The New York, Westchester & Boston Railway

Describing in Detail the Signaling, Interlocking and Telephone System on This Recently Completed Road

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This is the third and last of Mr. Loughridge's articles on the signaling and interlocking system on the New York, Westchester & Boston. This article describes the telephone system and underground conduit construction.

THE TELEPHONE SYSTEM.

The means of communication on a suburban railroad designed for high speed and dense traffic is a matter of the utmost importance. Not only is this so for directing the course of traffic under normal conditions, but it is infinitely more important under abnormal conditions such as delays and accidents. The short length of this line and the great number of stations suggested a means of communication that would be easily handled by any employee and readily accessible, in short,—a telephone system. While the operating conditions make the telephone so desirable there is one desideratum to its use from an electrical point of view, viz., the effects of induction from the single-phase propulsion current, effects which, however, are likely to affect the working of any system of communication. Certain safeguards were adopted and provision made for using compensating devices as may be necessary to overcome these inductive influences, which are hereafter referred to.

Fig. 35. View of a Tower Interior.

THE COMMUNICATING SYSTEM.

The communicating system is illustrated in Fig. 37 and consists of a train dispatcher system and a message system laid out with the object of anticipating the channels of communication that are likely to develop. The nature of traffic divides the line into two parts, one part is concerned with the operation of trains on the main line between Harlem river and New Rochelle and Portchester. The other part is concerned with the operation of trains between Harlem river and White Plains.

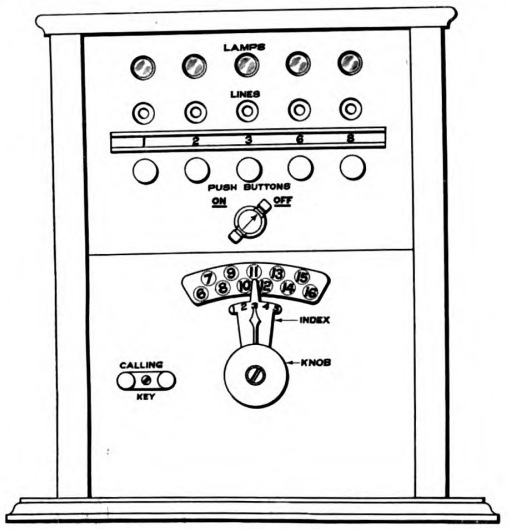

Fig. 36. The Intercalling Key.

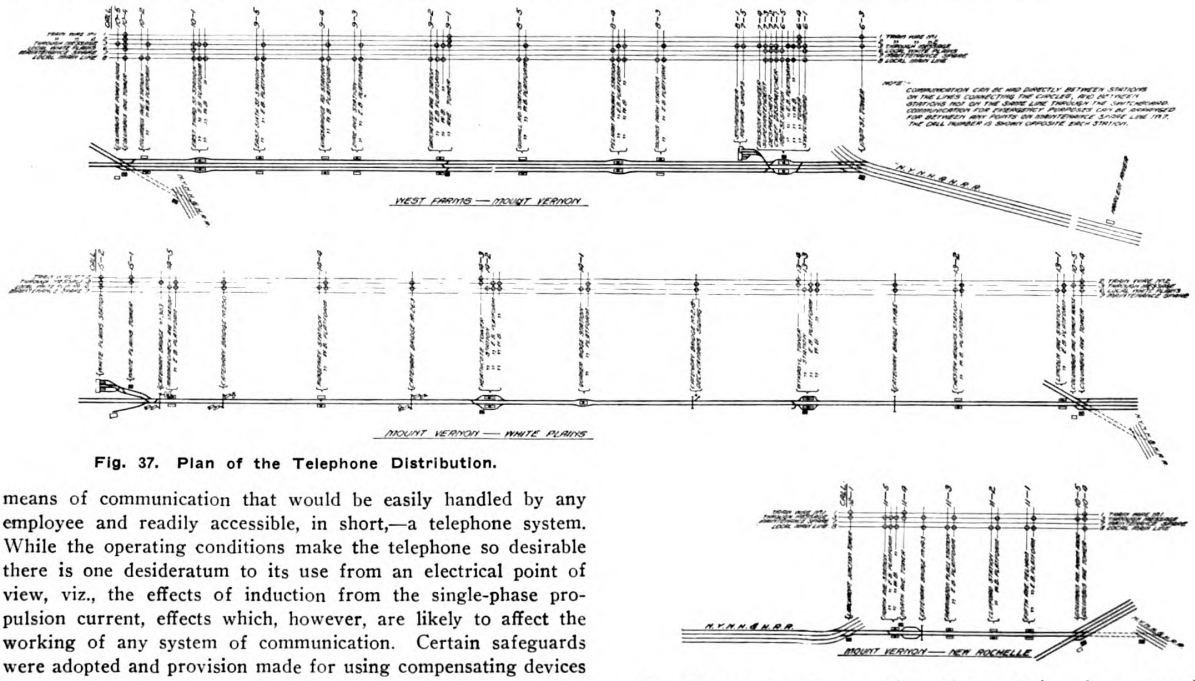

Fig. 37. Plan of the Telephone Distribution.

The dispatcher system consists of two train wires, one of which follows the main line to New Rochelle connecting into the

towers in this section. The other circuit follows the main line to the junction and continues to White Plains connecting the towers on the White Plains branch and the four-track section. These train wires are so arranged that they may be handled by one dispatcher, or each may have a separate dispatcher as may be necessary.

There are three message wires, as follows: one local wire connecting all stations on the main line, another local line connecting all stations on the White Plains branch and the express stations on the main line. The third or through message line connects the chief points on the main line and the White Plains branch such as towers, express stations, and terminals. In addition there is a line between towers whereby the towermen may communicate without using a through line. This line is intended to be used for the purpose of a future train describing system.

Direct communication is provided as follows:

(1) Interlocking towers on the four-track section on three wires;
(2) interlocking towers on the double-track sections on two wires;
(3) express stations on the four-track section on two wires;
(4) all other stations on one wire; and
(5) the principal executive offices are connected on the message lines.

An additional line is provided throughout, known as the maintenance spare, that can be substituted for defective wires in the other lines and also can be used for special conditions should traffic temporarily develop between two points.

Realizing the fundamental difference in the operation of telephones by unskilled operators as compared with the telegraph, it was very necessary to make them readily accessible. For this purpose telephones are installed on each platform at express stations and on alternate platforms at local stations. Also at the entrance to the interlockings remote from the towers and where the distance between stations exceeds one mile, outlying telephones are provided. Thus the trainmen can readily communicate over the system from the platforms, and at no point on the line does a track-walker have to travel over a half-mile to report trouble.

With this arrangement the number of stations on any one line does not exceed 20 and the greatest number of stations on any line that does not have an alternative speaking circuit is 10. Communications will, in most cases, be brief and with this number of stations the lines are not likely to be crowded.

Since the local lines are separated into two parts there cannot be direct communication between the stations on one line and those on the other, for instance, the local stations on the New Rochelle extension cannot call directly the local stations on the White Plains branch, neither can the latter call the local stations on the four-track section. Communication between these points requires the local lines to be connected together, which is done at the switchboard located in the executive offices at 180th street, this board being provided mainly for the use of the offices.

Fig. 38. Platform Telephone.

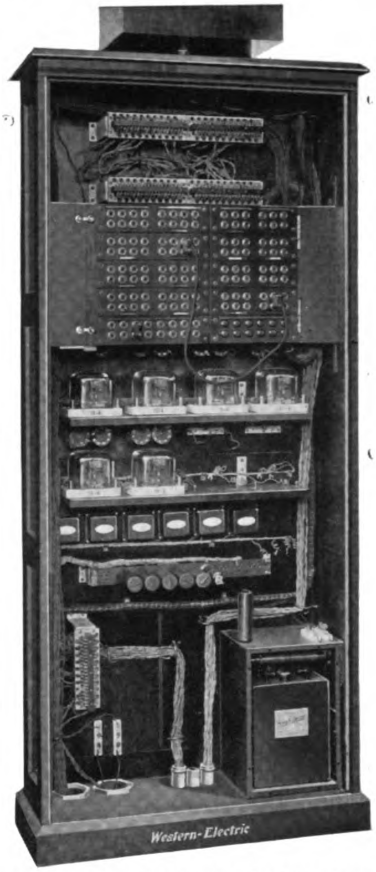

Fig. 41. Test Panel and Selector Case, Columbus Avenue Tower.

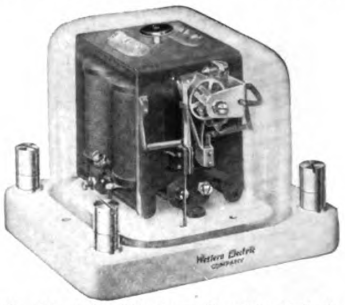

Fig. 39. The Western Electric Selector.

Fig. 40. View of a Jack Box in a Ticket Booth.

Fig. 42. Cable Pot-Heads in Columbus Avenue Tower.

THE INTERCALLING SYSTEM.

The business from a great many stations and outlying points extending over 18 miles is, under ordinary conditions, small and not likely to develop to any great extent. However, for reliable communication, especially in view of future extensions, a conductor of low resistance is desirable. The most economical way of securing this result is by the use of wires of large gauge with as many stations as possible connected on the same pair and an intercalling system between stations for the purpose of calling only the station desired. This requires perhaps a

greater variety of apparatus than a common battery telephone system but has several inherent advantages. The intercalling system is the nearest equivalent in telephony to the familiar Morse system in the telegraph. With the latter a code call is made, which is audible at all the stations on the line. The former improves on this, making the call only at the station desired and then giving both an audible and visual indication

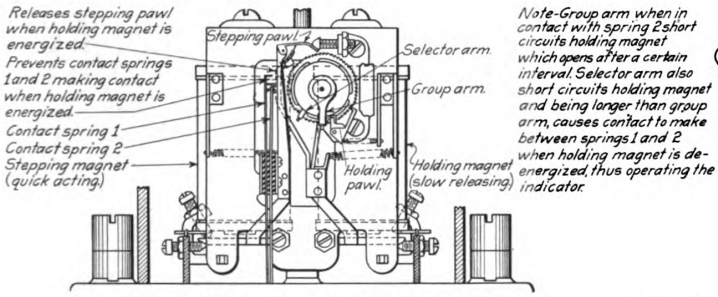

Fig. 43. Details of the Selector.

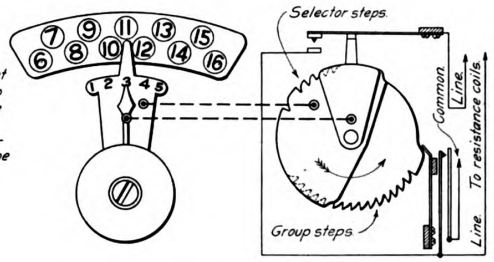

Fig. 44. Details of the Operation of the Intercalling Key.

until answered, besides informing the person making the call it has been recorded. This system consists of a means of selecting any station desired in response to its call number, as set up on a calling key, and the necesary indicating and speaking apparatus. The chief elements of the system, therefore, are the intercalling key and the selector.

THE INTERCALLING KEY.

The intercalling key, Fig. 36, forms a part of the jack box, which is, in fact, a miniature switchboard in itself. It consists of two indices adjusted by a knurled knob, Fig. 44; the large

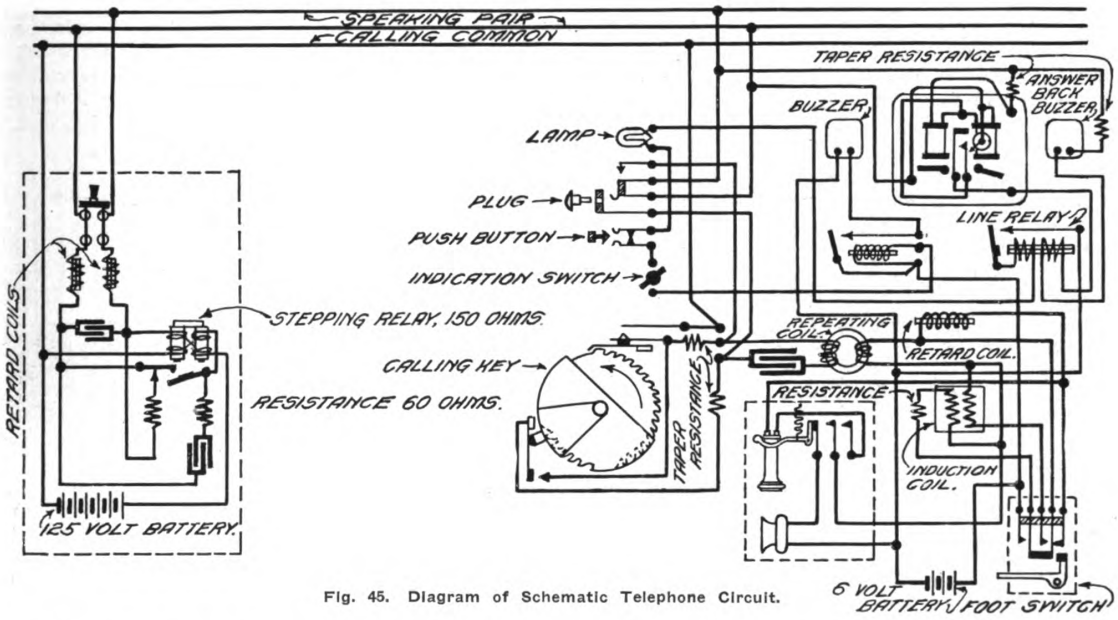

Fig. 45. Diagram of Schematic Telephone Circuit.

used to extinguish the light and stop the buzzer when answering the call. The "on" and "off" switch is provided to save the battery on the indicating apparatus when no attendant is present. This indicating apparatus is omitted at outlying telephones where there is no attendant.

The sequence of a communication is as follows: (1) obtain from the list the call numbers and line by which the desired parties can be reached, set the indices to the call numbers and insert the plug in the jack of the proper line; (2) ascertain if the line is in use and if so change to another line not in use and give

index figures 6 to 16 inclusive constitutes the first part of the call known as the group number and the small index from figures 1 to 5 inclusive is the second part of the call or selector number. The selector numbers are repeated into each of the group numbers, and it is therefore possible to make 55 different calls with this arrangement. The small index is set by pushing the knob in and giving it a turn after the large index is adjusted. The numbers represented by the indices are repeated in impulses sent out on the line when the calling key is operated, with however, a certain combination in which a long impulse follows the impulses due to the group numbers and another long impulse follows the selector impulses. The knob makes a complete the calling key a turn. If the call has been received a buzzing sound will be heard in the receiver, known as the "answer back"; (3) in answering the call, the plug is inserted in the jack below the indicator and the push button operated. The parties are now in comunication and when conversation is through, they merely hang up the receivers. The communication is thus between the two parties concerned which saves time and misunderstandings.

THE SELECTOR.

Selectors operate in response to the stepping impulses from the intercalling key. The station called is selected by the predetermined position of two contact arms on the stepping wheel

of the selector establishing the holding circuit of an indication relay after a combination of steps corresponding to the call numbers. The selector consists of a stepping and a holding magnet of high resistance bridged across the line (Fig. 43), the former being quick acting and the latter slow releasing. The first impulse, which is slightly longer than those immediately following, energizes both magnets of all selectors on the circuit and the slow releasing magnet remains energized, while the stepping magnet responds to the succeeding steps, thus moving around the stepping wheel. The group arm, in passing contact spring 2, as will be seen in the diagram of connections, short circuits the holding magnet. If this occurs during a short impulse this magnet will not release (being slow acting), but if it occurs during the long impulse between the group and selector numbers, it will deenergize and as soon as the stepping magnet releases the stepping pawl at the end of the impulse, the stepping wheel returns to the starting position by the action of a hair spring. Thus a group of five selectors are selected whose group arms are adjusted for the group numbers called. The holding magnets of the other selectors remain energized owing to the continuous impulse on the line. When the intercalling key moves around to the selector steps, these five selectors start again and the others continue to move the stepping wheel. Another long impulse follows these steps and the selector whose selector arm makes contact with contact spring 2 during this time also causes the holding magnet to deenergize, thus picking out the selector of the group called. The selector arm is slightly longer than the group arm thereby pushing contact spring 2 further back and causing it to make contact with spring 1 which establishes the circuit of the holding relay and buzzer in series with a resistance coil bridged across the line—there being no passing of contacts except that affecting

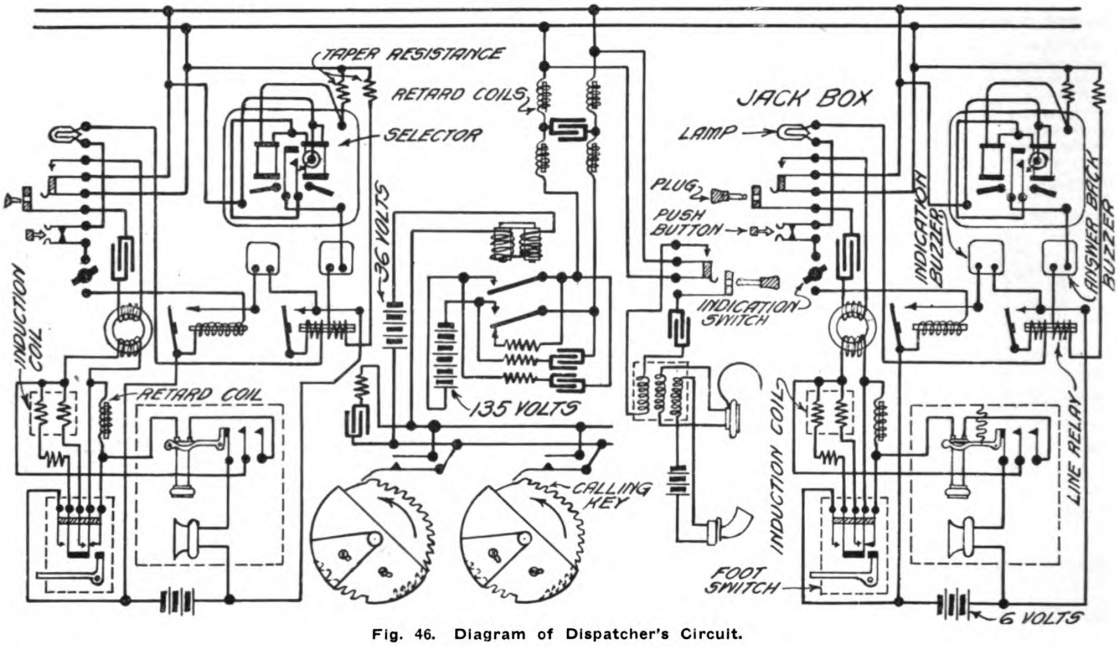

Fig. 46. Diagram of Dispatcher's Circuit.

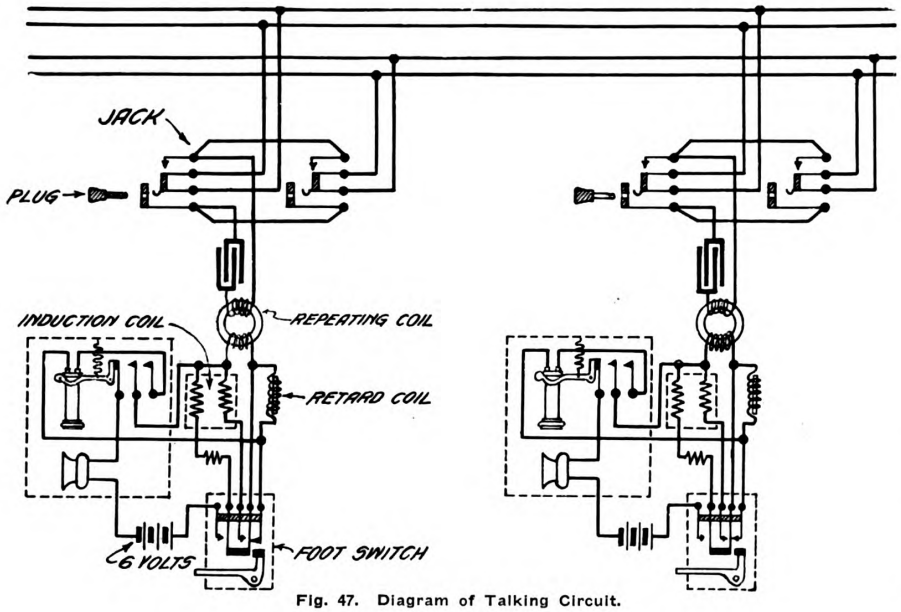

Fig. 47. Diagram of Talking Circuit.

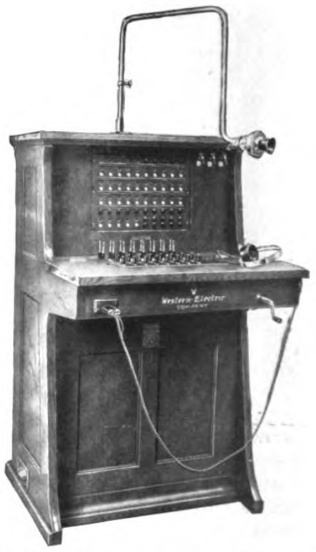

Fig. 48. Western Electric Telephone Switchboard (30 Lines).

the circuit of the slow-releasing magnet. The operation of this buzzer varies the resistance of the circuit, causing the buzzing sound for the answer back. When the intercalling key completes its revolution the circuit is deenergized and the stepping wheels return to their starting position by the action of the hair spring.

THE SWITCHBOARD.

Communication between parties on lines that are not directly connected can only be secured, as stated, through the switchboard operator, who can connect the desired parties, or may be secured by the party making the call after the lines are c nnected at the switchboard. It is apparent that any call may be made through the switchboard operator, as would be necessary when the call number of a party was unknown.

The chief object of the switchboard is for the use of the executive offices, it being handled by the operator who attends

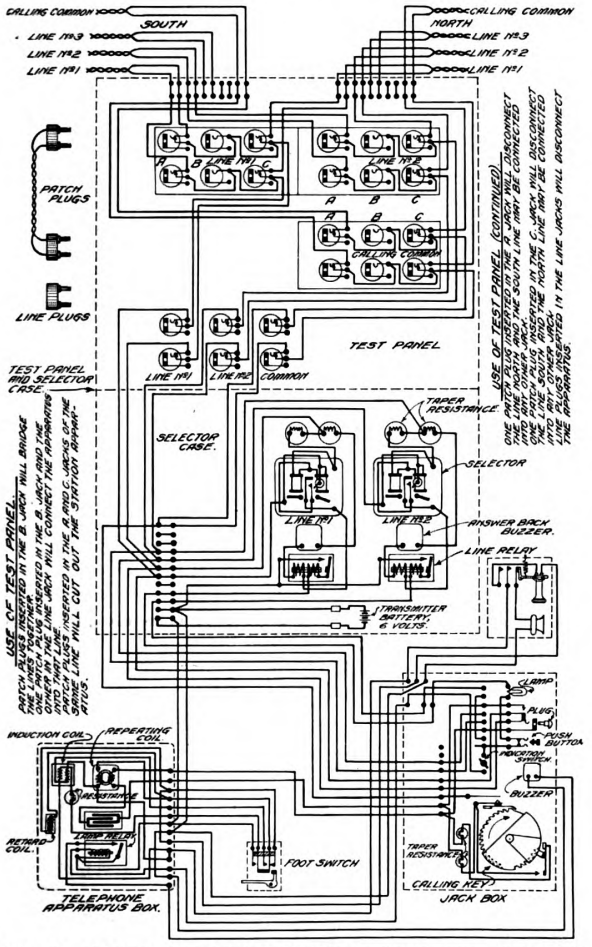

Fig. 49. Diagram of Complete Circuit for Three Lines in Towers.

the public telephone switchboard. A great number of these offices are closed at night when an operator at the switchboard is not necessary. In this case, if the business on all lines is light they may be connected together at the switchboard so that every point is intercommunicating. If this is undesirable, means are provided whereby the towerman at Columbus avenue Junction can bring the lines together for direct communication. In view of the non-attendance of the switchboard operator at certain intervals, some of the executive offices are connected into the message lines on selectors.

If desired, the system can be made entirely intercalling on all lines at any time, thus dispensing with the use of the switchboard. To do this it is only necessary to connect the lines that are not directly connected to the jack boxes so that they can be used for communication and calling. A station can thus get into the line to call another station on a line from which it could not itself be called. This avoids increasing the number of selectors bridged on the lines with the consequent undesirable increase in the voltage of the intercalling battery.

The train wires are reserved exclusively for the dispatchers use and ordinarily, communication can be had on these lines simply by inserting the plug in the jack. The dispatcher is provided with a head receiver and individual calling keys to expedite calling the towermen.

TELEPHONE CABLE.

The telephone lines are made of paper-insulated, lead-covered cable of No. 10 B. & S. gauge copper wire, placed in underground

Figs. 50 and 51. Showing Respectively Underground Conduit Construction on Two-Track and Four-Track Lines.

conduits. This cable has low electrostatic capacity and high dielectric strength. It will withstand an A.C. potential of 1000 volts without rupture, and has an insulation resistance of not less than 500 megohms per mile.

The cable for the four-track section consists of 16 pairs of which eight pairs are at present in use. Four pairs are for future use when the line is extended and four pairs are spare. The cable for the White Plains branch consists of 12 pairs of which six pairs are at present in use, four pairs are for future use, and two pairs are spare. On the New Rochelle extension a 10 pair cable is employed, of which six pairs are in use, three pairs are for future use, and one pair spare. The lines for future use include two pairs to be used in connection with compensating transformers as may be necessary to overcome the effects of induction, and one of the spare pairs is used for regu-

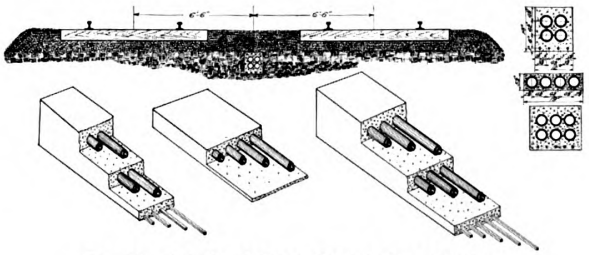

Fig. 52. Details of Fibre Conduit Construction.

lating the self winding clocks in the towers by the master clock in the dispatcher's office.

The cable is looped into the buildings where it terminates in pot-heads, the connections being taken off on rubber covered wire to a terminal strip and protectors. At stations these pot-heads are placed in the selector case, the lines being connected through and the station sets "bridged in." At towers, an iron case (Fig. 42) is provided for this purpose, from which connections are made for each wire to the test panel where all lines are available for testing and cross connecting. A test panel and selector case is shown in Fig. 41.

CIRCUITS.

The arrangement of circuits may be considered in two parts; which are readily distinguishable. One part is concerned with the intercalling system, and the other with the talking circuit.

The former includes a means of impressing on the selectors of a line the impulses of the battery due to the calling key at any station. The selectors are 16,000 ohms resistance and

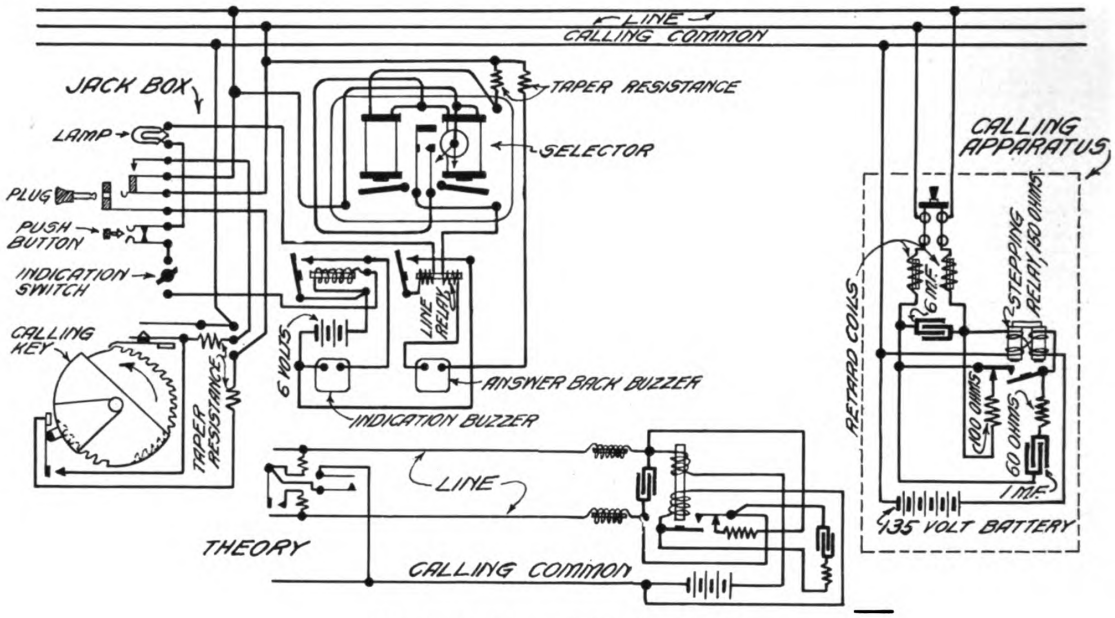

Fig. 53. Diagram of Intercalling Circuit.

are bridged across the line, requiring in this installation a 135-volt battery for their operation. In order to operate the system from a single battery at a central location another line circuit is necessary to operate the stepping relay in response to the calling key.

This is obtained by a simplex circuit on the line and a wire known as the intercalling common which avoids the use of a ground return. The stepping apparatus for each line consists of a stepping rela, having two separate windings. One of these windings is in series with one side of the line, the main battery and intercalling common, and when the relay is in the open position the other side of the line is also connected in series with this winding through a resistance of 100 ohms. The operation of the calling key connects the calling common at each step into each side of the line through a taper resistance. This completes a circuit from the battery through this winding of the stepping relay, causing it to energize, and picks up the armature, which connects the main battery across the line, thus operating the selectors. This selector current flows through the two windings of the relay differentially having no effect on its armature, which remains energized in response to the circuit through the intercalling common. The selectors are bridged across the line, connection being made through taper resistances which can be adjusted to compensate for varying distances from the battery so that the voltage at the selector terminals is constant throughout. The selector establishes the circuit of a line relay and the answer back buzzer. This relay has a local holding circuit which maintains the indication until the call is answered.

There may of course be any number of persons listening on the line when a call is being made, and in order to soften the effect of the pulsating current from the battery on the receivers which are 650 ohms resistance, impedence coils are placed on each leg and a condenser bridged across the line. This "silencing capacity" is discharged through the resistance coil on the back point of the relay which makes connection before the battery circuit opens. A condenser in series with a resistance is bridged across the relay terminals for the purpose of taking up the spark.

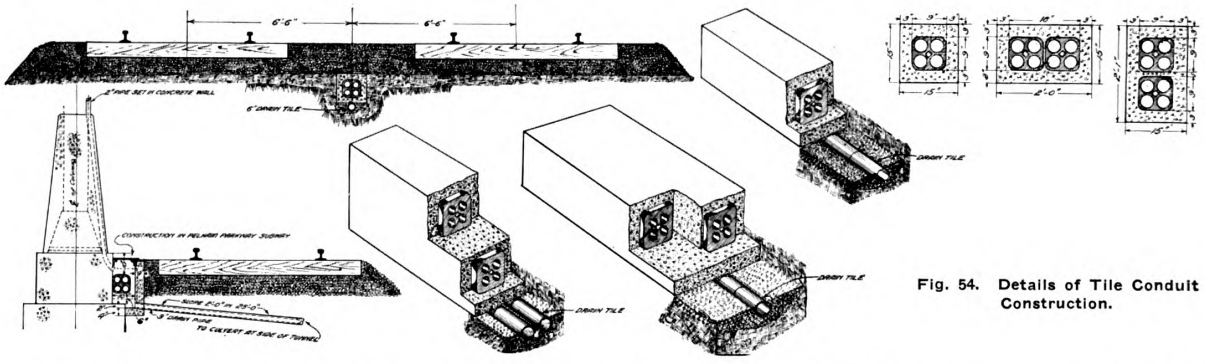

Fig. 54. Details of Tile Conduit Construction.

The dispatcher's calling circuit is somewhat different from that used on the message circuits as the dispatcher himself is the only person making calls on the train wire and he is located at the same point as the main battery, so that the use of the intercalling common is unnecessary as the dispatcher's keys operate the stepping relays in the local circuit, Fig. 46. Im-

pendance coils and condensers are used on the circuit for the same purpose as the message circuits.

THE TALKING CIRCUIT.

The talking circuit is somewhat modified from the standard telephone circuit by the use of repeating coils interposed between the line and the telephones. These coils have an insulation between windings that will withstand 1,000 volts A. C., and are to prevent persons using the telephone from being

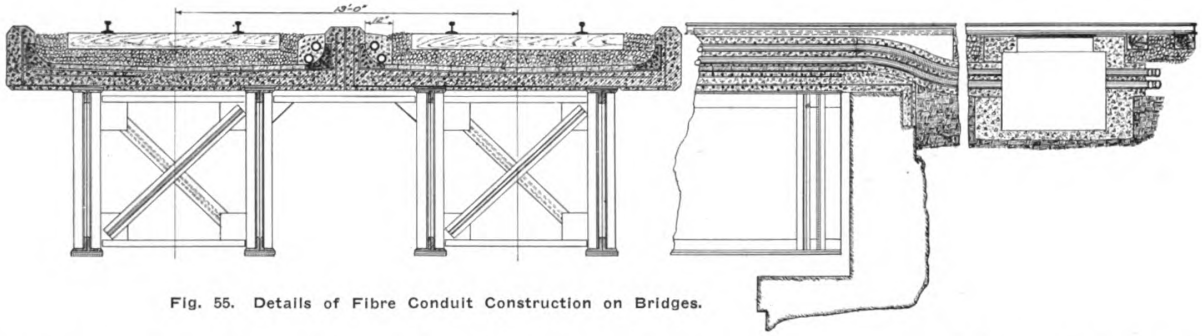

Fig. 55. Details of Fibre Conduit Construction on Bridges.

exposed to the lines. They are connected through condensers so as not to interfere with the calling circuit.

In order to obtain a greater efficiency when a number of persons are listening on the line, the circuit is arranged so that when listening the receiver alone is bridged across the secondary of the repeating coil. When talking the circuit is changed by means of a foot switch, Fig. 47, so that the secondary of the induction coil is connected across the secondary of the repeating coil and at the same time a retardation coil is connected in series with the receiver to prevent excessive side tones. Operating the foot switch also closes the circuit through the primary of the induction coil, the transmitter and battery. This arrangement gives a greater receiving and transmitting efficiency than can be obtained by the ordinary telephone circuit.

The dispatcher has a three-winding induction coil. The tertiary is connected through a condenser to the line, the receiver is in series with the secondary, and the primary is in series with the transmitter and battery. The insulation between the tertiary and the secondary and primary is tested to withstand 1,000 volts A.C., thus protecting the dispatcher from actual contact with the line wires.

TEST PANELS.

Test panels are provided in each interlocking tower. These consist of an arrangement of jacks whereby in the simple manipulation of plugs, lines may be disconnected in either direction for testing purposes, defective wires in one line may be patched by sound wires of another pair, lines may be bridged together, and the apparatus may be transferred from one pair to another. A complete circuit for three lines and the common, showing connections, to test panels, selectors apparatus and jack box is shown in Fig. 49.

TELEPHONE BATTERY.

A six-volt portable storage battery is used for the talking circuit, a 36-volt battery is used for the operation of the private branch exchange switchboard, and a 135-volt battery is used for the intercalling system. These batteries are of 20 ampere hour capacity and are charged by the motor generators used for the interlockings.

The battery for the intercalling system is located at the general offices which are at one end of the line. It is apparent that injury to the cable at this point would cripple the intercalling system. To provide for an emergency of this kind the main storage battery of the signal system can be used for the intercalling system, a switch for this purpose being provided in the apparatus box at Columbus avenue tower.

INDUCTION.

The exterior electrical influences to which the system is subject are due to three causes:—

(1) electrostatic induction due to the accumulated static charge from the catenary system;
(2) electromagnetic induction, due to the A.C. propulsion current; and
(3) earth potentials due to the drop in the power return circuit in the rails.

Experience shows that the effects from electrostatic inductions, which are so marked and often distastrous on aerial lines, are entirely dissipated in the earth without affecting the underground cable. In this position, however, the cable is more

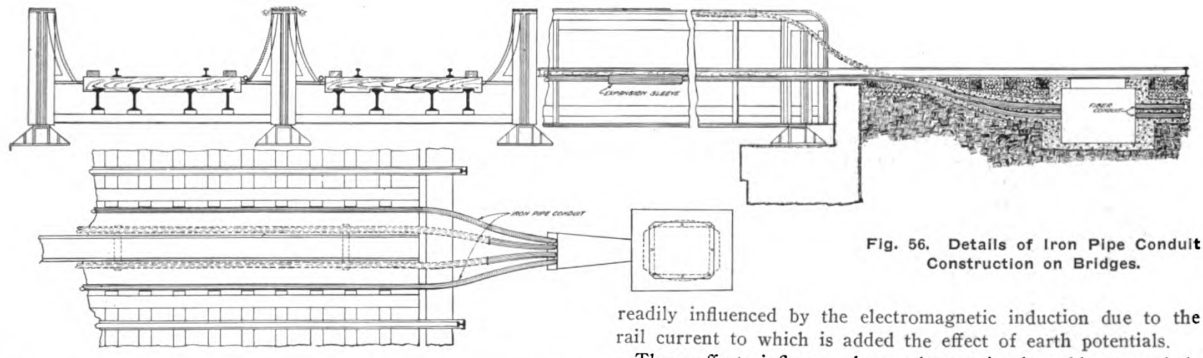

Fig. 56. Details of Iron Pipe Conduit Construction on Bridges.

readily influenced by the electromagnetic induction due to the rail current to which is added the effect of earth potentials.

These effects influence the conductors in the cable as a whole and not individually, so that the twisted pairs produce a noiseless talking circuit. It is therefore necessary only to guard against excessive potentials damaging the apparatus. On this account the cable and all apparatus connected to the lines are designed with a dielectric strength that will withstand 1,000 volts breakdown test, and no parts connected to the lines are exposed to persons using the telephones.

Tests show that a large percentage of the return current flows through the earth and earth potentials are present to such an extent as to prohibit the use of drainage coils. The insulation of the conductors is therefore maintained and protectors are used on each conductor which discharge when the potential between it and ground exceeds 450 volts.

Provision is made for installing compensating transformers for each cable if these disturbances, as the load increases, should warrant their use. The primaries of these transformers are in series connected by the same pairs in the cable. The induced current in them acts differentially on the potentials induced in the lines, nullifying its effect.

Where lines connect to the aerial cable of the New Haven system, the connection is made through an insulating transformer, thus avoiding any metallic connection between the two systems.

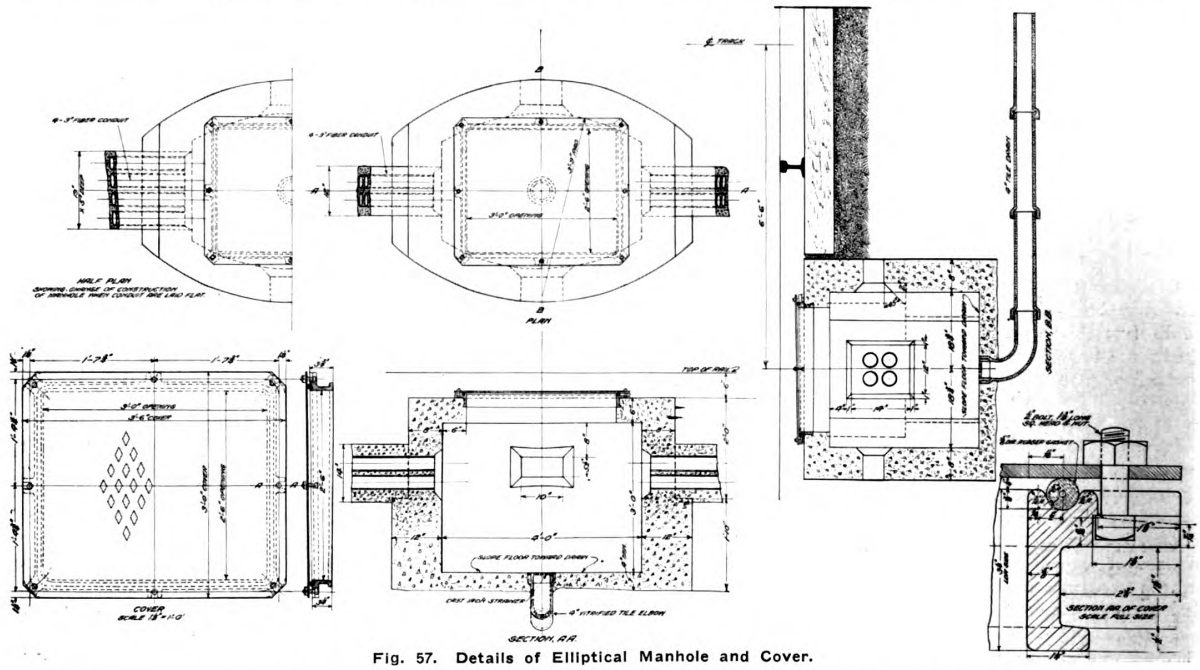

Fig. 57. Details of Elliptical Manhole and Cover.

UNDERGROUND CONDUIT SYSTEM.

In the beginning of this road, no provision was made for a pole line and the right-of-way in many places does not have sufficient space to build one. In the absence of a pole line, the catenary bridges are available from which the telephone cables could be suspended by messenger wire. A construction of this kind has nothing to recommend it except low first cost. A cable so suspended would be attached to the bridge legs directly under the 11000-volt feeders. In case of accidental contact between these wires and the cable, it does not take much imagination to see that the results would be disastrous to the cable and perhaps fatal to persons using the phones. In this location the cable would be almost parallel with the catenary wire and in a horizontal plane below the feeder wires and therefore in the strongest zone of the inductive disturbances.

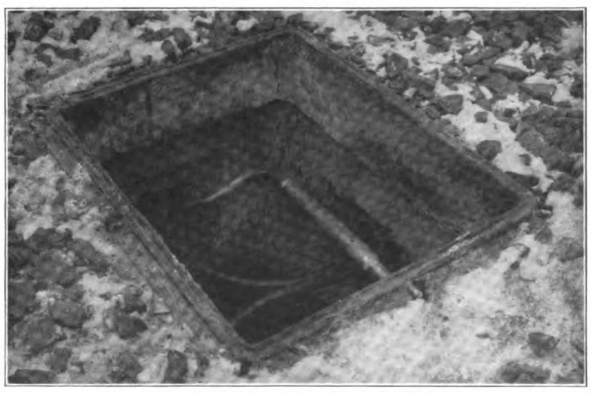

Fig. 58. One of the Elliptical Manholes.

These considerations naturally suggested building a conduit system for the telephone and signal cables which was readily taken up and acted upon as part of the policy in constructing the road. The heavy initial cost of this work is undoubtedly as justifiable as any other construction in the road. The building and maintenance of a pole line with over 45 wires on it would be a matter of considerable expense and these wires would be susceptible to damage from every storm with a possible interruption of traffic. When placed underground there is no unsightly line of poles to mar the appearance of the road, and appearance is a matter that has received a great deal of attention in building this road. Further, wires placed underground are not subject to the deteriorating influences of the weather and will therefore have a much longer life and a full salvage value.

The character of the roadbed was anything but favorable to this project. The subgrade on cuts was mostly on solid rock and the fills were "green" with a large percentage of voids on account of the large pieces of rock composing them, and therefore subject to considerable settlement. Neither of these conditions tended to lessen the cost or lengthen the life of the conduit system. A type of construction was adopted which it was thought would best meet these conditions, and the results so far are very satisfactory and indicate, after standing the test of a very severe winter, that it is not likely to cause any trouble.

The duct line follows the centre line and grade of the railroad and on level track has a grade from .25 to .5 per cent. Where possible the grade is in one direction between manholes and always descending towards the manholes with a drainage outlet. The distance between manholes does not exceed 500 ft., which was considered the maximum length of cable that could be conveniently handled. Manholes are somewhat closer than this on curves, and they are, of course, provided for outlets at buildings and signal locations.

THE DUCT CONSTRUCTION.

The conduit consists of a four-duct section of clay tile and of bituminized fibre. Each tile is two feet long having circular ducts 3½ in. in diameter. The fibre is three inches in diameter, with a ⅜-inch wall, and seven feet long with socket joints.

The tile duct is used in cuts. A trench was excavated 15 in.

below the subgrade. This was leveled off with a three-inch layer of concrete upon which the tile was laid as soon as the concrete had taken its initial set, Fig. 54. The joints in the tile were brought into alignment with the dowel pins and then wrapped with burlap and plastered with neat cement mortar. A three-inch wall of concrete on the sides and top of the tile was then poured in, the top of the finished duct line being flush with the subgrade.

FIBRE CONDUIT CONSTRUCTION.

The fibre conduit is used on the fills on account of the greater elasticity of a conduit line with this construction. In laying this work the bottom of the trench was tamped firm and leveled up with concrete in which ½-inch square iron re-inforcing rods are imbedded. The bottom row of ducts was then laid one inch apart and a filling of concrete was poured in, covering these ducts for one inch. When this concrete was set, the next row of ducts was laid, Fig. 52, followed by the concrete filling, and so on. Thus the ducts are one inch apart vertically and horizontally, which space is filled with concrete thoroughly tamped. A three-inch wall of concrete from the nearest duct is provided on the sides and top. The sides of the trench were built in such a way that forms were seldom necessary. The joints in the ducts were staggered proportional to the number of ducts, and were made by dipping the end of each length in sealing compound and wrapping the joint with burlap dipped in this compound. This construction has a good distribution of concrete, the weight of the ducts themselves is negligible and they add considerable to the reinforcing of the concrete especially adapting it to withstand the effect of vibration on new fills.

The bottom of the duct line in cuts is mostly below the drainage trench at the sides with the result that most of the surface water drains into it. In some places springs were encountered when excavating through rock, so that special provision had to be made to drain off this water. Water in the duct is undesirable on account of sediment that may be deposited in them, also the cable for the signal wires is merely braided which in time may become defective under water.

Tile drains were installed in the bottom of the trench, being made continuous in open drains in the manhole floors until drainage outlet was obtained. These drains are surrounded by loose trap rock upon which the concrete is placed.

On bridges of the solid floor type fibre conduit and tile duct are used, placed above the waterproofing on the bridge, Fig. 55, which is led off in an easy slope to the manhole, the connection with the latter being made through an expansion joint. On other bridges three-inch iron pipe conduits are installed having an expansion sleeve in the centre of the bridge. The pipe that is under ground leading to the abutment is embedded in concrete. Only two pipes are led across the bridge, as shown in Fig. 56.

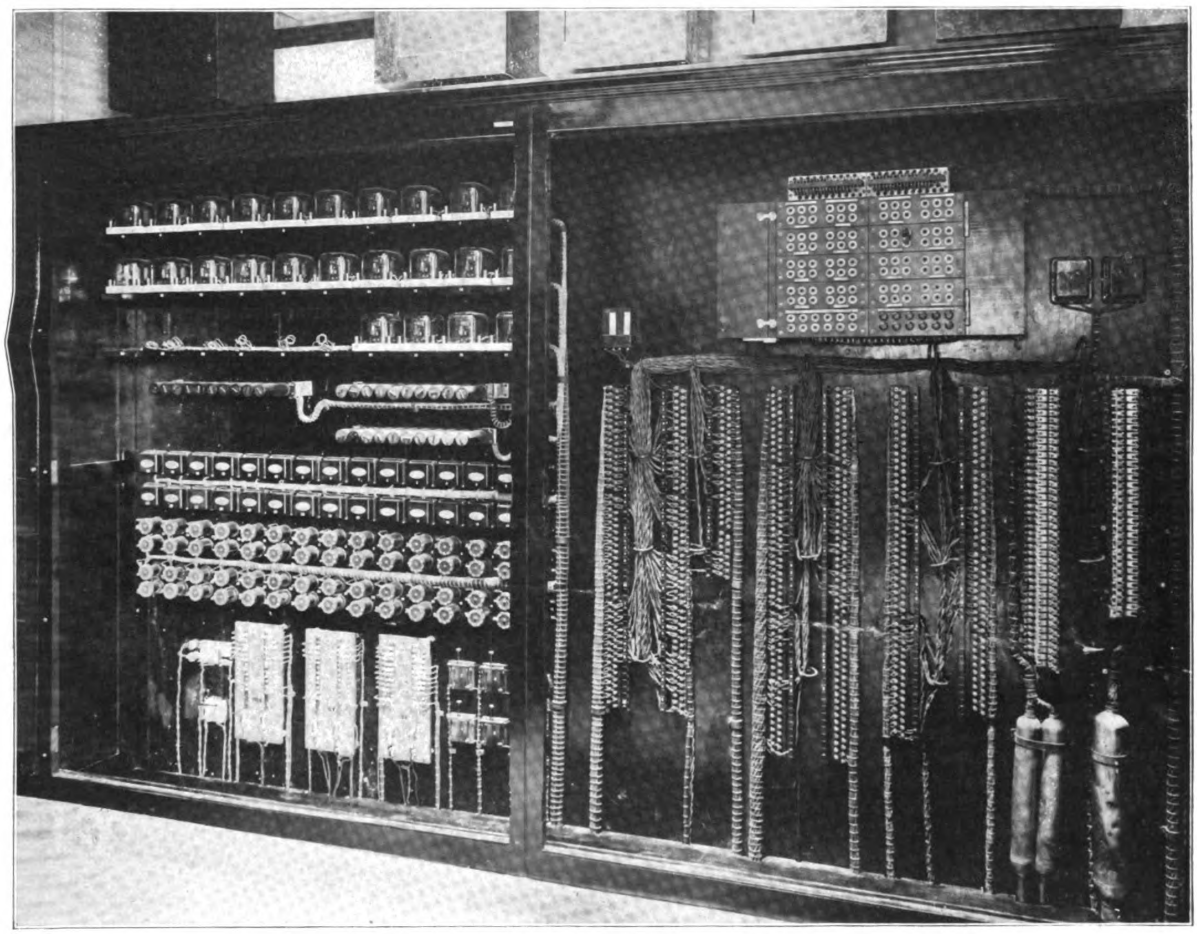

FIG. 59. Telephone Apparatus Cabinet, 180th Street Station.

Manholes are elliptical shaped, Fig. 57, four feet long and three feet wide and approximately three feet deep, with an opening three feet by two feet six inches. They are so designed that a person working in the manhole can stand erect. The cover is made of corrugated rolled steel plate secured by bolts, and can be removed and replaced by one man.

The entire telephone system was installed by the Western Electric Co. and the conduit was put in by G. M. Gest as subcontractor.