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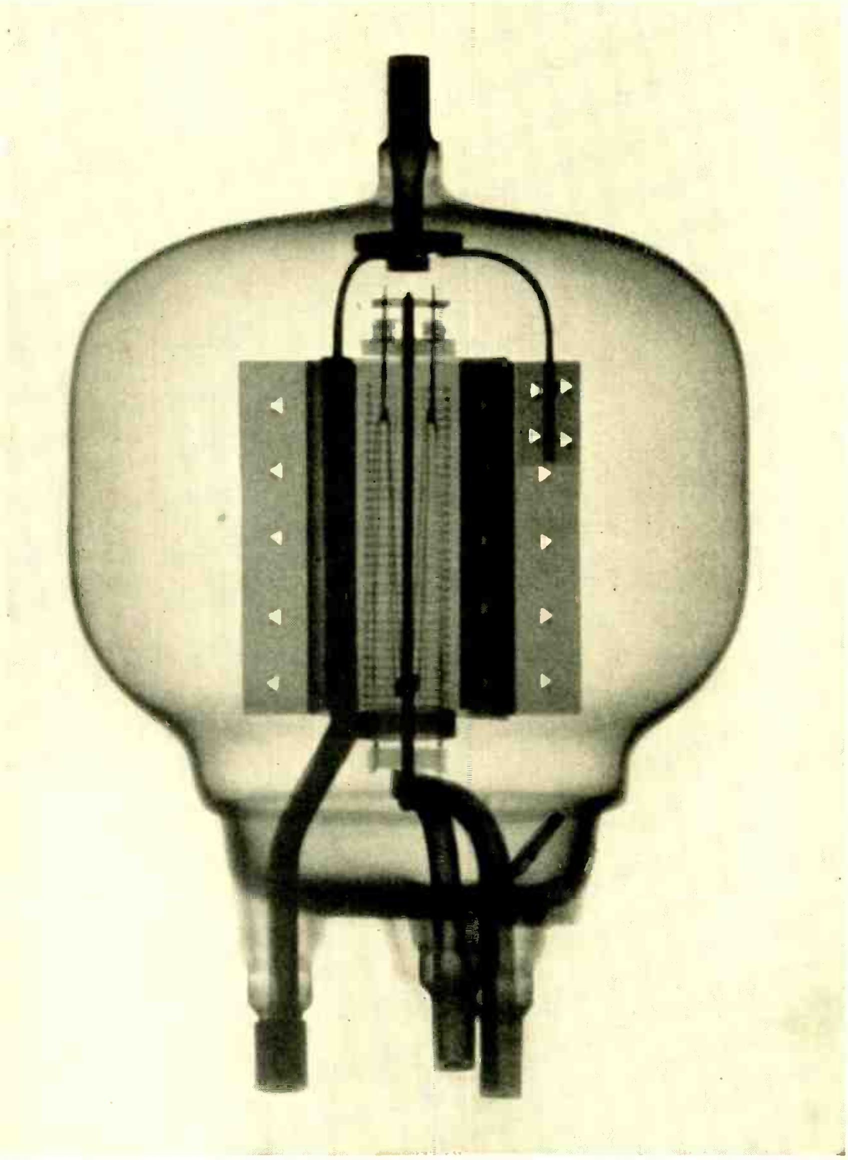
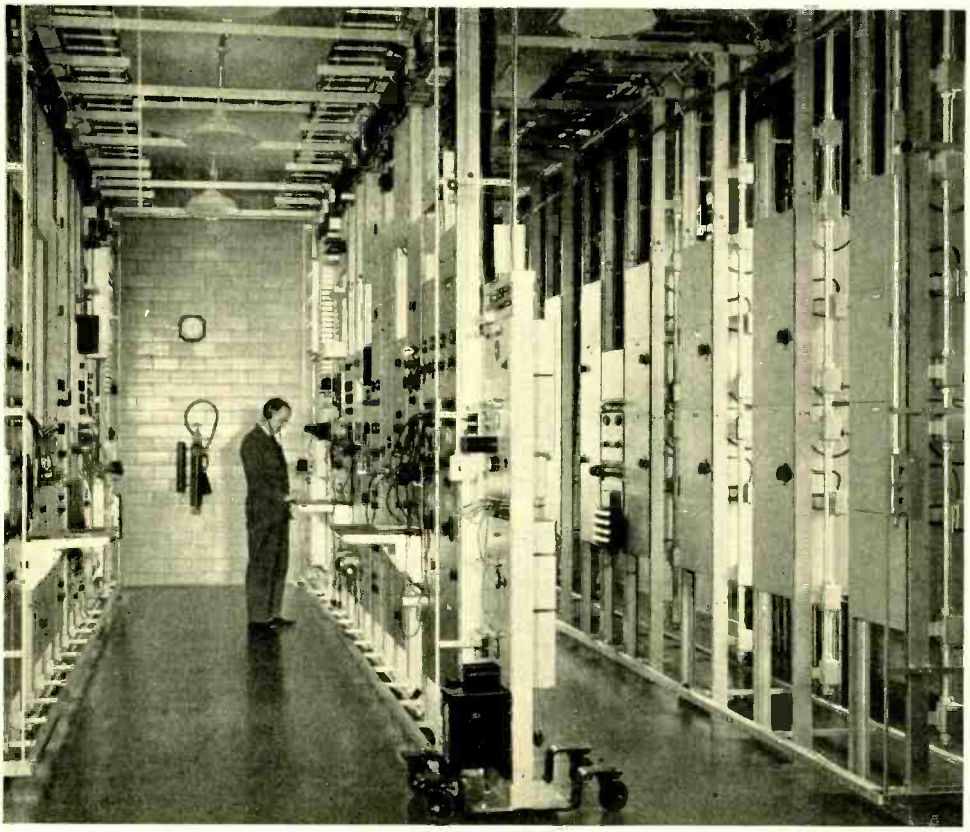


X-Ray photograph of the Western Electric 357A high-frequency power tube



The Manahawkin Musa

By A. A. OSWALD
Radio Development Engineer

IN MAY of 1939 the American Telephone and Telegraph Company began using a multiple-unit steerable antenna system, called a musa, in its London service. It is located at Manahawkin, New Jersey, about forty miles south of Asbury Park. The site is a salt marsh and remarkably flat; the deviations in the general trend of the ground are only of the order of six inches. Flat ground of high conductivity is very favorable to musa reception, and it was largely these characteristics that led to the selection of this particular location.

The musa is a multiple-unit antenna whose vertical angle of reception may be controlled over a considerable range. Its advantages in reducing noise have already been discussed* in connection with the experimental model at Holmdel. From this, however, the commercial musa differs considerably. It employs sixteen rhombic units, each 180 meters long, and occupies a space nearly two miles long in the direction of the great-circle path to Rugby, England. In addition, this installation is designed for auto-

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*Record, *June*, 1938, *p.* 148.

matic operation, and also for single-sideband* reduced-carrier reception.

Two complete receivers are provided, each capable of operating on any one of five frequency assignments. The frequency of either receiver may be changed quickly by switching the input filters ahead of the first detectors, and by changing the frequency of the beating oscillators. Each receiver provides simultaneous reception at three vertical angles independently adjustable. Since the time of transmission will be different over the three paths, delay equalizers are employed, but both the delay and angle adjustments are automatic.

Since the advantages of the musa are secured by combining signals from the sixteen component antennas in correct phase relationship, it is obvious that one of the important features of the design is the accurate control of phases. This problem divides into two parts: first, the precise shifting of the phases to control the direction of reception; and, second, the careful control of all the fixed phase shifts that are introduced by the circuit elements. This is a matter largely of duplicating and maintaining the same phase shift in each of the sixteen circuit elements ahead of the phase shifters, and in each of the four branches of each receiver behind the phase shifters. If extremely close limits were not established for the individual parts, the introduction of replacement units manufactured at some later time would require lengthy and cumbersome "line-up" procedures. In general the deviations are held to ±1 degree at twenty megacycles, although for a few elements ±3 degrees is permitted. From antenna to phase shifters the system includes about fifteen sources of phase shift, and the overall deviation is held to ±10 degrees. Credit is due to the design groups of the Apparatus Development Department for meeting the close requirements set on transformers, filters, and various elements of the delay circuits.

Each antenna is connected to the receiver through a coaxial transmission line. About eight miles less of transmission line was used by placing the receiver building near the middle of the antenna array. This introduced, however, an additional phasing problem. With the receivers at the end of the array, as in the experimental

Fig. 1—The line patching panel is in the middle of the first row of bays, which comprises the input filters and first detectors

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*Record, *November*, 1939, *p.* 84.

ulator circuits sensitive to phase differences, and relays are operated which cause motors to insert the correct amount of delay.

With this type of delay compensation, it is essential to use reconditioned carrier, since the carrier received at each angle must be used at the third detectors to demodulate the sideband received at that angle. If this were not done, the audio phase relations at the branch outputs would be random, and consequently could not be corrected by the delay.

At times, however, the transmission conditions are such that the reconditioned carrier is less satisfactory than carrier from a local source, which is free from noise and constant in amplitude. A second method of operation, known as branch selection, has also been provided at Manahawkin. It employs a local carrier and a system of modulators and relays that compare the speech volumes in the three branches differentially, and then connect the line to the branch that has the highest value at that moment.

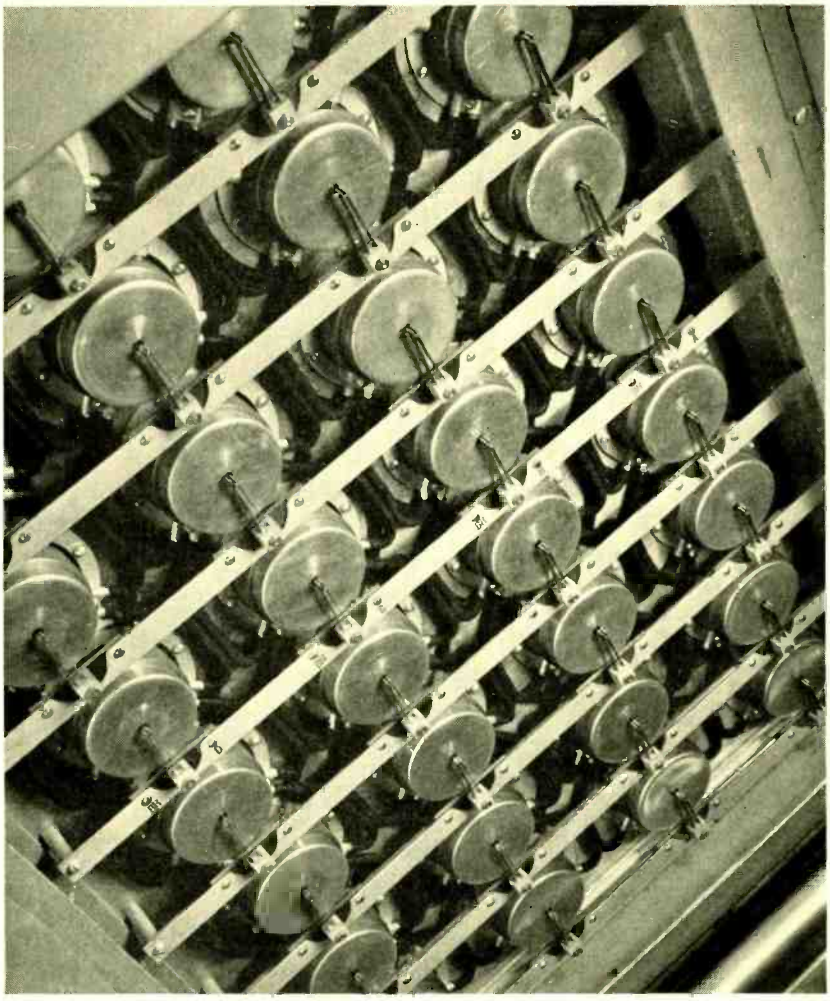
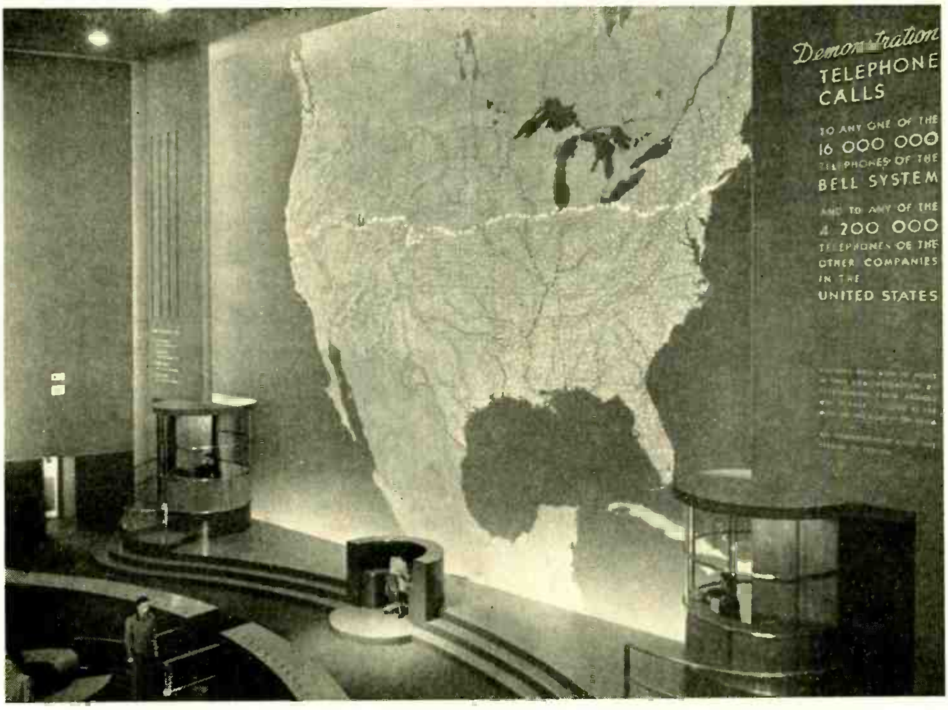


Fig. 4—Bottom group of phase shifters of a musa receiver



Equipment for the Demonstration Toll Call

By L. P. BARTHELD
Special Equipment Engineering

"THE best fun in town is over at the Fair's A. T. & T. Exhibit where, to date, an estimated 100,000 persons have gratified a latent human desire to eavesdrop on the telephone." This comment by Frederick Woltman in the *New York World-Telegram* for May 5, 1939, referred to the Long-Distance Telephone demonstration, which enabled visitors to the Bell System exhibit at the New York World's Fair to listen while others talked by long-distance telephone with friends or relatives any place in the United States. During the call, some 260 other visitors to the exhibit listen—hearing the operator set up the connection and both sides of the conversation. To prevent anything being said that the talkers would not want overheard, the distant talker is notified that it is a demonstration call and that people are listening. At the close of the season it was estimated that a million and a half people had listened to the toll calls, and over 25,000 had talked.

In the demonstration room, on a panel fifty feet high, is a huge map of the United States showing its chief lakes, streams, and mountain ranges. State boundaries are shown, and the positions of 3500 cities and towns are indicated by small glowing switch-brilliancy while the others remain less brilliant on the six-volt supply.

Circuits of this type are provided for the main toll routes leaving New York, for the secondary branch routes leaving the main toll centers, for tertiary routes branching from the secondary routes, and for quaternary routes branching from towns on the tertiary routes. If the call is to a main toll center, like Chicago, the operator, by inserting a plug in the Chicago jack, can bring to full brilliancy all lamps along the route between New York and Chicago. If it were to some city in Wisconsin reached through a branch line from Chicago, a plug is inserted in the Chicago jack and also one in the jack of the town of the proper branch circuit. For a town on a tertiary route, a third plug is used, and for one on a quaternary route, a fourth plug is used.

Fig. 5—Making a transmission test on one of the repeaters used for the demonstration toll call at the New York World's Fair. Three circuits are available: one in use, and two serving as spares. Each circuit has a repeater and a group of associated equipment. In addition there is a bridging amplifier that is used to supply the receivers for the visitors to the exhibit

As the number is given to the toll operator, the listening map operator plugs into the required jacks and operates the key which lights the route. When ringing begins, she operates the key to its "flash" position and these lamps flash eighty times a minute. When the distant subscriber answers, the key is again moved to the "steady" position.

On the back of the map is a lamp box for each state with a stencil carrying the state name, and space for another stencil to carry the town name. When these lamps are lighted, the names shine plainly through the map. Before a call is placed, an attendant in the rear of the map, notified of the town to be called, cuts a stencil for it and inserts it in the proper state box, as shown in Figure 3. Besides the jacks for each town on the map-control switchboard, there is another group with a jack for each state. When the call is placed, the map operator also inserts a plug-ended cord into the proper state jack, and thus lights both state and the city names.

A close-up of the map operator's position is shown in Figure 4. The small sloping panel at the lower left carries the key for lighting and flashing the route lamps, and a number of supervisory lamps to indicate various operating stages and conditions. The jacks immediately above this panel, under the heavy white lines, are for the state names. All the other jacks are for the route lamps.

On the pilaster at the extreme left are four fifteen-foot columns of red lamps. Each column times one step in handling a call. The lowest lamp in a column lights at the beginning of a step and successive lamps each second thereafter. The first column, "Placing the Call," times from the instant the handset is lifted until the toll operator has recorded the call. The second column, "Making the Connection," gives the time required by the operator to reach the operator at the called office, pass the number to her, and for ringing to start. The third times the ringing, and the fourth, obtaining the particular person after the telephone is answered. Only the first two measure telephone service, since the last two intervals depend on the called subscriber.

The time indicators are operated by a chain of ten counting relays under control of a timer giving sixty interruptions per minute and lighting one lamp a second. The tenth relay transfers the control of the ten lighted lamps to a holding relay, and releases the counting relays to count off the next ten seconds. Each indicator has a starting relay, which when operated seizes the counting circuit. Since the four intervals are immediately successive, the circuit is arranged so that operation of the second starting relay stops the first indicator and holds its lamps lighted. Similarly for the third and fourth indicators. The fourth is stopped by the map operator when the particular person called answers. The lights of all four are extinguished when the map operator transfers the outgoing toll circuit from one booth to the other booth.

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ETA KAPPA NU AWARD

Larned A. Meacham, inventor of the bridge-stabilized oscillator circuit described in the picture section of this issue, has just been chosen to receive the 1939 *Eta Kappa Nu Recognition of Outstanding Young Electrical Engineers. The award is made annually by this honorary electrical engineering society to electrical engineers who have been graduated not more than ten years and who are less than thirty-five years old, for "meritorious service in the interests of their fellow men." Mr. Meacham was cited for "his distinguished research in the generation of constant-frequency currents, and his exceptional participation in the cultural life of the community."*

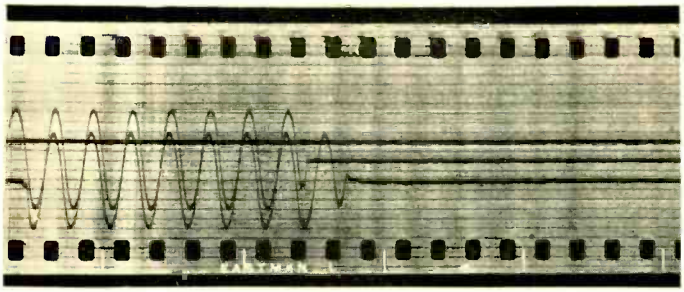


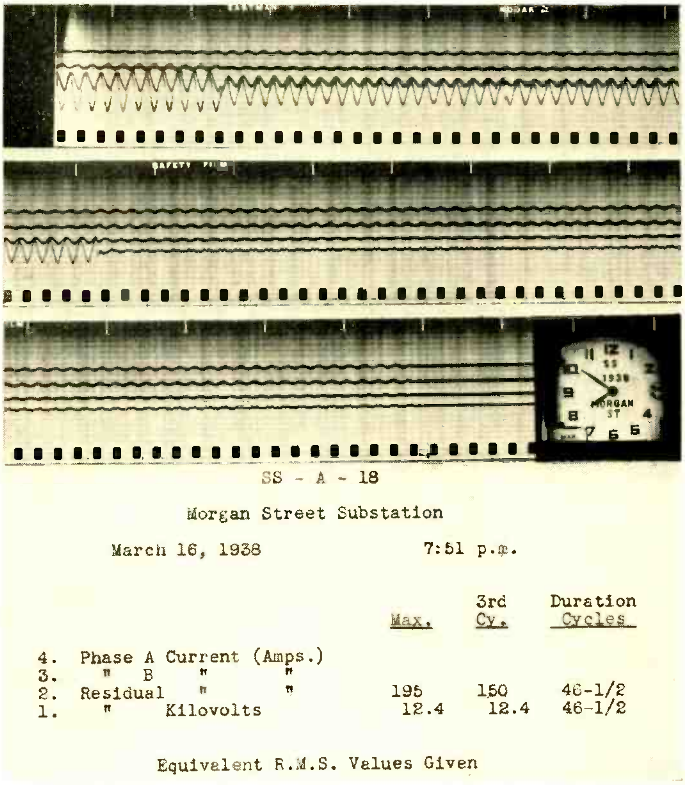
Fig. 2—Typical oscillogram made with the delay network in the circuit of the automatic oscillograph

first operated. After the first few turns of the sprocket, the spring is wound up, and the take-up is driven through it.

The first models of the machine used a reflecting type galvanometer. This instrument is rugged and simple and has a uniform response up to 800 cycles per second, but it is somewhat bulky and does not readily permit more than three or four simultaneous records to be made on the same strip of film.

The string galvanometer* is much more satisfactory in these respects, and it has been used in most of the more recent machines. It lends itself readily to multi-element construction, and as many as six elements have been built into a single field. The frequency characteristic of the string galvanometer is substantially better than that of the reflection type. With either resistance or resonant shunts for damping, its response is uniform up to 3000 cycles, and by use of suitable networks its uniform response can be extended to 10,000 cycles. Since its original application, the string galvanometer has been modified in order to secure greater stability of operation and smaller size and power consumption.

The original system used an exposed clock and a magnetically tripped shutter. As a result the pictures of the clock face varied in intensity due to the difference in illumination between day and night.



SS - A - 18

Morgan Street Substation

March 16, 1938 7:51 p.m.

	Max.	3rd Cy.	Duration Cycles
4. Phase A Current (Amps.)			
3. " B " "			
2. Residual " "	195	150	46-1/2
1. " Kilovolts	12.4	12.4	46-1/2

Equivalent R.M.S. Values Given

Fig. 3—Method of mounting films for study

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*Record, *March*, 1927, *p.* 225; *Aug.*, 1930, *p.* 580; *June*, 1935, *p.* 145.

Moreover the mechanical shutter gave some trouble in the field. In the more recent machines, therefore, a twin-face clock has been used, with one face exposed, where it may be seen and its time checked at any time, and the other face in a light-tight compartment with a lamp and lens system. The lamp is lighted by the sequence switch at the right moment and is held lighted just long enough to give the proper exposure, so that no shutter is needed.

In an automatic oscillograph, quick starting is essential; and it is important, therefore, either to keep the lamp burning continuously, which would be uneconomical, or to reduce the period ordinarily required for the filament to heat up. This has been done, first by using a two-watt flashlight lamp, which requires little heat to raise its temperature to the operating value because of the small size of the filament; second, by keeping the filament at a dull red heat all the time; and third, by using the charging current of a condenser to bring the filament of the lamp up to its operating temperature.

In the early instruments, high-speed polar relays were used to start the oscillograph, and two were required in each input circuit so as to operate regardless of the direction of the initial pulse of current. In the later machines, however, these relays have been replaced by cold-cathode tubes, which are faster, and since they operate on pulses in either direction, one tube replaces two relays. A discharge through any one of the cold cathode tubes will trip a hot-cathode gas tube that starts the oscillograph.

A simplified schematic of the circuit employed is shown in Figure 1. When any one of the cold-cathode tubes operates, the gas tube is tripped, and current from the 135-volt supply passes through the tube, and the relay winding to ground. Current also flows through two branch circuits, one including the clutch, and one the galvanometer lamp. This latter circuit has a feed also from a 24-volt source through a resistance, which supplies current for keeping the lamp at a dull heat during idle periods. The lamp is brought to full brightness by the initial pulse of current through the condenser, which will have more than 100 volts impressed across it. As the circuit approaches the steady-state condition, the condenser ceases to pass current and the resistance maintains the desired voltage across the lamp. When the relay operates, it locks itself in and also closes a contact that starts the sequence switch, which then controls the operation. Only its contacts in the 135-volt and ground leads are indicated on the diagram.

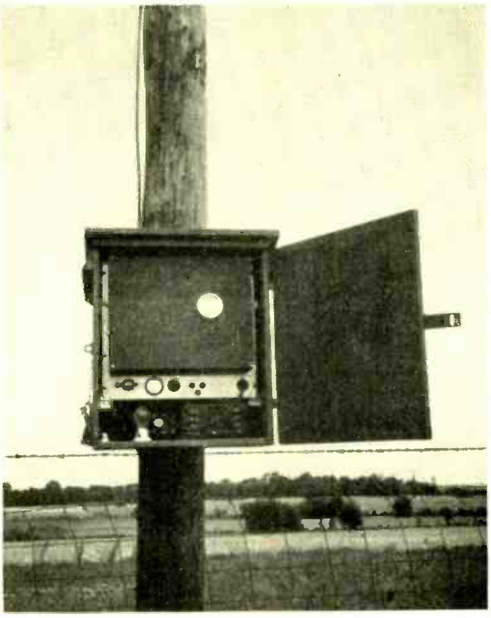


Fig. 4—Field installation of the small automatic recording oscillograph

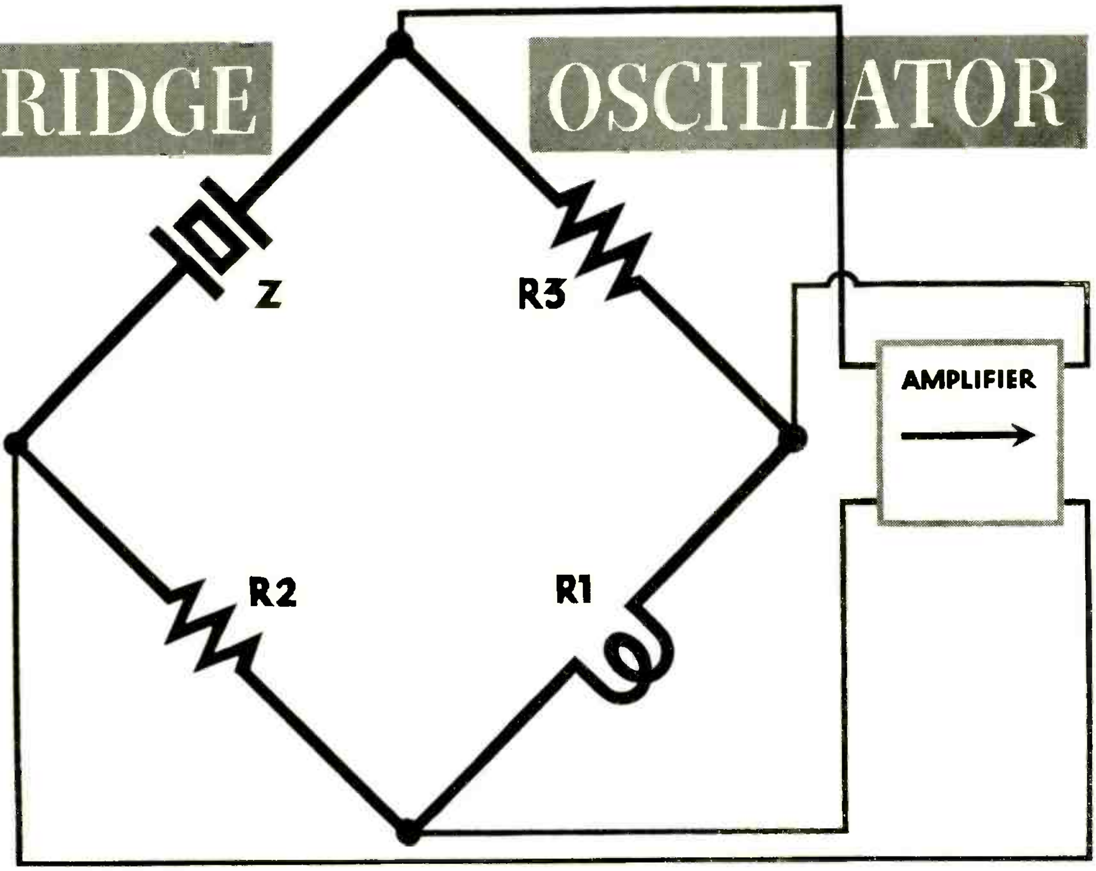
With this circuit, initiation of the record is possible within .01 second after the transient reaches the operating magnitude, and for many studies a delay of .01 second is not objectionable. Since there are cases where the initial portion of the disturbance is important, however, some means were required for recording it. A delay network was therefore designed that provided a delay of .016 second in the range from 25 to 513 cycles. This network, of course, is connected only in the galvanometer circuit—the gas tubes operating on the input circuit without delay. By this means a short section of film is exposed before the disturbance reaches the oscillograph strings, so that the entire disturbance is recorded. An oscillogram taken in this way is given as Figure 2. It shows the record of a sixty-cycle current on two strings—one connected directly to the circuit and one through the delay network. In the latter, a short section of zero disturbance is shown before the disturbance begins. The similarity of the two curves except for their time displacements indicates the very small amount of distortion that has been introduced by the delay circuit.

Another arrangement, which avoids the loss of most of the initial portions of a transient disturbance, has been used in the course of development work. A cathode-ray oscillograph has been constructed in which the starting time is less than ten micro-seconds. This permits the photographing on a film of the disturbance as registered on the cathode-ray screen.

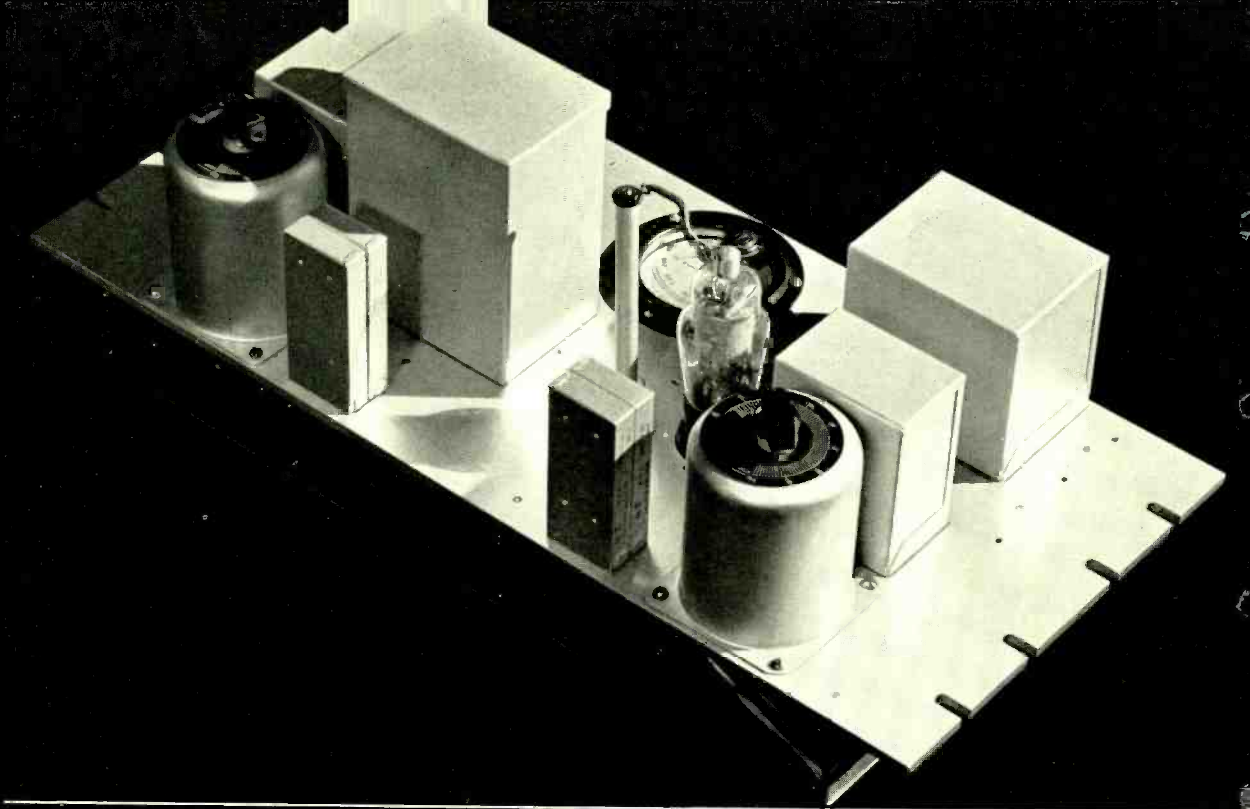
The automatic recording oscillograph has been in use since 1926 in a variety of studies in many locations. Although originally designed for recording disturbances on communication circuits, its use has been extended to power and electric railway lines to study disturbances that may affect adjacent communication circuits. Wherever installed, these types to date have been inspected and calibrated at intervals of from three to six months by a member of the Laboratories staff. In addition there is a routine maintenance, which includes a daily entry in a log, replacement of lamps and film, and forwarding of the log and film to New York for analysis. After the film has been developed, prints are made, and mounted for analysis as shown in Figure 3.

As already noted, these machines were modified from time to time as conditions warranted. More recently a smaller and less expensive form of the oscillograph has been developed for mounting on poles and similar places where space is at a premium. Sixteen-millimeter film and a permanent magnet galvanometer with two elements are employed. Only a single film speed of six inches per minute is provided, but this speed may be changed by a simple gear replacement. This machine occupies a panel space of only fifteen inches, and is installed in a totally enclosing cabinet. A field installation is shown in Figure 4.

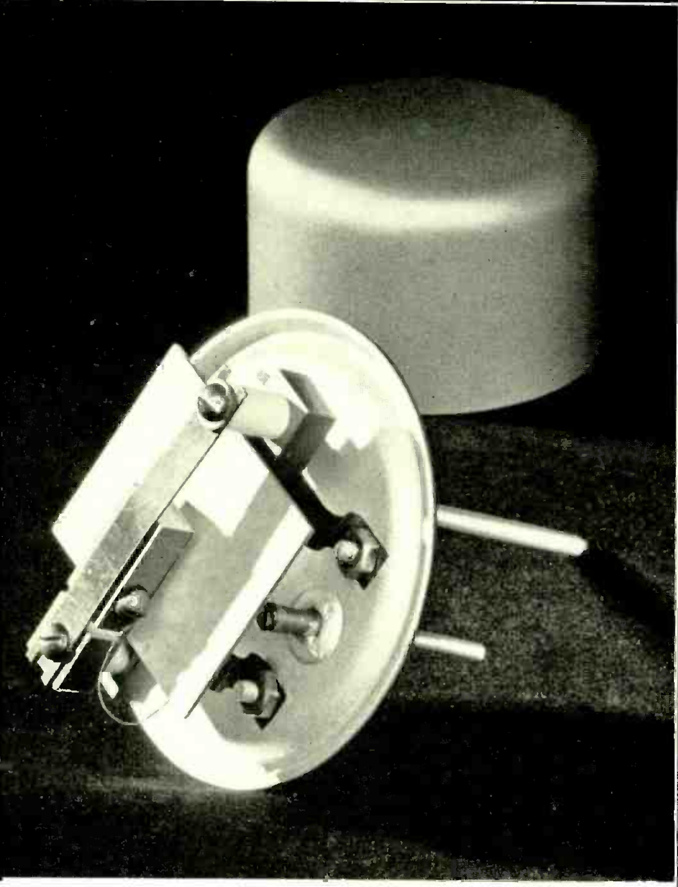
BRIDGE OSCILLATOR



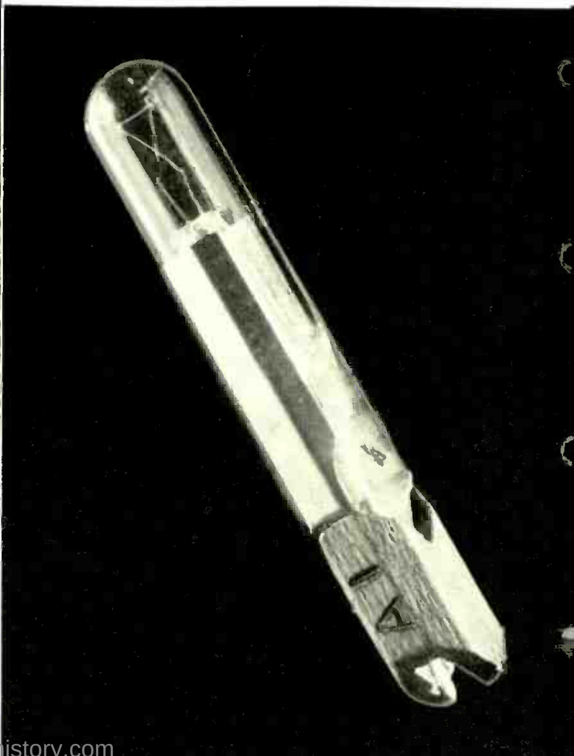
An ideal oscillator would maintain a fixed amplitude and frequency regardless of changes in operating conditions. This ideal is approached by the "Bridge Oscillator" whose circuit is shown above. A stable, high-Q crystal (Z) forming one leg of a Wheatstone bridge is driven by a class A amplifier. Two arms of the bridge are fixed resistances (R2, R3); the fourth (R1) is a lamp whose thermally controlled resistance is designed to keep the bridge out of balance just enough to sustain oscillation. As the temperature of the lamp filament depends upon the amplitude of oscillation, any small change in this amplitude or in the gain of the amplifier is immediately corrected by a slight readjustment of the bridge balance. The frequency is stabilized at the particular value for which the crystal impedance is a pure resistance. This is the only frequency at which the impedance arm of the Wheatstone bridge can approach balance with the three resistive arms.

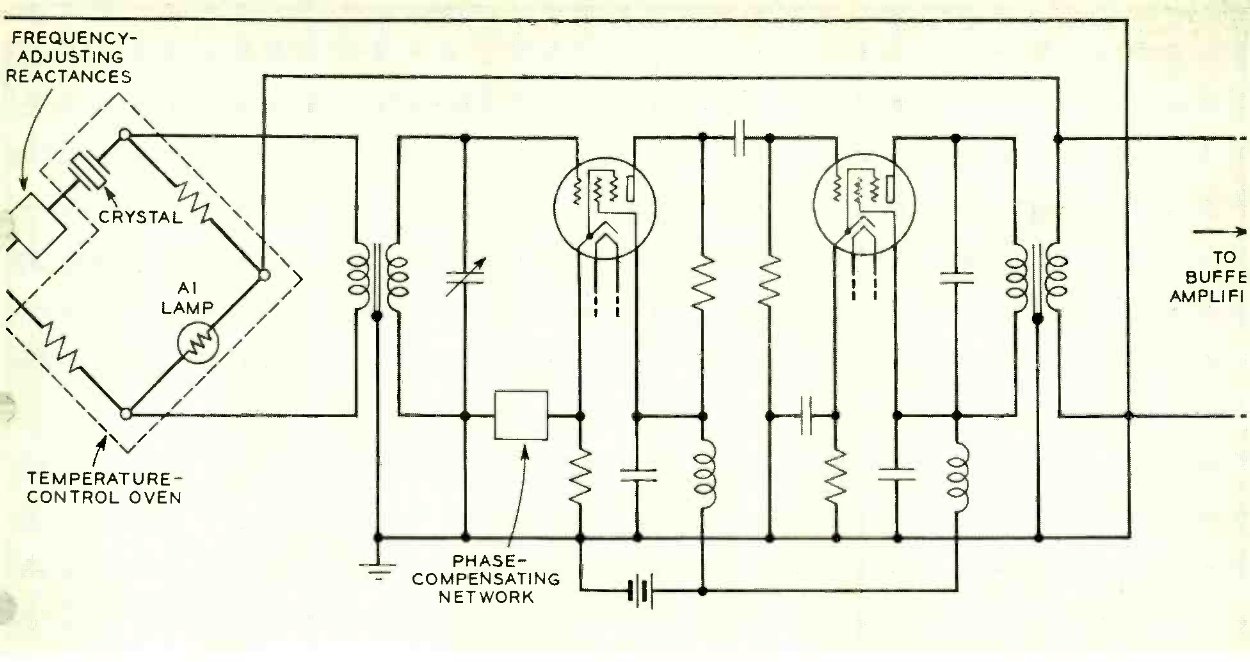


The bridge-stabilized type of oscillator was developed in the Laboratories for applications requiring extreme frequency stability. The experimental model shown above is used for testing 100-kc quartz resonators. It is arranged to be controlled in frequency by any suitable crystal, which is connected to terminals on the oscillator panel.



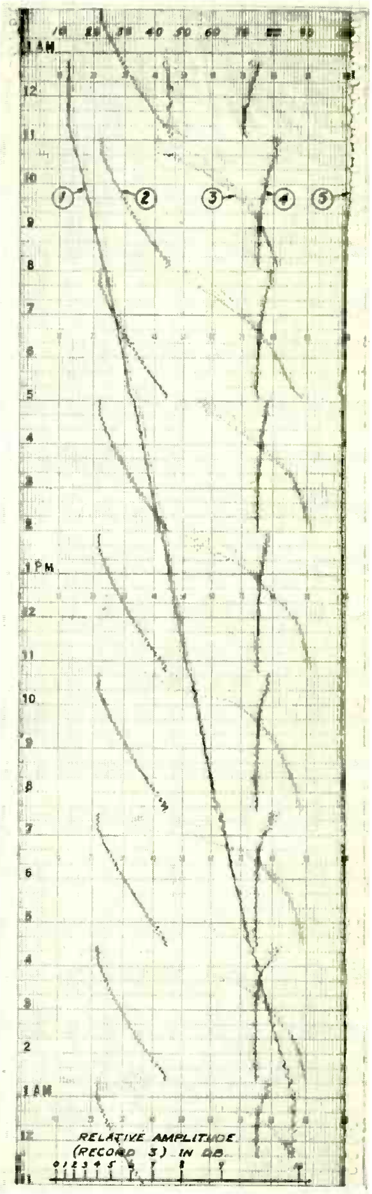
low temperature-coefficient crystal (above) adjusted
r use in a 100-kc bridge oscillator, ready for seal-
g in its vacuum container. The crystal and the
miliar switchboard lamp (right) form two arms of
e stabilizing bridge.



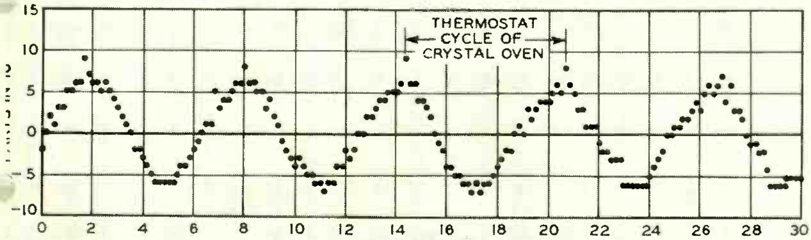


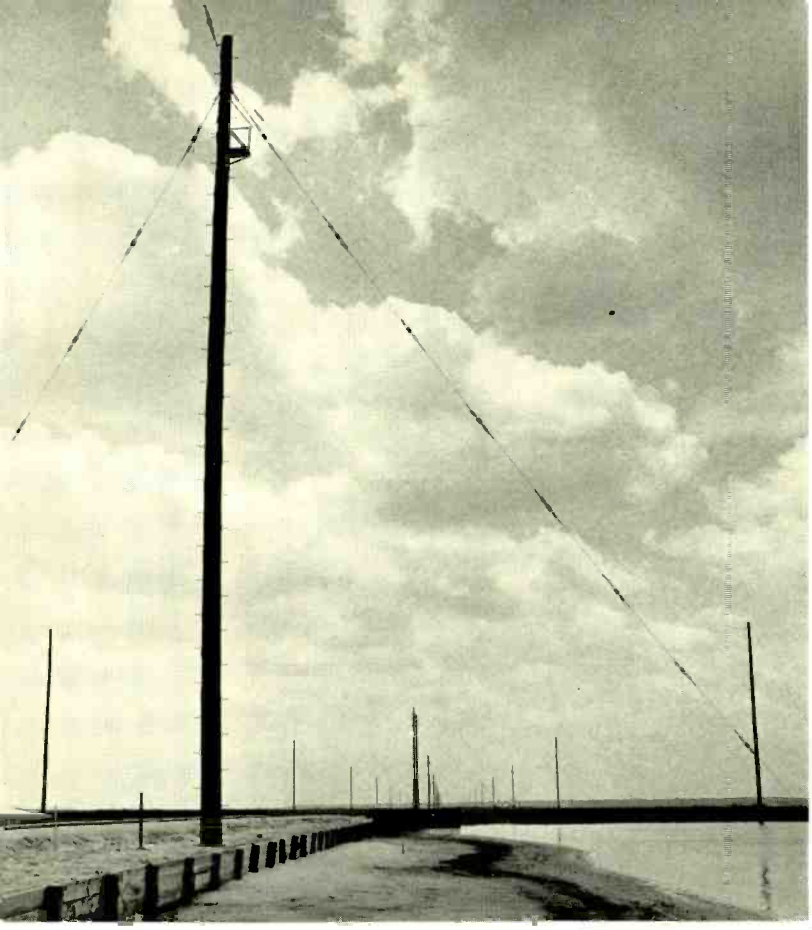
Simplified circuit schematic (above) of the bridge oscillator designed for the Bell System Frequency Standard by L. A. Meacham, who developed this type of oscillator. A two-stage amplifier provides high gain and correspondingly high stability. Variable reactances in series with the crystal afford manual adjustments of frequency over a narrow range. The phase-compensating network indicated in the cathode path of the first tube assists in overcoming any tendency of the circuit to break into undesired oscillation on account of its high gain.

At the right is a record of a laboratory test of the circuit above. (1) "B" supply voltage, varied from 174 to 25 volts by a motor-driven potentiometer. (2) "A" supply voltage, varied repeatedly from 22 to 11 volts (normal is 20 volts). (3) Oscillator output level; calibration is indicated at the bottom of the chart. (4) Oscillator frequency deviation; one division represents one part in 10^8. (5) Check of full-scale calibration of frequency-measuring apparatus.



In studying the short-time variations of these stable generators under their normal operating conditions, special measuring equipment of extremely high sensitivity has been used. By precise timing of consecutive beats between a pair of the oscillators, their stabilities from minute to minute have been determined within one part in 10^{10}. Typical results (below) show swings of ±6 parts in 10^{10}, introduced by the thermostatic controls of the crystal ovens.



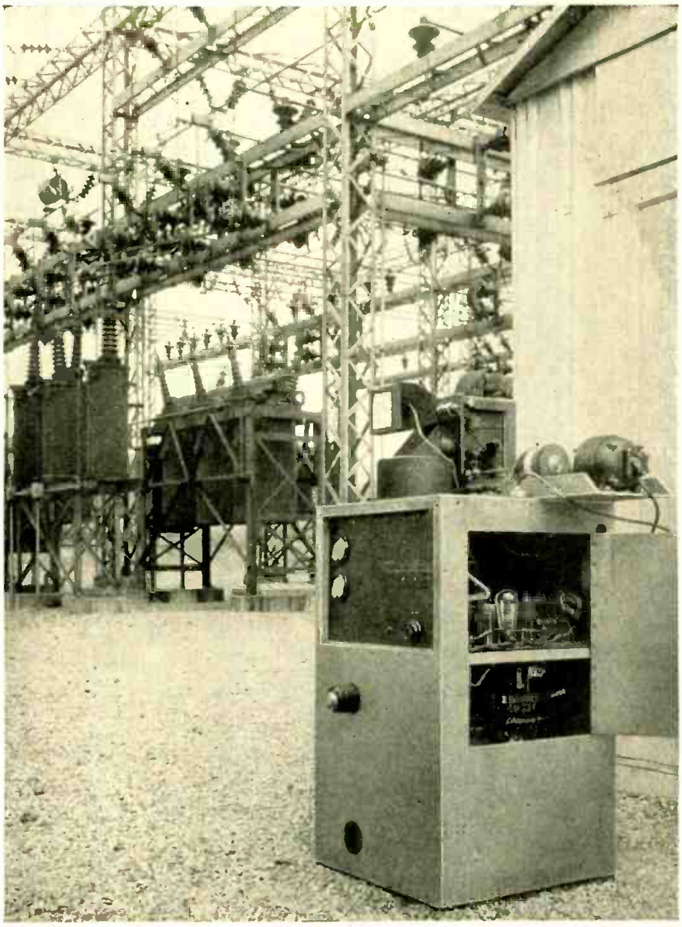


Bridge oscillators are used in th new single-sideband Musa systen (left) as references to whicl certain intermediate carrier frequencies are automatically adjusted in order that their sidebands may be properly locatec with respect to the pass bands o crystal filters.

Recording instruments (below of the Bell System Frequenc Standard, operated by the Laboratories. Four bridge oscillator are the prime generators of thi standard; any one of them ca be chosen to supply the standar frequency, while the others ar operated for standby and intercomparison purposes. L. A Meacham and W. A. Marriso are examining a record chart.

A crystal chronometer, consisting of a bridge oscillator, frequency-dividing circuits, and a timing motor, has been loaned by the Laboratories to the American Geophysical Union and used aboard the submarine *Barracuda* (below) in making undersea gravity measurements in the West Indies. Difficult operating conditions were met successfully.

Acme



Automatic Cathode-Ray Oscillograph

By W. L. GAINES
Protection Development

IN STUDYING transient currents in telephone circuits* and power systems, apparatus is required which will operate instantly and move quickly enough to record the initial part of the pulse. Oscillographs have been found suitable for this purpose. Usually they have been unattended and operated automatically by the disturbance to be recorded.

Until recently galvanometer-type instruments have been used. They were capable of recording only up to 3000 cycles and depended on film movement for wave-shape resolution. With instruments of this type a lamp must be lighted and the film started before recording begins. This takes at least a hundredth of a second, during which interval transients of importance may occur on the power system. Frequencies above 3000 cycles may also be involved. These deficiencies

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**Page* 140, *this issue.*

led to the search for a recorder capable of faster starting and of a greater frequency range.

An oscillograph with automatic features was chosen because it can record very high frequencies and requires only a few micro-seconds to release the beam. As developed by the Laboratories this oscillograph has, in addition to the cathode-ray tube, circuits which make the disturbance start the sweep action and the film movement. It also has power supplies and a photographic mechanism, including a lens system to project the trace from the screen of the cathode-ray tube to 35-mm motion picture film. The initial part of the record is made by sweeping the cathode-ray beam and during this interval the film

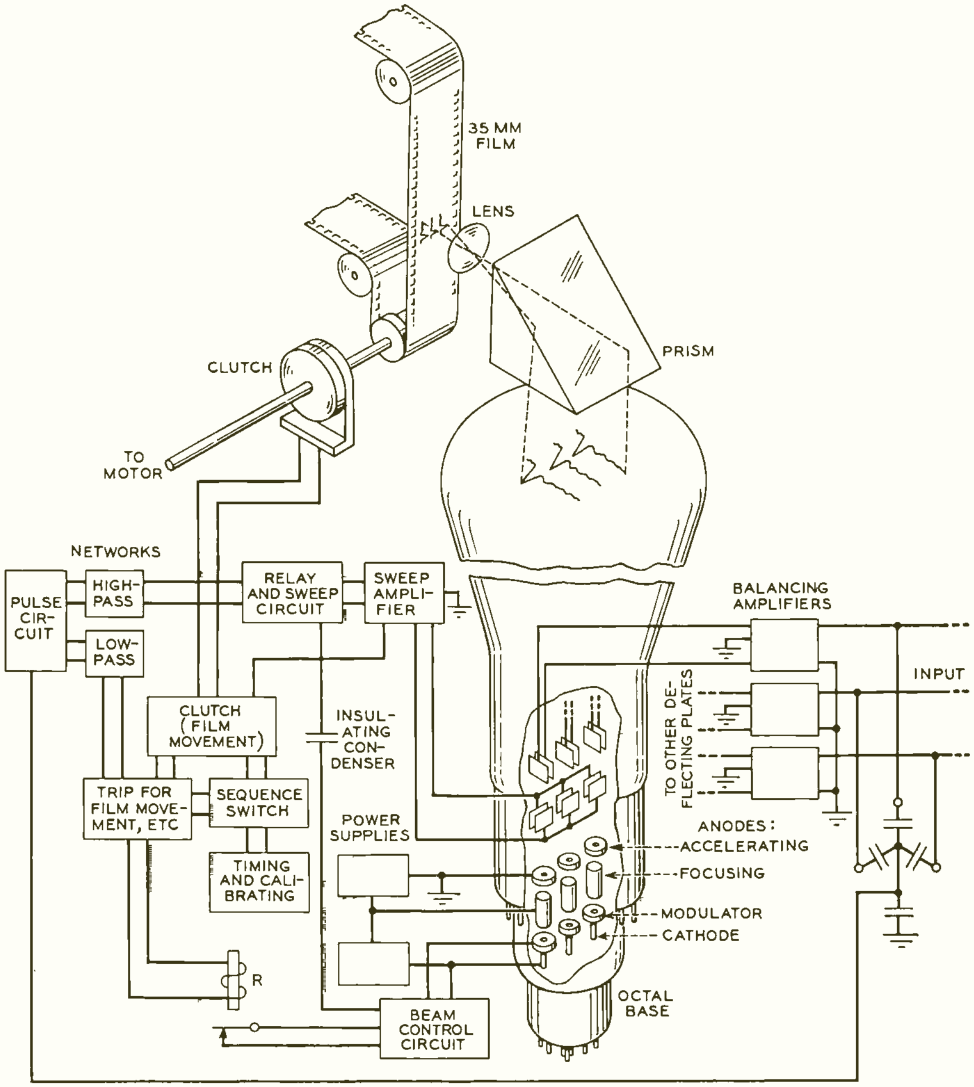

Fig. 1—To investigate the effects of three-phase power lines, the line-to-ground voltage of each phase of the system was applied to one set of deflecting plates of a three-beam cathode-ray oscillograph. The motion of the images was recorded on 35-mm film

starts to continue the recording. A complete record includes an automatic calibration and a clock picture to indicate the time the disturbance occurred. A schematic diagram of this oscillograph is given in Figure 1, with an outline of the circuits and a view of the photographic operating mechanism.

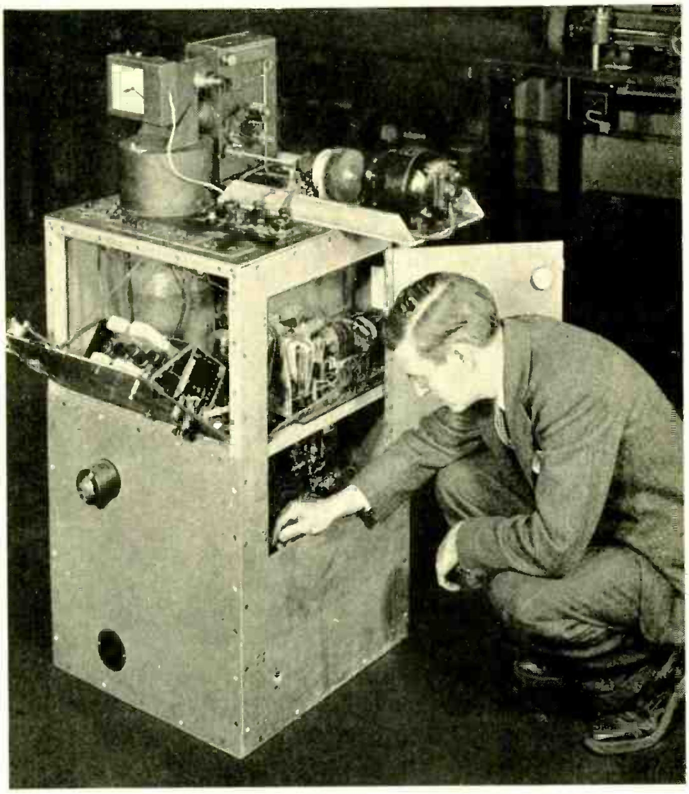

Fig. 2—The photographic mechanism of the oscillograph with the film magazine and clock are on top. The oscillograph tube is mounted in a metal cylinder, shown just below the clock, to protect it from stray magnetic fields

This apparatus was used in an investigation of overvoltages on a three-phase power system, conducted by the Joint Subcommittee on Development and Research of the Edison Electric Institute and the Bell System. Three recording elements were required, one for each phase, and this led to the choice of the Western Electric 330C cathode-ray tube, which is a development of the Laboratories. This tube has three complete units enclosed in a single glass envelope, thus making unnecessary three separate tubes with the attendant complication of the photographic system and increase in bulk. Each unit has a hot cathode, a modulator to control the magnitude of the beam current, a focusing electrode, and an accelerating electrode. The accelerating electrode imparts energy to the electrons and forms the beam, which strikes the screen where part of the energy is radiated as light. Two mutually perpendicular pairs of plates are provided for each unit. When a field is established between either pair of plates, the beam deflects toward the more positive one and the deflection is proportional to the amount of the applied voltage.*

The line-to-ground voltages of a three-phase system are applied to the deflecting plates through networks which provide a balanced input, because a well-focused beam is maintained only when the pair of plates is balanced with respect to the potential of the accelerating electrode. The other pair of plates in each group is connected to the sweep circuit to resolve the wave shape on the fluorescent screen.

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*A single-element tube of the same type is described in the RECORD, *December*, 1937, *p.* 110.

The power supply for the cathode-ray tube consists of two cascaded rectifiers with smoothing circuits designed so that the effect of the current drain of the cathode-ray tube is negligible. As a safety precaution, this supply is entirely enclosed in a compartment and is so arranged that the plate voltages to the rectifiers are cut off and the condensers shorted if the door of the compartment is opened.

Voltage to trip the oscillograph is obtained from the drop across a condenser between ground and the neutral formed by three Y-connected condensers as illustrated at the right in Figure 1. The other terminal of each of these condensers is connected to one phase of the three-phase circuit under observation. When unbalance occurs on the power circuit, voltage appears across the condenser in the neutral. This voltage is fed to a rectifying circuit which converts it into unidirectional pulses thus assuring that the succeeding trip circuits will operate on incoming waves of any polarity. The pulses are fed through discriminating networks to two trip circuits, one of which is high speed and the other slower and sensitive only to low frequencies.

The relay which trips the high-speed circuit consists of two electrically interlocked vacuum tubes. A pulse of any frequency above 1000 cycles per second, of sufficient magnitude to operate this relay, excites the beam and sweeps it always at the same rate across the screen. By adjusting this high-speed relay and the sweep circuit the sweep speed may be varied in discrete steps in the ratio of approximately $\sqrt{2}:1$, from about 1/200 to 1/6000 of a second. This range of speeds was considered adequate because the transients of interest in this study were those which arise within the power system itself due to the faulting of a conductor rather than those impressed on the system by lightning. The output of the sweep circuit is fed to an amplifier which delivers a balanced output to the deflecting plates. A portion of this voltage is used to energize the clutch circuit by means of a cold-cathode tube and relay. This clutch-energizing

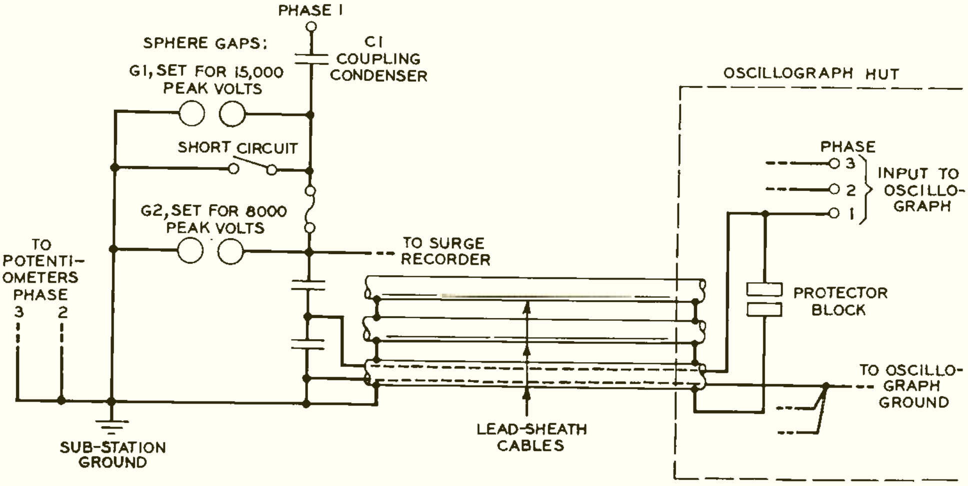


Fig. 3—Schematic diagram of the potentiometer, including protective equipment, by which the oscillograph is connected to the power line

circuit is self-resetting and, if the transient is short-lived, the clutch remains closed only long enough to give a film advance of about six inches so as to provide an unexposed piece of film for recording the next transient.

When the surge which trips the high-speed relay contains, or is followed by, power overvoltage a more extensive record is made. It includes the initial resolution by the sweep, about three seconds' resolution by film movement, a calibration and a clock picture. To obtain this additional record at the proper time, there was added a low-speed trip circuit, sensitive to sixty cycles and its lower harmonics. It consists of a cold-cathode tube and associated relays, which take control of the clutch and beam circuits and energize the sequence switch. The beam circuit is controlled by the insulated relay R (Figure 1) which actuates mechanically a contact, located in the high-voltage compartment, and keeps the beam active during the resolution of the record by film movement. The film movement initiated by the low-frequency trip circuit is terminated after a predetermined time by the sequence switch, which records on the film the calibration and a clock picture to show the time of operation. This film movement also resets the tripping circuit.

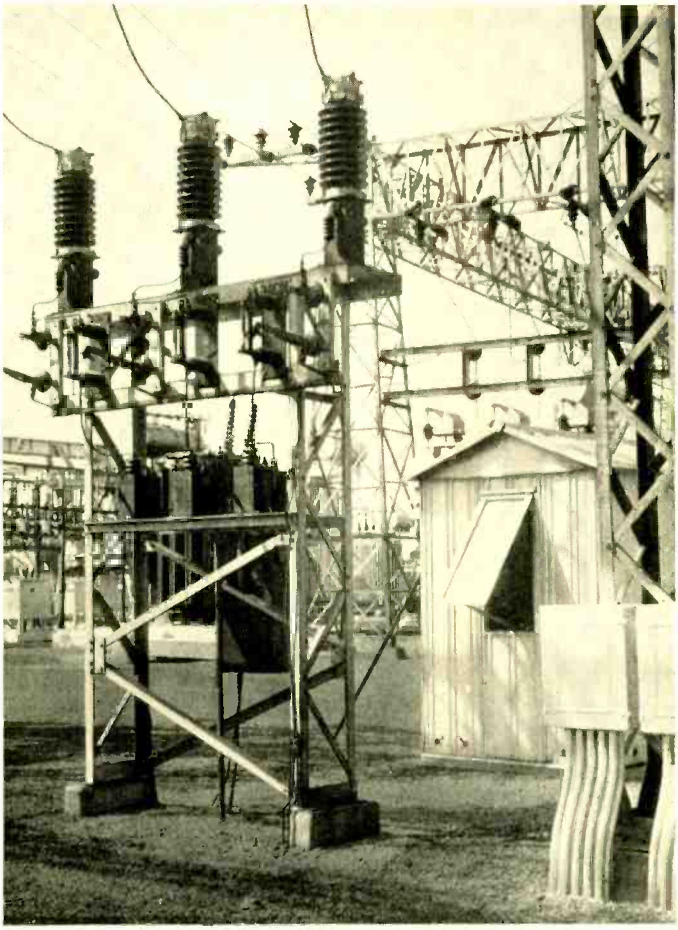


Fig. 4—Capacitance potentiometer and protective equipment as installed between the power lines and the oscillograph

Since the initiating transient of most power-system disturbances as well as those due to lightning contains higher frequency components, any disturbance will trip the relay and release the beams for the initial sweep, but a complete record will be made only when power-system overvoltage of fundamental frequency, or its lower harmonics, is present. Otherwise, the film only moves forward sufficiently to provide an unexposed section for a succeeding record.

The photographic system for recording the screen image is shown pictorially in Figure 1. The images on the screen are recorded on 35-mm motion picture film. The cathode-ray tube and the optical system are oriented so that the beam's path across the screen will be recorded with the time axis longitudinally along the film. A clock picture can be made at the end of a record to indicate the time of the disturbance.

Figure 2 shows a picture of the oscillograph. The photographic mechanism is on the top with the film magazine near the rear left-hand corner and a clock projecting in front of it. The clock has two faces, one visible so that the operator can check the time and the other enclosed for photographing. At the right of the film magazine are the clutch and the motor which drives the film. The panel at the front of the instrument carries the meters and the trip sensitivity controls. The projection under the panel is the motor which operates the ventilating fan. All the control apparatus and the power supply equipment are contained within the case.

This oscillograph has been used to record phase-to-ground voltage on a 44-kilovolt transmission line. Capacity potentiometers, one for each phase, reduced this voltage to a value suitable for the oscillograph. The schematic diagram of the potentiometer and its associated protective equipment is shown in Figure 3. The protection equipment is designed so that gap G2 will break down if condenser C1 fails. The resultant current will open the fuse and gap G1 will ground the system until it is cleared by circuit breakers. Additional protection is furnished by protector blocks at the terminals and by grounding the oscillograph case.

The records obtained with the original sweep speed, which was fairly high, did not disclose any very high frequencies in the initial part of the disturbance on the power system under observation. Consequently the circuits were rearranged so that the resolution due to the sweep gradually merges with that from the film movement, thereby producing a continuous record. An example of the results obtained by this method is shown in Figure 5. Comparison with records of faults obtained with a string oscillograph shows that the cathode-ray oscillograph has effectively closed the gap of approximately one cycle required to start the string oscillograph.

In addition to the extensive data on overvoltages which have been obtained in this investigation, much experience has been gathered on problems met in adapting oscillographs for continuous automatic operation under routine field conditions.

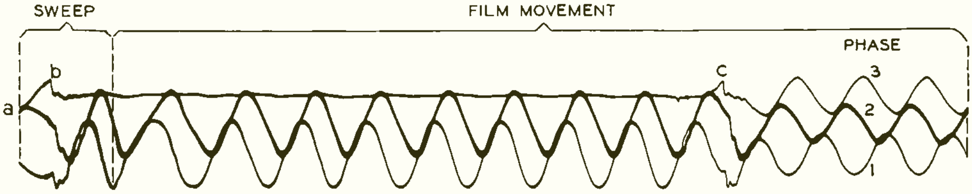
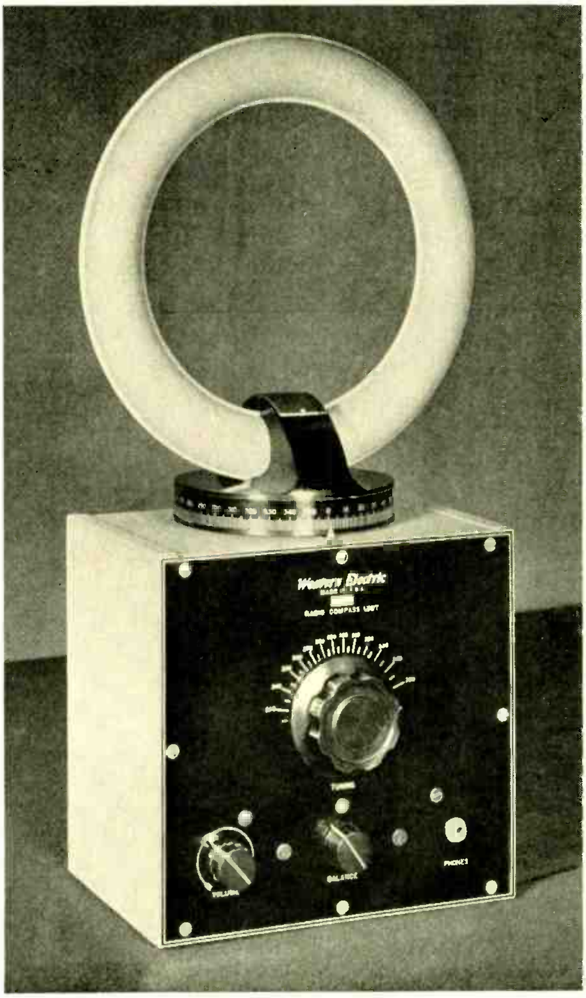


Fig. 5—Oscillograph record showing a fault on one phase (Ph. 3) of a power line. The cathode beams are swept across the screen when the fault occurs to record the voltages on all three phases for approximately the first cycle while the film movement is starting. The rest of the record is obtained on the moving film. At (a) transient disturbance operates high-speed trip; (b) phase-to-ground fault develops—low-frequency trip operates; (c) breaker clears fault

Radio Compass for Small Vessels

By W. E. REICHLE
Radio Development Department



MARINE radio-telephone equipment is finding wide use in pleasure craft of various types. Although it is employed primarily for ordinary communication with shore, it has great potential value for summoning assistance in emergencies. Previously, only the larger vessels equipped with radio telegraph and manned by a commercial operator had such facilities. To increase the usefulness of Western Electric marine telephone equipment, the Laboratories recently developed the 50A radio-compass unit. When associated with the telephone equipment this unit will permit radio bearings to be taken to determine the ship's position.

The compass unit consists of a small metal box carrying tuning and volume controls on the front, and the loop antenna on the top. Power is obtained from the radio-telephone unit, and the loudspeaker of this unit is also employed. A jack is provided on the compass unit, however, to permit a headset to be used instead of the loudspeaker if desired. A switch on the telephone set switches these circuits to the regular antenna or to the compass as desired.

The 50A compass unit covers the frequency band from 230 to 350 kc, which includes all of the marine radio beacons maintained by the United States Lighthouse service at strategic points on the Atlantic, Pacific, and Gulf coasts, and on the Great Lakes. By taking bearings on two of such stations, a ship's position may be determined regardless of fog or darkness. Also included in the band from 230 to 350 kc are numerous aircraft beacon stations operated by the Civil Aeronautics Authority.

Operation is simple. On installation, the compass box is permanently fastened in position, and the bearing scale on the base of the loop, which is adjustable in position, is set so that the zero gives a direction in line with the keel of the vessel. After a signal has been tuned in, the loop is turned to the position of minimum signal. The reading of the scale then gives the bearing in degrees with respect to the ship's keel. The true bearing of the station may then be determined by the application of the ship's course as obtained from the magnetic compass.

The 50A compass was designed particularly for use with the 227B Radio-Telephone Equipment—a small radio-telephone set operating on either 6 or 12 volts dc and designed primarily for small vessels. Only minor modifications are required, however, to permit it to be used with either the 224* or the 226† types of radio-telephone equipments.

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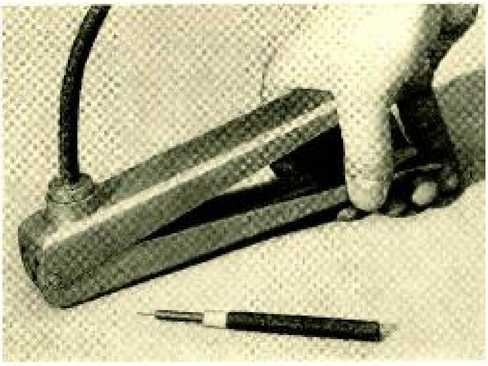
*Record, *June*, 1939, *p.* 358. †*Sept.*, 1939, *p.* 21.

Crimping Tool for Coaxial Conductors

Indoor wiring of high-frequency systems, such as coaxial and radio, is done with coaxial conductors. This comprises a central copper wire, which is covered with heavy rubber insulation, and an outside concentric conductor of braided copper. The copper braid is protected with a single layer of cotton fabric. To finish the ends of this wire neatly, a metal ferrule is squeezed on with a special crimping tool designed and developed by H. C. Hey. The ferrule is a tinned cylinder of soft brass. Before it is put on the cable the fabric insulation and the braided copper are stripped back and a small metal eyelet is slipped between the rubber insulation and the copper braid. This protects the inner conductor from accidental short circuit by a strand of the braid which might puncture the rubber insulation.



In the crimping tool is a hollow metal cylinder of sixteen segments, tapered on the outside and extending about three-quarters of the length. This cylinder fits over the ferrule and over it fits another cylinder tapered on its inside. When the handles of the tool are squeezed the outer cylinder forces the segments of the inner cylinder against the ferrule and compresses it against the cable. A lip on the inner cylinder folds the inner end of the ferrule into the fabric and secures a rigid clamping. There are two holes provided in the ferrule by means of which it is soldered to the braid.

Transpositions

By W. C. BABCOCK

Transmission Development

IN 1885, when a number of metallic circuits were provided on a pole line erected between New York and Philadelphia, a great deal of difficulty was experienced with crosstalk. A talker on one pair of wires could be overheard by a subscriber using any adjacent pair of wires. It was found, however, that this difficulty could be overcome by interchanging the relative positions of the wires of each pair at suitable points. This procedure is called transposing; and from that time on the design of transposition systems has been important in making possible long open-wire toll circuits.

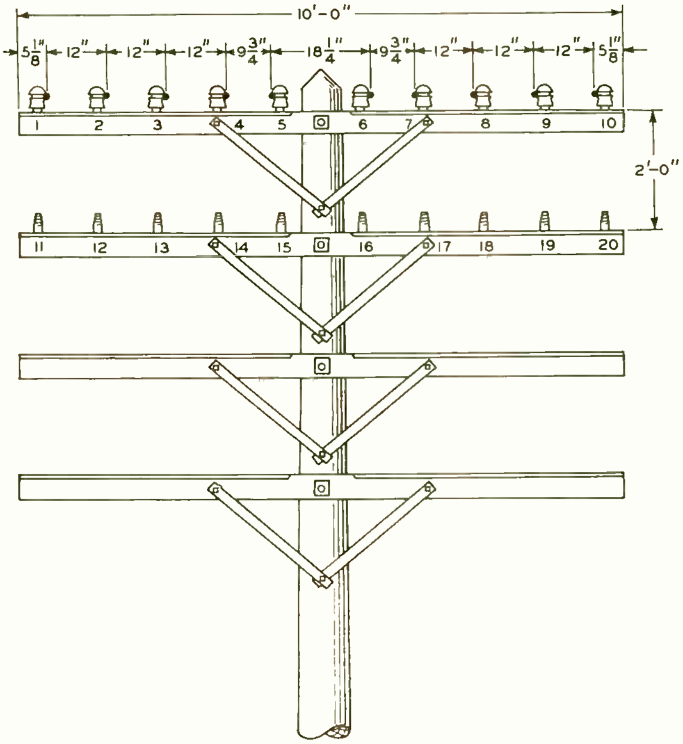


Fig. 1—Configuration of conductors of an open-wire line

The magnitude of the crosstalk* depends on the relative separation between the four wires forming the disturbed and the disturbing circuits. Transmission over the disturbing pair results in external magnetic and electric fields, which induce voltages in both wires of the disturbed pair. Because of the separation of the wires in this latter pair, a greater voltage is induced in one of them than in the other, so that there is a net voltage tending to cause a disturbing current to flow. When a transposition is introduced in one of the pairs, the direction of the disturbing current on one side of the transposition is opposite to that on the other side, so that there is a tendency for them to cancel each other. Because of the phase shift of the current as it passes along the line, however, there is never perfect cancellation. If, for example, the frequency of transmission is such that transpositions are a quarter wavelength apart, the disturbing currents

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*Record, *Nov.*, 1934, *p.* 66.

in the two segments adjacent to the transposition will assist each other, and the transposition will aggravate rather than improve the conditions.

For voice-frequency circuits, where the upper frequency is in the neighborhood of 3000 cycles, there is no difficulty in making the distance between transpositions short enough to give nearly complete cancellation in adjacent segments. Besides this factor, however, it is necessary to consider also the interaction of a large number of circuits on the same pole line. Figure 1 shows the cross-arm and pin arrangement that was long standard. Each arm carries ten wires or five pairs. The four outer wires on each arm are equally spaced, but the wires nearest the pole—comprising the pole pair—are spaced farther apart to allow a lineman to climb between them. With the large number of circuits that such a pole line might carry, the transpositions had to be arranged so as not always to appear at the same point on the pole line for adjacent or nearby circuits.

A study of the possible transposition schemes reveals the fundamental types or patterns of transpositions shown in Figure 2. This gives the different ways of transposing a pair of wires over a distance including thirty-two transposition poles. The distance between transpositions was originally taken as ten spans, each normally 130 feet, so that there was approximately a quarter of a mile between transpositions, and the length of the entire transposition section was eight miles. The various arrangements are desig-

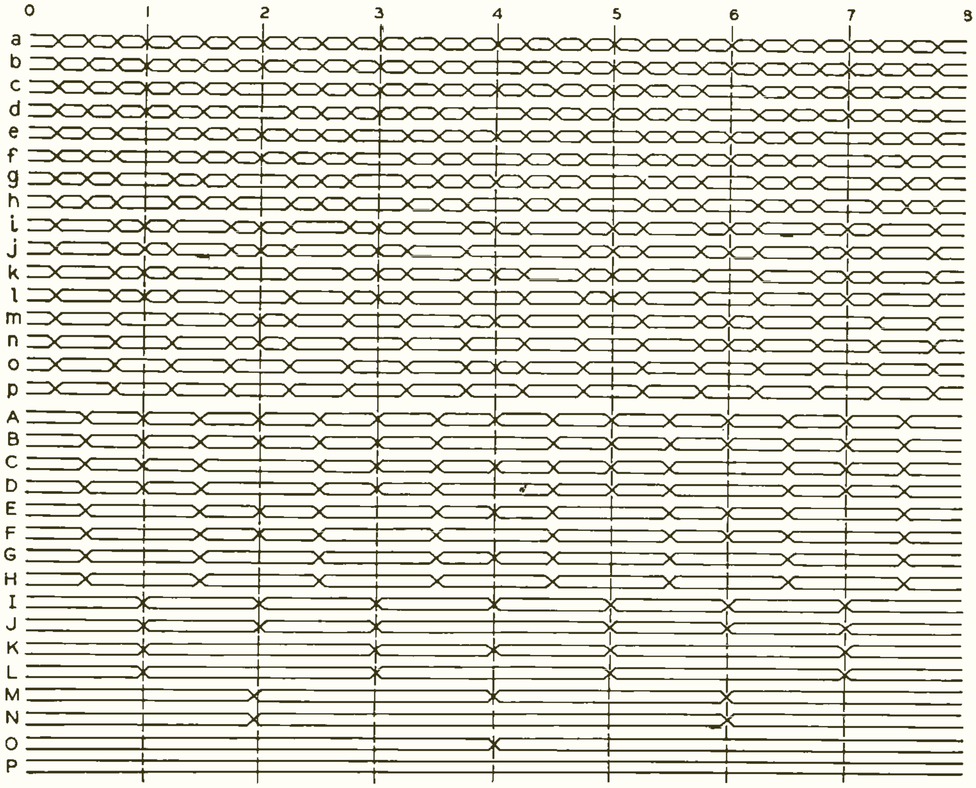
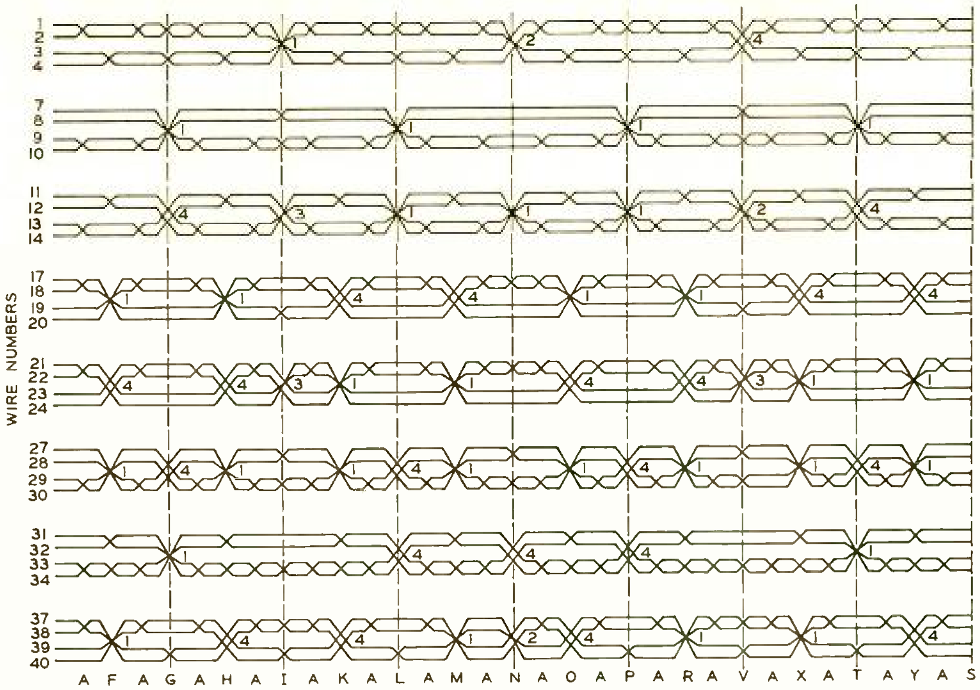


Fig. 2—Fundamental types of transpositions requiring 31 transposition poles



NOTES:— LINE TRANSPOSED IN DIRECTION OF ARROW ⟶
THE FIGURE AT EACH PHANTOM TRANSPOSITION INDICATES THE TYPE

Fig. 3—The "Standard" transposition system for four arms in an eight-mile section (Only non-pole pair groups are shown)

nated by small and large letters from a to p and A to P inclusive. Selections were made from these possibilities to meet the requirements of various pole lines.

This eight-mile section was the longest used, and for long lines a number of sections were required. For a single complete section the crosstalk is small, and so when branch lines are required, it is desirable to drop them off at the end of a section. Where many branch lines were required, therefore, it was necessary to use shorter sections of various lengths so that lines could be dropped off at suitable points. The standard section, always used where possible for crosstalk reduction, is never so effective over several short dissimilar sections as it is over a single long section.

The situation was soon complicated by the introduction of the phantom circuit. Such a circuit uses the two wires of a pair as one of its conductors and the two wires of an adjacent pair as its other conductor. In this way a third, or phantom circuit, is provided for each two pairs of conductors on the pole line. The circuits which result from this phantoming are referred to as the "side" circuits. When such phantom circuits were superimposed on an existing set of transposed circuits, it was necessary to superimpose a set of phantom transpositions on the existing pair transpositions.

During these early years a large number of transposition arrangements were worked out by various people, for both pairs alone and for pairs and phantoms, and it was not until 1908 that the "Standard" transposition system was designed by O. B. Blackwell. This arrangement for thirty-two poles, each with four crossarms, is shown in Figure 3. This figure shows only the phantom groups obtained from the non-pole pairs of each arm, but arrangements were also provided for the pole pairs, and for infrequent odd combinations of pole pairs and non-pole pairs.

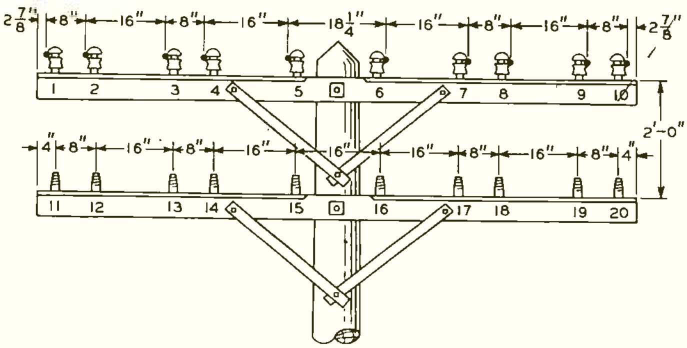


Fig. 4—Configuration of conductors using eight-inch spacing

Besides reducing crosstalk between circuits on the same pole line, transpositions also reduce the disturbances from outside sources, such as adjacent power lines. Where there was a severe exposure of this latter type, it was found that more transpositions were required than the Standard system provided, and in 1917 the "Exposed Line" system was designed. Later the "N" transposition system for exchange lines, where circuits drop off at frequent intervals, was designed. Only one transposition section was provided, but the transpositions were arranged so that no two pairs were untransposed with respect to each other for more than a short distance.

Shortly after the Exposed Line system was introduced, carrier systems were developed, and because of the higher frequencies, more transpositions were required. The type-C carrier system, for example, employs frequencies up to 30,000 cycles. At this frequency, the wave length is only one-tenth that at the top of the voice-frequency range, so that the requirement of holding the distance between transpositions to a small fraction of a wave length requires many transpositions. To simplify the transposition design, and thereby reduce its cost, several C carrier systems were designed with their frequency bands shifted somewhat with respect to each other. In this way the effects of crosstalk from one C system to another are reduced somewhat without any change at all in the transposition system. Additional transpositions were required, however, to reduce the crosstalk that still remained.

Since the transposition points had been ten spans apart, it was possible to introduce additional transpositions by transposing at every fifth pole as well as at every tenth. Such circuits were said to be transposed to single extra types. This did not prove adequate, and double extra types were employed. This required two additional transpositions between each two existing ones, and since ten spans cannot be divided into three equal parts, the two transpositions were put at the second and seventh poles. With such an arrangement, the crosstalk reduction is not so great as with uniform spacing.

Crosstalk induced in a circuit travels in both directions, that part going toward the same end of the line as the disturbing source being called near-end crosstalk, and that part going on to the distant end, far-end crosstalk. The former, or near-end crosstalk, has the greater effect. Consider, for example, a section between two repeater stations, with voice being transmitted from west to east over one pair, which acts as the disturbing pair, and a conversation being carried on over the other, which becomes the disturbed pair. At the output of the west amplifier of the disturbing pair, the voice currents are at their maximum value because they have just been amplified. On the disturbed pair, the voice currents traveling from west to east have also just been amplified, while those going from east to west are at their low level because of the attenuation of the line from the east repeater station. The induced crosstalk is thus greater relative to the west-bound speech in the disturbed circuit than it is to the east-bound. As a result the near-end crosstalk has a greater effect and is more difficult to control than far-end crosstalk. For this reason carrier systems are not designed to transmit in both directions at the same frequency on the same pole line. The east-to-west band of frequencies, for example, is made different from west-to-east, so that near-end crosstalk is automatically eliminated. Without this provision no practicable transposition design could reduce the crosstalk to satisfactory values.

The first transposition arrangement for carrier systems was known as the "Alternate Arm" system. It was designed to permit type-C carrier systems on the side circuits of the end phantom groups of the first and third crossarms. The additional transpositions required were superimposed on the Standard or Exposed Line systems in so far as possible.

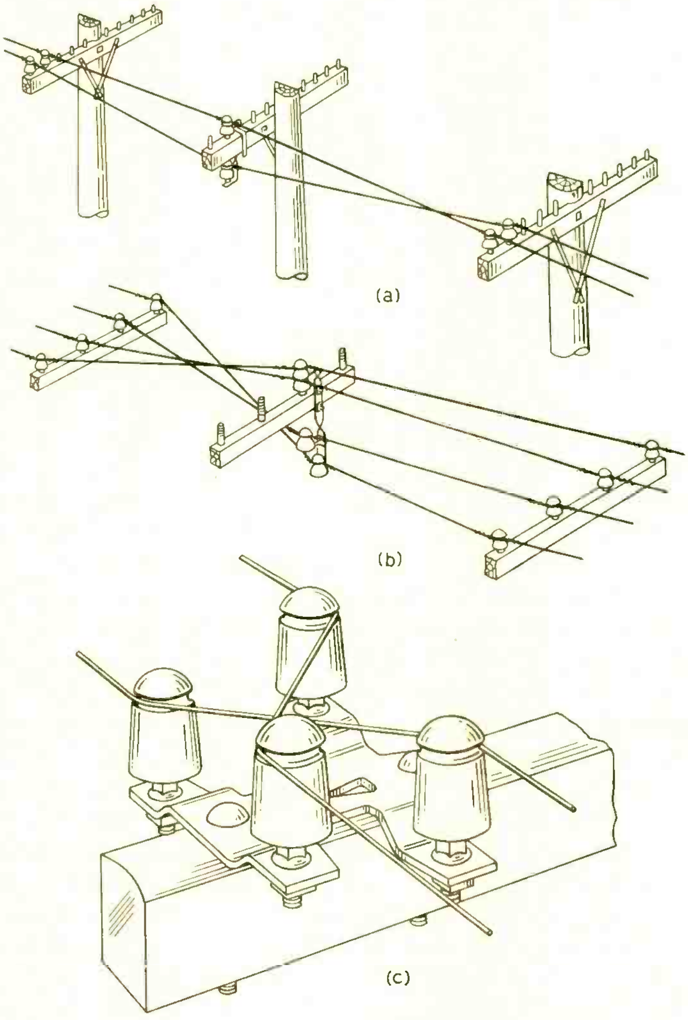


Fig. 5—Former construction for side circuits and phantoms, above, and the new point transposition for pairs, below

The "type-D" transposition system was next developed. It was designed for use with a single-channel carrier system having about 10,000 cycles as the top frequency. Crosstalk had to be controlled for circuit lengths only up to 200 miles, and single extra types were used on the side circuits of phantom groups. The type-D transpositions may be installed on Standard and Exposed Line transposition sections in one phantom group at a time without substantial modification of other circuits.

To permit more carrier circuits on a pole line and to facilitate greater crosstalk reduction than the Alternate Arm transposition system allowed, it was decided to discontinue the use of phantoms on all new toll lines except on the pole pairs, which are not used for carrier. In addition it was decided to use an eight-inch rather than a twelve-inch spacing for the two wires of a pair. The arrangement adopted is shown in Figure 4. Furthermore the spacing between transposition poles was changed from ten to eight spans so that triple extra transpositions could be used with equal spacing of all transposition points—the three transpositions being placed at the second, fourth and sixth poles.

With the reduction in wire spacing from twelve to eight inches, a new method of making the transposition was developed. Formerly a bracket carrying two insulators one above the other was employed at the transposition pole as shown in the upper part of Figure 5. For a phantom transposition a double bracket was used, as shown in the central sketch. With the new eight-inch spacing, the transposition was completely accomplished within a distance of a few inches at one pole by use of a new type of transposition bracket shown in the lower sketch. With the former method two spans were required for the transposition and the irregularities introduced in the wire spacing in these two spans proved to be a serious source of crosstalk. With the new "point" transposition, the very short distance within which the transposition is accomplished avoids this difficulty. Since phantoms will not be used for new carrier installations, no equivalent of the "point" system for phantoms is required.

Taking advantage of these modifications, a new transposition system known as the "K-8" was designed for application to all carrier systems on new lines. A new voice-frequency phantomed design was also prepared to coördinate with the K-8 design. Another transposition system, known as the "K-10" was designed to allow type-C carrier systems to be applied to all non-pole pairs on existing lines using the Standard or Exposed Line transposition systems. This kept the ten-span separation between main transposition points.

With the advent of the type-J carrier system having a top frequency in the neighborhood of 150,000 cycles, transposition engineers were faced with a five-fold increase in frequency as compared to the type-C system and with the possibility of reducing the spacing between transpositions to only one-half, since the K-8 system already used transpositions at every other pole, and extensive use of transpositions floating out in the span was considered impracticable. A new technique was required; but the manner in which this new problem was solved will be covered in another article.

Contributors to this Issue

W. C. **Babcock** received an A.B. degree from Harvard University in 1920 and a B.S. in Communication Engineering from the same university in 1922. He joined the Development and Research Department of the American Telephone and Telegraph Company in 1922, coming to the Bell Laboratories with that organization in the 1934 consolidation. His work has been largely on problems pertaining to crosstalk reduction in open-wire circuits in the Transmission Development Department.

A. A. **Oswald** received from Armour Institute of Technology the B.S. degree in 1916 and the E.E. degree in 1927. With the Laboratories since 1916, he has been continuously engaged in its successive radio projects. He took part in the development of long-wave transatlantic telephony, and was at Montauk during early transmission experiments. During the World War he had charge of the field-testing of airplane telephones for the Signal Corps, and devised a method of radio control for airplanes in flight. From 1919 to 1922 he assisted in the development of ship-to-shore communication. Since then he has been concerned with the development of long-wave and short-wave transoceanic systems.

O. D. **Grismore** graduated from Purdue University in 1927 with the B.S. degree in Electrical Engineering, and at once joined the Development and Research Department of the American Telephone and Telegraph Company. Here his work consisted chiefly in the development, field installation and maintenance of recording instruments for inductive coördination studies. After the consolidation of the D. and R. with the Laboratories, he continued working along the same lines, but has recently transferred to a group building equipment for television measurements.

W. L. **Gaines** joined the Department of Development and Research of the American Telephone and Telegraph Company in 1926, coming from the Massachusetts Institute of Technology where he studied electrical engineering. For the first three and one-half years he was with a test group in West Virginia, working on

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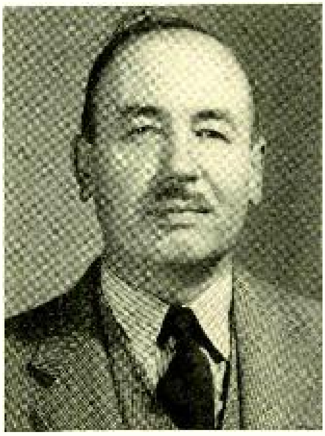

A. A. Oswald

O. D. Grismore

W. L. Gaines

W. E. Reichle

L. P. Bartheld

inductive interference problems created by a railroad electrification. In 1934 he came to the Protection Development Department of the Bell Telephone Laboratories where he has continued work on low-frequency induction problems and the design and construction of special apparatus for protection development studies, especially cathode-ray oscillographs for use in measurements on power-transmission systems and in lightning studies on apparatus that is used in the communication plant.

W. E. **Reichle** received a B.S. degree in Electrical Engineering from the University of Michigan in 1928, and immediately joined the Technical Staff of Bell Laboratories. Here, with the Radio Development group, he has been engaged in the development of aircraft radio receivers for both beacon service and two-way communication.

L. P. **Bartheld** graduated from Iowa State College in 1921, receiving the degree of B.S. in Electrical Engineering, and immediately entered the Engineering Department of the Western Electric. Here he associated with the Systems Development Department and worked on the design of toll-switchboard equipment until 1929. Since that time he has been with the special equipment engineering group as a supervisor in charge of numerous trial installations. During this period he has also had charge of the systems department's participation and the installation of the Chicago, Dallas, San Francisco, and New York Fairs.