchboard type but were superseded by the present board, which is a relay-rack structure conforming closely to the rest of the terminal room equipment. The jacks

*RECORD, *Dec.* 1928, *p.* 161, and *Feb.* 1933, *p.* 163.

†RECORD, *Feb.* 1931, *p.* 283.

are located in the upper unit and the testing equipment in the lower. The lower unit consists of a sheet metal framework upon which a keyshelf is mounted. The cords, keys, lamps, and voltmeter or Wheatstone bridge are mounted on the shelf, and other apparatus such as relays, resistances, etc., are mounted in the rear of the unit. This lower unit framework is also used for other types of test boards such as the non-multiple type test and control board No. 8, telegraph test board No. 9, and telegraph test board No. 15.

In small terminal offices where only a comparatively few toll lines terminate, it is uneconomical to install both a No. 5 toll test board and a test and control board No. 8. Consequently, toll test board No. 16 was developed, which includes the essential testing facilities of the No. 5 and No. 8 boards, except for the transmission testing equipment found in the latter board. The lower unit thus provides both voltmeter and Wheatstone bridge testing apparatus—two separate lower units are usually provided for this purpose in toll test board No. 5—and also the necessary signal-testing equipment. Provision is also made for a limited number of telegraph lines and subscribers' loops where these are few enough to render a separate telegraph test board uneconomical. The voltmeter acts also as a milliammeter and is thus used for

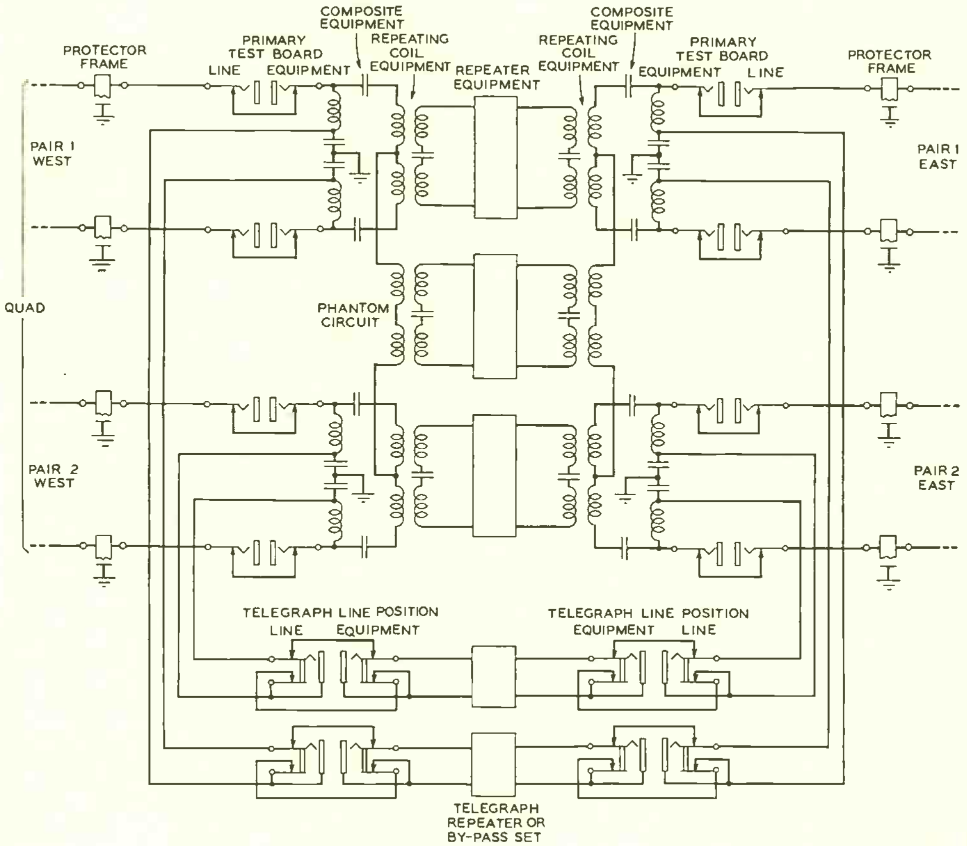


Fig. 3—Simplified schematic of a terminating toll line

measuring telegraph currents in addition to the regular voltmeter determination of line troubles.

Figure 4 shows a complete installation of toll test board No. 16, the overall equipment design of which is similar to that of toll test board No. 5; in fact, the same sheet metal framework is used for its lower unit. If the Wheatstone bridge is not required, it may be omitted and a blank panel substituted for it on the keyshelf. This lower unit may be employed in conjunction with a toll test board No. 5 upper unit where it is desirable to have both voltmeter and Wheatstone bridge testing mounted in the same position or where some telegraph lines go through jacks located in this board. This lower unit is also being used in special cases, as, for instance, in conjunction with the testing equipment for the recently installed short wave radio channels to Honolulu.

With these various facilities provided at toll offices and with an effective intercommunicating system, trouble on toll circuits may be located and removed efficiently. The patching facilities which have been provided make it possible to keep all circuits in practically continuous service and thereby to provide highly satisfactory service in the most economical manner.

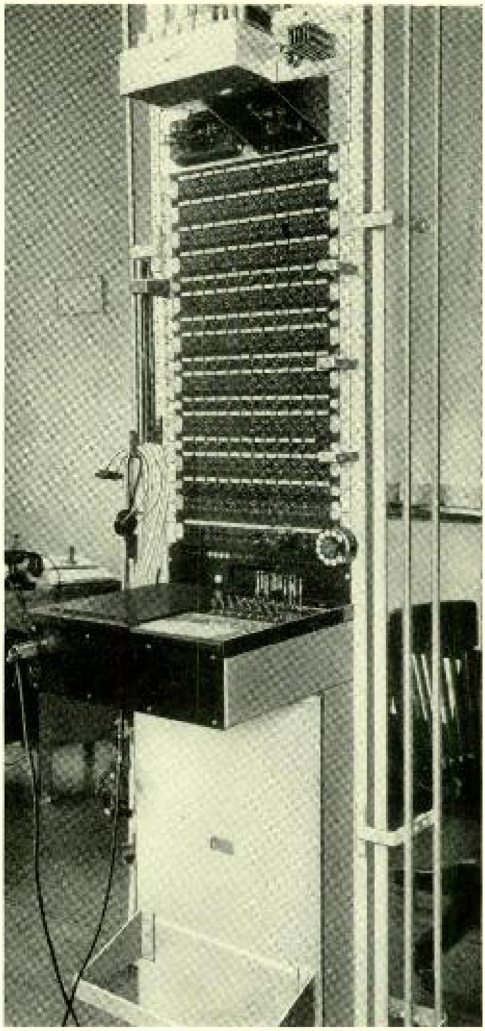
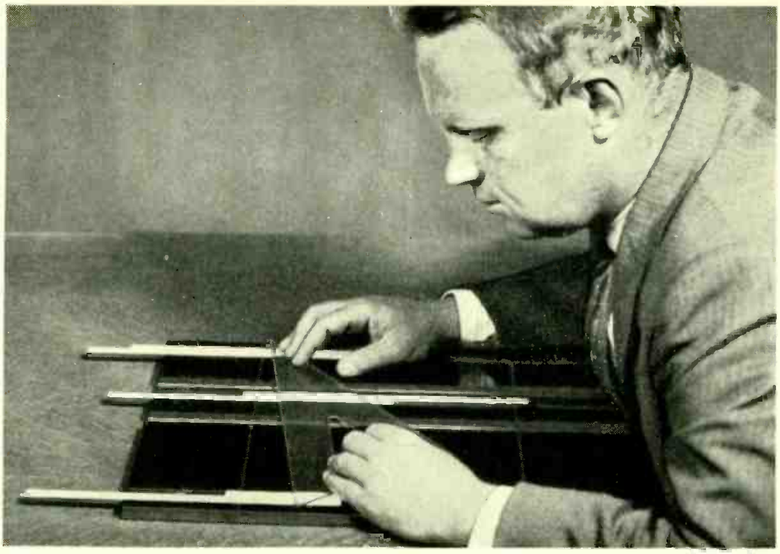


Fig. 4—The No. 16 toll test board provides a combined position for the smaller offices



Universal Alignment Chart

By R. L. PEEK, JR.
Telephone Apparatus Development

THERE is probably no invention more useful for engineering calculations than the ordinary slide rule. Essentially no more than a pair of logarithmic scales of which one is movable, it permits multiplication and division to be carried out with great rapidity and with an accuracy adequate for most engineering purposes. A vast majority of engineering calculations require no more equipment than the slide rule, a pencil, and some paper.

Where it is necessary to apply the same equation to a great many particular cases, however, the need is often felt for some device that will permit more rapid calculation than is possible with the slide rule. In consequence, much use has been made in recent years of nomograms, or alignment charts. An alignment chart is an arrangement of scales such that by setting a straight line to cut these scales, values may be read off which constitute a particular solution to some equation. As an example, an alignment chart could be constructed to solve the equation $P = W/\pi R^2$, which is used to calculate the pressure P corresponding to a given load W on a piston of radius R. Such a chart would have scales for P, W and R, and a straight edge set on particular values of W and R would cut the scale for P at the value corresponding to the given values of W and R. In most cases, alignment charts are superior to the slide rule in the ease and rapidity of their use. They apply, however, only to some particular equation and to a limited range of the variables involved. They are not conveniently used, therefore, except when the problem is a routine one involving equations that must be employed day after day.

As an outgrowth of the work done

in preparing alignment charts for several problems in Bell Telephone Laboratories, a device has been developed which involves a combination of the principles of the slide rule with those of the alignment chart. It retains many of the advantages of the latter while realizing something of the universal application of the slide rule. The device is essentially an alignment chart with movable scales. As shown in Figure 1, it consists of three parallel pairs of sliding scales held in grooves in a flat board. A convenient size for ordinary purposes is that of the model shown in the photograph at the head of this article, which is 14 by 20 inches. The scales are logarithmic and are marked on sliders which may be reversed, so that either the 10-inch scale which appears on one side of the slider, or one of the two scales appearing on the other side, 5-inch and 3.33-inch respectively, may be employed. The two scales denoted U and V fit together in the left-hand groove and two others Y and Z fit together in the right-hand groove. The other two scales W and X can be placed together in any one of the three central grooves. By a suitable choice of scales and of the groove in which the W and X scales are placed, the device can be used to solve any equation of the form:

$$U = V^a W^b X^c Y^d Z^e, \qquad (1)$$

where any of the exponents a, b, c, d, and e can (a few cases excepted) have any integral value from −4 to +4.

Most of the common formulas used in engineering are of the type of Equation 1, or involve at most the summation of a few terms of this form. The equation used to determine the ratio of load W to deflection D of a cantilever spring, for example, is

$$W = 0.25\, D d^3 L^{-3} b E \qquad (2)$$

where b, d, and L are the width, thickness, and length of the spring respectively, and E is Young's modulus. For the solution of this equation, the device is arranged as shown in Figure 1; the variables, W, D, d, L, b and E are then read on the U, V, W, X, Y and Z scales, respectively.

The theory upon which the operation of the device depends is that applying to alignment charts in general. In particular it can be shown that if three parallel scales, as in Figure 2, represent the functions $f_1(x)$, $f_2(y)$, and $f_3(z)$, a straight line will intersect them at values of x, y, and z that constitute a solution of the equation

$$f_1(x) + f_2(y) + f_3(z) = 0 \qquad (3)$$

The functions entering Equation 3 depend not only on the magnitude and character of the scales but also on their relative positions, i.e., the horizontal distance between them and the distances of their origins from the base line oo. By introducing two scales along each line, each logarithmic, it is possible to have each function of Equation 3 represent the product of two functions. With such an arrangement equation 3 becomes

$$\log U = a \log V + b \log W + c \log X + d \log Y + e \log Z$$

This equation is identical with 1 but is expressed in logarithmic form.

Theory further shows that if the ratio (d_1/d_3) of the distances d_1 and d_3 of Figure 2 be designated R, and the unit length of the six scales U to Z inclusive, are designated M_1, M_1', M_2, M_2', M_3, and M_3', Equation 1 will have the form

$$U^{M_1} = V^{M_1'} W^{M_2(R+1)} X^{M_2'(R+1)} Y^{M_3 R} Z^{M_3' R} \qquad (4)$$

The exponents will all be positive providing the U, W, and X scales read upward and the V, Y, and Z scales read downward. This normal condi-

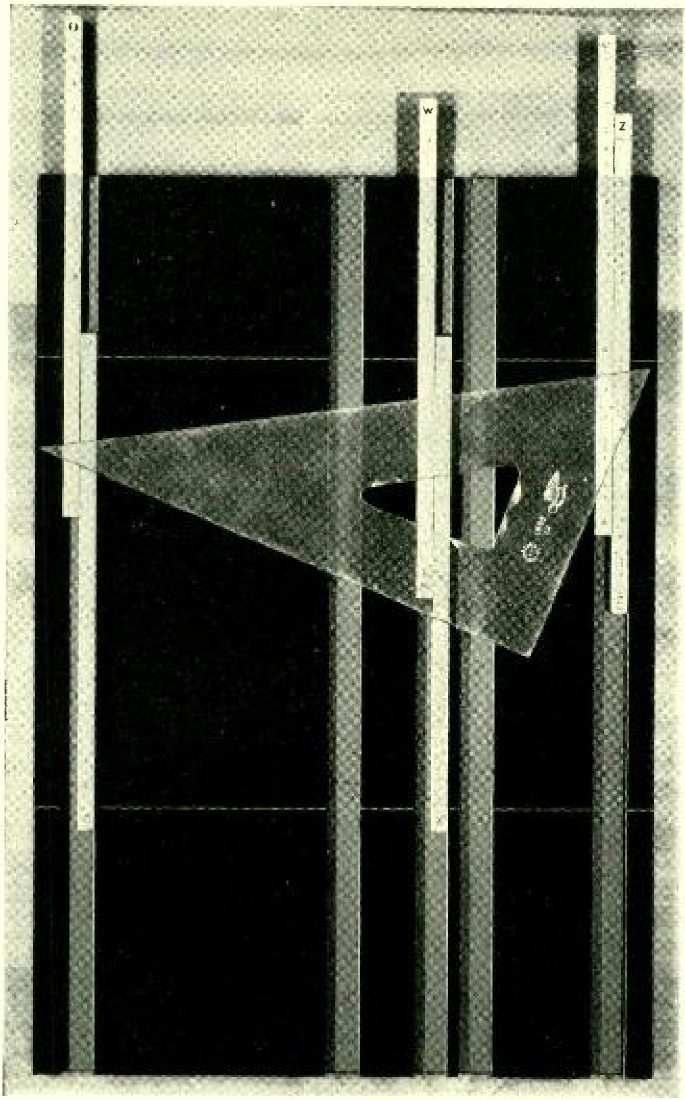


Fig. 1—Setting of the universal alignment chart to solve the equation $W = Dbd^3L^{-3}\ (E/4)$

tion is indicated by placing the figures on the scales so that they will be right side up for positive exponents and upside down for negative exponents.

Since three lengths of scales are provided, 10, 5, and 3.33 inches, the parameters M_1, M_1', M_2, M_2', M_3, and M_3' may take on values of 1, ½, or ⅓, while the three grooves provided for the middle slides permit values for R of 1, 2, or 3. By an appropriate combination of scales and grooves, therefore, a wide variety of exponents for equation 4 may be obtained. A partial list of the equations that may be solved together with an indication of the scales and grooves to be used is shown in Table I. R indicates the groove for the W-X scales: 1 indicating the left-hand groove, 2, the center groove, and 3, the right-hand groove.

To solve an equation, the product of the constants present is considered as one variable, for example Z. With equation 2, Z is taken as E/4. By comparing the exponents of this equation with those of Equation 4 it is found that the correct exponents will be obtained when $M_1 = 1, M_1' = 1, M_2 = 1, M_2' = 1, M_3 = ½, M_3' = ½$ and R = 2 (the eighth equation of Figure 3). In Figure 1, the board is set according to these values with scale X reversed to give the negative exponent. The solution indicated is for D = 0.20 inch, d = 0.025 inch, L = 3.00 inches, b = 0.25, and $E/4 = 4.5 \times 10^6$. The procedure is to set the V, X, and Z scales (D, L, and E/4 in the problem considered) on one or the other of the horizontal base lines. Then the zero

Equation	R	M_1 (u)	M_1' (V)	M_2 (W)	M_2' (X)	M_3 (Y)	M_3' (Z)
$U = V\ WXYZ$	1	1	1	½	½	1	1
$V\ WX^2YZ$	1	1	1	½	1	1	1
$V\ WX^3YZ$	2	1	1	⅓	1	½	½
$W^2V X^4YZ$	1	½	½	½	1	½	½
$V\ W^2X^2YZ$	1	1	1	1	1	1	1
$V\ WX^3YZ^2$	2	1	1	⅓	1	½	1
$V\ W^2X^4YZ$	1	½	½	½	1	½	½
$V\ W^3X^3YZ$	2	1	1	1	1	½	½
$W^2V X^4YZ^3$	3	1	1	½	1	⅓	1
$V\ W^4X^4YZ$	1	½	½	1	1	½	½
$V\ W^2X^2YZ^2$	1	½	½	½	½	½	1
$V\ WX^3Y^2Z^2$	2	1	1	⅓	1	1	1
$V\ W^2X^4YZ^2$	1	½	½	½	1	½	1
$V\ W^3X^3YZ^2$	2	1	1	1	1	½	1
$V\ W^2X^4YZ^3$	3	1	1	½	1	⅓	1
$V\ W^4X^4YZ^2$	1	½	½	1	1	½	1
$W^2V X^3Y^3Z^3$	1	⅓	⅓	⅓	½	1	1
$W^2V X^4Y^3Z^3$	3	1	1	½	1	1	1
$V\ W^4X^4YZ^3$	3	1	1	1	1	⅓	1
$V\ W^2X^2Y^2Z^2$	1	½	½	½	½	1	1
$V\ W^2X^3Y^2Z^2$	2	½	½	⅓	½	½	½
$V\ W^2X^4Y^2Z^2$	1	½	½	½	1	1	1
$V\ W^3X^3Y^2Z^2$	2	1	1	1	1	1	1
$V\ W^2X^3Y^2Z^4$	2	½	½	⅓	½	½	1
$V\ W^4X^4Y^2Z^2$	1	½	½	1	1	1	1
$V\ W^2X^3Y^3Z^3$	1	⅓	⅓	⅓	½	1	1
$V\ W^2X^4Y^3Z^3$	3	1	1	½	1	1	1
$V\ W^2X^3Y^4Z^4$	2	½	½	⅓	½	1	1
$V\ W^3X^3Y^3Z^3$	1	⅓	⅓	½	½	1	1
$V\ W^4X^4Y^3Z^3$	3	1	1	1	1	1	1

1 is written for full scale, ½ for half scale, ⅓ for third scale.

Table I—Equations that may be solved by the Universal Alignment Chart together with the scales and grooves to be used

points of the U, W, and Y scales (W, d, and b in the illustration) are set opposite the given values V, X, and Z respectively. A straight edge laid across the value of 0.25 on the Y scale and 0.025 on the W scale is then found to intersect the U scale at a value of 0.13.

As may be seen from this illustration the device cannot be employed to determine the decimal point, which must be obtained by mental calculation as in common slide rule practice. Because of this, either base line may be used; that being chosen which gives the most convenient setting. The time required to select and arrange the scales for solving a particular equation deprives the device of any advantage over the slide rule in solving single specific problems. When the same calculation is to be used repeatedly, however, it is much more rapid than the slide rule, and all settings may be readily checked at one time. When used for simple multiplication, for example, five variables and their product are set simultaneously, and all settings can be checked at the same time, while with the slide rule only two variables and their product can be thus checked.

When set up for a given formula, the device realizes practically all the advantages of an alignment chart designed for that particular formula. As compared with such charts, however, it has a great advantage in the rapidity of handling six variables in a single index setting—the ordinary alignment chart for more than three variables requiring an additional intermediate scale for each variable over three.

The design described is thought the simplest and best for ordinary engineering use, but it is capable of modi-

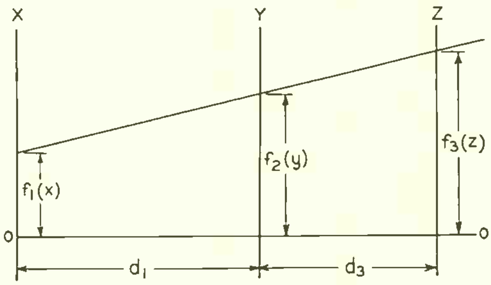
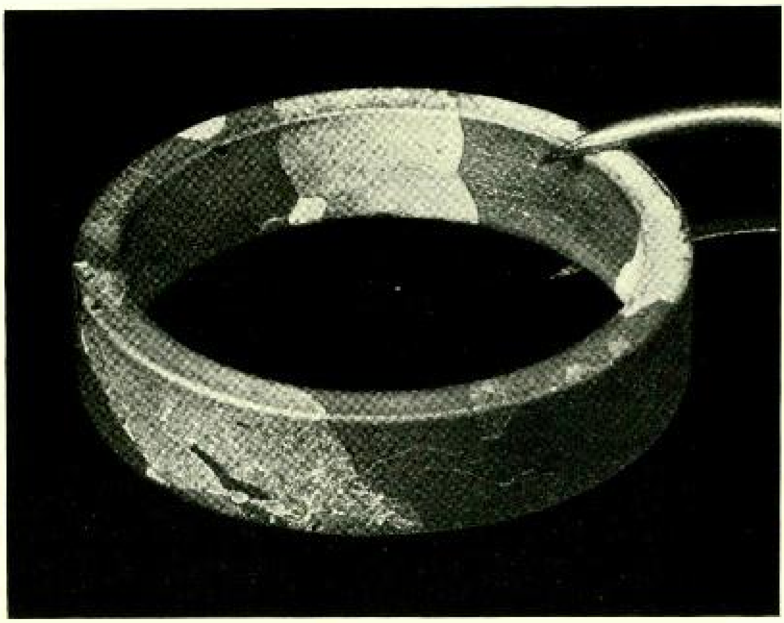


Fig. 2—A straight edge laid across three parallel scales representing $f_1(x)$, $f_2(y)$, and $f_3(z)$ will intersect them at values representing a solution of the equation $f_1(x) + f_2(y) + f_3(z) = 0$

fication to provide solutions for a wide variety of equations. Additional scales, in fact, may be provided which will permit the solution of any equation involving the product of functions of six variables. Trigonometric functions may be cited as an example of those that may be employed. Powers of variables higher than three or four may be introduced by providing additional grooves. Fractional exponents may be introduced by mounting the center pair of scales on rods at right angles to the scales, permitting any value of R to be used at will. The general principle of the device is capable of still further extension. Texts on alignment charts list a wide variety of functional forms which may be represented by alignment charts, and any such chart may be used as a basis for designing calculating devices similar to the one described here.



Hydrogen-Purified Iron

This iron ring, magnified in the photograph about three diameters, shows the large crystal grains characteristically produced by high-temperature treatment in hydrogen. Iron so treated has properties very different from those of ordinary annealed iron: particularly, a high magnetic permeability and low hysteresis loss. It has been suggested that the coarsened crystal structure might account for this change in properties, but evidence accumulated at the Laboratories tends to show that the change is rather the result of the removal of microscopic impurities.

Contributors to This Issue

After receiving the degree of B.S. from the University of California in 1920, Milton L. Almquist spent one year with the General Electric Company at Schenectady and then joined the Department of Development and Research of the American Telephone and Telegraph Company. There he engaged in the development of toll equipment, first with radio systems and later with toll signaling and carrier developments. In 1932 he was placed in charge of a group handling toll maintenance and test board development, which, with the merging of the D. & R. and the Laboratories last spring, became part of the Systems Development Department.

L. C. Krazinski graduated from Lehigh University in 1925, receiving the E.E. degree. Following graduation he spent several months with the Brooklyn Edison Company in connection with the transmission and distribution of power, and continued in this field with the Westchester Lighting Company, where he became District Engineer of the Portchester District. In 1929 he joined the Trial Installation group of these Laboratories, and a year later transferred to the Toll Equipment Development group. Here he has been concerned with the design of Toll and Telegraph Test Boards and Line and Balancing equipment.

V. L. Ronci joined the Engineering Department of the Western Electric Company in 1919 and at once engaged in the development of vacuum tubes. At that time the first water-cooled anode power tubes for transoceanic telephony were in process of development. Mr. Ronci played an important part in the perfection of the experimental models for the transoceanic telephone tests and in the ultimate standardization of these tubes for commercial manufacture. At that time most of the glasswork on large tubes and much of it on smaller tubes was done by highly skilled glassblowers. Mr. Ronci has developed many types of glassworking machines that have made possible the complete construction of all types of standard vacuum tubes with

M. L. Almquist

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J. C. Herber

J. F. Morrison

R. L. Peek, Jr.

glassworking machines. In recent years he has been in immediate charge of the mechanical development and design of all standard vacuum tubes.

J. C. Herber joined the Radio Research Department in 1918 and engaged in studies of static elimination and in miscellaneous research. In September of the following year he left the Laboratories to attend Washington State College, receiving the B.S. degree in 1922. He then joined the Radio Development Department of the Laboratories, where he engaged in transmitter development, working on both the 1 kw. and 5 kw. broadcast transmitters. In 1928 he transferred to the installation group and since then has been installing broadcast transmitters all over the country. Among these are the 50 kw. transmitters at WHAM in Rochester, at WABC, and the just completed one at WOR, Carteret.

After two years at the Electrical Vocational School, Buffalo, N. Y., J. F. Morrison joined the Engineering Department of the Federal Telephone and Telegraph Company in 1923, where he engaged in the development and manufacture of the earlier broadcast receivers and transmitters. In 1926 he left the Federal Company and joined the Long Lines Department of the American Telephone and Telegraph Company. The following year he was engaged as wireless operator by the Radio Corporation of America, and operated on Standard Oil Company ships between New York and South American ports. A year later he left to become Vice-President and Technical Director of the Buffalo Broadcasting Corporation which operated Radio Broadcast stations WKBW, WGR, WMAK and WKEN. In 1929 Mr. Morrison joined the radio development department of these Laboratories. His work in that department has included the supervising of radio broadcast transmitter installations, radio transmission studies, and broadcast antenna design.

R. L. Peek, Jr., is a graduate of Columbia University, having received the A.B. degree in 1921, and that of Met.E. in 1923. He joined the Laboratories in 1924, and was for several years in the Chemical Research Department, engaged in studies in physical chemistry, notably those concerned with the use of special methods of physical testing as guides to development work on new materials. In 1931 he transferred to the Materials Testing division of the Apparatus Development Department, where he is responsible for precision measurements, welding studies, and the development of new methods of physical testing.