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ELEMENTS OF THE AUTOMATIC TELEPHONE SYSTEM

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The following publication, entitled "Elements of the Automatic Telephone System," Wire Communication Pamphlet No. 11, is published for the information and guidance of all concerned.

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BY ORDER OF THE SECRETARY OF WAR:

JOHN J. PERSHING,
General of the Armies,
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OFFICIAL:
P. C. HARRIS,
The Adjutant General.

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ELEMENTS OF THE AUTOMATIC TELEPHONE SYSTEM.

SCOPE OF PAMPHLET.

The studies of the automatic system are divided into two parts. Part I is an elementary discussion of the system based on an article prepared for the Chief Signal Officer of the Army by the Automatic Electric Co. Part II was prepared by the telephone section of the Bureau of Standards for the Chief Signal Officer. Part II gives functionalized circuit drawings of the automatic system.

PART I.

ELEMENTARY DISCUSSION OF AUTOMATIC TELEPHONE SYSTEM.

SECTION I.

INTRODUCTION.

1. *Definition and advantages.*—An automatic telephone system is one in which connections between subscribers' substations are set up and released, not by central-office operators, but by machines which are controlled by the subscriber at the calling station. The advantages claimed for the automatic system described here (Strowger type) are briefly: Saving of operators' salaries, training expenses, and accommodations; positive and rapid sending of call number; positive and accurate busy or ringing signals; long life and immunity from faults; uniform speed of connection and disconnection which tends to reduce peak-load conditions.

2. *Purpose of switchboard mechanisms.*—The central-office mechanisms, or automatic switches, are grouped together and mounted in frames to form switchboards. Their purpose is essentially the same as that of an operator in a manual system, namely, to connect the calling station with the one desired, to test the called line and return

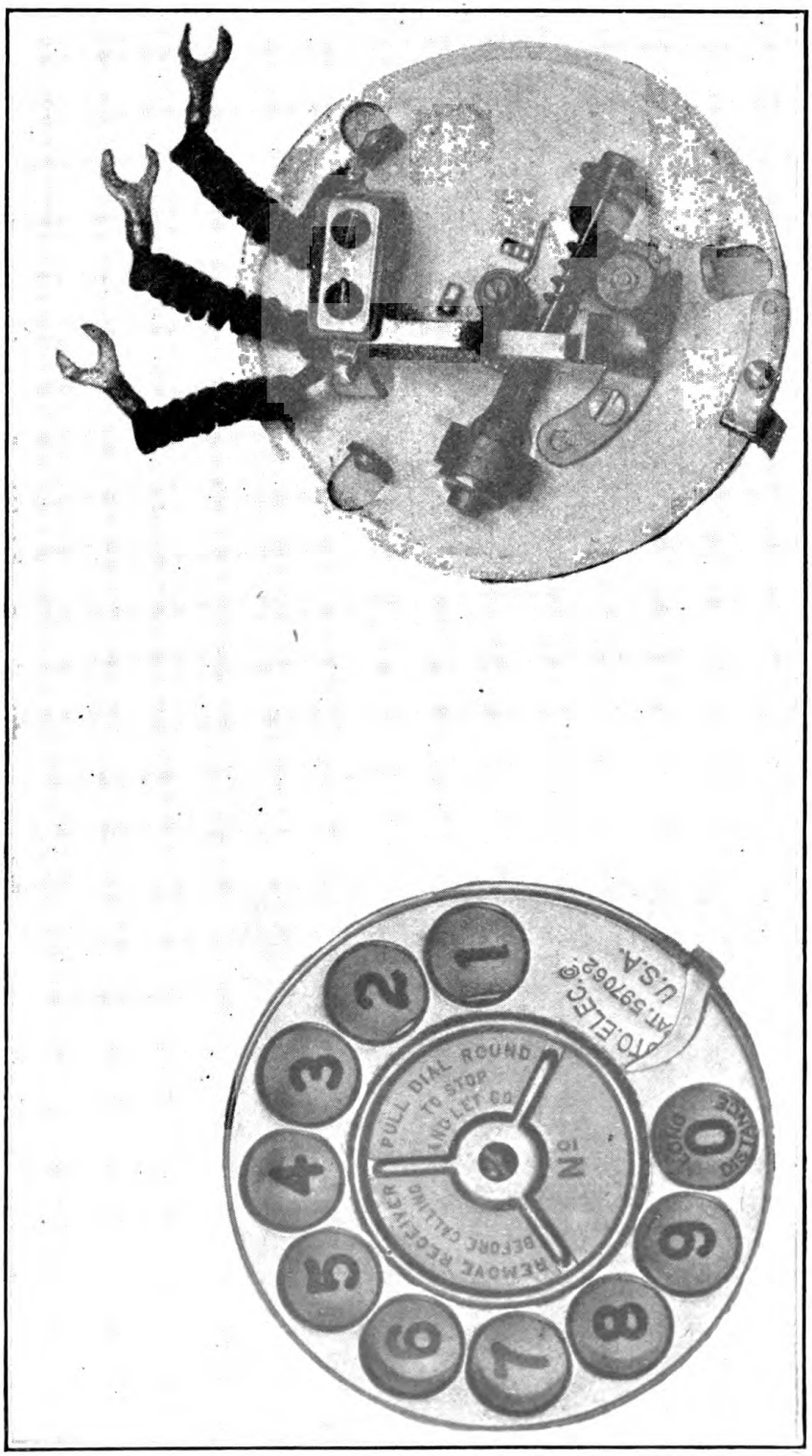


FIG. 1.—Dial calling device.

a definite signal if the line is busy, to ring the called bell if idle, to provide for the transmission of the voice, and to release the connection when conversation is finished.

3. *Method of calling a number.*—To enable the calling subscriber to control the central-office equipment so that it will connect his telephone with the proper station, his telephone is fitted with what is known as a dial calling device. (Fig. 1.) Besides this, there is of course the customary transmitter and receiver and bell box of the ordinary common battery telephone. To call a number on the automatic system the calling subscriber places his finger in a certain one of the holes in the dial and turns the dial until his finger strikes a stop. Upon releasing the dial it returns to normal and, in doing so, generates, by making and breaking a circuit having its battery at the central office, a number of electrical impulses which are transmitted to the central-office equipment. The operation is repeated for each figure of the call number.

4. *Equipment of a 100-line system.*—To facilitate the study of this system it is better at first to consider an exchange of only 100 lines. Such an exchange consists of 100 telephones and their lines (two wires each) leading to the central office, each line terminating in a line switch; 100-line switches (fig. 2), one attached to each line; a number of connector switches (fig. 3) sufficient to carry the traffic; and power equipment for supplying battery and ringing currents.

5. *Purpose of connector switch.*—The purpose of the connector switch is to do the work that is ordinarily done by an operator in a manual system. It must first search out the called line under the control of the calling subscribers' calling device, then test the line to see if it is busy or idle. If busy, the connector denies the connection and returns an audible busy signal on the calling line. If the line is idle, the connector rings the bell of the called station until the call is answered, or until the calling subscriber releases. When conversation is finished and both receivers are replaced, the connector switch is released ready for further use. (Sometimes the equipment is arranged so that the disconnection is made either by the calling or called party or both.) The number of connectors supplied for a 100-line board varies from 8 to 20. One connector switch is in use during one conversation. It will be convenient for our purpose to consider a 10-connector switchboard.

6. *Purpose of line switch.*—When the receiver is removed from the hook at the calling telephone, the line switch operates to connect the calling line with an idle connector. The line switch takes no further part in the connection, but releases when conversation is finished.

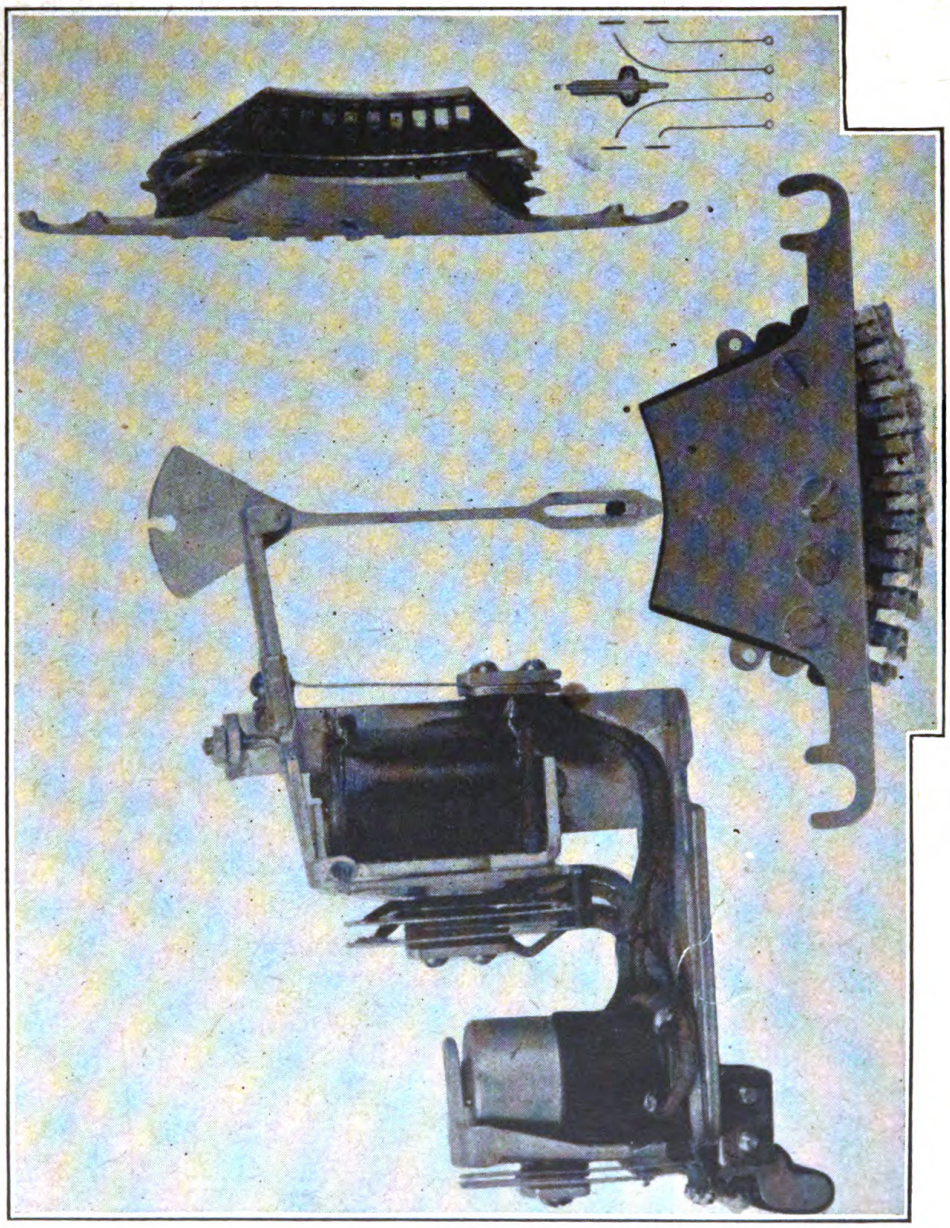


FIG. 2.—Plunger line switch with bank.

SECTION II.

DESCRIPTION OF CONNECTOR SWITCH.

7. *Parts of connector switch.*—The connector switch (fig. 3) consists essentially of the following parts:

(*a*) A vertical shaft (A) carrying on its lower end three wiper springs (W).

(*b*) Vertical magnet and ratchet (B) by means of which the shaft may be lifted a step at a time from 1 to 10 steps.

(*c*) Rotary magnet and ratchet (C) by means of which the shaft may be rotated a step at a time from 1 to 10 steps, beginning after any number of vertical steps. This rotary motion takes place against the action of a spring (D) at the top of the shaft.

(*d*) Release magnet which, when operated, serves to release the ratchet detent and permit the shaft to drop to its normal position.

(*e*) A group of relays for transmitting the selective impulse to the vertical and rotary magnets and for controlling the other operations of the connector.

(*f*) The line bank (E) consisting of 100 pairs of brass contacts arranged in 10 semicircular rows containing 10 pairs of contacts per row. These contacts are the terminals of the 100 telephone lines.

(*g*) Private bank (F) of 100 single contacts arranged in a similar manner and placed above the line bank. These contacts are for the purpose of guarding the called line for interior off-normal springs.

(*h*) A set of contact springs (G) which are arranged to operate at the first upward step of the shaft and to remain operated until the shaft returns to its normal position.

8. *Arrangement of wiper springs and contact banks.*—The relation between the wiper springs and the contact banks is such that when the shaft is given a certain number of vertical and rotary steps the private (upper) wiper spring and the two line (lower) wiper springs will rest on the line and private contact corresponding to the number of vertical and rotary steps made. If, for instance, the number 25 is called on the calling device, the vertical magnet is first operated twice, stepping the shaft up until the wipers are resting *in line with* the second row of contacts. Then the rotary magnet is operated five times, stepping the shaft around until the wipers are resting on the fifth set of contacts in the second row, which contacts are the terminals of (circuit) No. 25.

9. *Connections between different connectors.*—To make it possible for *any* connector switch to call *any* one of the 100 lines the corresponding contacts of all line and private banks are connected in multiple. That

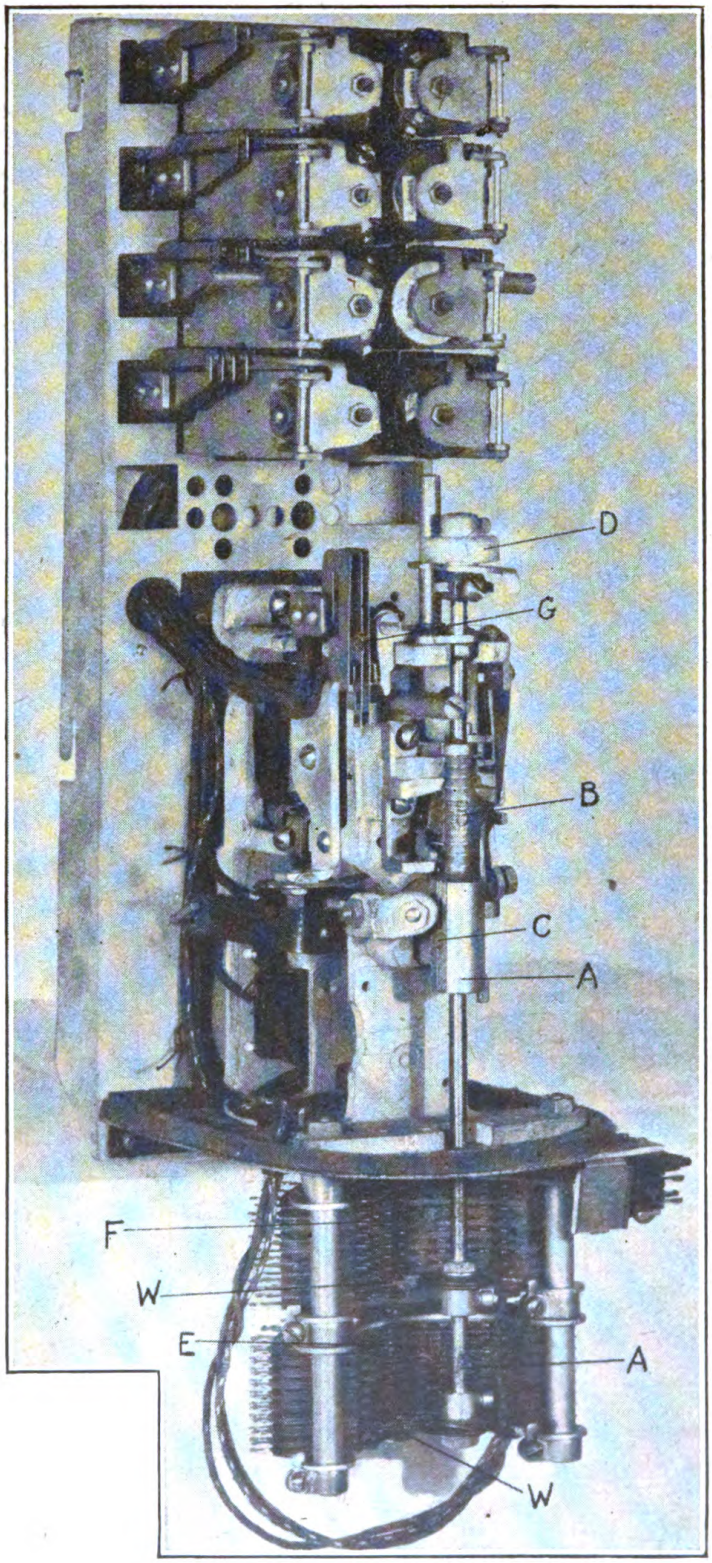


FIG. 3.—Connector with banks.

is, contacts No. 11 of the first switch are connected to contacts No. 11 of all other switches, and so on. It is to be remembered that there are 10 connector switches in the system here discussed.

SECTION III.

ACTION OF CIRCUIT FROM TELEPHONE TO CONNECTOR SWITCH.

10. *Condition of circuit.*—To facilitate further study of the system it is to be assumed at first that the receiver has already been lifted and that the telephone line has already been extended by means of the line switch to the connector switch. The action of the line switch will be described later.

11. *Details of the telephone instrument circuit.*—In its simplest form the telephone circuit consists of a bell and condenser in the signaling branch, a transmitter and receiver in the talking branch, a dial calling device, and a hook switch. With the exception of the dial, it is a simple common battery telephone. The dial calling device adds a pair of impulse springs (CD) for breaking and making the circuit so as to control the switches in the central office and a shunt spring which cuts out the talking apparatus during the time that the dial is in operation. These are shown in figure 4. This is done to reduce the noise in the receiver and to permit dialing to occur in a circuit of low resistance.

12. *How the action of the dial is transferred to the connector switch.*—In calling, say, the No. 56, the calling subscriber first places his finger in the hole of the dial through which the figure 5 appears. He then turns the dial in a clockwise direction until his finger strikes a stop. When the dial is released, it rotates back to normal, and in doing so causes the impulse springs to open and close a number of times corresponding to the figure dialed, in this case five. To call the second figure, 6, a similar operation is repeated.

The line circuit (fig. 4) includes at the central office a line relay (LR) and battery and at the telephone the impulse springs (CD) of the calling device. The dial by breaking and making the circuit causes the line relay to operate in groups of impulses, depending upon the number called. The line relay repeats these impulses through the release relay (Rel. Relay) and the series relay to the magnets (MAG) which operate the connector switch. It is to be noted that, in figure 4, the circuits and functions of the line switch are not shown. This is done for the sake of simplicity. The location of the line switch in the circuit is shown by the broken lines.

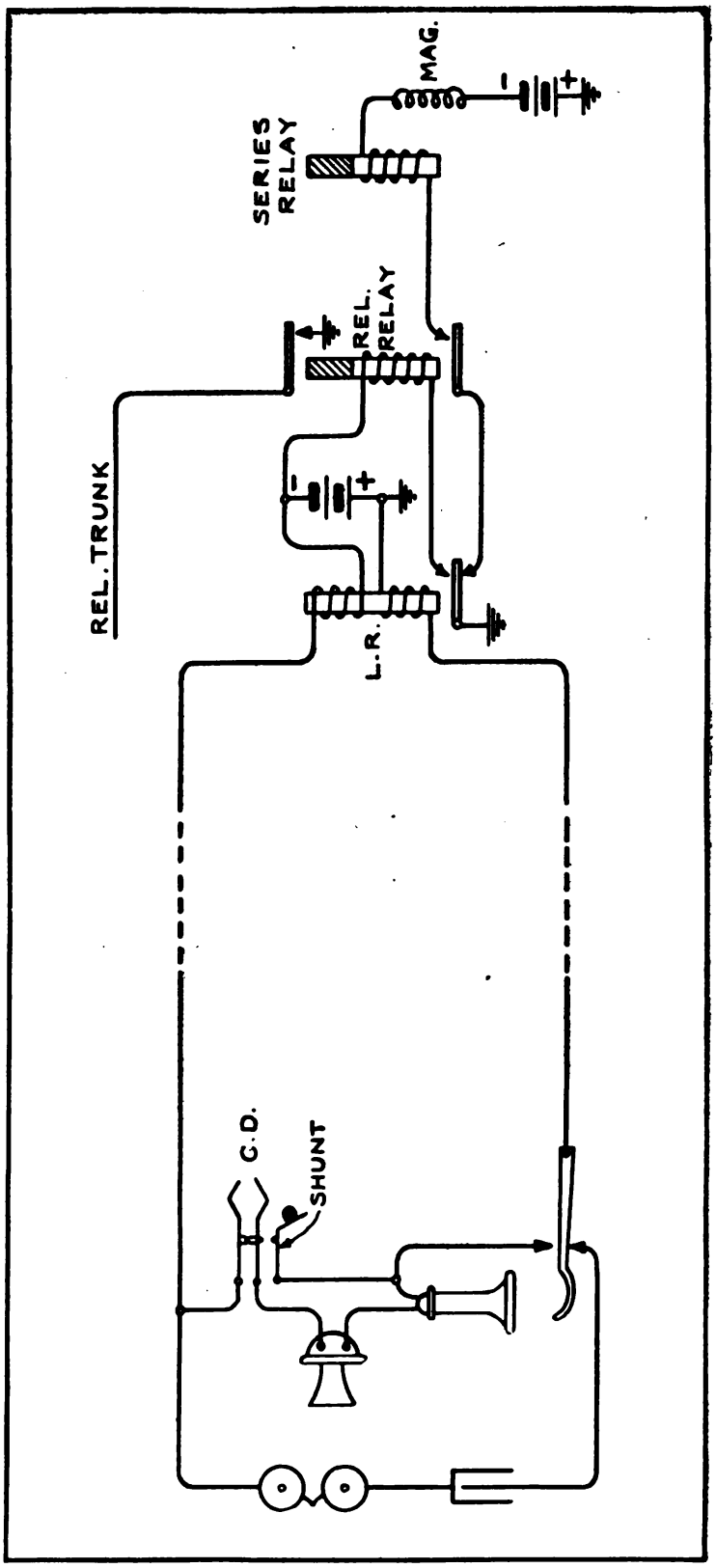


FIG. 4.—Simplified line circuit.

SECTION IV.

CONNECTOR SWITCH CIRCUITS.

13. *Function of connector switch.*—The functions of the connector switch are as follows: (1) To protect the calling line; (2) to lift and rotate the wipers to the desired pair of contacts under the control of the calling device; (3) to keep the wipers clear until the called line has been prepared for connection; (4) to test the called line to see if it is busy, preventing connection thereto and notifying the calling subscriber by a busy tone; (5) to seize the called line if it is free, sending ringing current to called telephone and cutting it off when the subscriber answers; (6) to furnish connections to battery for battery transmission of the voice; (7) to release connections when both subscribers hang up their receivers.

14. *Action of the release relay.*—When the subscriber takes his receiver from the hook, the line relay pulls up. It must be remembered throughout the following discussion that the line relay is always energized when the receiver is off the hook except when the connections are broken by the dial rotating. The line relay in turn energizes the release relay, which places a ground upon the wire marked "release trunk." (Fig. 4.) The release relay also connects through the series magnet the impulsing circuit to the vertical magnet of the connection (MAG). The release relay is of the slow release type. It will remain energized during a series of impulses made by the line relay and will fall back if the line relay is deenergized much longer than one impulse period. Part of the circuit shown in figure 4 is also shown in figure 5, A being the line relay; B, the release relay; C, the series relay; and "VERT," the vertical magnet.

15. *Action of the first series of impulses.*—Some provision must be made so that the first series of impulses generated by the line relay will operate the vertical magnet (VERT) and after a brief pause, a second group of impulses will operate the rotary magnet (ROT). This shifting is caused by the joint action of the series relay (C) and the off-normal springs (ONS). The line relay (A) contact moves in response to the calling device. The impulses which it generates pass through the off-normal springs (ONS), (as noted above, the release relay remains energized), the windings of the series relay (C),

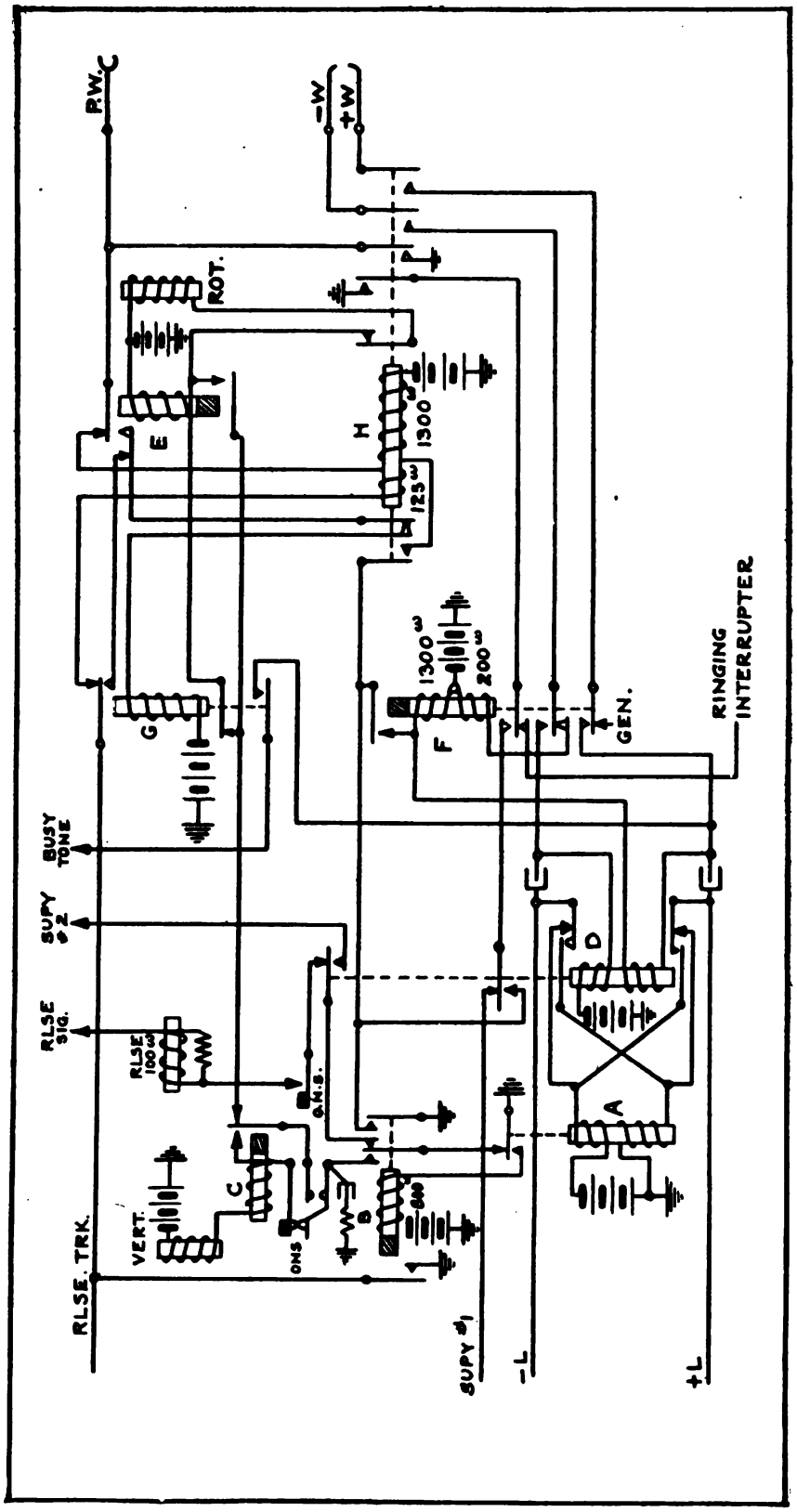


FIG. 5.—Simplified circuits of the connector switch.

and the windings of the vertical magnet. The first pulsation through this circuit energizes both devices. The series relay (C) pulls up ahead of the vertical magnet. When the vertical magnet lifts the shaft, the off-normal springs are operated by the shaft and remain operated until the shaft drops back to normal position. The off-normal springs cut off the direct connection to the series relay coil and establish it by way of the front contact of the same. The series relay is slow releasing. Consequently, as long as the pulsations continue to come, this circuit will be maintained. If, however, the line relay stops sending pulsations for a short time, the series relay (C) will fall back and divert the circuit from the vertical magnet to the rotary magnet and its associated slow release relay (E).

16. *Action of the second series of impulses.*—The second series of impulses generated by the line relay under the control of the calling device pass through the off-normal springs, back contact of series relay, back contact of relay (G), to the rotary magnet and relay (E) in parallel. The first impulse causes both of them to act together, relay (E) closing another contact, which permits pulsations to come regardless of the condition of contact of relay (G). Relay (E) is also slow releasing so that as long as the impulses come from the line relay (A) at the customary frequency, the circuit will be maintained. If contact of (G) should be open at the time that the line relay ceases giving impulses, relay (E) will fall back, thus breaking the circuit and rendering any further rotary motion impossible.

17. *Testing of a called line.*—The testing of a called line is the duty of relay (G). During the time that rotary impulses are being sent, relay (E) was energized. When rotary impulses stop coming, the line wipers (−W, +W) are resting upon the called line and the private wiper (PW) is resting upon the private contact which belongs to the same line, these connections having been made by the successive movements of the vertical and rotary magnets. If the called line is busy, there will be a positive battery or *ground* connection upon this private contact. This is the signal or indication that the line is occupied. If this is the case, current will immediately flow from this ground through the private wiper, front contact of relay (E)—which is energized—winding of relay (G) to negative battery. Relay (G) will therefore energize and make the busy-tone contact, placing a busy tone upon the positive line leading to the calling subscriber's telephone. Relay (E) will fall back because rotary pulsations have ceased, and therefore relay (G) will remain locked in an energized position through one of its own contacts to the ground at the release relay (B). The only thing the calling subscriber can do is to hang up his receiver. This breaks all connections and the apparatus returns to normal.

18. *Seizing the called circuit.*—If the called line is not busy, there will be no ground upon the private contact and relay (G) will not pull up. This permits the establishment of the seizing circuit. This seizing circuit passes from ground at the release relay (B), through the back contact on relay (G), the 125-ohm winding on relay (H), the back contact of relay (E), the private wiper (PW), the private bank contact (not in drawing) through a coil associated with the called line to negative battery. Relay (H) pulls up by its 125-ohm winding (there are seven makes or breaks) and locks itself by its 1,300-ohm winding, which obtains its ground at release relay (B). Relay (H) also places a dead ground upon the private wiper so as to prevent the called line from being seized by any other connector. The same relay (H) connects the ringing relay (F) to the line wipers so that ringing current will be sent to the called telephone.

19. *The ringing circuit.*—The ringing circuit comes through a grounded generator, through positive line wiper, through the called telephone bell, back to the negative line wiper, and through a 200-ohm winding on the ringing relay (F) to negative battery to ground. Relay (F) is made in such a form as to prevent its operation by the alternating current used for ringing. It will, however, operate with direct current which flows from the battery at (F) when the called subscriber lifts his receiver, thus substituting the talking apparatus for the *condenser* and bells. The ring-off relay (F) on pulling up by its 200-ohm winding locks itself through its 1,300-ohm winding, cuts off the ringing current, and switches the lines to the talking apparatus. The battery associated with relay (F) finds its ground near relay (B).

20. *The talking circuit.*—Conversation is carried on through the connector switch by means of relay impedances and condensers. The back bridge relay (D) supplies current to the called telephone. The line relay (A) performs the same function for the calling telephone. It is customary to arrange it so that the back bridge relay (D) reverses the connections of the line relay (A) as shown. This also permits the use of message registers on the line. The talking circuit, as well as other circuits, is shown separately in figure 6. These circuits are parts of the complete circuit shown in figure 5.

21. *Effect of hanging up receivers.*—When both subscribers hang up their receivers, line relay (A) and back bridge relay (D) both fall back and establish the release circuit. This release circuit also passes through the off-normal springs (ONS) which are closed as long as the shaft and wipers are away from normal. The operation of the release magnet causes the shaft and wipers to rotate and drop to normal, which opens the off-normal springs (ONS), cutting off the current.

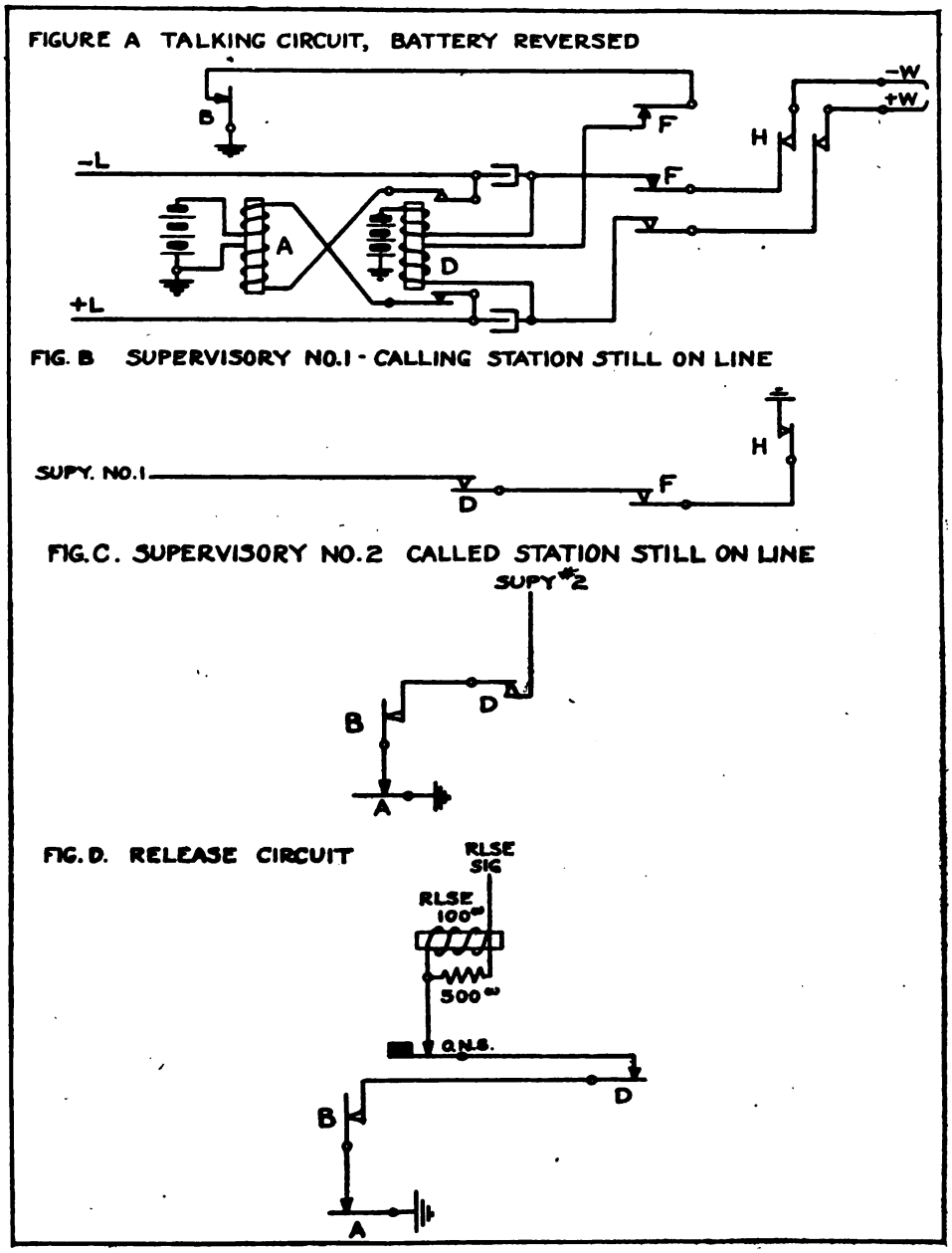


FIG. 6.—Circuits of the connector switch shown separately.

SECTION V.

THE ROTARY LINE SWITCH.

22. *Function of rotary line switch.*—There are two kinds of line switches, the rotary and plunger types. The functions of the rotary line switch are as follows: When a subscriber initiates a call, the switch must extend the line to an idle connector; it must protect the calling subscriber by placing a ground upon the private normal so that the connector switch will find the line busy; it must clear the talking circuit of the apparatus at the line switch. When a call is sent from a connector to the line to which the line switch belongs, its only function is to clear the talking circuit of the apparatus at the line switch.

23. *Description of rotary line switch.*—The rotary switch consists of three semicircular rows of contacts and three wiper springs driven by a single magnet through a ratchet. The wipers have no normal position, but rest where they were last used. Each rotary line switch has also its line and cut-off relays. Those relays are so arranged mechanically that unless the line relay is first energized, the cut-off relay can pull up only far enough to break its break contacts, but not make its make contacts. It is to be noted that the line relay of the switch is not identical with the line relay of the connector.

24. *Action of line switch on calling line—Private wipers on idle contact.*—The electrical circuits of the rotary line switch (fig. 7) involve a line relay (LR), a cut-off relay (COR), and a rotary magnet (ROT). The circuit from the telephone passes normally directly to ground on the positive side and through a 630-ohm slow release line relay on the negative side. When the subscriber initiates a call, the line relay closes two contacts, one of which places a dead ground on the private normal (PN) to protect the calling line from intrusion. In addition, they set up the trunk-hunting circuit, shown schematically in figure 7. There is a complete circuit extending from the ground at the line relay contact through the cut-off relay and the rotary magnet. There is a by-pass extending from a point between the rotary magnet and cut-off relay to the private wiper. If the private wiper is resting upon an idle *ungrounded* contact, the cut-off relay will immediately pull up, moving its contacts all the way up, switching the line to the connector and grounding the private wiper at the line relay contact. Since the line relay is now cut off, it must depend upon its slow releasing property to hold it energized until the connector line relay and connector release relay can place a ground

upon the release trunk which is connected to the bank contact upon which the private wiper is resting. After this the line relay of the line switch may fall back. There is ample time overlap to prevent any trouble. The cut-off relay now remains energized over the release trunk to the connector. The rotary magnet can not pull up through the resistance of the cut-off relay.

25. *Action of line switch on calling line—Private wipers on busy contact.*—If, when the subscriber initiates a call, the trunk upon which the wipers are resting is busy, there will be a ground on the private contact which the private wiper is touching. Hence, in the trunk-hunting circuit there will be a dead short circuit by-pass from ground to the point between the rotary and cut-off relay. The cut-off relay

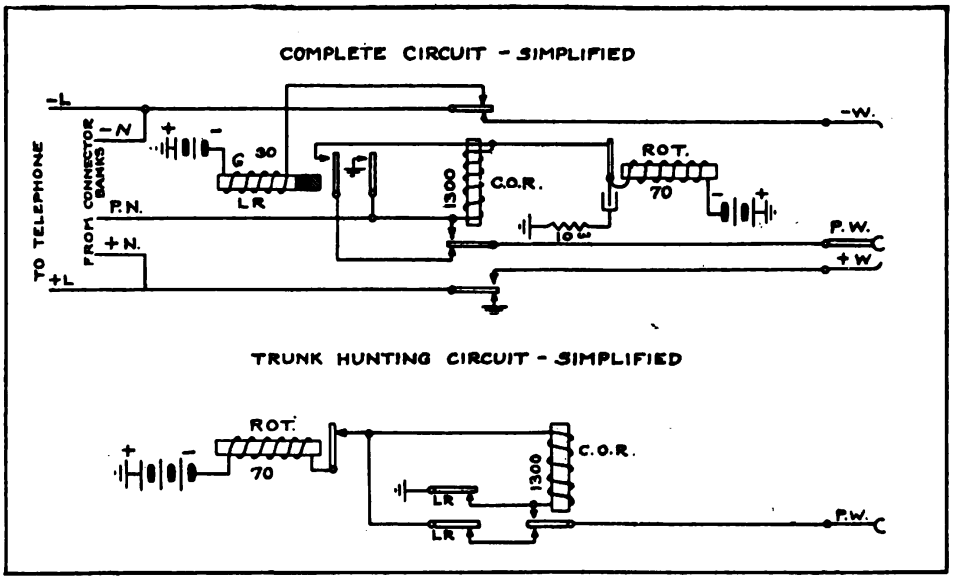


FIG. 7.—Rotary line switch circuit.

is, therefore, short circuited, and the armature of the rotary magnet will begin to vibrate like the armature of a door bell, driving the wipers off the busy contact and continuing to vibrate until the private wiper strikes an ungrounded contact. Then the cut-off relay will be able to pull up and switch the lines through as above described.

26. *Action of line switch on called line.*—When a call comes through a connector to the line whose line switch is being studied, it will arrive over the normal wires. The two line wires are marked "+N" and "−N" and the third wire is marked "PN." The connector switch first places a ground upon the private normal (PN), which energizes the cut-off relay. As has been previously stated, there is an interlocking device associated with the line relay and the cut-off relay which is so arranged that the cut-off relay can move its armature only half way up when the line relay is not energized. Since the line relay is not energized on an incoming call, the cut-off relay is therefore

able to move its armature only halfway, breaking all back contacts but not closing any front contact. This accomplishes the desired clearing of the line so that ringing and talking may proceed

SECTION VI.

THE PLUNGER LINE SWITCH.

27. *Functions of the plunger line switch.*—The functions of the line switch, together with its master switch, are briefly, as follows: When a subscriber initiates a call, the line switch must extend the line to an idle connector; it must protect the calling subscriber by placing a ground upon the private normal (PN), so that connector switches will find this line busy; it must inform the master switch that the trunk seized is now busy. This is done by placing a ground upon one of the master-switch bank contacts. The line switch must also clear the talking circuit of apparatus at the line switch, which it does by cutting off the line relay, battery, and ground. When a call is sent from a connector to the line to which this line switch belongs, it is only necessary to cut off the line relay and ground. There is one master switch to a group of line switches. The master switch directs all idle plungers of line switches to idle trunks.

28. *Principle of the plunger line switch.*—The plunger line switch is built upon radically different lines from the rotary type. Imagine 100 telephone lines running horizontally, of which only 8 are shown in the figure. (Fig. 8–A.) Imagine 10 trunks running vertically, of which only 4 are shown. Any telephone line could be connected to any trunk line by pinching two wires together at the point of intersection, as is shown by the heavy dots connecting line No. 1 to trunk No. 3, line No. 2 to trunk No. 1, etc. A little switch can be placed at each of the intersections. (Fig. 8–B.) Each little switch consists of a stationary plate attached to the trunk and a flexible spring attached to the subscriber's line. By pressing any flexible spring, we can connect a line to a trunk at will. The handle by means of which any switch is operated is called the plunger. It is mounted on a plunger arm which may be moved by a pull-down coil. The pull-down coil is under the control of the calling subscriber. The position of all the idle plungers is controlled by the master switch, which is so arranged as to direct all the idle plungers to idle trunks. (Fig. 8–C.)

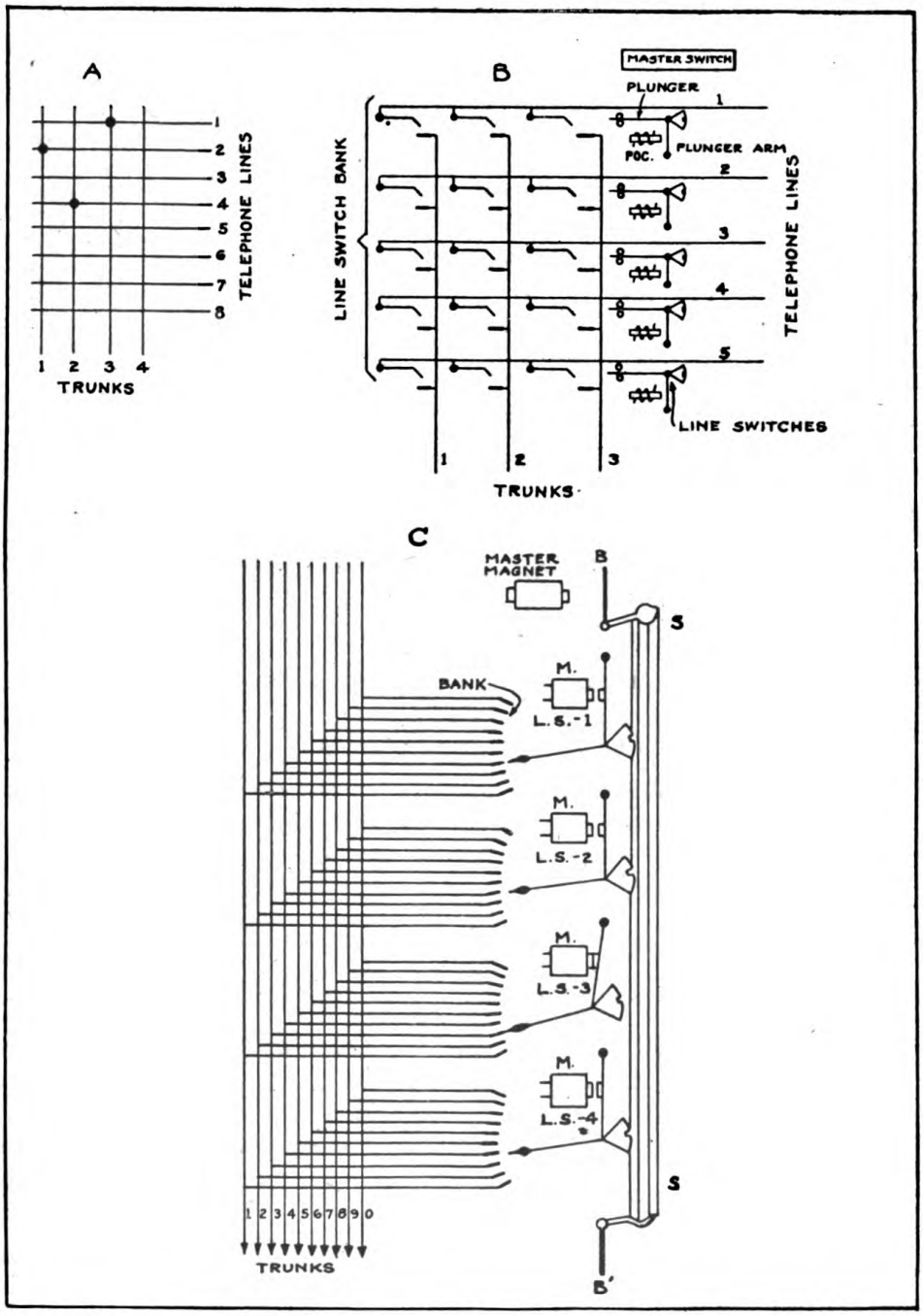


FIG. 8.—Scheme of the plunger line switch.

29. *Description of the plunger line switch.*—The plunger line switch (shown in fig. 9) consists of a slow-acting line relay (LR); a double wound combination pull-down coil (PDC) and cut-off relay (BCO); a cut-off armature (controlling contacts 11, 12, 13, and 14 in the figure); a plunger arm (PA) carrying the pivoted plunger; and a bank of contacts consisting of 10 sets of contacts of 8 in each set. Normally the plungers of idle line switches are kept in alignment opposite the same idle trunk by the master switch. When a call comes in to the switchboard, the pull-down coil pulls the plunger into the bank, and in doing so closes four pairs of contacts (1 to 8), thus connecting the calling line direct with a trunk leading to an idle connector. At the same time the master switch operates to move the plungers of the remaining idle line switch until they are resting opposite the contacts of the next idle trunk.

30. *Circuits of the line switch proper.*—The circuits of the plunger line switch are naturally divided into two parts—the line switch proper and the master switch. (Fig. 9.) The line switch proper has the line circuit containing the line relay and battery; the pull-down coil circuit, which derives its negative battery connection from the master switch; the bridge cut-off relay circuit, whose winding is on the pull-down coil core and extends through the private normal (PN) to the connector banks (not shown in figure) and through the line switch bank (2–6) to the release trunk.

31. *Action of line switch on calling line.*—The reader will imagine a subscriber's telephone instrument across the two-line wires, +line and −line. He will also imagine the line relay of a connector bridged across the trunk wires, +trunk and −trunk, and supplying battery to them. When the subscriber takes his receiver from the hook, the line relay (LR) pulls up and closes the circuit of the pull-down coil (PDC). Immediately, the pull-down coil attracts both the plunger arm (PA) and the cut-off armature. The plunger arm pulls the plunger away from the guide shaft and into the bank, operating all of the contacts numbered from 1 to 8. Springs No. 1 and No. 4 extend the connection to the connector switch so that immediately the line relay of the latter pulls up, energizes the release relay, and places a ground upon the release trunk. This sends current back through spring No. 2 on the line switch bank to the bridge cut-off coil (BCO). This coil is strong enough to hold both armatures even after the pull-down coil current has died away (circuit broken by action of the cut-off armature breaking the line relay circuit). The line relay is slow acting so that the pull-down coil circuit will not be broken at the line relay armature until after the connector switch has grounded the release trunk so that the bridge cut-off coil can hold the plunger in the bank. The same ground on the release trunk also furnishes protection by way of the

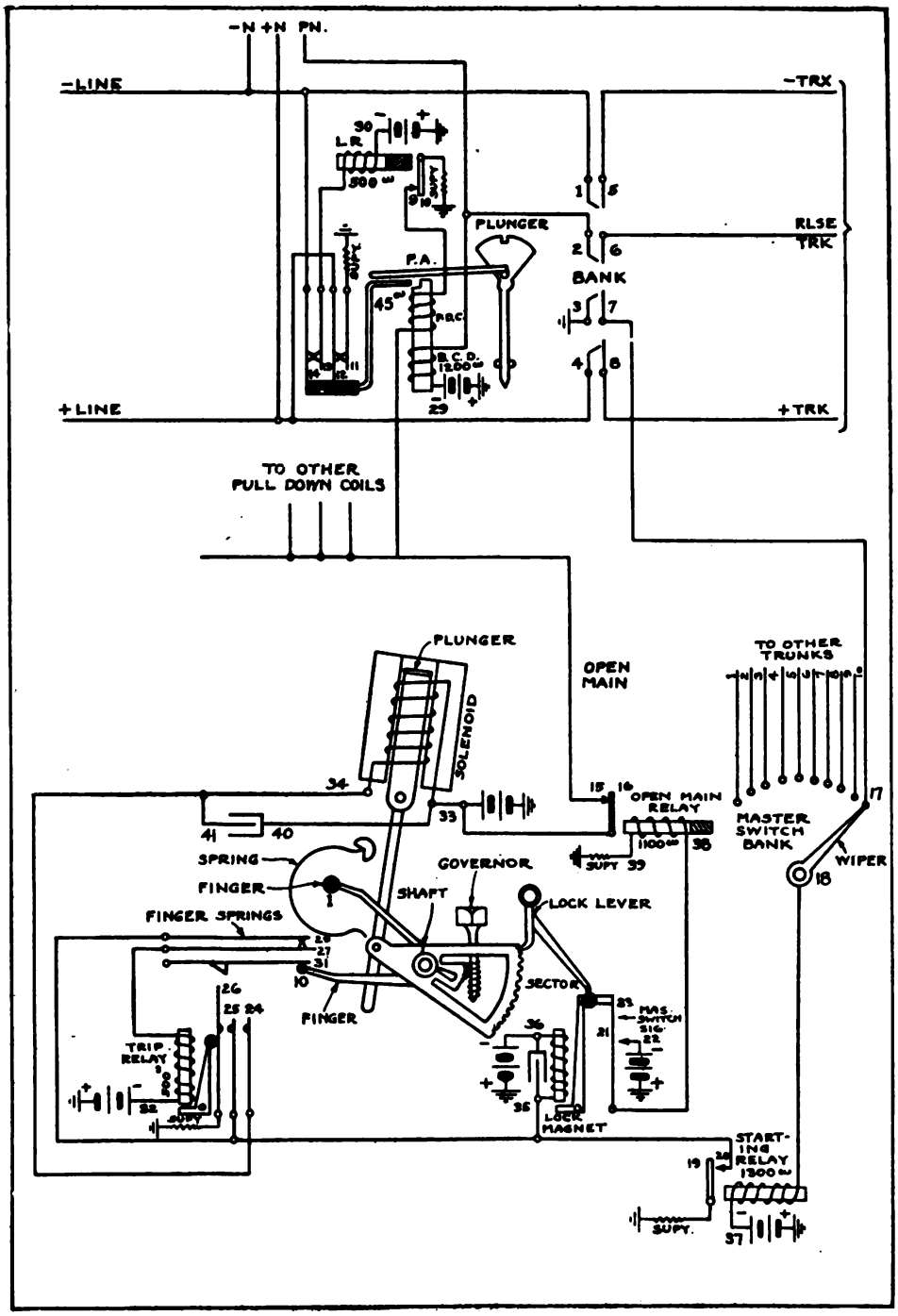


FIG. 9.—Plunger line and master switch circuits.

private normal (PN) to the connector banks. Bank spring No. 3 furnishes a ground to the master switch bank to indicate that the trunk is now busy. When the line relay of the connector is energized, it pulls up the release relay and the latter places a ground upon the release trunk. This action will be remembered as having been described for the connector switch.

32. *Action of the master switch.*—The master switch circuits consist of the starting relay, the lock magnet, the open main relay, the trip relay and solenoid magnet, all of which are shown in figure 9. When a trunk has become busy, the fact is indicated by a ground on the master-switch bank contact. This energizes the starting relay, which in turn pulls up the lock magnet. The lock magnet energizes the open main relay, thus disconnecting the battery supply of the pull-down coil of all line relays in this master switch group. This makes it impossible for any subscriber to operate his line switch while the master switch is hunting an idle trunk. The lock magnet also releases the escapement so that the spring may rotate the guide shaft, carrying the idle plungers toward other trunks. When the master switch wiper reaches an ungrounded contact, the starting relay falls back, the lock magnet lets go, and the escapement stops the guide shaft with all the plungers pointing toward this idle trunk. The open main relay now restores negative battery to the open main wire.

When the guide shaft reaches trunk No. 1, having passed over all the other trunks, the shaft finger No. 1 presses together the finger springs (27–28), closing one break in the circuit of the trip relay. Now, when trunk No. 1 is seized, the starting relay, in addition to pulling up the lock magnet, will also pull up the trip relay, which is mechanically locked in the operated position by the end of spring No. 26 catching on a lug on finger spring No. 31.

This action of the trip relay closes simultaneously the circuit of the lock magnet and of the solenoid magnet. The former releases the escapement, while the latter pulls the guide shaft back to trunk No. 10. During this motion, the guide shaft picks up any idle plungers which have been released from the bank. When the guide shaft arrives at trunk No. 10, shaft finger No. 10 presses spring No. 31 and releases the springs of the trip relay, cutting off the current from the solenoid and from the lock magnet. What follows depends upon the condition of trunk No. 10. If it is not busy, the shaft will stay there. If it is busy, the starting relay will cause the master switch to hunt the first idle trunk.

The lock magnet also controls contact No. 23, which leads to a master switch signal (not shown in figure). The adjustment is such that if the lock lever is not engaging the sector, current will be sent through the master-switch signal to indicate that something is wrong.

In series with the open main relay winding, is a supervisory relay (supy. 39, not shown in detail in figure) which operates after a certain time has elapsed. If all trunks should be busy, the master switch will vainly hunt an idle trunk. This means that the open main relay will be continuously energized. Supervisory No. 39 will indicate this fact, but will not respond to momentary action.

33. *Action of line switch on called line.*—When a call comes from a connector switch to the telephone to which this line switch belongs (through +N, −N, PN), the connector first grounds the private normal (PN) which results in energizing the bridge cut-off coil (BCO). As the magnet is not strong enough to move the plunger without the aid of the pull-down coil, only the cut-off armature responds, breaking the contacts No. 11, 12, 13, and 14, so as to clear the line of attachments. After this the connector sends out ringing current and later on conversation takes place.

SECTION VII.

SYSTEMS OF MORE THAN 100 LINES.

34. *1,000-line system.*—To build up a system of more than 100 lines, two or more such 100-line units must be provided, and provision made for the selection of the 100-line group containing the list desired. The trunking scheme of a 1,000-line system is indicated in figure 10. Upon the removal of the receiver the line switch extends the connection, not to a connector, but to a selector. Mechanically the selector is identical with the connector. Electrically it is much simpler, having but two signal functions, namely, to select the desired 100-line group, under the control of the calling device, and to select automatically a trunk leading to an idle connector serving that 100-line group.

Each level of contacts on a selector bank contains the terminal of 10 trunks leading to the 10 connectors of the corresponding 100-line group. If No. 261 (fig. 10) calls No. 805, for instance, he first dials the figure 8, which steps the shaft of the selector up until the wipers rest opposite the contacts of the eighth level. Immediately, and regardless of the calling device, the shaft rotates until the wipers are resting on the contact of a trunk leading to an idle connector. Dialing the two final digits operates the connector in the usual way.

35. *Systems larger than 1,000 lines.*—Systems larger than 1,000 lines are built up by grouping a number of 1,000-line systems in a similar way and providing another group of selectors, to choose the 1,000-line group desired. These two groups of selectors are known as second and first selectors, respectively.

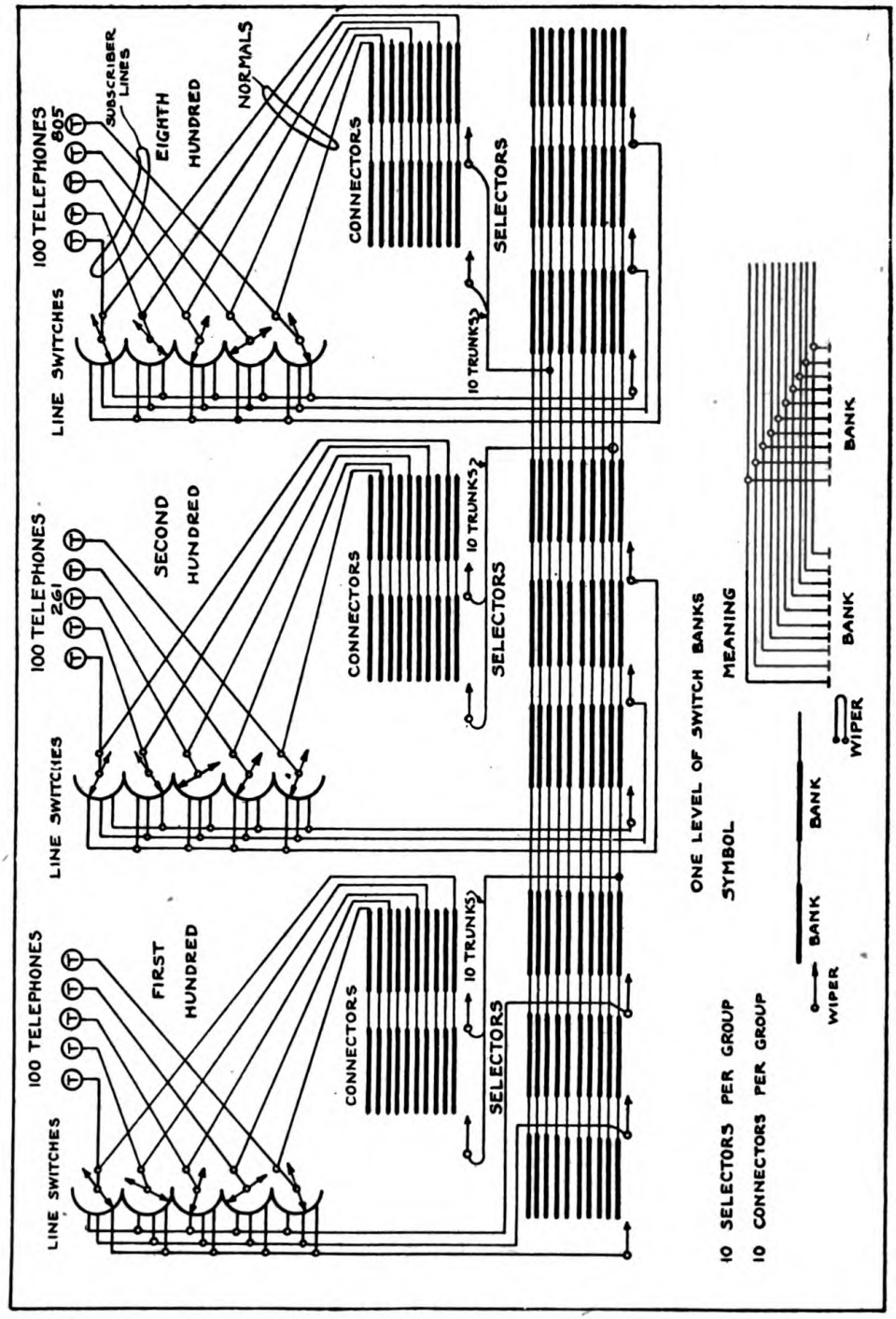


FIG. 10.—Trunk scheme—1,000 line automatic exchange using rotary line switch.

PART II.

CIRCUIT OPERATION OF THE PRIVATE AUTOMATIC TELEPHONE SYSTEM OF THE AUTOMATIC ELECTRIC CO.

SECTION I.

THE SYSTEM.

1. *Equipment described.*—The equipment covered by this description includes that which is required in the smaller so-called connector systems. Such systems require two types of switches, the fundamental selecting switch or connector and the line and master switch. These are arranged in units to serve either 50 or 100 lines.

2. *How a telephone line is selected automatically.*—The number of a line is the basis of its automatic selection. Lines are terminated on the multiple banks of the connectors and given a line number corresponding with the number of vertical and rotary steps the connector wipers (brushes) have to make to reach the called line terminals. Thus, when a connector lifts its wipers four vertical steps and rotates them eight steps the terminals of line 48 are engaged.

3. *Calling device.*—The calling device at the telephone is designed to open and then close the line circuit once or any number of times up to 10 at a uniform rate, the number of interruptions in a series being under control of the calling party. In a connector system there must be two of these series of interruptions, one to cause the vertical motion and one to cause the rotary motion.

4. *Purpose of line switches.*—If connectors were the only switches used, each line would have to be terminated on a connector switch for calling purposes as well as on the bank multiple. This would require as many connectors as there were lines and this would make the cost very high. To offset this is the purpose of the line and master switch. (The rotary line switch, as described in Part I, performs the same functions as both the line and master switches. Only the action of the latter is described, however, in Part II.) Each line is terminated on a line switch for calling purposes and on the connector multiple for incoming calls. These line switches are mounted in groups of 25

in two vertical rows, one row being mounted on each side of a spring assembly known as a trunk bank. Two of such groups of 25-line switches are required for a 50-line private automatic exchange and four for a 100-line private automatic exchange. The lines are multiple-wired horizontally to 10 sets of springs in the trunk bank. Ten trunks are multiple-wired vertically through the springs of the trunk bank. Thus each line has the possibility of being connected to any one of the 10 trunks.

5. *Purpose of master switch.*—The master switch determines the order of trunk selection. This it accomplishes by aligning the plungers of the associated idle line switches before an idle trunk after each call, in order that the next line switch will be also connected to an idle trunk. The distant end of the trunks terminate on connectors.

6. *Special services on automatic system.*—Most private automatic exchange installations are wired for special services such as watchman's recorder service, code call, etc., but the following description will not include their operation.

SECTION II.

THE LINE AND MASTER SWITCH.

7. *General functions.*—The line switch and the master switch, although separate mechanisms, are so interrelated that they will be considered jointly in the following description. Briefly stated, the purpose of the line and master switch is to connect any *calling line* in a relatively large group to one of a smaller number of selecting mechanisms, and later to disconnect the line from the selecting mechanism when the calling party hangs up the receiver. For instance, a private automatic exchange could have 45 working lines which would require 45 line switches. Supposing that 8 connectors (selecting mechanisms) were supplied, then it is the function of the line and master switch to connect any one of the 45 lines that may originate a call to an idle connector. The mechanics of the line and master switch will not be described here, as that can best be studied directly from the apparatus.

8. *Detailed functions of line switch.*—Taken alone, the detailed functions of the line switch are as follows:

When calling—(*a*) To disassociate itself from the master switch control, which determines the trunk selection, and to connect the calling line via an idle trunk to a connector.

(*b*) To clear the calling line of attachments—that is, the line relay and ground.

(*c*) To connect with the selecting device (connector) at far end of trunk in such a manner that that device will hold the calling line switch operated.

(*d*) To protect the calling line from intrusions—that is, make it test busy.

(*e*) To close the master switch circuit, which controls the trunk selection, so that when another line switch subsequently operates it will connect with another trunk.

(*f*) On release, to release the trunk, reconnect the line relay and ground to its line, and reassociate itself with the master switch control.

When the line is called—(*g*) To clear the called line of attachments—that is, the line relay and ground—without other operation.

9. *Detailed functions of the master switch.*—The functions of the master switch, considered alone, are as follows:

(*a*) After each connection of a calling line to an idle trunk, to so align the idle line switch plungers with respect to the trunk bank that the next connection will be made to an idle trunk.

(*b*) To prevent the operation of *any* line switch plunger during the process of realignment—that is, while those plungers still attached to the master shaft are in rotary motion.

SECTION III.

DETAIL OPERATION OF LINE AND MASTER SWITCH CIRCUIT.

10. *Conventions employed in diagrams.*

The following diagrams give a description of the functions and detailed circuit operation of the private automatic exchange type of line switch and master switch. Drawing I shows the line and master switch circuit in the normal or unoperated condition.

The following conventions are employed in the diagrams:

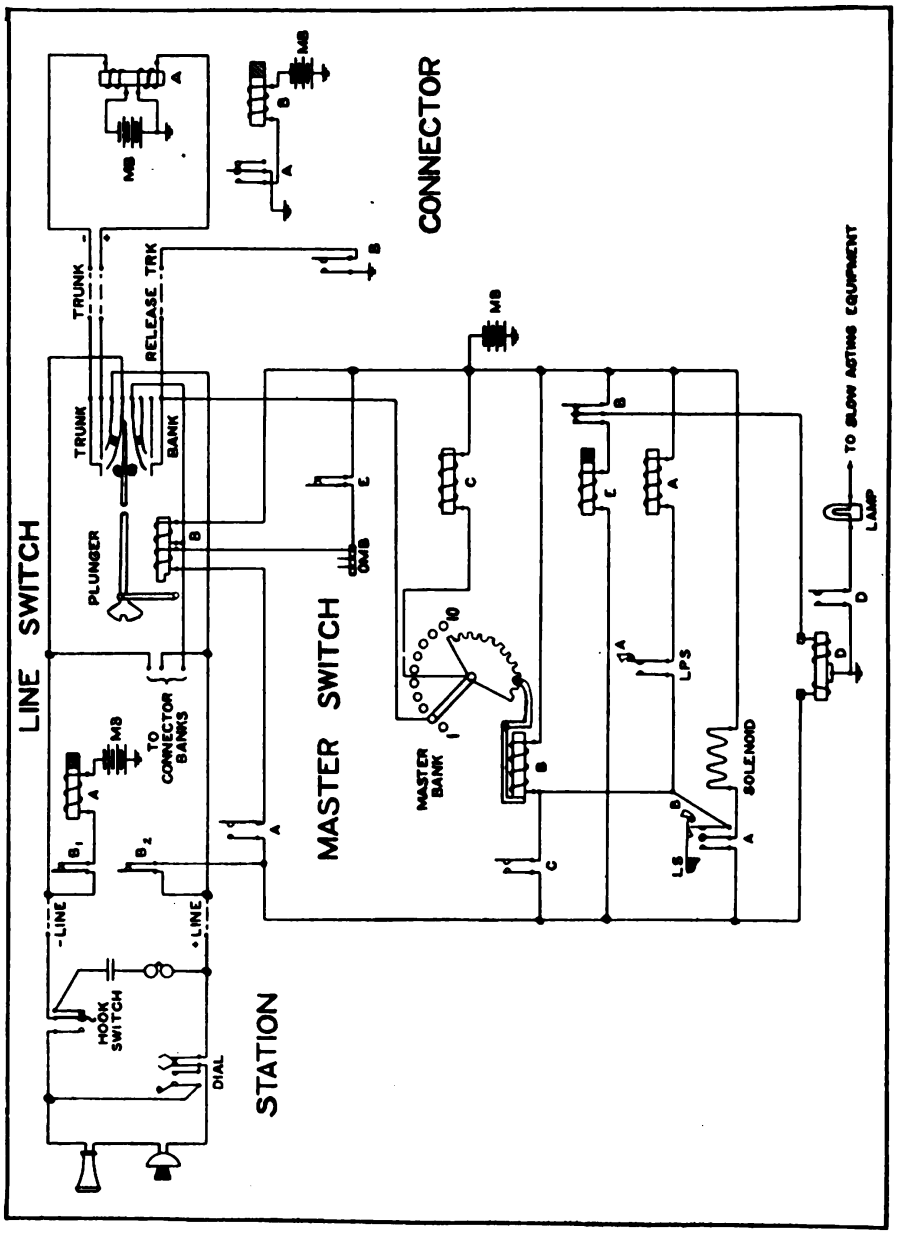
(*a*) To facilitate the tracing of the circuit, relay and magnet springs are shown separated from their coils.

(*b*) Energized relays and magnets are surrounded by magnetic fields.

(*c*) Conductors carrying current are shown by heavy lines.

(*d*) Component circuit elements are arranged as far as possible in order of first operation.

(*e*) Springs of contact sets are shown in parallel when in the normal or unoperated position.



DRAWING I.—Showing circuit in the unoperated condition.

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11. *Line calling—seizure of a trunk.*

(1) Subscriber lifts receiver from hook, operating hook switch. Disconnects bell and condenser from line and closes line circuit through line relay A, at the same time closing circuit of supervisory ground relay D.

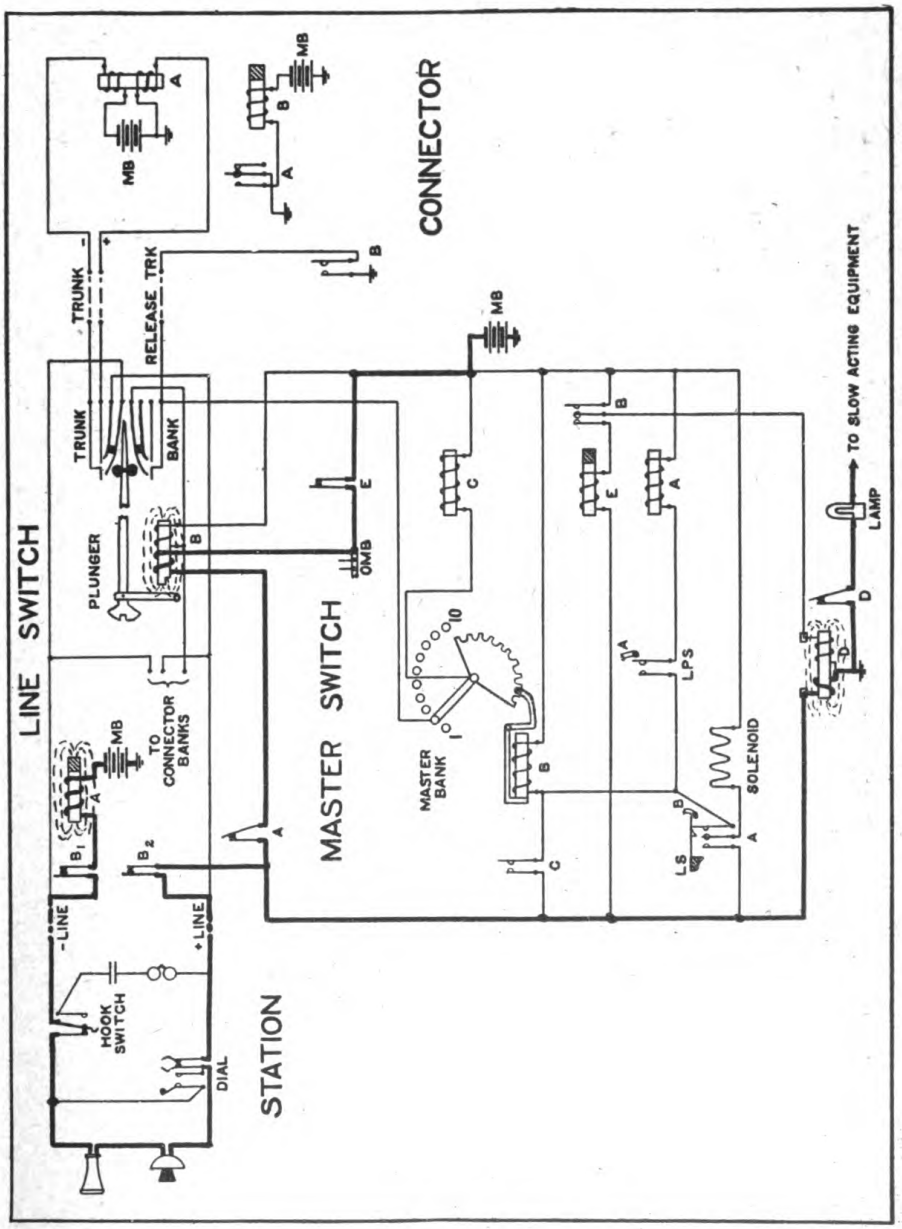
(2) Line relay A of line switch and supervisory ground relay D operate.

Contact relay A closes a circuit through one winding of the cut-off and plunger relay B of line switch. (Provided the master switch is not in motion. If this condition exists, then this circuit will be open at contacts E until master switch stops.)

Contact relay D closes circuit of supervisory lamp through the slow acting equipment. The lamp, however, does not light if the apparatus functions properly.

NOTE.—Conditions which cause the operation of the supervisory lamp will be discussed later.

Drawing II shows the circuit condition at this stage. The energization of the winding of the cut-off and plunger relay B of line switch causes the operation of the plunger and of the contact springs B_1 and B_2, but for convenience in the drawing these are considered as about to operate.



DRAWING II.—Showing circuit conditions as plunger is about to enter trunk bank.

11. *Line calling—seizure of a trunk*—Continued.

(3) Cut-off and plunger relay B of line switch operates.

Contacts B_1 and B_2 cut off the line relay A of the line switch. This relay is slow on release (delayed release) and holds its contacts operated for a brief interval. Plunger is driven into trunk bank.

(4) Trunk bank functions.

Closes line circuit through line relay of next switch. Closes a contact in the holding, guarding, and releasing circuit (release trunk circuit).

(5) Line relay A of connector operates.

Contacts A close circuit of release relay B of connector.

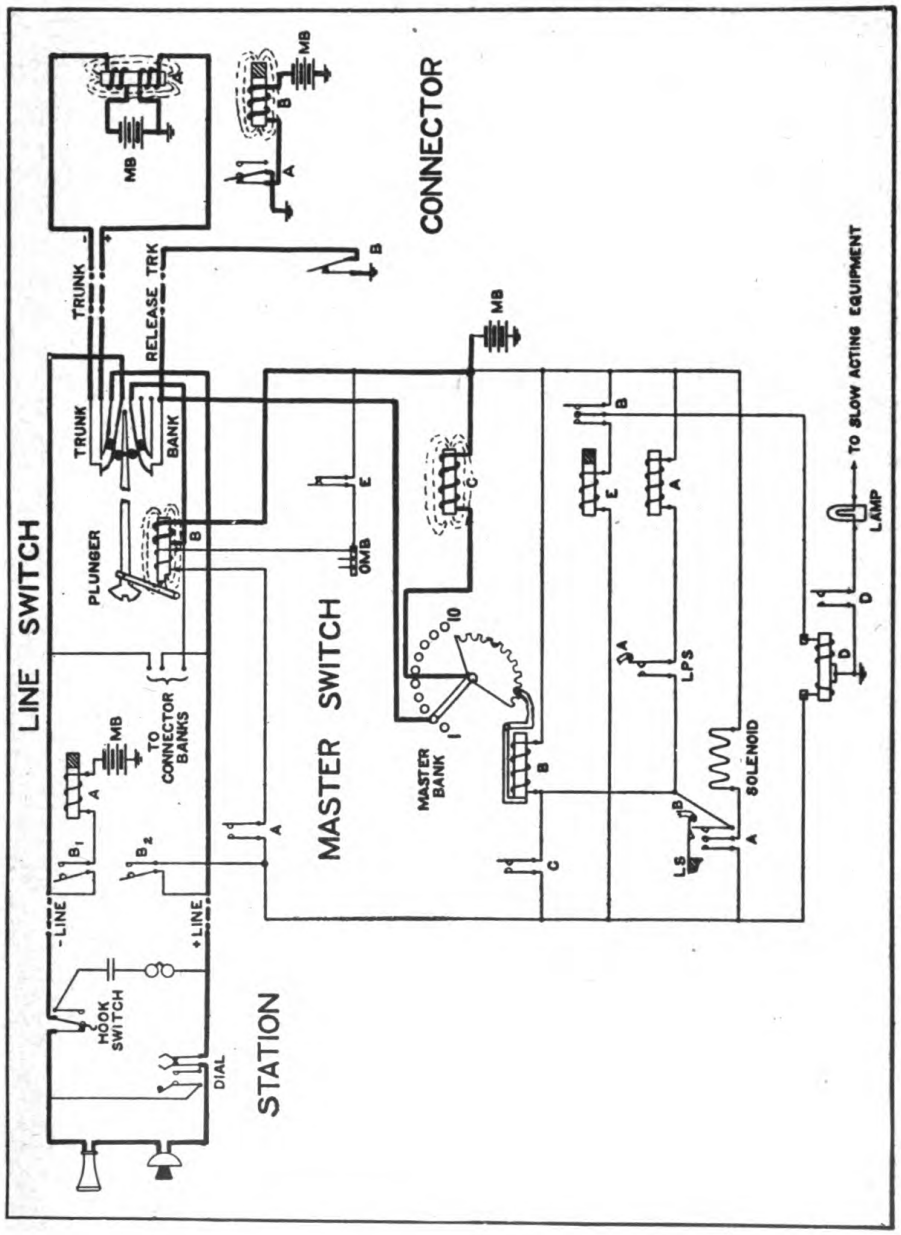
(6) Release relay B of connector operates.

Contact B closes release trunk circuit, energizing the second winding of the cut-off and plunger relay B of line switch in order to hold the line switch operated. It also grounds the master bank contact corresponding to the trunk seized to start the master switch and, further, ground is placed on the third wire of the connector multiple to guard the connection and make the calling line test busy.

(7) Line relay A of line switch releases its armature (slow release).

Contact A opens circuit of operating winding of cut-off and plunger relay B.

Drawing III shows circuit conditions with line cut through and master switch about to function to align idle plungers before an idle trunk. Relay C, shown energized, is considered as about to operate.



DRAWING III.—Showing line connected through and master switch about to function.

12. *Operation of the master switch.*

(8) Start relay C of master switch operates (closed to ground on master bank).

Contacts C close circuit of lock magnet B of master switch. This circuit includes one winding of supervisory relay D.

(9) Lock magnet B of master switch operates.

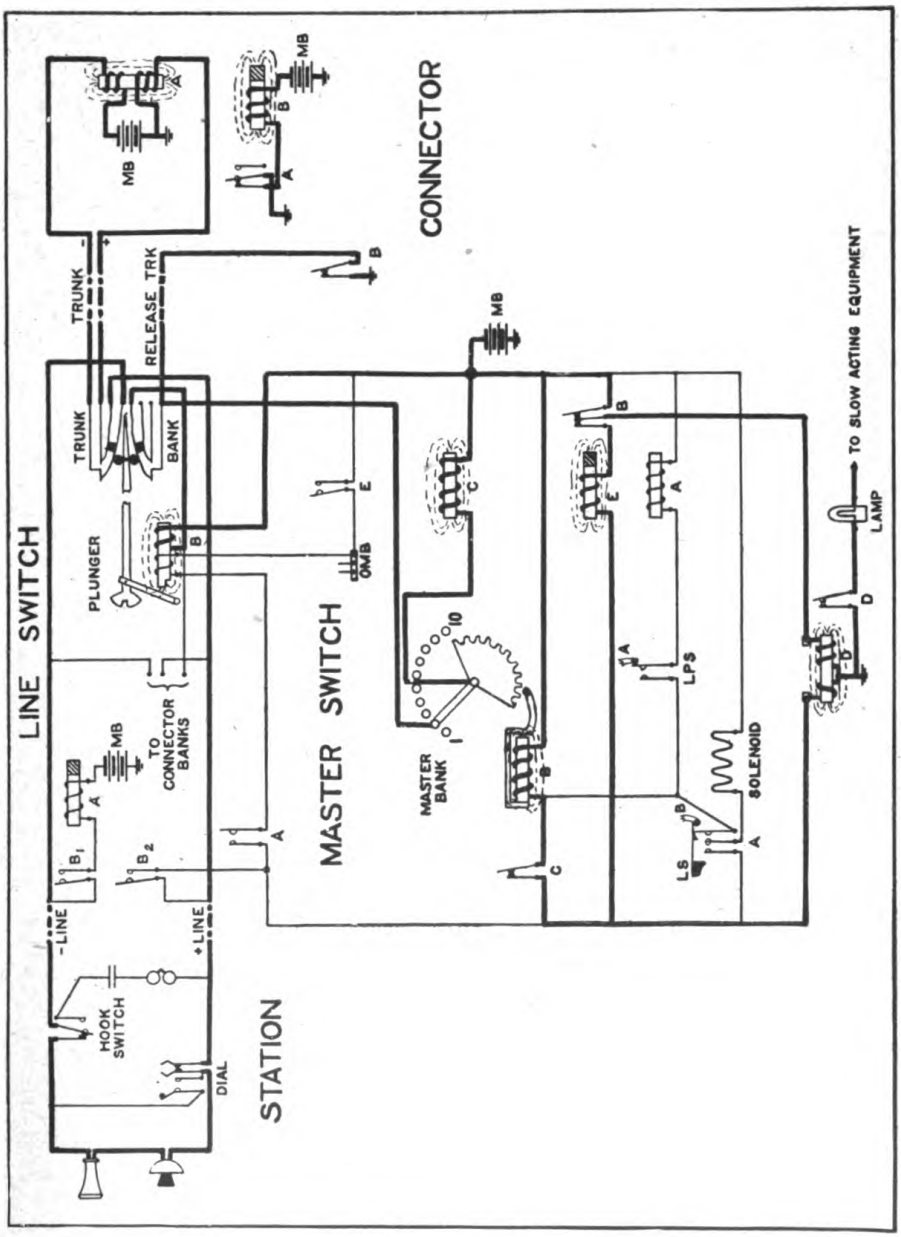
Contacts B close circuit of open main relay E, as well as the circuit of the second winding of the supervisory relay D.

Arm unlocks the sector on the master shaft.

(10) Open main relay E operates.

Contacts E open the common (main) battery feed to line switches, thus preventing operation of plungers while the master shaft is in motion.

Drawing IV shows the circuit condition as the master shaft is about to move under influence of a spring from position 2 to position 1 in the process of aligning idle plungers before an idle trunk.



DRAWING IV.—Showing circuit conditions as master shaft is about to move to position 1.

12. *Operation of the master switch*—Continued.

(11) Master shaft moves by spring from position 2 to position 1. (Trunk No. 1 assumed idle.)

Breaks circuit of start relay C on leaving position 2.

Arm "A" closes locking plate springs (LPS) when shaft reaches position 1 (extreme); the trip relay A of master switch, however, will not operate as contacts C open before this time.

(12) Start relay C released at beginning of motion of shaft.

Contacts C opened lock magnet B circuit, and also open circuit of one winding of supervisory relay D.

(13) Lock magnet B releases.

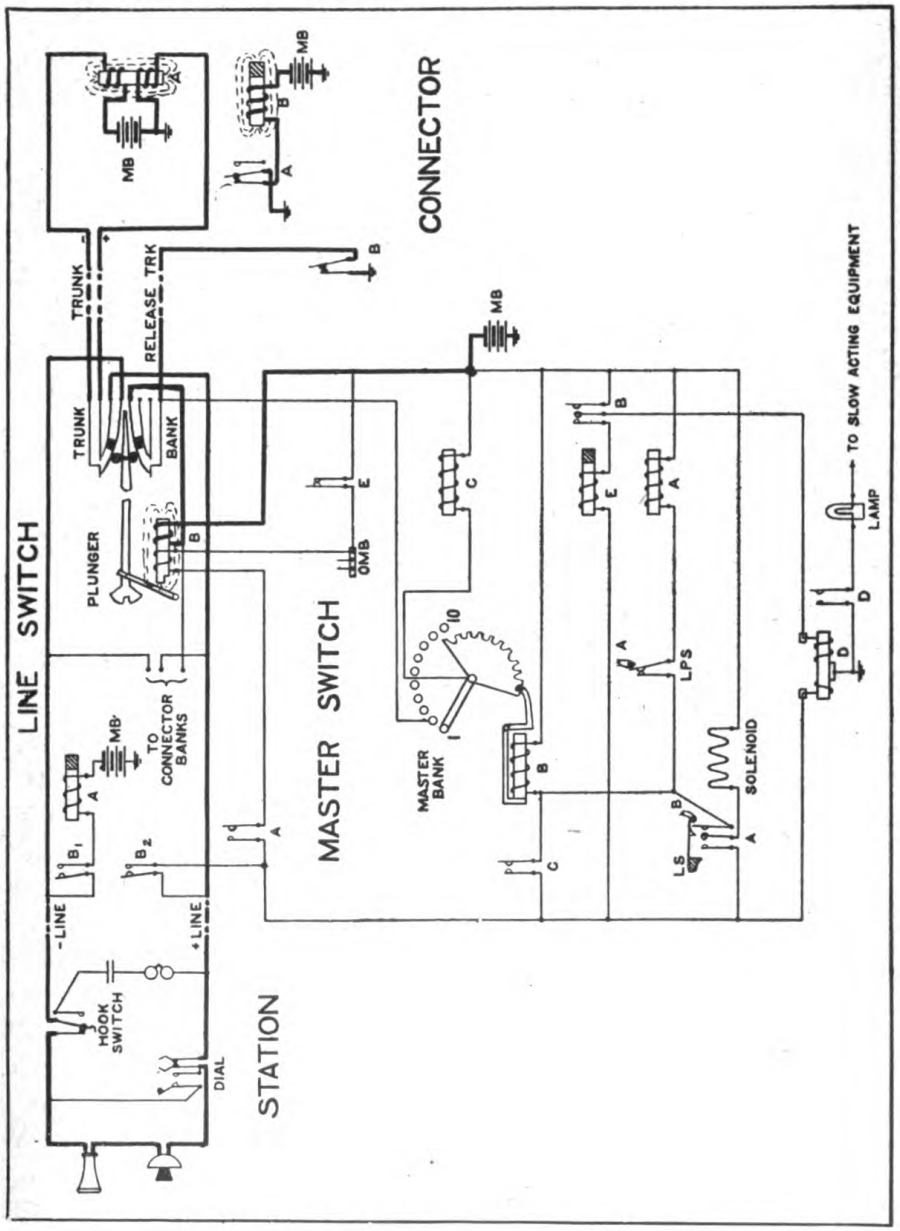
Contacts B open circuits of open main relay E and second winding of supervisory relay D.

Its arm locks sector when position 1 is reached.

(14) Open main relay E releases.

Contacts E close common (main) battery feed to line switches so that trunk No. 1 may now be seized.

Drawing V shows circuit conditions with idle plungers aligned before trunk No. 1, while trunk No. 2 is engaged by a calling line.



DRAWING V.—Showing circuit conditions when master shaft reaches position 1.

13. *Reverse motion of master shaft.*

If, now, a plunger is detached from the master shaft and driven into a terminal bank of trunk No. 1 by another originating call in this group, then the master switch will function to align all idle plungers before trunk No. 10 (assumed idle).

(15) A station calls, seizing trunk No. 1, grounding master bank contact No. 1.

Start relay C is energized.

(16) Start relay C operates.

Contacts C close circuits of lock magnet B and trip relay A, in series with one winding of supervisory relay D.

(17) Lock magnet B and trip relay A operate simultaneously.

Contacts B close open main relay E circuit and circuit of second winding of supervisory relay D

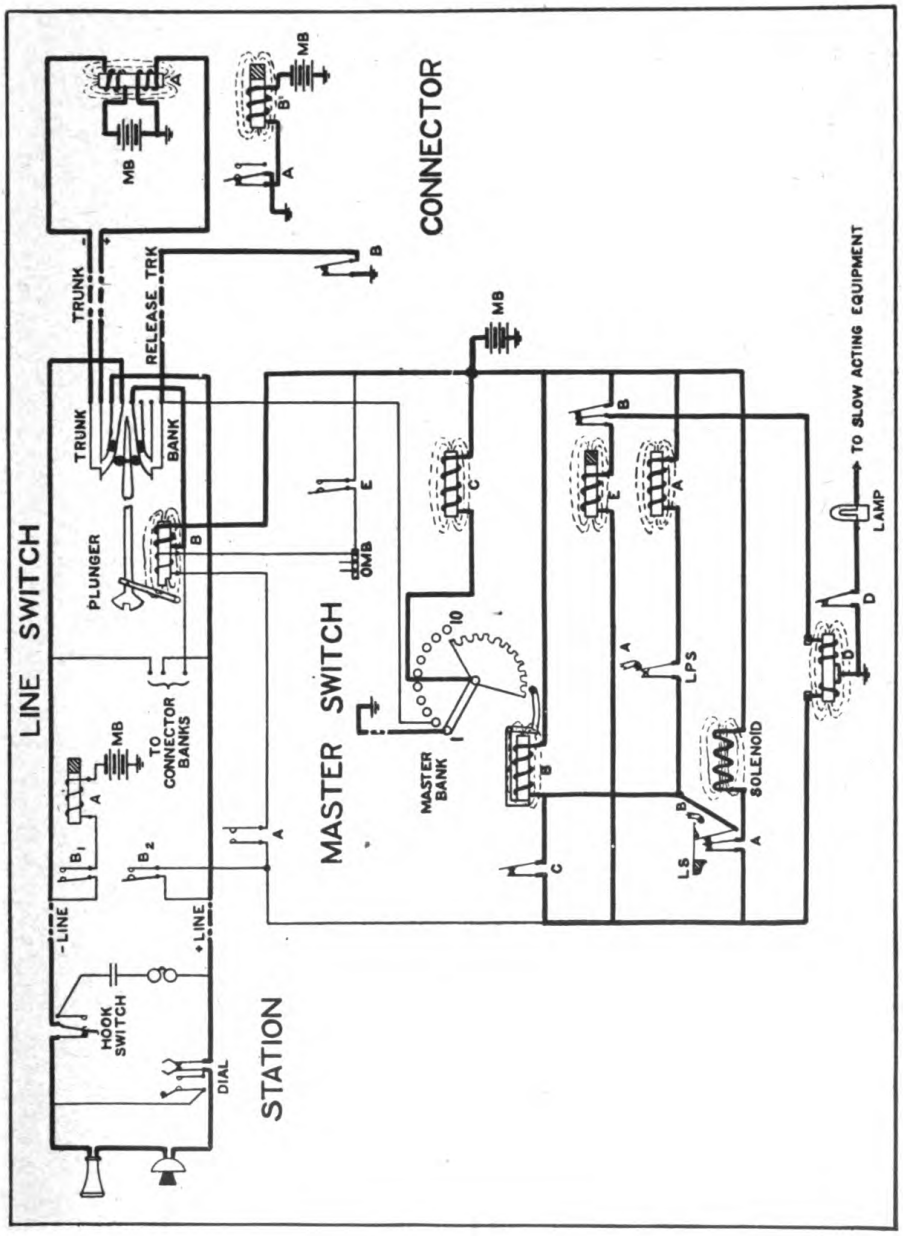
Lock magnet arm unlocks sector on the master shaft.

Contacts A close circuit of solenoid. Locking spring (LS) locks contacts A mechanically.

(18) Open main relay E operates.

Contacts E open common (main) battery feed to line switches. The solenoid will now cause the master shaft to move to position 10.

Drawing VI shows the circuit conditions just as the shaft carrying the plungers and contact arm is about to move under influence of the solenoid.



DRAWING VI.—Showing circuit conditions just as the reverse motion commences.

13. *Reverse motion of master shaft*—Continued.

(19) Solenoid acts on its plunger, moving master shaft against spring to position 10.
As master shaft leaves position 1, the arm A moves away from the LPS.
NOTE.—Idle plungers, before the trunk bank, are reengaged with the master shaft as it moves from position 1 to 10.

(20) Locking plate springs (LPS) return to normal (at beginning of motion).
Opens trip relay A circuit.

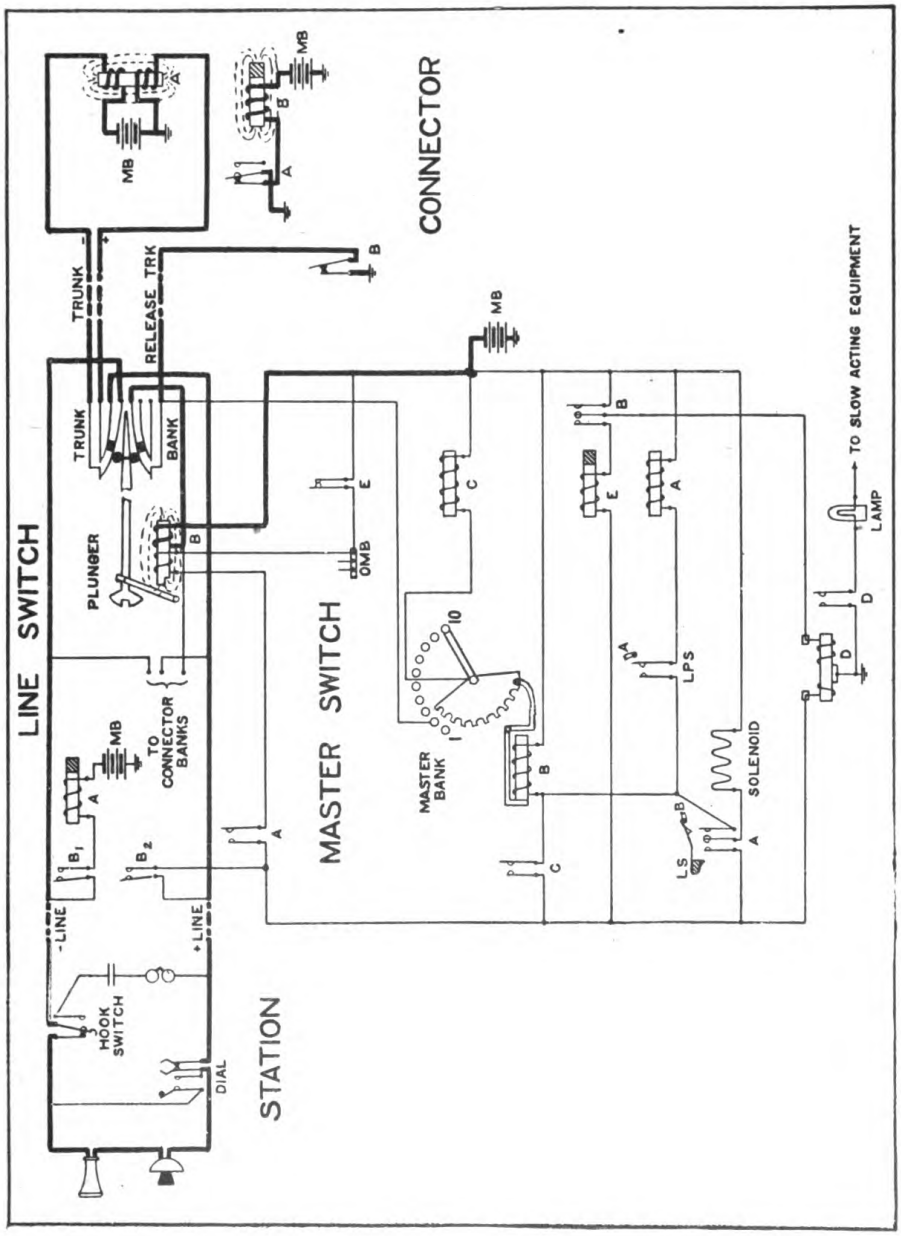
(21) Trip relay A releases armature.
Contacts A held locked by locking spring (LS).

(22) Locking spring (LS) deflected by arm A (when master shaft reaches position 10).
Contacts A return to normal position.

(23) Lock magnet B and solenoid deenergize (provided trunk number 10 is idle).
Contacts B open circuit of open main relay E and both windings of supervisory relay D.
Arm locks sector on master shaft.

(24) Open main relay E releases.
Contacts E close common (main) battery feed to line switches.

Drawing VII illustrates the circuit condition just after the reverse motion, the plungers now being aligned before trunk number 10 which was assumed idle. As each trunk becomes busy the master shaft will progress step by step to position 1 in a manner similar to that previously described except that arm A functions only in position 1 and arm B functions only in position 10.



DRAWING VII.—Showing circuit conditions just after the reverse motion.

14. *Release of line switch after an originating call.*

When the receiver is replaced on the hook the line circuit is opened, causing ground to be removed from the release trunk at the connector. The line switch releases and restores to the normal condition.

(25) Calling party replaces receiver on hook.

(26) Hook switch is returned to normal.

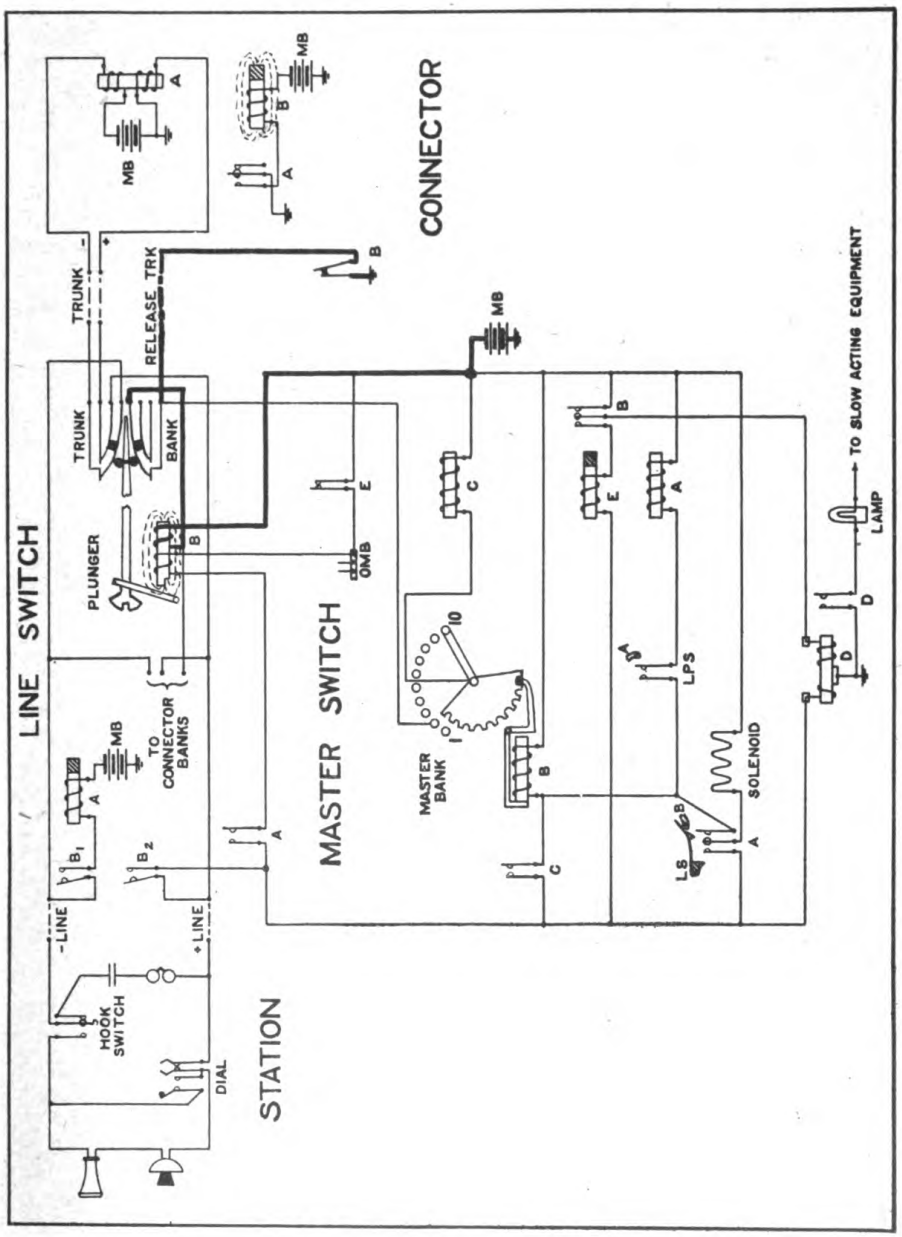
Opens line circuit.

Also reconnects bell and condenser to line.

(27) Line relay A of connector releases.

Opens circuit of release relay B of connector which is slow on release.

Drawing VIII shows this circuit condition. The release relay, which is about to release, will cause the restoration of the line switch.



DRAWING VIII.—Showing opening of line circuit at hook switch. Release relay about to release.

14. *Release of line switch after an originating call*—Continued.

(28) Release relay of connector releases.

Opens release trunk circuit.

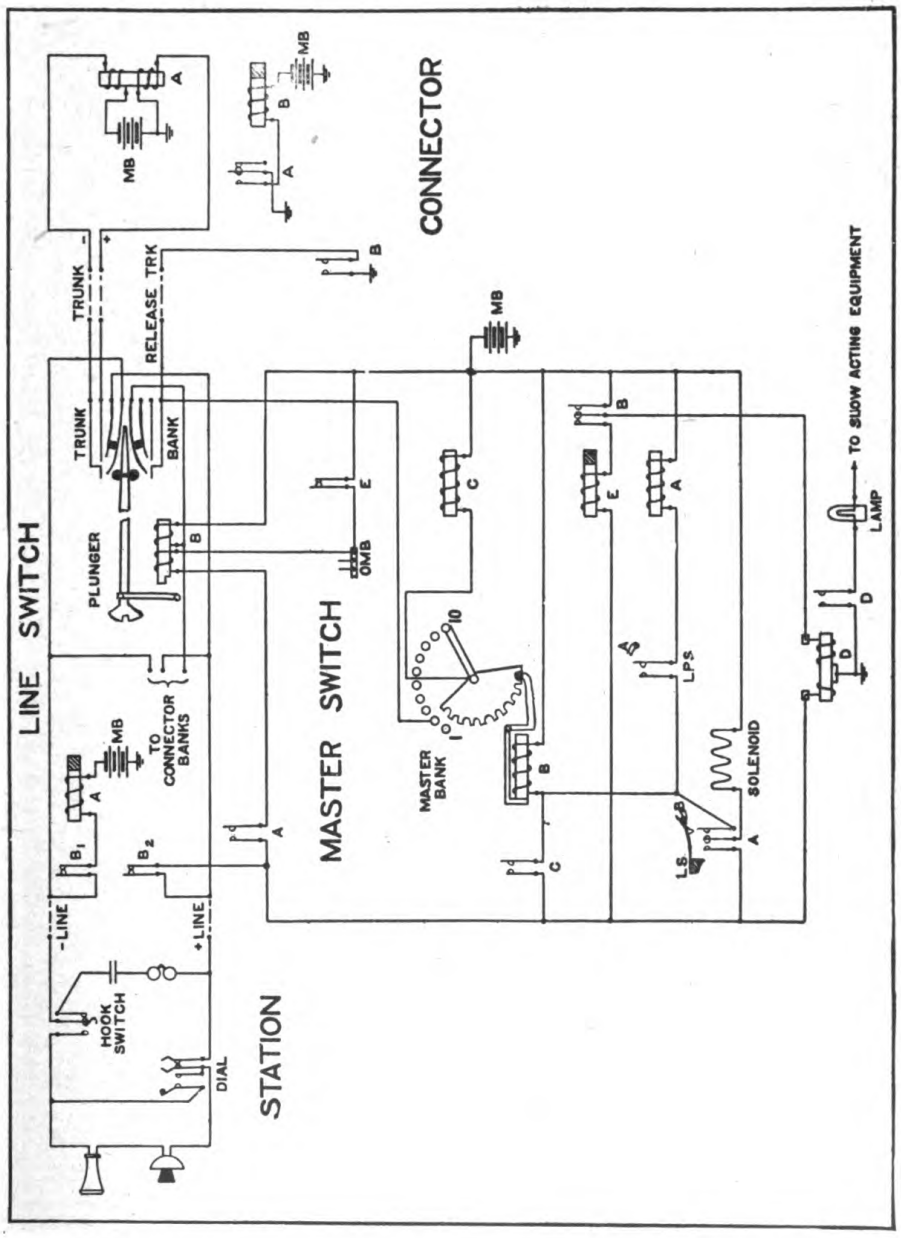
(29) Cut-off and plunger relay B of line switch releases.

Plunger is withdrawn from trunk bank by spring action and is free to reassociate itself with the master shaft.

Cut-off springs B_1 and B_2 reconnect line relay A of line switch to the line.

The line switch is now completely released and is ready for another call—either incoming or outgoing. The master switch is not directly affected by the release of the line switch.

Drawing IX illustrates the circuit conditions after the release of the switches.



DRAWING IX.—Showing circuit of switches completely released.

15. *Line being called—operation of line switch.*

When the line is called, the connector tests the line and, if idle, connects to it at the connector multiple. It next puts ringing current on the line, ringing the bell of the called station. If the line is busy, the connector does not connect, but places a busy tone on the calling line. The master switch has no function when a line is called.

(30) Wipers (brushes) of a connector engage terminals of the line at the connector multiple bank.

(31) If idle, the holding coil of the cut-off and plunger relay B of line switch is energized, the circuit being completed in the connector.

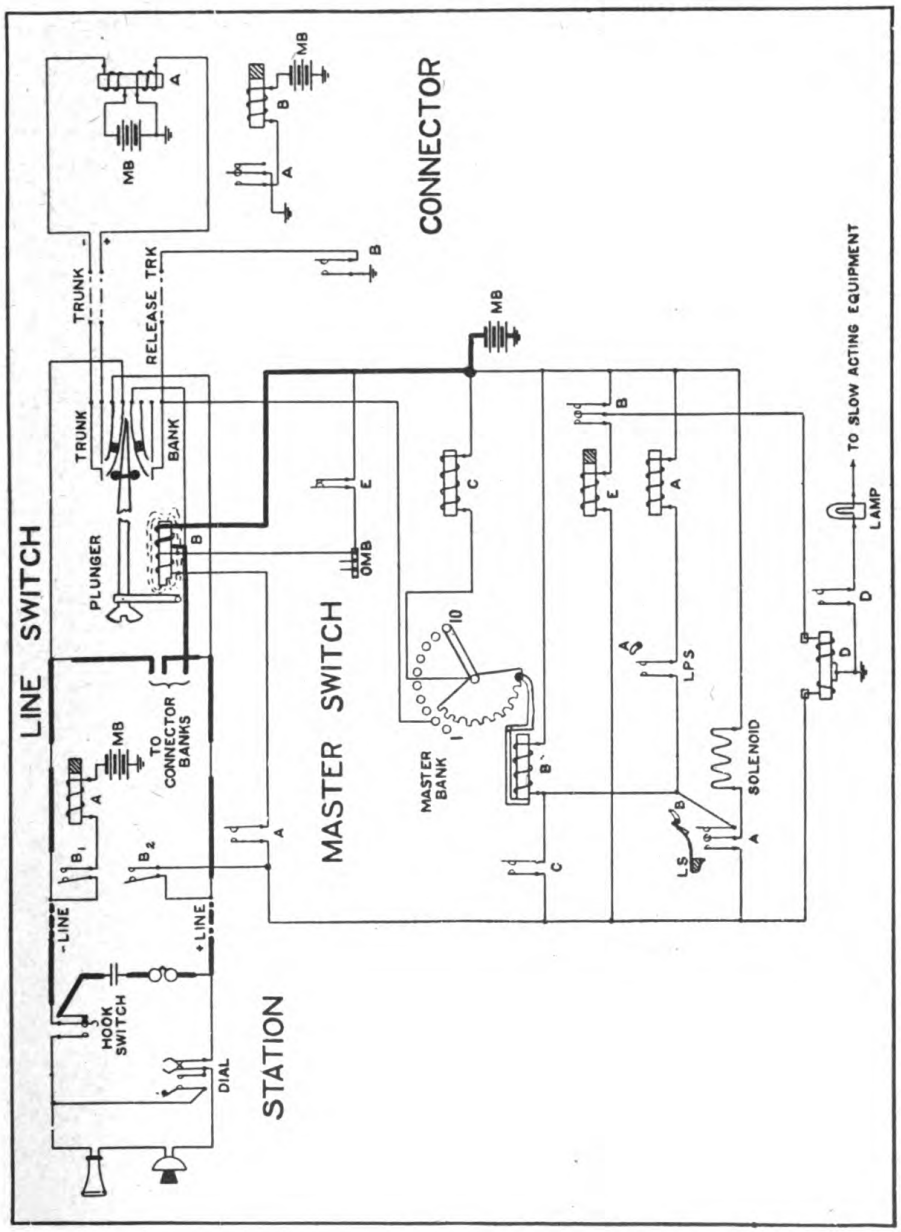
(32) Cut-off and plunger relay B of line switch operates its springs B_1 and B_2, but does not thrust plunger into the trunk bank.

Contacts B_1 and B_2 cut off bridged line relay A.

(33) Connector puts ringing current on called line.

Called party's bell rings.

Drawing X shows circuit conditions while called party's bell is being rung. Heavy dashed line indicates ringing current.



DRAWING X.—Showing circuit conditions while called party's bell is being rung.

15. *Line being called—operation of line switch*—Continued.

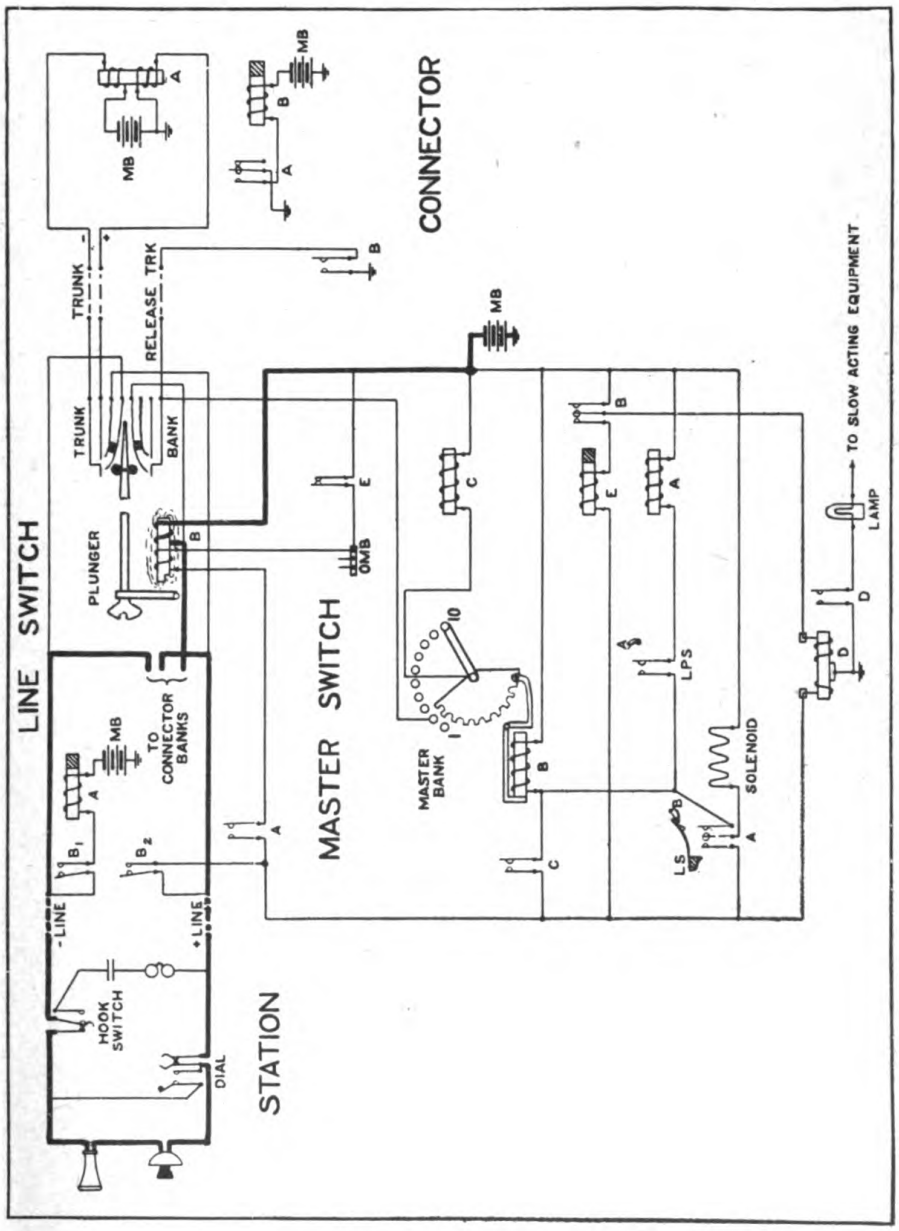
(34) Called party answers—lifts receiver from hook.

(35) Hook switch operates.

Disconnects bell and condenser from line and closes line circuit through the bank bridge relay of the connector.

(36) The two parties are now in communication.

Drawing XI shows the line switch in operated condition as resulting from an incoming call.



DRAWING XI.—Showing circuit conditions when called party lifts receiver from hook.

15. *Line being called—operation of line switch*—Continued.

(37) Both parties replace receivers on hooks.

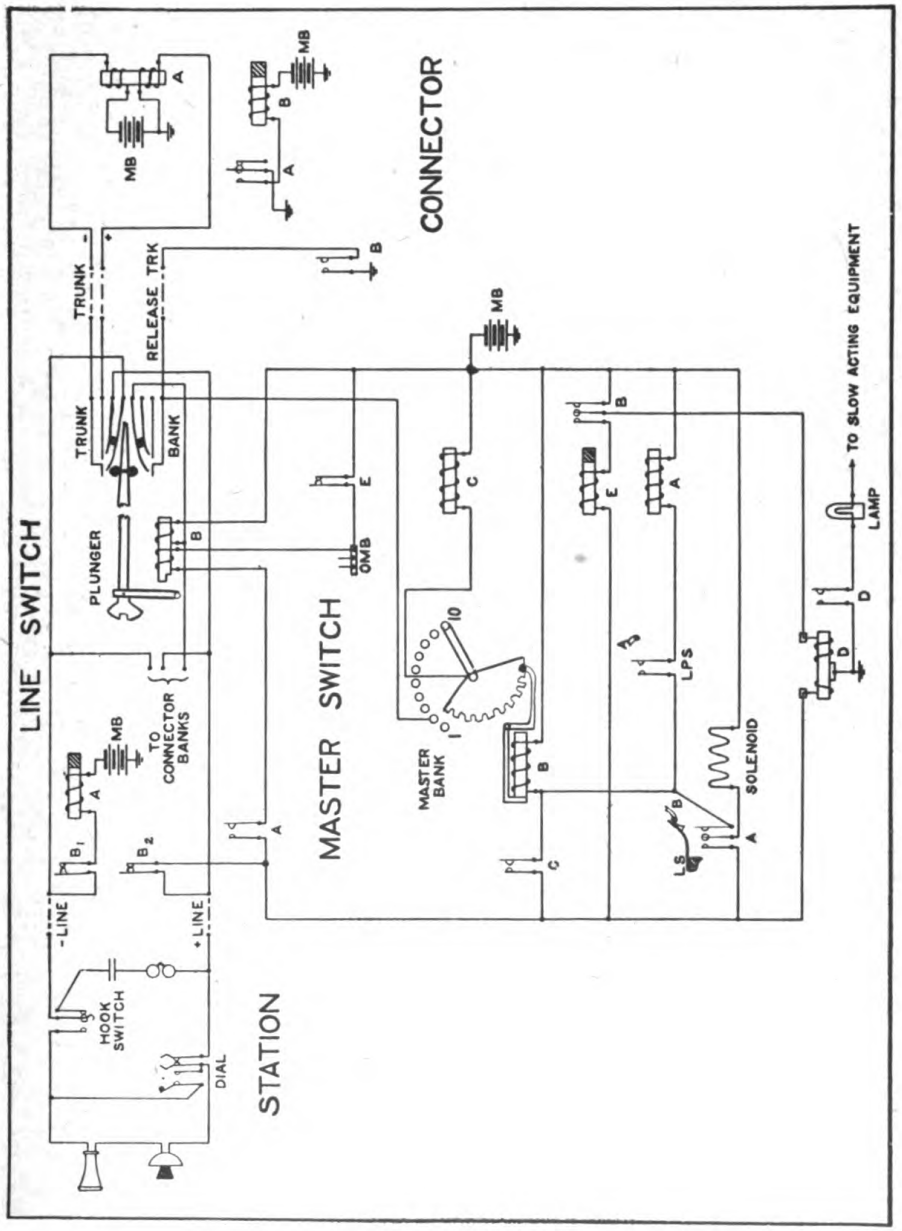
Connector is released. Bell and condenser are bridged across line by hook switch. Cut-off and plunger relay B of line switch is deenergized.

(38) Cut-off and plunger relay B of line switch releases.

Contacts B_1 and B_2 reconnect the line relay A. (Plunger was not operated.)

(39) The line switch is again in the unoperated condition.

Drawing XII shows the circuit conditions after both parties hang up.



DRAWING XII.—Showing unoperated circuit conditions after both parties have hung up.

16. *Functions of supervisory ground relay D.*—This relay controls a circuit which includes a lamp, an audible alarm, and slow-acting equipment. When the relay operates, nothing happens until after a time interval which is determined by the slow-acting device. Then the lamp shown on the drawing is lighted and an audible alarm is sounded.

With normal operation of the line and master switch the lamp and audible alarm are not operated, but any abnormal condition which causes the supervisory relay D to remain operated more than a few seconds will bring in the alarm.

Some of the more important abnormal conditions are:

(1) Line switch line relay permanently pulled up. This may be caused by the plunger failing to plunge into the bank for any one of a number of reasons or by the cut-off and plunger relay springs failing to break contact when that relay is energized.

(2) Line switch chattering because of having plunged in on an open trunk.

(3) Master switch rotating, resulting from all outgoing trunks being busy or trouble on the master switch.

(4) Master switch stuck. Any condition of the master switch wherein the starting relay is energized without break for an extended period will operate the alarm.

(5) Line crossed. If the positive side of line should get crossed with "foreign battery," the alarm will operate.

SECTION IV.

THE PRIVATE AUTOMATIC EXCHANGE CONNECTOR.

17. *Functions.*—As used in the smaller type of private automatic exchange, the general functions of the connector are to select the terminals of and to signal the called line under control of the calling party, and thereafter to complete a talking connection between the calling and called stations. To serve its purpose the connector must accomplish the following detailed functions:

(1) To feed battery to the calling line for selection, talking, and control of the release of the connector.

(2) To hold the calling line line switch operated during the connection.

(3) To execute the vertical movement of the shaft under control of the dial.

(4) To execute the rotary movement of the shaft under control of the dial.

(5) To test the called line for busy and if busy to prevent intrusion.

(6) To notify the calling party if the called line is busy. This is done by a distinctive "busy tone."

(7) To protect the called line from intrusion—that is, make it test busy.

(8) To clear the called line of attachments—its line switch.

(9) To ring the bell of the called station and to furnish a ring-back tone to the calling party.

(10) To cut off the ringing current upon answer of the called party and to connect the calling line to the called line.

(11) To supply battery to the called line in order that the called party may talk.

(12) To release the line switch under control of the calling party.

(13) To release without interfering with other lines and to release the called line.

SECTION V.

DETAIL OPERATION OF CONNECTOR CIRCUIT.

18. *Conventions employed in diagrams.*

The following diagrams give a description of the functions and detailed circuit operation of the private automatic exchange connector. Drawing I shows the connector circuit in the normal or unoperated condition.

The following conventions are employed in the diagrams:

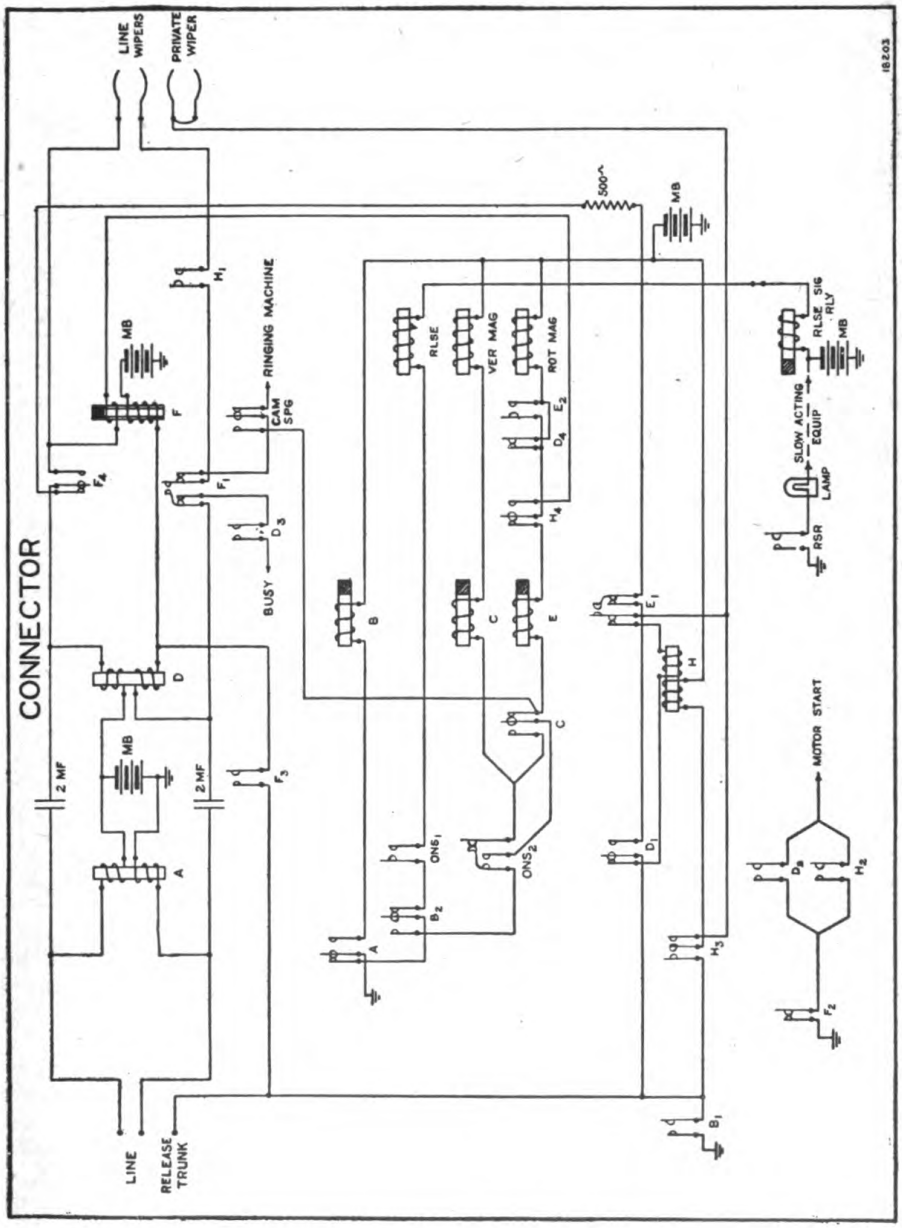
(*a*) To facilitate the tracing of the circuit, relay and magnet springs are shown separated from their coils.

(*b*) Energized relays and magnets are surrounded by magnetic fields.

(*c*) Conductors carrying current are shown by heavy lines.

(*d*) Component circuit elements are arranged as far as possible in order of first operation.

(*e*) Springs of contact sets are shown parallel when in the normal or unoperated position.



DRAWING I.—Simplified diagram of connector circuit in normal or unoperated condition.

19. *The seizure of the switch.*

(1) Line circuit switched over trunk to connector energizing line relay A.

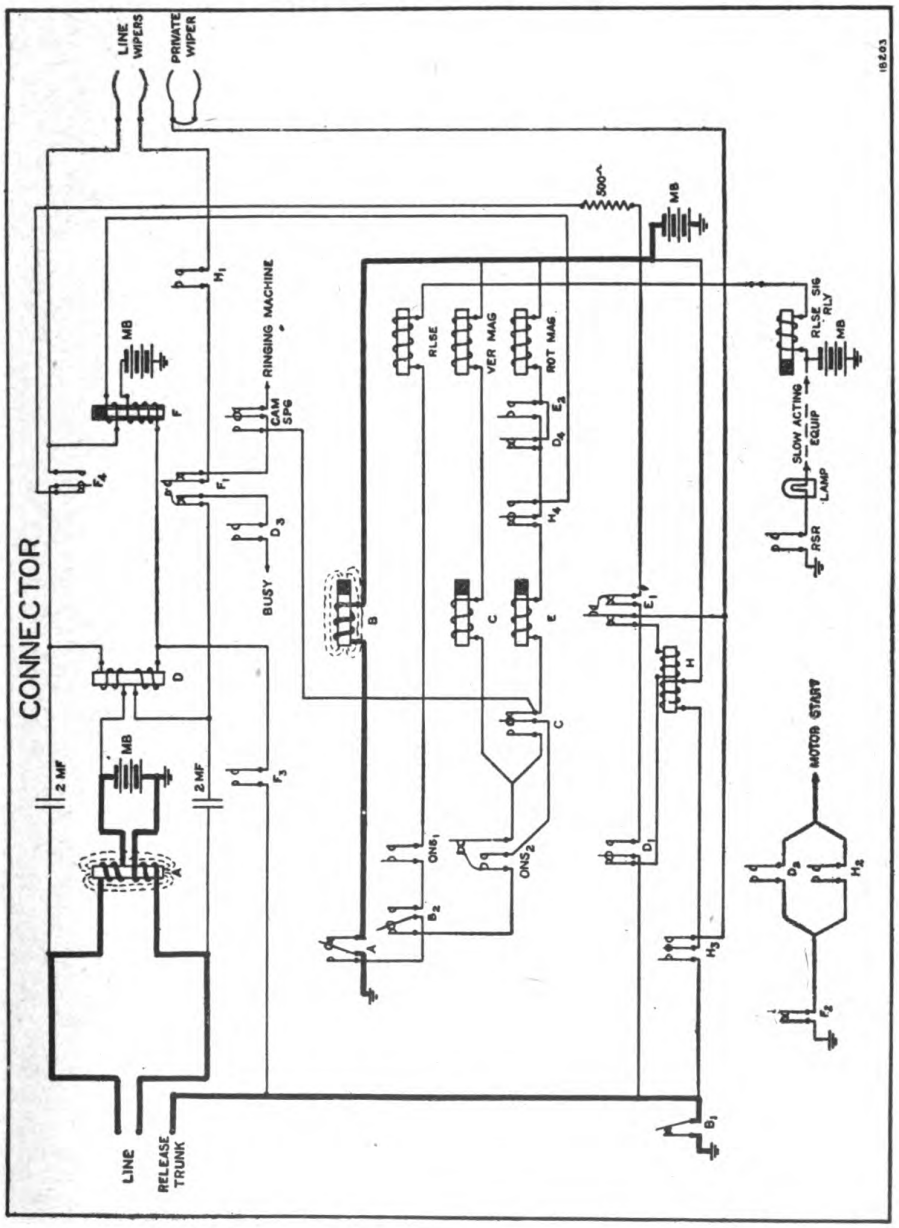
Contacts A open contact in circuit of release magnet and close circuit of release relay B.

(2) Release relay B operates.

Contacts B_1 ground release trunk to hold operated the line switch previously seized. This ground is common to other circuits which function later.

Contacts B_2 open a contact in the circuit of the release magnet and close a contact common to the vertical and rotary stepping circuits.

Drawing II shows the circuit conditions at this stage. The circuit remains thus until the dialing starts. When the calling party dials the first digit, his dial will interrupt the line current a number of times equal to the digit dialed.



DRAWING II.—Circuit conditions resulting from seizure of switch.

20. *The vertical stepping.*

First stage—First break of line circuit by dial.

(3) The dial opens the line circuit.

(4) Line relay A releases.

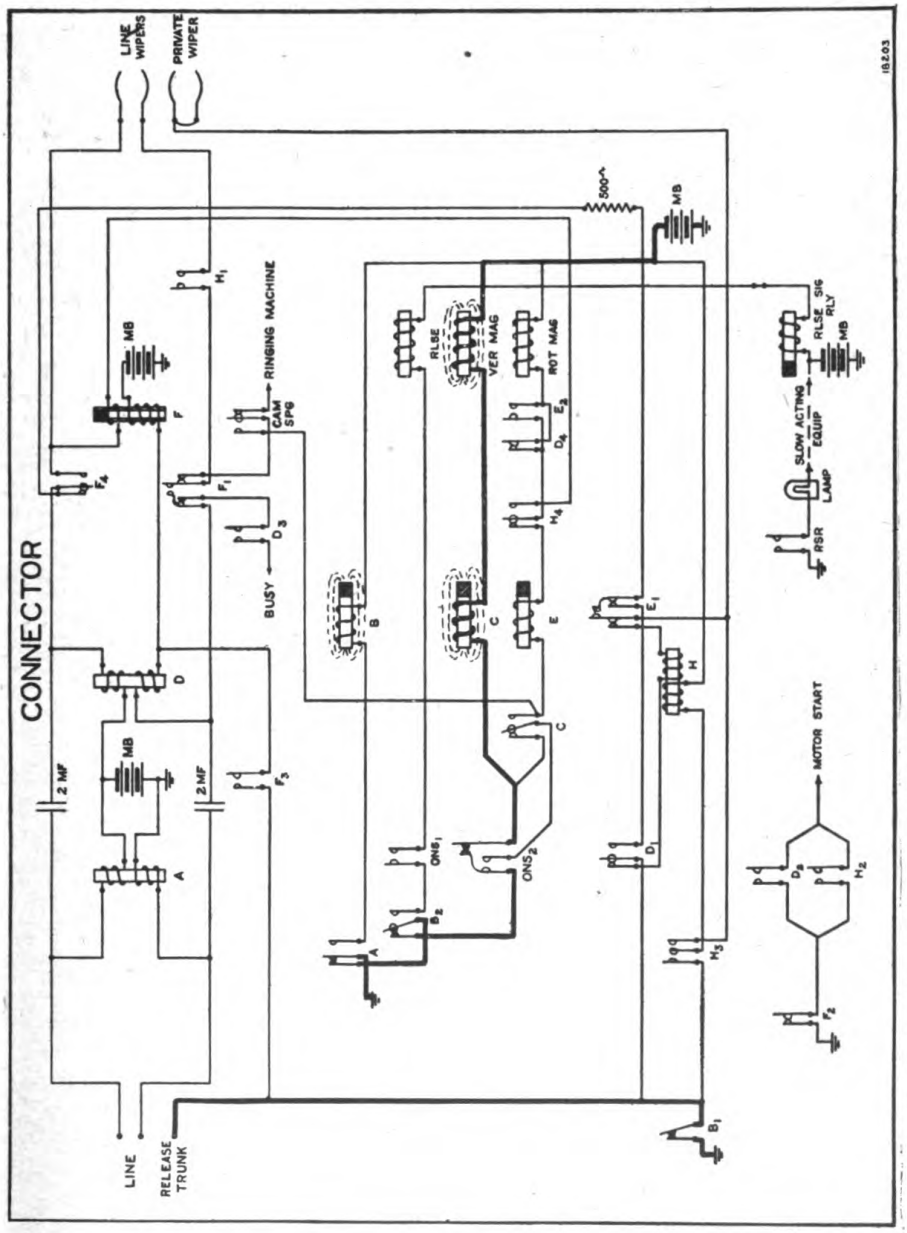
Contacts A open momentarily the circuit of the release relay B (which is slow on release and remains operated during the brief dial interruptions) and then close the vertical stepping circuit which includes the series relay C and the vertical magnet.

(5) Series relay C and vertical magnet operate.

Contacts C open a contact in the rotary stepping circuit and close a contact in the vertical stepping circuit for the second and succeeding current pulses.

The vertical magnet proceeds to lift the shaft carrying the wipers one vertical step.

Drawing III shows the circuit conditions at the stage of the first break of the line circuit by the dial, and the wipers about to be lifted one vertical step.



DRAWING III.—Circuit conditions resulting from first break of line circuit by dial showing first vertical stepping circuit.

20. *The vertical stepping*—Continued.

Second stage—Closure of line circuit after first dial interruption.

(6) Shaft and wipers lifted to first level by vertical magnet.

(7) Off normal switch (ONS) operates during first vertical step.

Contacts ONS_1 close a contact in the release magnet circuit.

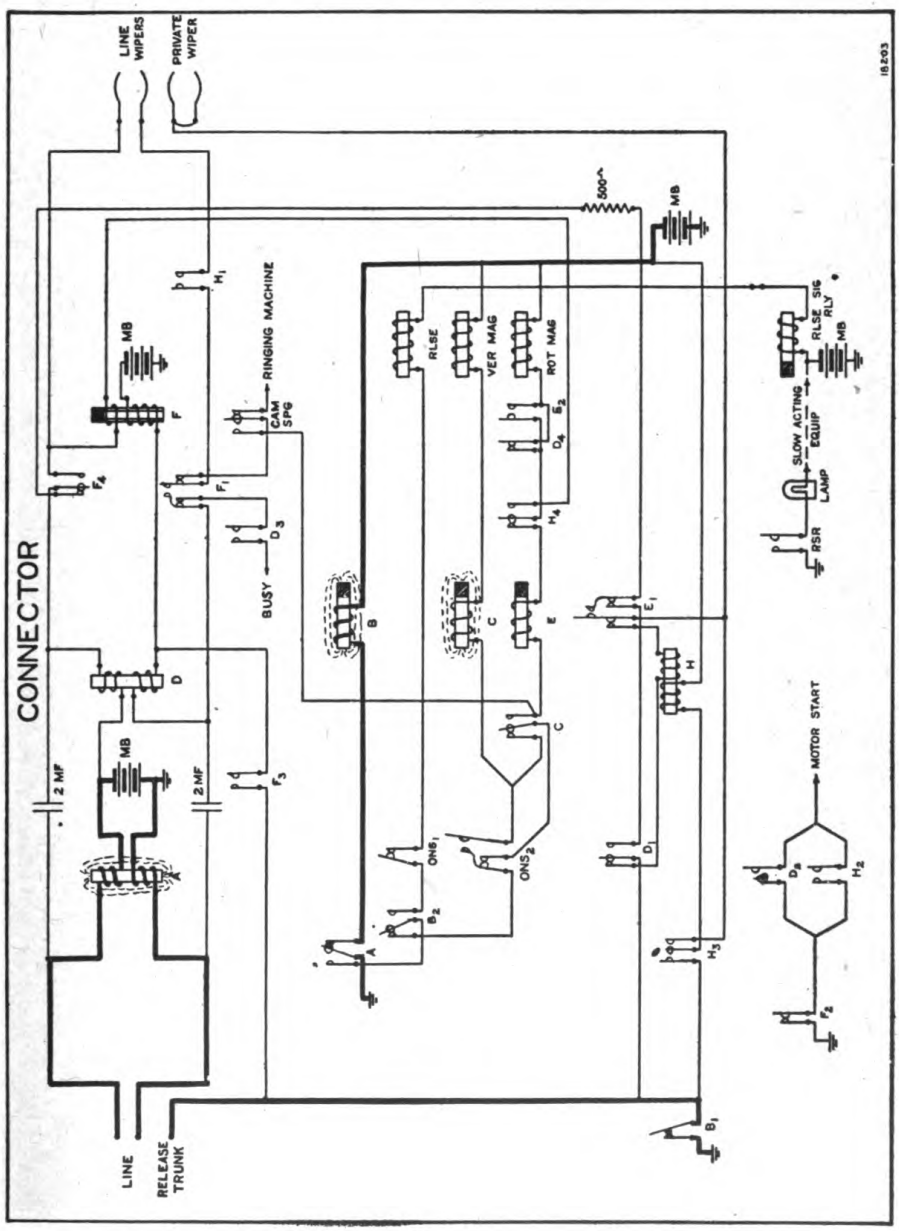
Contact ONS_2 switches the vertical stepping circuit, without opening it, so as to include contacts C of the series relay. This action is preparatory to the rotary stepping.

(8) Line circuit closed by dial after first interruption, energizing the line relay A.

Contacts A open the vertical stepping circuit (momentarily) and again close the circuit of the release relay B which remained operated during the brief interval its circuit was open by the dial.

NOTE.—The vertical magnet releases, but the series relay, being slow on release, holds until the next impulse (if any).

Drawing IV shows the circuit conditions at this instant.



DRAWING IV.—Circuit conditions between first and second vertical steps.

20. *The vertical stepping*—Continued.

Third stage—Second and subsequent opening of the line circuit by the dial.

(9) Dial opens line circuit second time. Line relay A releases (momentarily).

Contacts A open circuit of release relay B (which is slow on release and remains operated) and close the circuit of the series relay C and vertical magnet. This circuit now includes the contacts C of the series relay.

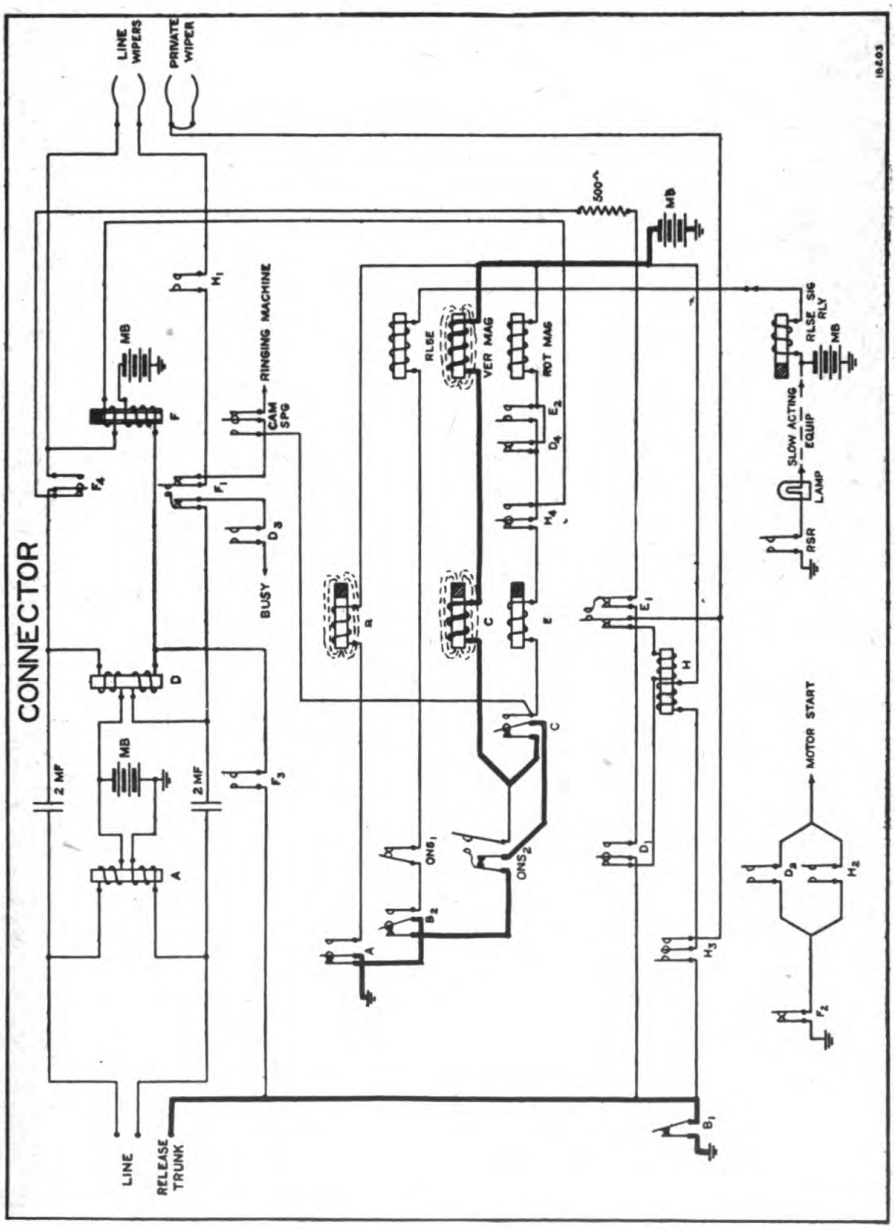
(10) Vertical magnet operates. (Series relay C operated.)

Lifts shaft and wipers one vertical step as before. (Second level.)

Drawing V shows the vertical stepping circuit for the second and succeeding vertical steps.

(11) Switching from vertical to rotary motion.

After the last interruption of the first series there is an interval during which the line relay A is energized. Its circuit being open over one-tenth second, the series relay C will release. Its contacts C will open the vertical stepping circuit and close a contact in the rotary stepping circuit preparatory to the next series of interruptions of the line circuit by the dial.



DRAWING V.—Showing vertical stepping circuit for second and succeeding vertical steps.

21. *The rotary stepping.*

First rotary step.

(12) The dial opens line circuit. Line relay A releases (momentarily).

Contacts A open circuit of release relay B (which holds) and close circuit of private relay E and rotary magnet in series.

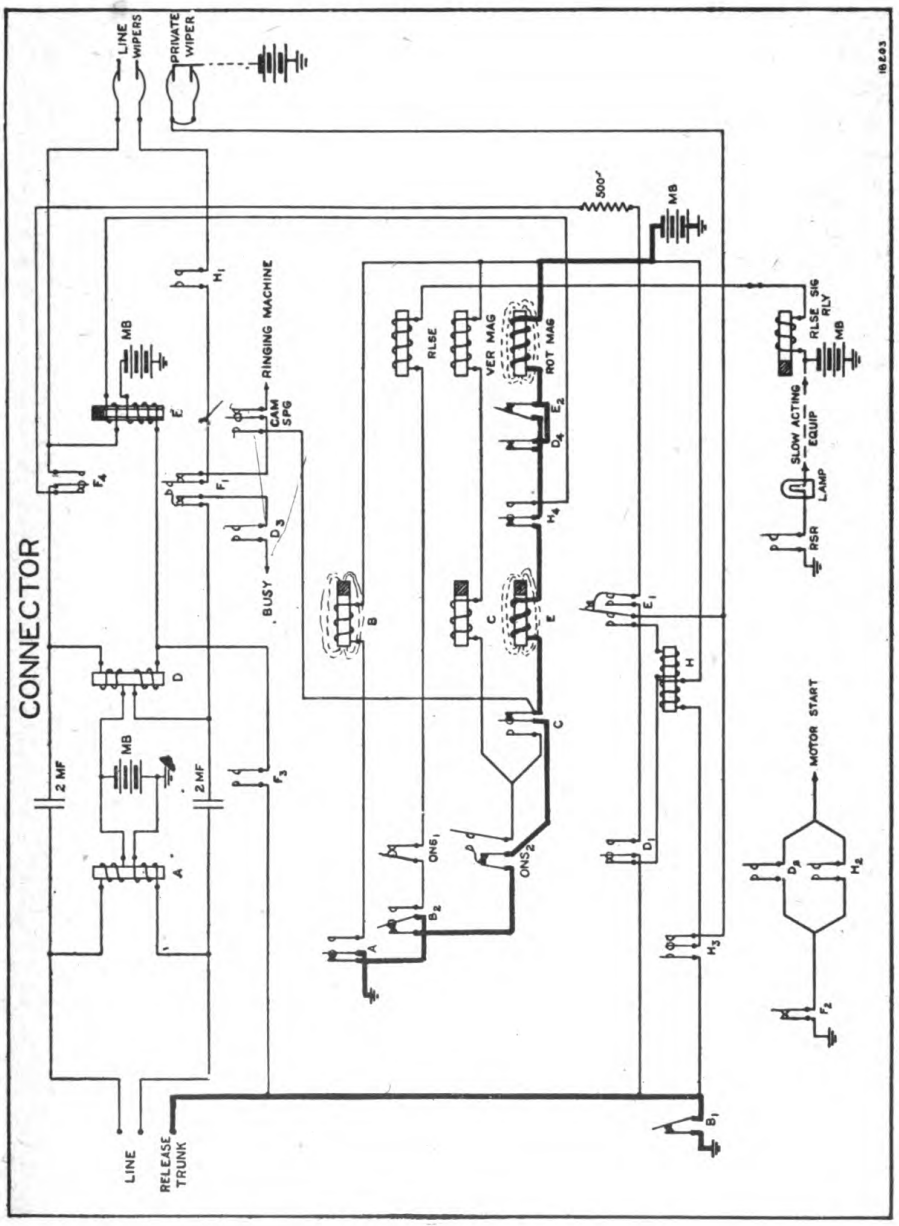
(13) Private relay E and rotary magnet operate.

Contacts E_1 prepare the busy test circuit to the private wiper for testing the called line. The back bridge and busy relay D serve to make the test.

Contacts E_2 short contacts D_4 to prevent opening of rotary stepping circuit when private wiper passes over busy lines.

Rotary magnet rotates shaft and wipers one step.

If we assume the first terminal on the level idle then the circuit condition at this instant is shown by Drawing VI.



DRAWING VI.—Circuit conditions for each rotary step. Private wiper passing over idle contact.

21. *The rotary stepping*—Continued.

Second and succeeding rotary steps.

(14) The line circuit is again closed after first interruption by the dial, operating line relay A.

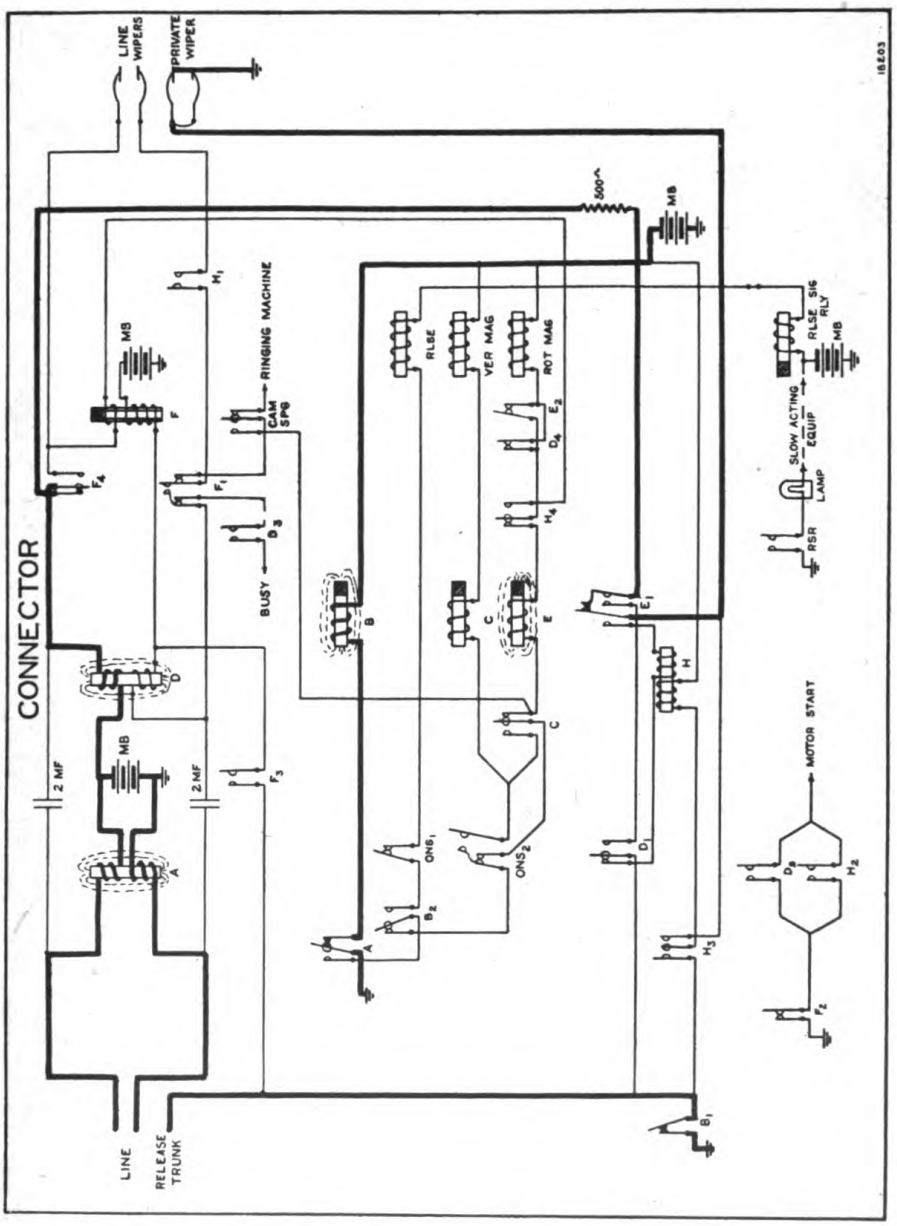
Contacts A open circuit of private relay E and rotary magnet and close circuit of release relay B.

(Private relay E holds over.)

Each succeeding interruption of the line circuit by the dial results in sending a pulse through the private relay E and rotary magnet. The rotary magnet steps the wipers to the terminals of the called line while the private relay E remains operated for an interval after these terminals have been reached.

If the called line is *busy*, then the private wiper will meet ground and the operating circuit of the busy and back bridge relay D will be closed.

Drawing VII shows the closure of the operating circuit of the busy and back bridge relay D. Private relay E is still holding, and relay D is considered as about to operate.



DRAWING VII.—Showing closure of operating circuit of busy and back bridge relay, D. Relay, D, about to operate.

21. *The rotary stepping*—Continued.

The busy test and notification.

(15) Busy and back bridge relay D is operated from ground at private wiper.

Contacts D_1 open operating circuit of line wiper relay H and partially close locking circuit of busy and back bridge relay D.

Contacts D_2 close circuit to start ringing machine which generates current for busy tone.

Contacts D_3 place busy tone on calling line to notify calling party that desired line is busy.

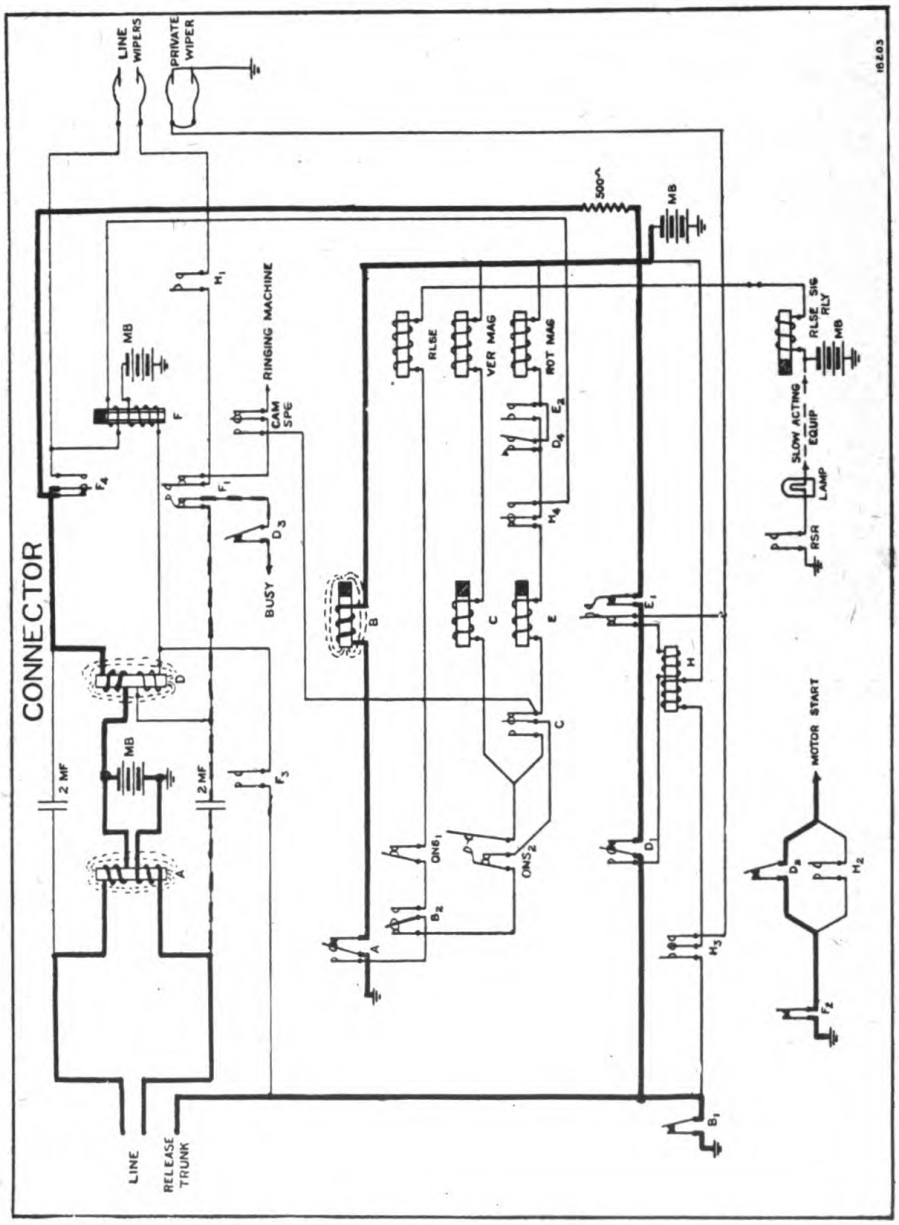
Contacts D_4 open contact in rotary magnet circuit.

(16) Private relay E releases (has been holding because of slow release feature).

Contacts E_1 close locking circuit of busy and back bridge relay D and open operating circuit of same relay.

Contacts E_2 open rotary stepping circuit at a second point to prevent any further stepping should the calling party again move the dial.

Drawing VIII shows the circuit conditions at this stage. The dashed line indicates the interrupted tone used to notify the calling party of the busy condition of the called line.



DRAWING VIII.—Circuit conditions when called line is found busy. Tone placed on calling line.

22. *Disconnection on a busy call.*

The calling party on hearing the busy tone hangs up his receiver.

(17) Line circuit is opened at calling station by action of hook switch.

(18) Line relay A releases.

Contacts A open circuit of release relay B and close ground contact in circuit of release magnet. The release circuit is still open at contacts B_2.

(19) Release relay B restores (after short interval).

Contacts B_1 remove ground from release trunk, thus releasing the calling line switch and also open circuit of busy and back bridge relay D.

Contacts B_2 close circuit of release magnet (in series with release signal relay).

(20) Busy and back bridge relay D releases and release magnet operates.

Contacts D_1 restore to normal.

Contacts D_2 open circuit of busy and ringing machine.

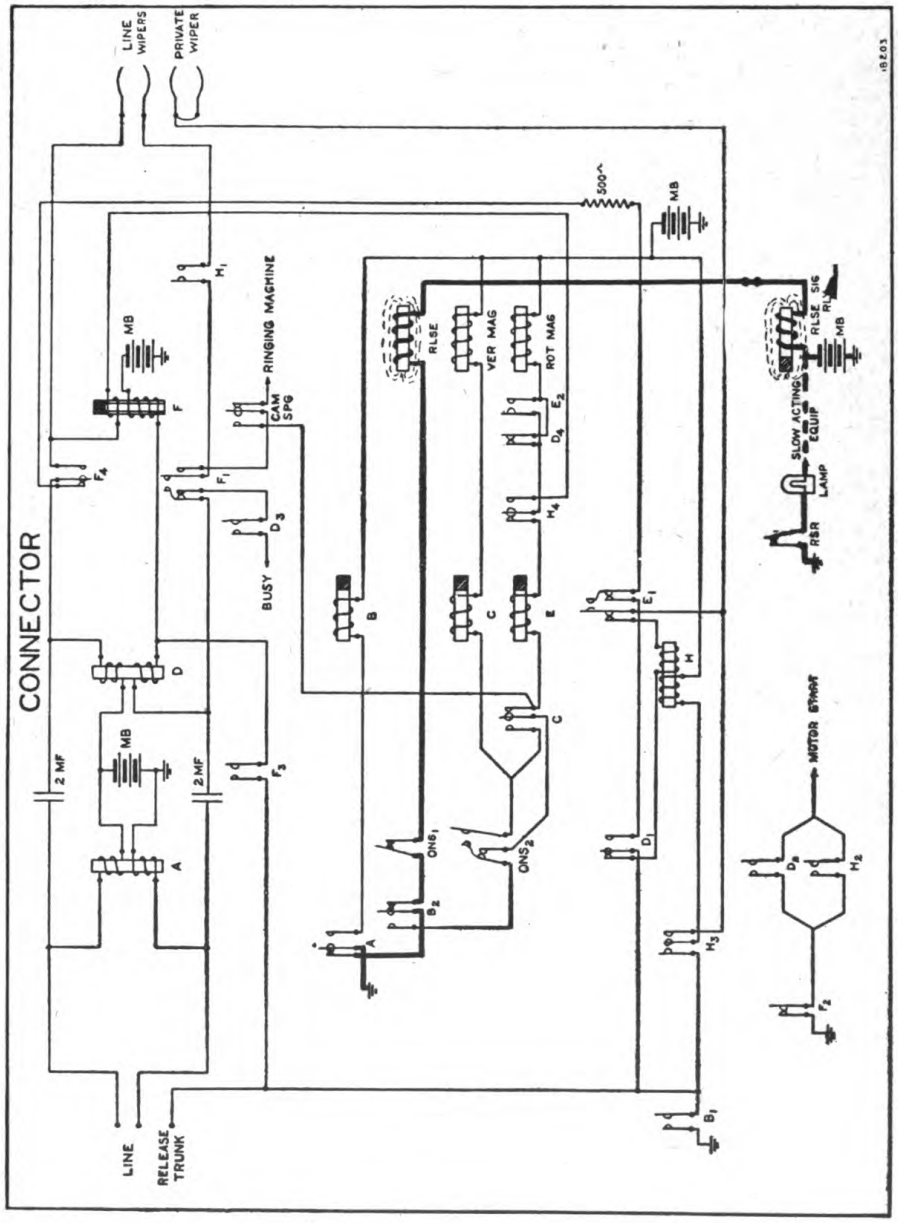
Contacts D_3 remove busy tone from line.

Contacts D_4 restore to normal.

Release magnet operates releasing mechanism.

NOTE.—The functions of the release signal relay will be described later.

Drawing IX shows the closure of the releasing circuit. The shaft and wipers now return to the normal position. The off-normal switch mechanically restores near end of downward motion of the shaft, at which time the circuit of the release magnet is opened and the entire circuit is restored to normal, as shown in Drawing I.



DRAWING IX.—Showing closure of release magnet circuit.

23. *The called line found idle.*

Ringing the called station.

(21) The called line is assumed idle. The private wiper meets battery via the bridge cut-off coil of the called line line switch. (Relay B.)

(22) The private relay E releases a brief interval after wipers reach bank terminals.

Contacts E_1 switch the private wiper from the busy circuit to the operating circuit of the line wiper relay H.

Contacts E_2 open a contact in the rotary stepping circuit.

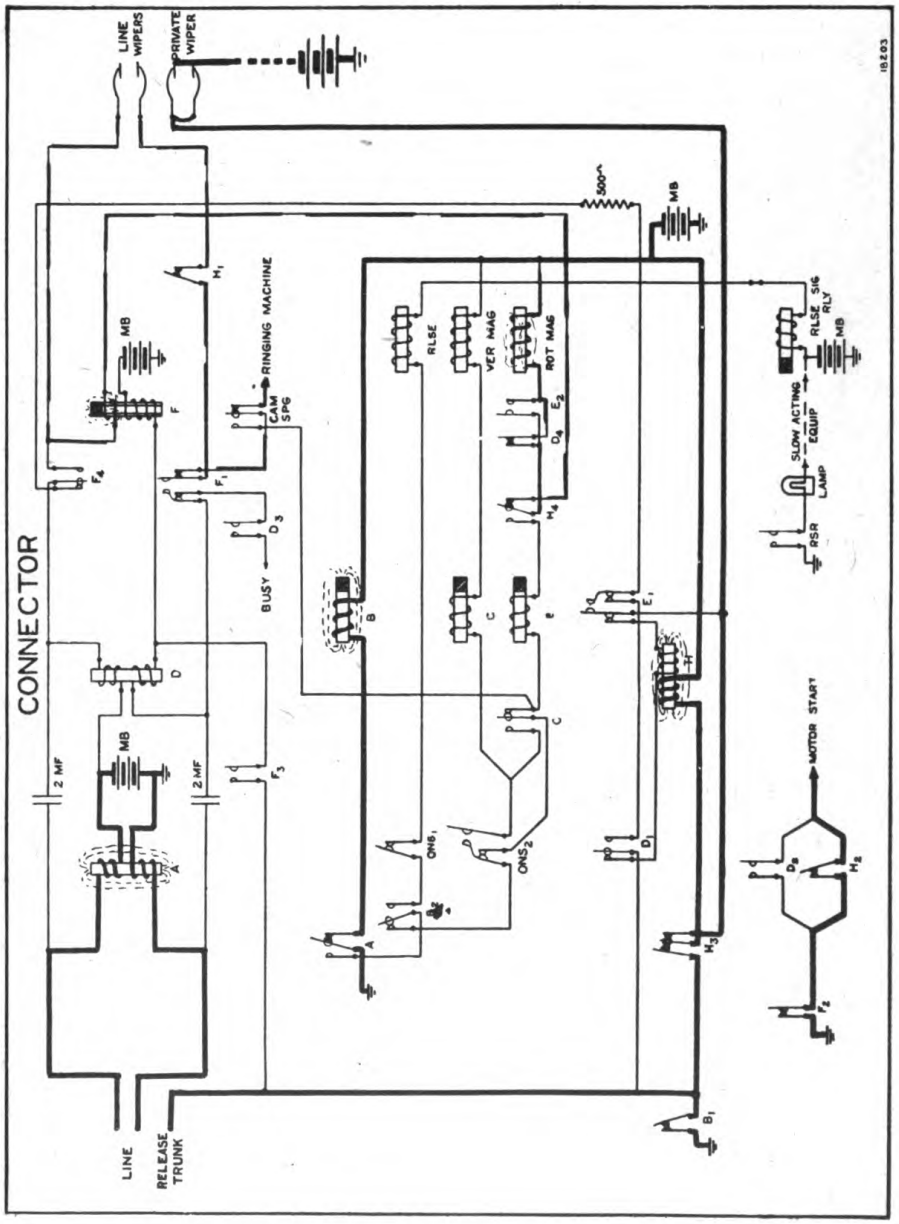
(23) The line wiper relay H operates (in series with the bridge cut-off coil of the called line line switch).

Contacts H_1 and H_4 close the ringing circuit to the called line—indicated by the dashed line on drawing X.

Contacts H_2 close circuit of ringing machine to start ringing.

Contacts H_3 close holding winding of relay H, short-circuit operating winding relay H, and place a ground on the private bank contact to make the line test busy.

Drawing X shows circuit conditions at this stage. The called line has been seized and the bell is being rung. Note that the high resistance holding winding of relay F acts as a secondary winding of an induction coil to put a ring back tone on the calling line.



DRAWING X.—Circuit conditions when called line has been seized and is being rung.

24. *The called party answers.*

Cutting through of the calling line.

(24) Called party lifts receiver from hook, disconnects bell and condenser and closes line circuit through the transmitter and receiver.

(25) The ringing cut-off relay F operates. This relay remained unoperated on the ringing current, but now operates on direct current.

Contacts F_1 and F_4 open circuits used for busy test and ringing and close the called line circuit through the busy and back bridge relay D, thus putting the two parties in communication.

Contacts F_2 open the circuit of the busy and ringing machine since it is not needed.

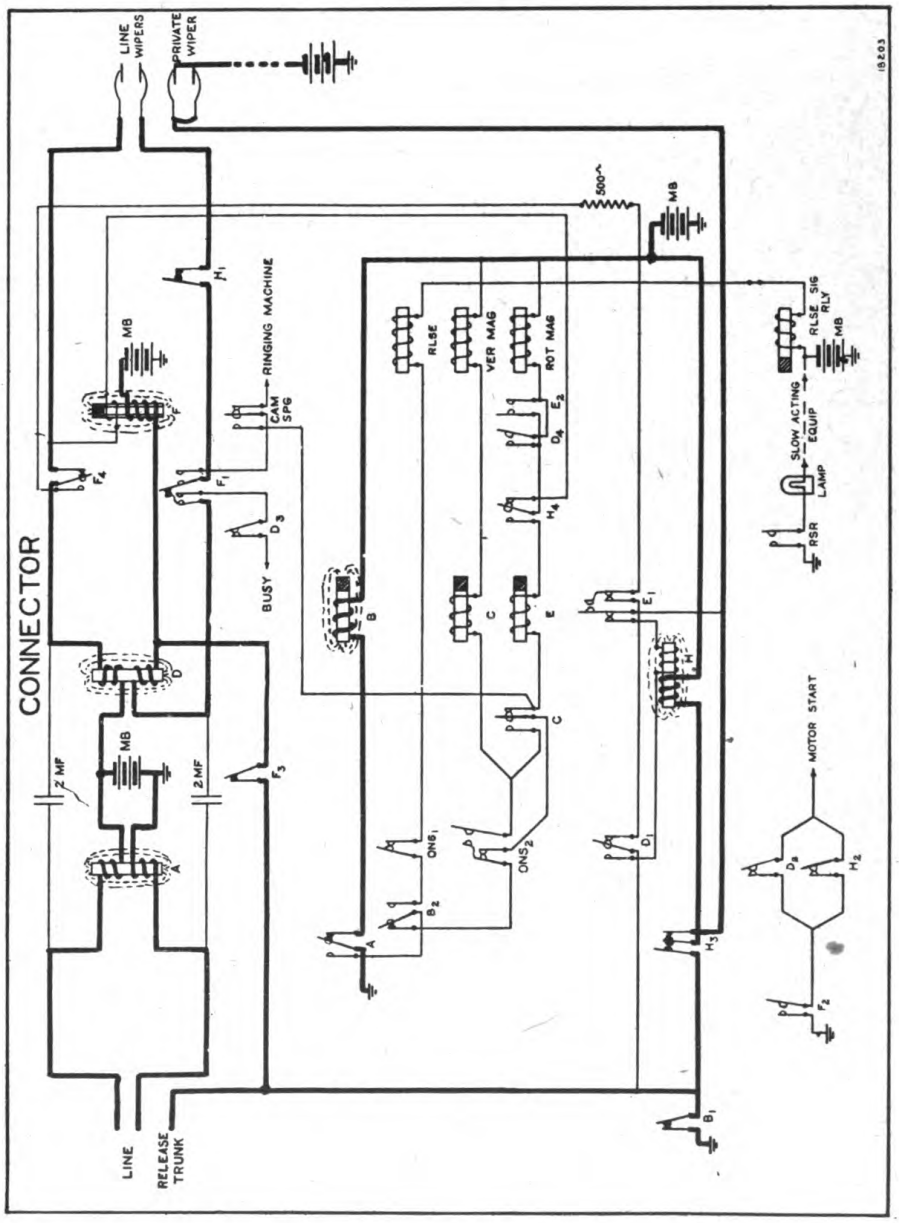
Contacts F_3 close the locking circuit of the ringing cut-off relay and at same time furnish a ground to close circuit of relay D.

(26) The busy and back bridge relay D operates.

Contacts D_1 shift circuits
Contacts D_2 close contact in motor start circuit
Contacts D_3 close contact in busy circuit
} Not significant at this time.

Contact D_4 opens a contact in rotary magnet circuit as a precaution against further rotary stepping.

The circuits, now in their normal operated condition, are shown in Drawing XI.



DRAWING XI.—Condition of circuit when connector is in its normal operated condition.

25. *Release of the connector.*

The control of the release of this connector is given entirely to the calling party. If the called party hangs up first, the busy and back bridge relay D merely releases without causing any significant circuit changes.

(27) Calling party hangs up receiver and opens calling line.

(28) Line relay A releases.

Contacts A open circuit of release relay B and close contact in circuit of release magnet.

(29) Release relay B releases.

Contacts B_1 remove ground from release trunk, thus releasing the line switches of both the calling and called line and opening the circuits of line wiper relay H and ringing cut-off relay F. (Relay F holds over because of slow release.)

Contacts B_2 close circuit of release magnet (in series with release signal relay).

(30) Line wiper relay H releases while release magnet operates.

Contacts H_1 open called line circuit, which includes busy and back bridge relay D.

Contacts H_2 open contact in motor start circuit.

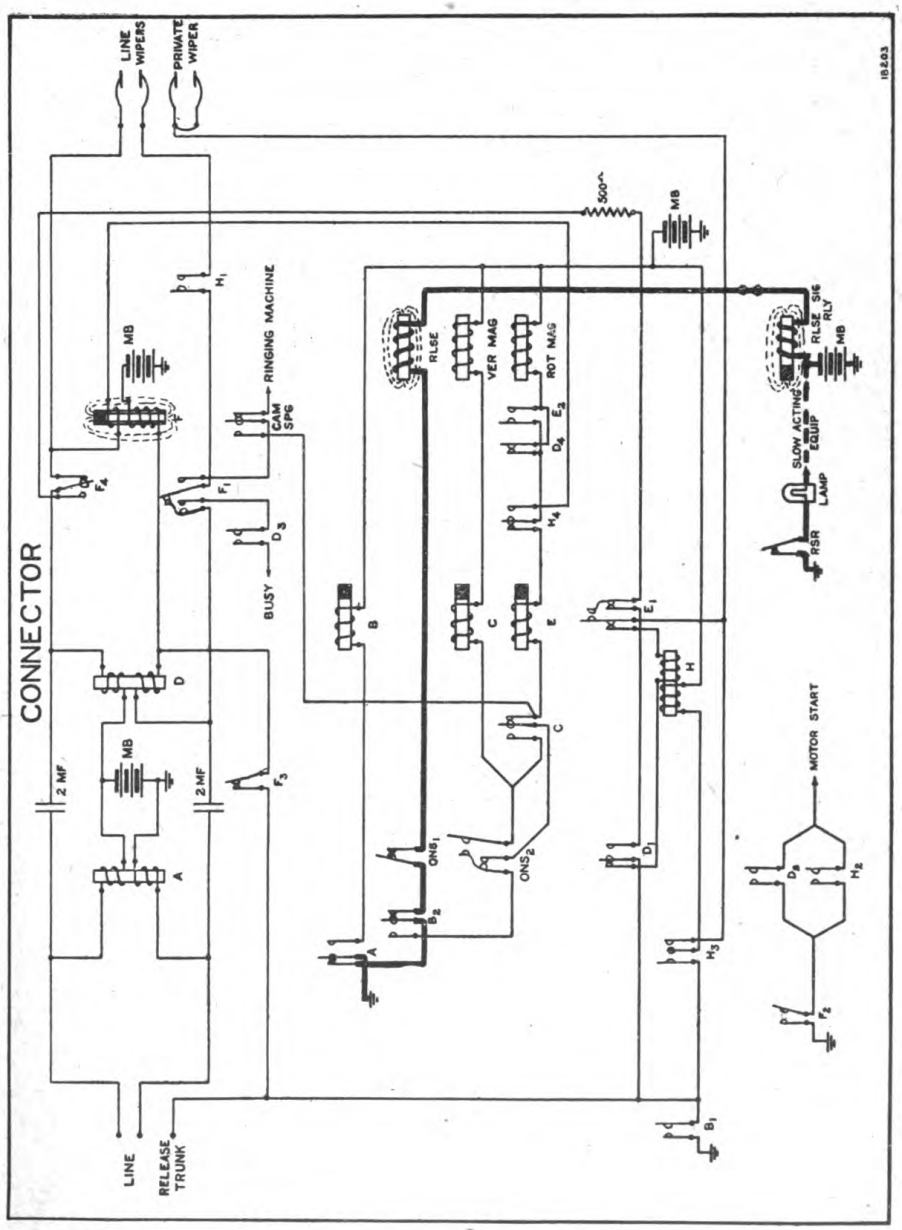
Contacts H_3 open contact in the locking circuit of relay H and disassociate the release trunk and private wiper.

Contacts H_4 restore, this action not being significant at this time.

(31) Busy and back bridge relay D releases.

Contacts D_1, D_2, D_3, and D_4 restore to normal preparatory to the release of the switch.

Drawing XII shows the circuit conditions at this instant, the release magnet circuit being about to release the mechanism. Ringing cut-off relay F is holding because of its slow release feature.



DRAWING XII.—Circuit condition causing release of connector and calling and called line switches, relay F holding for a brief interval.

25. *Release of the connector*—Continued.

(32) Ringing cut-off relay F releases.

Contacts F_1, F_2, F_3, and F_4 restore to normal preparatory to release.

(33) Release magnet operates releasing mechanism.

The shaft and wipers now return to the normal position. The off-normal switch is mechanically restored near the end of the downward motion of the shaft, at which time the release magnet is deenergized and the entire circuit is restored to normal, as shown in Drawing I.

26. *Function of the release signal relay.*

There is one release signal relay furnished to a connector board, and the release magnets of all the connectors on the board receive battery through this relay. Thus whenever a release magnet is energized the release signal relay is also energized. The relay has a pair of contact springs which close a circuit containing a lamp and slow acting equipment so arranged that if a release magnet is energized for a certain period the signal (including the lamps and an audible alarm) will be brought in. If a connector fails to release properly, the resulting alarm signal notifies the attendant of the trouble. The release signal relay may also be provided with an additional pair of contact springs which may be wired to a meter. This meter will then register the number of originating calls.

SIGNAL CORPS PAMPHLETS.

(Corrected to February, 1922.)

RADIO COMMUNICATION PAMPHLETS.

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26. Sets, U. W. Radio Telegraph (Types SCR-127 and SCR-130). W. D. D. 1056 (edition of Nov., 1921).
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7. Signal Corps Universal Test Set (Type EE-65) (edition of Dec., 1921). W. D. D. 1020.
10. Wire Axis Installation and Maintenance within the Division. W. D. D. 1068.
11. Elements of the Automatic Telephone System. W. D. D. 1096.

TRAINING PAMPHLETS.

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2. Instructions for Using the Cipher Device, Type M-94. (W. D. D. 1097.) FOR OFFICIAL USE ONLY.
4. Visual Signaling.
5. The Homing Pigeon, Care and Training. W. D. D. 1000.
7. Primary Batteries (edition of 6-9-22).
8. Storage Batteries (formerly designated Radio Pamphlet No. 8).

FIELD PAMPHLETS.

1. Directions for Using the 24-CM. Signal Lamp (Type EE-7).
2. Directions for Using the 14-CM. Signal Lamp (Type EE-6).