AUTOMATIC TELEPHONY

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A COMPREHENSIVE TREATISE ON AUTOMATIC AND SEMI-AUTOMATIC SYSTEMS

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To

MR. ALEXANDER ELLSWORTH KEITH

WHO BY HIS GREAT RESOURCEFULNESS, UNLIMITED ENTHUSIASM,
STEADY DETERMINATION AND KEEN FORESIGHT
HAS BEEN FOR TWENTY YEARS THE LEADER IN THE
DEVELOPMENT OF AUTOMATIC TELEPHONY,
THIS VOLUME IS RESPECTFULLY DEDICATED.

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CHAPTER I

TRUNKING

Automatic trunking is based upon the "transfer line" or trunk, which was used in early manual switchboards, but abandoned because of the inefficiency of human beings as switches. Trunking is of two kinds, local and inter-office. Local trunking concerns itself with connections between stations served by one office or switchboard, inter-office trunking connects different offices in the same exchange.

Inter-office Trunking.—Where an exchange is composed of several offices, the traffic between them is usually handled by a network of direct trunks.

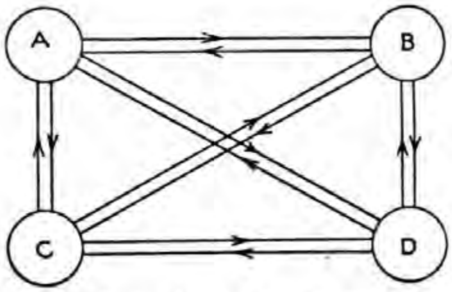


FIG. 1.—Inter-office trunks.

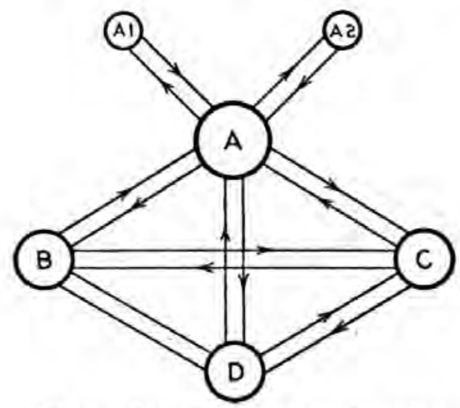


FIG. 2.—Indirect inter-office trunking.

This is illustrated by four offices in Fig. 1. Each line connecting two offices represents a group of trunks carrying traffic in one direction. There are therefore two groups between each two offices, carrying traffic as arrowed.

The number of trunk groups as above defined increases greatly with the number of offices. To obtain the number of trunk groups for any given case, multiply the number of offices in the exchange by one less than this number. Thus, a ten-office exchange would require $10 \times 9 = 90$ groups of trunks.

Indirect trunking has in some cases been used to reduce the complexity of the system, but with the result of slowing down the service. We may suppose (Fig. 2) an exchange having four offices, A, B, C, and D, with a system of direct trunks between them. Two offices, *A*-1 and *A*-2, are tributary to office *A* and receive all their connections with the other offices through the operators or apparatus belonging to "*A*." In connection with automatic switching, there is no slowing down of the service.

Since there is a great similarity between certain operators' duties and the switching actions of some of the automatic switches, the trunking arrangement employed in some large exchanges will be here described.

In Fig. 3 four offices in one exchange are represented. The subscribers' lines entering each office are multipled before the "*B*" operators only. The "*A*" operators have nothing but the answering jacks and line

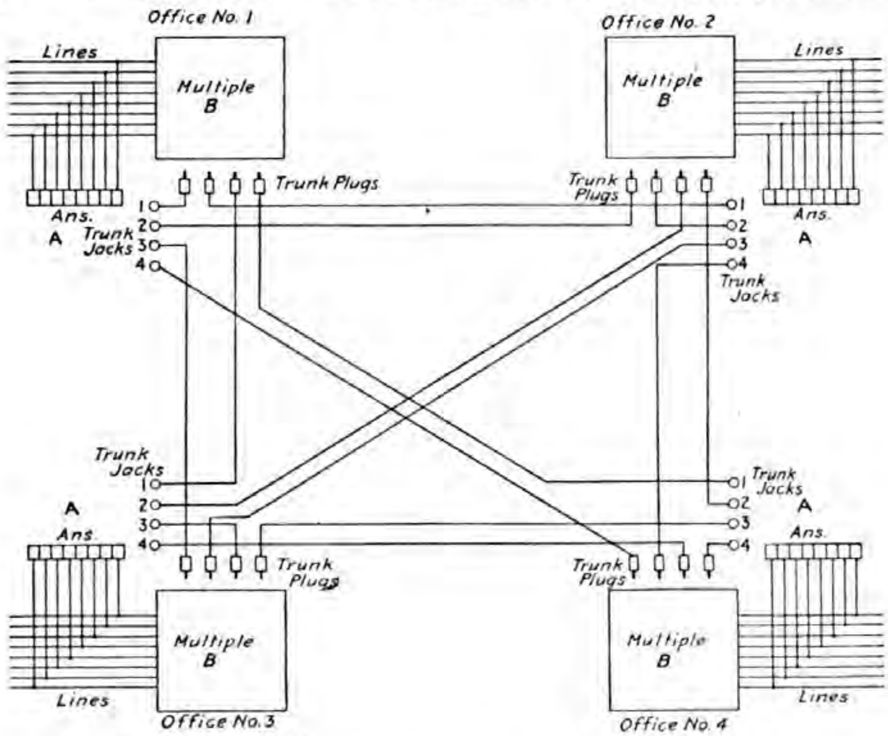


FIG. 3.—Manual inter-office trunking without "*A*" multiple.

signals, indicated by "*Ans.*," and the trunk jacks for trunks leading to all the offices. Though only one trunk per office is shown, it must be understood that there are in each case as many trunks in a group as are necessary to carry the traffic.

In establishing a connection, the calling subscriber is first met by the "*A*" operator in his own office. This operator, after ascertaining the desired number, extends the circuit through her cord, a trunk jack, and a trunk line to the office desired. Here the "*B*" operator receives the number from the "*A*" operator and inserts the trunk plug into the multiple jack of the called line.

In a system such as just described, the "*A*" operators perform the primary switching act and the "*B*" operators the secondary switching act. In other words, the "*A*" operators are "office choosers" or "group choosers" while the "*B*" operators are "connectors."

Trunking in Automatic Exchanges.—The methods of trunking which are about to be described are peculiarly adapted to automatic switching, and are among the chief factors in the success of automatic systems. The general plan of an automatic exchange divides the subscribers' lines into groups and subgroups. A 10,000-line exchange is composed of ten groups, each having 1000 lines. Generally each 1000-line group is subdivided into ten smaller groups of 100 lines each. Two variations from this plan should be noted, namely, a final subdivision into fifty-line groups (practised by the American Automatic Telephone Company) and into 200-line groups practised by the Western Electric Company). These variations will be referred to more fully later and the present discussion will be confined to the plan more generally used. For the purpose of selecting the line of any subscriber the 100 lines of any unit are usually considered as made up of ten groups each having ten lines.

The groups and subgroups need not follow the decimal system, but it is more convenient to have them do so, since the numbers in common use are thus expressed and may be used as call numbers without change.

When the decimal system of grouping is used, the digits of the call number indicate the location of the line to which it belongs. Thus, No. 4375 indicates line No. 75 in the third hundred of the fourth thousand.

The selection of a line proceeds by successive choice. First the thousand is selected, then a certain hundred in that thousand, and finally the ten and unit in the selected hundred.

We will first describe a 100-line system and build it up to the larger sizes.

One-hundred-line System.—One hundred telephones may be given service by equipping each line with a connector switch, which has the ability, under the control of the subscriber, to connect with any of the hundred lines. In Fig. 4, let the calling telephone be connected by two wires to a pair of springs or wipers. Associated with these wipers is a bank of contacts, each of which is a small flat brass piece. They are arranged in pairs (100 pairs) one for each subscriber's line. The subscriber at the calling telephone can move the line wipers of his connector switch so that they will come into contact with any pair of the hundred.

The numbering of each pair of the bank contacts is based upon the number of steps required to lift and rotate the wipers to them. It requires only one step to lift the wipers to the first or lowest level, hence all numbers in that level begin with "1." After having been lifted to the first level, four steps are required to rotate the wipers to contact 4, so that this will be termed "14." Similarly, to connect with telephone 47 requires four vertical steps and seven rotary steps.

The order of numbers shown for the bottom level is characteristic of all the levels. It starts with "11" and runs in regular order to "19," which is followed, not by "20" but by "10." This is because the digit "0" means "ten," so that the number "10" signifies one vertical step and ten rotary steps.

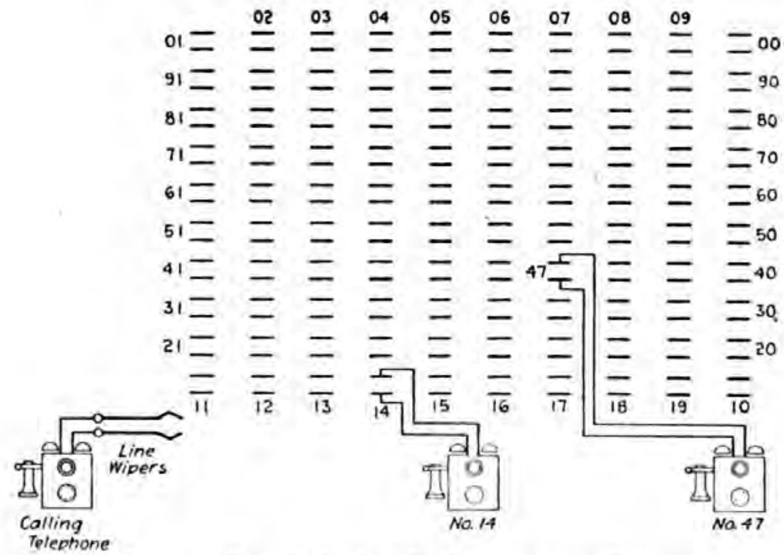


FIG. 4.—Essential principle of connector switch.

A complete 100-line automatic exchange requires only 100 connector switches, interconnected so that any subscriber can extend his line to that of any other subscriber. (Fig. 5.) Three telephones are here used to show the

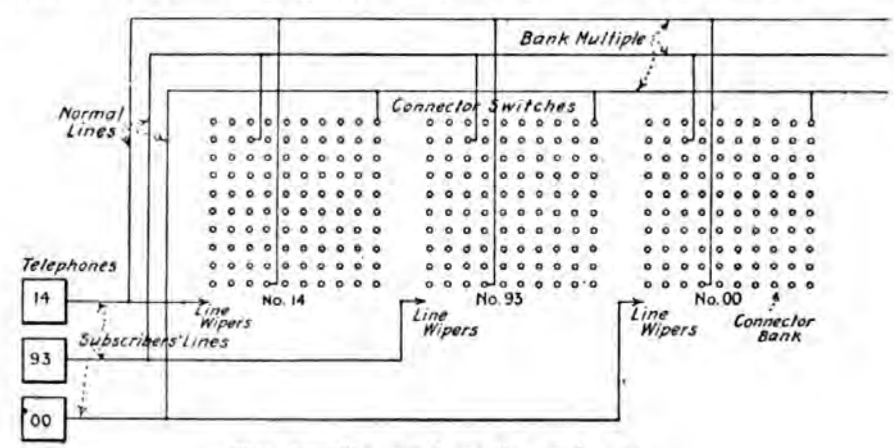


FIG. 5.—Theory of 100-line exchange.

relations of the entire hundred. Imagine that the single line running from each telephone to its line wipers consists of two wires, and that each little circle in the connector bank represents two or more contacts. Each telephone has its own connector switch, the wipers of which are represented by an arrow.

Besides being connected to the line wipers of its own connector, each line is multipled to a contact pair in every bank. For example, the line from telephone No. 14 runs to the wipers of connector No. 14, and also to contact pair No. 14 in every connector switch in the hundred. Those wires which join the bank contacts together are termed the "bank multiple," and those wires which connect the bank multiple to the subscribers' lines are called "normal lines."

Upon the connector switch devolve certain duties, among which may be mentioned the control of the wipers by the subscriber, a busy test, means for ringing, and means for releasing. If the system be designed for common battery talking, the connector must furnish direct current to the lines.

One-thousand-line System.—An automatic telephone exchange of 1000 lines may be built up by assembling ten 100-line groups. The subscriber must then be provided with means for selecting the group or hundred which he desires, in addition to controlling a connector in that group.

At the extreme left in Fig. 6 are squares representing the telephones, two out of each hundred. Each telephone is connected to its own selector, but no longer has the exclusive use of any connector switch. Instead, a number of connector switches sufficient to handle the maximum number of connections which are likely to be made to the lines in each hundred group are assigned to that group and are used in common by all subscribers calling into it. The number of connectors per group is usually ten.

There are 1000 selectors. The banks of all the selectors are multipled together and wired to the connectors, which are at the extreme right. There are ten connectors per hundred—100 connectors total. From the connector banks come the normal cables, which are attached to the subscribers' lines at the selectors.

The essential duties of a selector are two, first to select the desired hundred, second, to seize a trunk line leading to an idle connector belonging to that hundred. The first of these functions must be completely under the control of the calling subscriber, the second should be entirely automatic, for it is of no interest to the subscriber which trunk line he gets.

The connectors are represented by arrows for wipers and heavy lines for the bank levels. Each heavy line must be taken to mean a level of ten sets of contacts like those shown in Fig. 4. The light lines connecting the levels of one connector with the levels of the next connector are the bank multiples, as shown in Fig. 5.

The tracing of a call will show the relations of the switches and trunks. Let us suppose that telephone No. 234 desires a connection with telephone No. 482. The subscriber will first operate the dial of the calling device to send four impulses over his line. In response to these signals, the selector No. 234 will lift its wipers to the fourth level. Then, without the subscriber's volition, it will rotate its wipers until it finds an idle trunk line. On tracing

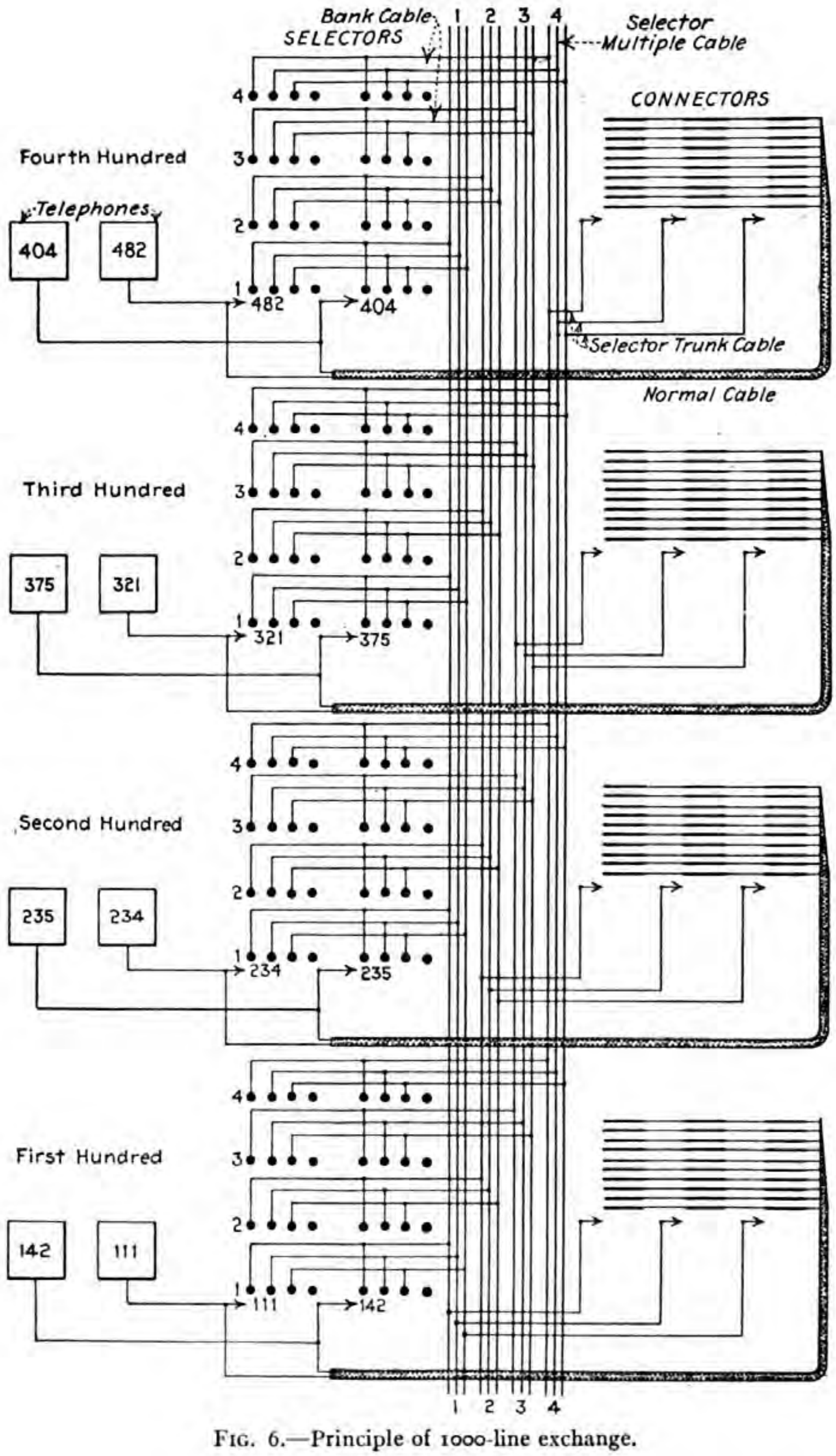


Fig. 6.—Principle of 1000-line exchange.

first selector X, so that each frame or board contains 100 of them. The second selectors are shown at Y and the connectors at Z. There are ten of each on a board.

The wires from the banks of the first selectors are gathered into the "first selector bank cable," 5, and carried to a terminal rack, 6. A "first selector multiple cable," 7, connects these various banks together from board to board, running between like hundreds in the different thousands. All these cables carry 100 trunks, corresponding to the capacity of a selector bank. A small cable, 11, called the "first selector cable," taps off ten trunks at each board and runs them to the ten second selectors on each board.

The distribution of trunks from the banks of the second selectors follows the same plan, which is like that described for the selectors of the 1000-line system. The second selector bank cables run to a terminal board (not shown) and are connected together from board to board in the same thousand by the second selector multiple cable, 13. Small taps of ten trunks each are taken off through the second selector trunk cables, 12, which terminate in the connector switches, Z.

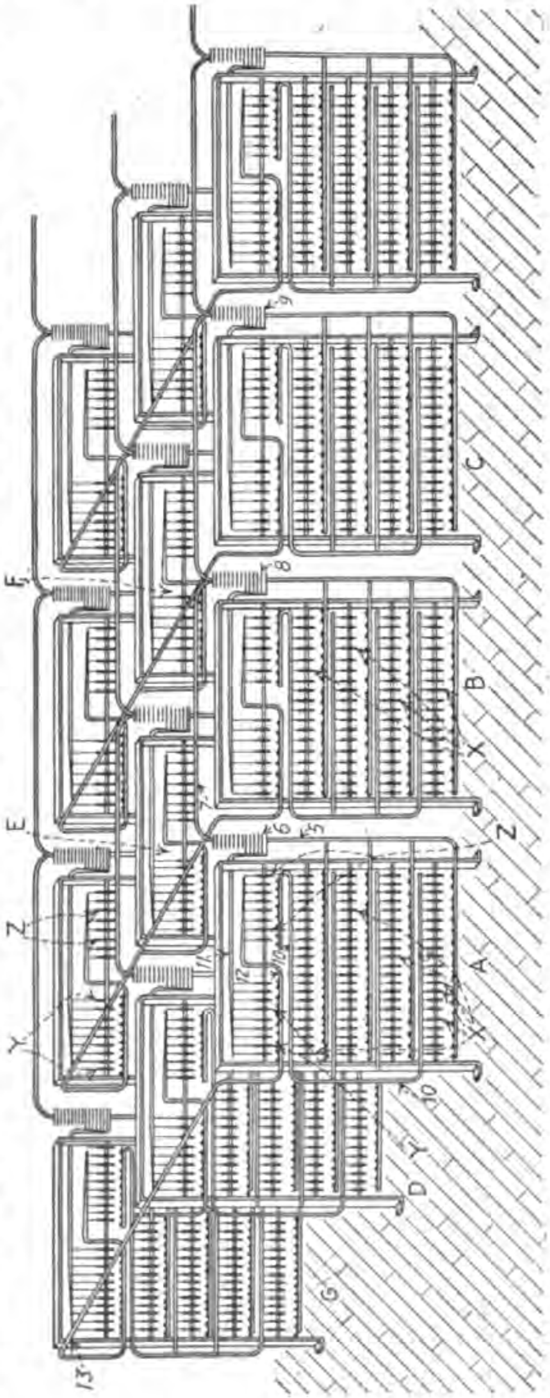


Fig. 8.—View of part of 10,000-line board (U.S. Pat. 831,876 perspective, Fig. 2).

The trunking from the banks of the first selectors is shown by levels in

Fig. 9. Three 100-line boards are indicated, each being in a different thousand. The backbone of the scheme is the first selector multiple cable, which joins all the boards of like number together. Each of the ten lines by which it is represented in the figure, signifies ten trunks which are wired to a certain bank level. Thus, the bottom group of ten trunks belongs to the first level, the group above it to the second level, and so on. This gives every first selector in the like boards access to the same trunks, level for level.

In each board ten trunks are tapped off the multiple cable and run to the second selectors located there. In the "1100" board, these second selectors are wired from the ten trunks belonging to the first level, because they must

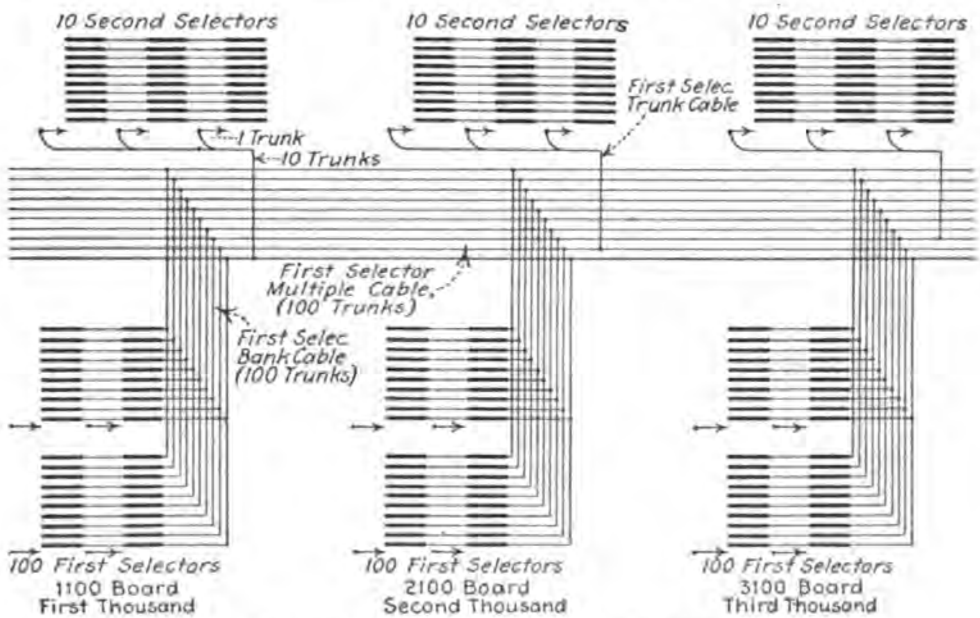


FIG. 9.—Trunking of first selectors by levels.

handle all the calls from these boards into the first thousand. In the "2100" board, the second selectors are attached to the ten trunks which come from the second level, since these selectors carry the traffic into the second thousand. Thus each little group of ten second selectors carries all the traffic from 1000 telephones into the particular thousand to which it belongs. The 1000 lines from which the calls emanate are made up of ten like 100-line groups, each in a different numerical thousand, as 1100, 2100, 3100, 4100, 5100, 6100, 7100, 8100, 9100, and 0100. Or we may take as examples the following hundreds; 1200, 2200, 3200, 4200, 5200, 6200, 7200, 8200, 9200, 0200. On the other hand, the thousand into which each group of second selectors delivers calls is made up of ten 100-line groups in numerical order as follows: 1100, 1200, 1300, 1400, 1500, 1600, 1700, 1800, 1900, 1000, or the following, 3100, 3200, 3300, 3400, 3500, 3600, 3700, 3800, 3900, 3000.

The trunking from the banks of the second selectors to the connectors may be seen by a study of Fig. 6, which has already been presented and described.

Bank Slip.—That method of bank multipling known as "bank slip" was invented by Mr. A. E. Keith (patent No. 831,876). Its object is to shorten the time necessary for a selector to find an idle trunk, to reduce the possibility of two selectors seizing the same trunk and to equalize the wear on the switches by distributing the work.

If we were to take out of a selector bank one level of contacts, we would have ten contacts arranged on the arc of a circle as shown at "1," Fig. 10. The arrow indicates the wiper which is adapted to move from left to right over these ten terminals. The corresponding levels in nine other switches are shown to the right of "1" and are numbered in accordance with the numbers of the selectors from which they are taken. Notice that these bank contacts are multipled together with the "straight" multipling, trunk No. 1 being attached to contact No. 1 of each bank, and the others to their respective contacts, point for point. By this method, each switch has the same trunk as its first choice.

The advancing bank slip is shown in Fig. 11. Bank No. 1 is wired straight, that is, trunk 1 to contact 1, trunk 2 to contact 2, etc. On bank 2 all the trunks are in the same order, but have been advanced one step. Trunk 1 is on contact 2, trunk 2 is on contact 3, etc. It will be noted that switch 1 has trunk 1 as its first choice, switch 2 has trunk 10 as its first choice, switch 3 has trunk 9, switch 4 has trunk 8, etc. This method has never been used in practice, within the knowledge of the writers.

The retrograde bank slip, Fig. 12, is the one which is in general use in most automatic exchanges. As in the two other multiples, the first bank is wired straight. Bank 2 is wired with the trunks in the same order, but slipped one step back. Trunk 1 is on contact 10, trunk 2 is on contact 1, trunk 3 is on contact 2, etc. By this means, the first choice of each switch is made to be the trunk whose number corresponds with the number of the switch on the shelf. Switch 5 has trunk 5 as its first choice, switch 8 has trunk 8, etc. This system has the advantage of simplicity and ease in tracing calls.

The rule for tracing a call forward (from a first selector to a second selector, etc.) is to add to the number of the switch the number of the bank contact upon which the wipers are resting, and subtract one. Thus, if switch No. 3 be resting on contacts 5 of its own bank, it will be connected to trunk 7, for $3 + 5 - 1 = 7$. Examination of Fig. 12 will show the correctness of the calculation. If switch No. 9 be resting on contacts No. 5 of its bank, we apply the rule thus, $9 + 5 - 1 = 13$. There being no trunk No. 13, we subtract 10, and find that the wipers of the switch in question are resting on trunk No. 3.

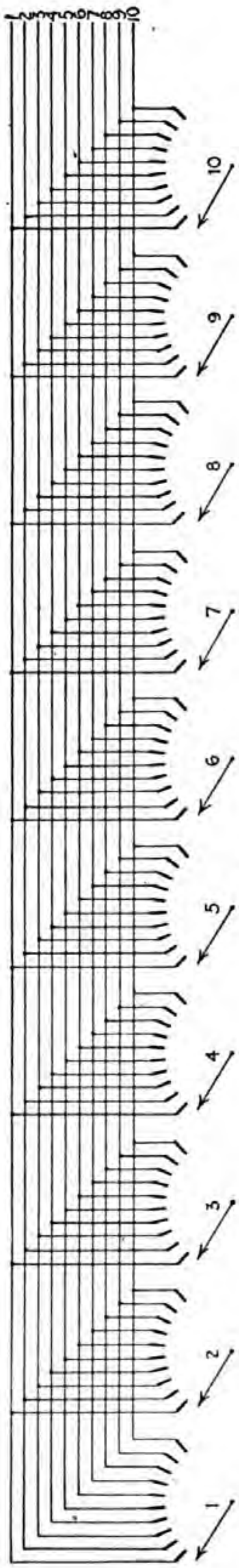


Fig. 10.

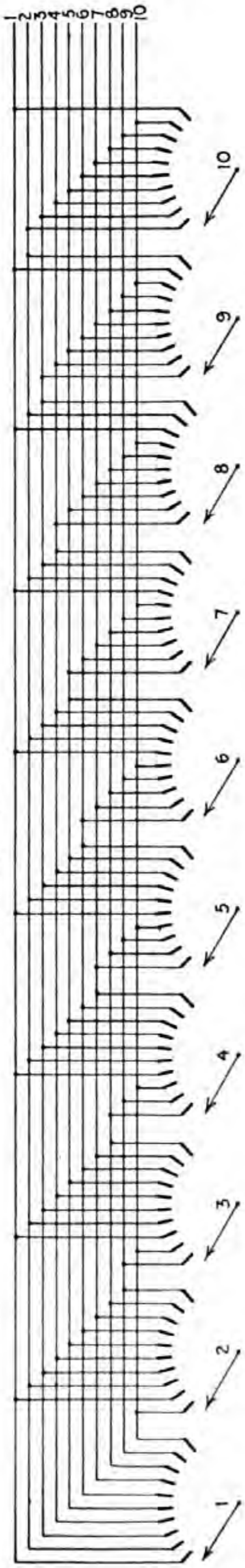


Fig. 11.

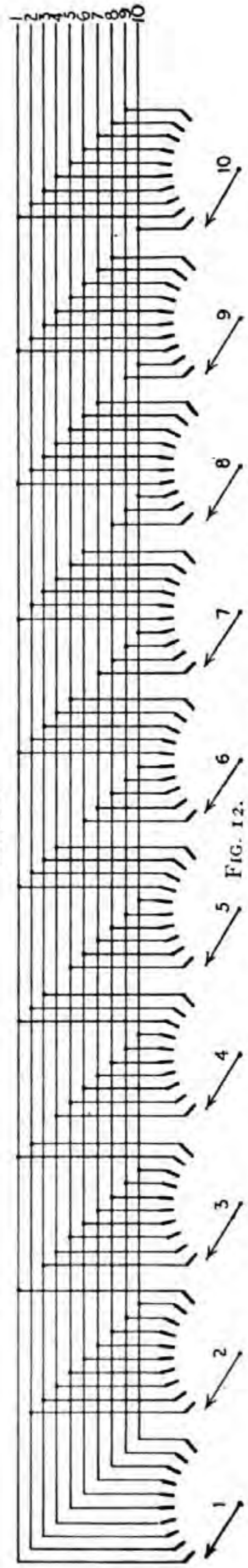


Fig. 12.

Fig. 10—One level of selector banks, straight multiple.
Fig. 11—One level of selector banks, advancing bank slip
Fig. 12—One level of selector banks, retrograde bank slip.

plishes the same result of scattering the traffic over all the trunks more evenly. In this case it is the ten switches of a shelf which have the same order in the choice of trunks.

FIG. 14—Bank slip in multiple cable.

A very simple symbol for bank slip has been derived from Fig. 14. If we examine the terminal strips at the right of the figure we will notice that the multipling from one rack to another exists in the form of diagonal lines, each jogged over from right to left as we proceed from the upper part of the diagram to the lower. Each row of ten trunks designated by the word "rack" in Fig. 14 represents a certain level, the same level in each of the shelves. We may, therefore, take these rack terminals and assemble them in a diagram by themselves. This has been done in Fig. 15. The trunks are seen at the top of the figure, numbered from left to right from 1 to 10. The top row of terminals stands for the certain level of ten trunks on a certain shelf of selectors; the next row below it stands for the corresponding level in any shelf of selectors, and so on, until ten shelves

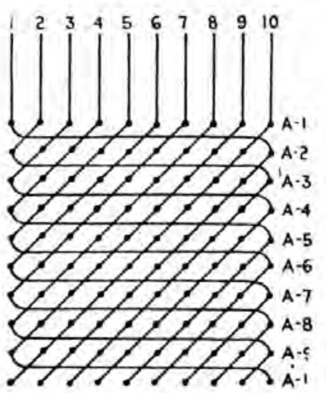


FIG. 15.—Symbol for bank slip.

have been connected. It will be seen that the retrograde nature of the bank slip is very clearly shown, inasmuch as each trunk slips backward one contact for each shelf connected.

Automatic exchanges have been installed with either type of retrograde bank slip as above described. The slip in the multiple cable seems to be more in favor at the present time.

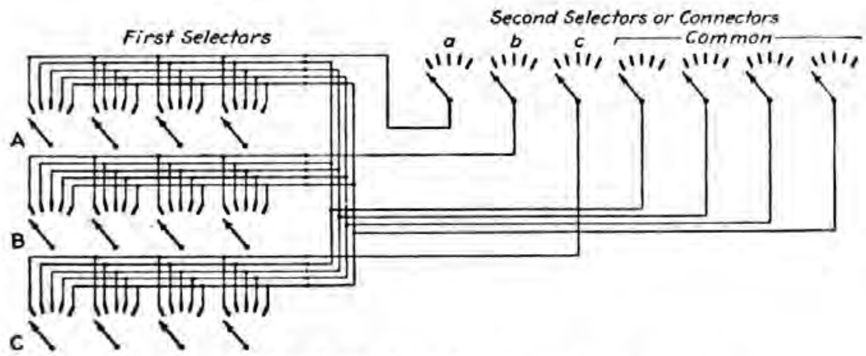


FIG. 16.—Individual trunks with common group.

Individual Trunks.—The first automatic exchanges had individual trunks only, so that each switch or group of switches had but one trunk leading to any other group. The simple individual method, however, can hardly be said to be economical of trunks, for the reason that the trunks of one group

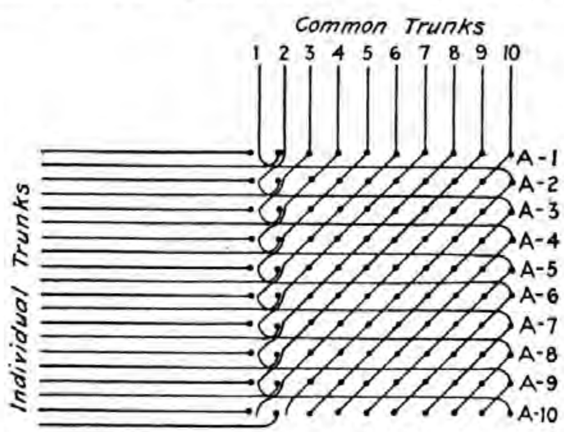


FIG. 17.—Individual trunks with slipped common trunks.

might be entirely used up, while idle trunks are still available in other groups. For this reason individual trunks if used are always combined with a common group, through which calls may be made if all the individual trunks have been occupied.

The individual trunk method used by the American Automatic Telephone Company is shown in Fig. 16. *A*, *B* and *C* represent three shelves or groups of first selectors and only five trunks are shown outgoing from each shelf.

The first trunk is individual, as from shelf A a single trunk runs to second selector a; from shelf B, an individual trunk to second selector b, and so forth. There are four common trunks multipled to all the shelves, each trunk ending in a connector, indicated by the word "common."

The method of individual trunks used by the Automatic Electric Company is shown in Fig. 17. It consists essentially of one or more individual trunks and a group of common trunks, the latter, however, consisting of ten trunks which are given a bank slip between the different shelves, although only a fraction of the total number of common trunks are used on any one shelf. This method of trunking was arrived at in the following manner: Suppose the ten shelves indicated in Fig. 17 to have been originally installed without individual trunks but with the customary bank slip between the shelves. Then imagine the common trunks to be removed from the first two contacts of each level and to be replaced by individual trunks. The result is the condition of affairs shown in Fig. 17. By this means the out-trunking from 100 switches (ten shelves of ten switches each) is increased from ten trunks to thirty trunks.

If we consider any given shelf the switches of which are multipled to each other point-for-point (i.e., without bank slip), we will see that whenever a switch seeks an idle trunk it will stop on the first one which is found disengaged. This means that the first trunk will get the heaviest traffic, the second trunk less, and so on, diminishing to the last trunk in the level, which may rarely, if ever, receive a call. Tests have shown that from 50 to 75 per cent. of all the calls handled by a fairly busy group of ten trunks are handled by the first three trunks.

From this we may draw the very natural conclusion that individual trunks offer a powerful remedy to relieve overcrowded trunk groups, so that if an exchange which has been installed in the usual way shows signs of overloading in any particular trunk group, this may be relieved by noting the most busy shelves which feed into this trunk group and installing individual trunks to divert enough of the traffic to bring down to a safe figure the total load remaining on common trunks.

Modern Trunking with Line or Finder Switches.—The foregoing discussion of trunking indicates the use of a first selector switch for each subscriber's line. This was formerly the arrangement, but in recent plants the use of line switches or finder switches makes it possible to install small groups of first selectors, each available to a large number of lines, just as the second selectors have always been.

In general, a line or a finder switch is a device which enables a number of lines to use a smaller number of trunk lines, so that when any line comes into use it will be automatically connected to an idle trunk line and protected from intrusion. A very common arrangement is to assign ten trunks to 100 subscribers' lines. When any subscriber removes his receiver from the hook, automatically find and seize an idle one of a number of trunks. In Fig. 18 four out of the 100 lines are shown. The arrow in which each line terminates represents the necessary wipers and the five small circles indicate the bank contacts over which the wipers may play. The banks of all the rotary line switches in this group are multipled together and run to the first selectors.

Two methods of operation have been proposed. The first is to have the wipers rest in a normal position out of contact with any trunks and to rotate and seek a trunk when the subscriber initiates a call. The second method allows the wipers to rest in any position in contact with some trunk, so that when the subscriber takes his receiver from the hook, the trunk will be immediately available. If, however, the trunk were occupied by some other subscriber, the switch would rotate to the next idle contact, before allowing the subscriber's line to be connected.

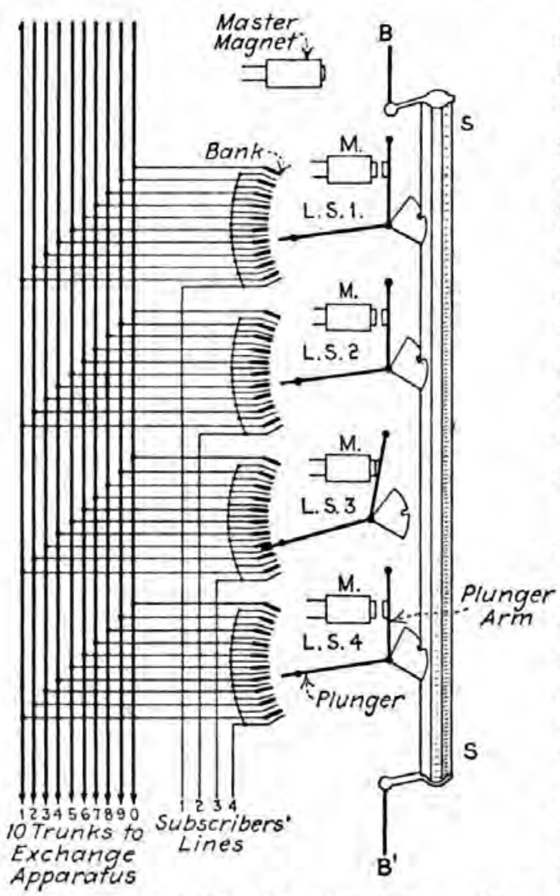


FIG. 20.—Principle of Keith type line switch.

In the Keith type line switch, the relation of the subscriber's lines to the trunks may be illustrated by the lines crossing each other at right angles in Fig. 19. Each subscriber's line is shown as extending across the trunks, indicating the possibility of connection with any of them. The heavy spots show connections which have been made by subscribers in putting through their calls. Line 1 has been connected to trunk 5, line 8 to trunk 6, line 4 to trunk 7, and line 19 to trunk 8.

In its mechanical structure the Keith type line switch is essentially a number of switches with a portable handle. The idea is shown by Fig. 20. Each subscriber's line is multipled to ten flexible springs, arranged on the arc of a circle. Each spring is associated with a contact, which is wired to a trunk line. The portable handle is called the "plunger" and is carried on the end of a lever called the "plunger arm." The rear end of the plunger has a notch which fits onto the master shaft, *S*. The point of the plunger carries insulation. When the plunger is forced away from the shaft and into the bank, it presses one of the flexible springs against its contact, thereby connecting the subscriber's line to one of the trunk lines.

The completed line-switch unit for 100 lines comprises three elements, the bank, the plunger and magnet (line switch proper), and the master switch. The bank and plunger have been described. The duty of the master switch is to keep all the plungers pointed at the contacts of an idle trunk, so that the next subscriber who makes a call will find a circuit ready for him. The pre-selection of trunks is an important feature of the Keith line switch.

One-hundred-line System.—The effect of line switches on a 100-line system of line switches of either type is to reduce the connectors from one

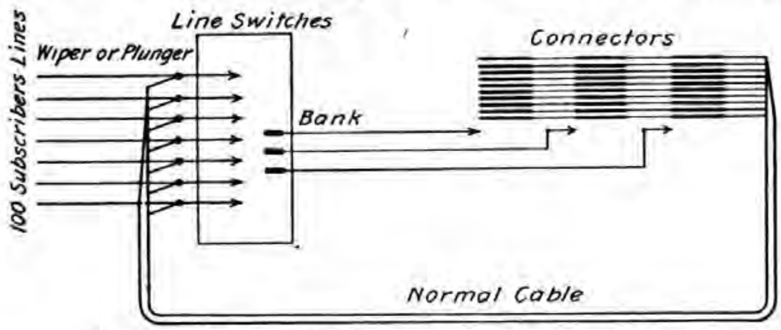


FIG. 21.—One-hundred-line system with line switches.

hundred to ten. In Fig. 21 the symbol for a line-switch unit is placed near the center, with the connectors at the right. Three connectors are shown, but any number up to ten must be understood.

The normal cable, starting from the multipled banks of the connectors, runs to the plunger side of the line switches, each line being attached at that point to the subscriber's line to which it belongs. This cable may be very short, for the connectors are often mounted on the back side of the same frame which carries the line switches.

When a subscriber takes his receiver from the hook, his line switch operates and connects his line to a trunk and therefore to a connector switch. The subscriber then operates his dial, lifting and rotating the wipers of the connector to the desired contacts. The connection now extends through the normal cable to the line switch of the called line and thence to the called telephone. The line switch of the called telephone is merely a meeting point: the line does not go through it.

One-thousand-line System.—The general plan of a 1000-line system is shown in Fig. 22. The lines from subscribers' telephones enter the office at the left and terminate in line switches. From the banks of the line switches run the trunks to the selectors, of which there are ten for each 100 lines. The banks of the selectors are multipled together, level by level, each line in the figure representing ten trunks. One of these groups of ten is tapped off to the ten connector switches of the first hundred, another ten to the connectors of the second hundred, and so on for all the hundreds. The banks of the connectors are multipled together and run to the line switches and subscribers' lines of their own boards.

The tracing of two calls will assist the reader to grasp the working of the system. If telephone No. 125 calls No. 342, the line of the former will be extended through line switch No. 125, a trunk to a first selector, through its

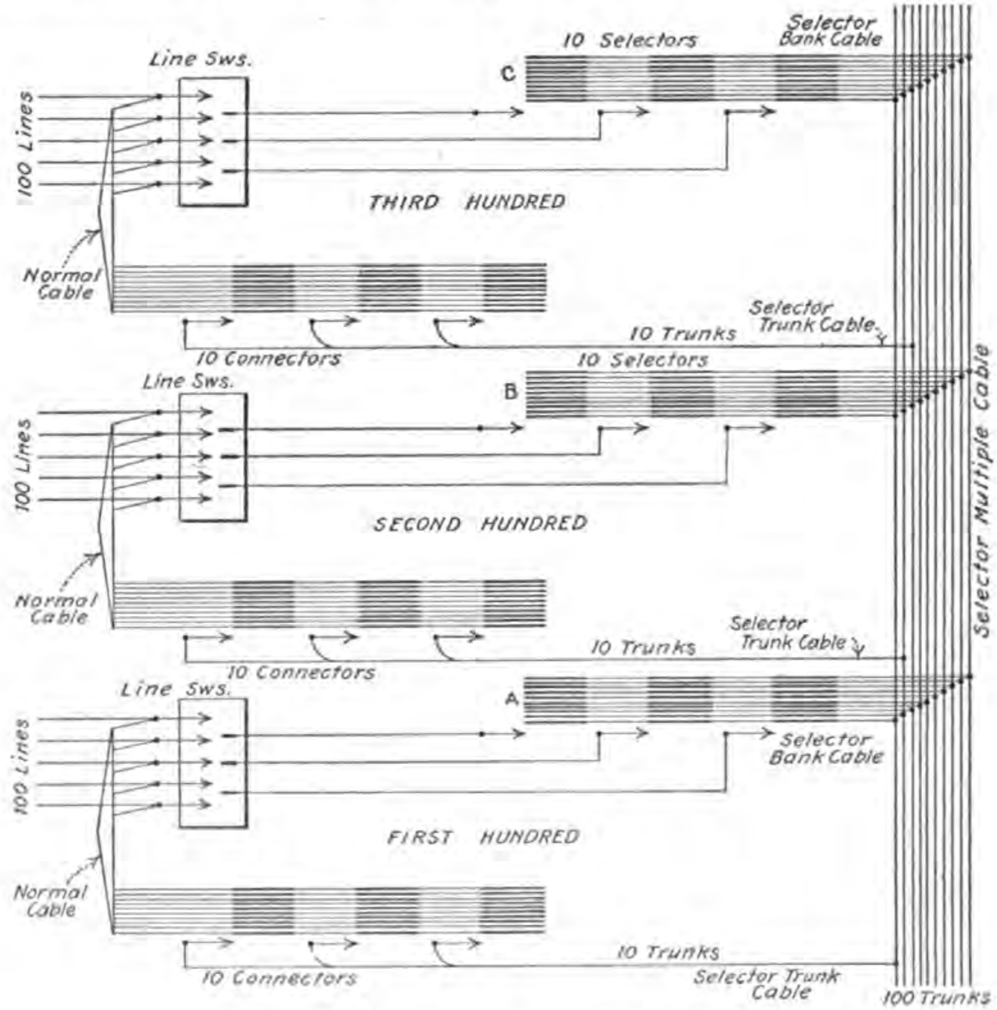


FIG. 22.—One-thousand-line system with line switches.

bank level 3 over a trunk to a connector in the third hundred, through contact 2 in level 4 (42) through the normal cable to line switch No. 342 and out over the subscriber's line to the called telephone.

If No. 125 calls some other telephone in the same hundred, such as 175, for example, the path will be as follows: line switch No. 125, a trunk to a selector, some contact in the first level and through a trunk to a connector in

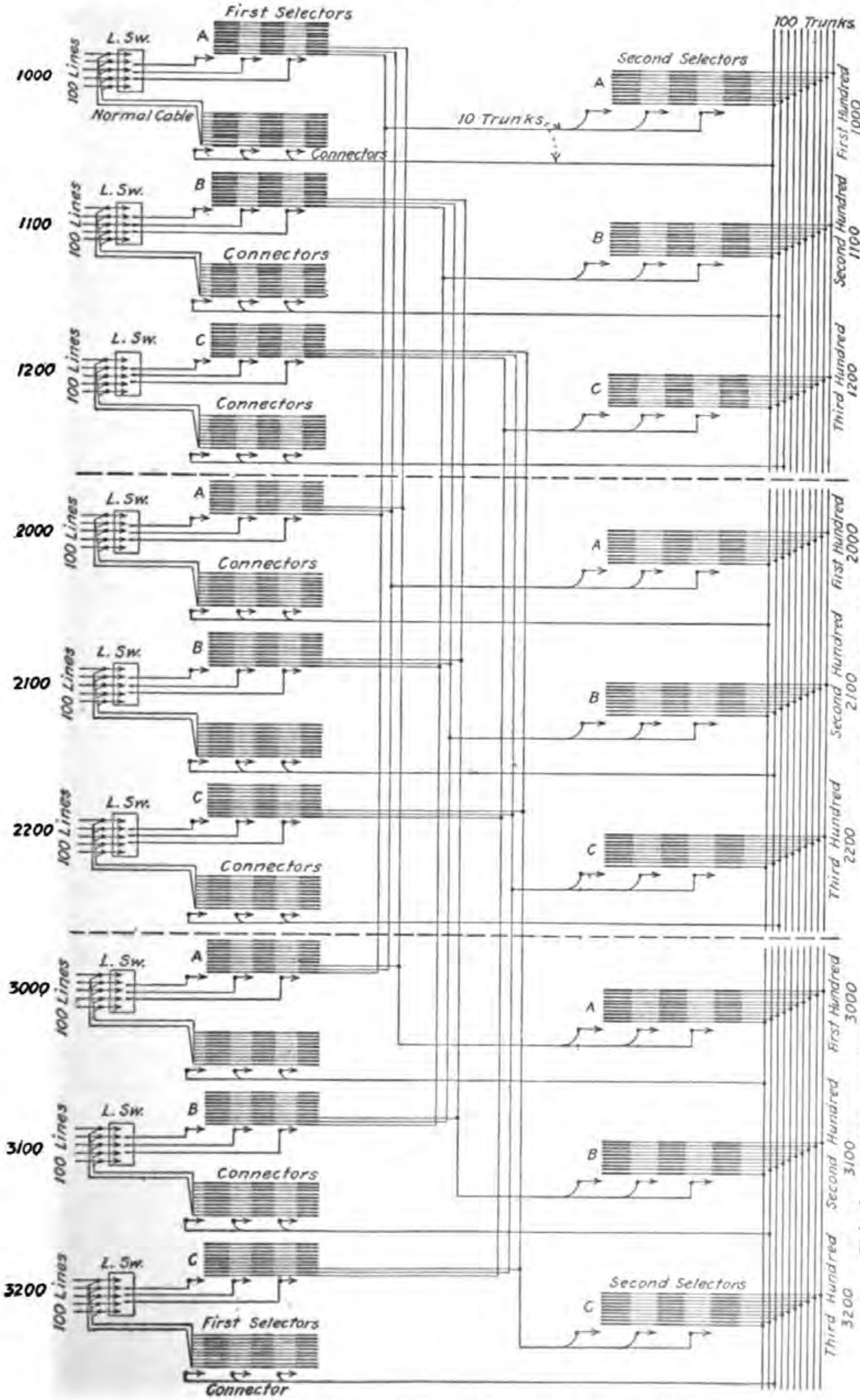


FIG. 23.—Ten-thousand-line exchange with line switches.

the same hundred, through contact 5 in the seventh level (75) through the normal cable to line switch No. 175 and out on the line to the called telephone.

Ten-thousand-line System.—The size of a 10,000-line automatic exchange is such that it is impossible to draw a diagram of its trunking in all of its entirety and keep within the bounds set by the ordinary book. For this reason the reader will be asked to imagine the entire plan from diagrams which present only part of the apparatus. For instance, in Fig. 23, three 100-line boards are used to represent ten boards, or 1000 lines. Also, three 1000-line groups are used to represent the entire system of 10,000 lines.

To a certain degree each thousand is separate and distinct from the others. It has its own subscribers' lines coming into the office at the left in the illustration, and running through line switches to first selectors. It has also second selectors for distributing calls to the different hundreds in the thousand. The connector switches are also part of the apparatus which is separated by thousands.

Each 100-line board is also somewhat distinct from the others, even in the same thousand. It has its own line switches, first selectors and connectors. The second selectors are, however, common to the thousand, because any second selector can select any hundred and any connector in that thousand.

The banks of the first selectors and the multiple cable connecting them together form the link which unites the entire exchange into one. In the same way, it is the banks and multiple cable of the second selectors which bind together the different hundreds of a thousand into one group.

The first selectors are arranged in groups of ten switches each, termed "shelves." There are ten shelves in each thousand and they are lettered from *A* to *J*. Since each thousand has the same equipment of first selector shelves, there will be in a complete office ten "*A*" shelves, ten "*B*" shelves, ten "*C*" shelves, etc.

In multipling the banks of the first selectors together for trunking to the second selectors, like shelves are connected together. Accordingly, levels No. 1 of all the "*A*" shelves are multipled together and trunked to the "*A*" shelf of second selectors in the first thousand. The levels No. 2 of all the "*A*" shelves of first selectors are multipled together and run to the "*A*" shelf of second selectors in the second thousand. In this way each level of all the "*A*" first selectors is led to the thousand to which it corresponds. Or, to look at it from a different point of view, each shelf of second selectors in a given thousand receives all the traffic for that thousand which comes through first selectors having the same shelf letter; that is to say, in the second thousand, the "*B*" shelf of second selectors handles the traffic from the "*B*" first selectors in all the thousands.

We will trace three calls, illustrating three different conditions in trunking which will be met in actual traffic. They are a call from a number to another number in the same hundred, from a number to another in a different hundred in the same thousand, and between numbers in different thousands.

Let No. 2125 call No. 2170. On taking the receiver from the hook, the line switch No. 25 on the "2100" board connects the line to an idle first selector on shelf *B*. Pulling "2" on the dial lifts the wipers of that first selector to the second level and automatically picks out an idle trunk leading to shelf *B* in the same thousand. The second operation of the calling device sends one impulse, which lifts the wipers of this second selector to the first level and causes them to seize an idle trunk to a connector in the hundred, known as the "2100" hundred. The last two pulls of the dial, 7 and 0, lift the wipers to the seventh level and rotate them to the tenth set of contacts in that level, which is numbered "70." The line now extends through the normal cable to the jacks of line switch 70 and out to the called telephone.

Let telephone No. 2030 call No. 2241. The call will extend from line switch 20 on the 2000 board to an idle first selector on the "*A*" shelf. Thence it is trunked through the second level to a second selector on shelf *A* in the same thousand. From here it goes through the second level to a connector attached to the "2200" board, and from the forty-first set of contacts, through the normal cable to line-switch jacks 41, and out to the telephone No. 2041.

If telephone No. 3255 calls No. 1267, the call will be routed as follows: line switch 55 on the "3200" board, idle first selector on "*C*" shelf, first level of first selector to idle second selector on "*C*" shelf of first thousand, third level of this second selector to idle connector on "1200" board, and by the usual manner to the line No. 1267.

The Secondary Line Switch.—The object of the secondary line switch is to reduce the number of trunks and trunking apparatus by taking advantage of the economies offered by larger groups of trunks. It has been proved by experience that small trunk groups can not handle as many calls *per trunk* as large groups can handle. The saving effected by large trunk groups is treated more at length in the chapter on "Traffic," to which the reader is referred.

The general principle of trunking by primary and secondary line switches is shown by Fig. 24. The subscribers' lines are attached to the primary line switches. The secondary line-switch boards are shown at the right.

As many as 2500 lines have been put in one large group or division, though on account of the space only 1000 have been shown in the figure. If the traffic from each 100 lines is not too great, only ten trunks will be allowed per 100, as illustrated.

The trunks from the banks of the primary line switches run to the secondary line switches, indicated by the arrows marked "plungers." From the banks of the secondary line switches the trunks run to first selectors, ten

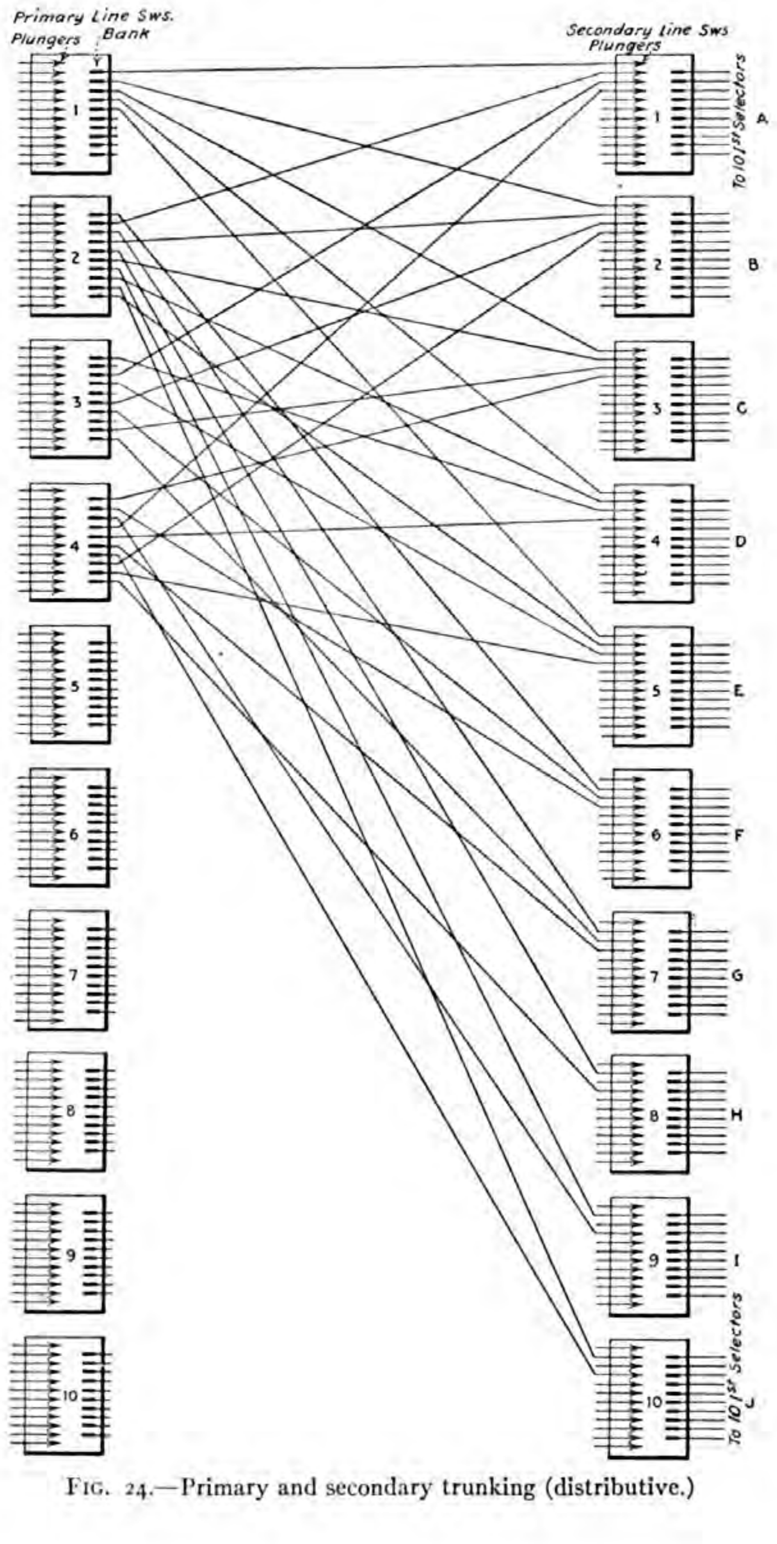


FIG. 24.—Primary and secondary trunking (distributive.)

secondaries are used. Usually fifty subscribers' lines are served by six primary or line finder switches.

Secondary Finder Switches.—The scheme of trunking where secondary finder switches are used is shown in Fig. 26. The subscribers' lines are arranged in groups of fifty, each group terminating in the bank multiple of a set of five or six primary or line finder switches. Attached to the wipers of these finders are trunks which terminate in the banks of the secondary finder switches. The wipers of the secondaries lead to first selector switches.

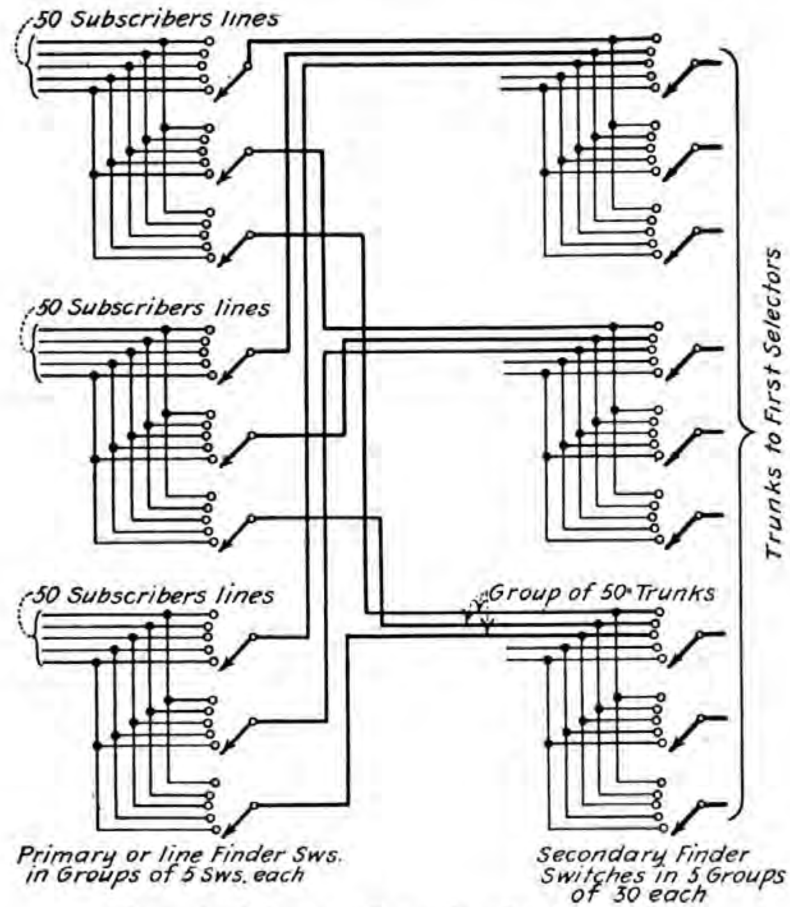


FIG. 26.—Primary and secondary line finders.

The number of secondary line switches in each group would generally equal about three-fifths of the number of contacts in the bank of each secondary switch. This means that there would be about thirty outgoing trunks from each group of secondaries (thirty secondary finders) if its bank multiple had fifty trunks coming into it. The total result of the plan shown in Fig. 26 would be to supply 2500 lines with 250 primary finders and trunks terminating in the banks of 150 secondary finders and through them reaching

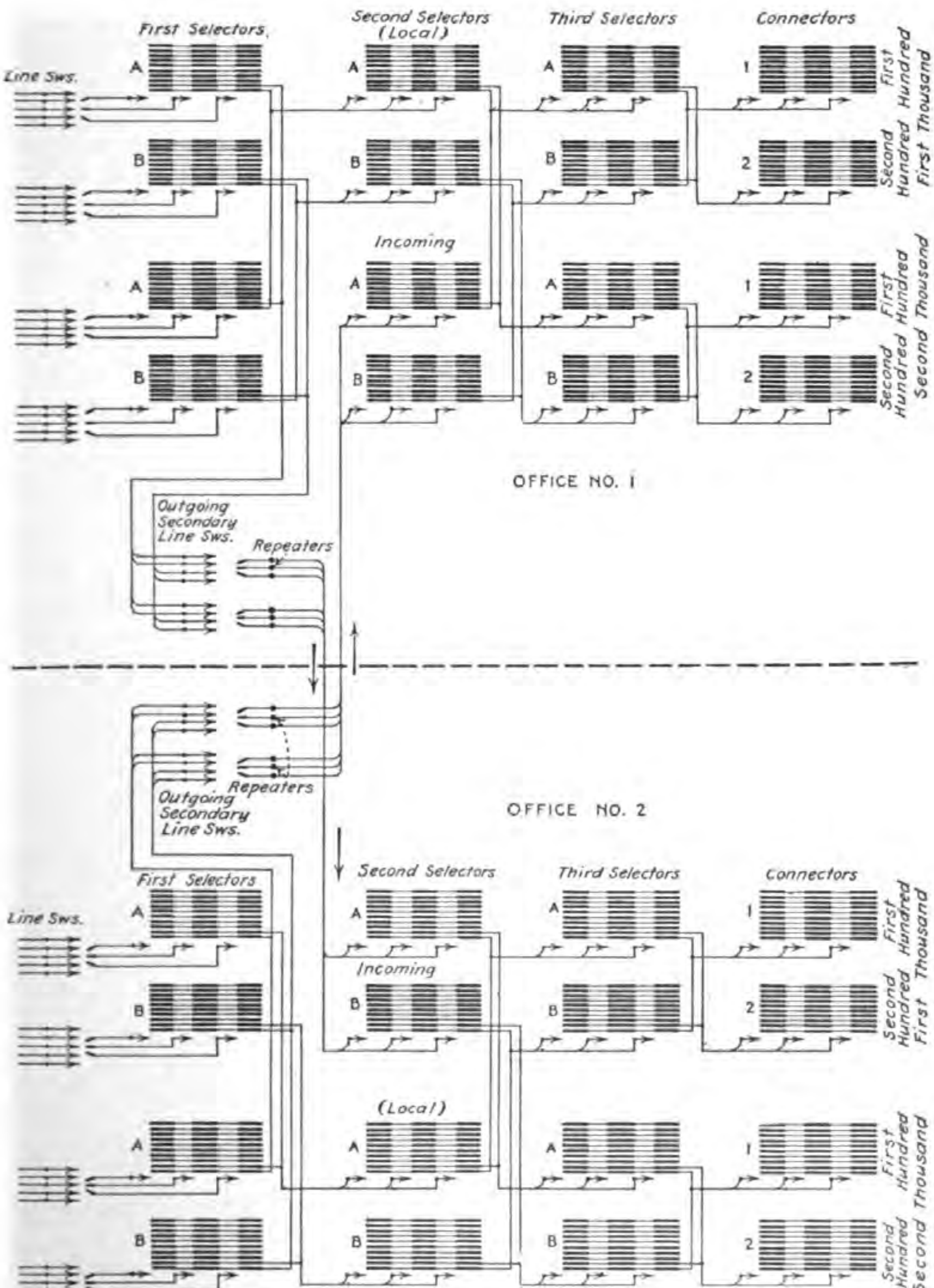


FIG. 27.—Inter-office trunking (100,000-line system).

150 first selector switches. The exact number of switches used would depend upon the traffic in each instance.

Inter-office Trunking.—The essentials of inter-office trunking are shown in Fig. 27. The horizontal broken line divides office No. 1 from office No. 2. These two offices are assumed to be part of a 100,000-line system with an ultimate capacity of 10,000 lines in each office, and there are, therefore, line switches, first, second and third selectors and connectors. The subscribers' lines pass through line switches directly to first selectors arranged on shelves *A*, *B*, etc. Since inter-office trunking begins at the first selector banks, we need not bother ourselves as to whether there are primary or secondary line switches.

Since the first selectors are the office choosing switches, the levels, excepting the level corresponding to the home office, will be trunked to other offices. In office No. 1, level 1 is trunked to local second selectors which distribute the traffic among the different thousands. Level 2 of the first selector banks is trunked through cables to office No. 2, where the trunks end in incoming second selectors. If there be other offices in the system, levels 3, 4, 5, etc., will be handled in a similar manner to their respective offices. In office No. 2, level 1 from the first selectors is trunked to incoming second selectors in office No. 1. The trunks from the second level of first selectors in office No. 2 are carried to local second selectors in office No. 2.

It sometimes happens that economies can be secured by bringing into one group all the trunks from one office to another. To secure this end outgoing secondary line switches are interposed between the first selector banks and the outgoing trunks in the originating office. The trunks from any given shelf of first selectors are distributed among several shelves of secondary line switches in order that each shelf of first selectors may have access to all the trunks leaving the office. In this way the several groups of trunks leaving the secondary line switches become in fact a common group. In case any one shelf becomes busy, the traffic will be carried by the remaining shelves and each shelf of first selectors will have only one trunk made busy.

Repeaters are inserted in the trunks just before they leave the originating office. They reduce the number of trunk wires to two instead of three, besides affording other advantages which are discussed in the text which treats of the circuits.

The second selectors in any office perform the same function which is performed by the first selectors in a 10,000-line system, that is to say, they distribute the traffic to the different thousands.

The multiple cables connecting the banks of the second selectors form the connecting link between the different thousands. By multipling together shelves having the same letter, the traffic from outside offices coming through incoming second selectors is mingled with the local traffic.

District Stations.—The district station office is a very simple variation in the general scheme of trunking. Suppose there is, at some distance from the nearest office, a group of subscribers such that the cabling of these lines to the office is a matter of considerable expense. A few trunks could just as well handle the traffic as to install subscribers' lines complete, running the entire distance. To handle such a condition, simply remove one or more line- or line-switch units from the office and locate them at the center of distribution to this group of subscribers. We may imagine the trunk lines connecting this unit with the rest of the exchange to be stretched out to reach between the center of distribution and the office. Such an installation will constitute a district station. There will be two kinds of trunks, outgoing trunks from the district station and incoming trunks to it. The outgoing trunks run from the banks of the line switches or the wipers of finder switches and terminate in first selectors in the main office. The incoming trunks run from the banks of second or third selectors (depending upon the size of the system) and terminate in jacks of connector switches in the district station.

In order to reduce the number of trunk wires required between the banks of the line switches or the finder switches and the first selectors in the main office, it has been customary to install a repeater in the district station between the line-switch bank and each outgoing trunk. This also furnishes a convenient point for the supply of battery current to the calling subscriber, because the greater the distance over which battery current must be supplied the weaker will be the transmission. In cases where the distance from the district station to the main office is short enough to warrant depending upon battery supplied from the main office, the "series" type of repeater may be used. This repeater has the simple function of grounding the release trunk and preventing the premature release of the line switch.

In the foregoing pages of this chapter the practice of the Automatic Electric Company has been described quite fully in order to give the reader a clear idea of the general principles of trunking as practised with some variations by all of the companies manufacturing automatic or semi-automatic equipment. Certain of the variations from the Automatic Electric Company's practice have been noted, so that the following concise statements of the trunking schemes of other manufacturers will complete this chapter.

The practices of the Automatic Telephone Manufacturing Company, of Liverpool, and that of the Compagnie Francaise pour l'Exploitation des Procedes Thomson-Houston of Paris are the same as those of the Automatic Electric Company.

The practice of the Siemens & Halske Company is the same as that of the Automatic Electric Company, except that it employs rotary line switches instead of line switches of the Keith or plunger type. The primary and secondary line switches used by the Siemens & Halske Company in full automatic systems have a capacity of ten trunks each, while in its traffic first and second selectors together and for distributing the load by means of "slip" wiring are the same as those used by the Automatic Electric Company.

In the Western Electric Company's system, primary and secondary finder switches are used. These switches have a capacity of sixty lines or trunks each. Each secondary finder is tied "tail to tail" to a first selector switch. In the semi-automatic system of this company each of these trunks from a secondary finder switch to a first selector passes through an operator's position.

In either system the first selectors, second selectors and connectors have 200-point banks. The selector banks are arranged in ten sets of twenty trunks each. The lower five levels of the second selector banks lead to connector groups in one thousand and the upper five levels to connector groups in another thousand. It is obvious that since each connector switch has a capacity of 200 lines, but five groups of such switches are required for completing connections to 1000 lines, instead of ten groups as in the Strowger system. The trunking system of the Western Electric Company is described in detail in the chapter devoted to that company's apparatus.

In the Lorimer system finder switches are used which have access to 100 lines each. These are single-motion switches as in the Western Electric system. Each switch has ten sets of wipers which are selectively chosen. Each finder is tied to a first selector and each first selector has as many second selectors, or "interconnectors" as they are called, as there are thousands. The connectors have a capacity of 100 lines each. All switches have a rotary wiper movement only.

of a dial pivoted at its center, so that it may be turned in a clockwise direction. For convenience in turning the dial it has finger holes, ten in number,

FIG. 29.—Wall telephone instrument.

FIG. 30.—Desk telephone instrument.

around its outer edge. Through each finger hole a number is seen; these numbers are consecutive from "1" to "9" and through the tenth finger hole, geared to the ratchet wheel and are therefore operated as the dial rotates back to its normal position. Each time the cam revolves, it breaks the contact between the impulse springs twice.

The principles involved in the operation of the dial are carefully worked out and are essential to rapid and accurate calling. Every turn of the dial

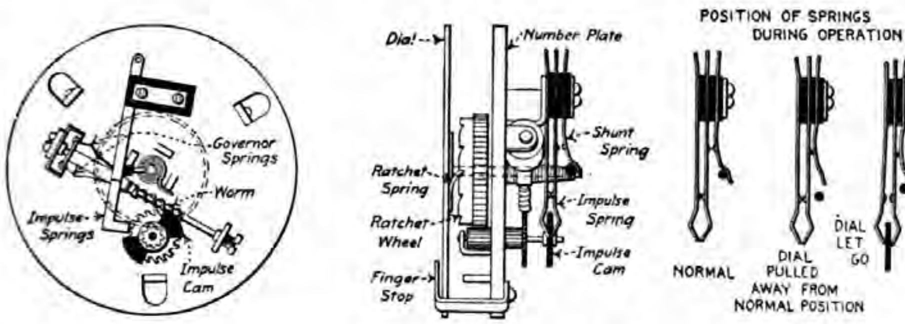


FIG. 32.—Details of calling device.

is positive and correct, regardless of the speed at which it is made. Anyone who has experienced the slow and painstaking care required to manipulate the dial of an ordinary office safe to bring each successive number opposite the stopping point without first passing it, will readily appreciate that any calling device which would require the subscriber to stop each number opposite a pointer or, vice versa, to stop a pointer opposite each number, would be very slow and inaccurate in comparison with a calling device like that shown in the illustrations.

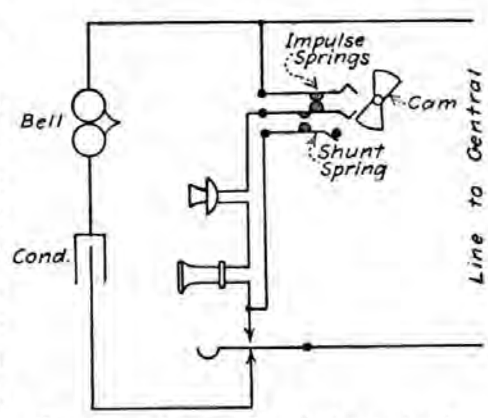


FIG. 33.—Automatic telephone circuit.

The only feature of the telephone which is peculiar to automatic systems is the calling device. The signaling, receiving and transmitting circuits and apparatus may be the same as those used in any common battery manual telephone. It is essential, however, that the circuits just mentioned be connected through the calling device in such a way that they will be automatically disconnected or shunted out while the calling device is being operated.

Telephone Circuit Diagram.—A diagram of a typical circuit is shown in Fig. 33. When the receiver is removed and the switch hook rises, the bell is switched out of circuit and the transmitter, receiver and impulse springs are connected across the line.

Each time the impulse cam breaks the contact between the impulse and the two-spool switch later. A photograph of a single-spool switch with a detached line-switch bank is reproduced in Fig. 36. The single-magnet spool has four windings and three armatures. The lower armature is the line relay armature, the one carrying the "plunger" is called the plunger armature, and that beneath the plunger armature is the cut-off relay armature. The plunger consists of a formed piece of clock-spring steel which carries near its point a roller or wheel about $\frac{1}{4}$ in. in diameter made of hard rubber.

Each set of bank contacts consists of four movable springs, each of which is pressed against a contact plate when the plunger thrusts its roller into the bank. Between the inner two rows of movable bank springs is a "comb,"

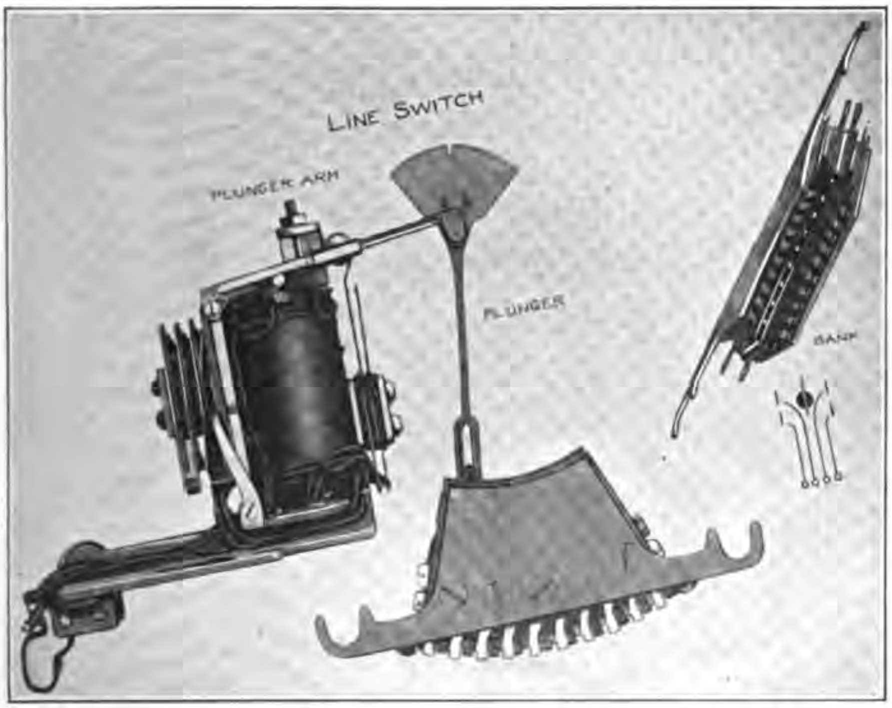


Fig. 36.—Single-spool Keith line switch with an unwired bank.

between the teeth of which the point of the plunger passes, so that the teeth act as guides for the plunger movements.

These line switches are mounted in four sets of twenty-five each on an "upright" or "unit" as shown in Fig. 37. Each set of twenty-five has a master shaft. Ordinarily, the four master shafts are linked together and controlled by one master switch, but in some cases the traffic is so heavy that it is necessary to provide more than ten trunks for 100 lines. In such a case, the line switches are divided into two sets of fifty each and one master switch is mounted for controlling the two guide shafts of each set. The design of the upright contemplates this, for the line switches are mounted on two hinged shelves, each of which carries one-half of the switches and is arranged so that a master switch may be mounted on it midway between its top and bottom and between its two groups of twenty-five line switches each.

The line-switch unit in the illustration has two master switches mounted upon it, although one is disconnected and the master shafts are all placed under the control of the other by means of the connecting rod with a turnbuckle at its center which links together the lower ends of the upper two guide shafts. Any line switch may be readily removed from its shelf without disconnecting any wires, because all of the wiring of each switch is connected to a set of jack springs as shown in Fig. 36.

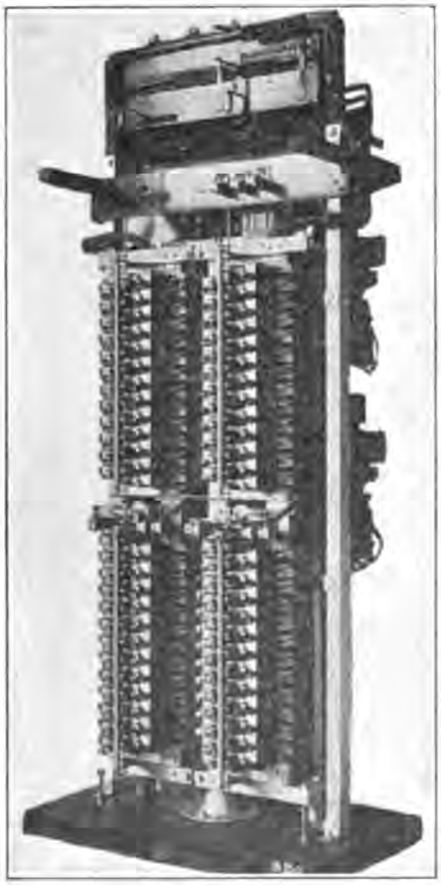


FIG. 37.—Keith line switch unit carrying 100-line switches.

The switch jacks engage corresponding shelf jack springs as shown in Fig. 38, which gives a clearer view of a master switch and a few mounted line switches. The line switches in this illustration are of the two-spool type.

Line-switch Circuits.—The circuit of the line switch which will here be discussed has its duties divided into two parts:

First.—Those duties which must be performed while the subscriber is calling into the exchange.

Second.—Those duties to be performed while the subscriber is being called by some other subscriber through a connector switch.

The duties devolving upon the line-switch circuit while calling are as follows:

1. Operate the plunger to extend the circuit to the connector.
2. Clear the line of line relay and ground connections.
3. Drive away other plungers so that privacy of the trunk may be secured.
4. Protect the subscriber's line at the connector bank so that no connector can seize this line.

Before a detailed explanation of the circuit shown in Fig. 39 is undertaken, it should be understood that the so-called single-magnet spool is really two spools, because it is divided into two sections by a Norway iron head or wall by means of which it is secured to and makes a magnetic joint with its heel piece. The upper section of the spool carries the cut-off relay and pull-down coil windings and the lower section, which is to all intents and purposes a separate relay carries the line relay and holding coil windings.

The operation of the line-switch circuit proceeds as follows: When a subscriber lifts his receiver from the switch hook the circuit is closed from earth at the line switch through spring 3 to the positive side of line to the telephone, through the telephone receiver and transmitter, back on the negative side of line through springs 6 and 5 and the line relay winding, *L.R.*, of the line switch, to the negative pole of battery. As soon as this circuit is established the line relay attracts its armature, presses spring 1 against ground spring 2, closing the circuit from ground through the "pull-down" coil, *P.D.C.*, holding coil, *H.C.*, to "open-main" battery busbar, which is always connected to the negative pole of battery except when the master

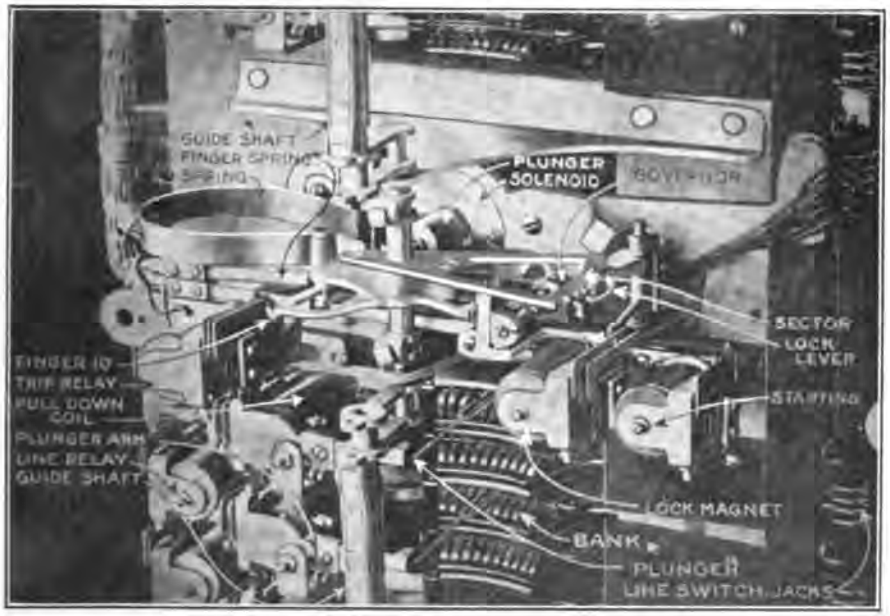


FIG. 38.—Master switch mounted on shelf of Keith line-switch unit.

switch is moving the line-switch plungers from one trunk to another. (See Fig. 41.)

When the "pull-down" coil is energized, it attracts the bridge cut-off relay, *B.C.O.*, armature, which disconnects the line relay coil from the line. But the line relay armature is temporarily retained by the holding coil. Following the quick-acting cut-off relay armature, the pull-down coil, *P.D.C.*, more slowly draws down the plunger arm, thus thrusting the plunger into the bank. As the plunger arm comes down it closes the contact between the plunger springs, *P.S.*, which short-circuits the holding coil.

When the plunger is thrust into the bank, circuit is closed from the release trunk (connected to earth at its other end) through springs 1 and 2 of the line-

Master Switches.—The master switch used in the two-wire system is shown in Fig. 40, and its circuits are given in Fig. 41, which shows also a connection from a calling telephone through its line switch and a connector switch to a called line with its line switch and telephone. Our present discussion will be confined to the master switch.

The power for moving the master switch in one direction is supplied by the solenoid. As the solenoid draws in its plunger, it not only moves the master shaft but it also draws down the master switch, *U*, spring so that when the master-switch shaft has reached the limit of its arc of movement in one direction, the master-switch spring is ready to supply the power for drawing it back to the other end of the arc. The speed with which the master shaft

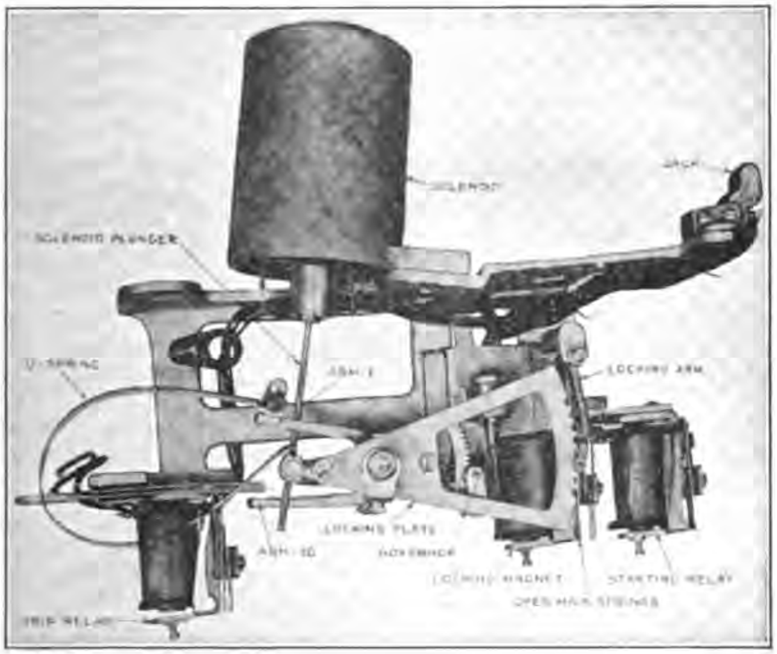


FIG. 40.—Unmounted master switch.

moves is controlled by the governor, which is of the same type as that used in the calling devices.

When a line-switch plunger enters its bank, it connects the corresponding contact of the master switch bank, *M.S.B.*, to earth, through the circuit already explained, and, if the master-switch wiper is resting on that particular contact, the circuit is continued through it and the master-switch starting relay to the negative pole of battery.

The starting relay closes circuit from earth through the one half-ohm ground supervisory relay and the winding of the locking magnet to the negative pole of battery. The operation of the locking magnet does two things. It breaks contact between its springs 1 and 2, which opens the

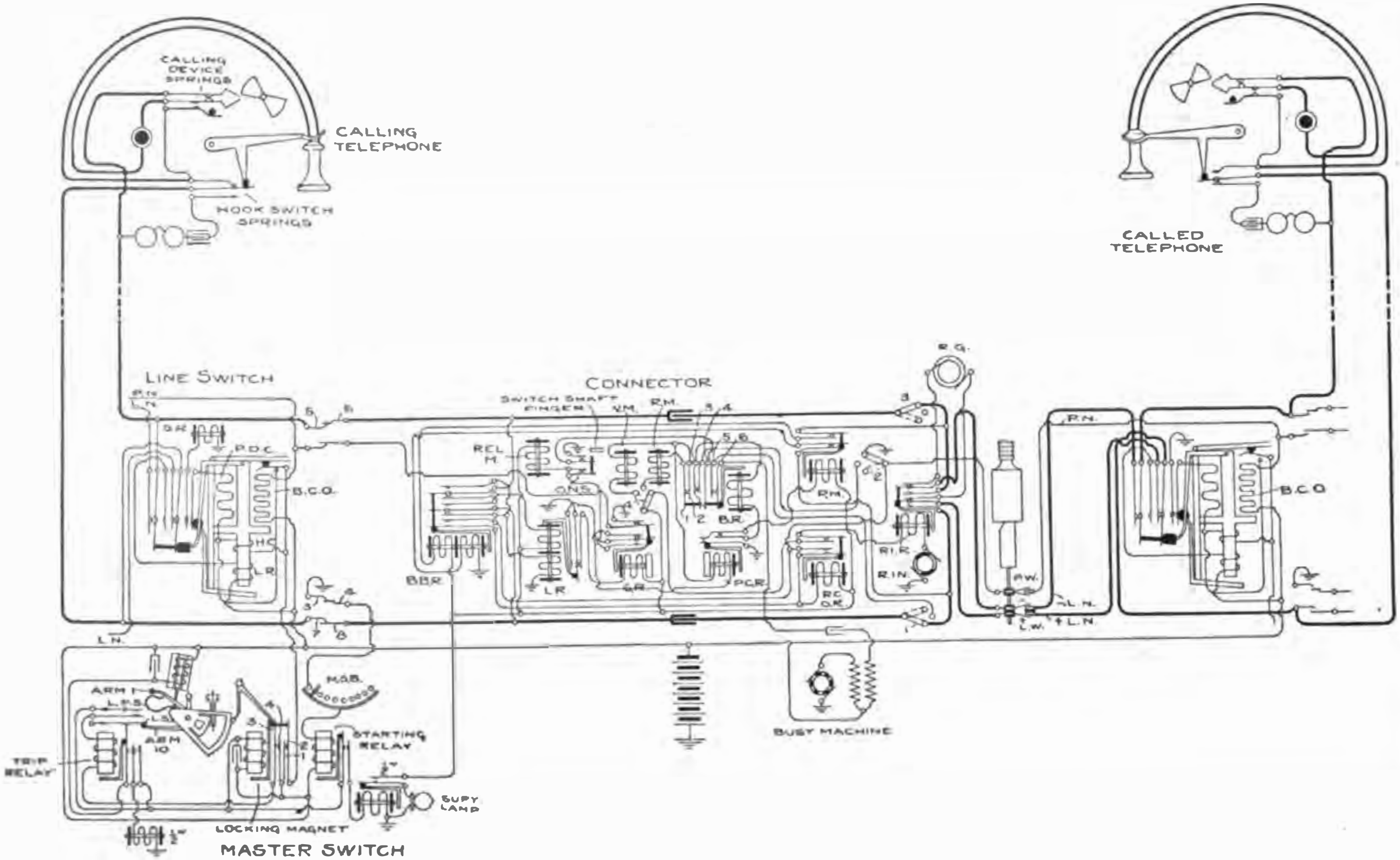


FIG. 41.—Complete circuit from a calling to a called station in a system of 100 lines capacity.

circuit between the negative battery and the "open-main" busbars, so that no line-switch plunger can be operated during the movement of the master switch. It also swings the locking arm enough to move the catch on its end out of engagement with the locking plate or sector so that the master-switch shaft is free to move under the action of the solenoid, or its spring.

The locking magnet also closes contact between springs 3 and 4 which, in the event that the locking plate springs, *L.P.S.*, are in contact, closes circuit from the negative pole of battery through the trip relay coil, the locking plate springs and the springs of the starting relay to earth. The circuit through this relay can only be closed when under the influence of the master-switch spring, the shaft has swung to the end of its arc (position 1).

The trip relay closes the circuit from earth through the locking magnet, and at the same time through the solenoid winding to the negative pole of battery. The solenoid, therefore, draws in its plunger, which causes the master-switch shaft instantly to swing to the other end of its arc (position 10) ready to be again drawn back step by step, by the spring. The circuit through the trip relay is broken as soon as the shaft leaves position 1 but the trip relay springs are held in contact with each other by the locking spring, *L.S.*, until this spring is tripped by the cam arm when the shaft reaches position 10. This breaks the circuit through the solenoid and also through the locking magnet and allows the lock to drop into the locking plate to prevent further movement of the master switch, due to the tension of the master-switch spring.

While the power for moving the master shaft, its wiper and plunger is being supplied by the master-switch spring, the interlocking of the locking arm and plate is the only means for stopping the shaft at the proper points.

The two half m.f. condensers shown in the circuit are bridged across coils to reduce the sparking at the platinum contact points of the relay springs.

The Connector Switch.—As already stated, the functions of the connector switch resemble those of a manual operator and her equipment.

This switch is able to connect a calling party's line with any one of the 100 subscribers whose lines are terminated in its banks. It makes the busy test and switches the busy signal on to the calling party's line or ringing current on to the called party's line as may be required. It switches the current for energizing the transmitters. When conversation is completed it closes circuits which cause all of the switches used in setting up the connection to return to normal. The banks of this switch correspond to the line jacks before an operator in a manual board equipped for 100 lines only. The shaft of the switch corresponds to the operator's hand and arm and the shaft wipers to the plug which the operator's hand and arm manipulate. The wiper cords take the place of the switchboard cord. In other words, this switch is an automatically operated and controlled cord circuit.

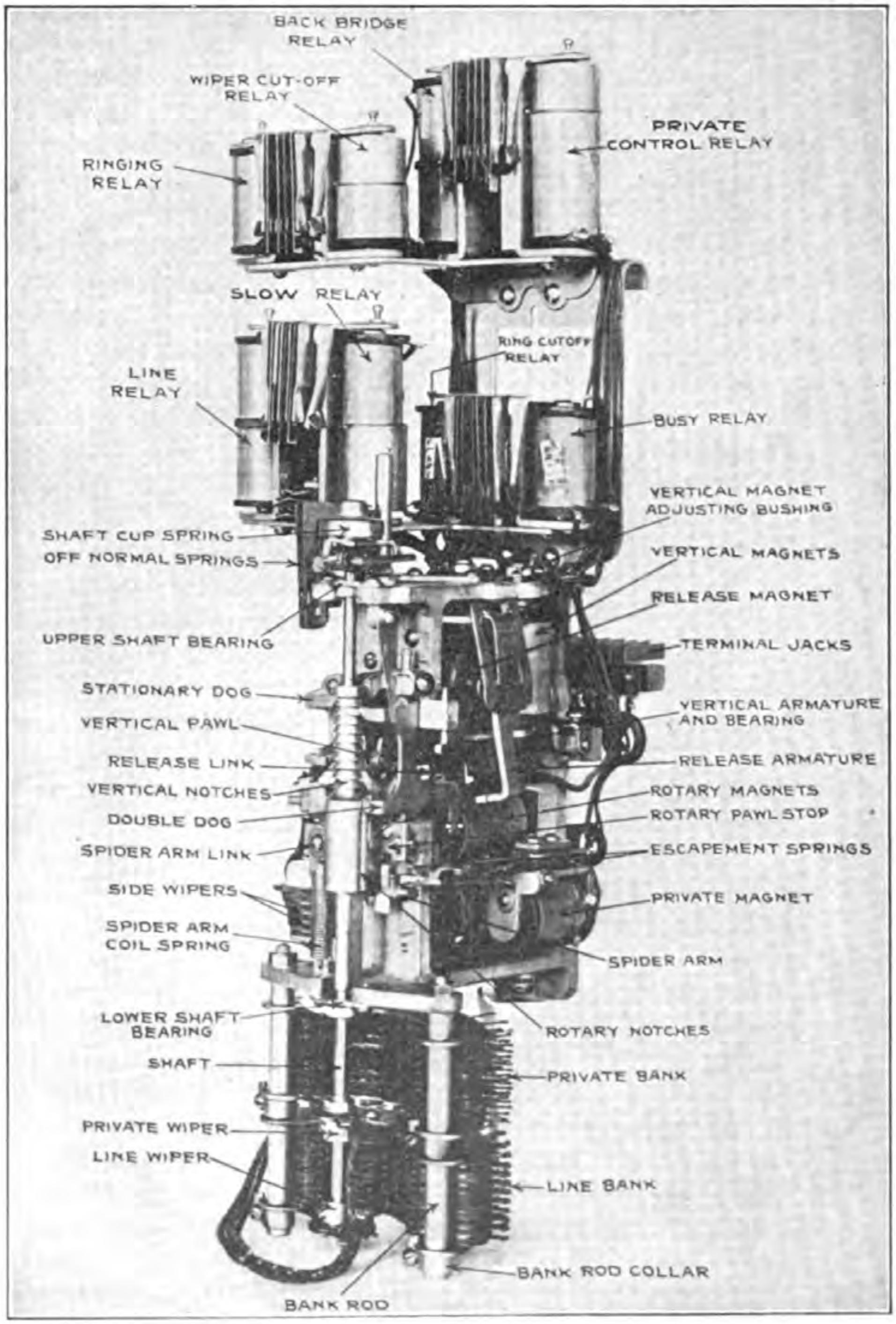


FIG. 42.—Two-wire connector switch.

by the breaking and remaking of the circuit by the calling device of the subscriber's telephone instrument.

Each time a short break occurs the quick-acting line relay releases its armature, but the slow-acting relay retains its armature. Consequently, at each short break, the circuit is closed from ground through the back contact of the line relay, the springs of the slow relay, the 2 1/2-ohm slow-acting private control relay, *P.C.R.*, the vertical magnet, *V.M.*, and side switch 4 to the negative pole of the battery. The result is that each time a short break

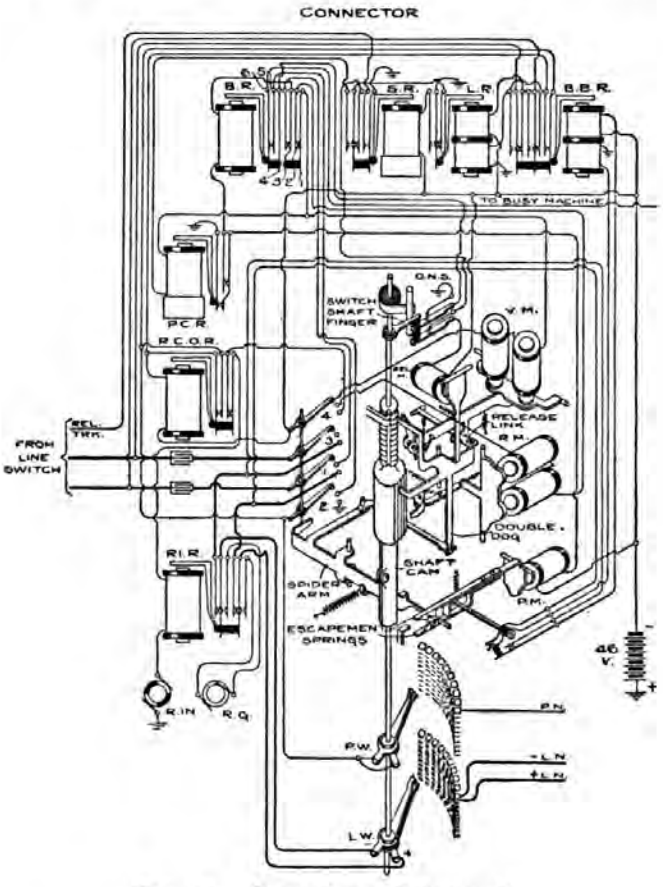


FIG. 50.—Connector-switch circuit.

occurs in the circuit at the subscriber's station, the vertical magnet attracts its armature once and raises the switch shaft one step.

When the circuit at the subscriber's station has been broken the desired number of times, the dial of the calling device has, of course, returned to normal, and the circuit is again established through the receiver and transmitter for a considerable time, i.e., until the subscriber again turns his dial. This interval of time is so long that the private control relay, *P.C.R.*, which retained its armature during the making and breaking of the circuit through

Selector Switches.—The uses of first, second and third selector switches are explained at length in the chapter on trunking.

Since a selector is used for selecting trunks only, its circuit is much simpler than that of the connector. The switch mechanism proper is practically the same, except that the modern types of selectors do not employ side switches. A photograph of a selector switch with a set of unwired banks mounted upon it is reproduced in Fig. 54. It employs the same type of shaft,

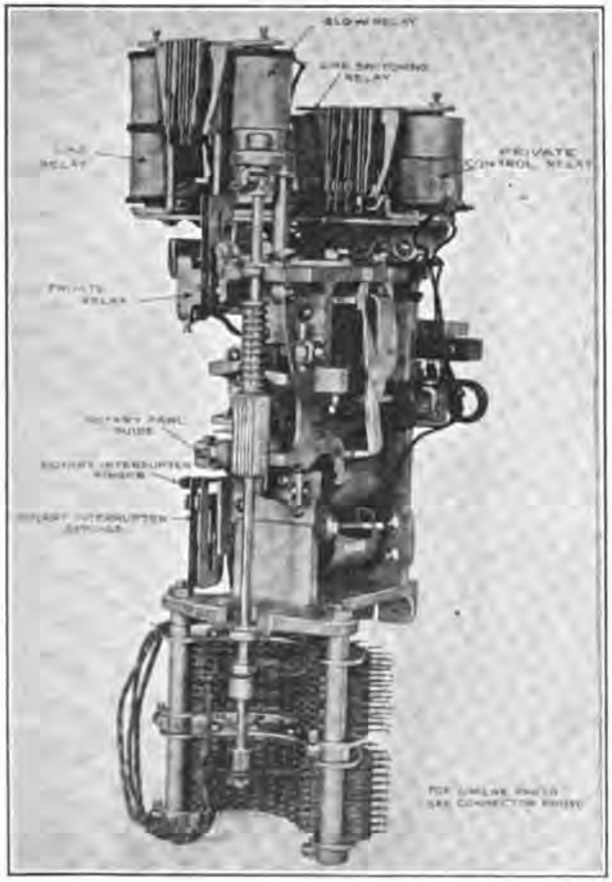


FIG. 54.—Two-wire selector switch.

wipers, banks, vertical and rotary ratchet movements, release mechanism, etc., as the connector switch does. One essential difference, however, is that the vertical movement only is controlled from the calling party's calling device. The rotary movement is entirely automatic and is used to select an idle trunk from the set of trunks represented by the row of bank contacts to which the wipers have been directed in the vertical movement of the switch shaft. This is fully discussed in the chapter on trunking.

Briefly, the duties of a selector may be summarized as follows:

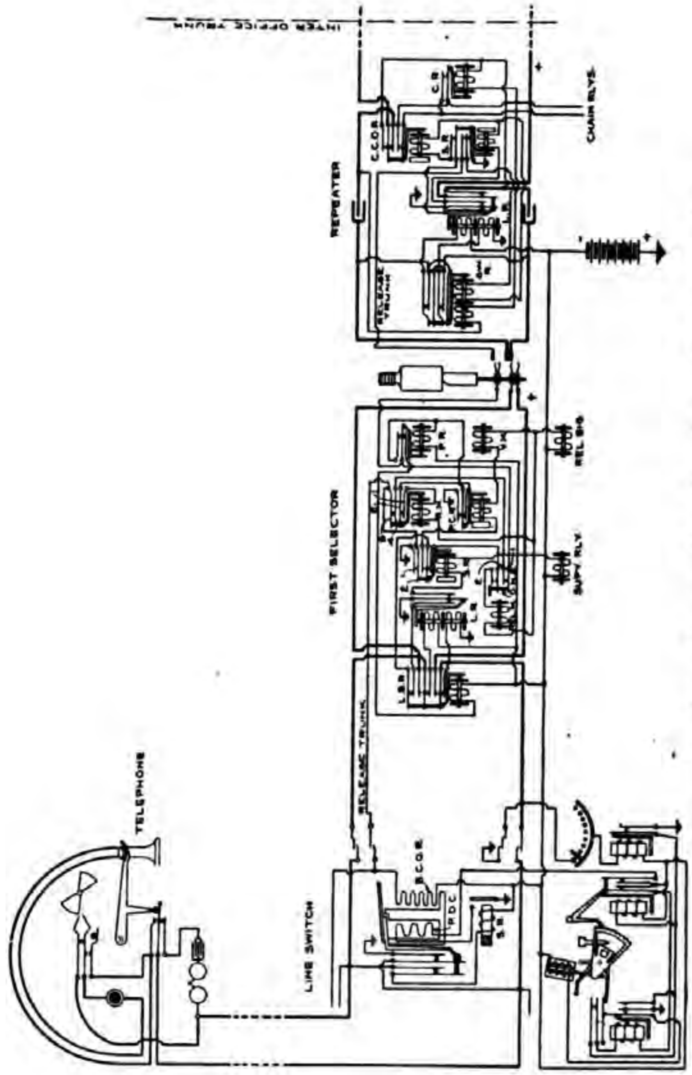


FIG. 55a.—Sending office portion of an inter-office connection.

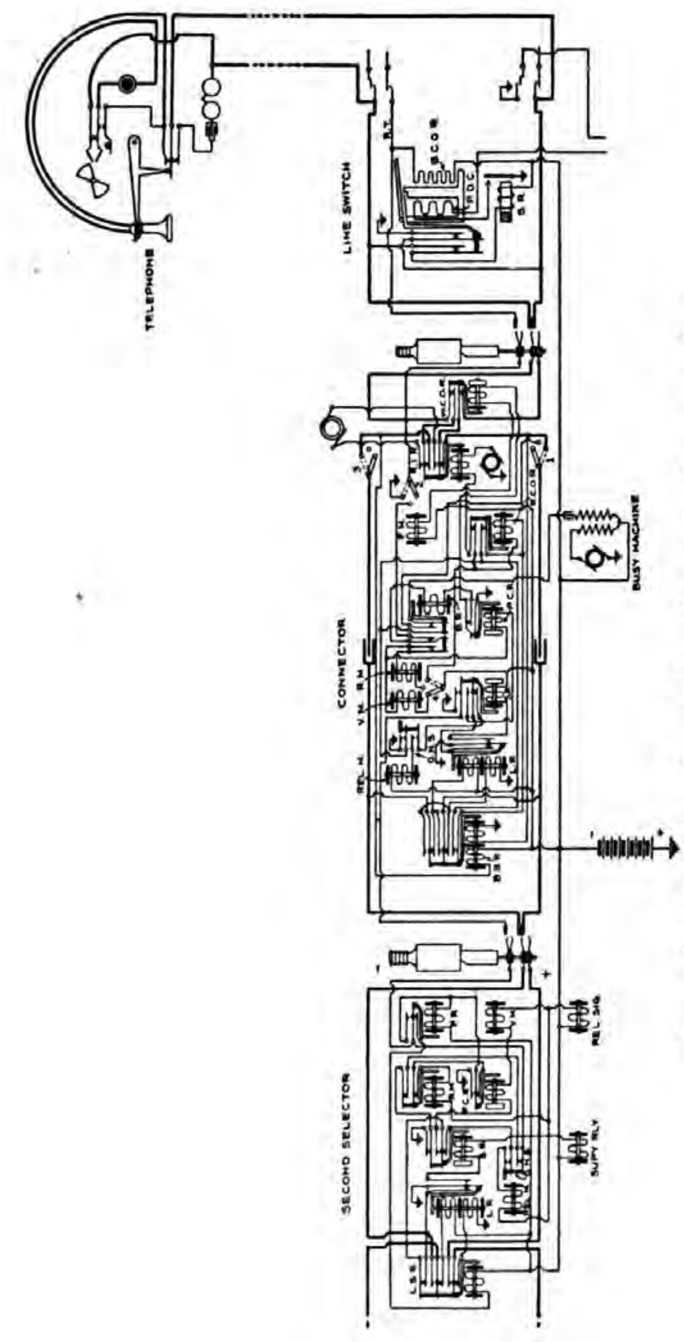


FIG. 55*b*.—Receiving office portion of an inter-office connection.

Each time the rotary magnet attracts its armature, it breaks the circuit between its springs 1 and 2, so that its armature drops back again. This reciprocating motion of the armature is kept up until the private wiper finds an idle contact and the private relay releases its armature, as already mentioned. When the private wiper stops on the contact corresponding to an idle trunk, guarding potential is placed on this contact and its multiples by the slow relay, *S.R.*, of the repeater in the trunk to the second selector, because this relay connects the release trunk to earth, so soon as the line is extended through to the repeater. The line is closed through to the repeater by the operation of the line switching relay, *L.S.R.*, the circuit of which is kept open at the break contact of the private relay until trunk selection has been completed. *L.S.R.* then is energized for an instant, through the circuit already described, and which was used to keep the private relay and rotary magnet energized during the rotation of the shaft. When *L.S.R.* operates, however, it switches the line relay out of circuit and consequently the slow relay releases its armature and breaks the earth connection of *L.S.R.* By this time the slow relay of the repeater will have operated and have closed the circuit of *L.S.R.* to earth, through the release trunk.

The first selector switch may be released either before trunk selection has taken place or afterward. Before trunk selection takes place the release is accomplished by the operation of the circuit and mechanism of the switch itself. Immediately after trunk selection has taken place, release is controlled from the next switch in the connection (which in Fig. 55 is the repeater) through the release trunk. If a connection has been completely established, and does not include a repeater the control of the release is vested in the connector switch.

If the subscriber places his receiver on the switch hook, thus breaking the circuit, before trunk selection has taken place, the line relay and the slow relay, *S.R.*, both release their armatures. The result is that a circuit is closed through the back contact of the line-relay springs through springs of the line switching relay, of the slow relay, off-normal springs, *O.N.S.*, and the release magnet to the negative battery busbar. So soon as this circuit is established the "kick-off" release mechanism kicks the double dog out of engagement with the shaft and into engagement with the release link. As the shaft, thus freed, completes its descent to normal, it breaks the contact between the off-normal springs and thus opens the circuit through the release magnet.

After trunk selection has taken place, release is accomplished by breaking the circuit between the release trunk and ground at the switch controlling that connection at the time. When this happens the line switching relay immediately releases its armature, allowing contact between its springs to close the circuit to the release magnet, causing release to take place in the way just explained. Since the release trunk of the first selector extends back to the line switch through off-normal springs 1 and 2 and rotary magnet springs 4 and 3, the disconnection of ground from this trunk allows the line switch to release also.

Repeater Circuits.—The purposes of the repeater are:

1. Ground the release trunk to permit the use of two-wire trunks between offices.

2. Supply talking current to calling station from home office.

3. Repeat impulses to distant office.

When the trunk circuit is extended through to the repeater by the first selector switch, the line relay, *L.R.*, of the repeater is energized through its two windings in series with the two sides of the line. This relay closes circuit through the slow-relay coil, *S.R.*, making up the customary combination found on the selector and connector switches. The slow relay connects the release trunk to the first selector switch to earth.

The line relay is arranged so that each time its armature drops back in unison with the circuit break at the calling party's telephone, it opens the bridge ordinarily maintained across the called section of the trunk by opening the positive side of the trunk. Each time an impulse is sent, that is to say, each time the line-relay armature drops back while *S.R.* is retaining its armature, a circuit is completed from earth, through the springs of *L.R.* and *S.R.*, through the condenser cut-off relay, *C.C.O.R.*, to main battery. The result is that the first time the circuit is broken at the calling party's telephone, *C.C.O.R.* switches the negative side of the trunk from its condenser, direct to the other side of the trunk. Since *C.C.O.R.* is slow acting, it retains its armature until all subsequent impulses of the series have been sent.

As already stated, in unison with each break of the calling party's loop, the line relay opens the bridge across the called section of the trunk. In this manner each series of circuit breaks made by the calling party's calling device is passed on. When the called party responds, by removing his receiver from the switch hook, and the direction of current flow through the trunk is reversed, as mentioned in the description of the connector circuit, then a corresponding reversal of current occurs in the calling party's loop, as a result of the following circuit changes at the repeater:

The switching relay, *Sw.R.*, has two windings, one of which is bridged across the line in series with the chain relay coil, *C.R.*, except when impulses are being transmitted. The other winding is energized through a circuit closed from earth by the slow relay to negative battery. Until the reversal of current takes place, when the called party answers, the magnetic effects of these windings oppose each other, and although the two will not be exactly balanced, on account of variations in the resistance of the inter-office trunk, the core of the switching relay is so slightly energized that it does not attract its armature. When the direction of the current of the trunk is reversed, however, then the two windings act together, the armature is immediately attracted and the shifting of its springs switches the terminals of each side of the calling subscriber's loop to the opposite pole of battery, as clearly shown by the circuit diagram.

It will be noted that when relays *C.C.O.R.* and *C.R.* operate, connection is closed between the two chain-relay busbars. These contacts are not essential to the operation of the system, but when properly connected up in series with the condenser cut-off and chain relays of other repeaters of the same group, they may be very useful in operating a supervisory signal to indicate when all of the repeaters of a group are engaged simultaneously, or to operate a meter showing how often this event occurs.

Release of the Connection.—The release of the equipment in each of the two offices, through which the connection indicated in the diagram extends, is under control of the last piece of mechanism used in each office; that is to say, when the calling party places his receiver on the switch hook, the repeater in office No. 1 governs the release circuits for the first selector and line switch in that office, and the connector in office No. 2 controls its own release circuits and those of the second selector. When the circuit is broken at the calling

FIG. 56.—Talking circuit of an inter-office connection.

telephone, and the line relay of the repeater in office No. 1 releases, its armature breaks the circuit through the slow relay, *S.R.*, and opens the positive side of the inter-office trunk. *S.R.* allows the contact to open between the release trunk and earth, permitting the first selector and line switch to release. When the positive side of the inter-office trunk is opened, the connector in office 2 operates, taking earth potential off of the release trunk of the second selector, which allows it to release and at the same time the connector switch itself releases.

In Fig. 56 is shown in simple form the talking circuit of the inter-office connection, which has just been described in detail. This diagram emphasizes an important feature, namely, that the talking current for the calling telephone is supplied from its own office, and for the called telephone from its office. This practice of always supplying talking current to a telephone from its own office, regardless of how many offices the connection may pass through, results in a very high standard of transmission efficiency.

Secondary Line Switches.—Mention has already been made of secondary line switches, both in the chapter on "Trunking" and in the early portion of this chapter. These switches are used with economy in systems with an ultimate capacity of 100,000 lines, in systems with an ultimate capacity of 10,000 lines number of primary line-switch groups, the number of trunks from primary line switches to secondary line switches, the number of secondary line-switch groups, the number of trunks from secondary line switches to first selectors, and from first to second selectors, that might be used in a typical office of 4000 lines, using third selector switches.

Sometimes secondary line switches are used to reduce trunks between main offices, and they are then generally placed between the first selector switches and the repeaters on the outgoing trunks. When the secondary switches are inserted between the line switches and the first selectors, the circuit is such that when a subscriber lifts his receiver from the switch hook, preparatory to making a call, his primary line switch and the secondary line switch to which it connects him operate almost in unison, so that the first selector secured is operated by the first motion of the dial as usual.

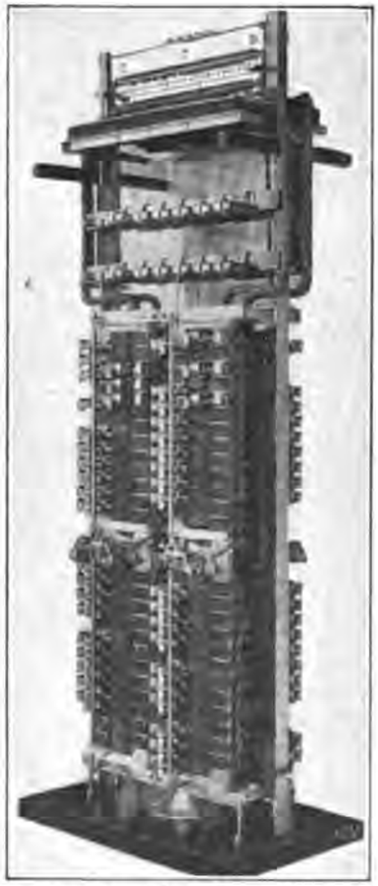


FIG. 58.—Secondary line-switch unit.

Fig. 60 shows a circuit from a calling telephone through a primary and secondary line switch to a first selector trunk. When the primary line-switch plunger enters its bank it completes circuit from ground through the "holding" trunk, through the pull-down coil *P.D.C.* of the secondary line switch, through its springs, the winding of the slow relay *S.R.* and open main battery busbar to the negative pole of the battery. The slow relay temporarily closes circuit from the holding trunk to the release trunk. The release trunk circuit through to the first selector is completed almost instantly, because, at the same time the slow relay is energized, the secondary line switch draws down its armature and plunger.

When the plunger enters the bank, spring 1 is pressed against contact 2, thus continuing the release circuit. Contact between springs 5 and 6 continues one side of the line through the first selector and contact between springs 7 and 8 continues the other side of the line. Contact between springs 4 and 3 puts a guarding potential on the proper master switch bank contact.

To economize in current consumption a change takes place in the circuit arrangement of the secondary coil windings when it draws down its armature. This change consists in switching the pull-down coil out of circuit with the low-wound slow-relay winding and into circuit with the high-resistance hold

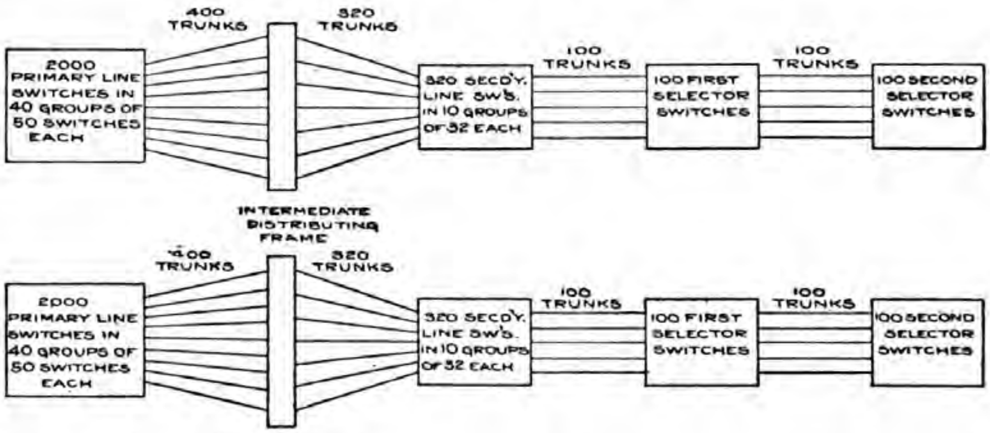


FIG. 59.—Diagram illustrating scheme of using secondary line switches to reduce first and second selectors.

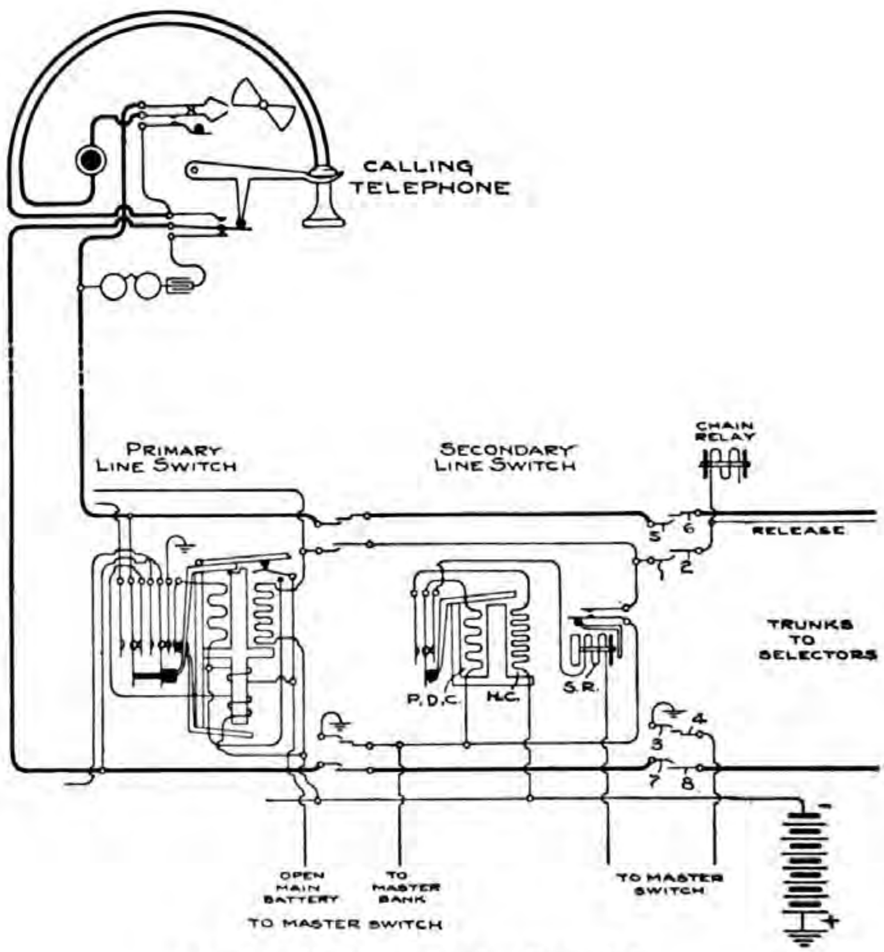


FIG. 60.—Circuit of secondary line switch.

Incidentally, these relays also prevent the master switch of the busy secondary group from searching for an idle trunk when none is to be found.

When the ten chain relays (*C.R.*) (Fig. 61) belonging to the outgoing trunks of any secondary line-switch group are operated in unison, a circuit is closed from ground through the springs of the chain relays in series and the stop relay of the master switch to battery. This relay opens the circuit of the 2.3-ohm winding of the supervisory relay, through which the negative pole of battery is connected to the master-switch circuits so that the master switch immediately stops and remains still until one of the outgoing trunks

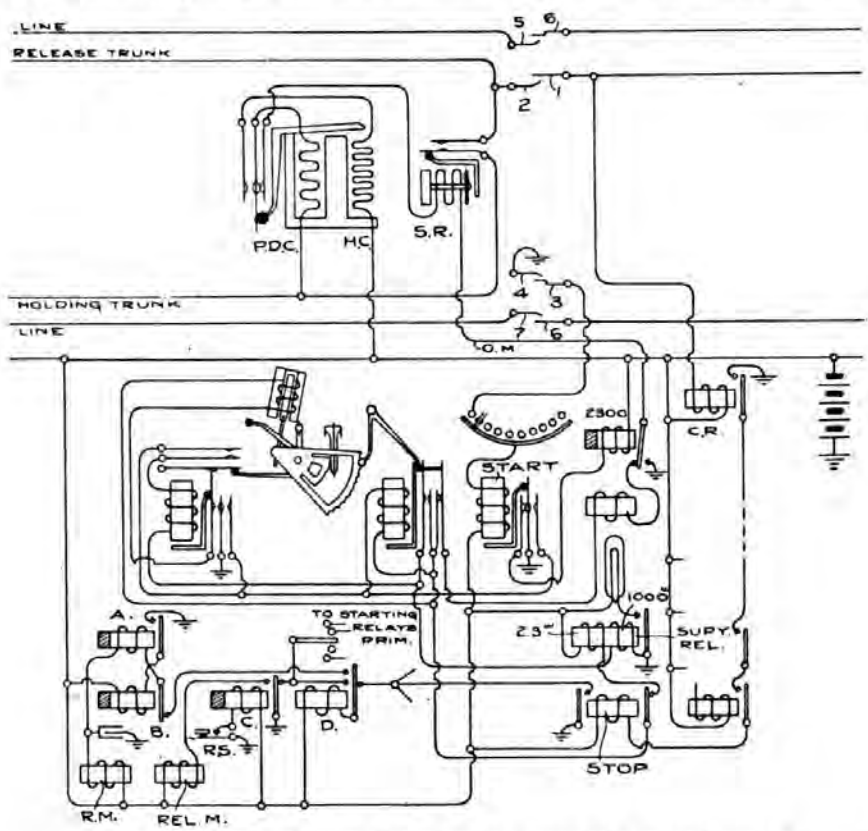


FIG. 61.—Circuit of chain relays and an associated master switch.

is vacated. The stop relay also closes circuit from earth to the stop-relay busbar, which is common to all ten groups of secondary line switches and may be connected to earth by the stop relay on any one of them. Whenever this occurs the special rotary switch, used to cause the master switches of all of the primary line-switch units to operate temporarily to pick up any plunger out of engagement, is operated in the following manner:

Current from earth through the stop relay busbar passes through rotary switch relay *D* to battery, causing this relay to pull up its armature and lock itself, through circuit from battery, winding of relay *D* and the break contact of relay *C* to earth. Relay *D* closes the circuit of relay *A*, also through the break contact of relay *C*, the springs of relay *D*, the back contact of relay *B*, the winding of relay *A*, and the winding of the rotary magnet, thus energizing relay *A* and the rotary magnet *R.M.* in series. The rotary magnet causes the shaft to make one rotary step but, by this time, relay *A* has attracted its armature, closing circuit from earth through the slow-acting relay *B*, which opens the circuit through relay *A* and the rotary magnet.

The result is that the armatures of both drop back, then the armature of relay *B* drops back, re-establishing the circuit through relay *A* and the rotary magnet. This action is repeated over and over and causes a slow step by step motion of the wiper carried by the switch shaft over its bank contacts. As indicated by the drawing, each of these bank contacts is connected to one or more starting relays of the primary line switchboard master switches, so that as the wiper pauses on each contact it causes each corresponding master switch to operate its shaft.

After the wiper has completed its rotary movement over all of its bank contacts, the special rotary switch is released by a circuit closed by the release springs, *R.S.*, from earth to negative battery through relay *C* which closes circuit from earth through the release magnet, *Rel.M.*, to negative battery, releasing the switch. Relay *C* is slow acting and at the same time that it closes circuit through the release magnet, it breaks the connection from earth to the wiper and to the rotary magnet and holds it open long enough for the wiper to return to normal. It also breaks the lock-up circuit through relay *D*, so that its armature drops back again, closing the circuit to the stop-relay busbar.

It will be noted that the circuits of the master switch of the secondary line switchboard are very similar to those already given in the description of the primary line-switch units. In the former circuits, however, the supervisory relay was connected in the earth terminal of the master switch instead of in the negative battery terminal.

Two other features which are shown in the present circuit were not shown in the former one. One is the slow-acting 2300-ohm relay, energized from earth through the break contact of the starting relay. There is one of these relays for each group of secondary line switches. It normally is energized and keeps the circuit closed from the secondary line switch to open main battery busbar.

Whenever a starting relay of the secondary master switch is energized, i.e., whenever the secondary master switch is in motion, searching for an idle trunk, this 2300-ohm relay releases its armature, with the result that a circuit is established from earth, through the slow relay of the secondary line switch and its pull-down coil to the holding trunk, thence to the master-switch bank contact of the primary switch. The result is that whenever the master switch of a secondary line-switch group is in motion, all trunks leading to that group from primary line-switch units are temporarily made busy, so that it is impossible for calling subscribers to be switched to the secondary group until its plungers are poised over an idle trunk.

The other feature of this secondary line-switch circuit, which should be noted, is the second winding of the supervisory relay. Circuit through this is completed from earth, through the 1000 ohm winding of the supervisory relay, the make contact of the locking magnet, the break contact of the stop relay and the other winding of the supervisory relay to battery, whenever the locking magnet make contact is closed. This may be closed in the customary manner, or it may be closed because the parts of the master switch are not properly adjusted, causing the master switch to stop when the lock is resting on top of one of the teeth of the locking plate instead of resting in a depression between the teeth. When this occurs this second winding of the tell-tale alarm relay serves to give an alarm to the attendant in charge which calls his attention to the difficulty.

Party Line Equipment.—Selective ringing party line equipment is furnished by the Automatic Electric Company for use in connection with its local battery three-wire system, its common battery three-wire system and its two-wire system; but, since the general method of operation is quite similar in all of these systems, a detailed explanation will be given of the circuits used with the two-wire system only.

Two, three or four-party line service is supplied. The selective ringing feature of the telephone generally consists of what is called a "harmonic ringer"; that is to say, a ringer whose clapper is mounted on a tuned reed instead of on pivots. On a four-party line one reed is tuned to respond to alternating currents of 16.6 cycles frequency, another to currents of 33.3 cycles frequency, a third to 50 cycles frequency and the fourth to 66.6 cycles frequency. There is nothing about the construction of these ringers which is peculiar to automatic systems. Ringers of similar design are furnished by manufacturers of manual telephones and switchboards. Two-party line service is sometimes given by using ordinary ringers and connecting a ringer of one telephone between the positive side of the line and earth, and the ringer of the other telephone between the negative side of line and earth. This also is commonly used in manual telephone practice.

Central Office Equipment.—On a four-party line each telephone has its own individual number. These numbers are generally assigned so that to 100 four-party lines a consecutive series of 400 numbers will be assigned; for example, a series like 4100, 4200, 4300 and 4400. With this particular series the numbers given to the individual telephones on line 24 of this one hundred lines would be "4124," "4224," "4324" and "4424"; while the numbers assigned to the telephones on line 36 would be "4136," "4236," "4336" and "4436."

A set of connector switches is installed for each of the hundreds of numbers in the usual way; one set for the "4100" numbers, a second set for "4200," a third for "4300" and a fourth for "4400." The banks of these four sets of connector switches are multipled together so that if a subscriber has called number "4224," for example, and has consequently placed a guarding potential on the private bank contact corresponding to that number, this guarding potential will be established through the multiple on the private bank contacts of "4124," "4324" and "4424" also. Therefore, only one of the four parties on a line may be called at a time, and any one attempting to call that party, or any of the others on the line, while that party is using it, will receive the customary busy signal.

Selective ringing is easily and simply accomplished, by supplying 16.6-cycle ringing current to the ringing relay busbars of the "4100" group of connector switches, 33.3-cycle ringing current to the ringing busbars of the "4200" group of connector switches, 50-cycle ringing current to the busbars of the "4300" group, and 66.6-cycle ringing current to the busbars of the "4400" group. Consequently, when a subscriber calls "4424" he secures the same line that he would secure if he called "4124," but projects 666-cycle ringing current on to the line instead of 16.6-cycle, and the only bell which is rung is that of telephone "4424."

While, as already stated, there is a separate group of connector switches for each 100, these groups are smaller than those installed for calling straight-line numbers, and, as explained in the chapter on traffic, for four-party line service it is customary to install five connector switches in each group. For two-party line service, seven connector switches are generally put in each group.

Although four numbers are used, only one line switch is necessary for each line; therefore, 100 party lines are served by one line-switch unit, which carries on one side the customary set of 100 line switches with their master switches, and on its other side, the four groups of connector switches, to give four-party line service; or, the two or three groups of connector switches required to give two or three-party line service.

The banks of each group of connector switches are brought out to terminals and are there connected together by jumpers. This is done so that if any number on a party line should be out of use, but still appear in the directory, and, therefore, be subject to calls by subscribers, the bank multiple corresponding to this particular number can readily be disconnected at the terminal from the multiple of the remaining three numbers, and be connected through a dead-number trunk to the information operator's desk.

When one subscriber on a party line has secured a connection, none of the other subscribers can release him, because a connection can only be released by opening the circuit, which does not occur until all of the subscribers on the line hang up their receivers.

Reverting Calls.—This term is applied to a call of one subscriber on a four-party line for another subscriber on the same line. It is entirely feasible to arrange it so that a calling subscriber need not know when he is calling another on his own line, and will, therefore, make the call in the same way that he would if he was calling a party belonging to an entirely different line. While this is a desirable feature, the number of reverting calls is usually small, and it is, therefore, not considered good practice to put in the special line switches and connector switches required for handling them in this manner. There are two other methods commonly used in two-wire systems. The first

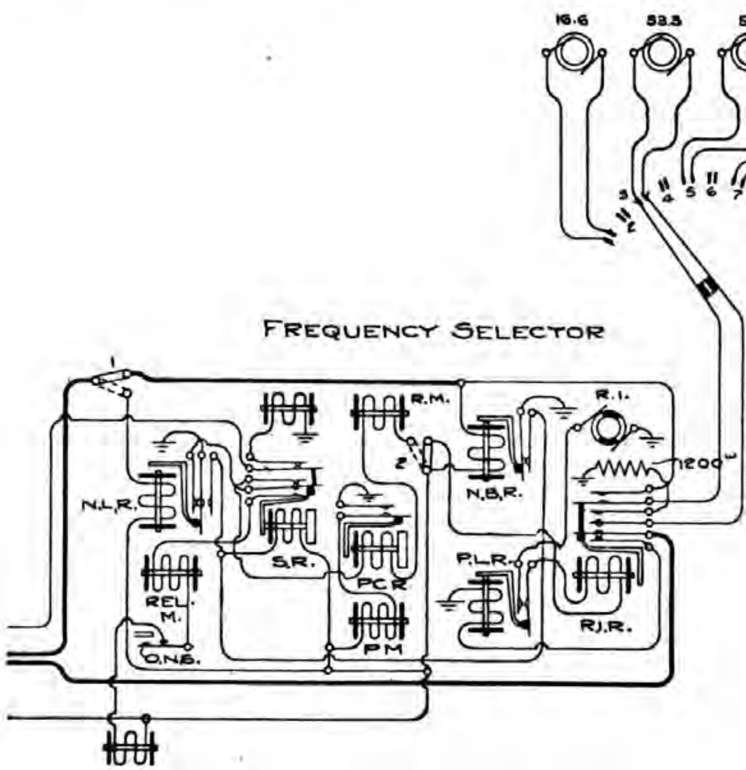


FIG. 62.—Circuit of a frequency selector.

method is to instruct each party line subscriber, either by a special notation in his directory, or by an instruction card mounted on his telephone, that when he wishes to call the numbers on his own line he must signal the information clerk and ask her to ring the bell of the desired party for him. It should be arranged so that the information clerk is secured by making a single motion, or by making two motions of the calling device dial. Then trunks to the information clerk would lead either from first selector banks or from second selector switch banks, so that when a connection was completed it would be clear from the subscriber's telephone to the information desk. This makes it practicable for the information clerk to tell the calling party yet been assigned to any of the subscribers. Now suppose that an arrangement is made to furnish some subscriber, who has a large business, with five lines or trunks all of which are to appear in the directory under one number. The five vacant bank contacts, just mentioned, may be used for this purpose by assigning to the new subscriber the number "2311," and the circuits of the rotary connector switches are such that when a calling party operates any one of the group, to call "2311," it will step its wipers on to the first pair of contacts in the set of five. If this pair of contacts is already engaged in a previous connection, the switch will automatically step its wipers on to pair of contacts 2. If these are busy the wipers will be stepped on to pair of contacts 3. This process is kept up until an idle pair of contacts is found;

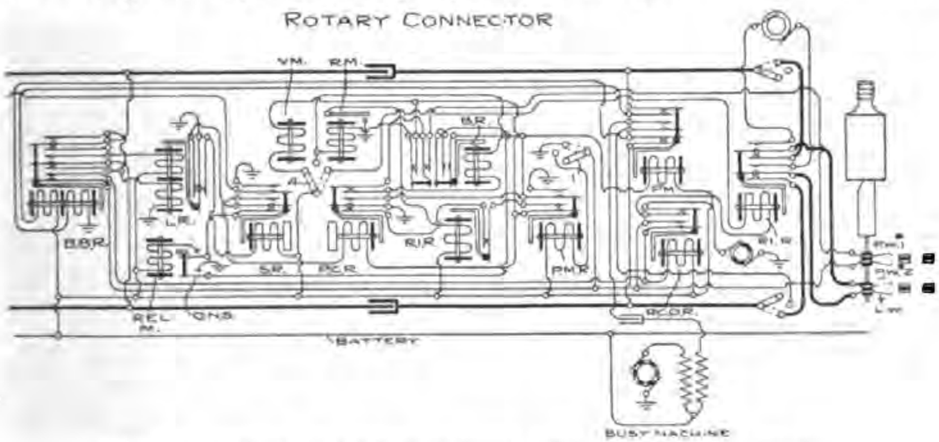


FIG. 63.—Circuit of a rotary or trunk selecting connector switch.

or, if all pairs of contacts should be busy, the wipers will stop on the last pair in the set, and the switch will give the busy signal to the calling party.

For this purpose the private bank used with rotary connector switches is equipped with pairs of contacts like the line-switch bank, instead of the commonly used single contacts, and the two contacts in the last pair in the set of private bank contacts corresponding to the set of five line bank pairs of the subscriber "2311" are connected together.

The circuits of a reversing-battery rotary-connector switch are shown by the diagram Fig. 63. This switch has the usual slow relay *S.R.* and double-wound line relay *L.R.* which is responsive to the breaking of the calling party's loop by his calling device for operating the vertical magnet to raise the switch shaft. In series with the vertical magnet *V.M.* is the usual private control relay *P.C.R.*, which closes the circuit through the private magnet *P.M.*, so soon as the circuit is closed through the winding of *P.C.R.* and the vertical magnet the first time. When the vertical series of impulses has been completed, *P.C.R.* and *P.M.* release their armatures, and the spider arm and side-switch wipers are allowed to move to second position, with the result that side-switch wiper 4 switches the vertical magnet out of circuit and closes circuit from negative battery through the rotary magnet, *R.M.*, winding, one of the contacts of the busy relay *B.R.*, and the winding of *P.C.R.* to the springs of the slow relay *S.R.* The result is that when the calling subscriber's dial is turned, after being pulled around for the last time, the rotary magnet is operated and rotates the shaft wipers on to the bank contacts corresponding to the called line. If these contacts should be busy, then a circuit will be established from earth potential on the guarded private bank contact, through private wiper 2, side-switch wiper 1, winding of private magnet relay, *P.M.R.* to battery. This relay closes circuit from earth through the private magnet to battery, thus causing the private magnet winding to remain energized, although the armature of *P.C.R.* drops back, and to hold the side switch in second position. At the same time *P.M.R.* closes circuit from earth, through one of the break contacts of private control relay, *P.C.R.*, the contact of the rotary interrupter relay, *R.I.R.*, the springs of *P.M.R.*, a break contact of *B.R.*, and the rotary magnet winding and side switch 4 to battery. The result is that the rotary magnet is again energized and steps the shaft wipers off of the bank contact on which they have stopped and on to the next set of bank contacts.

When the rotary magnet attracts its armature, closing circuit through its springs from earth, through the rotary interrupter relay to battery, *R.I.R.* breaks the circuit through the rotary magnet which releases its armature and, in turn, breaks the circuit through *R.I.R.* The desired reciprocating motion for stepping the wipers around until an idle set of contacts is found is thus secured. Should all of the pairs of contacts in the set be busy, the wipers will stop when they reach the last pair, due to the connection permanently placed between the two contacts of the last private bank pair. By means of this connection, circuit is closed from earth potential on the busy private bank contact through private wiper spring, *P.W.*, a break contact of busy relay, *B.R.*, a break contact of relay, *P.C.R.*, the winding of *B.R.* and side switch 4 to battery. When *B.R.* attracts its armature, it closes a circuit that keeps the private magnet energized to hold the side switch in second position. This circuit runs from earth through off-normal springs *O.N.S.*, springs of *B.R.* and the private magnet winding to battery. Through this same off-normal spring earth connection, the busy relay locks itself and as it does so it breaks the circuit to private wiper spring, *PW.* The busy relay also breaks the circuit through the rotary magnet, so that if the subscriber should make another revolution of his dial, he will not operate the rotary magnet. The busy signal is transmitted to the calling party on account of the connection made between the positive side of the calling party's loop and the busy signal busbar by the springs controlled by the private magnet.

If all of the called party'strunk lines should not be engaged, then the automatic rotation of the shaft wipers will cease so soon as they pass on to

Rotary connector switches are mounted on the backs of line-switch units as ordinary connector switches are, but, as mentioned in the chapter on "Traffic," banks are generally provided for fifteen or twenty of them instead of for but ten. The mounting of the line switches is the same as usual, and the wiring is, of course, the same, as there can be but one trunk line and consequently one line switch for each of the 100 pairs of connector switch bank contacts.

Fig. 64 is a reproduction of a photograph taken in the central office equipped with automatic switchboards for 3500 lines in Regina, Saskatchewan, Canada. At the left and in the center of the picture are the line and connector switch units arranged in rows of five each. At the distant end of the room two "trunking" switchboard sections, which contain selector switches, are to be seen.

CHAPTER III

SUBSCRIBERS' STATION EQUIPMENT FOR USE WITH AUTOMATIC ELECTRIC COMPANY'S TWO-WIRE SYSTEMS

All of the various types of subscribers' station equipment which are used in connection with manually operated switchboards are used with automatic switchboards also. Therefore a description of subscribers' station apparatus for use with the latter system must include the following:

1. Ordinary wall and desk telephone instruments for use at individual line and party line stations.

2. Intercommunicating systems of the push-button type with and without secret service features.

3. Manually operated private branch exchange switchboards of the cordless type.

4. Manually operated private branch exchange switchboards using cords and plugs.

5. Full automatic private branch exchanges both with and without supervised trunks.

Typical circuits and equipment used in connection with the Automatic Electric Company's two-wire systems for each of these classes of stations will be taken up and described in the order in which they have just been mentioned.

It should not be inferred that subscribers' station apparatus similar to that about to be described is not or may not be used with each of the different makes of automatic switchboard equipment, but space in this book does not permit descriptions of the circuits and details used for adapting the various classes of subscribers' station equipment to each of the types of automatic systems. Therefore this chapter is confined to one system, viz., the Automatic Electric Company's, which is known to the largest number of students of the art. It should be understood that the purpose of the chapter is to show fundamental principles and standard practices, which have been adapted or may be adapted to substation apparatus connected to any of the makes of central office equipment described in this volume.

First Class.—Subscribers' Station using a Single Telephone or a Telephone with Extension.—The photographs, of both a wall and a desk telephone are shown in Chapter II, and with them are shown the circuits of each.

The circuits require the use of direct-current receivers, but ordinary polarized receivers with induction coils are also used to a small extent with this system.

Fig. 65 shows the circuit of a desk telephone of the direct-current receiver type just as the instrument is wired.

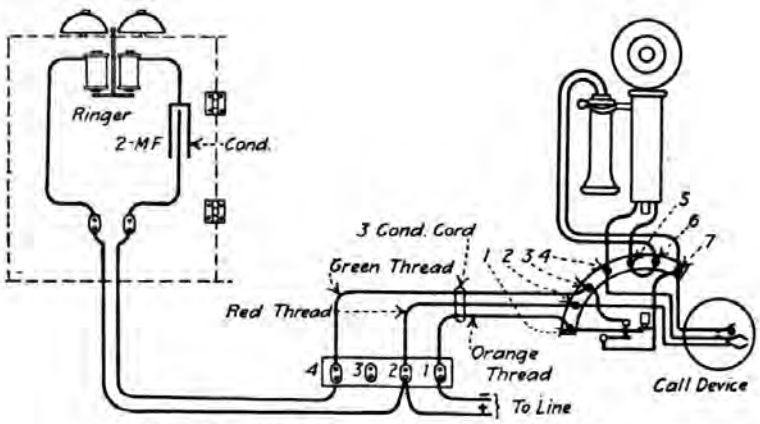


FIG. 65.—Desk telephone wiring diagram.

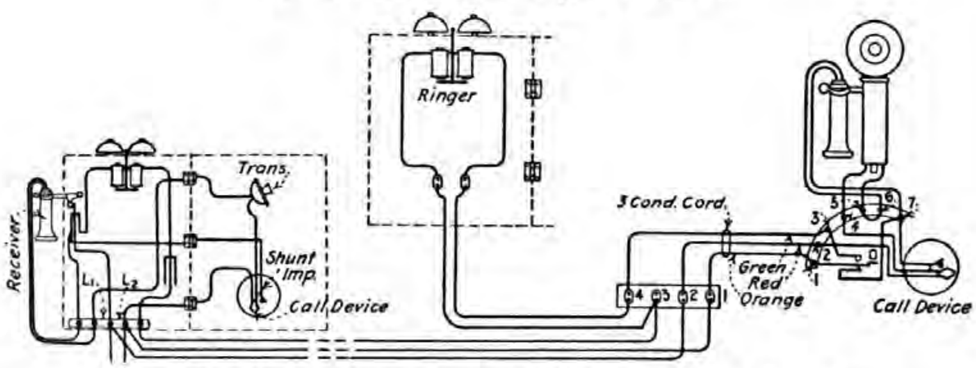


FIG. 66.—Wiring diagram for a wall telephone with an extension.

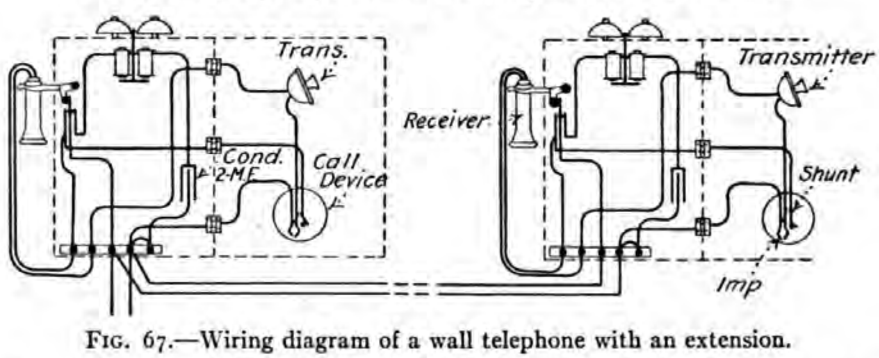


FIG. 67.—Wiring diagram of a wall telephone with an extension.

Figs. 66 and 67 show two different arrangements for connecting up a wall telephone with an extension so that when either is called both bells will be rung. Of course if an arrangement is desired whereby the bell will be used at one telephone only, the other bell is simply omitted from the circuit.

Fig. 68 shows an extension circuit for a desk telephone of the direct-current receiver type.

When a third wire is not used between a desk or a wall telephone and its extension a biasing spring connected to one end of the ringer armature should be utilized to prevent the bell of one of the telephones on the line tingling when a call is made from the other telephone. By using this biasing spring the tingling may be stopped although it may be necessary to reverse the connections to the ringer coil terminals so that the discharge of the condenser, when calls are made, will flow through them in the proper direction.

Since the circuits of telephones used with different types of coin collectors and meters are shown in Chapter IV they will not be repeated here.

Second Class.—Intercommunicating Systems of the Push-button Type.—Push-button intercommunicating systems such as have been widely used in connection with manual central office equipment and trunks are also quite generally used at the stations of subscribers to automatic telephone service, and are arranged with one or more trunks to the automatic central office. These systems are convenient and well adapted to private branch exchanges up to a capacity of ten or fifteen stations, but larger sizes are so expensive to install and so expensive to enlarge or change that their use is generally not warranted.

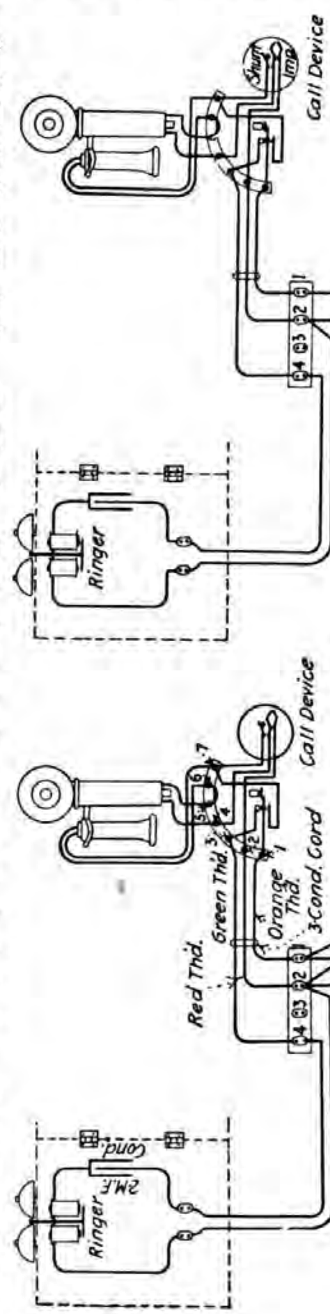


FIG. 68.—Wiring diagram of a desk telephone with an extension.

When but one trunk is used for a little system it may terminate in a line switch and connector switch banks the same as any subscribers' line does at the central office, but when two trunks are used they should terminate in the banks of rotary connector switches and line switches so that a subscriber calling this private branch will be automatically switched to whichever trunk is idle.

Incoming Calls.—An incoming call over a trunk will ring the regular telephone bell (Fig. 69). When the attendant answers by removing her receiver from the switch hook and pressing the key marked "*TK*," circuit is closed from one end of the signaling battery through the 100-ohm winding of the double-wound trunk relay and the key contact to the other terminal of the battery. The trunk-line relay closes circuit from one side of the trunk to the other through the 500-ohm holding coil, but this circuit is kept open for the time being by the break contact of the key which is open as long as the button is pushed down.

The trunk relay also closes circuit from one terminal of the signal battery through its 250-ohm winding through the hook springs of the attendant's telephone to the other terminal of the signal battery. This circuit locks the relay until the attendant replaces her receiver on its switch hook.

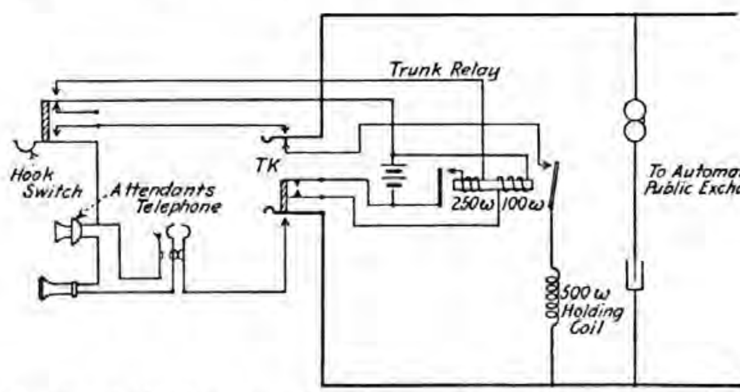


FIG. 69.—Trunk circuit to attendant's station of a push key inter-communicating system.

When the attendant responds to the call she learns the number which the calling party wishes and then presses the key corresponding to the desired station. When she does this, the trunk key snaps back to normal and closes the circuit already described through the 500-ohm trunk holding coil.

The called person then presses his trunk key and holds conversation.

When the attendant hangs up her receiver, the trunk relay unlocks, leaving the called station alone to hold the trunk.

Talking current for trunk calls is always supplied from the main battery at the central office.

Outgoing Trunk Calls.—When a party at one of the stations of this little system wishes to make an outgoing call he may do so directly himself by pressing either one of the trunk keys in his push-button box and, if he finds that the trunk is not in use, calling the desired party by means of his calling device just as if he had a direct line to the central office. If he wishes the attendant to secure the desired party for him and then notify him, he signals and talks to her as for local calls. He then hangs up his receiver and awaits notification. She connects her set to an idle trunk by using one or the other of the trunk keys in her push-button box and calls the desired party. She then presses the key corresponding to the line of the local party by whom the trunk connection was ordered and thus signals the local party and informs him that his connection is ready on trunk No. 1 or trunk No. 2, as the case may be. He presses the corresponding trunk key, bridging his telephone across the trunk, and talks to his party.

When the attendant presses the key corresponding to the local party's line, the trunk key used by her to set up the connection instantly snaps back to normal position, but when it does so it closes the circuit through the break contact springs which are in series with the holding coil and the springs of the trunk relay. The contacts of the trunk relay are closed while the attendant's receiver is off the switch hook after the trunk key has once been depressed, therefore the circuit through the holding coil is closed and holds the trunk connection up while the attendant talks to the local party. When the attendant replaces her receiver on the switch hook she breaks the circuit of the 250-ohm winding of the line relay which in turn breaks the circuit through the holding coil.

Secret Service Push-button Intercommunicating System.—An ingenious type of secret service, push-button, intercommunicating system for use with automatic switchboard central offices is that manufactured by the Corwin Telephone Manufacturing Company. Like the system just described, the Corwin system is a self-operating exchange in which each party can establish all local connections without the aid of an operator, and each party whose station is equipped with a calling device can establish his own outgoing trunk connections. One station, called the "attendant's" station, is set aside for answering incoming calls and transferring them from the incoming trunk to the proper local party. The attendant, or some other party, whose telephone is equipped with a calling device must, of course, make the outgoing calls for any local party who is not furnished with a calling device.

Very extended descriptions of the circuits and mechanisms employed in this system have been published by its manufacturers, and since space is not available in this chapter to repeat the long explanation required to make the details of construction and operation clear, it is omitted.

Third Class—Manually Operated Private Branch Exchange Switchboards of the Cordless Type.—As an example of a switchboard of this kind a description will be given of a seven-line three-trunk board. The equipment is mounted in a small cabinet (see Fig. 70) about 14 in. long, 14 in. high and 12 in. deep. It may be set on any convenient desk or table. It is practically self-contained as the only apparatus required outside of the cabinet is a small battery for operating the night alarm buzzer and the operator's telephone equipment, which consists of a standard automatic desk telephone.

The switchboard is designed to operate with the usual battery and is equipped with a key to switch from hand generator to ringing current fed from the automatic central office. Each trunk and line is multipled through one of the vertical rows of keys. The first three vertical rows of keys on the left-hand side of the switchboard are for trunks and the remaining seven are for local lines. Directly above the keys are the incoming signal drops for the trunks and the visual signals for the local lines. Above these are located the supervisory signals—three for the trunks and five for the intercommunicating switching circuits. The keys for the night alarm, generator switching and battery cut-off are mounted in the lower rail of the switchboard.

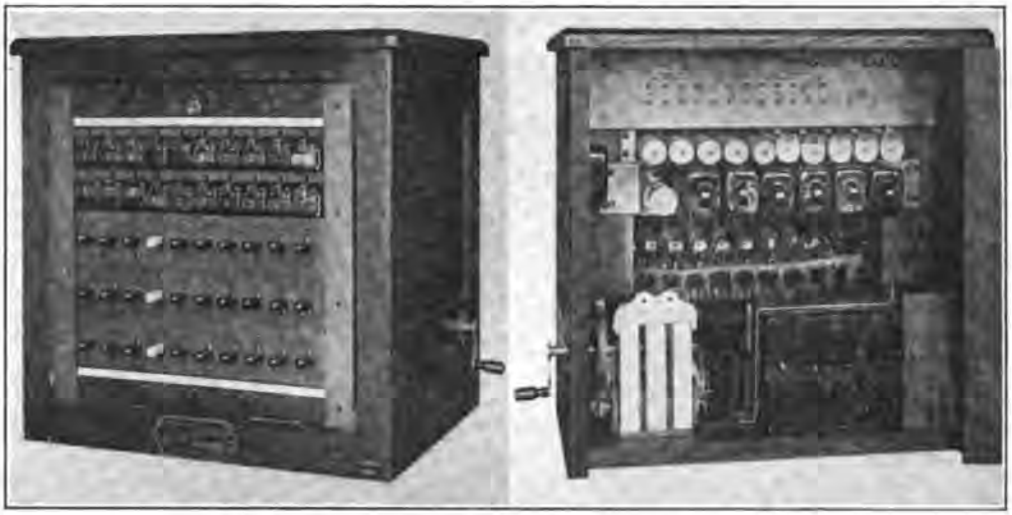


FIG. 70.—Cordless private branch switchboard.

Functions of the Keys.—The circuit of this board is shown in Fig. 71. The throwing up of any two key handles in the upper horizontal row of keys switches the keys together and constitutes switching circuit No. 1. Throwing down the handles of any two keys in this row switches the keys together and constitutes switching circuit No. 2. Likewise the keys in the middle row control switching circuits Nos. 3 and 4. Throwing up the handles of any two keys in the lower horizontal row switches them together and makes switching circuit No. 5. Throwing down any handle in the lower horizontal row of local line keys enables the operator to ring that particular line. Throwing down either key handle in the lower horizontal row of trunk keys holds that particular trunk.

Operation.—For example, line No. 5 wishes to be connected with line No. 2. The removal of the receiver from the switch hook of the telephone of line No. 5 closes circuit which pulls up the incoming visual signal of No. 5 line. The operator responds to the signal by throwing the answering keys (white) of her telephone and line No. 5 to connect the two together through

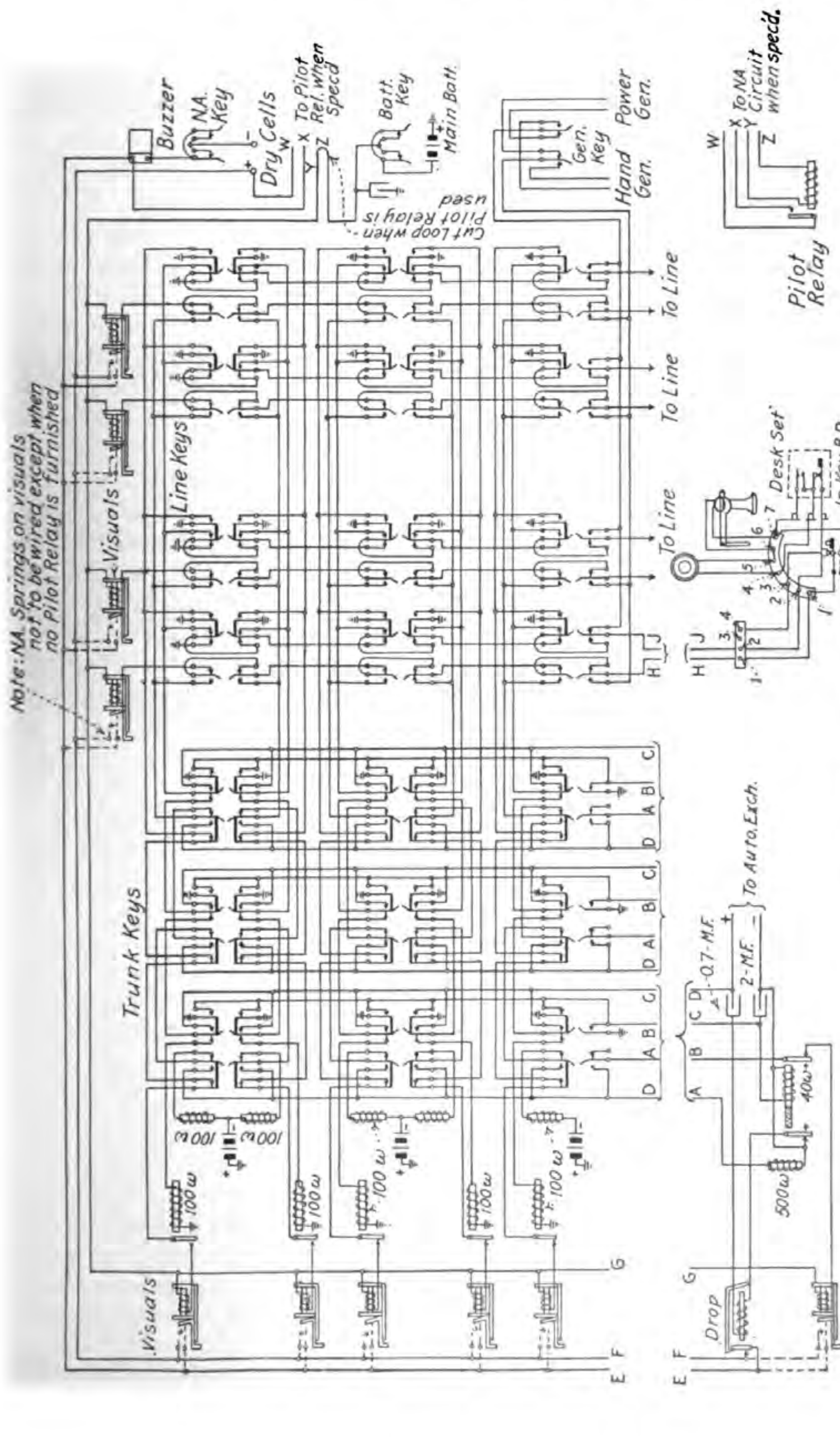


FIG. 71.—Circuits of cordless private branch switchboard.

any switching circuit which is not busy at the time. Learning that No. 2 is the line desired she throws the ringing key of that line and, if ringing current is not furnished from the central office, operates the hand generator. She then throws the answering key of line No. 2 into the switching circuit used to connect her telephone with line No. 5 and when the connection is established restores her answering key. When the parties hang up the supervisory signal on the switching circuit will operate and indicate that the conversation is completed. The operator then restores all keys to normal.

On an incoming call from the automatic central office the ringing current sent out by the connector switch operates the drop associated with the trunk. The operator responds by throwing the answering key of her telephone and of the trunk line into a non-busy switching circuit. When she does this, the 40-ohm line relay, connected in series in one side of the trunk and bridged by a condenser, operates and cuts off the drop and visual signal associated with the trunk. Learning the local number wanted the operator throws the trunk-holding key and restores the trunk-answering key. This holds the trunk by bridging the 500-ohm coil across it and pulls up the trunk supervisory or holding signal. The operator is now disconnected from the trunk and calls the local number. When she has the desired party on the line she throws the answering key of that line and of the trunk on which the calling party is waiting into a non-busy switching circuit and restores the trunk-holding key.

With this method of operation it is apparent that the operator can speak to the local party wanted and ascertain if he wishes to talk to the party who has called, without the calling party overhearing her. If the local party does not wish to talk to the caller she can then convey that information to the calling party, thus protecting users of this little system from intruders. Furthermore, if the local party wanted is not found in his customary place she can endeavor to locate him by trying the different stations on her system and thus be of material assistance to the calling party.

When a local party wishes to make an outgoing call he signals the local operator. She responds, takes his order in the customary way, restores her answering key and connects her telephone through a non-busy switching circuit to one of the trunks which is idle. She then operates her calling device and secures the automatic party desired. The slow-acting 40-ohm signal cut-off relay of the trunk keeps the line clear even during the instants that the circuit is opened by the calling device. Meanwhile the local party may have waited on the line or have hung up as best suited his convenience. When she has secured the desired automatic subscriber she signals the local party, if he has not waited on the line, and throws the keys necessary to connect him into the switching circuit connected to the trunk on which the automatic subscriber is waiting. She then restores her own answering key to normal.

When the parties hang up, the automatic connection is released and the supervisory signals on the switching circuit and on the trunk indicate the fact to the operator, who then restores to normal the keys used in switching them together.

If desired, each telephone connected to a cordless private branch switchboard of this type may be equipped with an automatic calling device so that it will only be necessary, when an outgoing call is to be made, for the operator to throw the keys required to switch the line of the party who desires to

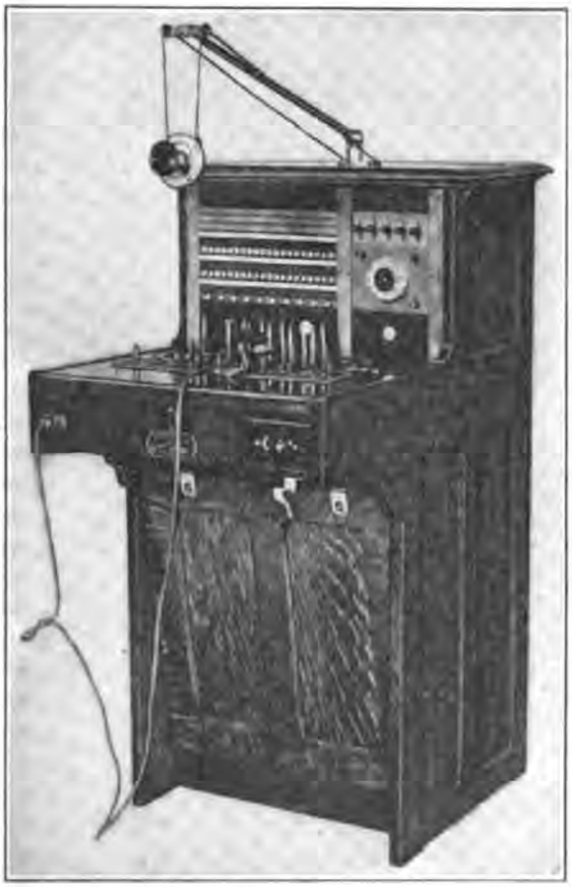


FIG. 72.—Private branch exchange switchboard.

make the call to an idle trunk and he can then proceed to call whom he wishes without further aid from her. When he finishes she will receive the usual supervisory signal and will restore the switching keys to normal.

Fourth Class—Manually Operated Private Branch Exchange Switchboards Using Cords and Plugs.—A reproduction of a photograph of a single position switchboard of this type with a capacity of about sixty lines is given in Fig. 72. This type of board is commonly equipped with regular

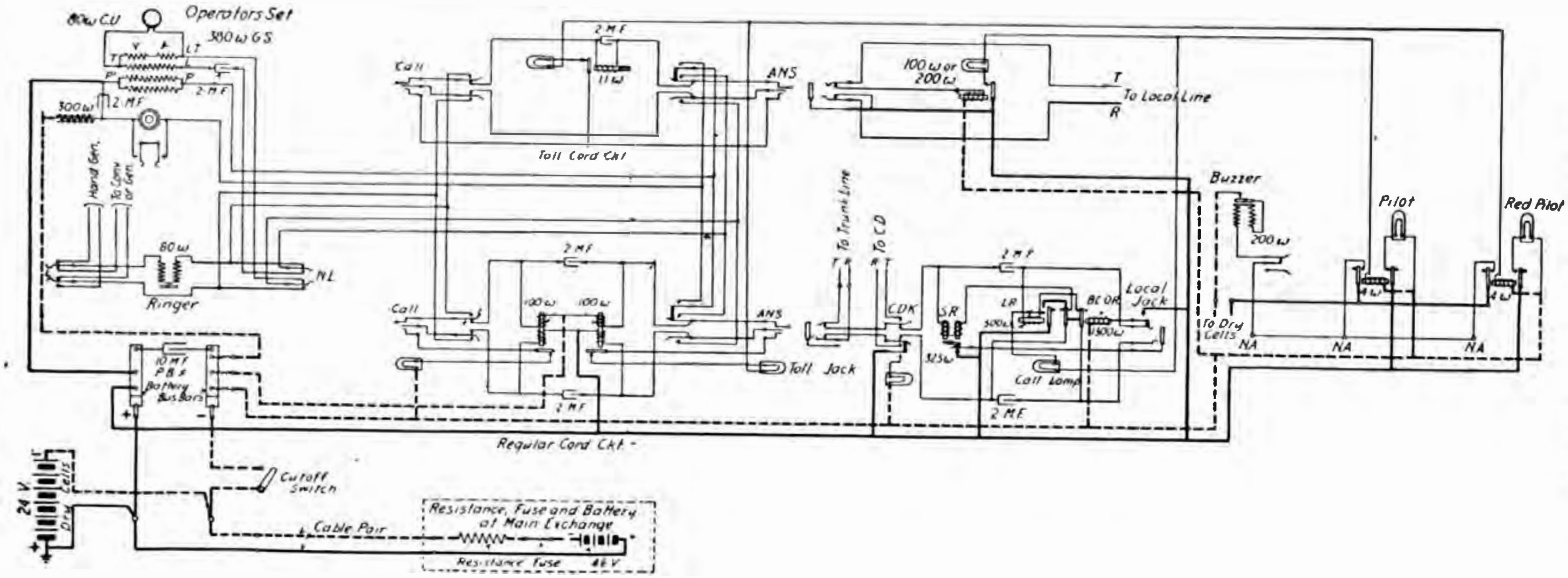


FIG. 73.—Circuits of private branch exchange switchboard.

cord circuits for interconnecting local lines and for connecting them to the trunks; and also with two or three toll-cord circuits which are used for connecting up subscribers for "through" calling and long-distance connections, when talking current is to be fed direct from the toll board or from the switches at the central office. This board has the customary supervisory and night-alarm circuits.

A general diagrammatic scheme of the circuits is shown in Fig. 73. The line circuit is equipped with relay and lamp signals. The regular cord circuit is of the common battery type with double-lamp supervision. The supervisory lamps operate through a third conductor in the cord.

The toll-cord circuit contains no relay except one low-wound supervisory relay connected in series in one side of the cord and bridged by a 2 m.f. condenser. The trunk circuit is made two-way to economize in the trunks required and to simplify the operation.

The battery current for this type of switchboard is generally fed from storage batteries at the automatic central office. A local battery of dry cells giving 24 volts is installed at the switchboard and multipled across the pair of wires which supplies current from the central office storage battery. Thisin connection with a set of condensers of 10 m.f. bridged across the battery leads, as shown, is sufficient to prevent noises and cross talk in the private branch switchboard due to the resistance of the cable pair used to supply the current from the central office.

Outgoing Trunk Calls.—If a calling party desires an outgoing trunk connection, the operator places the calling plug of the cord circuit in the local jack of the trunk circuit. When she does this, circuit is closed through the jack springs from positive battery through the high-wound bridge cut-off relay *B.C.O.R.* winding to negative battery. This relay opens the circuit through the line relay *L.R.*, which is normally bridged across the trunk circuit, and closes the circuit of the polarized supervisory relay *S.R.* across the trunk. At the same time that the operator inserts the calling plug in the outjack she throws the calling device key *C.D.K.* which connects the calling device direct to the trunk line and cuts off the supervisory relay leaving the trunk line clear for the calling device. She then operates the calling device to call the desired party in the usual way and, as soon as she has done so restores the calling device key to normal. The connector switch used in setting up the connection at central office automatically rings the called party. During the operation of the calling device a guard lamp is lit through circuits clearly shown in the diagram to warn the operator if she does not restore her key to normal promptly.

When the called party responds the reversing battery type of connector used reverses the direction of current flow in its calling party's loop and this causes the polarized supervisory relay *S.R.* associated with the *P.B.X.* trunk circuit to operate and break the circuit which was established when the plug was inserted in the local jack through the contact of this relay, the sleeve of the jack, the sleeve conductor of the cord and the supervisory lamp of the calling end of the cord.

If desired, any one of the telephones at the local stations may be equipped with an automatic calling device and the user may ask the operator to connect him up to a trunk so that he can make his own calls. The operator can do this by using a toll-cord circuit and by inserting the calling plug of this circuit into the toll jack of the trunk, which cuts off all of the supervisory circuits of the trunk and leaves the line entirely clear from the local automatic telephone through to the central office.

On such a connection talking current is supplied to the telephone from the central office and all supervision required is furnished by the cord supervisory relay. This relay keeps the circuit through the supervisory lamp open until the calling party restores his receiver to the switch hook. If the relay were not slow acting it might close the circuit through the supervisory lamp for a fraction of a second each time the calling device impulse springs broke the circuit.

Incoming Trunk Calls.—On an incoming trunk call the generator current from the connector switch used by the calling party operates the trunk-line relay *L.R.* through the 2 m.f. condenser inserted in each side of the trunk. This relay locks itself mechanically and closes the circuit through the call lamp. The operator responds by inserting the answering plug of an idle cord circuit into the local jack of the trunk. The cut-off relay operates, opening the line relay and closing the polarized supervisory relay circuit as before and mechanically unlocks the line relay. The operator then takes the incoming party's order and completes the connection in the usual way. The polarized supervisory relay is energized in such a direction that it operates during the conversation. When the calling party releases, this relay's armature is returned to normal position by the action of the current through the line relay of the line switch belonging to the trunk and closes the circuit through the cord supervisory lamp.

If the incoming call should be from the long-distance switchboard, the operator so soon as she learns this, withdraws the answering plug used to respond to the call and inserts the answering plug of one of the special toll-cord circuits into the toll jack and then uses the calling plug of that cord circuit to complete the connection to the local line.

Fifth Class—Full Automatic Private Branch Exchanges with or without Supervised Trunks.—A full automatic private branch exchange uses equipment of the same character as that installed at the automatic central office and, generally speaking, is essentially a small branch office. As a rule these branch exchanges are equipped with line switches, first selectors and connectors so that local connections are completed by using three digits and turning the dial three times to call each number. The local directory is entirely separate and distinct from the public exchange directory.

Incoming Trunk Calls.—For handling incoming trunk calls the local switchboard is equipped with one or more incoming trunk connector switches, the banks of which are multipled with the banks of the connectors used for local interconnections. The incoming trunks to these connector switches terminate in selector switch banks at the central office. Whether they terminate in the banks of first, second, third, or fourth selectors depends upon local conditions. If the central office is part of a system of 100,000 lines ultimate capacity they would usually terminate in the banks of either third or fourth selectors. Suppose for example that third selector switches in the fifty-eighth thousand section of the central office are decided upon in a given instance and that the first level of those banks is to be used for trunks to a given automatic branch exchange. Then a calling party would have to call "581" to secure a trunk terminating in an idle incoming trunk connector switch at the automatic *P.B.X.*

To complete the connection to the *P.B.X.* subscriber he must also call the last two digits of the subscriber's local number. If the subscriber's local number were "237" it would appear in the public exchange directory as "58137" and any subscriber to the public exchange calling that number would secure connection to it just as if it were connected direct to one of the public central offices.

The circuit for such a connection does not differ in any way from that already shown in Chapter II for a connection passing through a central office connector switch; consequently a diagram and description of it will not be given here.

Outgoing Trunk Connections.—The outgoing trunks from the automatic *P.B.X.* to the central office usually terminate in first selector banks at the *P.B.X.* and in line switches or first selector switches (generally the former) at the central office. Each trunk is equipped with a repeater at the *P.B.X.* A *P.B.X.* subscriber, when calling a telephone connected to the public central office, does so in the usual way with the exception that before calling the subscriber's number as it appears in the public directory he calls a preliminary digit which was decided upon when the *P.B.X.* was installed and which is required to place the wipers of the *P.B.X.* first selector in connection with the bank contacts of an idle outgoing trunk. For example, if the trunks terminate in the third level of the first selector bank contacts, a *P.B.X.* subscriber desiring to call "2487" would dial "3-2487."

Limited Service.—It frequently is desirable to limit the service of certain *P.B.X.* stations to intercommunication only. Such stations may be prevented from receiving incoming trunk calls by disconnecting their normals from the connector bank multiple of the incoming trunk connector switches, leaving the normals connected to the multiple of the local connector switches only; or a station which is not to receive incoming trunk calls may be prevented from doing so by having its private bank contact permanently grounded at the incoming trunk connector switch bank terminal. This causes anyone, who attempts to call that station, to receive the busy signal. They may be prevented from making outgoing trunk calls by the use of a special type of repeater on the outgoing trunks and the use of a 350-ohm resistance coil shunt across the terminals of the bridge cut-off relay winding of each switch which is to be allowed to have outgoing trunk service.

The circuits of a line switch and repeater arranged for this discriminating service are shown in Fig. 74. As already indicated, the line-switch circuit is of the usual type with the exception of the resistance coil bridged across the bridge-cut-off coil terminals. The repeater has the customary double-

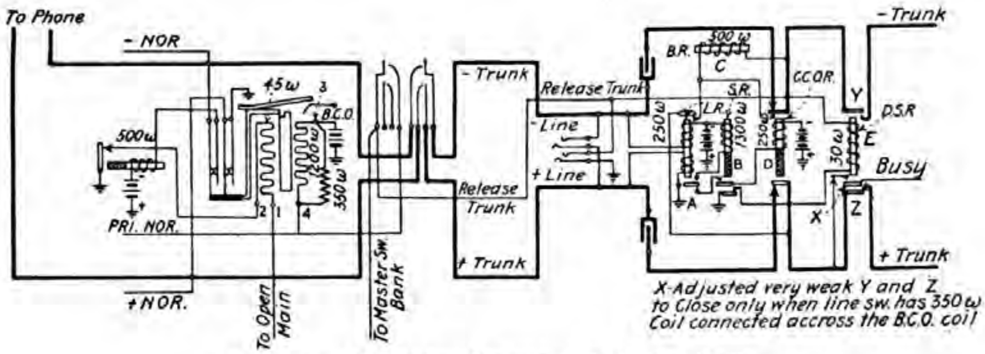


FIG. 74.—Discriminating outgoing trunk circuit.

wound quick-acting line relay *L.R.*, slow relay *S.R.*, condenser cut-off relay *C.C.O.R.*, and trunk-holding bridge coil *B.R.* The release trunk instead of being connected direct to earth by a contact controlled by the slow relay, passes through the winding of the 30-ohm discriminating service relay (*D.S.R.*) Since this relay is of comparatively low resistance, it is a simple matter to adjust it so that it will not pull down its armature when the line switch connected to the repeater does not have the 350-ohm shunt across the terminals of the bridge cut-off winding, i.e., it is adjusted so that it will pull down its armature through 350 ohms and 1300 ohms in multiple but will not do so when it receives current through a 1300-ohm resistance.

If this relay does not attract its armature the trunk is not closed through to the central office and the calling party receives the busy signal because the springs are so adjusted that the relay will have strength enough to close the contact from the positive side of the trunk to the busy busbar although it does not have strength enough to close the trunk contacts.

Automatic Private Branch Exchanges with Supervised Incoming and Outgoing Trunks.—Where outgoing trunk calls are to be made by the users of the automatic private branch exchange without the aid of an operator or where subscribers to the public telephone are allowed to call the various private branch exchange telephones directly without an operator's assistance provision for supervising the calls going in either direction may be very simple and inexpensive—in fact, all that is required is a series relay of low resistance (about 10 ohms) connected in one side of each trunk and bridged by a condenser. If the springs of this relay are arranged to close the circuit through a supervisory lamp then a signal light corresponding to each trunk will glow whenever that trunk is in use. This series relay should be slow acting, so that it will not flutter when ringing or calling device impulses are passing over the trunk.

A switch should be arranged so that the pilot lamps can be cut out of circuit except when they are required. With these pilot lamps to indicate when connections are established, a key associated with each trunk may be used to bridge a receiver in series with a $\frac{1}{2}$ m.f. condenser across the trunk so that a supervisor can hear what is being said without the knowledge of the parties talking. If desired it can be arranged so that by throwing the same key in the opposite direction and using a receiver of the direct-current type a transmitter can be connected in series with the receiver and the condenser shunted out so that the supervisor can speak to either of the parties on the line if desired.

The operator should always throw her receiver with condenser in series on to the line first, however, so that if the calling party should be in the act of setting up his connection to the called party she will not interfere with him.

Trunk Calls set up by an Operator.—Where it is desirable to install equipment so that either the outgoing or the incoming trunk calls are to be set up by an operator at the private branch exchange more elaborate provisions than those mentioned in the foregoing paragraphs are required.

A comparatively simple equipment may be used, however, installed in a small cabinet of the cordless manual private branch exchange type already described, and all switching may be done by means of keys. The circuits for calls going in either direction may be arranged so that after the operator has set up the connection she need pay no further attention to it because the ringing will be done automatically by the connector switch employed and when the parties hang up their receivers the releasing of the switches used in the connection will be effected automatically.

The circuits may be arranged so that the operator can listen in on the connections after she has set them up or so that it will be impossible for her to do so.

Incoming Calls.—A circuit arrangement for an equipment of this character is shown in Fig. 75. This diagram illustrates the circuit of a non-secret equipment for use on a trunk which terminates in rotary connector banks at the central office and in a line switch, first selector or connector switch at the automatic private branch exchange. The connector switch used for this circuit at the private branch should be of the reversing battery type in order to operate the supervisory features.

When a connector switch at the central office connects to this trunk, the 500-ohm bridge coil is energized and closes the circuit from earth through the trunk signalling lamp. The operator responds by throwing the key in the direction that will bridge her telephone across the trunk and close circuit from earth through the 1300-ohm release control relay. When this relay attracts its armature it breaks the circuit through the signal lamp and locks itself by closing circuit to earth through the contact of the 500-ohm

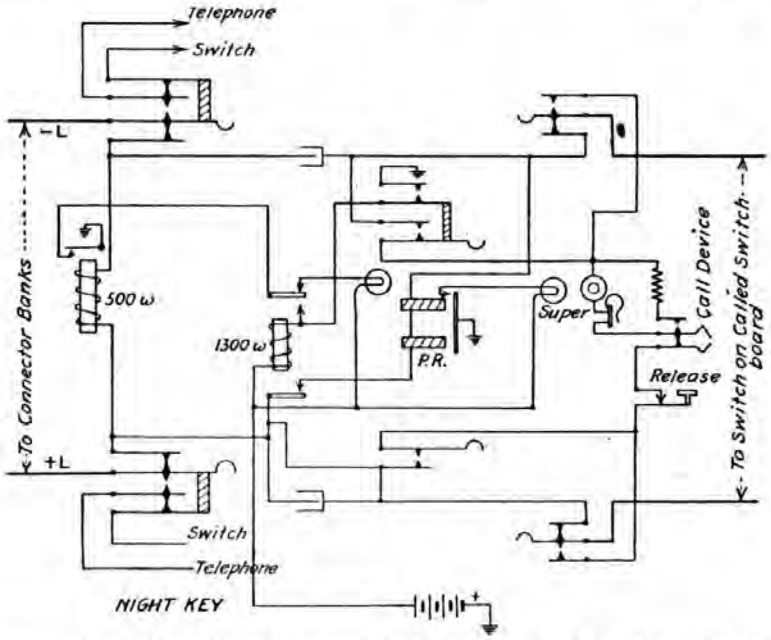


FIG. 75.—Circuit through an automatic *P.B.X.* attendant's cabinet (non-secret).

bridge relay. After the operator has taken a subscriber's number she throws her key in the opposite direction, which opens the trunk and connects her calling device to the local switchboard end of it, then operates her calling device to call the particular number desired and restores her key to normal. The connector switch rings the called party automatically and, meanwhile, supervision is furnished and the connection as established is prevented from releasing by the bridge across the line through the polarized supervisory relay *P.R.* When the called party responds and the direction of current flow is consequently reversed through this polarized relay the circuit through the supervisory lamp is broken and the parties proceed with their conversation. If the called party should wish to signal the operator for any reason—for example to tell her to switch the calling party to some other local station—he can secure her attention by moving his receiver switch hook up and down slowly. This causes the polarized relay to make and break the circuit through the supervisory lamp thus giving the usual flash signal to the operator. The operator can release the local connection at any time when her calling device is in circuit by simply pressing the release button and can then call another party without interfering with the incoming connection. After having once established the connection the operator need pay no further attention to it unless signalled by the local party.

When the calling party releases the switches in the central office, the switches on the branch switchboard are released automatically because when

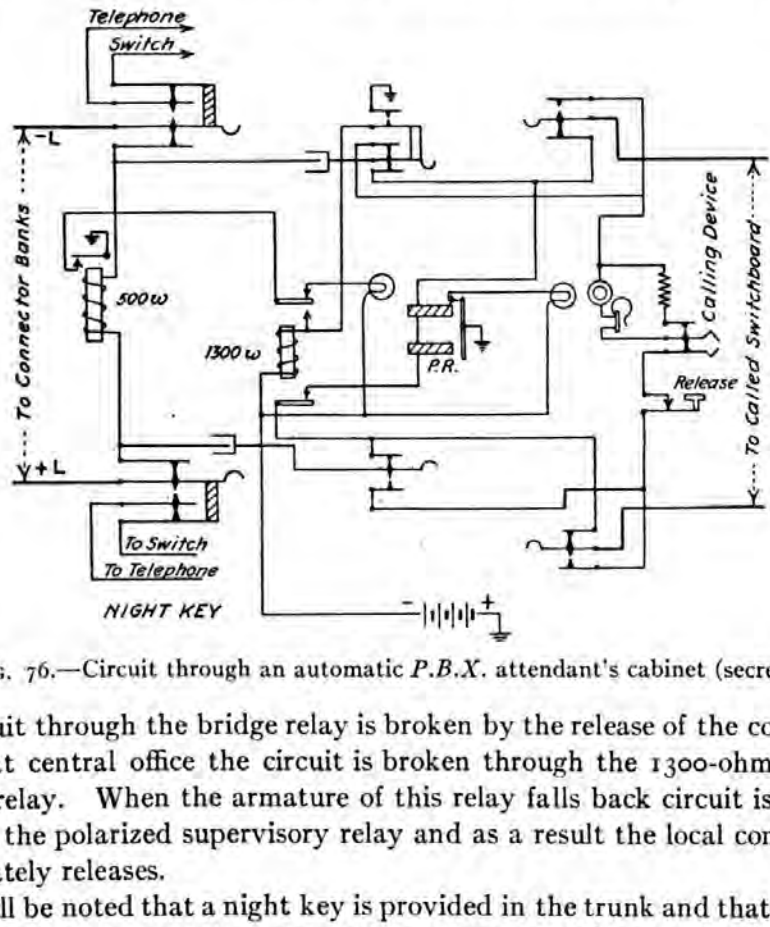


FIG. 76.—Circuit through an automatic *P.B.X.* attendant's cabinet (secret).

the circuit through the bridge relay is broken by the release of the connector switch at central office the circuit is broken through the 1300-ohm release control relay. When the armature of this relay falls back circuit is broken through the polarized supervisory relay and as a result the local connection immediately releases.

It will be noted that a night key is provided in the trunk and that when it is thrown it cuts out the operator's equipment and connects the trunk directly to a line which may lead to any local station. At the same time, it disconnects the line of this particular telephone from the local switchboard. Another arrangement, similar to the one in Fig. 75, is shown in Fig. 76. In fact, the only difference between the two is that the latter is "secret." This is accomplished by making the trunk key connections such that when the operator listens in on the incoming section of the trunk she can converse with the calling party only. When she throws the key in the opposite direction she can converse with the called party but the calling party is cut off. With this exception the operation of this trunk is the same as that in the former figure.

Outgoing Trunk Calls.—Either of the circuits just described may be reversed and thereby used equally well on a trunk outgoing from a branch automatic switchboard to central office. The operation would be the same as that just described with the exception that the night key can not be used and should not be installed in connection with an outgoing trunk.

If the trunk coming from the local switchboard terminates in selector banks instead of in connector banks then the incoming trunk portion of the operator's equipment should be arranged as in Fig. 77 so that the double

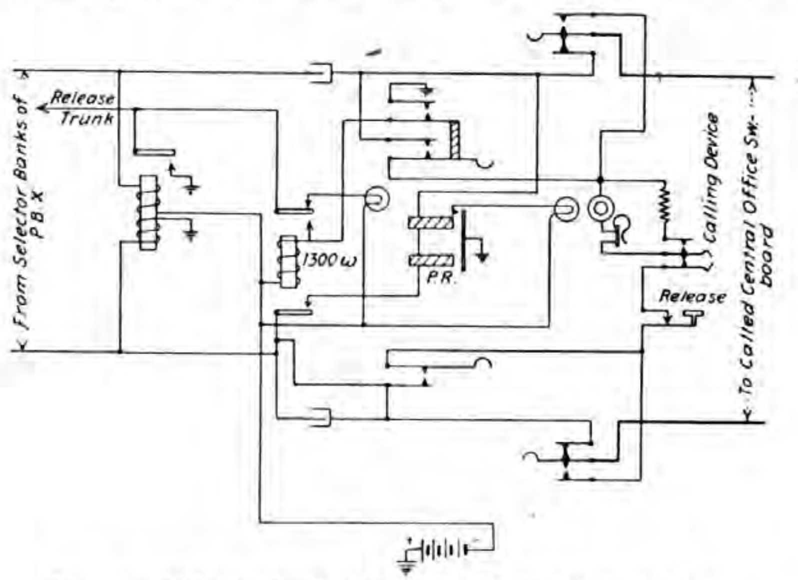


Fig. 77.—Outgoing trunk circuit through attendant's cabinet.

wound coil will supply talking current to the calling party and will connect the release trunk to earth so as to hold up the incoming connection and light the signal lamp until the operator responds. With the exception of the substitution of this double wound relay for the bridge relay this circuit is the same as the two previously described.

As a rule it would not be advisable to have the trunks incoming from the public exchange to equipment of this character terminate in selector banks in the public exchange because it would make it somewhat more difficult to switch the trunks through to the telephone for night service due to the necessity of providing some means for ringing the night telephone when called.

Because an operator's equipment using any one of the circuits just described is provided in connection with an automatic private branch exchange it does not necessarily follow that either all of the incoming or all of the outgoing trunks should pass through it. Sometimes it is desirable to have all of the incoming trunks except one terminate in selector banks at the central office and pass directly to the local switchboard. The line excepted may terminate in a regular connector multiple at the central office and be designated under its proper number in the public directory as the information clerk's telephone of the establishment in which the automatic private branch exchange is installed. With this arrangement subscribers to the public exchange can call the various local stations automatically but if they do not know whom to call or wish for any reason to secure the services of the local operator, they call the number which appears in the directory as that of the information operator and thus secure connection to an incoming trunk terminating in a circuit like that shown in Fig. 75 or 76 in the operator's cabinet. The information clerk responds to each such call, gives the information wanted, and if desired sets up the local connection for the calling party.

A similar plan may be used on outgoing trunks, the arrangement being such that certain privileged parties may make all outgoing connections without the help of the operator while the others can make outgoing connections with her aid and approval only.

Apartment House Automatic Private Branch Exchange.—This is a type of private branch exchange which has been developed and used to a large extent in San Francisco, which, especially at certain seasons of the year has a large tourist population. For the accommodation of families of tourists this city contains many family hotels or apartment houses which make a specialty of supplying furnished apartments.

It will readily be understood that the number of intercommunicating calls between the occupants of the apartments of any building will generally be very small and in fact almost negligible but that the occupants will desire to make outgoing trunk calls, to receive incoming trunk calls, and to communicate with the janitor, office or landlord of the building. It has therefore been found that equipment most suitable for these houses is similar to that used in district stations rather than that used in regular automatic private branch exchanges and that using the district station type of apparatus facilitates central office supervision of the apartment house apparatus.

The apartment house equipment used in San Francisco has been quite fully described by Mr. Gerald Deakin in a paper presented by him at the Pacific Coast Meeting of the American Institute of Electrical Engineers at Portland, Oregon, April 16–20, 1912, and published in full in the transactions of the Institute.

CHAPTER IV

MEASURED SERVICE EQUIPMENT

Measured service is a title which is commonly applied to service which is charged for in accordance with the rate at which it is used by the customer. Generally the charge is based on the number of messages sent by each customer, no attention being paid to the number of messages received by him.

There is no scientific reason apparent for charging a fixed rate per message for local service in automatic telephone systems. Since the connections are handled by machinery, a comparatively wide variation in the number of connections per line per day for which apparatus must be provided, makes a very small difference in the first cost of the central office equipment, no difference whatever in the cost of the subscriber's station and line equipment and makes but a small difference in the cost of keeping the apparatus in good working order.

While measured service decreases the traffic and consequently permits a reduction in the trunk lines and switches, the saving in the installation and maintenance costs of the trunking equipment is largely if not entirely offset by the installation and maintenance costs of the equipment required for counting the calls made by each subscriber. It would therefore seem that measured local service in automatic telephone systems must be justified almost entirely on the ground of expediency.

Such service may be given for one or more of the following reasons:

1. To satisfy legal requirements or to comply with the demands of a public utility commission.

2. As a means of gauging the charge which it is expedient to make for each patron's service. Telephone rates must be regulated to some extent by charging what the "traffic will bear." This is generally recognized by charging more for business service than for residence service, although the average first cost of a residence line is considerably more than the average first cost of a business line and the difference in the operating cost does not justify the difference in the rates between the two.

3. Such service is given in hotels, railway stations, and other public places where the telephones are installed for the convenience of the general public and where, since no one patron can be expected to pay for all of the service, each must be charged a fee for his connection.

4. It affords a means of supplying cash service to patrons whose credit is questionable.

There are three different methods of giving measured local service employed in automatic systems; viz: using meters at the central office, using coin collectors at the subscribers' stations and using meters at the subscribers' stations.

Central Office Meters.—Where meters are used in central offices in systems of the Automatic Electric Company's manufacture they are so arranged that there is a meter associated with the line switch of each line on which the service is to be measured. When a subscriber makes a call his meter does not register it until the called party responds and it does not register even then if the subscriber has called a long-distance operator, an information or complaint operator, the wire chief, manager or some other employe of the company. Sometimes it is arranged also so that the meter will not register if the subscriber calls the police department or fire department.

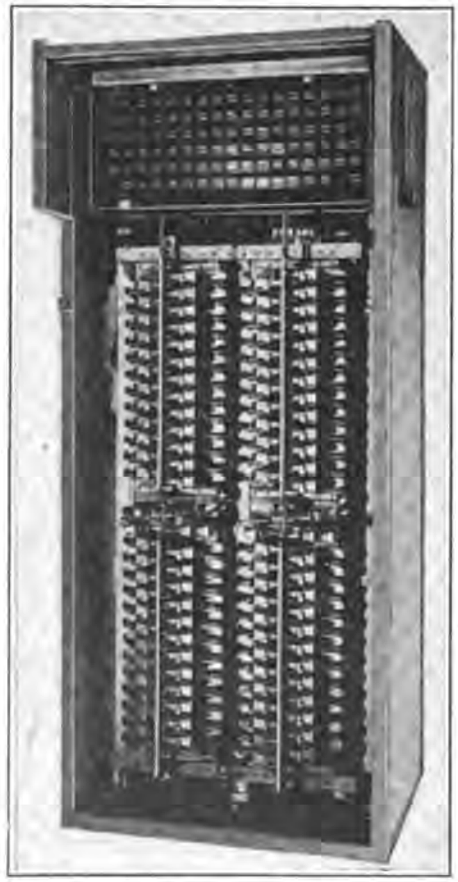


FIG. 78.—Line switch unit with meters at top.

In Fig. 78 is shown a photograph of a line switch unit on which the meters are seen mounted in a group above the line switches. The mechanical design of the meters is the same as that of those which are widely used in manual practice.

A circuit showing a line switch with meter and a reversing battery two-wire connector switch is illustrated in Fig. 79. It will be noted that there is no difference between this connector switch and those commonly used in two-wire systems which have already been fully described. The only difference between the line switch and those described heretofore is the addition of a pair of springs closed by the plunger when it is drawn down. The operation of the circuit in so far as the meter is concerned is as follows:

When the calling subscriber lifts his receiver from the switch hook, the line-switch plunger enters its bank and extends the circuit to a connector switch in the usual way. As the plunger moves toward its pole piece it closes circuit through the outside winding of the meter from negative battery to the private normal, which is of course connected to earth. At the same

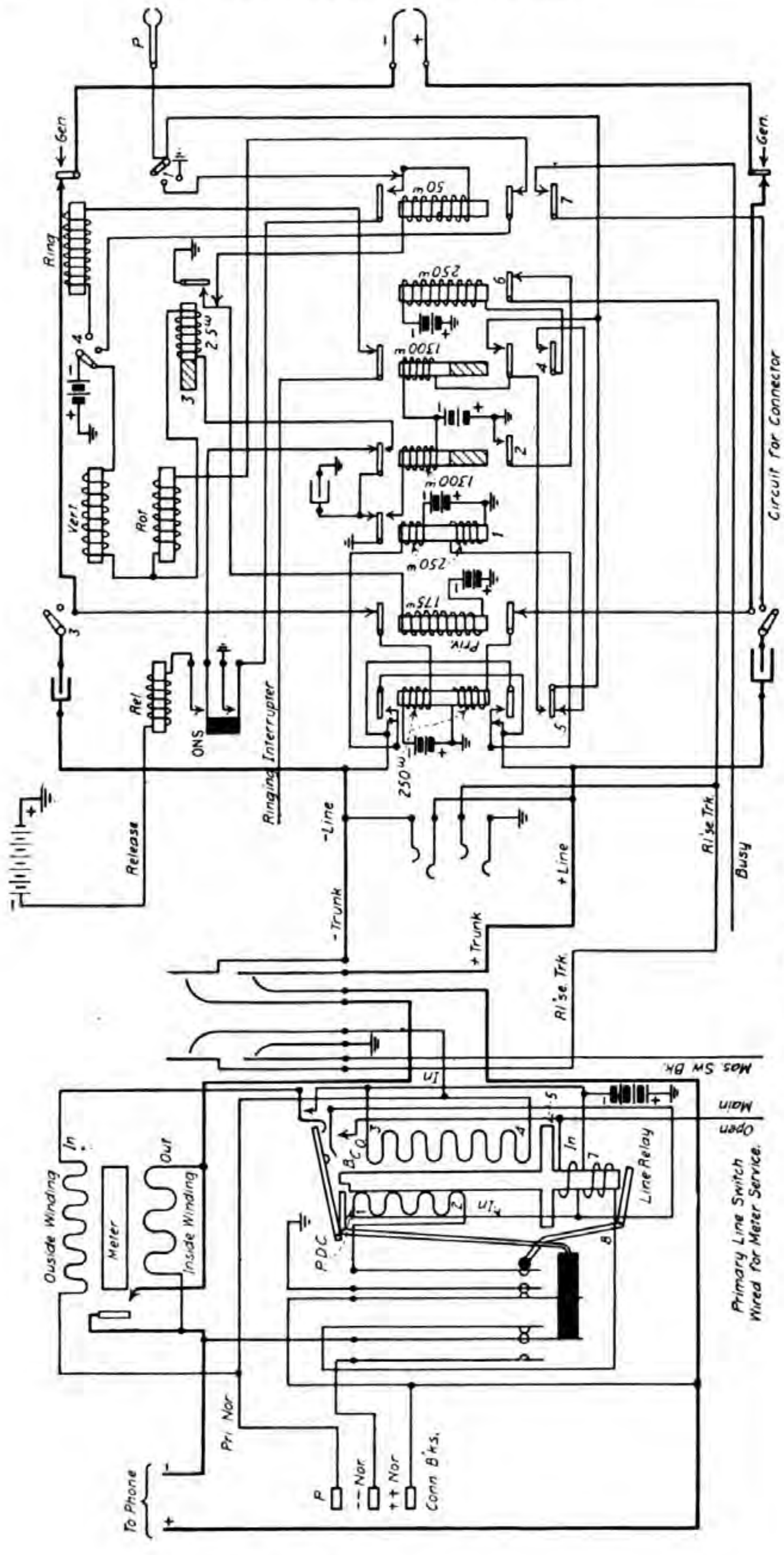


FIG. 79.—Circuit of line and connector switches with meter.

time however circuit has been closed through the inside winding of the meter, which is connected in series in the negative side of the trunk to the connector and is therefore energized by the current flowing through the line relay windings of the connector and the subscriber's loop. At this stage of the connection these two windings oppose each other so that the meter armature is not attracted. When the called party responds, however, and his connector reverses the direction of the current flow in the calling party's loop then the inside meter winding assists the outside winding and the meter armature is drawn down causing the meter to register and shunting out the inside winding.

The outside winding retains the armature until conversation is completed so that the calling party's talking circuit is left entirely clear the same as when no meter is used.

If the calling party instead of setting up a connection with another subscriber calls some number to which he is to be afforded free service—for example the long-distance operator—his meter does not register because the equipment is arranged so that the trunk to her position terminates in the banks of a selector switch and does not pass through a connector switch, and her cord circuits are designed so that when she responds to his signal she does not reverse the direction of current flow in his loop. Therefore the two meter windings continue to oppose each other and the meter does not register, neither does it short-circuit its inside winding. This winding, however, is of very low resistance and while its impedance is almost negligible, it may be reduced to nil by shunting it with a condenser, a non-inductive resistance coil or, better and simpler still, by placing a thin pure copper sleeve over the core of the meter.

Free service may be given on connections which pass through connector switches also by segregating such lines and connecting them to the banks of a group of connectors which do not reverse the direction of current flow in the calling party's loop when the called party responds. It is readily apparent that these connectors would be the same as those shown in the diagram excepting a very slight difference in the connecting of the back bridge relay springs.

Coin Collectors for Subscribers Stations.—Fig. 80 is a photographic reproduction of two views of a coin collector—one with the cover on and one with the cover removed—of a type that is employed to a considerable extent in automatic exchanges.

Fig. 81 (right) is a diagram of the circuit of this collector in connection with the ordinary two-wire wall telephone. The essential feature of the collector is a polarized relay *P.R.* which through its armature arm and a trigger controls three contact springs which are so connected up that when they are closed together they short-circuit the telephone transmitter and place a low resistance shunt across its receiver. The trigger is arranged so that it will be tripped when a suitable coin or token passes through the coin chute to the coin box. The windings of the polarized relay *P.R.* are connected in series in one side of the subscriber's loop, but in order that they may not reduce transmission they are of very low impedance and bridged by a 2 m.f. condenser. To reduce the impedance to the lowest possible amount, a copper sleeve is placed over the core of each coil.

The operation of the mechanism as a subscriber makes a call is as follows:

When the subscriber lifts his receiver from the switch hook, current flows from the central office through his loop energizing the polarized relay windings and causing the armature to swing its arm away from the coin chute. The

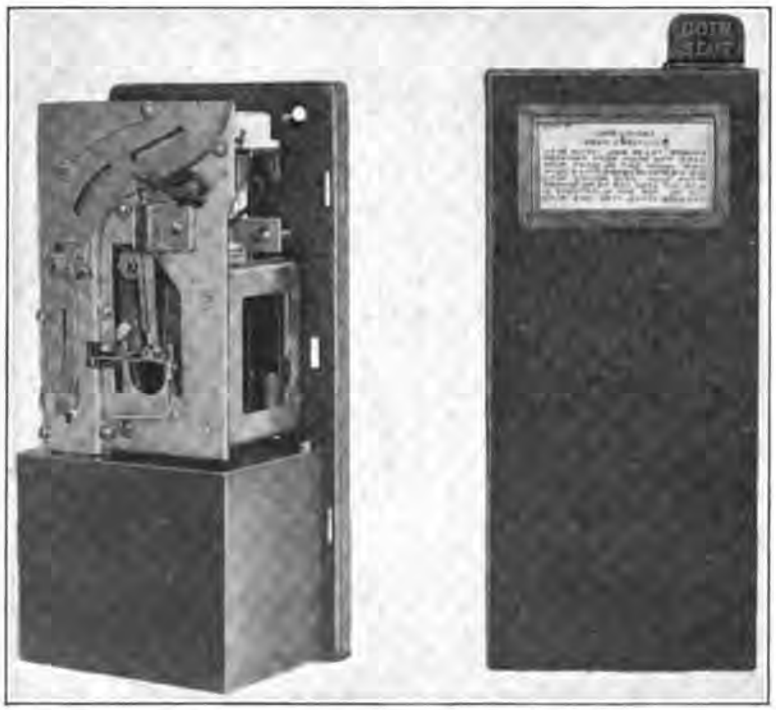


FIG. 80.—Interior and exterior views of automatic coin collector.

subscriber proceeds to call the party he wishes in the customary manner and, when the called party responds, the direction of the current flow is reversed in the calling party's loop by the action of the reversing battery-connector switch with the result that the polarized relay *P.R.* swings its arm in the opposite direction, i.e., toward the coin chute and thereby causes its trigger to draw the three shunt springs into contact with each other thus short-circuiting the transmitter and placing the 30 ohm shunt across the receiver terminals. All of this happens in an instant so that when the called party speaks into his transmitter in response to the call the calling party is able to hear him but can not talk to him. The calling party immediately deposits the required coin in the coin chute, however, and as it drops to the coin box it strikes the trigger, knocking it out of engagement with the lever. The shunt springs spread apart and the calling party is enabled to converse with the called party in the usual way.

Should the calling party receive the "busy" signal or receive no response whatever to his call he saves the coin by not depositing it. The purpose of the low-resistance shunt placed across the receiver terminals is to prevent the calling party defeating the purpose of the collector by using his receiver as a transmitter.

Calls to long-distance operators, information operators and other telephone company employees may be made and conversation carried on without the deposit of a coin because, as explained in the description of the meter circuits, arrangements are made so that the direction of the current flow in the calling party's loop is not reversed during conversation, consequently the polarized relay *P.R.* of the collector does not close the shunt springs.

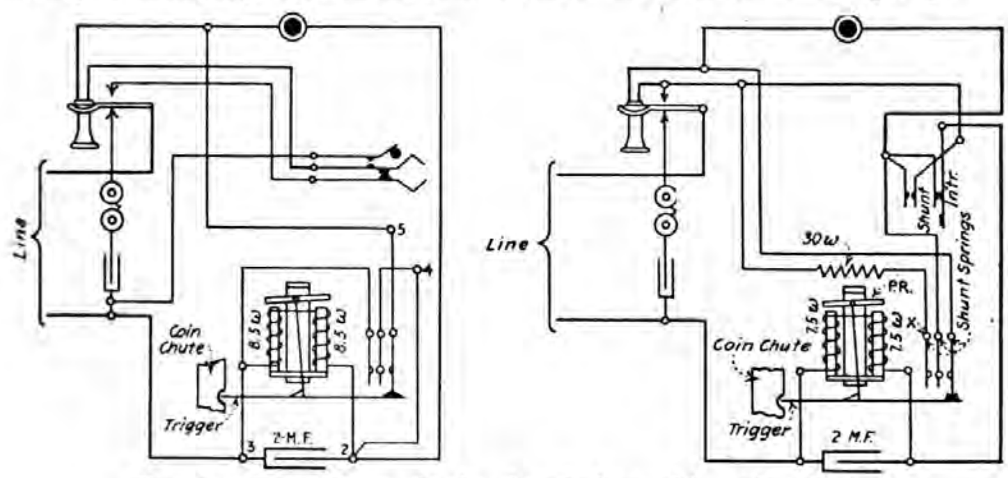


FIG. 81.—Two different circuits of a telephone with a coin collector.

Fig. 81 (left) is a diagram of a wall telephone connected to a collector, the circuit of which is slightly different from that just described. The special feature of this collector is that it gives a "tick tick" signal to a party called by another party from a telephone equipped with a collector, for the purpose of reminding the called party that he should respond to the call by giving his own name, the name of the company or firm to which the called telephone belongs, or preferably the number of the called telephone so that the calling party will be sure that he has made his call correctly and has the number that he wishes before he deposits the coin in the collector.

The mechanical features of this collector are the same as those in the one previously described but when the polarized relay swings its arm toward the coin chute, thus drawing the shunt springs together, it short-circuits its own windings at the same time that it places a shunt across the calling party's transmitter. When short-circuiting takes place the polarized relay arm immediately swings back to original position opening its shunt, and then immediately swings toward the coin chute again. Thus the polarized relay arm is moved back and forth repeatedly making and breaking the contact between the shunt springs so that a moderately loud "tick tick" is heard by the called party due to the shunting in and out of the transmitter and polarized relay windings. When the calling party drops the required coin the trigger is tripped and the circuits of the telephone are left clear for conversation.

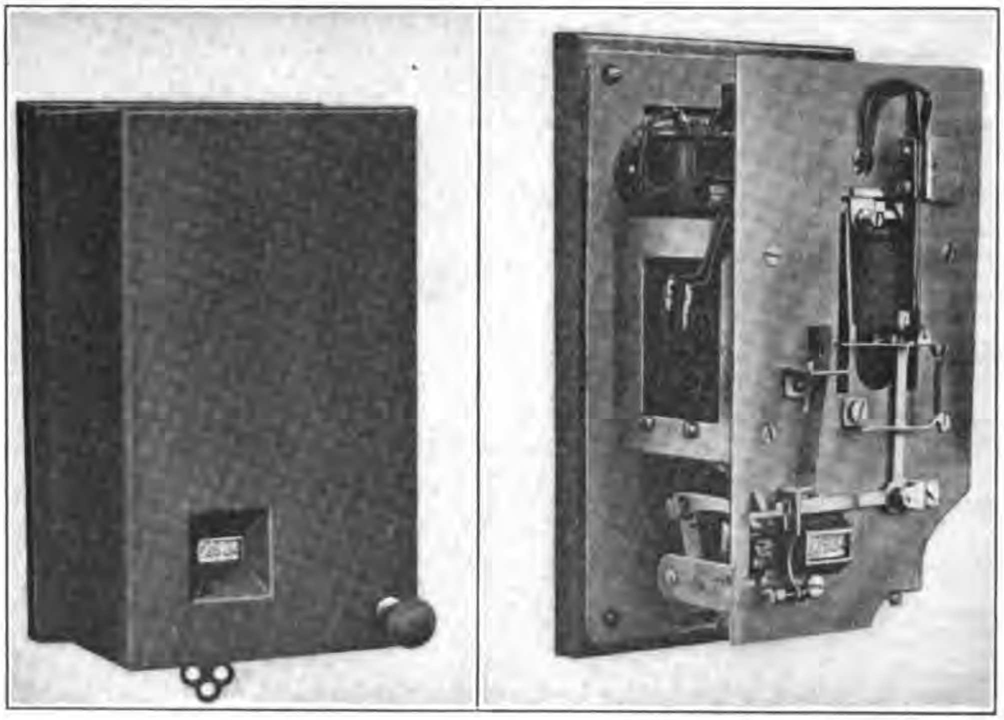


FIG. 82.—A subscriber's station meter.

Subscribers' Station Meters.—Meters instead of coin collectors are sometimes installed at subscriber's stations. The circuit of these devices may be the same as shown in Fig. 81 for use with coin collectors. The mechanical features of the meter being such that the subscriber pushes a button which trips the trigger controlling the shunt springs instead of dropping a coin to do so.

A photograph of one of these subscribers' station meters is shown in Fig. 82. The meter digitals are operated mechanically when the button is pushed. The design is such that the meter will register but once for each call although the button may be pushed several times during each connection.

Pay Station for Long Distance and Local Service.—It is the general practice to install in hotel lobbies and other places, from which a considerable number of long-distance calls may be expected to emanate, common battery manual telephones equipped with coin collectors arranged with chutes for coins of three or four sizes, each chute being equipped with a suitable device for giving a signal to the operator who is supervising the deposit of the coins.

Fig. 83.—A combination telephone and coin collector for both local and toll-line service.

The lines from these pay-station telephones are connected to the long-distance board and are handled by the operators of that board. Connections to long-distance lines or other pay-station lines are put up manually and connections from pay-station lines to subscriber's automatic stations are set up by using a calling device installed in the operator's position for the purpose.

It has been found desirable in some locations however to install automatic telephone pay stations instead of manual telephone pay stations and to equip the station with a coin-collecting device which may be used either for collecting the coin deposited for a local call, which is not supervised, or for a long-distance call on which the operator's aid and supervision is employed. Such a collector usually has three slots—one for 5-cent pieces, one for dimes and one for quarter dollars. A photograph of one of these devices manufactured by the Baird Manufacturing Company is reproduced in Fig. 83 and the circuit of it is shown in Fig. 84.

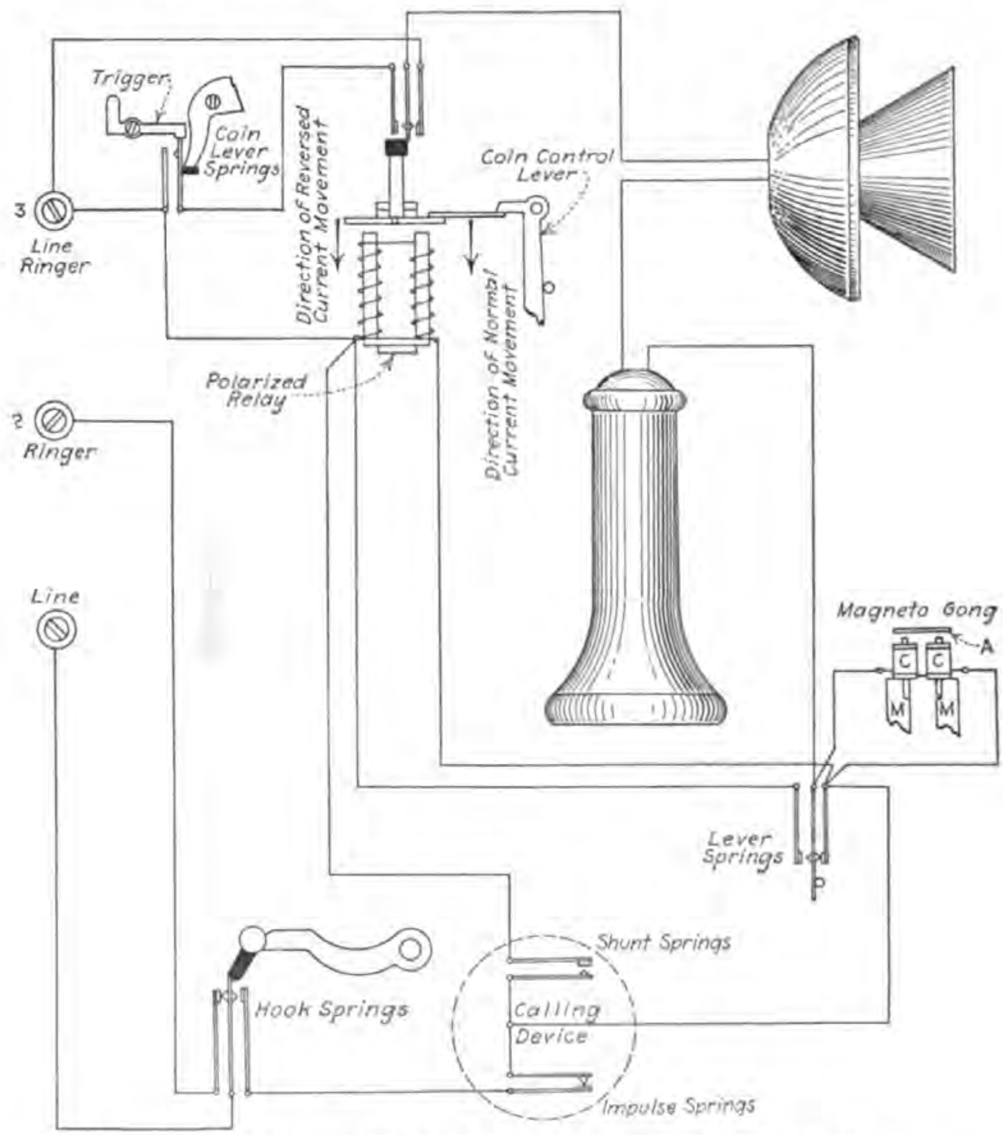


FIG. 84.—Circuit of combination telephone and collector shown in Fig. 83.

When the party using this station desires to make a long-distance call he turns his dial from the "O" finger hole which secures the recording operator in the customary manner. She follows the usual practice, i.e., she takes his order, tells him to hang up his receiver and that he will be called when his party has been secured. When the line operator has set up the desired long-distance connection she calls the local party waiting at the pay station by using her calling device to secure connection through the automatic switchboard. She then instructs him to deposit the required coins and checks them by signals sent over the line indicating the denomination of each coin when the subscriber pulls the lever at the side of the box after each coin is dropped in its proper chute.

Referring to the circuit diagram, it is seen that this combined coin collector and telephone has the usual receiver hook springs, calling device impulse and shunt springs, and the polarized relay with springs controlling the talking circuit, as in the coin collectors already described. It also has a set of springs called, "lever springs," which, each time the lever at the side of the box is pulled forward after a coin has been deposited, opens the shunt around the magneto gong and switches one end of the magneto gong circuit on to the side of the line leading direct to the line-ringer terminal (No. 3).

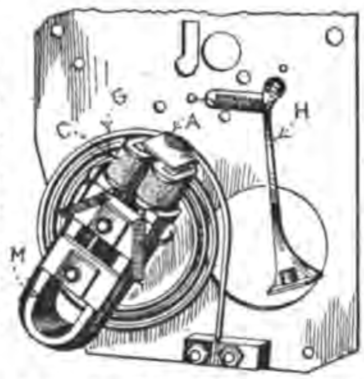


FIG. 85.—Magneto gong of collector in Fig. 83.

Each time he pulls the lever forward, after having deposited a coin, a mechanical arrangement causes a hammer *H* to strike a coiled spring gong *G* associated with a form of magneto transmitter (*A*, *C*, *N*,) as shown in Fig. 85. A nickel causes the hammer to strike once, a dime twice, and a quarter three times. Each time the gong is struck, the soft-iron armature *A*, which is rigidly fastened to the gong spring, vibrates in the field of the permanent magnet *M*, upon the pole pieces of which are wound the coils *CC*. At the same time the shunt around the gong is opened so that the current generated in the magneto transmitter is transmitted directly over the line to the listening operator's circuit; and since, at this time, the subscriber's receiver is shunted out, he does not hear the tone.

The collector also has a pair of springs called the "coin-lever springs." The arrangement of the mechanism controlling these springs is such that whenever the lever is pulled, after a coin of any denomination is dropped, the lever will press the springs together allowing the trigger to drop down and hold them in contact with each other.

When the calling party removes his receiver from the switch hook, the circuit is closed by the hook springs and the polarized relay springs, through the receiver and transmitter thus completing the subscriber's loop. The arrangement of the long-distance board circuit is such that when the operator calls him, or responds to a call which he has made, the direction of current flow is not reversed in his loop. It is therefore unnecessary for a party to deposit a nickel to call the recording operator, or, if he does so, the coin will be returned to him when he replaces his receiver on the switch hook.

To call a local party automatically, a nickel should be placed in the proper chute and the lever pulled as soon as the receiver is removed from the switch hook. This is necessary in order to close the coin lever springs together and complete the talking circuit, because when the party at the called automatic telephone responds, the connector switch used reverses the direction of the current flow through the polarized relay of the collector, thus breaking the shunt around the coin lever springs so that unless the coin lever springs are in contact the receiver and transmitter circuit of the pay station is opened. After having deposited the nickel and pulled the lever, the party proceeds to make the call in the usual way. When the called party answers and the polarized relay operates, it moves the coin control lever, allowing the nickel, which has heretofore been held in suspense in the instrument, to pass through to the coin box. If the called party does not respond, the coin is returned to the caller by being passed down to the little cup shown on the front and near the base of the collector, when the called party replaces his receiver on the switch hook.

The collectors are arranged to return nickels only, because in the cities where they have been used, other coins are not dropped except on connections supervised by operators. On such connections the party is instructed not to place the coins in the chutes until told to do so by the operator. The construction is such that whenever there is a coin in one of the chutes its weight causes a mechanical arrangement to close the other chutes until the lever has been pulled, allowing the first coin to pass on.

CHAPTER V

AUTOMATIC SYSTEM OF THE AMERICAN AUTOMATIC TELEPHONE COMPANY

The system of the American Automatic Telephone Company grew out of the work of Lattig, Goodrum, and Dunham. They had some experience with the apparatus of the Automatic Electric Company and took as their problem its improvement. Their earliest work was a three-wire common battery system described in patent No. 920350, applied for in 1903, issued 1906, and British patents No. 16479 and 16479A of 1906. Their later apparatus was two-wire, as installed at Urbana, Ohio, Crawfordsville, Indiana, and elsewhere.

Description of the System.—The chief features of interest are the group-

FIG. 86.—Dial.

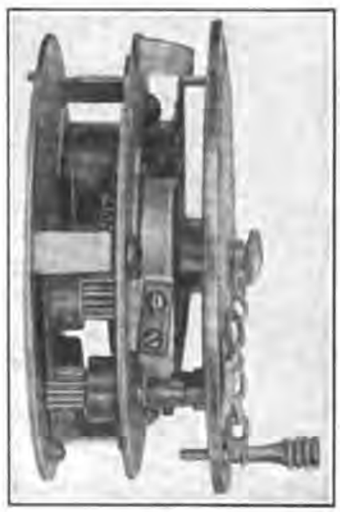


FIG. 87.—Calling device mechanism.

ing of subscribers' lines by fifties instead of hundreds, and the use of a single motion fifty contact switch used as a line finder also as a selector and as a connector. As a selector, its bank contacts are divided into ten groups of five each, with automatic trunk selection among the five trunks of a group. As a connector, it carries traffic into a group of fifty lines, reaching the desired line by a single series of steps varying from one to fifty. The calling device gives fifty impulses as its maximum.

Other detail items are as follows: The use of a dial lock to prevent premature use of the dial (before the finder switch has seized the calling line); and a two-position side switch operated by a direct acting private magnet.

The calling device (Fig. 86) is equipped with fifty holes. A small pin is provided as a handle by which to operate the dial. To call a number such as "48," the pin is inserted in the hole, and the dial rotated clockwise until the pin strikes a stop. The hand is then removed and the dial allowed to rotate back to normal, during which time the impulses are sent in to the office.

In the side view of the calling device, Fig. 87, the impulse device may be seen at the bottom and just behind the dial. It consists of a cylinder which is half brass and half fiber. Two brass springs rest on the cylinder

FIG. 88.—Wall telephone with later calling device.

FIG. 89.—Desk telephone.

so as to be normally connected by the brass portion. When the dial is rotating back to normal, the cylinder revolves, bringing the fiber part of it between the springs intermittently, so as to interrupt the current. At the top is the dial stop against which the pin strikes to limit the motion. Between the middle and back plates are the gear wheels and the clock spring which move the dial and interrupter, and a friction governor.

A later type of calling device is that shown mounted on the wall telephone in Fig. 88 and the desk telephone in Fig. 89. The dial is turned by means of a pin on a rotatable arm. A pointer is provided on an angle with the pin-arm but is an integral part of it. The method of operation is to take the button at the end of the pin-arm between the fingers and swing the arm in either direction until the pointer points to the number to be called. The button is then depressed, pushing the pin into whatever hole it happens to be over. The dial is turned in clockwise direction until the pin strikes a stop. The button is then released and the dial returns to normal position under the influence of a clock spring.

It should be noted, also, that letters, as well as figures are used on this calling device, so that subscribers' numbers may be made easier to remember. For example, "40-15" may be written "K-15," because "K" and "40" are associated with the same hole in the dial.

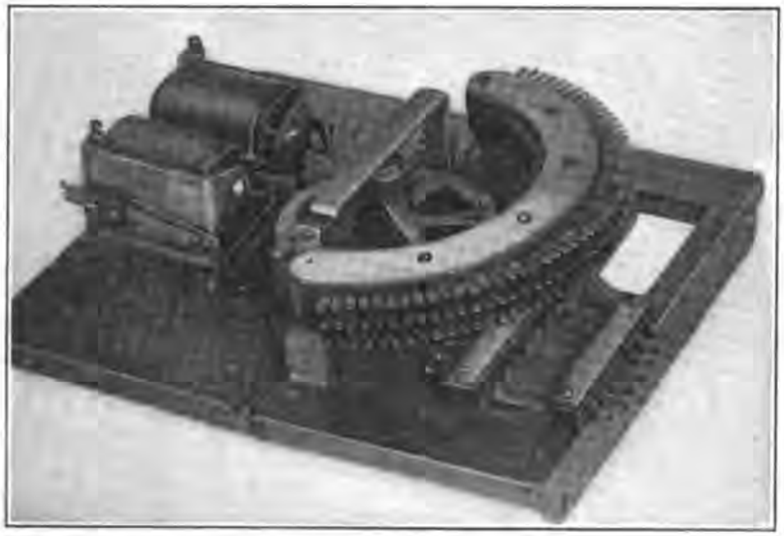


FIG. 90.—Switch bank and wipers.

The selector, Fig. 90, is made in three parts, only two of which are shown. The bank is fixed to the plate at the right which carries the jack, ordinarily fixed. The motor magnet, release magnet and wipers are mounted on the next plate to the left. It fits onto the bank plate and is aligned by V-shaped grooves inside the latter. The plate carrying the relays is to be attached to the left end of the magnet plate. Its alignment is of minor importance.

The plan view, Fig. 91 and 92, shows more clearly the structure of the magnets and ratchets. At the right is the motor magnet, which is back acting, moving the wipers on its return stroke instead of on the pull-up stroke. The detent is almost hidden by the pawl. The release magnet is at the left. Current is carried to the wipers by means of springs which reach from the right to sectors on the hub and part of the wipers. There is an off-normal switch at the left. The pin which holds the bushing for operating it may be seen on the ratchet wheel, to the left of the wipers.

The telephone and calling-device circuit, Fig. 93, has the transmitter, primary of induction coil and interrupter contact in series. The lock magnet is in series, but normally short-circuited. The first motion of the dial opens the short-circuiting springs, so that if there is current on the line, the lock magnet will be pulled up and unlock the dial, permitting its complete rotation. If there is no current on the line, the lock magnet will not pull up even when the shunt is removed, and the lug on the dial will strike the magnet lever, preventing more than a slight rotation. The object of this lock is explained later in the detailed description of the circuits.

FIG. 91.—Finder switch with magnets and relays.

Description of Layout and Trunking.—The following account describes typical conditions. Fig. 94 shows six groups of subscribers, fifty subscribers in each group. The groups are subdivided into two divisions, one known as the "*B*" division and the other known as the "*C*" division. For each group of lines there are provided as many finders as necessary on whose banks they terminate. The straight-line groups are provided with six finders and the party-line groups with seven or eight.

Finders and Bank Slip by Tens.—Each finder is provided with a bank having fifty sets of contacts, one set per subscriber. The sets are divided into five groups of ten each. The terminals of the first ten lines in the bank of the first finder occupy the first ten sets of contacts. In the bank of the second finder they occupy the "11–20" inclusive sets of contacts and in the bank of the third finder the "21–30" inclusive sets of contacts. In order to indicate this slipping in small space the banks of the finders have been indicated in five sections, one beside the other.

Finders and First Selectors.—Each finder has its own first selector. They are tied jack to jack. Each line has individual to it a line relay and a cut-off relay.

The function of the first selectors is to pick out grand divisions. For example, Fig. 94, a subscriber upon removing his receiver causes a finder to establish connection with his line and thereby has connection extended from his telephone to a first selector. If the first selector is operated so that the wipers are carried to the "*B*" section or group, from that point on, then, only subscribers in the "*B*" group, such as the subscribers "*BA*," "*BB*," etc., can be reached.

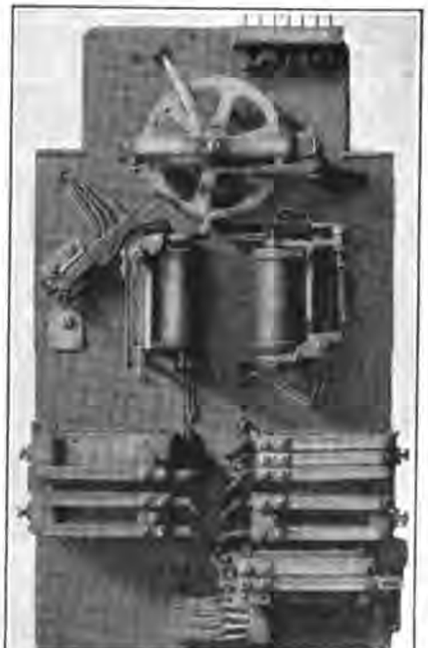


FIG. 92.—Selector switch, magnets and relays.

First Selector Bank Multiples.—The banks of the first selectors have no slipping between the contacts in the same group. The trunking between divisions, such as between the "*B*" and the "*C*" divisions, is very much the same as the trunking in other systems between thousands. If a subscriber in any "*B*" group, the "*BA*" group for example, wishes to call any other subscriber in the same division —that is to say, the "*B*" division, he gets a "*BA*" second selector. The second selector is then operated to establish connection with a group of trunks running to a connector switch of the group of the subscriber desired. On the other hand, if the subscriber in the "*B*" division (the "*BA*" group, for example) wishes to call a subscriber in another division (the "*CB*" group), he will first establish connection with a first selector of the "*BA*" group, then trunk across to a second selector in the group in the division to which he is trunking corresponding to his own group. That is, from the "*BA*" or first group in the "*B*" division he trunks across to the "*CA*" or first group in the "*C*" division. This is the equivalent in other systems to trunking from a board in one thousand to a corresponding board in some other thousand. After this the second selector is operated to establish connection with a connector in the group of the desired subscriber, namely, a connector in the "*CB*" group.

First Selector Bank Slip.—As indicated in Fig. 94 there is slipping between divisions, as, for example, between the "*B*" and the "*C*" divisions. A subscriber in the "*BA*" group in calling a subscriber in the "*C*" division operates his first selector to reach the "*C*" division. Assuming that the first selector stops on the first contact of the group, he will get the second switch in the group of five second selectors. The second contact gives the third switch, and so on.

Letters for Group Numbers.—The banks of the first selectors are arranged in ten groups, as indicated by the letters *A*, *B*, *C*, *D*, *E*, *F*, *H*, *J*, *K*, *M* on the dial. The letter *G* is omitted to avoid a confusion with the letter *C* when spoken. The letter *I* has probably been omitted to avoid its being taken for a 1 in the directories.

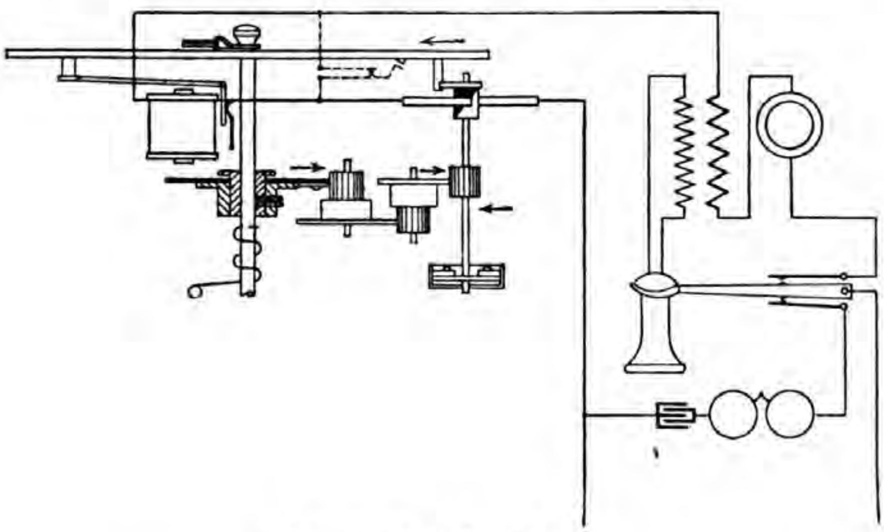


FIG. 93.—Telephone circuit.

Second Selector Bank Multiples—Individual Trunks.—The banks of the second selectors in Fig. 94 are shown a little differently from the banks of the first selectors. The bank contacts are actually shown three per group. The first connector in the "*BA*" group is individual to the "*BA*" and the "*BB*" groups and is connected to the first contacts of the first selectors of these two groups. The second connector of the "*BA*" group is individual to the "*BC*" and "*BD*" groups of second selectors, being connected to the first contacts of these two groups. The fifth and the sixth connectors are common to all of the "*B*" groups. The first connector of the "*BB*" group is individual to the "*BA*" and "*BB*" groups; the second connector is individual to the "*BC*" and "*BD*" groups, etc.

Party Lines and Frequency Selectors.—The party line connectors *CC* are each provided with a frequency selector, indicated by the small circles.

Long Distance Trunks.—The "*A*" section on the banks of first selectors is

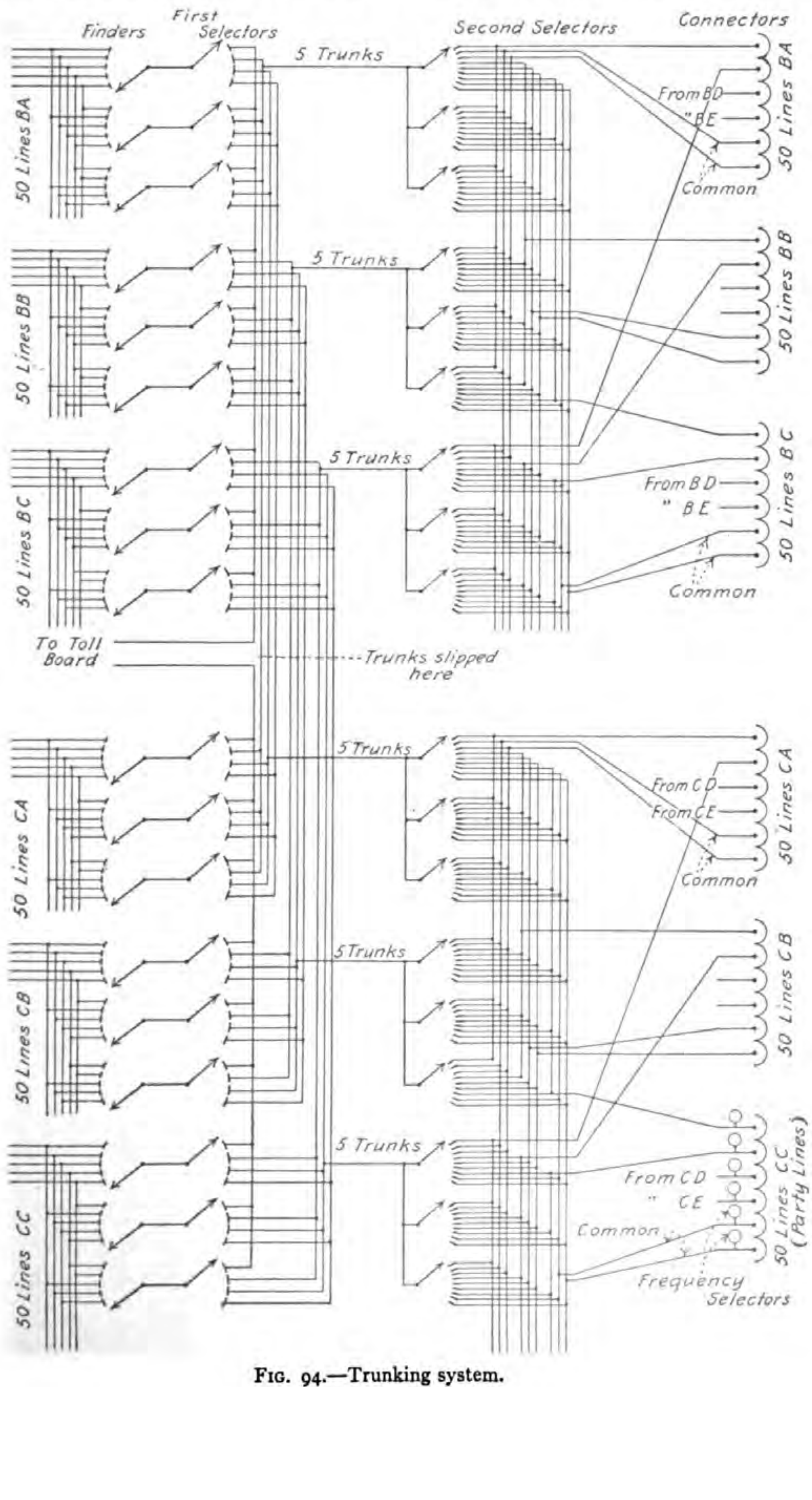


FIG. 94.—Trunking system.

devoted to trunks to the toll board. Each grand division ("*B*" and "*C*") has its own set of trunks. They are slipped between adjacent groups of first selectors. The long-distance operators are provided with two groups of connectors, one for the "*B*" and one for the "*C*" division. By means of these a connection can be automatically set up from a toll line to any local telephone.

DESCRIPTION OF CIRCUITS

The Through Circuit.—Fig. 95 shows the circuits between a calling subscriber *DA*-21 and the called subscriber *FC*-42, the connection between the two subscribers extending through a finder, a first selector, a second selector and a connector.

The Telephone Circuit.—The telephone *DA*-21 is provided with a switch hook 20, bell 21, a rotary impulse maker 22, a receiver 23, an induction coil 24, and a lock magnet 25. Normally the switch hook is down and the lock magnet 25 de-energized. The dial (not shown) is held locked by the armature of "25."

Dial Lock.—The locking of the dial is resorted to because the subscriber may operate his dial before the finder switch finds the calling line, causing some of the impulses to be lost and resulting in getting a wrong number.

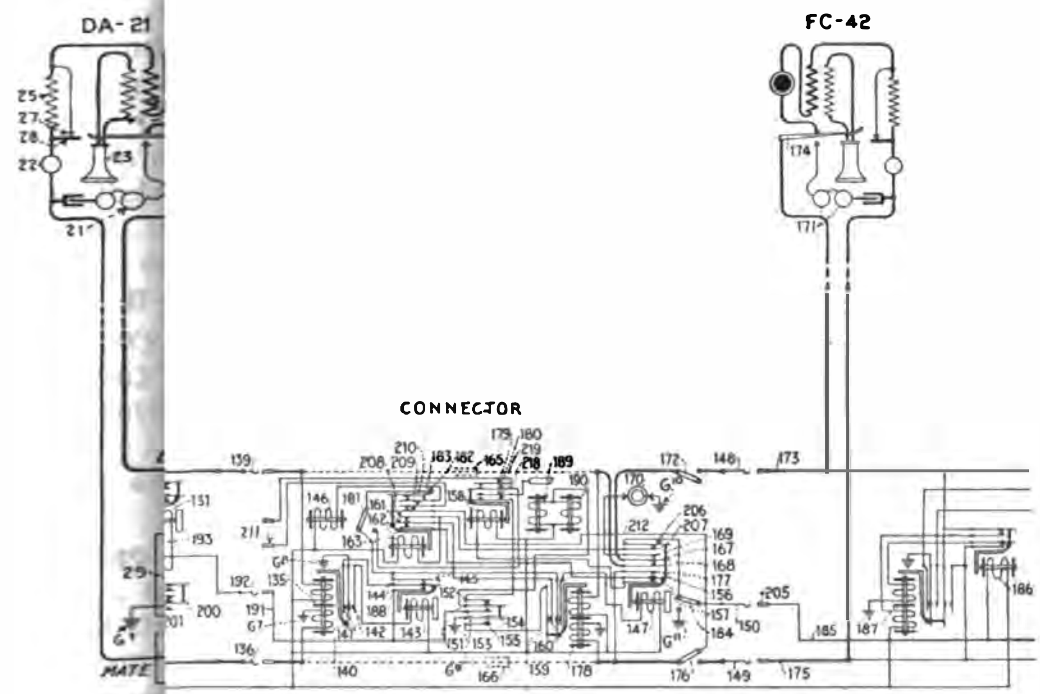
Dial Lock Abandoned.—It turned out in practice that the locking of the dial was unnecessary because of the rapid operation of the finder switches, the slow operation of the dial by the subscribers, and the slipping of the banks of the finder switches, to prevent the finders from having to rotate very far when *any* subscriber calls.

OPERATION OF CIRCUITS

Initiation of a Call.—When the subscriber removes the receiver, he disconnects the bell and substitutes the transmitter 26, primary winding of induction coil and the impulse transmitter 22. As soon as this circuit is closed the line relay 29 pulls up.

Object of Short-circuit on Dial-lock Coil.—The object in having the lock coil 25 at the telephone normally short-circuited is to insure the positive operation of the line relay 29. This shunt, however, is removed each time that the dial is operated and in sufficient time to permit "25" to energize and unlock the dial provided the armature of the locking coil is performing its intended function, which, as already noted, is not the case in practice.

Functions of Line Relay—Short-circuit Line and Remove Guard.—One of the functions of the line relay 29 is to close springs 34 and 35 for short-circuiting the line. The object is to prevent the subscriber from energizing the locking coil 25 at the telephone before the finder finds the line, as will be the case if the subscriber operates his dial and removes the shunt from "25."



(Facing page 118)

Another function of the relay 29 is to remove ground from the guard conductor 36 of the calling line by opening springs 37 and 38 to enable the finder switch to stop on the line after it has been started.

Finder Will Keep Rotating if Once Started.—The character of the finder is such that when once started it continues to rotate by virtue of the grounded condition of the guard contacts 39 over which the wiper 40 passes. As soon as it finds a guard contact without such a ground, the switch stops.

Stealing a Finder.—It will be apparent that if a finder started by the subscriber *DA*-21 should before reaching *DA*-21 pass over some other line, whose line relay is pulled up, the finder will stop on this line which it encounters first and the subscriber *DA*-21 will then have to wait for another finder which is automatically started as soon as the first finder stops. However, because of the slipping arrangement in the banks of the finder switches referred to in connection, Fig. 94, such possibilities are minimized.

Line Relay Starts Finder.—At the same time that the relay 29 performs this office, it grounds the starter wire by springs 37 and 42. The motor relay 43 is energized over a circuit extending from ground via the starter wire, the off-normal springs 44 and 45 of the finder switch, springs 46 and 47 of the rotary magnet 48 through 43 to battery.

Relay 43 Pulls up.—The motor relay 43 energizes and in turn energizes the slow-acting switching relay 49 of the finder by establishing a circuit from ground *G*-3 at relay 50, thence through the springs 51 and 52 and through the springs 53 and 54 of the motor relay 43, to and through the relay 49 to battery.

Relay 49 Pulls up.—The switching relay 49, in energizing, disconnects the line, mate, and bridge cut-off wipers 55, 56 and 57, respectively, from the circuits of the finder.

Contact 62-64 closes a circuit through relay 50 and the rotary magnet 48 simultaneously. This circuit extends from ground *G*-4 through springs 62 and 64, the two additional springs 65 and 66 of the motor relay 43 and thence via one branch through "50" to battery, and through another branch through "48" to battery.

Relay 50 Pulls up.—The relay 50, of course, energizes and upon doing so closes springs 67 and 68, thereby energizing the slow-acting starter changing relay 69, which, in turn, by separating springs 70 and 71 and also 72 and 73, opens up respectively the starter circuit to the next finder and a release circuit of the finder now operating. The object in opening the finder circuit of the next finder switch is to prevent the second finder being started uselessly, as would be the case as soon as the finder now in operation closes the off-normal springs 44 and 74 at the first step of the wipers. The object of opening the release circuit is to prevent the finder now in operation from releasing as soon as the off-normal springs 75 and 76 close in contact, which would be the case, since the release circuit is normally grounded at "*G*-5" in the first selector.

Slow-acting Relays and the Motor Magnet.—Returning to the operation of the rotary relay 50 it will be seen that, upon energizing, spring 52 touches spring 77, via which springs ground will be provided, when wiper 40 is advanced, at the spring 46 of the rotary magnet 48, which spring 46 is just at this instant separated from the spring 47 by the energization of the motor magnet 48. Because of the separation of the springs 46 and 47 of the motor magnet 48 and the separation of the springs 51 and 52 of relay 50, the circuits of the starting relay 43 and of the relay 49 are interrupted at substantially the same time. As the switching relay 49 is slow acting, as already stated, it will not fall back instantly when the circuit is broken at "51" and "52," giving the motor magnet 48 time to de-energize as a result of the separation of the springs 65 and 66 of the starting relay 43, as above indicated. It will be seen that the circuit of relay 50 is interrupted at the same time with the circuit of the motor magnet 48 when the springs 53 and 54 separate, but because relay 50 is slow acting its armature does not fall back instantly, but holds up sufficiently long to allow its energizing circuit to be re-established.

Motor Magnet Rotates Wipers.—The motor magnet, upon falling back, rotates the shaft and carries the guard wiper 40 into engagement with the first bank contact, which is grounded (assuming that the subscriber *DA*-1 is not calling), which ground is now substituted at spring 53 for the ground *G*-3. At the same time that the motor magnet 48 advances wipers 40, 55, 57 and 56, the off-normal springs 44 and 45 are separated, switching the starter wire from the motor relay 43 onto the spring 71 in the starter changing relay. At the same time the release magnet 78 is put in connection with the spring 73 of the relay 69 by closure of contact between the springs 75 and 76.

Circuit Changed to Test Wipers.—As soon as the motor magnet accomplishes this shifting of wipers and shifting of the off-normal springs, it closes an energizing circuit for the motor relay 43, extending from ground *G*-5 through the relay springs 52 and 77, through the rotary magnet springs 46 and 47, through "43" to battery. The relay 43 now energizes again and restores a new energizing circuit to the switching relay 49 before "49" has had time to de-energize. Its new circuit extends from "*G*-5" via the grounded bank contact, the guard wiper 40, through the springs 53 and 54 and through "49" to battery.

Automatic Action of Motor Magnet.—At the same time the springs 65 and 66 are again brought into contact and the energizing circuit for the motor magnet 48 and for the rotary relay 50 is again closed. The relay 50, being slow acting, has not fallen back, but the rotory magnet 48, being quick acting, has advanced the wipers one step. Upon energizing again, "48" breaks the circuit of "43," and "43" breaks the circuit of "49," "50" and "48." "49" and "50," of course, do not fall back, because of their slow character, but "48" does, and again advances the wipers another step. As soon as it falls back it again closes the circuit of "43," "43" pulling up again establishes the energizing circuits for "49," "50" and "48." It is obvious, therefore, that the see saw action between "48" and "43" causes the wipers to be rotated while at the same time the relays 49 and 50 are held up.

Finding the Calling Line.—As soon as the wiper 40 is carried beyond the grounded contacts and onto a non-grounded contact, the motor relay 43 can no longer be pulled up and therefore the switch can no longer be rotated and stops with the wiper 40 on the non-grounded contact.

Seizing the Line.—Ground having been removed from the guard wiper 40, not only is the relay 43 prevented from energizing, but the switching relay 49 is caused to de-energize. This cuts through the wipers 55 and 56, extending the calling subscriber's line to the first selector.

Cut-off Relay Operated.—By permitting springs 62 and 63 to come in contact, the cut-off relay 79 is energized through springs 62 and 63, cut-off wiper 57, conductor 80, and relay 79. This disconnects the line relay 29 from the calling line, *DA*-21, thereby causing "29" to de-energize, removing a short-circuit from across the line (springs 34 and 35); ground is removed from the starter conductor 41 and restored to the guard conductor 36 and to the guard contact 39 on which the wiper 40 has stopped. The object in restoring ground to contact 39 is to prevent another finder from stopping on line *DA*-21. The ground is removed from the starter conductor 41 to prevent the next finder switch from being started as soon as the starter changing relay 69 de-energizes as will be presently explained.

Relay 50 Opens Motor Relay Circuit.—The failure of relay 43 to pull up not only causes "49" to de-energize, but it also causes relay 50 to de-energize and thereby break the contacts 52 and 77. This must be done before the line relay 29 has had time to put ground on the guard conductor 36 in order to prevent the starter relay 43 from pulling up.

Double Protection.—It does not make much difference whether the line relay 29 delays in putting ground on the guard conductor 36, because, as soon as relay 50 de-energizes and closes springs 51 and 52, a ground is provided at the guard wiper 40 from ground *G*-3, and this will protect the line.

Relay 69 Extends Starter and Release Trunk.—As soon as the springs 67 and 68 of 50 separate the energizing circuit for the starter changing relay 69 is broken. The relay 69 then de-energizes and permits the sets of springs which it controls to close contact, thereby closing or extending the release circuit from the selector and extending the starter circuit from the starter that has just been operated to the next idle starter. Connection having been extended as explained to the first selector the subscriber is now ready to operate his dial in accordance with the letter *D*.

First Operation of the Dial D.—The extension of circuit from the telephone to the first selector pulls up operating relay 81 at the first selector. As soon as relay 81 energizes, the auxiliary operating relay 87 (slow acting) is pulled up through contacts 82 and 83.

Auxiliary Operating Relay Energizes.—The auxiliary operating relay 87 lights a lamp through contacts 88–89. At the same time the springs 90 and 91 prepare the circuit of the motor magnet 92 via springs 93 and 94 of relay 95, thence via springs 96 and 97 of relay 98 and via the said springs 91 and 90 to the spring 84 of the operating relay 81.

Subscriber Pulls Dial.—The subscriber, upon drawing the dial down to *D*, puts it in position to transmit fifteen impulses by breaking the circuit of "81" fifteen times, as the dial goes back. At the first impulse, the springs 84 and 85 are brought into engagement, thereby extending the ground connection from ground *G* 5 through the side-switch wiper 99 and through the springs 85 and 84 of relay 81 and springs 90 and 91 of relay 87, through a conductor. From this conductor, one branch of the circuit extends through relay 101 to battery and the other branch extends through the motor magnet 92 to battery via the springs of relays 98 and 95, as already shown. The relay 101, being slow acting, remains energized while the impulses are being transmitted and maintains the springs it controls separate for preventing the relays 98 and 95 from possible energization while the impulses are being transmitted.

Wipers Rotate to Group.—Each time that the relay 81 de-energizes, the motor magnet 92 is operated one step, carrying the wipers 102, 103 and 104 step by step until they reach the proper group of second selectors corresponding to the letter *D*.

Trunk Selection.—After reaching this group the first selector continues to operate automatically regardless of the dial until it finds an idle trunk line leading to a second selector of the "*D*" group. This automatic rotation is accomplished as follows: As soon as the impulses cease to come in, the operating relay 81 energizes and remains so, grounding the spring 86. Relay 87 is also maintained energized. Shortly after the impulses cease, relay 101 de-energizes and closes springs 106 and 107. The off-normal springs 108 and 109 having at the first rotary step of the switch been carried into contact, the circuit established by the closure of "106–107" and "108–109" while the relay 81 is energized causes the relay 98 to energize as follows: From ground *G*-5 throughthe springs 86 and 85 to a conductor, through the springs 110 and 111 of the motor magnet 92, thence through the off-normal springs 108 and 109 and through the springs 107 and 106 over a wire to the motor relay 98 to battery. "98" pulls up and presses in contact the springs 96 and 113, thereby closing an energizing circuit again through the magnet 92, which also controls the energizing circuit of "98." "92" upon energizing, advances the wipers another step and breaks the circuit of "98."

"98" falls back and breaks the circuit of "92" and the see-saw action between "92" and "98" operates to rotate the first selector automatically until an idle trunk is found.

In the banks of the first selectors, as well as in the banks of the second selector, an idle trunk is identified by a grounded contact. As shown in the drawings, for example, when the second selector is idle, the bank contact 114 is normally connected to ground *G*-6. As soon as the wiper 104 strikes the grounded idle contact 114 an energizing circuit is established through private magnet 95 which, as will be seen, controls the energizing circuit of the motor magnet 92. As soon as "95" energizes, the motor magnet 92 will no longer be able to operate and the first selector will come to a standstill in engagement with an idle second selector.

The private magnet 95 also trips the side switch as soon as it pulls up, with the result that the side-switch wiper 115 breaks the energizing circuit of "95" and the side-switch wiper 99 disconnects ground from the operating relay spring 85 and at the same time the side-switch wipers 116 and 117 cut the line and mate conductors through to the second selector after disconnecting the operating relay 81 from the line. The switching of the side-switch wiper 115 permits the release of private magnet 95, whereas the switching of side-switch wiper 99 permits the restoration of "98" and prevents the motor magnet 92 from being energized when the side-switch wipers 116 and 117 cut the operating relay 81 off and cause the springs 84 and 85 to resume normal engagement. When the switch leaves normal, the off-normal spring 118 breaks the circuit of the release magnet 120 to prevent it from energizing when the private magnet 95 energizes. Spring 118 at the same time engages spring 121 and connects the release circuits between the finder and the first selector.

When the operating relay 81 de-energizes, it causes the de-energization of the relay 87, restoring to normal all of the springs which it controls. By the restoration of contact between the springs 122 and 123 the release circuit from the second selector is connected with the release circuit of the first selector.

Because of the normal engagement between spring 90 and its back contact, the selector can not remain off normal unless in use, because the release magnets will energize through side-switch wiper 99, springs 85 and 84, spring 90, conductor 124, and off-normal springs 121 and 118.

Connection having been extended to the second selector, the operating relay 125 will energize. The second selector being exactly the same as the first selector, it will respond when the calling subscriber operates his dial in accordance with the digit *C* in the same manner as was described and the connection extended to the connector switch. Comparing the first and second selectors, shows that relay 81 in the first selector is duplicated by the relay 125 in the second selector. Magnets 87, 98, 95, 92, 101 and 120 are duplicated by the magnets 127, 128, 129, 130, 131, and 132 in the second selector. In these two switches, the magnets 120 and 132 are the release magnets that restore the shaft and wipers, whereas the magnets 133 and 134 are the magnets that release the side switches of their respective switches. These magnets 133 and 134 energize respectively in multiple with the release magnets 120 and 132.

The operating relay 135 of the connector energizes for the same reason and in the same manner as the relays 81 and 125 energized in the preceding switches. Operating relay 135, upon energizing, pulls up the auxilary operating relay 143 (slow acting). The latter prepares a circuit from spring 141 to the motor magnet 146 and the ringing relay 147.

As soon as the subscriber operates the dial for the digit 42 he causes the relay 135 to de-energize forty-two times. Each time that this happens, the motor magnet 146 is energized once, rotating the shaft wipers 148, 149 and 150. Since the relays 143 and 147 are slow acting, they do not de-energize while the impulses are being transmitted. At the first rotary step of the switch, the off-normal springs are operated so that the spring 151 switches from "152" to spring 153. At the same time the spring 154 engages the spring 155.

By the time the impulses have ceased, the wipers 148, 149 and 150 have arrived on the contacts of the called line and the ringer relay 147 will de-energize. This energizes the side-switch trip magnet 158 through the off-normal springs 154 and 155, back bridge relay springs 159 and 160, springs 161 and 162 of the locking relay 163, a conductor and springs 156 and 157.

As soon as relay 158 energizes, the side switch passes to second or talking position, extending connection from the calling subscriber to the called subscriber's line, through condensers 165 and 166. It also closes springs 179 and 180 lighting a supervisory lamp through spring 179, spring 180, side-switch wiper 181 (second position), springs 182 and 183 of the busy locking relay 163, and the motor magnet 146. When the side-switch wiper 184 passes to second position, ground is placed on the private normal conductor 185. This energizes the cut-off relay 186 of the called subscriber's line which disconnects the line relay 187 to prevent the called subscriber operating the finder when he removes the receiver. A guarding potential on the private normal 185 of course prevents any other connector from occupying the called subscriber's line *FC*-42.

The calling subscriber now signals the called subscriber by giving his dial an extra turn. The result is that the line relay 135 again operates, causing the slow-acting relay 147 to energize again. This rings the bell 171 at the called subscriber's station by current from the generator 170 the ground return being through 177–156, 162–161, 160–159, 155–154, *G*-9, *G*-10.

Upon being signaled, the called subscriber removes his receiver from the switch hook 174, disconnecting bell 171 and substituting his talking set.

The result of this is that the double-wound back-bridge relay 178 is energized. This breaks the energizing circuit of ringing relay 147 and also disconnects ground *G*-9 from the spring 161 of the busy locking relay 163. The cutting off of the ground *G*-9 by the back-bridge relay 178 permits the side-switch trip magnet 158 to de-energize, thereby breaking the circuit of the supervisory signal, causing the signal to retire.

The subscribers may now communicate with each other.

Release.—After the talking is over, if the called subscriber hangs up the receiver before the calling subscriber hangs up his, the back-bridge relay 178 de-energizes, pulls up the side-switch trip magnet 158, and again closes the supervisory circuit through springs 179 and 180.

When the calling subscriber hangs up the receiver he opens his line circuit and permits the operating relay 135 of the connector to de-energize. This causes the slow acting auxiliary operating relay 143, to de-energize and pull up the release magnets 189 and 190, restoring both wipers and side switch to normal.

As soon as the shaft reaches the normal point off-normal springs 151–153 cut off the release magnets 189 and 190. Springs 154 and 155 cut off the magnet 158 and the supervisory signal is retired.

The same ground impulse which causes the release of the connector switch releases the second selector. The current, after passing to the auxiliary relay spring 188, divides and also passes over the trunk release conductor 191, the release wiper 192 of the second selector, to the side-switch wiper 193 now in second position. From this point the impulse extends through conductor 194 and springs 197 and 196 of relay 127 to a conductor. From here the current again divides, part passing through the side-switch release magnet 134 and part through the switch shaft release magnet 132.

The magnet 132, upon energizing, restores the switch shaft and locks itself through springs 198 and 199. As soon as the switch shaft reaches the normal point, the off-normal springs 200–201 break the locking circuit for the release magnet 132. In the meantime the release magnet 134 has restored the side switch to normal.

The same impulse that releases the second selector extends to the first selector by the off-normal springs 200 and 201, reaching the release magnets 133 and 120 of the first selector. It also continues to the finder switch by the off-normal springs 118 and 121 of the first selector, the trunk release conductor, the off-normal springs 75 and 76 of the finder to the release magnet 78 of the finder. The release magnet 132 of the second selector, by closing the springs 198 and 199, reinforces this impulse, insuring the release of the first selector.

The release of the first selector is accomplished in exactly the same manner as the release of the second selector, the release magnet 120 in turn assisting the release impulse of the finder by closing springs 202 and 203. The magnet 120 is de-energized as soon as the switch shaft reaches normal and separates the off-normal springs 118 and 121. The release impulse reaches the finder over the trunk release conductor 203, the starter changing relay springs 72 and 73, the off-normal spring 76 and 75 and energizes the release magnet 78, restoring the switch shaft. The release magnet 78 is also provided with a couple of springs 204 and 205 which cause the switching relay 49 to energize, thereby disconnecting the wipers from the circuits while the switch is releasing. As soon as the switch shaft reaches the normal point, the off-normal springs 75 and 76 are separated and de-energize the release magnet 78. This breaks the energizing circuit of the relay 49. As soon as the ground connection is removed from the cut-off relay conductor 80, the cut-off relay 79 of the calling line is restored and this subscriber is in a position to initiate another call, if he so desires.

Called Line Busy.—If the called line is busy the private normal conductor 185 is grounded. The private wiper 150 of the connector reaches the contact 205 connected to this conductor at the last impulse of the digit 42. The ringing relay 147 de-energizes immediately after, and permits the springs 206 and 207 to engage, sending an impulse through the busy locking relay 163. The energizing circuit runs from the grounded private normal conductor 185, through contact 205, wiper 150, side-switch wiper 184 (first position), ringing relay springs 206 and 207 through relay 163 to battery. Upon energizing, it closes a locking circuit for itself from ground *G*-9 through off-normal springs 154 and 155, back-bridge relay springs 159 and 160, springs 161 and 208 of the relay 163.

Relay 163 also connects the busy busbar to the mate side of the line by springs 209 and 210. The busy tone current passes through the busy terminal 211 springs 210 and 209, conductor 212, side-switch wiper 176, to conductor 213 on the mate side, then through the condenser 166 to the calling subscriber's line and back. The calling subscriber, upon receiving the busy signal, hangs up the receiver and releases the switches. The first selector side-switch trip magnet 95 has springs 214 and 215 to make it impossible to trip the side switch off normal while the switch is at normal. The second selector is likewise equipped.

Frequency Selectors.—Frequency selectors are provided in combination with the connectors for calling party line subscribers (see Fig. 96). The operation of the connector is as follows: As soon as the second selector seizes the connector, the operating relay 220 and the auxiliary operating relay 223 energize. The latter shifts the spring 224 into engagement with the spring 225, as in the ordinary connector.

As soon as the impulses begin the motor magnet 225a is operated in the usual manner. At the same time and in multiple therewith the ringing relay 226 energizes and being slow acting remains energized during the impulses.

Springs 227 and 228 separate to prevent the busy locking relay 229 from operating prematurely.

As soon as relay 226 de-energizes, springs 230 and 231a close and energize the side-switch trip magnet 232 from *G*-10 off-normal springs 233 and 234. Magnet 232 remains energized until the called subscriber answers. As soon as "232" energizes, the side switch trips to second position, the side-switch wiper 235 touching contact 236, extending connection to the motor magnet 237 of the frequency selector.

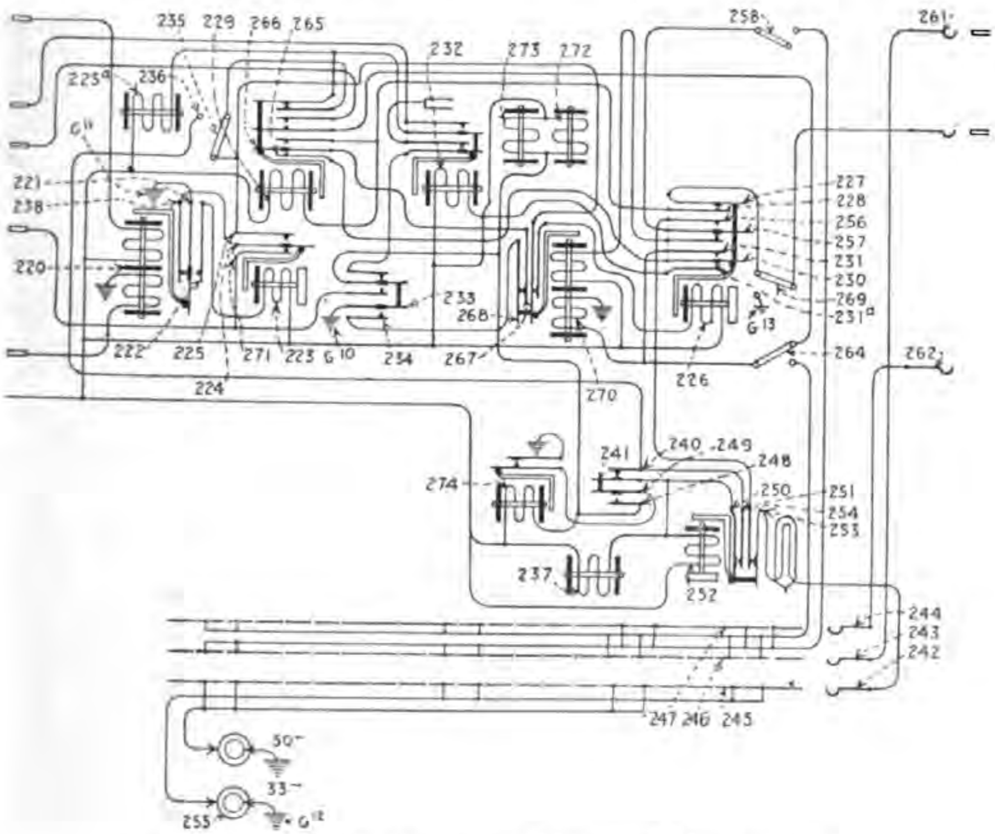


FIG. 96.—Party line connector and frequency selector circuit.

The calling subscriber now operates his dial in accordance with some digit representing the frequency desired for signalling the called subscriber. Assuming that three impulses are sent in, the operating relay 220 of the connector sends three impulses to the motor magnet 237 over the following path: From ground *G*-11 through the springs 221 and 238, springs 224 and 225, side-switch wiper 235, to a conductor, springs 240 and 241 to the motor magnet 237 and to battery. The motor magnet energizes and rotates the wipers 242, 243 and 244 of the frequency selector to the desired point, for example, to the contacts 245, 246 and 247. At the first rotary step the off-normal springs 240 and 241 are separated and the springs 248 and 249 engage. After the first impulse the motor magnet 237 is energized via the springs 250 and 251 of the relay 252 which comes into contact as soon as this relay 252 energizes, which it does at the very first impulse and at the instant that the springs 240 and 241 separate. At the same time that "250" and "251" come in contact the springs 253 and 254 separate.

After the impulses cease, the magnet 252 de-energizes, separating the springs 250 and 251, making it impossible for the motor magnet 247 or the magnet 252 to energize.

FIG. 97.—View of a switch room.

The subscriber now operates his dial to ring the bell. The line relay 220, by operating in response, energizes the ringing relay 226, thereby projecting ringing current from the ringing generator 255 out on the called line. The flow of current is from the ringing generator 255 to the bank contact 245, wiper 242, springs 253 and 254, and ringer relays springs 256 and 257 to the wiper 258, thence through a conductor to the frequency selector bank contact 247 and by wiper 244 to the connector line wiper 262. Current then passes through the called subscriber's line and back over the other side through the wiper 261, frequency selector wiper 243, bank contact 246, side-switch wiper 264, ringer relay springs 231 and 230, springs 265 and 266 of the relay 229, back bridge relay springs 267 and 268, off-normal springs

234 and 233 to ground *G*-10, thence to ground *G*-12 and back to the generator 255.

The cut-off relay on the called subscriber's line is energized as soon as the connector side-switch wiper 269 passes to ground on *G*-13. As soon as the called subscriber answers the back-bridge relay 270 energizes, cutting off the ringing current.

When the calling subscriber hangs up, he causes relay 220 to fall back, whereupon springs 221 and 222 de-energize the release relay 223, permitting the springs 224 and 271 to touch. The release impulses are simultaneously sent to the switch shaft release magnet 272, the side switch release magnet 273 and to the release magnet 274. These magnets restore both the connector and frequency selector switches. Each time that the calling subscriber releases after the called subscriber has restored his receiver, the bell of the called subscriber will be given a short ring during the interval that it takes the release relay 223 to de-energize.

An interior view of a complete working central office containing an equipment of the type described in this chapter is shown in Fig. 97.

CHAPTER VI

SIEMENS & HALSKE SYSTEM

The Siemens & Halske Company, of Germany, operating under rights acquired from the Automatic Electric Company, of the United States, have developed a number of interesting variations in automatic working. These have to do with forms of apparatus and electrical circuits. In general,

Fig. 98.—Desk telephone.

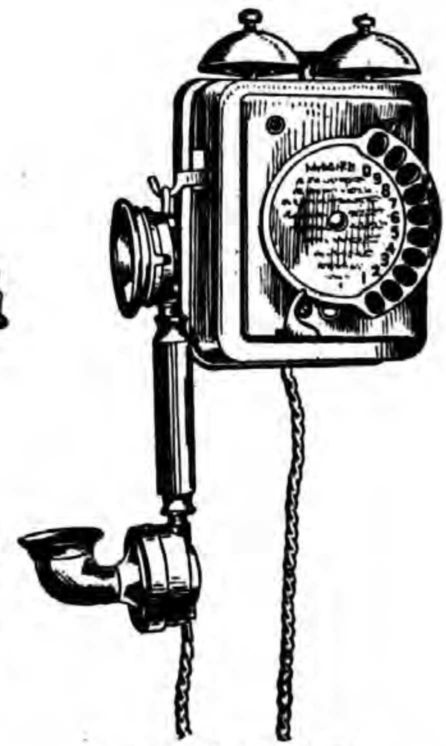


Fig. 99.—Wall telephone.

the trunking employed is the same, although even here some differences are to be noted.

They have put upon the market a full automatic system, a semi-automatic system, and certain forms of private branch exchanges or intercommunicating systems. Our first remarks will be directed toward the full automatic and the apparatus which is common to automatic and semi-automatic, since these are fundamental to the entire production.

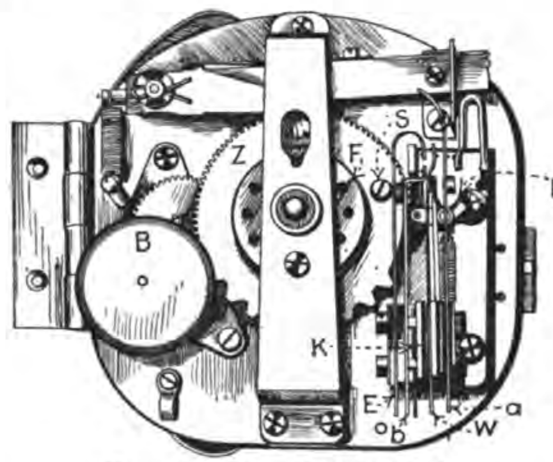


FIG. 100.—Rear of calling device.

The telephone instrument follows the general form which is so popular on the Continent, making large use of the combined transmitter and receiver, sometimes known as the hand microphone set. An automatic desk

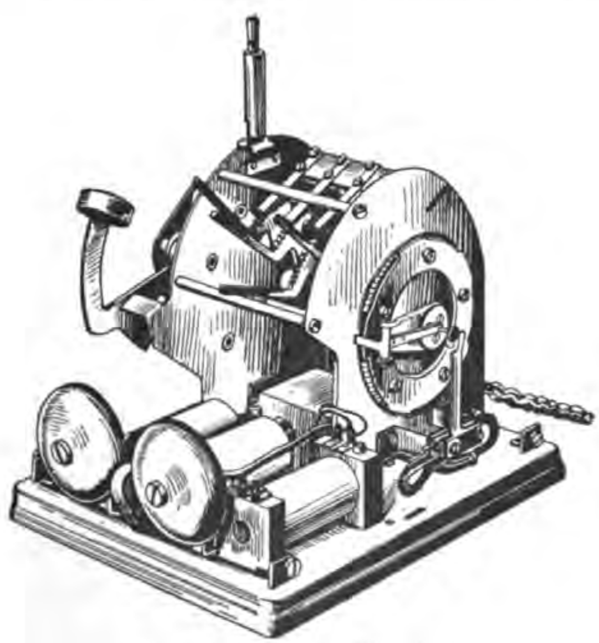


FIG. 101.—Lever calling device.

set (Fig. 98) has the calling device dial mounted on the sloping front of the containing box. The hand microphone set rests upon a pronged fork which operates the hook switch within the box. The wall set (Fig. 99) differs from the above chiefly by having a simple hook switch.

The mechanism of the calling device is shown in Fig. 100, which is a rear view. *F* is a case containing a clock spring, *Z* is a wheel attached to the dial shaft. It has two sizes of teeth. The small ones engage a pinion at the left, driving the governor in casing *B*. The large teeth, or lugs, on the lower side of *Z* give the impulses. *R* is the impulse lever. Its left end is pushed up harmlessly when the dial is rotated by the finger to the finger stop. When the dial is returning to rest, the lugs press the left end of the lever *R* down and to the right, causing the right end of *R* to press the impulse spring *a* to the left. This breaks the circuit and sends the impulses. When the dial is at rest, the bushing *S* presses the springs *E* and *b* away from a contact which carries the telephone. During the sending of impulses the bushing *S* allows the springs *E* and *b* to touch the above-mentioned contact. The part which this plays in the sending of impulses will be more fully understood when the line circuit is discussed. When the receiver is on the hook, it depresses the lever whose broken end may be seen in the upper right-hand corner of the figure and which is pivoted at the upper left-hand corner, and retained by a cotter pin. The lever carries a bushing which presses the upper curved end of spring *a* away from its contact, thereby opening the telephone circuit.

FIG. 102.—Rotary line switch.

They make another form of calling device in which the number is set up by means of levers. In Fig. 101, the cover has been removed, revealing the interior mechanism. With five levers the subscriber sets up the number, moving each lever, which protrudes through a slot, to a point opposite the digit to which it corresponds. After setting up the number, the button on the end of a curved arm at the left is pressed. Then follows the running down of the clockwork, which causes the transmission of the called number, figure by figure. It is somewhat slower than the free dial. With the latter a call of four figures (10,000-line system) requires from six to seven seconds and a five-figure number (100,000-line system) from eight to nine seconds. The lever type of calling device requires at least eighteen seconds to transmit a four-figure number, which is about three times as long as is occupied by the simpler dial.

Line Switch.—This company has produced the rotary line switch shown in Fig. 102. The bank contains eleven contacts. The wipers have three arms, one of which is always in contact with the bank. The motion is continuously rotary, there being no backward return to a normal position. A curved metal indicator carries numbers which show the trunk upon which

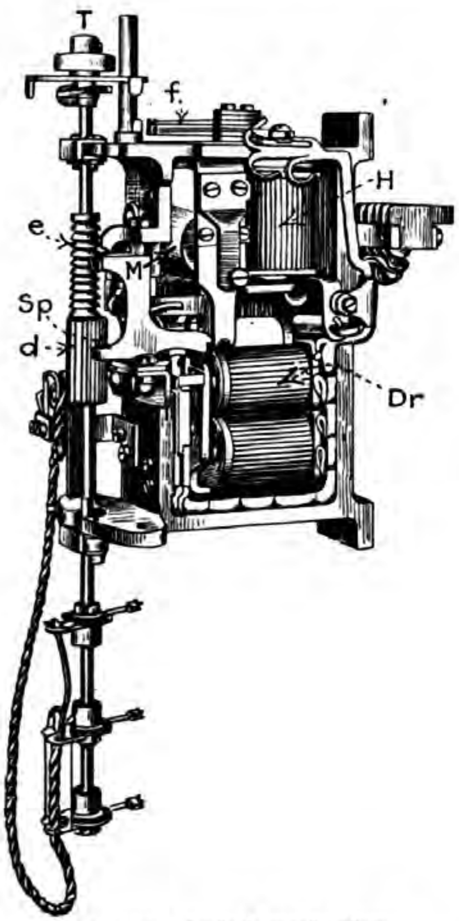


Fig. 103.—Switch mechanism.

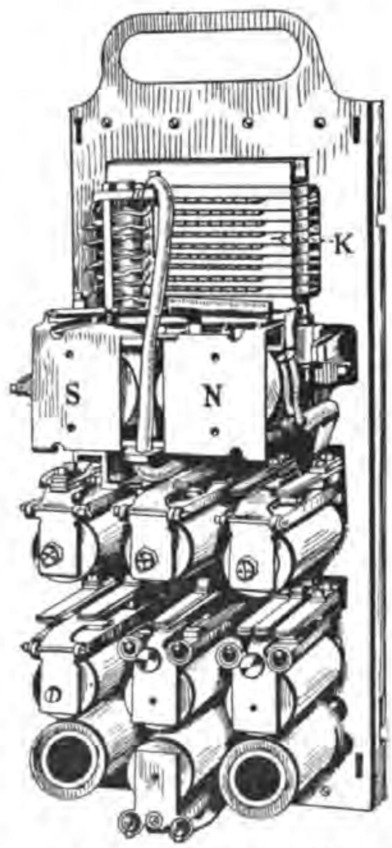


Fig. 104.—Relay assembly.

the line switch is resting. The end of each wiper is divided into two parts for the sake of greater flexibility. The contact ends trail backward. The rotary magnet acts upon a ratchet wheel which may be dimly seen to the right and rear.

Selectors and Connectors.—The form of the selector and connector has been changed in a number of ways. The relays have been entirely separated from the bank, wiper shaft and operating magnets. The magnet and shaft assembly is shown in Fig. 103, which very closely follows the lines of American practice. The relay assembly (Fig. 104) employs two types of armature, both, however, approximating the manual type. The core is carried by a return limb or heel-piece. The "*L*" shaped armature rests over the free pole of the return limb, on a knife-edge pivot. The springs are mounted on the return limb. The armature is held in position in two ways, the upper relays have a retaining pin, the lower relays a pair of curved projections or horns.

The side-switch, *K*, has been greatly developed. It is operated by a back-acting magnet *S*, which, when energized, causes a pawl (*p*, Fig. 105) to engage a tooth on the sector *U*. When de-energized, the force of the spring *S* moves the wipers to the next contact. The release is effected by a magnet

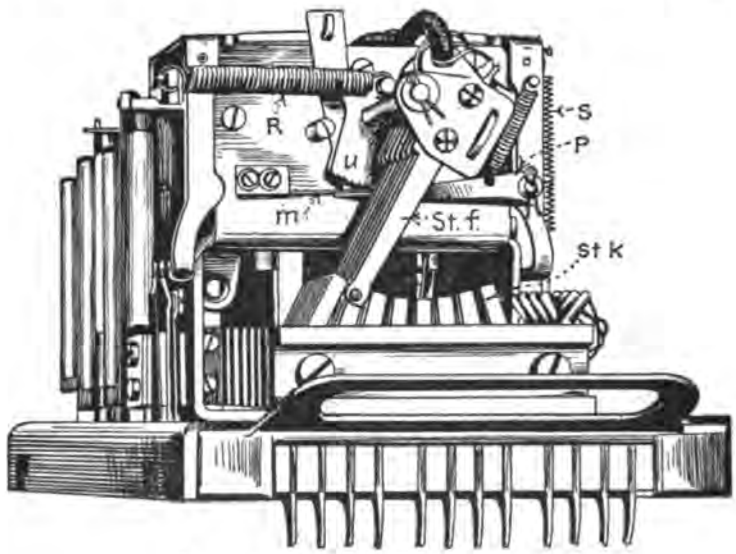


FIG. 105.—Side switch (top view).

N, which merely disengages the detent, *m*, allowing the spring *R* to return the wipers to normal. This side switch has as many as nine levels with from seven to nine contacts per level, depending upon the switch with which it is used.

CIRCUITS AND OPERATION

Rotary Line Switch.—The subscriber's line, Fig. 106, divides into two branches, one leading to connector banks and the other to the main springs of the cut-off relay *T*-1 through whose back contacts connection exists to the two windings of the line relay *R*-1 and battery. The private normal wire *c* leading from the banks of the connectors, passes through 350 ohms resistance, through an off-normal contact on the line switch to the 10-ohm winding of the cut-off relay *T*-1. The other terminal of the 10-ohm winding is connected to the 600-ohm winding, whose other end, in turn, is connected through an off-normal contact to negative battery. In this way when a connector seizes the subscriber's line, current is sent through the cut-off relay, clearing the line for ringing and talking.

When a subscriber initiates a call, the current flow through the telephone energizes line relay *R*-1. This energizes and connects a circuit for the rotary

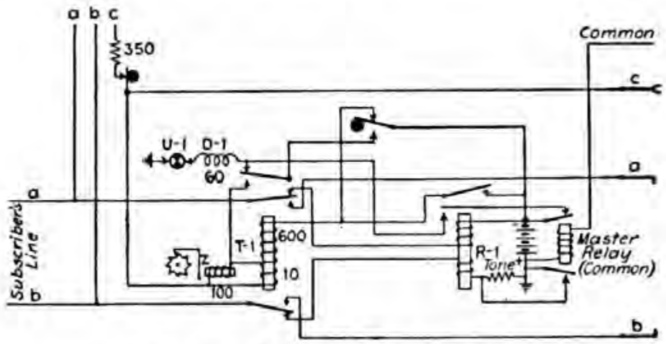


FIG. 106.—Rotary line-switch circuit.

magnet *D*-1 through the interrupter *U*-1. The first motion operates the off-normal springs. The private normal wire is opened to give a busy indication to calls coming through connectors. Negative battery is removed from the cut-off relay but is retained by the line relay contact so that the circuit used for testing to find an idle trunk extends from wiper *c*, both windings of the cut-off relay *T*-1, contact of line relay *R*-1 to negative battery. On finding a first selector which is disengaged (indicated by ground on the

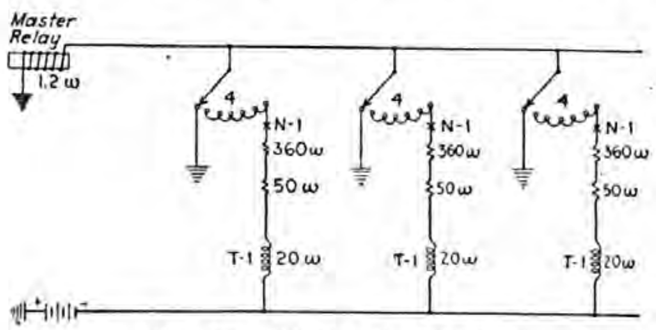


FIG. 107.—Master relay circuit.

release trunk *c*), the cut-off relay of the rotary line switch will pull up. This cuts off the line relay, which, on falling back, severs the connection of the rotary magnet, causing the wiper to stop. The cut-off relay also connects the lines directly to the line-switch wipers and thence to the first selector.

In case all the trunks of a group leading from the banks of certain line switches are busy, the master relay cuts off the circuit for energizing the rotary magnets and introduces the secondary winding of the tone transformer into the circuit of the line relays of all subscribers' lines affected.

The master relay (Fig. 107) is connected to ground and a common wire running to side switch 4 of all the first selectors of the group. In the normal condition, these side-switch wipers rest upon a grounded contact, so that no current passes through the master relay. When a selector is seized, its side-switch wiper moves from the ground connection and comes into the holding circuit. The latter comes from negative battery through the 20-ohm winding of the cut-off relay *T*-1; two non-inductive resistances, 50 and 360 ohms, respectively; contact on release magnet, *N*-1; side switch 4, in any position except the first, to the common wire. As long as there is one switch of the group which is not occupied, its side-switch wiper 4 will act as a short-circuit on the master relay. When, however, the last first selector has been occupied, its side-switch wiper 4, on moving over, will remove the last short-circuit on the master relay, which will now carry the entire holding current of all the switches of the group. It will then energize, cut off the rotary magnet circuit, and give the busy tone to all subscribers who thereafter attempt to call.

First Selector.—The line circuit (Fig. 108) from the telephone to the first selector is equipped with three line relays: *A*, lying in the path from un-

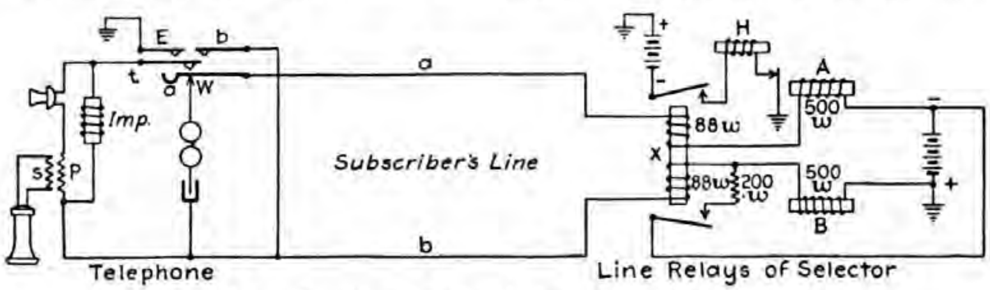


FIG. 108.—Line circuit (telephone to selector).

grounded battery to line *a*; *B* in the path from grounded battery to line *b* and relay *X* differentially wound, carrying both wires.

When the receiver of a telephone is taken from the hook, the main spring *a* rises, breaking contact with *W*, cutting off the bell and closing contact *t* leading to the telephone apparatus. The line switch at once connects the telephone to a selector as shown in Fig. 108. Relays *A* and *B* pull up, while relay *X* does not, because it is differentially wound. When the calling device is rotated, a bushing causes contact springs *E* and *b* to touch spring *t* which short-circuits the telephone apparatus and places ground upon both line wires. Instantly relay *X* pulls up, performing two functions. First it closes a circuit through a 200-ohm resistance to prevent relay *B* from falling back, since the latter is now short-circuited. Second, it closes a circuit from the ungrounded battery terminal to the vertical magnet *H*. Since relay *A* is still energized, its back contact is open, so that the vertical magnet receives no current. When the dial is allowed to rotate back to rest, impulses are sent by causing spring *a* of the telephone to break its contact with *t* but not enough to come into contact with *W*. Every time this occurs relay *A* will be de-energized and, falling back, will give an impulse to the vertical magnet *H*, stepping the shaft up. Relay *X* will be prevented from falling back by the current fed from ungrounded battery through its own contact and the 200-ohm resistance to the point between relay *B* and the *b* winding of relay *X*. At the end of the series of impulses, the calling device comes to rest with spring *a* in contact with spring *t* and springs *E* and *b* severed from spring *t*. This restores the circuits to their initial condition and relay *X* de-energizes, disconnecting battery from the vertical magnet and from the 200-ohm resistance.

The complete circuits of a first selector are shown in Fig. 109. The various

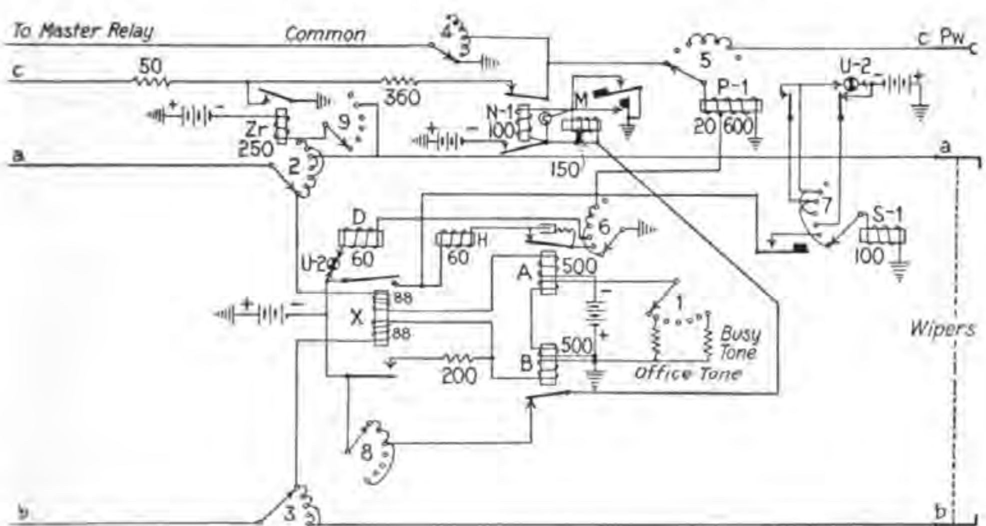


FIG. 109.—First selector circuit.

members of the side switch (in normal position) have been distributed in such a manner as to make the flow of the current simple and easy to trace. The two line wires *a* and *b* normally pass through side-switch members 2 and 3 to relays *X*, *A*, and *B*. The release trunk *c* passes through two non-inductive resistances to relay *P*-1 and ground. The magnet *S*-1 controls the side switch by the back-acting ratchet action described. *N*-1 is the release magnet for the side switch and *M* for the wiper shaft. The vertical off-normal switch has two members, one wired to side switch 7 and the other to the release magnet *M* and *N*-1. Also wired to these two magnets is an off-normal switch which is operated by the first movement of the side switch from normal. A constantly rotating interrupter, *U*-2, furnishes impulses.

The reader will notice that a great deal of apparatus has been grouped around the release trunk *c*. The initial current required for setting in motion the selector apparatus comes in part over the release trunk.

The seizure of a first selector is marked by the pulling up of line relays *A* and *B* and the movement of the side switch one step off normal. Relay *B* breaks the circuits of the release magnets to prevent premature release. *A* breaks the circuit of the vertical magnet *H*. Current in release trunk *c*, energizes the 20-ohm winding of the relay *P*-1. This closes a circuit for the side-switch magnet *S*-1. One impulse delivered by the interrupter causes this magnet to rotate the side switch one step, cutting off further impulses by the shifting of member 7 to its second point. At side-switch member 4 a common ground wire, through the low resistance master relay, is switched on to the release trunk *c* in place of the relay *P*-1 which has been cut off by side-switch member 5. At side switch 6 a ground connection has been established for the vertical magnet *H*. We are now ready to receive the impulses from the calling device.

When the calling device is operated, lines *a* and *b* are grounded and impulses delivered by a series of breaks in line wire *a*. The unbalancing of the circuits, due to the simultaneous grounding of the two line wires, energizes relay *X* which, on pulling up, supplies negative battery to the vertical magnet, also through a 200-ohm resistance to relay *B*, and the lower coil of relay *X*. This locks relays *B* and *X* energized during the series of impulses. Relay *A* vibrates with the impulses caused by the interruptions in line *a* and thereby steps up the shaft of the desired level. At the conclusion of the vertical impulses, the dial in the calling device comes to rest with lines *a* and *b* closed through the telephone but cleared from earth. This causes relay *X* to fall back. During this series of impulses the side-switch magnet *S*-1 is continually energized. When the current is cut off by the falling back of relay *X* the side-switch magnet drives the side switch over to position 3. The circuit of the side-switch magnet is at once closed again through side switch 7 position 3 and back contact of relay *P*-1. This pulls the pawl so that it engages another tooth and remains in this position. A trunk-testing circuit now extends from the private wiper *c* through both windings of *P*-1 to ground. The circuit for the automatic rotation of the shaft is closed through side switch 6 position 3, rotary magnet *D*, and interrupter *U*-2. The rotary magnet thus causes the line wipers *a* and *b* and the private wiper *c* to rotate over the trunks. If the first trunk is busy the private wiper will encounter absence of negative battery which will allow *P*-1 to remain de-energized and the rotation to continue. When, however, an idle trunk is reached, the private wiper will find negative battery potential, energizing relay *P*-1, cutting the current off from magnet *S*-1, and allowing the side switch to be driven to position 4, which cuts off the rotary magnet and stops the wipers.

The movement of side switch 6 to position 4 has placed a 20-ohm ground (*P*-1) upon the private wiper. It has also extended the circuit of the telephone through wires *a* and *b*, side switches 2 and 3 in position 4 to the wipers *a* and *b*. Side-switch magnet *S*-1 is connected directly to the interrupter *U*-2 from which it receives immediately a single impulse, driving the side switch to position 5. Here the side switch remains, because the release trunk *c* is opened in the second selector (by its relay *B*) so that relay *P*-1 of the first selector is de-energized and the circuit of the magnet *S*-1 opened. This is the position in which the switch remains during conversation.

If the connection is released before the completion of the call a strong current is sent back over the release trunk and private wiper *c* energizing relay *P*-1 through its 20-ohm winding. This gives the side-switch magnet *S*-1 one impulse, rotating the side switch to position 6, where another impulse

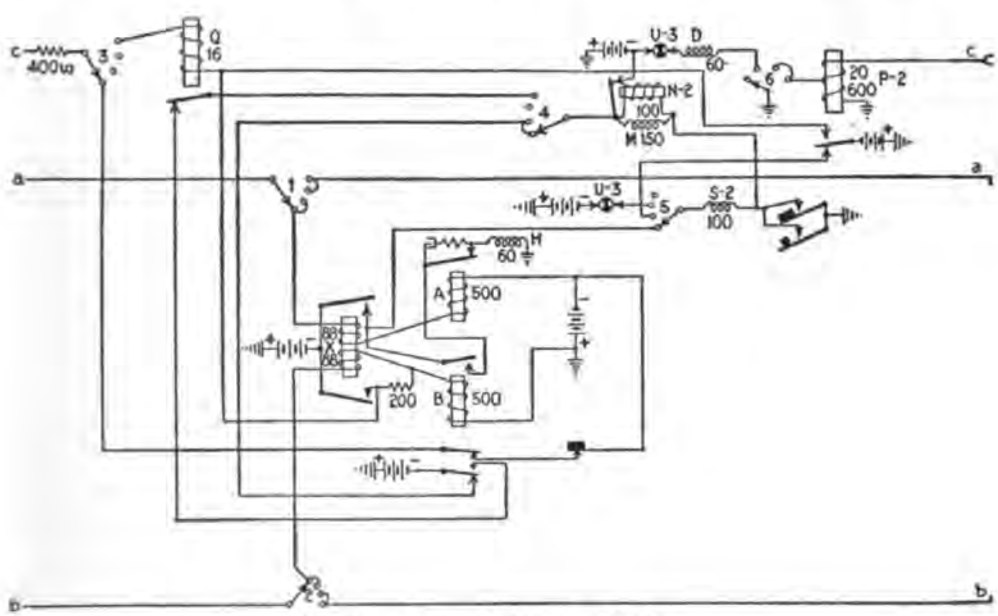


FIG. 110.—Second selector circuit.

drives it to position 7. In position 7 side-switch 8 delivers current through the back contact of relay *B* to release magnets, *N*-1 and *M* in parallel. *N*-1 disengages the pawls of the side switch, allowing them to restore to normal, also closing a connection to negative battery directly, which prevents the release magnets from being cut off from ground by the restoration of the side switch. Ground connection is also assured by the two off-normal switches, the latter being in parallel so that the circuit is opened only when the wiper shaft reaches its bottom or normal position. The side-switch release magnet also opens the release trunk *c* and releases the rotary line switch.

The second selector diagram is shown in Fig. 110. The circuits are very much simpler than those of the first selector. The side switch has only six members, with four positions each. The arrangement of line relays is unchanged. When the second selector is seized and occupied, two circuits are closed at once—the line circuit, which energizes relays A and B, and the release trunk which is, however, immediately opened by relay B. There is no preliminary movement of the side switch. The breaking of the release trunk causes the relay P-1 of the first selector to fall back after the operation of that switch.

During the series of impulses which operates the second selector, relays X and B are energized as described. Relay A vibrates, giving impulses to the vertical magnet H, whose circuit is closed by relays B and X. With the grounding of the lines preliminary to the series of impulses, relay X furnishes battery to side-switch magnet S-2. When the vertical magnet lifts the shaft one step, the off-normal switch closes the circuit of the side-switch magnet to ground, thereby causing it to pull up its pawl so as to be ready to move the side switch. At the end of the impulses, relay A comes to rest energized and relay X falls back, cutting off the side-switch magnet. This allows the side switch to step to position 2. In this position the rotary magnet receives impulses from the interrupter U-3 the circuit being completed through side switch 6 position 2. The testing circuit includes the private wiper c and both windings of the relay P-2. Magnet S-2 energizes through side switch 5 position 2 and the back contact on the testing relay P-2.

When an idle third selector or connector is reached, the private wiper c finds negative battery potential on the bank contact. This quickly energizes P-2, which releases side-switch magnet S-2, causing side switch to be driven to position 3. Side switch 6 cuts off the rotary magnet and stops the wipers on the trunk. At side switch 5 position 3 the interrupter gives an impulse to the side-switch magnet, driving the side switch to position 4. This is the position for conversation. The line relays A, B, and X are cut off from the line and the lines a and b extended through to the wipers and to the connector switch. The line relays of the connector at once pull up removing negative battery potential from the release trunk so that relay P-2 of the second selector is allowed to fall back. Side switch 6 being in the fourth position, the 600-ohm winding is short-circuited so that there is a ground of 20 ohms on the release trunk.

The release trunk from the first selector now passes through 400 ohms resistance, relay Q, 16 ohms, 200 ohms resistance, relay B 500 ohms to ground. There is, however, a wire running from relay Q to the front contact of relay P-2 by means of which the release will be effected.

When conversation has been completed and the receiver of the calling subscriber hung up on the hook the connector will send back over the release trunk current strong enough to pull up relay P-2 through its 20-ohm winding. This will send a strong current through a divided circuit of two parts:

First, relay Q, side switch 3, 400 ohms resistance, release trunk to first selector, through relay *P*-1, 20-ohm winding to ground at side switch 6. This will release the first selector.

Second, 200-ohm resistance, relay *B* to ground. This will energize relay *B* and on pulling it up send a current from negative battery through its front contact through a back contact on relay *Q*. As soon as the first selector releases, relay *Q* will fall back. This completes the circuit through side switch 4 position 4 to the release magnets *N*-2 and *M*, the former operating on the side switch, the latter on the wiper shaft. Ground connection is secured through the two off-normal switches. The circuit of these two release magnets is locked to negative battery by *N*-2. With the first movement of the side switch toward normal the circuit to the relay *B* is cut off, allowing it to fall back. Ground is maintained in both release magnets until both the side switch and the wiper shaft have returned to normal positions, where circuit is broken by the off-normal springs.

If the subscriber desires to release after occupying the second selector and before having pulled the dial it will occur in the following manner: On hanging up the receiver, relays *A* and *B* will fall back. Relay *B* will make direct connection from negative battery through the vertical off-normal switch, its own back contact, side switch 3 position 1, 400-ohm resistance, release trunk to relay *P*-1 of the first selector, which will cause its release in the manner described.

Connector Switch.—The connector switch, whose circuit is shown in Fig. 111, is equipped with the same arrangement of line relays *A*, *B* and *X* as is found in the selectors. It has, however, a much larger side switch, there being nine members with eight contacts to each level. Battery current is supplied to the called station by relays *Y*-1 and *Y*-2 of 500 ohms resistance each. The current supply circuits are separated by 1 m.f. condensers. The ringing current is controlled by side-switches 2 and 3 and relay *L*. The rotary magnet *D* is made subject to impulses from the line relay *A* the same as the vertical magnet *H*.

When the connector is occupied by a second selector the line relays *A* and *B* pull up. The release trunk circuit which was closed in order to allow the switch to be seized is now opened at the back contact of relay *B*, preventing the relay *P*-2 of the second selector from being energized. Relay *B* also breaks the circuit of the 3-ohm winding of relay *Q* and prepares a circuit for the ringing relay *L*, in anticipation of later needs.

The series of impulses for the tens digit of the call number causes relay *X* to be energized, locking itself and relay *B*, while relay *A* delivers impulses to the vertical magnet *H*. At the same time relay *X* has energized the side-switch magnet *S*-3. At the end of the series of impulses relay *A* comes to rest energized, relay *X* falls back, cutting off the current from the side-switch magnet *S*-3, allowing the side switch to step into position 2. In this position the release trunk circuit is broken at another point, namely, contact 1 of side switch 7. The ground connection is removed from the vertical magnet *H* and given to the rotary magnet *D* by side switch 6. The next series of impulses is, therefore, delivered to the rotary magnet *D*, rotating the wipers to the contacts belonging to the desired line. At the conclusion of the series of impulses, the side switch is stepped to position 3 as before described. The side switch does not, however, remain in position 3 longer than a moment because the interrupter *U*-4 gives it a passing impulse, actuating the coil once and driving the side switch to position 4. In the brief time that the side switch was resting on position 3 a busy test circuit to ascertain the condition of the called line was established from ground through the winding of relay *Y*-1, member 5 of side switch in position 3, through the private wiper *c*. If the subscriber's line is not busy there will be negative battery potential on

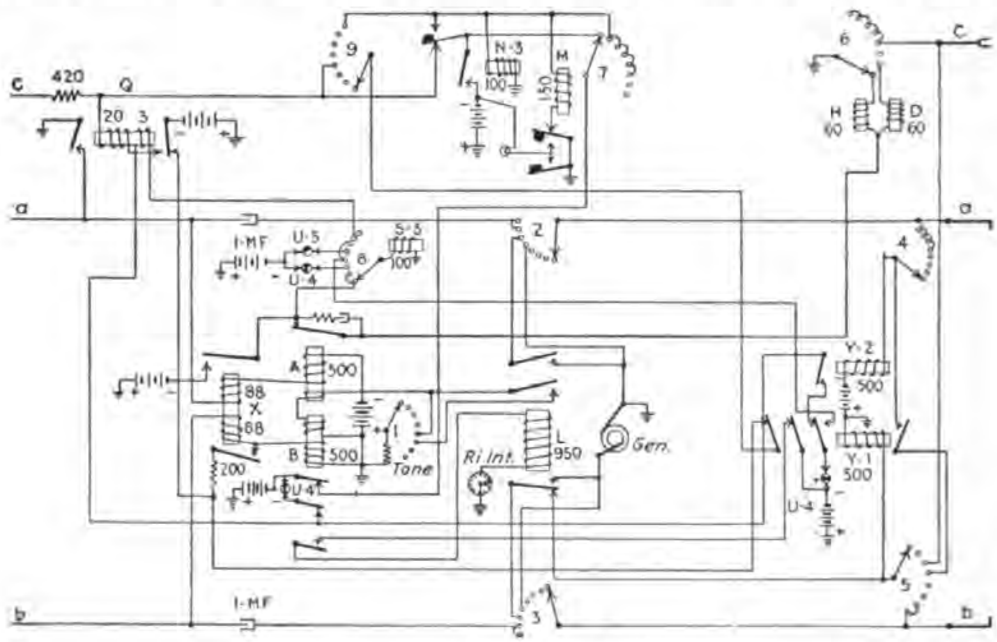


FIG. 111.—Connector circuit.

the private contact and relay *Y*-1 will be thereby energized. On pulling up it will close a circuit by one of its front contacts so that when the side switch moves on to position 4 relays *Y*-1 and *Y*-2 will be locked energized over the following circuit: positive battery or ground, winding of relay *Y*-1, side switch 5 position 4, contact of relay *Y*-1, winding of relay *Y*-2 to negative battery. The purpose of locking relay *Y*-1 is to remove the negative battery connection from side switch 9 which would give a premature release. It will be seen that since relay *Y*-1 is energized when the side switch is in position 4 the circuit leading from negative battery, back contact of relay *Q* through the back contact of relay *Y*-1 is broken so that the wiper 9 of the side switch can cause no change in the release trunk.

The side switch will remain in position 4 only long enough to receive a single impulse from the interrupter *U*-4 which comes over the following circuit: negative battery, interrupter *U*-4, front contact relay *Y*-1, contact 4 of side-switch 8, side switch magnet *S*-3 to ground. As the side switch moves away from position 4 the circuit through relays *Y*-1 and *Y*-2 is broken, allowing both relays to fall back. From the time that the side switch occupied position 4, wiper 6 maintains a ground on private wiper *c*. This ground causes the operation of the cut-off relay *T*-1 of a called line over the following circuit: ground, side switch 6 position 4, private wiper *c*, private normal wire to the line switch of called line (see Fig. 106) through 350-ohm resistance, rotary off-normal contact, both windings 10 and 600 ohms of cut-off relay, back contact of off-normal spring to negative battery. On energizing, the cut-off relay clears the line of the calling apparatus.

Position 5 of the side switch is not a waiting point, because the interrupter *U*-5 gives an impulse to the side-switch magnet *S*-3. However, during the short interval in which position 5 is occupied, ringing current is sent over the line to the called station. This preliminary ring is to insure a prompt signal because the spacing of ringing interruptions is rather slow. Side switch 1 also connects tone current through the line relays *A* and *B* so as to inform the calling subscriber that the called line is free.

Position 6 of the side switch is the regular ringing position. Interrupted current is supplied to the ringing relay *L* by the ringing interrupter (*Ri. Int.*). The code of signals is approximately a ring of one second duration, repeated at ten-second intervals. If the subscriber does not respond to the preliminary ring, this signal at ten-second intervals serves as a gentle reminder until the call is answered or the calling subscriber releases. During each ring the tone is connected to the line relays so that the calling subscriber is notified of the ringing. Every time the ringing relay *L* falls back a connection is established from ground through the relay *Y*-1 to the *b* line, so that if the subscriber answers current will flow through both relays *Y*-1 and *Y*-2 to terminate the ringing. *Y*-1, on energizing, sends a single pulsation of current through interrupter *U*-4 to the side-switch magnet *S*-3, driving the side switch to position 7. In this position the current supplied relay *Y*-1 is connected through side switch 5 to the *b* line and the conversation circuit is completed between subscribers at side switches 2 and 3.

With the side switch in position 7 conversation will take place, current being supplied by the line relays *A*, *B* and *X* to the calling subscriber and relays *Y*-1 and *Y*-2 to the called subscriber. The impedance coils have a total resistance of 1176 ohms on the calling and 1000 ohms on the called end of the line. Inasmuch as the battery voltage is about 60 volts, the current supplied could not exceed 60 milliamperes, allowing nothing for telephone or line resistance.

If the called line is engaged the switches will be released and the busy indication given to the calling subscriber from the first selector. When the side switch of the connector makes its passing movement over contact 3, relay *Y*-1 failed to receive the impulse from negative battery so that it remains de-energized. When the side switch arrives on position 4 it stops there. A circuit is now closed to the release trunk as follows: negative battery, back contact relay *Q*, back contact of relay *Y*-1, side switch 9 position 4, 420-ohm resistance, release trunk to second selector and thus to ground through a 20-ohm winding of relay *P*-2 at side switch 6. This releases the second selector.

The connector switch now releases. The releasing of the second selector caused relays *A* and *B* of the connector to be de-energized. The falling back of relay *B* closed a circuit through side switch 7 position 4, to the side-switch release magnet *N*-3 releasing the side switch. When its off-normal switch has been operated by return to normal it energizes the release magnet, *M*, which restores the wiper shaft to its initial position. It thus opens the circuit for itself and *N*-3 and also puts out the supervisory lamp.

At the time of releasing the second selector, a strong current is sent over the release trunk by relay *P*-2 of the second selector. This causes relay *P*-1 to pull up, whereupon the interrupter *U*-2 drives the side switch to position 6, stopping only long enough to give the line relays *A* and *B* time to pull up to prevent a premature release. The interrupter then drives the side switch to position 7. In this position the busy tone is heard by the subscriber. At side switch 1 position 7 the secondary of a tone transformer or induction coil is connected in series with a winding on each of the line relays *A* and *B*, so that the tone current in passing through them is transferred into the calling subscriber's circuit by a transformer or repeating coil effect in the line relays.

The subscriber now hangs the receiver upon the hook and releases the first selector and line switch. The line relays of the first selector, upon being deprived of current, fall back. Relay *B* closes the circuit to the two release magnets *M* and *N*-1 in parallel. Release magnet *N*-1, besides resetting the side switch to normal, locks the two release magnets to negative battery and opens the release truck *c* leading back to the side switch. When both side switch and wiper shaft have returned to normal the ground connections of the release magnets are removed.

The line switch, being deprived of current by the action of the first selector, releases. This is accomplished by the falling back of the cut-off relay *T*-1, which energizes the rotary magnet *D*-1. The rotary magnet drives the wipers forward until they reach their normal position, at which the off-normal switch cuts off the current from the rotary magnet and connects up the cut-off relay through 350 ohms to the private normal.

Service Meter.—When the called subscriber is not busy the release operates the message register (service meter) by current sent back from the connector switch over the *A* wire to the first selector. At this point it is relayed into the release trunk with a sufficiently strong impulse to pull up the 100-ohm meter winding, although it is in parallel with the 10-ohm winding of the cut-off relay *T*-1.

The details of the operation are as follows: During conversation the side switch of the connector is in position 7. We will suppose that the called subscriber has replaced his receiver upon the hook. This causes both relays *Y*-1 and *Y*-2 to fall back but does not release the switch. When the calling subscriber hangs his receiver upon the hook, relays *A* and *B*, Figs. 111–112, become de-energized. Relay *B* sends one impulse from interrupter *U*-4, through the 3-ohm winding of relay *Q*, and side-switch magnet *S*-3. This drives the side switch to position 8. Relay *Q* is also energized and locks itself through *P*-2 of the second selector. Relay *Q* also places a ground on the *a* wire.

The current sent back over the release trunk to the second selector causes *P*-2 to relay the impulse over the release trunk to *P*-1 of the first selector. *P*-1 pulls up and allows the interrupter *U*-2 to drive the side switch on

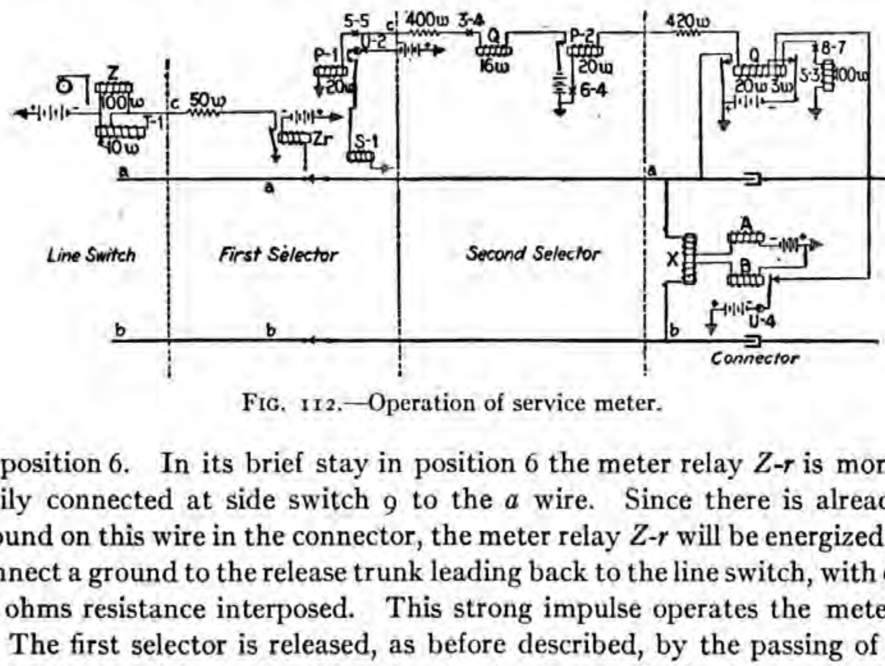


FIG. 112.—Operation of service meter.

to position 6. In its brief stay in position 6 the meter relay *Z-r* is momentarily connected at side switch 9 to the *a* wire. Since there is already a ground on this wire in the connector, the meter relay *Z-r* will be energized and connect a ground to the release trunk leading back to the line switch, with only 50 ohms resistance interposed. This strong impulse operates the meter *Z*.

The first selector is released, as before described, by the passing of side switch 8 to position 7, in which the circuit through the back contact of line relay *B* leads current into the release magnets.

The second selector is released in the following manner: At the same time that the relay *P*-2, Fig. 110, gives the impulse to release the first selector it also sends current through its own line relay *B* which closes the circuit to the release magnets through the back contact relay *Q* (de-energized by the release of the first selector), side switch 4, position 4, release magnets *M* and *N*-2 in parallel, to ground through the rotary and vertical off-normal switches. *N*-2 locks both magnets to negative battery until the completion of their work.

The release of the connector takes place as follows: The same impulse given by interrupter *U*-4, Fig. 111, through the back contact of relay *B* which energized relay *Q*, energized also the side-switch magnet *S*-3 which stepped the side switch to position 8. Relay *Q* remains energized until the second selector has released, whereupon it falls back and energizes the release magnet *N*-3 through the back contact relay *Y*-1 and side switch 9, position 8. *N*-3 locks itself through its own contact, and a vertical off-normal contact and resets side switch to normal. The latter action energizes release magnet *M* which releases the wiper shaft.

Although the called subscriber can not release the connection by the mere act of hanging up his receiver, he can free himself by a single turn of his dial. By the rotation of the dial, relay *Y*-2 is energized, while *Y*-1 is cut off by the grounding of line *b*. A circuit is then closed from negative battery through the interrupter *U*-4, back contact of relay *Y*-1, front contact of relay *Y*-2, 3-ohm winding of relay *Q* to side-switch magnet *S*-3 to ground. This will cause the release of the switches, as has been described.

Automatic Toll Service Trunk.—In order to give the toll operator access to any subscriber's line, special selector switches have been arranged to reach special toll connectors which give the toll operator control over a subscriber's line, even to the extent of releasing an existing connection, if necessary. The selector possesses a unique feature in the selection of one out of two connectors in each hundred group.

A simplified diagram of the essential features found in the toll selector and operator's cord circuit is given in Fig. 113. At the left the local cord is shown with normal connection from the plug through several keys (including the calling device), to an impedance coil and thence to ground and battery. The service trunks are multipled to several positions and carried directly to the jacks of the selector, a part of whose diagram is shown. The tip of the circuit is carried through the *a* line to the *A* line relay and thence to negative battery while the ring side of the line is carried through the *b* line through the *B* line relay to ground. No *X* relay is employed. The sleeve side of the circuit operates an auxiliary relay *U* in the selector.

Both vertical and rotary motions are subject to the control of the calling device in the hands of the toll operator. There are, however, two line banks and the wiper shaft is equipped with two sets of wipers. In any given position the wipers rest upon trunks in each bank, both trunks leading to separate connectors in the same hundred group of subscribers' lines. In making a call, the selector wipers move up and around to a definite point and the selection of the idle connector is made by the selection of the set of wipers to be used.

When the toll operator plugs the local plug into the jack, current flows over the sleeve wire of the circuit, pulling up relay *U*. A preliminary impulse from the interrupter is thereby given to the side-switch magnet *S* moving it to position 2. This connects the line relays A and B to the lines. Each line relay is pulled up over an independent circuit, owing to the battery polarity on the cord.

Each code of signals sent from the calling device consists of a series of impulses on the contact T-1 followed by one impulse on contact T-2. The impulses sent by contact T-1 cause the line relay A to fall back a number of times, operating the vertical magnet and stepping the shaft up to the desired level. The off-normal switch closes a circuit from the back contact of relay B to side switch 4 for the further operation of the side switch. At the conclusion of the series of impulses which corresponds to the tens digit, the single impulse given by contact T-2 causes relay B to fall back and pull up once. This steps the side switch to position 3. This allows relay A to control the rotary magnet D on the next series of impulses corresponding to the units

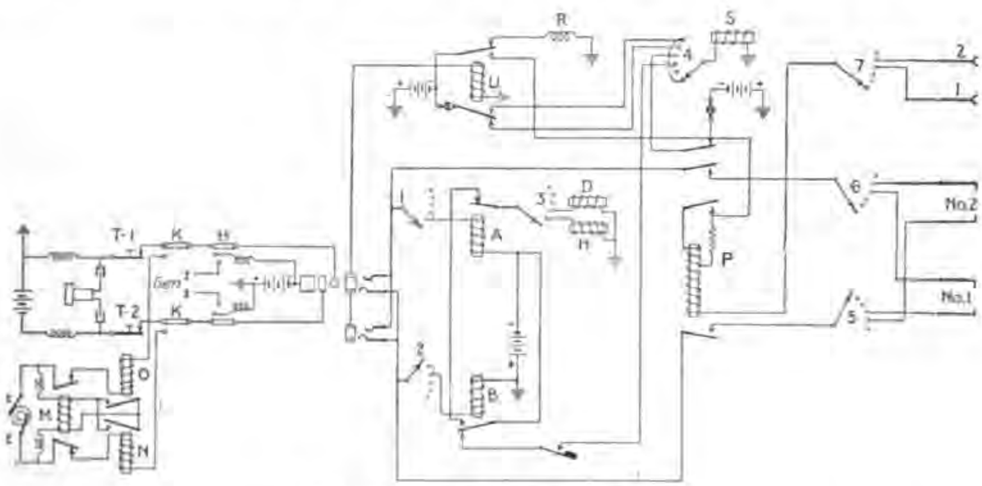


FIG. 113.—Toll selector circuit.

digit. At the conclusion of this series, one impulse on relay B steps the side switch to position 4. This is the position in which the selection between the two sets of wipers is made. If connector No. 1 is free, there will be ground potential on the private contact, so that relay P will energize promptly and prevent the side switch from moving. Relay P will also close the lines to the No. 1 wipers. The movement of the side switch from the third to fourth position also cuts off the line relays. The operator now has a clear pair of wires extending from the cord circuit to the connector.

Should, however, connector No. 1 be engaged, there will be no ground potential on the private contact and relay P will, therefore, not energize. This will allow the interrupter to send a single impulse to move the side switch to position 5. This switches the connections to wipers No. 2 and if this connector is free relay P will be energized and the other actions take place as before.

The connector circuit in skeleton is shown in Fig. 114. When the connector is seized, relay *U* becomes energized and gives one interrupter impulse to the side-switch magnet *S*, stepping it to position 2. This connects up the line relays *A* and *B*, which, energizing, prepare the circuit for the vertical and rotary magnets. Impulses are sent in by the toll operator in the same manner as to the selector, lifting and rotating the shaft until the wipers rest on the desired contact.

The side switch is now in position 4, in which a testing circuit is closed, from private wiper *c*, through relay *P*-5 relay *P*-1, front contact of relay *U*, off-normal switch, to negative battery. If the called line is not engaged, current will flow through the cut-off relay of that line, energizing relays *P*-1 and *P*-5 of the connector, as well as the cut-off relay of the called line. Hearing no busy tone, the operator will press key *T*-2, operating relay *B* and sending the side switch into position 5. This cuts off the line relays *A* and *B* at the

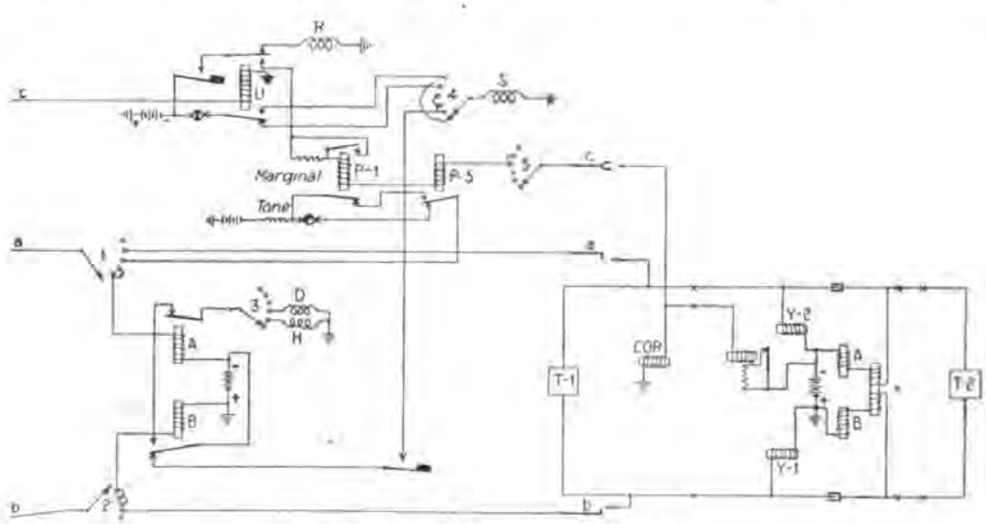


FIG. 114.—Toll connector circuit.

side-switch members 1 and 2. The toll operator now has a clear pair of wires to the telephone, whose bell she rings with a key and suitable ringing current.

If the line is busy it will be in the condition shown and the side switch of the connector will be in position 4. There will be sufficient fall of potential across the cut-off relay to prevent relay *P*-1 from energizing, but *P*-5 will pull up. Thereupon the operator, listening, will hear a uniform tone which will indicate that the line is busy. She may now either release or proceed to take the line. We will assume that the latter is the course decided upon. By cutting the ground from relay *B*, which is still connected in the circuit at side switch 2, she can send an impulse to the side-switch magnet *S* and step the side switch into position 5, in which the lines *a* and *b* are connected through to the called line. She may now notify the subscribers of the toll connection and wait until they have finished and released or she may herself cause the release of the switches.

The release of the existing connection is caused by the switching in of a low frequency alternating current by the operation of key K, Fig. 113. This low-frequency current passes over the lines to the bridged relays in the existing connections between the two subscribers and is graduated to such a strength that when it flows in a certain direction it will neutralize the current flowing in the relays and cause them to release the connection. The called subscriber's line is, however, immediately seized by the toll connector through the pulling up of the cut-off relay, in the ordinary manner. It is said that but little noise is caused in the subscriber's receiver. The associated relays, M, N, and O, Fig. 113, are for the purpose of regulating the strength of the current. During that part of the cycle in which the current is too strong relay M pulls up and cuts off the circuit.

The simple withdrawal of the plug from the jack causes the release of the connection by allowing relay U of the selector to fall back. This energizes not only the release magnets of the selector but cuts off the current from the relay P of the connector and U of the connector, the latter closing the release magnet circuit of that switch.

Auxiliary Finder Switch for Private Branch Exchange Trunks.—The auxiliary finder switch is an interesting variation which has been installed in several exchanges. The general plan is shown in Fig. 115. At the left is indicated a group of ten connector switches, one level of each being shown. The group of *P.B.X.* lines is found at the right. Instead of multipling these trunks to all the connector banks they are given one auxiliary finder switch each. From the banks of these finder switches trunks are run to the connector banks, there being but one trunk from each connector. The gain in space in the connector bank and the flexibility as regards number of trunks are at once evident.

When a call comes through a connector for a certain private branch exchange, the wipers of the connector switch will be lifted and rotated to a definite set of contacts. At once an idle finder switch rotates and picks up the trunk which the connector has occupied, thereby extending the call to the private branch exchange.

In order to select the idle finder switch, a novel though complicated system of elimination is employed. This is shown in Fig. 116. A group of connectors is shown at the left in skeleton form. In the center and to the right are two groups of *P.B.X.* trunks, with three trunks to the group. We may assume that the group No. 1 runs to private branch exchange No. 1 and that the other group runs to private branch exchange No. 2. There is a general starting relay K and one group starting relay A-n for each group of trunks and, finally, an individual starting relay C-r-1, etc., for each of the trunks in each of the groups.

The starting of the finder switch and its stopping upon the proper trunk are conditioned by two circuits: first, the closure of a contact *C*-1 etc., to a common starting wire which operates relay *K*; second, the placing of a ground upon the release trunk *c* by the private wiper of the calling connector switch. The first may be likened to a general alarm and the second to the location of the fire.

When a connector switch has had its wipers lifted and rotated to contact

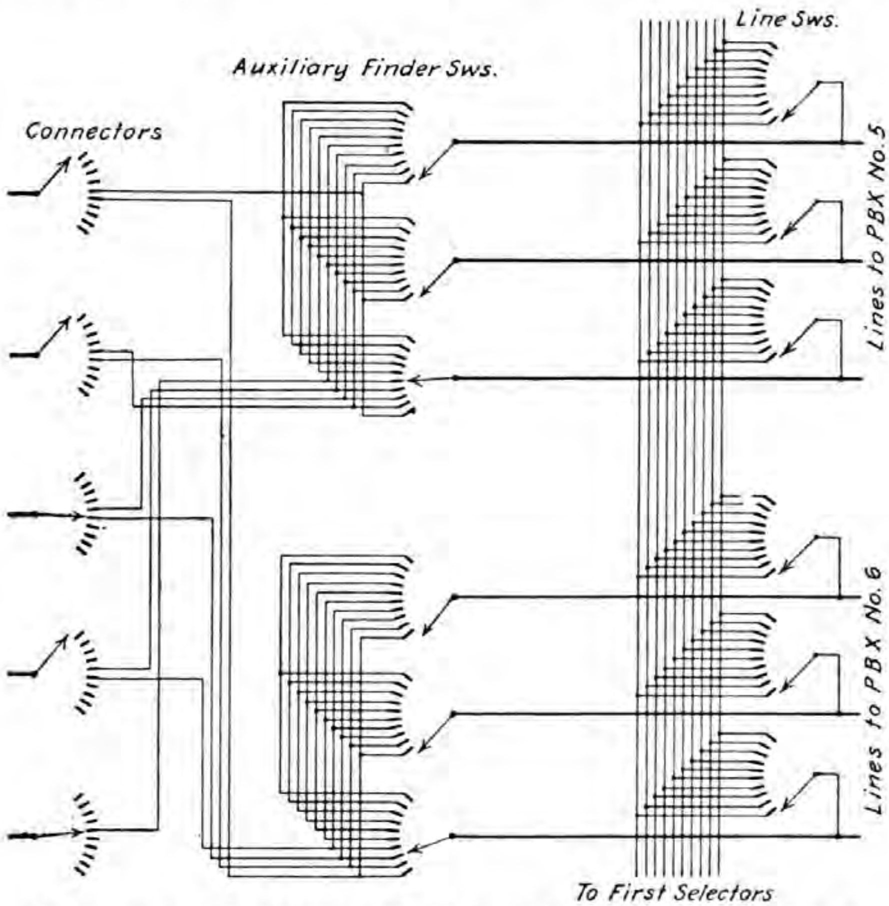


Fig. 115.—Trunking through auxiliary finders to private branch exchanges.

with a given trunk, the contact *C*-1 pulls up the common relay *K*. This in turn energizes a relay *CR*-1, *CR*-2, etc., in all the groups of trunks, there being one relay for each trunk. These relays are of high resistance, 6100 ohms. Each of these relays provides two actions—it connects negative battery to a wire leading to the group relay *A*-*n* and connects its own individual starting relay *C*-*r*-1, etc., to a common starting wire controlled by the relay *A*-*n*. Although all of the relays *CR* are energized, the only group starting relay (*A*-*n*) to be energized is the one in the group which is being called, because the circuit for this relay must be closed through a ground connection at the private wiper of the connector which is calling.

The pulling up of the group switching relay *A-n* puts a ground on the wire leading to the relays *C-r*, so that there is a tendency to pull them up in parallel. However, the first one which pulls up will cut off the current to the rest of the relays. For this reason, only one auxillary finder switch will be started out to hunt the calling connector. From this point on, we shall need to examine the circuits of the trunk in detail.

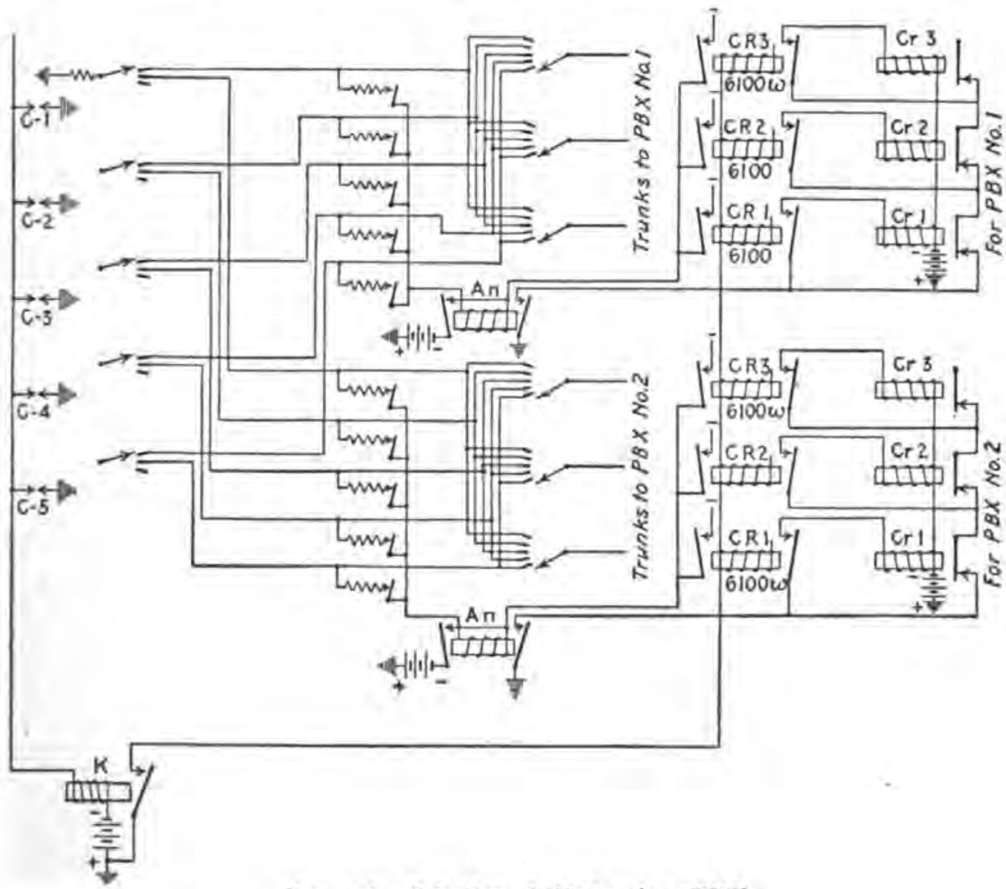


FIG. 116.—Selection of idle trunk to *PBX*.

Referring to Fig. 117, the essential parts of the connector are shown at the left in the diagram. The auxiliary finder switch is shown at the center with certain parts of the ordinary rotary line switch at the right. The finder switch is equipped with a rotary magnet *D* and a switching relay *H* besides the two previously mentioned starting relays *CR*-1 and *C-r*-1.

When the common starting relay *K* causes the energization of the relay *CR*-1, negative battery is connected to relay *A-n* which pulls up and locks to the circuit leading through a back contact of the relay *A-B*, 1000 ohms resistance, private wiper of the connector through the winding of relay *P* to ground. The starting relay *C-r-*1 connects up simultaneously a testing circuit and a rotary magnet circuit. The testing circuit proceeds from negative battery through the 900-ohm winding of the switching relay *H* through contact on the relay *C-r-*1, 29-ohm winding of relay *H*, to the private wiper *c* of the finder switch. The rotary magnet circuit extends from ground through an interrupter, front contact of relay *C-r-*1, back contact of relay *H*, rotary magnet *D* to negative battery. The switch, therefore, rotates until the wiper *c* comes in contact with ground potential. Since relay *P* of the connector has but 29 ohms resistance, relay *H* will pull up. Besides connecting the talking circuit through, it cuts off the rotary magnet,

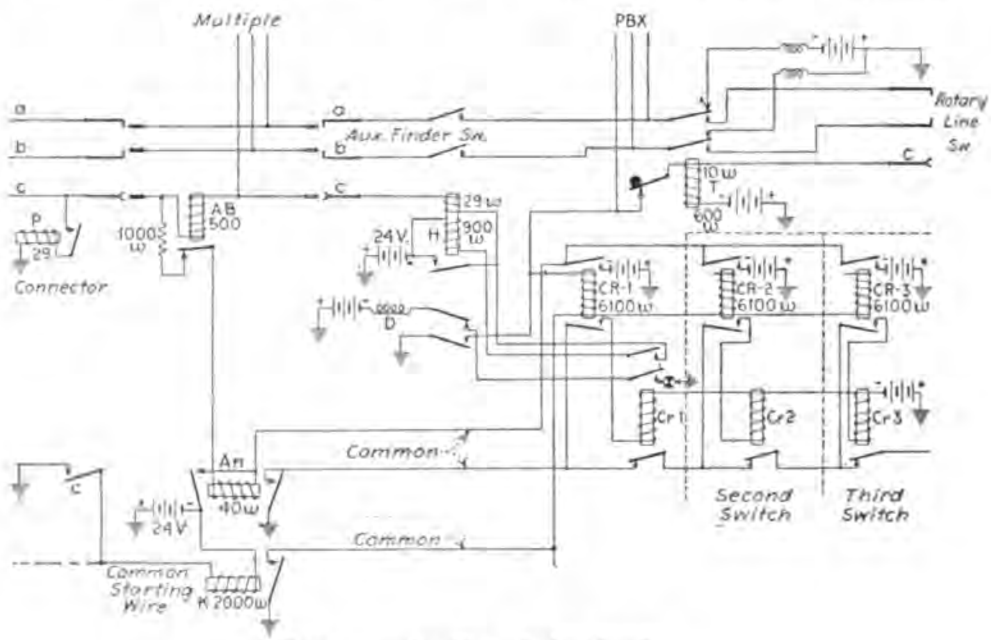


FIG. 117.—Auxiliary finder circuit.

short-circuits its 900-ohm winding and places a ground on the winding of relay *CR-*1, causing the release of the latter. The trunk relay *A-B* is also energized, cutting off the connection to relay *A-n*, so that the latter is unlocked and caused to release, taking the ground off the group starting wire, so that another call may be received. The action of grounding the relay *CR-*1 caused the pulling up of the cut-off relay *T* which clears the trunk of the line relay belonging to the rotary line switch.

The removal of the relay *CR-*1 from circuit is accomplished in a rather unusual manner by the grounding of that terminal of its winding which formerly was connected to the ungrounded terminal of the battery, though allowing the winding to remain connected to the common starting wire from relay *K*. (Fig. 118.) Each relay *CR* is attached to the same starting wire and its own 6100 ohms, added to the 610 ohms of the cut-off relay *T*, makes a total of 6710 ohms from negative battery to the common starting wire. The action of relay *K* will cause all of these relays *CR* to pull up in parallel. When, however, one of the trunks is in use, a dead ground exists at the point between the cut-off relay *T* and the relay *CR*. Thus there is a continual leakage of current from ground through the relay *CR* of the trunk which is in use and back to negative battery through all the other relays *CR* of the same and other groups of trunks which are served by the same group of connectors. However, this resistance is too high to allow the other relays to energize. As more and more of the trunks become occupied more and more of the relays *CR* are put to ground, one by one.

At the close of conversation, ground will be cut off from the release trunk by the restoration of the connector wipers to normal. (Fig. 117.) Relay *A-B* will fall back, reconnecting the release trunk to the common wire, as

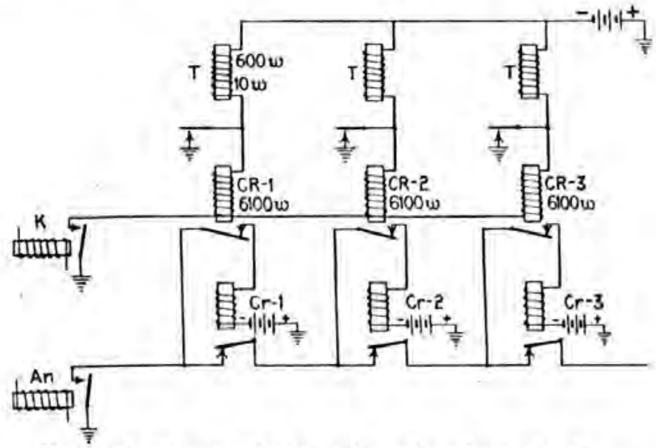


FIG. 118.—Removal of starting relays from circuit.

before. Switching relay *H* will also fall back, opening the talking circuit, preparing the circuit for the rotary magnet and taking ground from the relay *C-R-1* so as to permit it to operate again when needed. The wipers of the auxiliary finder switch do not move from the contacts where last used, but remain there until such time as same switch is called for again.

Semi-automatic.—The Siemens & Halske Company have installed several semi-automatic telephone exchanges.

The equipment consists of a full automatic plant, with the exception that the subscribers' telephones are of the manual type and the calling devices are given into the charge of operators. The duties of each operator are restricted to the receiving of the number of the required telephone and the starting of the automatic apparatus which completes the connection. After this the operator is cut off and the conversation and release take place under the conditions found in full automatic exchanges. In place of the usual dia the operator is equipped with an assembly of keys which control the circuits of an impulse machine located at any convenient place. The operator has no listening or ringing keys to manipulate.

The general scheme is illustrated in Fig. 119. The subscribers' lines are shown coming in at the left, each terminating in a rotary line switch similar to that which has been described. Each line switch has access to ten trunks which, for the sake of simplicity, we will assume run directly to the jacks connectors, although in the case of a large office these run to first selectors. At the bottom of the diagram are shown a number of operators' positions.

Attached to each trunk is a service trunk which terminates in a switch which has been termed a service switch. These service switches have

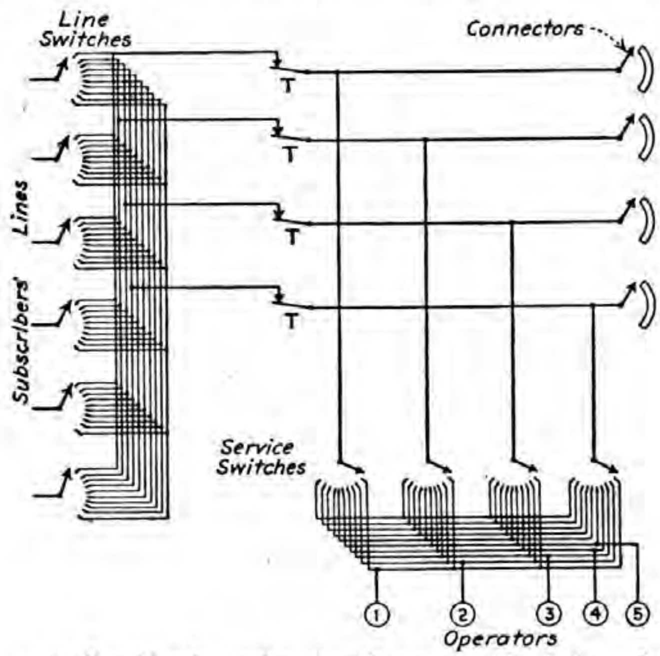


FIG. 119.—Trunking in semi-automatic system with service switches.

twenty-five sets of bank contacts each, but in other respects very closely resemble the rotary line switch of the subscriber.

When the subscriber initiates a call his rotary line switch hunts up and connects with an idle connector switch. Immediately the service switch associated therewith rotates until it finds an idle operator's position, at which it lights a lamp. The operator answers the call and sets it up by pressing push-buttons which are arranged in parallel rows corresponding to the digits of the call number. The pushing of the last or units button starts the impulse machine to sending impulses. It also cuts off the subscriber's line by operating a relay whose contact is indicated at T, so that during the sending of impulses the subscriber will not be annoyed nor his apparatus be allowed to interfere with the selector. When the call has been set up the contact T is closed and the service switch restored to normal in the same manner as has been described for the subscriber's line switch.

The detailed operation of the service trunk is as follows: When a subscriber seizes the connector (Fig. 120) the line relays A and B become energized. Relay B closes a circuit from an intermediate tap of the battery to a wire running to relay V in the service switch and the private wiper d. This is the testing circuit. Relay A closes the starting circuit which sends current through the rotary magnet D and an interrupter. The impulses rotate the service switch. The condition of disengagement is a connection from ground through a resistance and a lamp as shown. When an idle position is reached, a current flows from ground through the resistance and lamp, through a key K-4 at operator's position, through the private wiper d, the

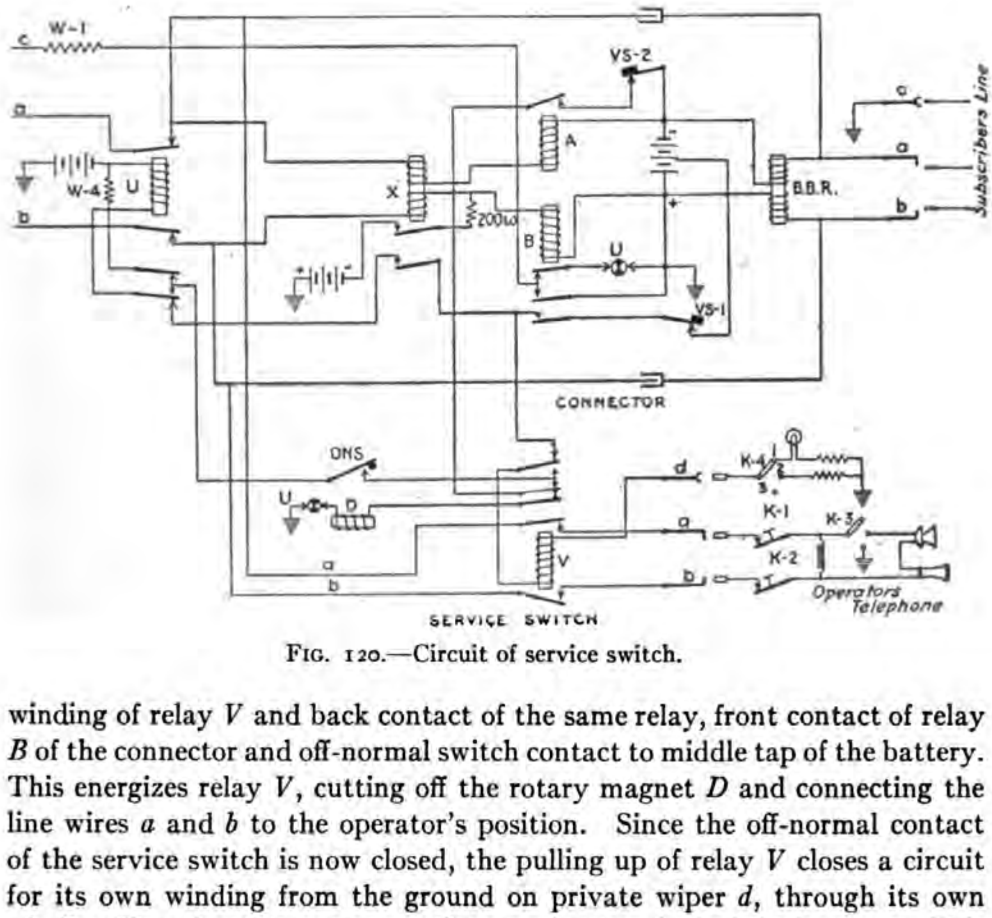


FIG. 120.—Circuit of service switch.

winding of relay V and back contact of the same relay, front contact of relay B of the connector and off-normal switch contact to middle tap of the battery. This energizes relay V, cutting off the rotary magnet D and connecting the line wires a and b to the operator's position. Since the off-normal contact of the service switch is now closed, the pulling up of relay V closes a circuit for its own winding from the ground on private wiper d, through its own winding V, and resistance w-4 to the negative terminal of the battery. This locks the relay V in position.

Seeing the light the operator speaks and obtains the desired number. The calling device, when set into motion, grounds the line by key K-3 contact 3, which causes relay X to be energized by the short-circuiting of its lower winding. On pulling up it connects negative battery through a 200-ohm resistance to a point between its winding and that of relay *B* so that both relays are retained in an energized condition by means of this current. The impulses are sent by a series of breaks in contact *K*-1 which actuate relay *A* in the usual manner, which has been described.

When relay *X* pulled up, it cut relay *U* into service to sever the connection from the subscriber's station. The front contact of relay *X* closed a circuit from the middle tap of the battery through an off-normal contact, front contact of relay *B*, front contact relay *X*, back contact relay *U*, winding of relay *U* to negative battery. On pulling up, relay *U*, beside cutting off lines *a* and *b*, switches resistance *w*-4 out of circuit and its own winding into circuit in place of it, so that during the time that impulses are being sent relay *U* is in series with relay *V*. When the sending in of the call is completed, the release trunk circuit through the private wiper *d* is broken at switch *K*-4 so that both relays *V* and *U* fall back. Relay *U* closes the circuits of the line *a*-*b* and switches the resistance *w*-4 into circuit to the off-normal springs. The falling back of relay *V* connects up the circuit of the rotary magnet *D* through the off-normal springs and the resistance *w*-4 so that the interrupter will cause the switch to be driven forward until it reaches normal position, where the off-normal springs open and stop further rotation.

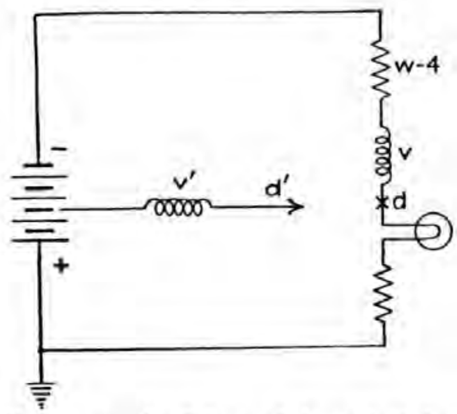


FIG. 121.—Conditions of busy test for finding a free operator.

During the time that the service trunk is in use it is protected in the manner shown by Fig. 121. The release trunk circuit which has been described extends from ground through a resistance and lamp to private wiper contact *d* and through the winding of relay *V* and the resistance *w*-4 to negative battery. The private wiper contact *d* has approximately the same potential as the middle point of the battery. The testing circuit, it will be remembered, proceeds from the middle point of the battery through the winding of relay *V* to the private wiper *d*. Consequently, when some other service switch is rotating to find an idle operator's position, the testing circuit of it will, in wiping past this busy trunk, find there a very small change in the difference of potential so that relay *V'* will not be operated.

They have another system of semi-automatic working in which they use the inverse principle, causing the finder switch attached to the operator's circuit to rotate and find a calling trunk line. The general scheme is shown in Fig. 122. The subscriber's lines are shown coming in at the left, each ter-

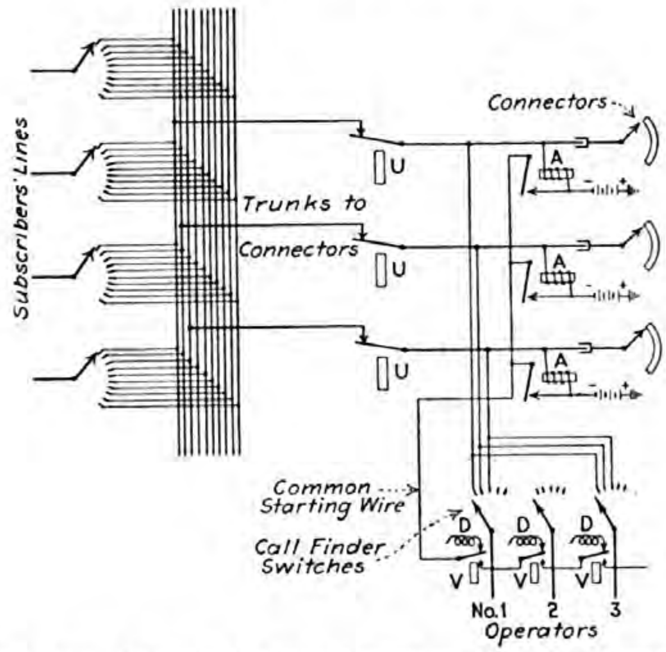


FIG. 122.—Trunking in semi-automatic system with call finders.

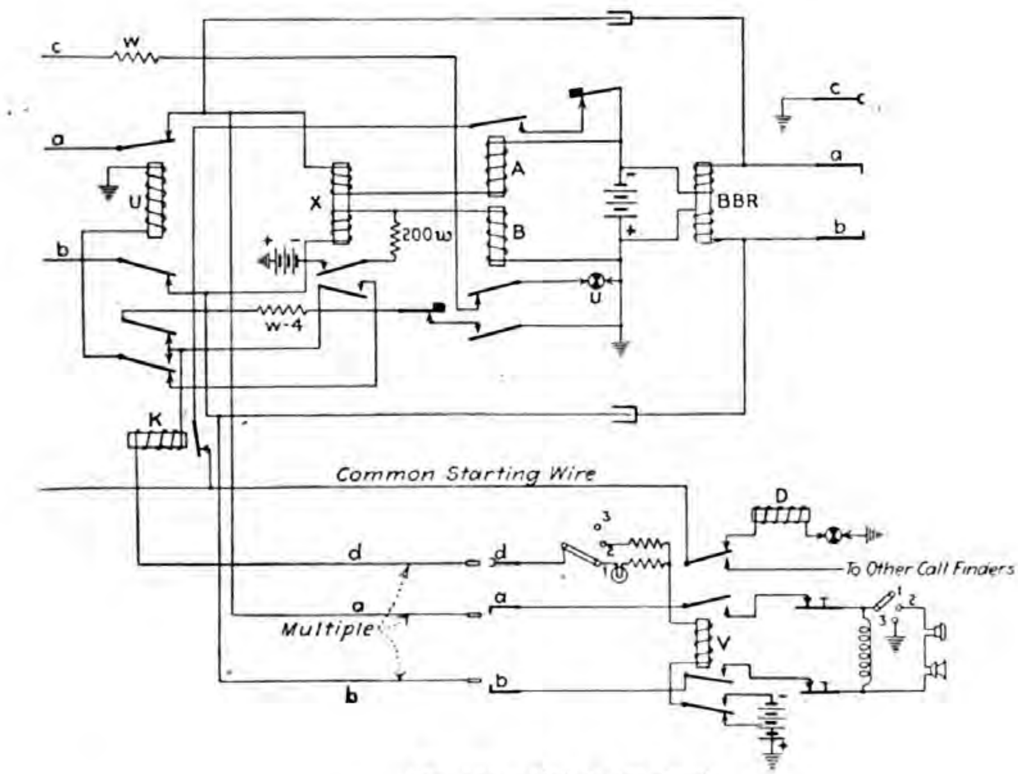


FIG. 123.—Call-finder circuit.

minating in a rotary line switch. Multipled to the banks of the several line switches are trunks which we will assume run directly to the jacks of connectors. At the bottom of the diagram are shown a number of operators' positions, each equipped with a call finder switch, whose banks are multipled together with lines, which are merely taps from the several connectors. When a call is originated by a subscriber, his rotary line switch selects an idle connector switch. A common starting wire is controlled by the seized connector which causes the call finder of the first idle operator to rotate until it finds the tap coming from the seized connector. Without pressing a key the operator is thus automatically connected to the subscriber's line and, after receiving the call, can cut off the subscriber, operate the apparatus and, finally, be cut off from the connection.

By a simple switching device any incoming call is diverted from the first, second third or other idle operators to those who are not at the moment engaged in handling a call.

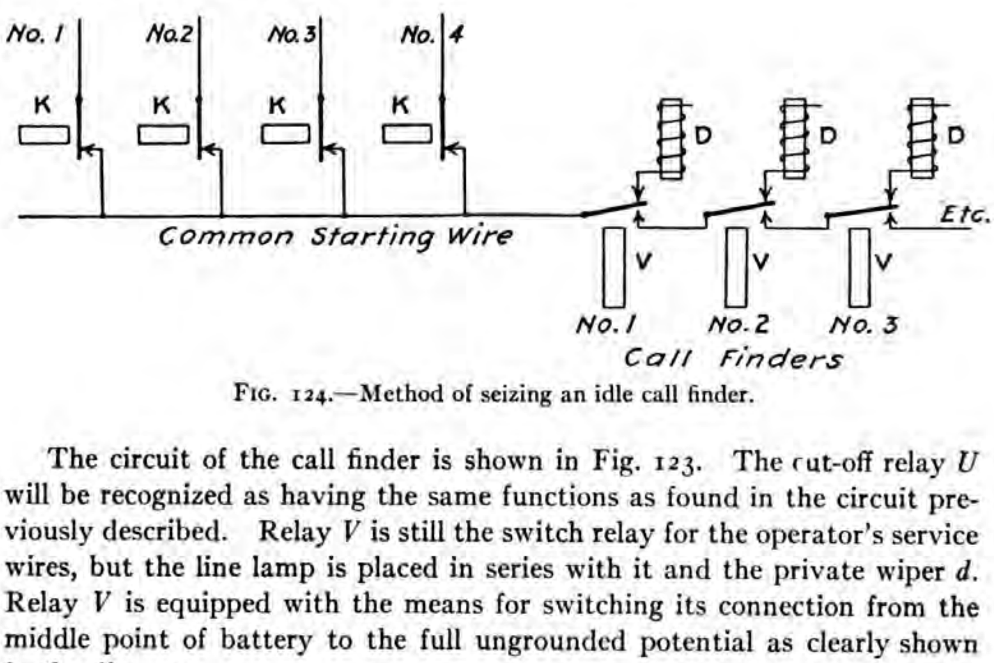


FIG. 124.—Method of seizing an idle call finder.

The circuit of the call finder is shown in Fig. 123. The cut-off relay *U* will be recognized as having the same functions as found in the circuit previously described. Relay *V* is still the switch relay for the operator's service wires, but the line lamp is placed in series with it and the private wiper *d*. Relay *V* is equipped with the means for switching its connection from the middle point of battery to the full ungrounded potential as clearly shown in the diagram.

There is a common starting wire arranged so as to be accessible to a number of trunks. This wire is controlled by line relay *A* of the connector and is looped through contacts on relay *V* of each of the call finder switches which are intended to take traffic from these trunks. The general scheme of this relationship is shown in Fig. 124. Each relay *A* has its contact connected to the common starting wire through the contact of a relay *K* associated with the trunks so that when the starting action is no longer needed, relay *K* can cut off relay *A* from the starting wire to allow the latter to be used by other trunks and connectors. When a call finder has picked up a call, its relay *V* switches the common starting wire from its own rotary magnet to the rotary magnet of the next call finder in the group. Should a second call be initiated before the call finder No. 1 has completed finding its trunk, the second call might wait until relay *V* of the first call finder pulled up, when immediately call finder No. 2 would be started out to find the second call.

The protection of a call finder switch is practically identical with that described for the service switch, except that the switching of the release trunk takes place in the call finder switch instead of in the connector switch. The

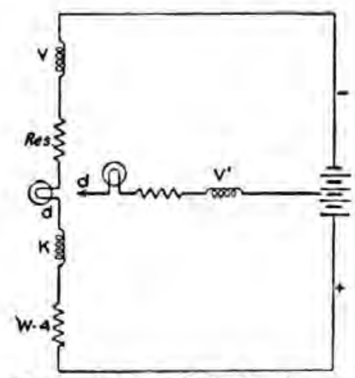


FIG. 125.—Protection of call finder from other finders.

exact conditions are shown in Fig. 125 and, in view of the description given, call for no further comment.

The winding of relay *V* (see Fig. 123) is cut into circuit by the preliminary grounding of the line, as was described above. On the pulling up of relay *X* the winding of relay *U* is brought into circuit in parallel with the resistance *w*-4. On pulling up, relay *U* cuts out this resistance and retains its own winding in place.

CHAPTER VII

THE LORIMER SYSTEM

The system is the product of the three Lorimer brothers—George W. Lorimer, Hoyt Lorimer, aided, to some extent, by their youngest brother, Egbert S. For a time the Lorimer apparatus was manufactured at Piqua, Ohio, by the American Machine Telephone Company, and in Canada by the Canadian Machine Telephone Company. The object of the inventors was to produce an automatic switchboard following the sectional bookcase idea. The switching apparatus was to be divided into sections, each capable of serving 100 subscribers' lines and arranged so that one section could be installed and operated as a unit. When the number of subscribers exceeded 100, another section could be installed and connected to the first section, the two operating with each other. In this way they expected to build up a complete system of any size. Another of their objects was to employ large, heavy substantial contacts, like those used in power switches. This naturally led them to use power drive instead of electromagnets. Another object was the complete elimination of individual line apparatus, or at least its suppression to the lowest possible limit, making everything, as far as possible, on the percentage idea. For this purpose they subdivided each section, serving 100 lines, into ten divisions, each division corresponding to a cord circuit and capable of connecting subscribers together.

Trunking in Thousand-line System.—The general layout for a 1000-line system (Fig. 126) is indicated by three sections, each serving 100 lines. Each section is shown equipped with three divisions. A primary connector is a switch capable of connecting itself to any one of 100 subscribers' lines. Permanently connected to each primary connector is an interconnector, whose duty it is to select the proper hundred and to establish a connection with an idle trunk leading to a secondary connector in that section. The secondary connectors are identical with the primary connectors and have the subscribers' lines multipled to their banks. Structurally the primary connector, the interconnector and the secondary connector are alike. The banks of the interconnectors form a connecting link between the different sections. The trunks are arranged in groups of ten each, though for simplicity only three groups of three trunks each are shown.

When the subscriber sets up a call number upon the signal transmitter (calling device) and pulls the starting lever, a primary connector belonging to an idle division seizes the calling line. Accessory apparatus then causes the movement of the signal transmitter at the telephone which, in turn, controls the movements of the interconnector so as to pick out the proper group of trunks and select an idle trunk to the desired section. It then causes the proper impulses to be sent to the secondary connector, which completes the circuit to the called station.

The Lorimer system employs the "0 to 9" system of numbering. "0" represents one step, "1" represents two steps, etc., "9" representing ten steps, in the selection of lines. The result is that the first 100 is called the "0" hundred, and contains all numbers from "000 to 099"; the second hundred is called the first hundred, and contains all numbers from "100 to 199." The highest number in the system is, therefore, "999."

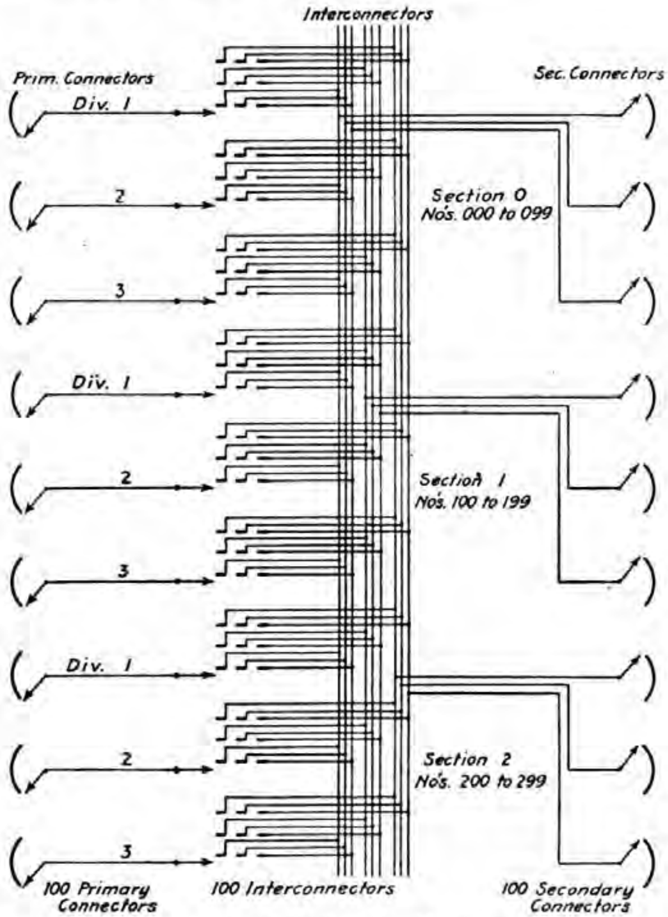


FIG. 126.—1000-line trunking system.

The Switches.—The cylinder switch is an important part of the system. It consists essentially of twelve complete circular rows of contacts, arranged on the inner surface of a complete cylinder, Fig. 127. There are forty-four contacts in each row, making 528 contacts in all. There are four sets of wipers, 61, resting on the inner ends of the contacts, whose outer ends may be seen at "60." A central shaft, 62, carries a casting, 70, upon which these brushes or wipers, 61, are mounted, but from which they are insulated. The

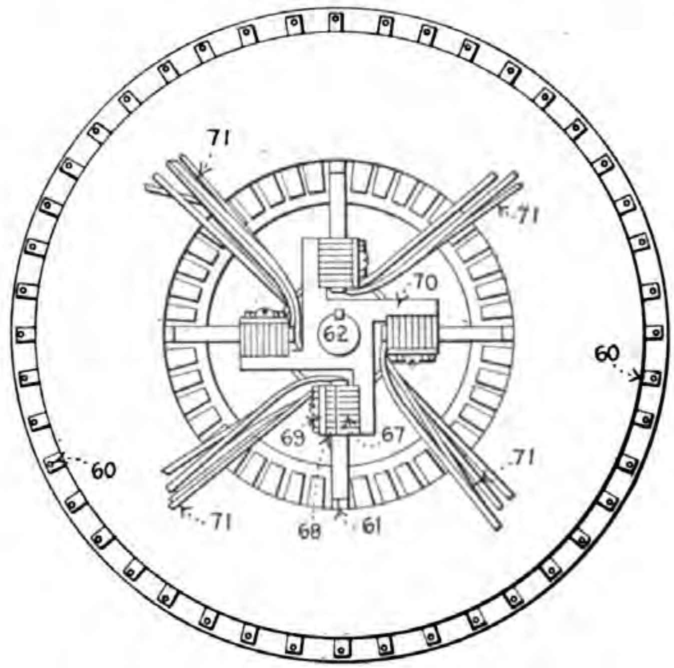


FIG. 127.—Top view of cylinder switch.

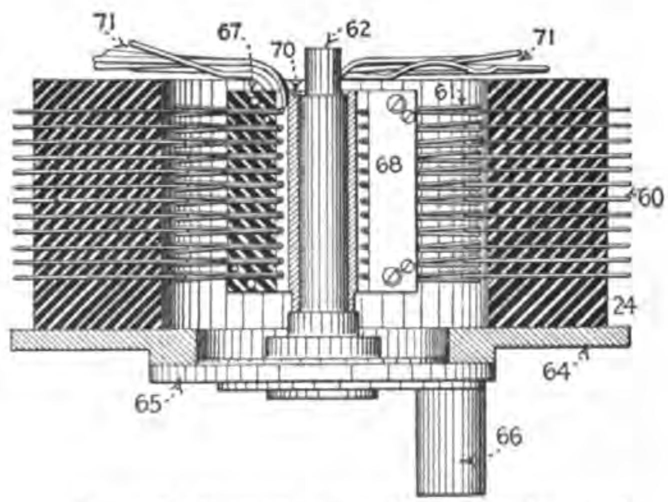


FIG. 128.—Vertical cross-section of cylinder switch.

wires 71 attached to the brushes, serve to connect them to apparatus mounted on a top plate. A vertical section of the cylinder switch is shown in Fig. 128. When the shaft is rotated all of the brushes or wipers will simultaneously move over contacts. By suitable connections to the brushes a large variety of circuit changes can be effected.

To identify any contact, we shall employ two numbers joined by a hyphen. The first number means the number of the contact counted from left to right, the second number means the row counted from the top downward. Thus, "5-3" means the fifth contact to the right in the third row from the top.

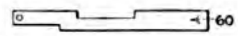


FIG. 129.—Bank contact.

The bank contacts, 60, shown in Fig. 129, are held in position by a plaster-of-Paris casting, which is dried and impregnated with a moisture-repelling

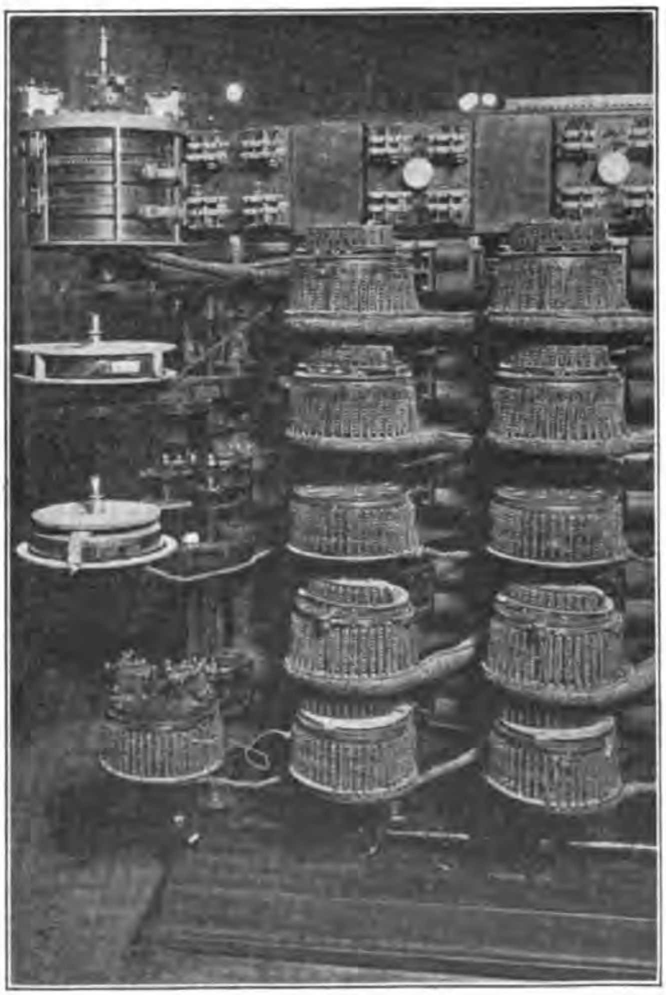


FIG. 130.—View of switchboard.

compound. The shape of the contact punching is such as to prevent its longitudinal movement. Eleven complete cylinder switches are shown in Fig. 130.

The two-coil clutch magnets are of low resistance. Their great current consumption makes them powerful. During the setting up of a connection the current frequently rises to 10 or 20 amperes for brief intervals.

At the top of the mounting frame is a row of switchboard lamps, one for each line. These are to indicate which line is calling. The lamp will go out when the call has received attention from the apparatus.

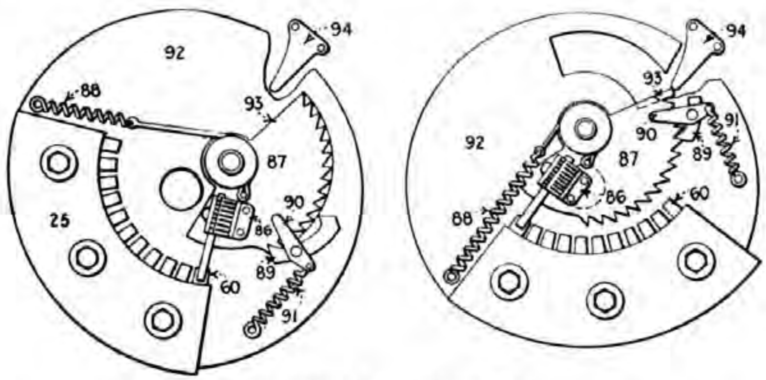


FIG. 131.—Register switch.

The fourth cylinder switch from the top is the interconnector. At the front on the switch is the pair of normally closed contacts which will later be treated as Nos. 351 and 352. At the right on the switch is a metal button, capable of being operated by member 351, though no electrical connection exists between the two. The spring contact which is closed by the metal button when acted upon by "351" is referred to later in the text as the "brush gear wheel contact."

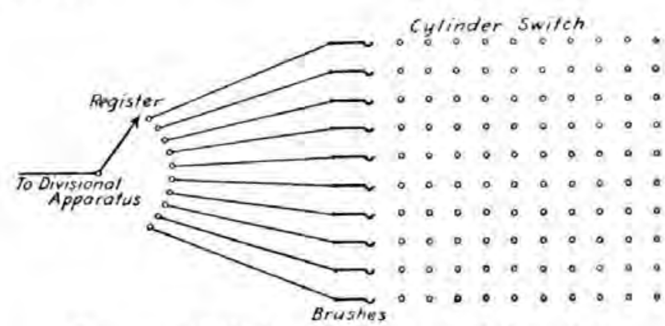


FIG. 132.—Relation of register to cylinder switch.

Several of the cylinder switches have associated with them another switch called the register. It is an eleven-position switch, with escapement-controlled wipers.

The structure is shown in Fig. 131. The bank 25 contains eleven sets of contacts, 60. Mounted upon a sector 87, which is pivoted upon a fixed post, is a set of wipers 86. The spring 88 tends to cause the rotation of the wipers from the normal position toward the other end of the bank. This is resisted by the escapement 89. An escapement magnet not shown in the figure has a finger which is adapted to engage lever 90, which controls the movement of the escapement 89. By this means the wipers may be allowed to escape, notch by notch, so as to bring them into contact with any desired set of terminals. In Fig. 130 these registers are shown mounted on the tops of eight of the cylinder switches.

The primary connector, the secondary connector and the interconnector each consists of the combination of a register and a cylinder switch. This is shown schematically in Fig. 132. Suppose the cylinder switch and register

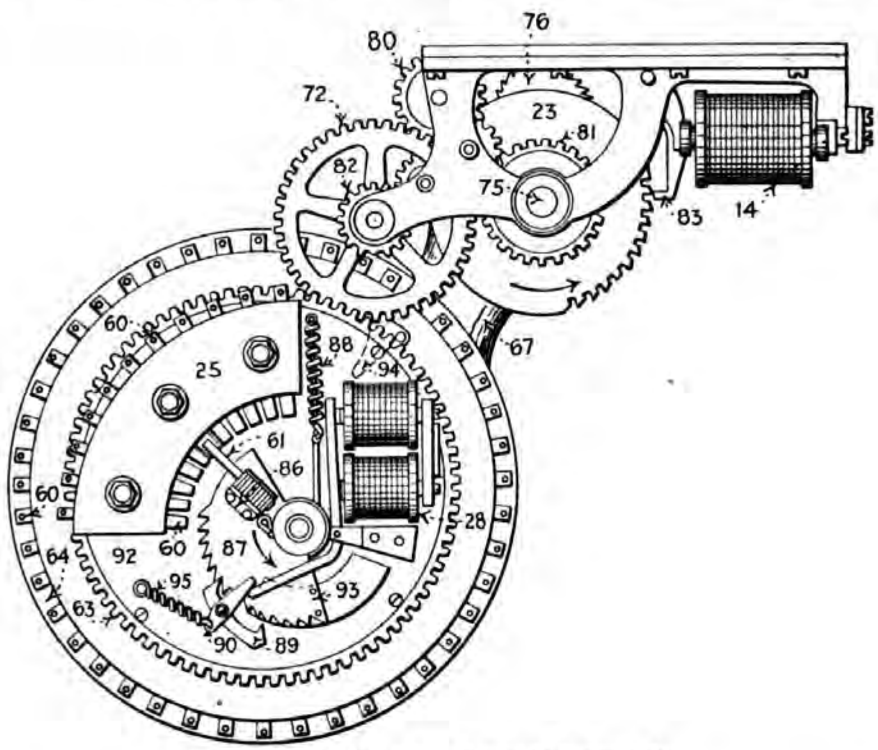


Fig. 133.—Driving gear for cylinder switch.

are to be used to connect with any one of 100 telephone lines. The cylinder brushes will be arranged in ten groups. In the figure we will show only ten brushes, as if one were required for each line. Now, by the rotation of the register into contact with any one cylinder brush and by the rotation of all the cylinder brushes simultaneously, the connection may be made to any one of the subscribers' lines.

The assembly of a cylinder switch and register are shown in Fig. 133. The largest circle embraces the cylinder switch, with the register on the top. "28" is the magnet which operates the escapement 89. The wipers 61 are shown as having been moved to a position off normal.

The register is mounted upon a plate 92, which is carried by the central shaft 62, Fig. 127. The edge of this plate 92, Fig. 133, is equipped with teeth, 63, which engage the gear wheel 72. "75" is the constantly rotating power-driven shaft. The clutch magnet 14 has two functions. One is the locking of the gear wheels by means of the detent 83. In the case of the primary and secondary connectors and the interconnector, only a portion of the circumference of this disk is equipped with teeth, the rest being omitted for the purpose of causing the wipers to rotate continuously until they reach the normal position. The other function of the clutch magnet is that of causing the clutch wheel 76 to engage for the purpose of driving the cylinder brushes.

The details of the clutch and lock are shown in Fig. 134. "74" is a toothed wheel on the constantly rotating shaft, which is moving in the direction of the small curved arrow. Pivoted on the shaft which bears the gear wheels, 79–80, is a link 77, which carries on its right extremity two wheels shown

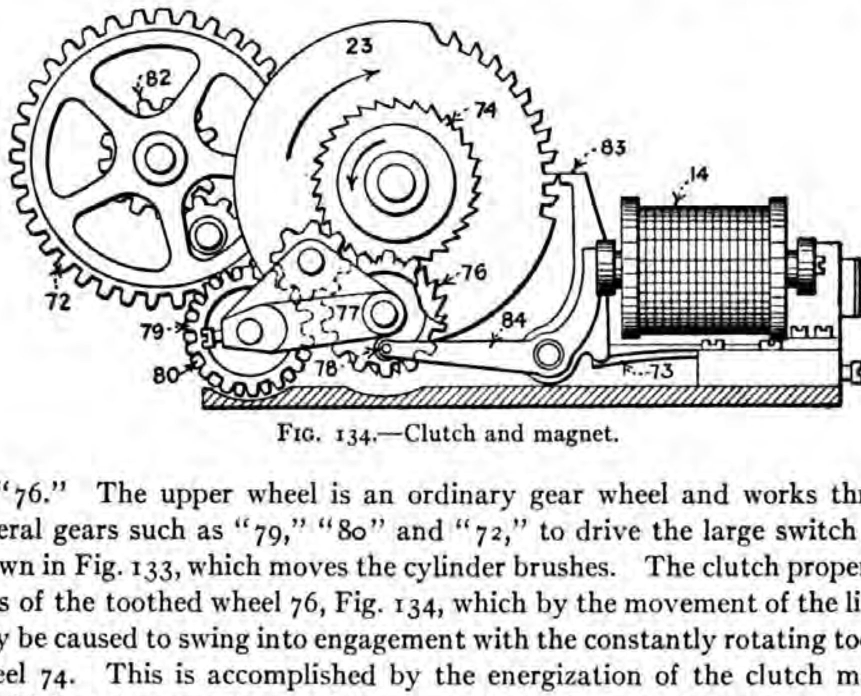


FIG. 134.—Clutch and magnet.

at "76." The upper wheel is an ordinary gear wheel and works through several gears such as "79," "80" and "72," to drive the large switch plate shown in Fig. 133, which moves the cylinder brushes. The clutch proper consists of the toothed wheel 76, Fig. 134, which by the movement of the link 77 may be caused to swing into engagement with the constantly rotating toothed wheel 74. This is accomplished by the energization of the clutch magnet 14 which at the same time withdraws the detent 83 from the notch and brings the two toothed wheels into engagement.

In the assembly apparatus shown in Fig. 130, attention is directed to the right-hand vertical row, consisting of five switches. At the top is the primary connector and immediately below it are the secondary connector, signal transmitter controller, interconnector and rotary switch.

Ten-thousand-line System.—The essentials of the 10,000-line system are shown in Fig. 135, in which three thousands are indicated, each made up

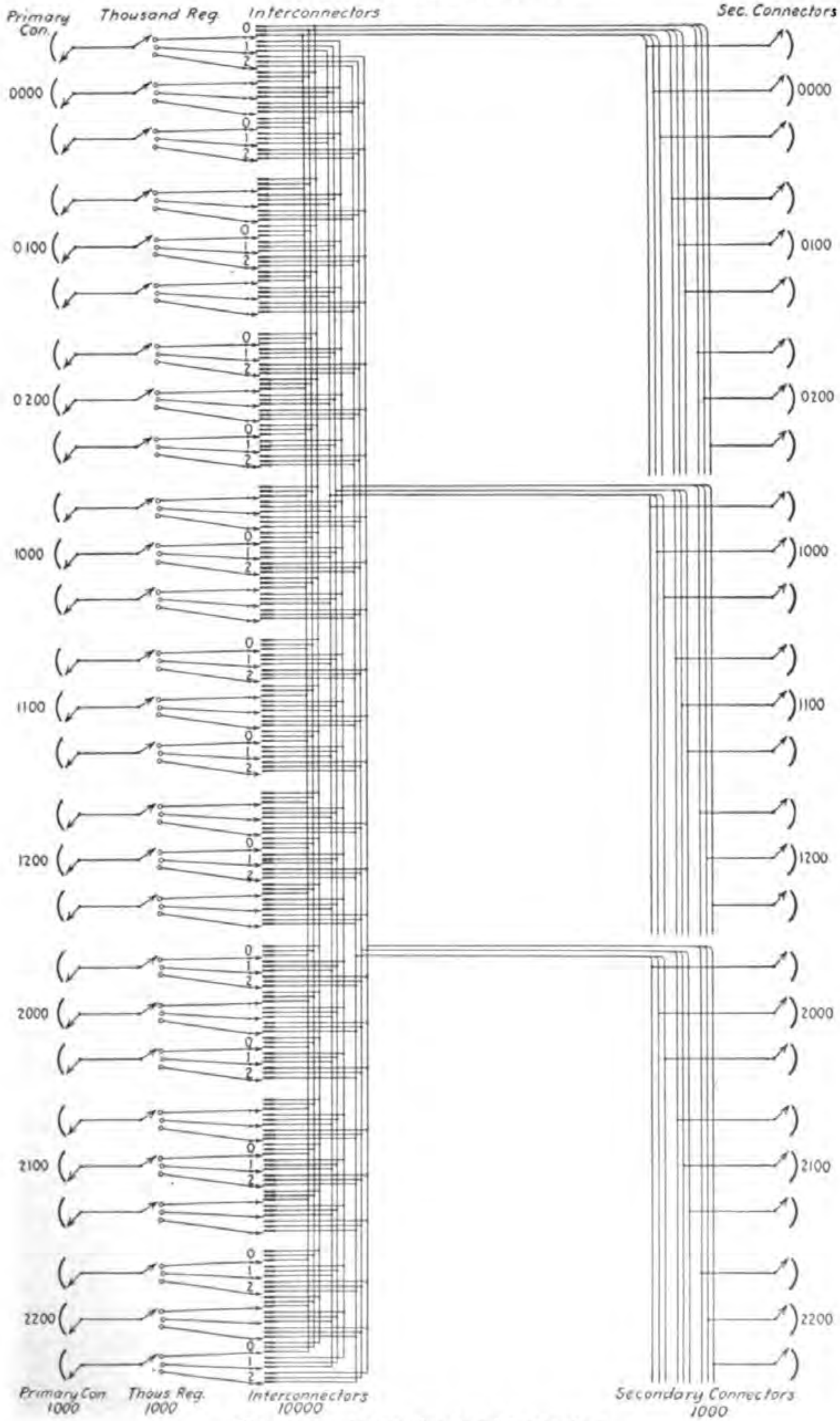


FIG. 135.—10,000-line trunking system.

of three sections, each section possessing three divisions. It is assumed that the number 3 will illustrate as well as "10," the latter being the full number which would be installed in a 10,000-line exchange. Between the primary connector and the interconnectors of any division is inserted the thousands register. It is merely an eleven-point switch like the other registers described, and is mounted upon the rotary switch. This trunking system is complex because each division of apparatus must possess as many interconnectors as there are thousands in the exchange. In a complete 10,000-line exchange the numbers of switches of the principal types will be as follows:

Primary connectors, 1000 (10 per cent. basis),

Thousands registers, 1000,

Interconnectors, 10,000,

Secondary connectors, 1000.

There is also one rotary switch per division. It is the "clearing house" for circuit changes.

The process of establishing a connection is as follows: the initiation of the call will cause the primary connector of an idle division to rotate and seize the calling line. The first impulses will set the thousands register, extending the subscriber's line to the brushes of the interconnector belonging to that division which is equipped with trunks leading to the thousand desired. This interconnector will then receive impulses for selecting the particular hundred in that thousand and will then pick out an idle secondary connector. The last two sets of impulses will set the brushes of the secondary connector for the tens and units of the called number, completing the connection.

Common Sectional Apparatus.—Associated with each section (accommodating 100 lines) are a number of common pieces of apparatus, which direct the activities of the divisions. Only one call in a section can be attended to at one time, so that there is need of some device to have the general oversight of the traffic. This apparatus is the decimal indicator. Its first duty is to receive and act upon the initial impulse sent in from the subscriber's telephone. The further duties of the decimal indicator are to co-operate with the primary connector in setting the cylinder brushes of the latter switch to the calling line and to co-operate with the decimal register controller in setting the register brushes of the primary connector to the proper set of cylinder brushes to complete the connection to the calling line. The decimal indicator also starts a switch known as the division starter.

Associated with the decimal indicator are the decimal register controller and the division starter. The former gives the impulses for setting the decimal register brushes on the primary connector, corresponding to the tens digit of the calling line. The division starter determines which division of apparatus shall care for the incoming call. It is in direct connection with the rotary switches of the various divisions, finds out which of them is idle, and starts it hunting for the calling line. In Fig. 130 the pieces of apparatus common to the section may be seen. At the upper left-hand corner is the decimal indicator. At the extreme bottom of the vertical row containing the decimal indicator is the division starter which is a cylinder switch. Immediately above the division starter is the decimal register controller. Just at the right of these switches is a vertical driving shaft which is in constant rotation.

The decimal indicator is the apparatus to which all calls come initially. Its brushes are normally in constant rotation, and are stopped only while tending to an incoming call. These brushes are mounted upon a cage carried by the top plate, upon which may be seen several relays. This plate is driven by friction, so that the stopping magnet (15 in Fig. 136) has only to engage a tooth (124), while the shaft keeps on rotating. The decimal register controller and the division starter are both equipped with the clutch and lock which have been previously described.

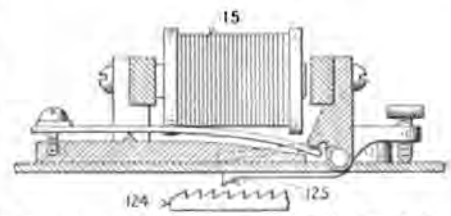


FIG. 136.—Stop magnet of decimal indicator.

Telephone and Signal Transmitter.—The telephone, Fig. 137, is very simple, consisting of a transmitter in series with a Dean bridged coil. The signal transmitter is quite complicated, both electrically and mechanically. It is built around a circle consisting of ninety pins. Resting upon one of the pins in its normal position is a contact carried by arm 142. This arm, insulated from the signal transmitter mechanism has a wiper which engages a feed ring 174 which is wired to the bottom contact of hook switch lever 47, which in turn is connected to line No. 1 (*L*-1). Line No. 2 is connected to hook switch lever 48 which, through its bottom contact connects with the bell, so that the latter is normally across the line. When the receiver is taken from the hook, the bell and the signal transmitter circuit are cut off and the talking apparatus substituted. During the progress of sending in a call, the arm 142 must be driven around the circle. The energy for doing this comes from a spring which is wound up by means of the starting handle. The latter must be rotated as far as possible to the right and then returned to normal before action can take place.

The working contacts of the circle of pins are divided into four groups, since we are considering a four-figure or 10,000-line exchange. Alternate contacts are wired up to separate groups of indicator points shown at the left in the diagram. These four groups are marked thousands, hundreds, tens and units respectively. By means of four levers, one for each group of points, the subscriber sets up the call number. This results in grounding one of the indicator contact points in each group. If we suppose that the subscriber is calling for "0234," then the points will be grounded as shown in the figure.

The general scheme of signal transmission may be more clearly seen by referring to Fig. 138. The lines *L*-1 and *L*-2, connect the signal transmitter with the central office. *L*-2 transmits impulses from the central office to step the wiper, 142, around the circle. At the same time, local impulses are delivered within the switchboard to the step-by-step magnet of the switch being operated. When the wiper 142 strikes a ground, momentary current flows over *L*-1, which pulls up and locks a relay, *R*-6, cutting off further impulses from the switch.

The signal transmitter controller has two wipers, *W*-1 and *W*-2, which move together. *W*-1 sends impulses to *L*-2 and the escapement magnet,

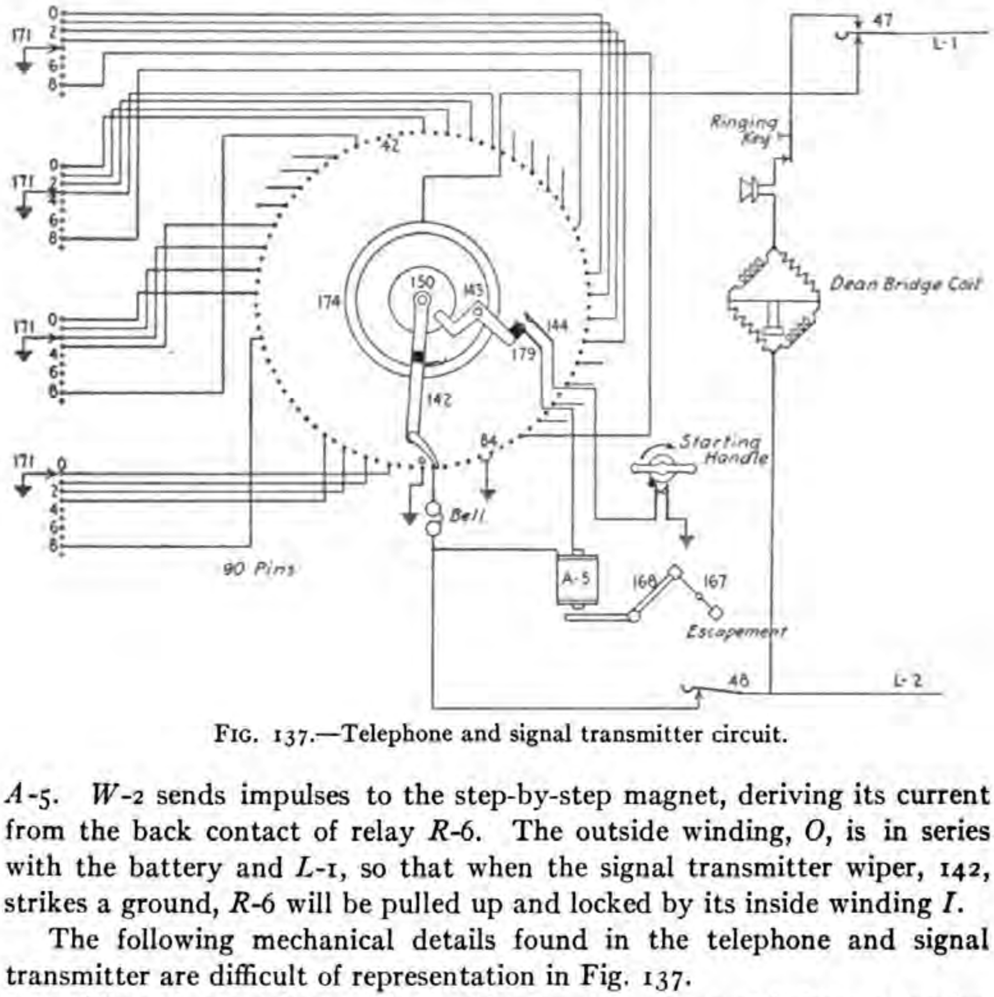


FIG. 137.—Telephone and signal transmitter circuit.

A-5. *W*-2 sends impulses to the step-by-step magnet, deriving its current from the back contact of relay *R*-6. The outside winding, *O*, is in series with the battery and *L*-1, so that when the signal transmitter wiper, 142, strikes a ground, *R*-6 will be pulled up and locked by its inside winding *I*.

The following mechanical details found in the telephone and signal transmitter are difficult of representation in Fig. 137.

1. There is a ratchet on the starting handle to prevent it from returning to normal until it has been rotated to the end of its motion.

2. The two grounding springs for the escapement magnet circuit *A*-5, are open, except when the starting handle is at normal. This is to insure the return of the handle to normal.

3. There is a lever normally in a notch on a disk attached to the starting handle shaft, which is forced out of the notch when the handle is rotated from normal. This lever acts on the escapement lever, 168, without moving the armature of magnet *A*-5. It prepares the escapement to let the signal transmitter contact arm 142 jump forward to the grounded contact, when the handle rotates back to normal. This gives the preliminary impulse over line 1.

4. After the starting handle has been rotated and returned to normal a dog locks it in normal position until the contact arm has moved around to normal again.

5. Lever 143 is connected to the hook switch and normally stands in the notch of disk 150, which is attached to the main shaft. If the hook is up the disk can not turn and hence the handle can not turn. If the hook is down, and the disk turned, the hook switch is locked down until the contact arm has gone around.

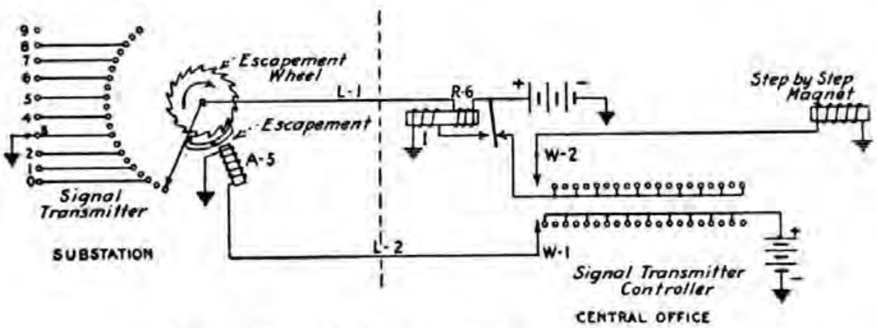


FIG. 138.—Line circuit (telephone to switches).

6. During the rotation of the wiper arm 142 the lever 143 holds the springs 144 and 179 in contact, thus completing the circuit of the escapement magnet *A*-5.

7. The escapement may be represented by the member 167 which can rotate half a revolution each time the lever 168 moves. In this way magnet *A*-5 regulates the rotation of the wiper 142. Each time *A*-5 is energized and released, wiper 142 moves over two pins.

Details of Circuit Operation.—For the purpose of explaining the operation of the system it will be assumed that a certain subscriber desires to call "0234." Accordingly, he sets up the numbers on the indicator, which results in grounding the wires as shown at the left in Fig. 137. He then turns the starting handle as far to the right as it will go, allows it to return to normal and removes the receiver from the hook. The hook switch, however, does not rise, since it is locked down. The wiper arm has been advanced one notch so that it now rests upon a grounded pin, thus grounding Line No. 1.

Figs. 139 to 146 inclusive may be considered laid edge to edge as indicated by the numbered wires at the edges of the diagrams and as shown in Fig. 138a.

At the switchboard the subscriber's line *L*-1 (see Fig. 139) passes through the back contact of a cut-off relay to one of the segments in a stationary commutator 101. This commutator contains 100 segments. The wipers of the decimal indicator, 111, 112, 113, 114, 115 and 116, are in constant rotation in the direction of the arrows. When wiper 111 strikes the *L*-1 wire of the calling line, it closes a circuit as follows: from ground at the subscriber's station over *L*-1 winding of relay *R*-1, 57 ohms, wire *r*-100 to rotary switch position 23-5 through the bridged brushes to positive battery. Relay *R*-1 operates *C*-1 and *R*-2 as follows: from positive battery at rotary switch 23-5, through wire *r*-100, ring 103, brush 113, *R*-4 (47 ohms) and *C*-1 (11

FIG.139 DECIMAL INDICATOR CIRCUIT	FIG.142 PRIMARY CONNECTOR CIRCUIT
FIG.140 DECIMAL REGISTER CONTROLLER CIRCUIT	FIG.143 ROTARY SWITCH CIRCUIT
FIG.141 DIVISION STARTER CIRCUIT	FIG.144 SIGNAL TRANSMITTER CONROLLER CIRCUIT
	FIG.145 INTERCONNECTOR CIRCUIT
	FIG.146 SECONDARY CONNECTOR CIRCUIT

FIG. 138a.—Arrangement of diagrams.

ohms) in parallel, front contact of *R*-1, brush 112, ring 102, wire *r*-1, back contact of relay *X*, looped through bridged brushes on rotary switch at position 23-3, wire *r*-101, to *R*-2 of division starter. *C*-1 stops the decimal indicator. *R*-2 starts the division starter.

The division starter (Fig. 141) determines the condition of a division by the wire *c*-5, which comes from the rotary switch and has negative battery potential on it when the switch is off normal. The brushes of the division starter are normally resting upon the contacts *N*. When relay *R*-2 pulls up it energizes the clutch magnet *C*-2. This magnet unlocks the wheel and engages the clutch, which drives the wipers of the division starter to the right. The bridging wipers between rows 3 and 4 soon close the contact of wire *c*-3 to positive battery, energizing the clutch magnet *C*-3 of the rotary switch. The impulse is only momentary and the wipers of the rotary switch are thereby driven from position *N* to position *I*.

The circuit changes which are made by the rotary switch on moving from normal position to position *I* are as follows:

Positive battery is placed upon relay *R*-20 of the primary connector. Negative battery is placed upon the clutch magnet *C*-5 of the same. A passing impulse is given over wire *c*-7 to the clutch magnet *C*-4 of the decimal register controller, starting it upon a complete half revolution.

Negative battery is placed upon a feed ring in the primary connector

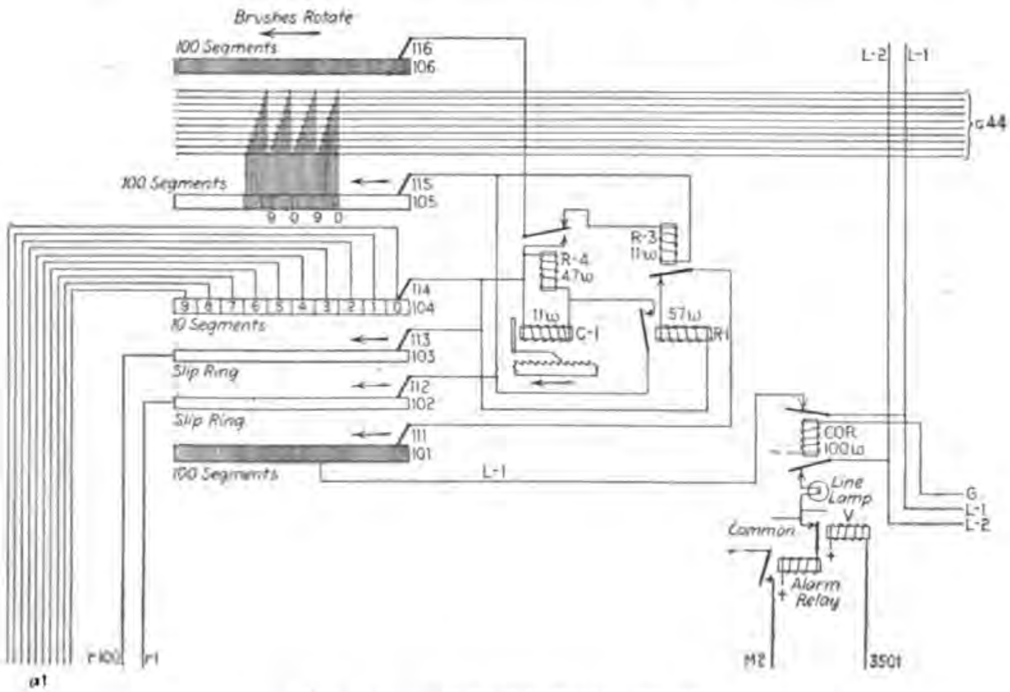


FIG. 139.—Decimal indicator circuit.

to supply current to the register magnet *A*-1. The control of clutch magnet *C*-3 of the rotary switch is given to the decimal register controller through "*c*-11." The common divisional supervisory relay *U* is energized, lights the supervisory lamp, and starts the time limit apparatus. If the divisional apparatus completes its work within the proper time, the time limit will be immediately reset to zero and the supervisory lamp extinguished. The time-limit alarm is very often unused.

Two important operations now begin, the rotation of the decimal register controller wipers and the rotation of the cylinder brushes of the primary connector. The latter operation we will consider first:

As soon as the clutch magnet *C*-5 of the primary connector, Fig. 142 (also

Fig. 147), has been energized, the cylinder wipers begin rotation. When they have moved from normal position, the circuit of relay *R*-20 will be completed by way of feed ring 3 in the fourth quadrant through bridged brushes to contacts in the top row of the second quadrant. These contacts have attached to them wires designated by *c*-44 which are connected to segments in the commutator 105 of the decimal indicator. The brush 115 will be resting upon one of these segments and will give it negative battery potential. When the exploring brush in the second quadrant strikes the wire, upon whose

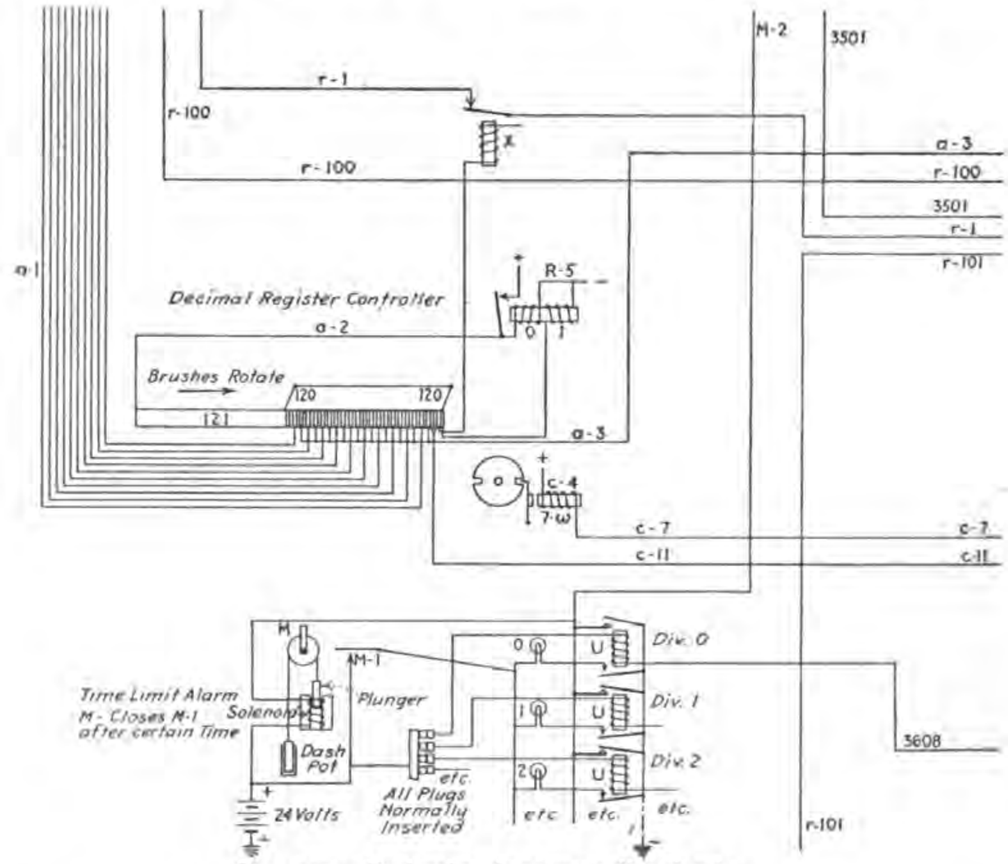


FIG. 140.—Decimal register controller circuit.

segment 105 the brush 115 is resting, relay *R*-20 will be energized, cutting off the current from magnet *C*-5 and stopping the primary connector cylinder brushes upon contacts corresponding to the units digit of the calling line.

In the meantime the decimal register controller has been sending impulses to the escapement magnet *A*-1 of the decimal register on the primary connector. The wires labeled *a*-1 are capable of indicating the tens digits of the calling line. Each of the segments 104 is as long as ten of the individual segments of the commutators 101, 105 or 106. When in its rotation brush 120 strikes a segment which is connected to the segment of 104 upon which

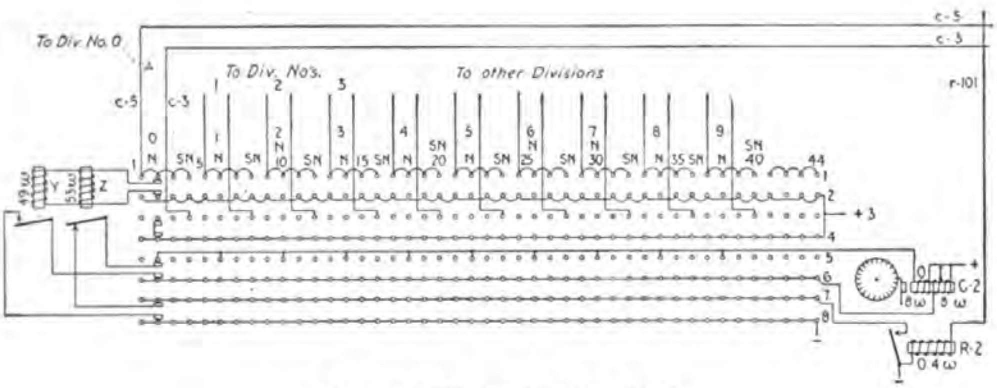


FIG. 141.—Division starter circuit.

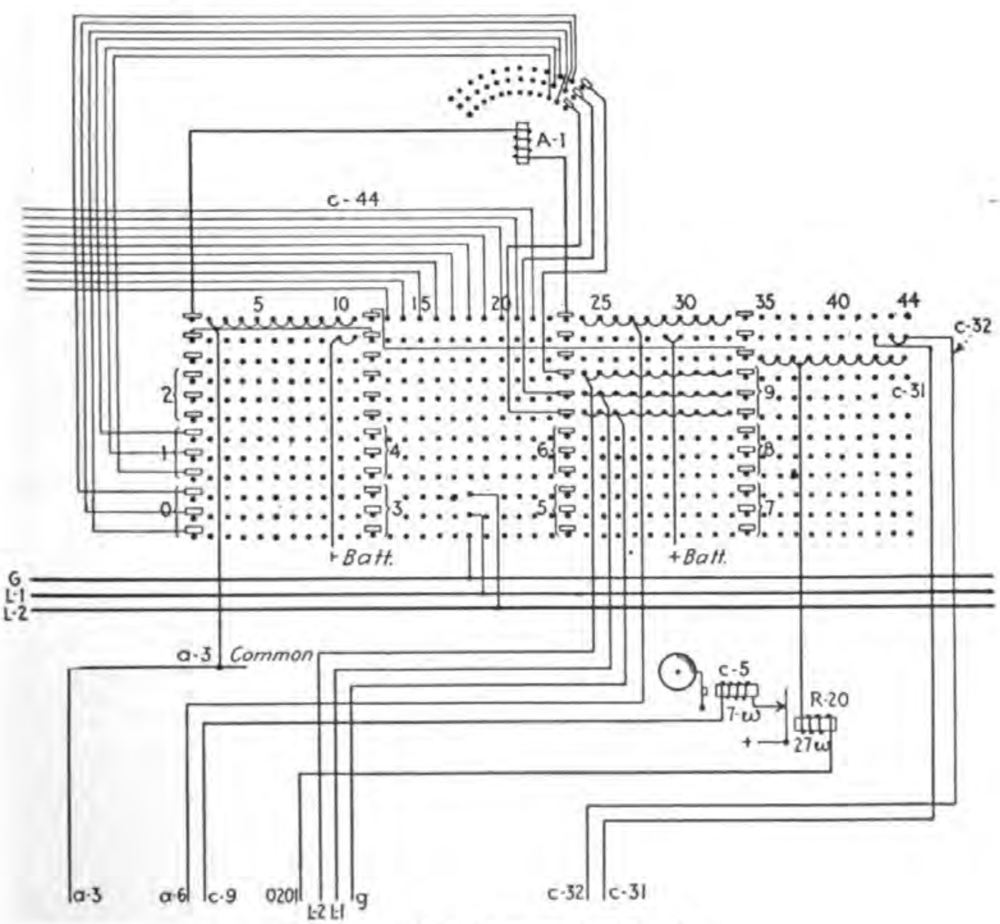


FIG. 142.—Primary connector circuit.

brush 114 is resting, relay *R*-5 will receive current and pull up, locking itself to positive battery. Thereafter brush 20 carries full positive battery potential.

Immediately after leaving the segment upon which the brush 120 received the energizing current it wipes over contacts to which wire *A*-3 is attached. There will be delivered to wire *A*-3 as many impulses as there are segments between the point of energization and the end of the series of segments.

These impulses set the decimal register brushes into contact with the set of cylinder brushes which are now resting upon the calling line. The decimal

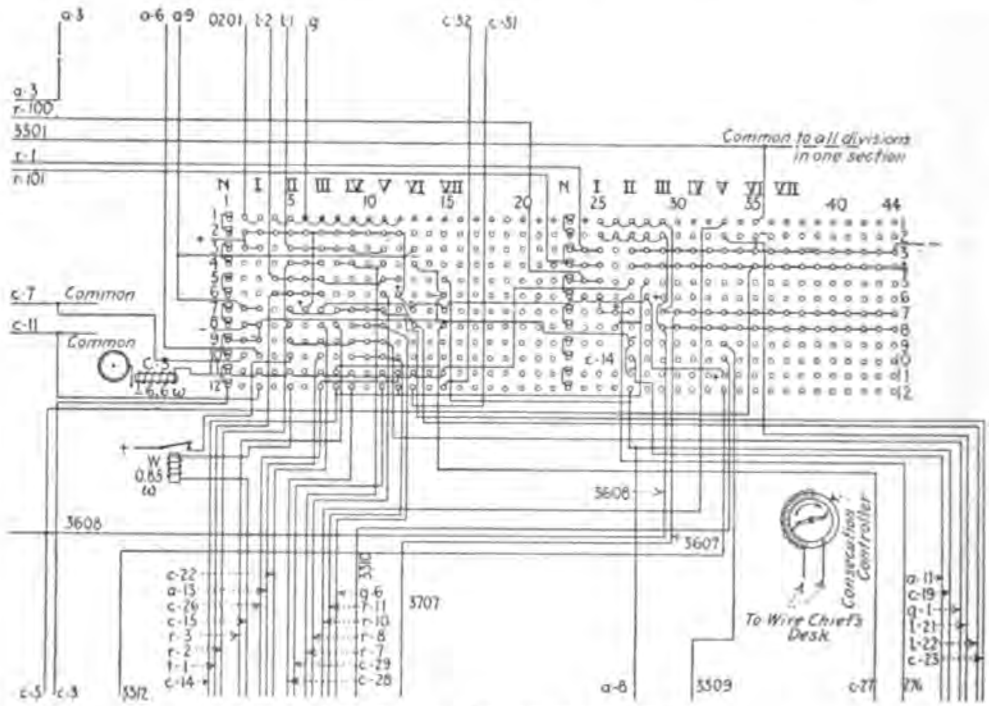


FIG. 143.—Rotary switch circuit.

register thus corresponds in position to the tens digit of the calling line. The decimal register controller, after finishing the delivery of impulses to the decimal register, gives an impulse of positive battery to the clutch magnet *C*-3 of the rotary switch, moving the latter from position *I* to position *II*. The last act of the decimal register controller is to send current through the inside winding of its relay *R*-5 so as to neutralize it and unlock its armature and stop its wipers.

The circuit changes made by the rotary switch in moving from position *I* to position *II* are as follows:

1. Positive battery is cut off from relay *R*-20.
2. Positive battery is placed on wire *g* which, passing through feed seg-

ment on the primary connector, and the inner brush on the decimal register to the *G* wire of the calling line, operates the cut-off relay.

3. Connects line *l*-1 to the outside winding of relay *R*-6 and positive battery. This is to control the locally delivered impulses.

4. Connects line *l*-2 to the top feed ring of the signal transmitter controller to send impulses to the escapement magnet *A*-5 of the signal transmitter in the telephone.

5. Removes negative battery from clutch magnet *C*-5 of primary con-

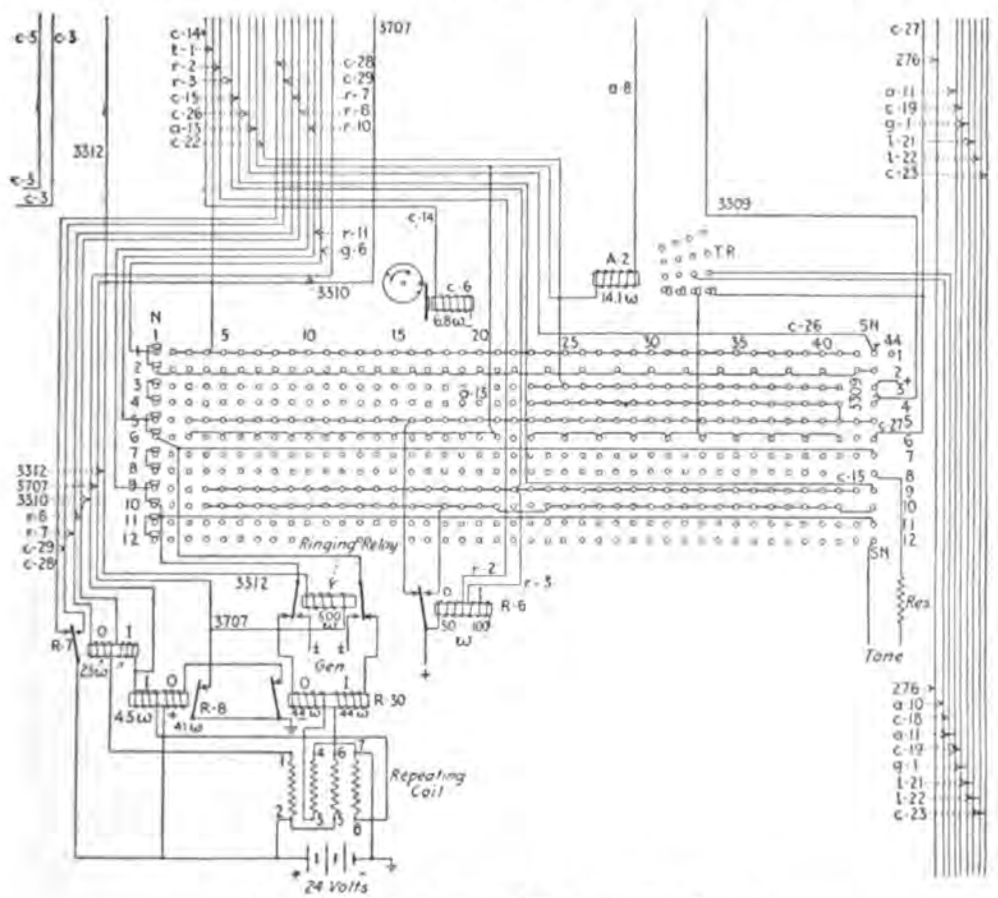


FIG. 144.—Signal transmitter controller circuit.

nector. Establishes a side connection from *l*-1 to top feed segment of interconnector in the second quadrant. This circuit is as follows: rotary switch, bridging wipers 7 and 8, wire *c*-23 to interconnector, top feed ring second quadrant.

6. Closes a circuit from the front contact of relay *W* to third feed segment of the interconnector. The circuit is as follows: front contact of relay *W*, bridged wipers of rotary switch 9 and 10, wire *g*-1 to the interconnector, fourth feed segment of quadrant 2.

12

7. Switches control of the clutch magnet *C*-3 of the rotary switch from decimal register controller to the signal transmitter controller. The circuit is as follows: from negative battery, winding of clutch magnet *C*-3, bridged brushes 11 and 12 of rotary switch, winding of relay *W*, wire *c*-15 to signal transmitter controller, bank contact in row 9 subnormal position *S*-*N*.

8. Puts negative battery on the guard wire leading to division starter to render the division busy.

9. Connects a circuit from the clutch magnet *C*-3 of the rotary switch

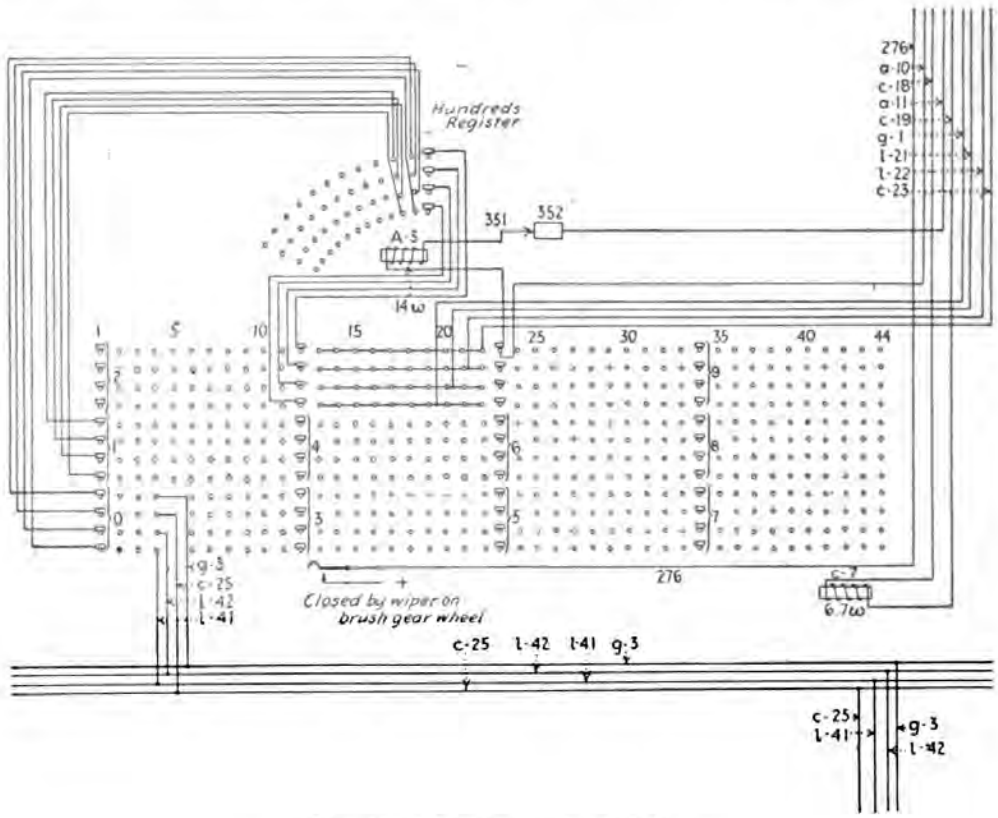


Fig. 145.—Interconnector circuit.

to a contact operated by the brush gear wheel on the interconnector for the purpose of feeding positive battery to the clutch magnet of the rotary switch. The circuit is as follows: negative battery through winding of the clutch *C*-3 contact 27-5 of rotary switch through bridged brushes to contact 27-6 through wire 276 to interconnector, special contact above mentioned which is normally open.

10. Puts negative battery on register magnet *A*-3 of the interconnector. The circuit is as follows: negative battery on contact 27-9 through bridged brushes to contact 27-10 over wire *a*-11 through contacts 352 and 351 of the

interconnector, winding of relay A-3 to brush resting on contact 23-1 of the interconnector, through wire a-10 to inside contact of the thousands register, through the brush resting thereon, through wire a-9 to impulse segment 6 of the signal transmitter controller. This is to deliver impulses for setting the register of the interconnector.

11. Puts negative battery on the clutch magnet C-7 of the interconnector. The circuit is as follows: from negative battery on contact 27-11 of rotary switch through bridged brushes, contact 27-12, wire c-19, through winding of clutch magnet C-7 of interconnector through wire c-18 to outside contact of thousands register through the brush resting thereon to contact 43-6 of the signal transmitter controller.

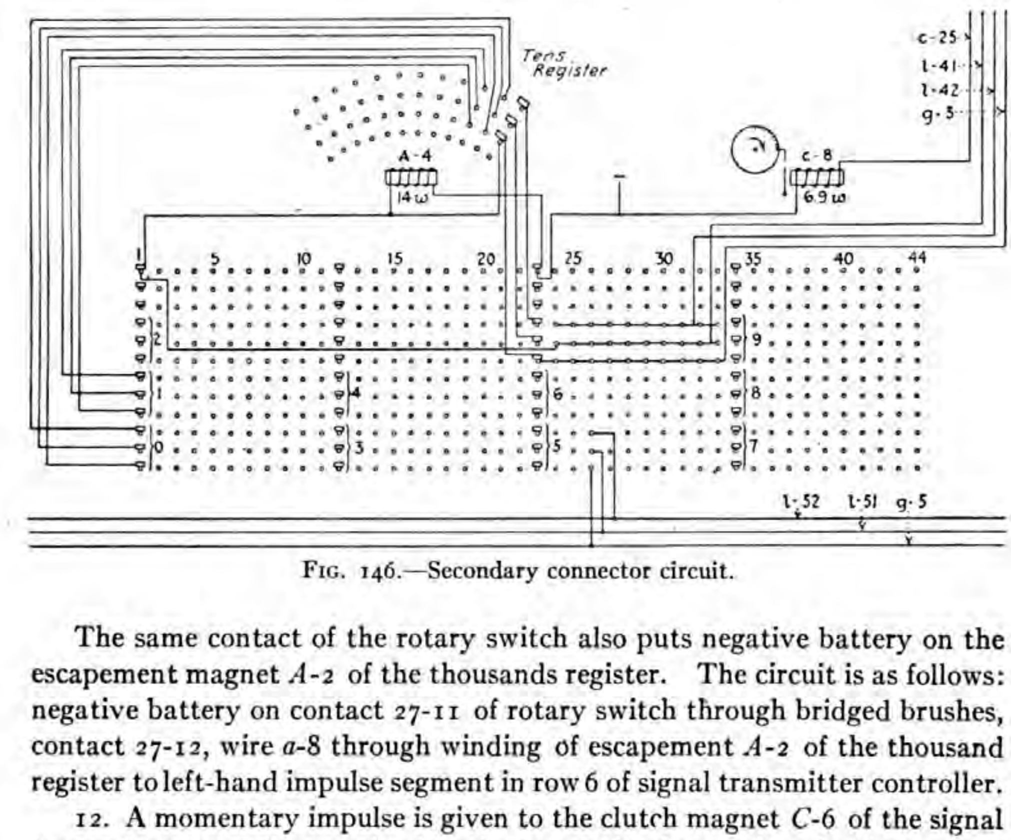


FIG. 146.—Secondary connector circuit.

The same contact of the rotary switch also puts negative battery on the escapement magnet A-2 of the thousands register. The circuit is as follows: negative battery on contact 27-11 of rotary switch through bridged brushes, contact 27-12, wire a-8 through winding of escapement A-2 of the thousand register to left-hand impulse segment in row 6 of signal transmitter controller.

12. A momentary impulse is given to the clutch magnet C-6 of the signal transmitter controller starting it on its first cycle of operations for the purpose of receiving the thousands and hundreds digits of the called number. During its cycle of rotation, the signal transmitter controller feeds impulses to the escapement magnet on the signal transmitter at the subscriber's telephone over wire L-2, at the same time delivering impulses first to the thousands register and after that to the hundreds register on the interconnector. As soon as the brush 142 of the signal transmitter at the telephone strikes a grounded contact pin, relay R-6 of the signal transmitter controller is ener-

gized, thereby cutting off the impulses which are being delivered locally to the thousands register or to the hundreds register. By this means the adjustments of the indicators on the telephone control the positions to which the thousands and hundreds registers are moved.

Relay *R*-6 is locked in its energizing position by means of its inside winding. At the end of the first set of impulses, the relay *R*-6 is unlocked by the omission of two contact pins, 22-10 and 23-10. At the end of the hundreds digit, the relay is unlocked again by the omission of contact 42-10.

A separate interconnector is provided in each division for each thousand, so that when the brushes of the thousands register are moved, the wires connected to them are brought into contact with the two wires *a*-10 and *c*-18 which lead respectively to the hundreds register magnet *A*-3 and the clutch magnet *C*-7 of the selected interconnector. The hundreds register picks out

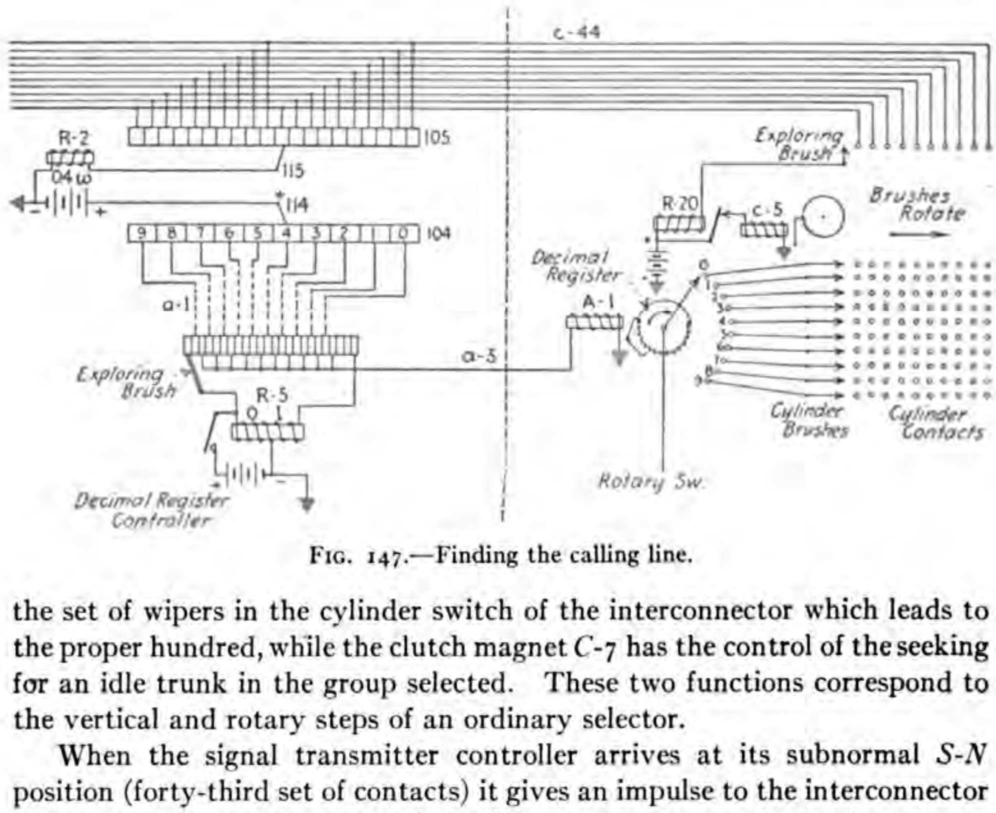


FIG. 147.—Finding the calling line.

the set of wipers in the cylinder switch of the interconnector which leads to the proper hundred, while the clutch magnet *C*-7 has the control of the seeking for an idle trunk in the group selected. These two functions correspond to the vertical and rotary steps of an ordinary selector.

When the signal transmitter controller arrives at its subnormal *S-N* position (forty-third set of contacts) it gives an impulse to the interconnector clutch magnet, starting the cylinder brushes of the same to hunting for an idle trunk. The circuit is as follows: from plus battery, back contact of relay *R*-6 through contact 43-5 of signal transmitter controller bridged brushes, contact 43-6, wire *c*-17, outer brush on the thousands register, wire *c*-18 to clutch magnet *C*-7 of interconnector, through wire *c*-19 through contact 27-12 of rotary switch, bridged brushes to negative battery at contact 27-11.

At this point the clutch magnet *C*-3 of the rotary switch is waiting and will be energized whenever relay *R*-6 is pulled up.

The trunk-testing circuit which determines which secondary connector shall be seized, includes the outside winding of relay *R*-6 of the signal transmitter controller. It has under its control (at its back contact) the current supplied to the clutch magnet *C*-7 of the interconnector, so that whenever the relay *R*-6 is energized the cylinder brushes of the interconnector will stop. This trunk-testing circuit is as follows: from plus battery, outside winding of relay *R*-6 wire *r*-2, contact 5-8 of rotary switch, through bridged brushes, contact 5-7, wire *c*-23, through top feed segment second quadrant of interconnector, through the brush resting thereon, through the outside brush of the hundreds register, to the top brush in the set of four wiping over the cylinder contacts. The condition of idleness is that wire *g*-3 attached

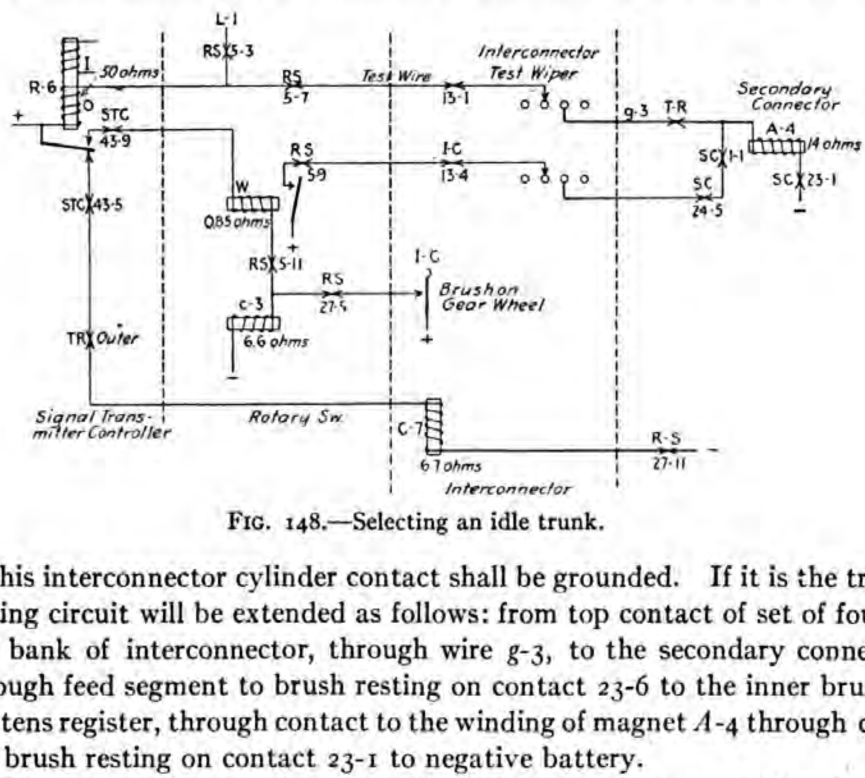


FIG. 148.—Selecting an idle trunk.

to this interconnector cylinder contact shall be grounded. If it is the trunk-testing circuit will be extended as follows: from top contact of set of four on the bank of interconnector, through wire *g*-3, to the secondary connector, through feed segment to brush resting on contact 23-6 to the inner brush of the tens register, through contact to the winding of magnet *A*-4 through cylinder brush resting on contact 23-1 to negative battery.

The action of the trunk-testing circuit is shown more comprehensively in Fig. 148. Beginning with plus battery in the upper left-hand corner, the test circuit runs through the outside winding of relay *R*-6 to the test wiper at the interconnector. The ground on wire *g*-3 is through 14 ohms in *A*-4 of the secondary connector. During the period of trunk seeking, the interconnector clutch magnet, *C*-7, is energized through the back contact of *R*-6.

When the test wiper strikes the grounded wire, *g*-3, *R*-6 pulls up but *A*-4 does not. *R*-6 cuts off *C*-7 and energizes *W* and *C*-3. *C*-7 stops the interconnector on the seized trunk. *W* gives a full battery impulse to *A*-4 moving the tens register one step off normal, breaking the connection at *T-R* so as to render the *g*-3 wire busy (no ground). *C*-3 moves the rotary switch to position *III*.

In passing from position *II* to position *III* (Fig. 143) the rotary switch makes the following changes: A circuit is established from the signal transmitter controller to the tens register magnet *A*-4 of the secondary connector. The circuit is as follows: from left-hand impulse segment 6 of the signal transmitter controller, through wire *a*-13 to the rotary switch contact 7-10, across bridged brushes to contact 7-9, through wire *g*-1 to bottom feed segment of the interconnector, through the brush resting thereon, to inner brush of hundreds register to bottom brush in set of four in the cylinder switch, through wire *l*-41 to middle feed segment on the secondary connector to contact 1-1 secondary connector-bank through tens register magnet *A*-4 to brush resting on contact 23-1, to negative battery.

The control of the rotary switch by means of the clutch magnet *C*-3 is given over to contact 43-1 of the signal transmitter controller.

A single impulse of battery current is given to the clutch magnet *C*-6 of the signal transmitter controller, causing the latter to move from subnormal through another cycle of operations to subnormal again. When the bridged brushes on the first and second levels of the signal transmitter controller wipe over their contacts they again send impulses to the escapement magnet *A*-5 of the signal transmitter at the telephone, causing the brush 142 to pass over the third and fourth quadrants of contact pins. During the first half of this second cycle of the signal transmitter controller impulses are sent to the tens register magnet *A*-4 of the secondary connector, setting it to correspond with the tens digit of the number of the called line. The circuit is as follows: from positive battery, back contact of relay *R*-6 feed segment 5, by bridged brushes to impulse contacts, left hand of row 6, through wire *a*-13 to contact 7-10 on the rotary switch, through bridged brushes to contact 7-9, through wire *g*-1 bottom feed segment on interconnector, through the brush resting thereon, inside brush of hundreds register to bottom wiper of four resting on cylinder contacts, through wire *l*-41 to contact 1-1 of secondary connector through brush resting thereon, through magnet *A*-4 through brush resting on contact 23-1 to negative battery.

When the contact arm 142 at the telephone strikes a grounded pin corresponding to the tens digit, an impulse is sent over line *l*-1 which pulls up relay *R*-6, locks it, and cuts off further impulses to the tens register of the secondary connector. The circuit is the same as was described before, except that it is through contacts 7-5 and 7-6 of the rotary switch. *R*-6 is unlocked when the signal transmitter controller brushes arrive at 22-10.

During the second half of its cycle, the signal transmitter controller delivers current to the clutch magnet *C*-8 of the secondary connector, causing it to rotate the cylinder brush to the contact of the called line. The circuit is as follows: from positive battery, back contact of relay *R*-6 feed segment 5 of signal transmitter controller through feed segment 4 across bridged brushes to feed segment 3, through wire *c*-22 to contact 7-8 on the rotary switch, through bridged brushes of contact 7-7 through *l*-22 to second feed segment in the interconnector, through brush resting thereon to second brush on the hundreds register, through second cylinder brush in set of four to back contact, through wire *c*-25, through clutch magnet *c*-8 of secondary connector to negative battery. The accuracy with which the cylinder brushes of the secondary connector are set depends upon the synchronism with which the signal transmitter controller and secondary connector cylinder brushes are driven. Since they are fed from a common source, they will move together, so that the result will be practically the same as if impulses had determined the degree of rotation of the secondary connector cylinder brushes. When the wiper arm 142 of the signal transmitter at the telephone arrives at the grounded pin which was set by the subscriber to correspond with the units digit of the call number, an impulse is sent over line *L*-1, pulling up and locking relay *R*-6 as before. This cuts off the current from the clutch magnet *C*-8 of the secondary connector, allowing it to stop the cylinder brushes of the secondary connector upon the desired line.

The signal transmitter controller, coming to rest upon the subnormal contacts, energizes the clutch magnet *C*-3 of the rotary switch and sends it on from position *III* to position *IV*.

The changes made by the rotary switch in moving from position *III* to position *IV* are as follows:

1. Line *l*-1 is disconnected from the outside winding of relay *R*-6 and connscted to the outside winding of relay *R*-7.

2. The inside winding of relay *R*-6 is connected momentarily through to the *G* wire of the called line of the apparatus, testing it to see if the line is busy. The circuit is as follows: from negative battery through inside winding of relay *R*-6 through wire *r*-3 to contact 8-8 of the rotary switch, across bridged brushes to contact 8-7, through wire *c*-23 to top feed ring of interconnector through cylinder brush resting thereon to outside brush of hundreds register, to upper cylinder brush in set of four, through wire *g*-3 to lower segment of secondary connector, to cylinder brush resting thereon, to inside brush of tens register, to bottom cylinder brush in set of three to the *G* contact of the called line through wire *g*-5 to the cut-off relay of the called line and thence to negative battery. If the line be busy the *G* wire will have positive potential on it and relay *R*-6 will be energized.

If the line is not engaged, the *G* wire will be found to have negative battery potential and therefore relay *R*-6 will not pull up. This leaves a plus battery connection on the subnormal *S-N* contact of the signal transmitter controller so that when the rotary switch passes over its contacts

8-11, 8-12 it will energize the clutch magnet *C*-6 and send the signal transmitter controller from subnormal *S-N* to normal *N*.

The moving of the signal transmitter controller to its normal position places positive battery potential on the *G* wire of the called line, guarding it from interruption and also pulling up the cut-off relay for the purpose of disconnecting its wires from the decimal indicator and the line lamp.

The circuit is as follows: positive battery at signal transmitter controller, bridged brushes from 1-2 to 1-1, wire *g*-6 to rotary switch through contacts 9-8 and 9-7, through wire *c*-23 to top feed ring in the interconnector, through outside brush of hundreds register, to top cylinder brush in set of four, through wire *g*-3 to secondary connector, bottom feed ring through inside brush of tens register, through bottom brush in set of three in cylinder, to wire *g*-5 which is the *G* wire of the called line, thence through the cut-off relay to negative battery.

The signal transmitter controller also connects the called line through the ringing relay contacts, the windings of relay *R*-30 and the repeating coil windings 3-4 and 7-8 to the positive and negative terminals of the battery.

The contact arm 142 of the signal transmitter is now resting on grounded contact 84 and relay *R*-7 is energized. At this point the hook switch of the telephone rises, either by the subscriber taking off the receiver, upon observing that the signal transmitter has stopped its motions, or by being unlocked mechanically by the signal transmitter having arrived at this point in its rotation. This action of the hook switch cuts the ground from line *L*-1 and bridges the telephone across the circuit in the usual manner. Relay *R*-7 now falls back and closes the circuit which sends the rotary switch from position *IV* to position *V*.

In moving from position *IV* to position *V* the rotary switch connects up *L*-2 through the inside winding of *R*-7, inside winding of relay *R*-8 and the 7-8 winding of the repeating coil to negative battery. This completes the circuit of the calling telephone, so that current will flow through and energize relay *R*-8. Relay *R*-7 will, however, not be pulled up because its windings are equal and oppositely connected, so that the rotary switch will be left at position *V* during conversation.

The subscriber, Fig. 149, now presses the ringing button which opens the line and allows the relay *R*-8 to fall back. This will give current to the ringing relay and the latter projects ringing current upon the calling line.

Upon releasing the ringing button the current pulls up relay *R*-8 and stops the ringing of the bell. When the called subscriber answers by taking the receiver from the hook, his telephone set is cut across the line in place of the bell. The current flow thus caused will energize relay *R*-30 which, by closing the circuit through the outside winding of relay *R*-8, will hold the latter energized, so as to prevent the ringing relay from operating in case the calling subscriber should hang up his receiver. Conversation now takes place.

At the conclusion of conversation both subscribers hang up their receivers. The hook switch at the calling station restores the ground on the *L*-1, which pulls up relay *R*-7 and sends the rotary switch from position *V* to position *VI*.

In moving from position *V* to position *VI* the rotary switch removes the guarding potential from the *G* wire of both lines, allowing the cut-off relays to fall back. It also gives a momentary pulsation to *L*-2 of the calling line, moving the signal transmitter around to its normal position. The rotary switch also sends the secondary connector and the primary connector both around to normal by energizing their clutch magnets *C*-8 and *C*-5. In so doing each of the connectors resets its register back to normal by means of a finger extending through the mounting plate.

The circuit for energizing the clutch magnet of the secondary connector is as follows: From plus battery on contact 13-7 of rotary switch, across bridged brushes through contact 13-8, wire 1-22 to second feed ring of interconnector,

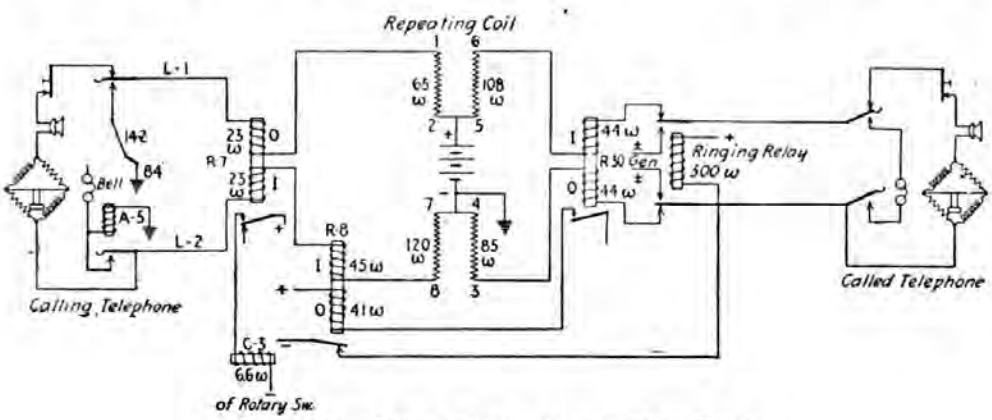


FIG. 149.—Talking circuit between subscribers.

through second brush on the hundreds register, through second brush in set of four in the cylinder, through wire *c*-25, through clutch magnet *C*-8 of secondary connector to negative battery. Inasmuch as the notches on the circumference of the cylinder brush disks of both connectors extend over only one-fourth of the circumference, it is sufficient to keep the clutch magnets energized until they have passed this portion of the circumference. After this they may be de-energized so that when the brushes arrive at normal, the lock will drop into the first notch and the clutch be thereby released. The cutting off of the current is secured by the action of the primary connector. Before the primary connector arrives at its normal position it gives an impulse to the clutch magnet of the rotary switch, sending the latter from position *VI* to position *VII*.

In moving from position *VI* to position *VII* the rotary switch cuts the current from *C*-5 of the primary connector so that it will stop when it arrives at normal. It performs the same action for clutch magnet *C*-8 of the secondary connector. The rotary switch also energizes the clutch magnet *C*-7 of the interconnector, starting the latter on its journey around to normal.

The circuit of the latter is as follows: From negative battery at contact 15-6 of rotary switch through bridged brushes, contact 15-5, wire *c*-19 to the interconnector, through clutch magnet *C*-7 through wire *c*-18, outside contact of brush on thousands register, wire *c*-27, to rotary switch, contact 15-8, through bridged brushes to positive battery on contact 15-7.

Just before the primary connector arrives at its normal position, it gives another momentary impulse to the clutch magnet of the rotary switch, which sends the latter from position *VII* to normal. This complete cycle of the rotary switch requires only that cylinder brushes shall move through one-half a circle, since all the combinations are performed by pairs of bridged brushes which are in two sets, allowing each set to perform the work of the other.

In moving from position *VII* to *N* the rotary switch removes negative battery from wire *c*-5, giving a free indication to the division starter so that this division to which the rotary switch belongs may be used for another call. It cuts relay *U* from back contact of relay *R*-8 so as to remove the general supervisory signal. It also removes ground from clutch magnet *C*-7 of the interconnector and restores normal connection of the clutch magnet *C*-3 for receiving any call.

SPECIAL CONDITIONS

All Trunks Busy.—If all the trunks from the interconnector to the desired section are busy, the interconnector will be unable to find a stopping point and will continue in its rotation. After having passed all the trunk contacts, an extra pair of springs on the disk will be closed. This will give current to the clutch magnet *C*-3 of the rotary switch and will move it on from position *II* to position *III*. At this time the signal transmitter controller is in its subnormal *S-N* position, having moved only from normal to subnormal. It has still to move from subnormal to subnormal again and then on to normal, in order to complete its cycle.

In moving from position *II* to position *III* the rotary switch gives an impulse which sends the signal transmitter controller from *S-N* to *S-N*, exactly as if nothing had happened. The signal transmitter controller moves the signal transmitter arm 142 at the telephone around the circle, causing it to arrive at contact 84, although unable to deliver impulses to any secondary connector. The signal transmitter controller will finally send the rotary switch from position *III* to position *IV*.

We are now at the same point at which we would have arrived had the interconnector found an idle trunk, excepting that our call ends at the interconnector with the latter at normal. The subscriber on removing his receiver from the hook will get nothing. When he releases the usual events will take place with the exception that there is no resetting of the secondary connector, since the latter was not used. The interconnector will be sent around once more but will not be stopped on a trunk, because there is nothing to stop it.

Called Line Busy.—If the called line is busy, the *G* wire will be charged with positive battery potential. This will cause the testing circuit to be energized in time to prevent the signal transmitter controller from moving from the subnormal position and will cause it to deliver the busy tone to the calling line without allowing the connection to be established to the called line. In order to make the action clear we will briefly recall the conditions existing at the time of the busy test.

The primary and secondary connectors have their cylinder brushes resting upon the two lines and the interconnector is resting upon the proper trunk, so that the called line would be connected to the repeating coil if it were not for the break at the signal transmitter controller due to the latter being in subnormal instead of normal position. The rotary switch is just passing between position *III* and position *IV* with the test circuit closed. This circuit is as follows: from negative battery through inside winding of relay *R*-6 through wire *r*-3 to the rotary switch contact 8-8 through bridged brushes and contact 8-7, through wire *c*-23 to top feed segment of interconnector, outside brush of hundreds register, upper cylinder brush in set of four, wire *g*-3 to secondary connector through bottom feed ring, through inside tens register brush contact, through bottom cylinder brush in set of three to the *G* wire of the called line.

On account of the positive potential found on the *G* wire of the called line, relay *R*-6 at the signal transmitter controller will be energized, cutting off the positive battery potential from contact 43-5 of the signal transmitter controller. This prevents *C*-6 of the signal transmitter controller from receiving an impulse, so that the rotary switch will pass on to position *IV* without moving the signal transmitter controller from position *S-N*. In the subnormal position the tone current is connected through resistance to the windings of the repeating coil.

The circuit is as follows: from tone coil through a wire to contact 43-12 of signal transmitter controller across bridged brushes through contact 43-11 through back contact of the ringing relay, through outside winding of relay *R*-30, through winding 3-4 of repeating coil to negative battery through the battery out at its positive terminal, through winding 5-6 of repeating coil, through inside of relay *R*-30 through back contact of the ringing relay, contact 43-7 of signal transmitter controller across bridged brushes, through contact 43-8, through the resistance back to the tone generator.

Since the rotary switch has gone on to position *IV*, the substation apparatus will be in the same condition as if the line had been properly seized and the hook switch will rise. The cutting off of current from *L*-1 will de-energize relay *R*-7 allowing its arm to fall back and give current to the clutch magnet *C*-3 of the rotary switch, sending it on from position *IV* to position *V*. This connects up *L*-2 of the calling line to the repeating coil and since the tone current is already circulating through two of the windings the calling subscriber will hear it. He will then hang his receiver on the hook, which will again energize relay *R*-7 giving current to the clutch magnet *C*-3 of the rotary switch to send it from position *V* to position *VI*. The release proceeds as has been described before except that the signal transmitter controller is off normal and must be sent from subnormal to normal. This is done by a momentary impulse delivered while passing from position *V* to position *VI*. The circuit is as follows: From positive battery on contact 43-2 of signal transmitter controller, across bridged brushes through contact 43-1, through wire *c*-26 to rotary switch contact 12-11, across bridged brushes contact 12-12, through wire *c*-14, through clutch magnet *C*-6 of signal transmitter controller to negative battery.

As a precaution against sending ringing current into the tone generator, relay *R*-8 is energized by the signal transmitter controller when at *SN* and rotary switch at the *V* position. Wire 3310 forms the connecting link between *R*-8 and rotary switch 33-10, from which the circuit goes through bridge brushes 33-9, wire 3309 to signal transmitter controller 43-4, 43-3 to plus battery.

CHAPTER VIII

AUTOMATIC TRAFFIC DISTRIBUTOR EQUIPMENT

While traffic distributor equipment is composed of automatic switching mechanisms, it is used to increase the efficiency of manually operated switchboards and not to give automatic telephone service. This apparatus can be employed in full automatic systems but by itself does not make automatic connections between subscribers. It is used only for distributing the traffic among "A" or "B" manual switchboard operators in such a manner that their efficiency is greatly increased. Considerable of the increase in efficiency of semi-automatic or automanual systems (automatic switchboards worked by operators) is due to the traffic distributor features which form a part of these systems, and is by no means all due to the fact that the operators set up the calls by means of push-button calling devices instead of by means of cords and plugs.

The same or similar traffic distributor features may be and have been applied equally well to offices in which the operators complete the connections by using cords and plugs.

Reasons for Loss of Efficiency in Manual Offices.—There are four principal difficulties in the way of bringing the work of manual switchboard operators up to maximum efficiency.

First.—The wide variations in the traffic load during the hours of each day.

Second.—The variations between positions in the hour that the heaviest traffic occurs.

Third.—The momentary traffic rushes and corresponding comparatively idle moments which are especially aggravated in small trunk groups.

Fourth.—Since it is impossible to supply each operator with a constant stream of work at the maximum rate at which she can handle it, it is very difficult if not impossible to apply the bonus or premium method of regulating her wages which efficiency engineers have learned is an essential to high efficiency on the part of most wage earners.

Taking up the discussion of these four difficulties in detail and in order it should be said:

First.—The manual switchboard operator works at her greatest efficiency during the busy hours when the calls are coming in at their maximum rate for the day. In fact the total number of positions which shall be equipped in a manual switchboard is calculated by dividing the busy hour calls for the whole office by the busy hour calls which one operator handles. As the load on the board falls off each operator has less to do. Consequently telephone companies attempt to maintain the efficiency of their operators by reducing the number at times of light load. This is termed "adjusting the operators to the load curve." This method is obviously cheaper than maintaining the full force all day. Yet it leaves much to be desired. When an operator has to handle more than one position she can not answer calls so fast since she must reach further and with more effort on each connection. The reduction of efficiency is clearly shown by the curve in Fig. 150.

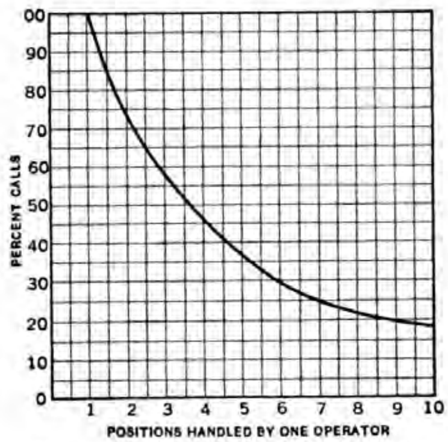


FIG. 150.—Curve showing relative efficiencies of a manual operator covering various numbers of positions.

Starting with a standard of 100 per cent. as the load which she can handle at one position, she can care for only 73 per cent. as many calls when two positions are assigned to her. For night work when one operator must tend many positions, the efficiency is very low. Ten positions give us a load only 18 per cent. of her full one-position ability. Thus the expedient of adjusting the number of operators to the load results in great loss of efficiency without making the work any easier on the girls.

Second.—The busy periods do not occur at exactly the same time on all positions. This causes a further loss in efficiency. Fig. 151 was taken from an actual peg count and illustrates the inequality very well. From 6 to 7 A.M. position 9 is the only one to have an appreciable load. From 10 to 11 A.M. positions 4, 6, and 9 have an increased load, while 5, 7, 8, and 10 have very much less to do. The afternoon peak comes between 4 and 5 on positions 5 and 9, between 5 and 6 on positions 7 and 10, while it is as late as between 7 and 8 on positions 4 and 8.

In general the traffic manager aims to rearrange the lines at the intermediate distributing frame so that so far as possible the busy hour load of the office will be evenly divided among the operators. This distribution is a matter of difficulty for it requires constant attention and much thought and labor. Very few exchanges are successful in securing it.

Third.—There is another great loss of efficiency due to the evil of "rushes." For instance when we say that 225 calls were handled by one operator in one hour we have only a partial idea of her speed. During that hour the calls did not come to her in an even, steady stream. There were periods of rush when she may have been answering calls at the rate of 300 or 400 per hour followed by short periods of slow calling or even idleness. Formerly the only known method of reducing the inequality was "team work." Each operator is trained to keep a lookout over the position to her right and left so that if her neighbor has more than she can do assistance can be given. Though this reduces the evil a little, it still fails to get at the root of the matter. The wide variations which take place in the traffic passing over small trunk groups as compared with large groups are shown in the chapter on traffic. (Fig. 263.) These curves clearly indicate that a moderately steady flow of

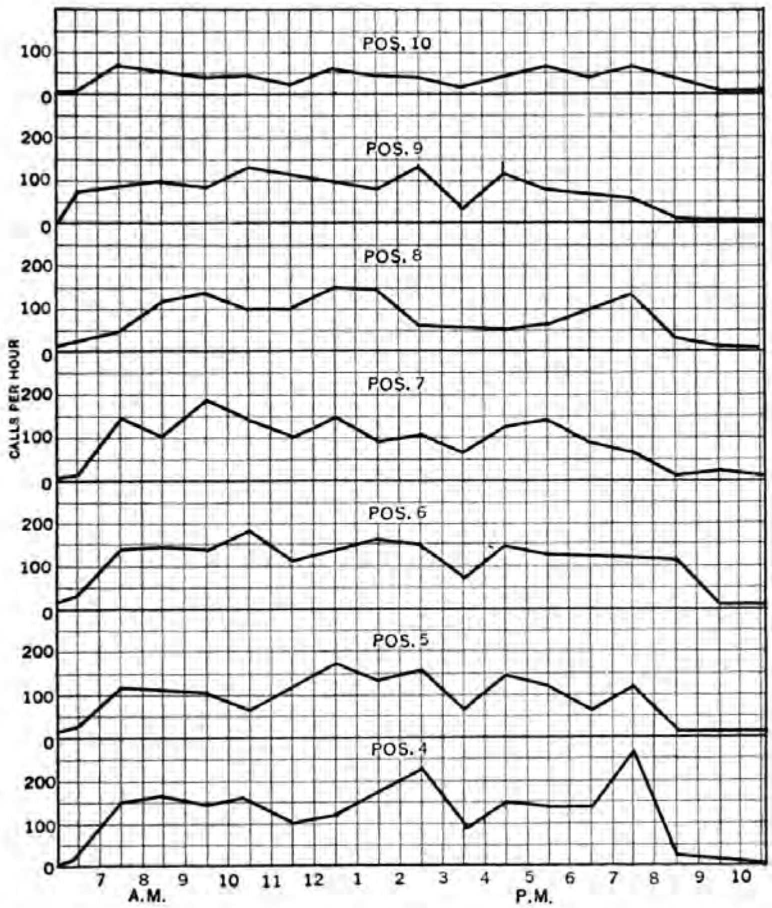


FIG. 151.—Simultaneous load curves of manual switchboard operators' positions.

traffic can be expected only from groups made up from large numbers (several thousand or more) of lines.

Fourth.—Efficiency engineers have found that a workman who is making or assembling the same piece over and over in a factory, or a bricklayer who is applying mortar and laying bricks over and over all day long can in most—if not all cases, be induced to work at his highest efficiency only when (*a*) scientific standards of attainment, determined by proper motion studies and studies of conditions are placed before the workman to be striven for; (*b*) the materials for his work are supplied to him in such a way that they are always available at the proper time, at the proper place, and in the proper condition; and (*c*) his wages are materially increased when he brings his work up to or within striking distance of standard.

Contrast these conditions with those of an operator, who is assigned an arbitrary group of lines to serve, and who can, therefore, handle the calls only as the erratic load fluctuations allow her to do so.

A fifth difficulty is found in the way to high efficiency of "*B*" operators due to the fact that if the number of trunks between the "*A*" operators in one office and the "*B*" switchboard in another is sufficiently great to require the services of two or more "*B*" operators, and the "*A*" operators are consequently provided with order wires to each of the "*B*" operators so that in the event that the "*B*" operator regularly assigned to an "*A*" operator is busy she can switch her call to another operator, it has been found that it is not unusual for the "*A*" operators to distribute the work unevenly among the "*B*" operators. This is due to two reasons; in the first place the arbitrary assignment of order wires among the "*A*" operators may be at fault; secondly "*A*" operators sometimes become convinced that some particular "*B*" operator gives them better attention than the others do, with the result that they are inclined to send calls through to the favored operator which should go to other operators and thus overload her while her mates are not working at their full capacity.

The Ideal Condition.—It is apparent from the foregoing paragraphs that to secure the ideal condition of maximum efficiency in manual operation it is necessary to supply the work during all hours of the day to each operator on duty in her own position so that she never has to reach into the positions on either side of her; to supply the same amount of work to her during each hour of the day and during each moment of each hour; to supply the work at the maximum rate at which she can handle it properly, without excessive nervous or physical strain; and, in the case of "*B*" operators, to make it impossible for the "*A*" operators to show favoritism. The nature of telephone traffic is such that it is impossible fully to realize all of these conditions, but several kinds of equipment which have been more or less successfully used to secure the ideal condition will be described in the remaining portion of this chapter.

Christensen's Electropneumatic Selector.—This selector which is the invention of Mr. T. V. Christensen, assistant chief engineer of the Copenhagen Telephone Company, Copenhagen, Denmark, and is patented and manufactured by the L. M. Ericcson Manufacturing Company of Stockholm, Sweden, is used in Scandinavia as an auxiliary to manual switchboards to distribute the load among "*A*" operators and among "*B*" operators. The system for promoting better distribution among "*A*" operators is called the "Operator's Aid System" and is an application of the Christensen selector devised by Director Fr. Johannsen of the Copenhagen Telephone Company,

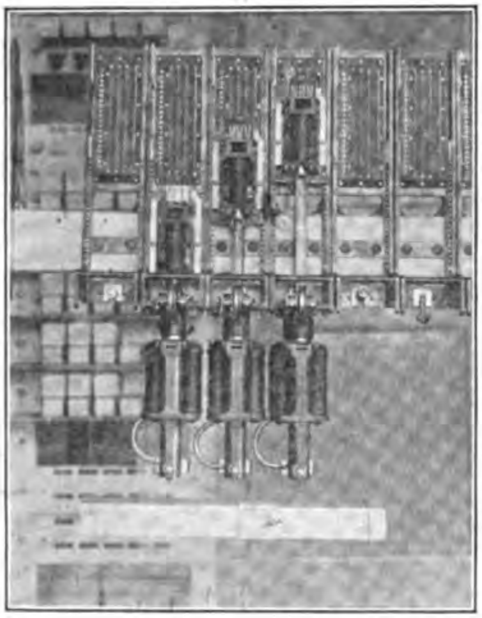


FIG. 152.—View from below of three Christensen pneumatic selectors.

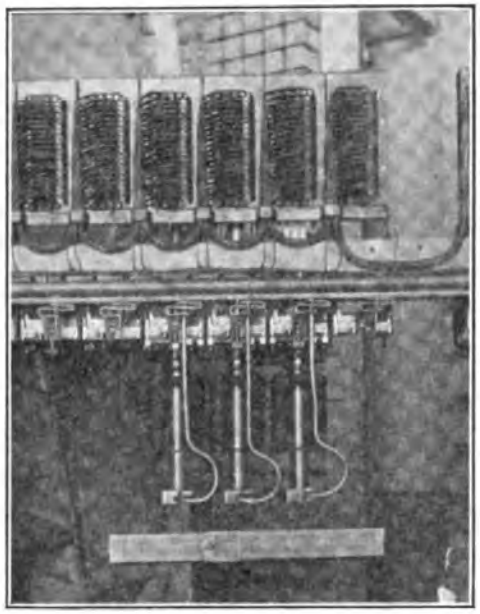


FIG. 153.—View from above of Christensen pneumatic selectors.

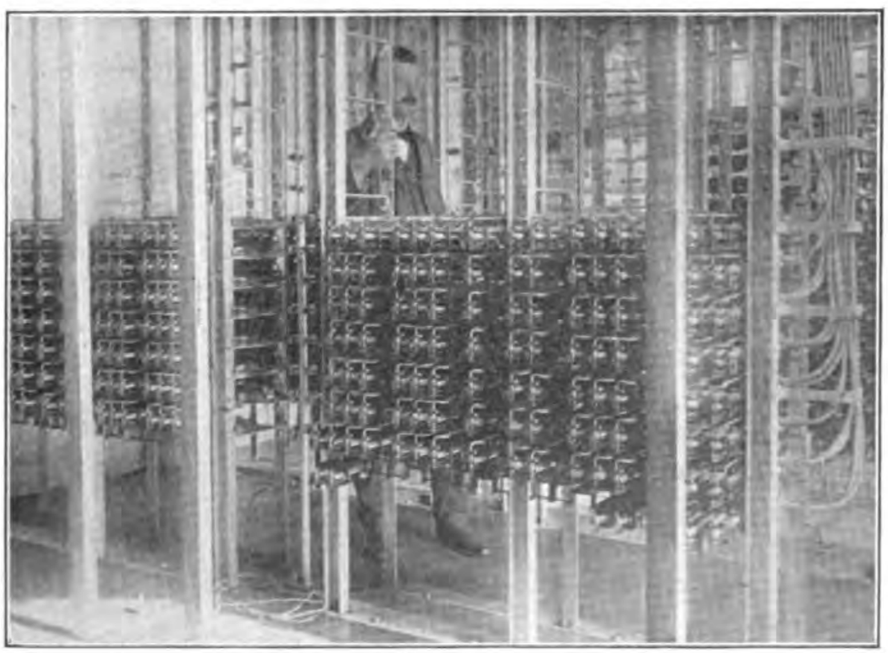


FIG. 154.—Racks with Christensen pneumatic selectors mounted upon them.

while the system for securing better distribution of the work among "*B*" operators is called the "Automatic Order Wire System."

This selector, which belongs to the line switch type, differs from other

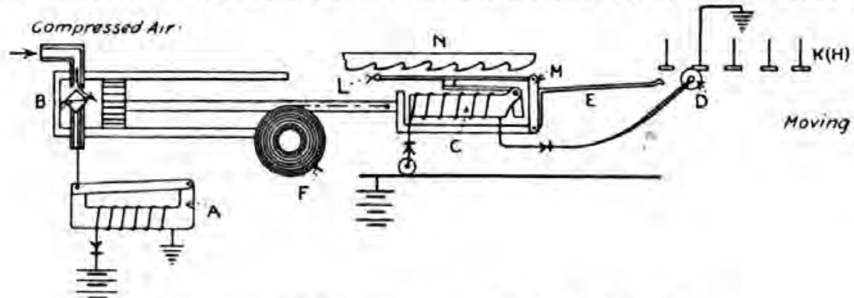


FIG. 155.—Christensen pneumatic selector moving.

well-known selectors both in its construction and in its method of operation. The motion is rectilinear (not rotating) and the selectors are constructed to find an idle line among twenty lines.

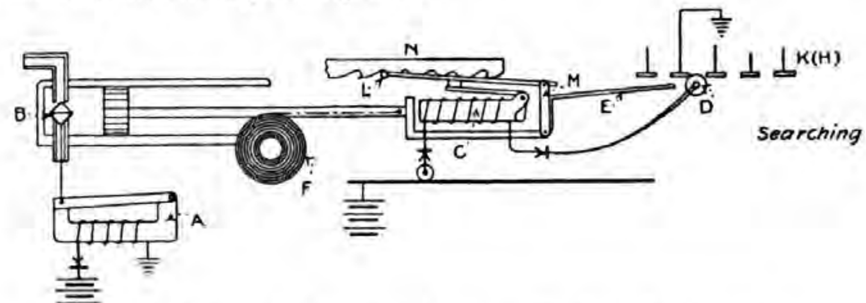


FIG. 156.—Christensen pneumatic selector "searching."

Fig. 152 is a view of the selectors from below, and Fig. 153 is a view from above. For comparing the dimensions an ordinary slide rule is shown.

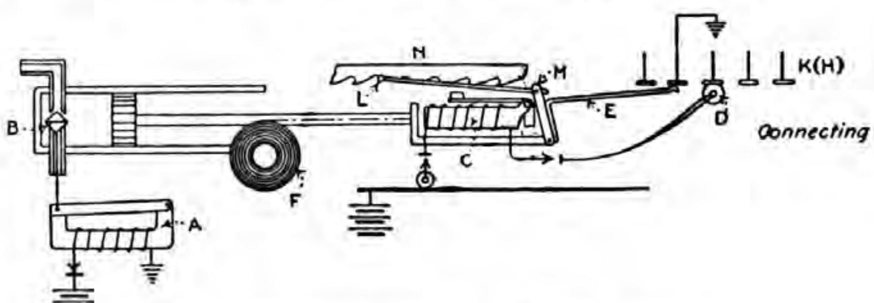


FIG. 157.—Christensen pneumatic selector "connecting."

Fig. 154 shows the iron framework with the selectors arranged in horizontal rows, each row having space for twenty.

Figs. 155 to 157 are sketches showing the working method of the selector.

Fig. 158 is a diagram of the selector parts and circuits.

The motive power consists of compressed air. A two-coiled electromagnet. *A* opens a valve *B* which admits the compressed air into a cylinder and causes a piston to move onward (Fig. 155). The search mechanism with the search magnet *C* and the searching contact roller *D* besides the necessary contact springs *E* are attached to the piston rod. The return motion takes place by the aid of a watch spring *F* when the valve closes off the compressed air.

In most selector constructions the motion ceases when the motive power (electrical current) is cut off, but in this selector the motive power (air pressure) continues while the motion is stopped by a mechanical catching device. This is arranged in such a way that the air, when the motion ceases, presses

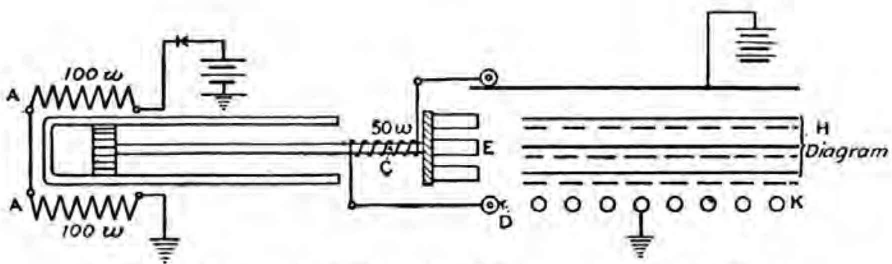


FIG. 158.—Diagram of circuit of Christensen pneumatic selector.

the moving contact springs *E* against the fixed contact pieces *H* belonging to the talking and signalling wires of the selected line. When the searching contact roller *D* slides over a search contact *K* which is in connection with an idle line, this contact being grounded, the search magnet will attract its armature. This will cause a pin *L* which is connected by the means of an elastic link system *M* to the search magnet to be raised up into a slanting notch in the brass rail *N* (Fig. 156). Here the pin catches and while the air continues to press on the piston the link system will yield and cause the movable contact springs *E* to be pressed upward against the fixed contact pieces and the contact strips *H*, by a pressure of 200 gr. per contact. The contact springs will thus connect the contact strips with the selected wire's bank contact pieces (Fig. 157) and the circuit desired will be completed.

When the controlling magnet *A* is deprived of current the valve *B* closes off the compressed air and the watch spring *F* draws the piston back. When returning the pin will be prevented from catching in the notches in the brass rail *N* by the shape of the notches.

In case of the selector not finding an idle line at first, a contact is arranged in the circuit of the magnet *A* which causes the selector to go backward and forward until it finds an idle line. The speed of the selector is such that but 0.6 second is required for an investigation of 20 lines.

The amount of air necessary is very small as each selector consumes only about 1.2 liters of air at atmospheric pressure per hour.

The entire movable part of the mechanism can be exchanged in about 35 seconds should any complications arise.

The Automatic Order Wire System.—Fig. 159 is a diagram of the circuit of the Christensen selector employed on order wires from "*A*" operators' positions to "*B*" operators' positions. The selector is also used between "*A*" operators' positions and toll-recording positions, between "*A*" operators' positions and information operators, etc.

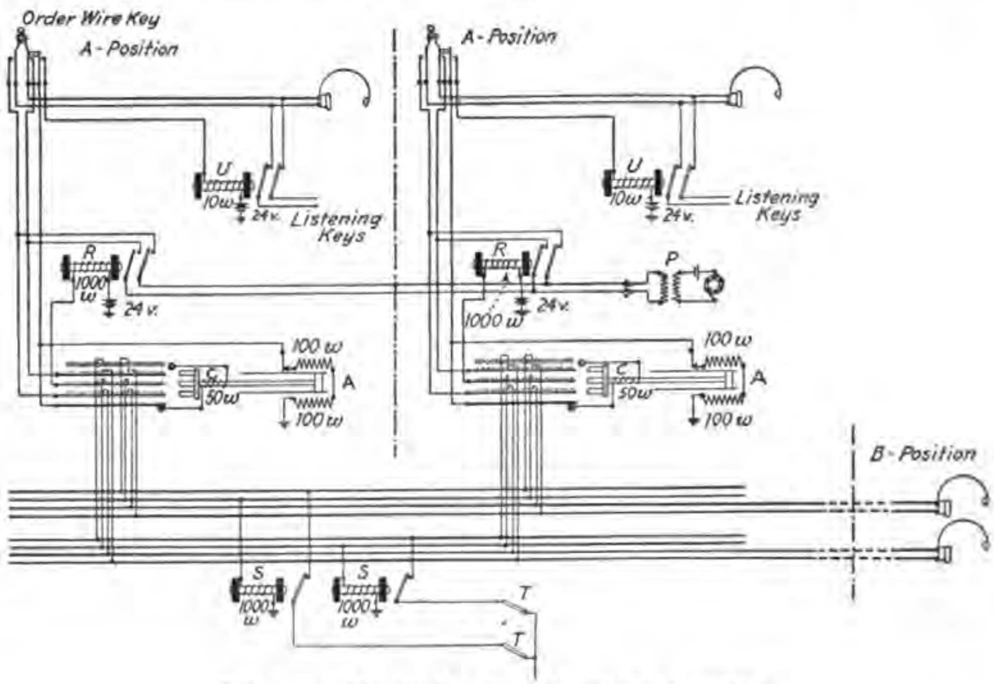


FIG. 159.—Circuit of automatic order wire system.

The operation of the circuit between "*A*" and "*B*" operators is as follows: When the "*A*" operator presses her order wire key she closes circuit from battery through the relay *U* and the two 100-ohm windings of electromagnet *A* to earth. Relay *U* disconnects the operator's telephone circuit from the listening keys of her cord circuits thus automatically cutting off the waiting subscriber while a "*B*" operator is selected and given the subscriber's order. The electromagnet *A* admits air to the piston of the selector, the contact fingers of which immediately move forward over the bank contacts. As soon as contacts corresponding to an idle order wire are found the search magnet *C* is energized through circuit from earth through one of the switches *T* the back contact of the 1000-ohm relay *S*, corresponding to the particular order wire on which the searcher stops, the bank multiples of this order wire, the corresponding search contact, the roller of the searcher, winding of *C*, the other roller of the searcher and thence to battery through the winding of relay *U*.

The energization of *C* causes it to attract its armature which instantly stops the searcher and presses the contact fingers down on to the banks. The order wire seized is immediately guarded against seizure by another searcher because the corresponding guard relay *S* attracts its armature and breaks the circuit from earth through the search contact multiple of the order wire. The circuit through *S* is from earth through the winding of *S*, the contact finger of the searcher, the winding of relay *R* to battery.

While the searcher is in motion a buzzer signal is given to the "*A*" operator from the buzzer current generating machine *P* through the back contacts of relay *R* and the contacts of the order wire key, but as soon as the searcher finds an idle order wire and *R* is energized through the circuit just described the buzzing stops, the operator thereby knows that she is on an idle order wire and she immediately transmits the order to the "*B*" operator who assigns an idle trunk in the usual way. When the "*A*" operator releases her order wire key the electromagnet *A* will release the air and the selector will return to normal position and relay *S* will again connect the search contacts to ground. Each "*B*" operator can be easily cut off at any time by throwing the switch *T* of the corresponding order wire.

With this arrangement each operator needs but one order wire key for each office to which she trunks connections. The efficiency of the "*A*" operators and the "*B*" operators is considerably increased and the overloading of "*B*" operators is made practically impossible.

Operators' Aid-System.—The "Aid-System," which can be used not only in new but also in old exchanges employing either magneto or common battery switchboards of the double cord type, is designed to lighten the burden of the "*A*" operators in busy moments. It requires only slight alterations in the switchboard. As installed in Copenhagen, three of the answering cords in each operator's position are connected with automatic selectors, and in this way changed into "transfer cords." When an operator uses one of these cords to respond to a call, the call is automatically transferred to a disengaged colleague by the automatic selecting device, which can search for an idle operator in a group of as many as twenty operators. Even in extremely busy moments the probability of finding every operator engaged in the group of twenty is small, and consequently the transferred subscriber will quickly secure attention.

For receiving "transfer calls" there are four "receiving cords" installed in each position. Both the transfer and the receiving cords are of the single type, or in other words, when a transfer has been completed the transfer cord and plug used to answer the subscriber constitute one end of a complete cord circuit, and the receiving cord and plug used to complete the connection

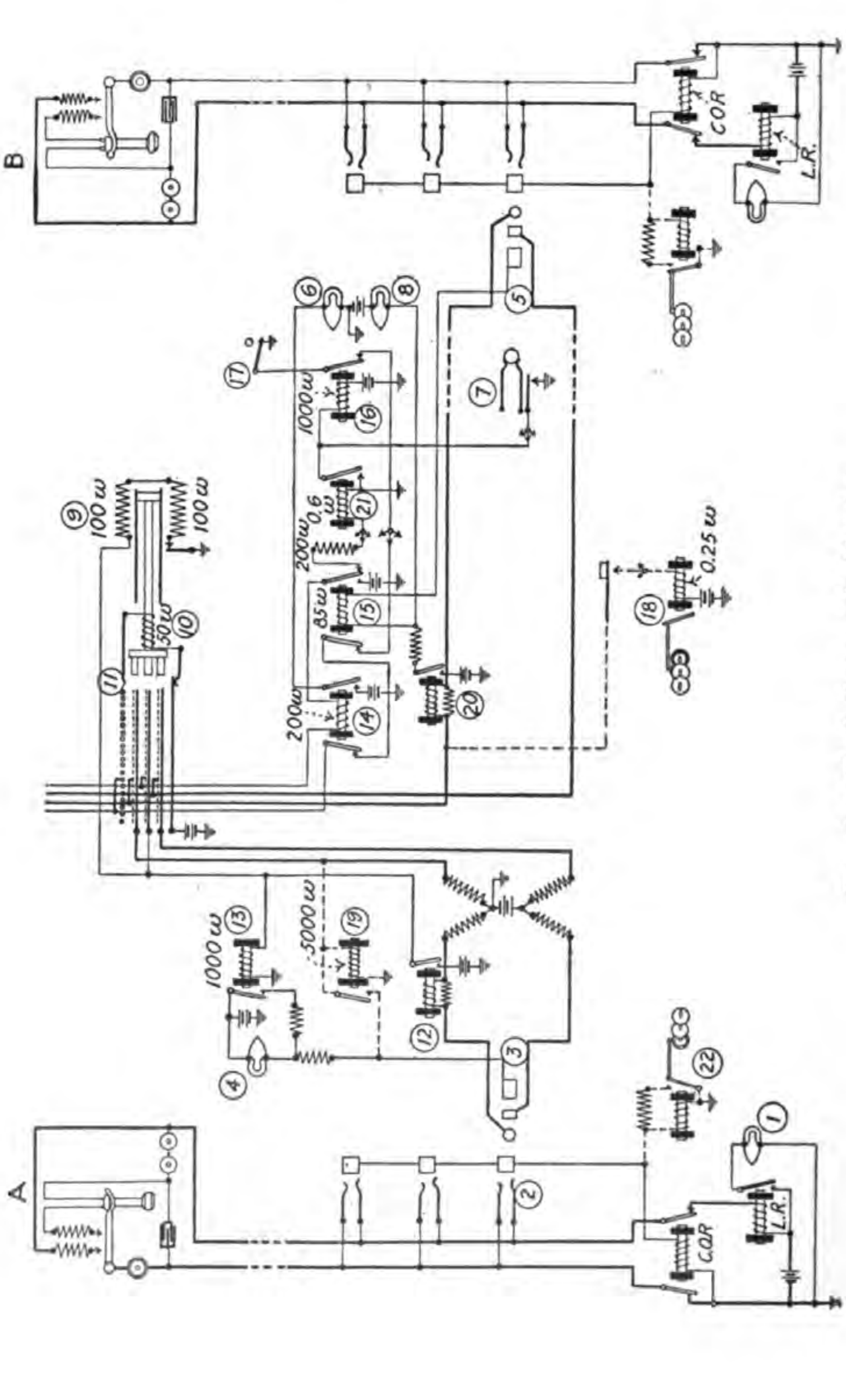


FIG. 160.—Circuit of operator's aid system.

to the called party constitute, for the time being, the other end of the same cord circuit.

When a selector transfers a connection to an idle cord in an idle operator's position, a lamp associated with the cord lights, calling the attention of the operator at that position to the transferred call. The detailed circuits of the system as installed in Copenhagen are shown in Fig. 160.

If subscriber *A* should remove his receiver from the switchhook to make a call, current will flow through his loop and line relay *L.R.*, which will close the circuit through the line signal lamp 1. When the operator responds, by inserting the plug (3) in the jack (2), current will flow from earth, through one winding of the repeating coil, the cord relay 12, tip of the plug, tip spring of the jack, the subscriber's loop, the ring spring of the jack, ring of the plug and the other winding of the repeating coil to battery. When relay 12 operates it will close circuit from battery, through relay 13 to earth. At the same time the cut-off relay *C.O.R.* of the line will cut off the line relay because it will be energized through circuit from earth, through winding of *C.O.R.*, sleeve of the jack, the sleeve of the plug, lamp 4 and the contact of relay 13 in multiple to battery. At the same time that relay 12 closes the circuit through the relay 13, it will also close circuit through the double wound electromagnet 9 of the pneumatic selector. The operation of this electromagnet will admit air to the cylinder of the selector, which will shove the piston head forward and cause the search spring 11 to move over the search contacts until an idle contact, that is a contact connected to earth, is found. Then a circuit will be closed from battery through the search magnet winding 10, search spring 11, search contact, the break contacts of relays 14, 15 and 16, and the switch 17 to earth. Search magnet 10 will immediately press the three contact fingers down so that each will close circuit between its respective rail and the bank contact corresponding to the idle search contact. The two sides of the talking circuit, shown in heavy lines in the drawing, will thereby be extended through to the receiving cord plug 5. At the same time circuit will be closed from battery, which is connected to the middle rail of the bank through the contact controlled by relay 12, through relay 14 and relay 21 in series to earth. While relay 14 is operated, circuit will be closed through the lamp 6, corresponding to the receiving cord, which signals the operator at the position in which the receiving cord is placed. When the operator inserts plug 5 into the jack of the line leading to the telephone (*B*) of the party to be called, current will flow from earth through the cut-off relay *COR* of the called line, the sleeve of the jack, the sleeve of the plug, relay 15 and the lamp 8 to battery. When "15" operates, it breaks the circuit through "14," which in turn breaks the circuit through lamp 6. Lamp 8 glows until the called party responds, when the talking current operates the cord relay 20, which shunts out lamp 8. When the calling subscriber hangs up his receiver, relay 12 will release its armature and then relay 14 will again attract its armature, being energized by circuit from earth through relay 13, the middle rail and the corresponding bank contact of the selector to the winding of relay 14 and the make contact of relay 15 to battery. This will cause the lamp 6 to light again and give the disconnect signal to the operator at the receiving cord position.

When the plug 5 is removed from the jack, the relay 15 will drop its armature, breaking the circuit through 14, and at the same time breaking the circuit through the electromagnet 9, and as a consequence, the piston of the selector will return to normal position. If the called party hangs up his receiver before the plug is withdrawn from the jack, the lamp 8 will give the disconnect signal so soon as the armature of the cord relay 20 falls back.

It was stated that the selector, when searching, would stop on a cord, the search contact of which was connected to earth through the back contact of its relay 16. The wiring of this relay in each position is such that if any listening key (7) in a position is thrown, the earth connection made thereby will complete the circuit through "16" and cause it to break the earth connection of all search contacts corresponding to receiving cords in that position. By this feature the selector is prevented from transferring a call to an operator who is engaged. It is therefore seen that the selector not only picks out idle cords, but idle operators also. When any operator's position is vacant, the switch 17, corresponding to the position, is thrown and this prevents the transfer of any calls to it.

Counting Messages.—In Copenhagen no count is made of the messages, and therefore in the "Aid-System," as installed in that city, no provision is made for counting them. The design of the circuit is such that message counters could readily be added by connecting them in as shown in the circuit diagram of the "Aid-System." A dotted line shows how a push-button may be connected to the tip side of the receiving cord so that when it is depressed it will not only operate the position counter 18, but will also operate the subscriber's message counter by causing the 5000-ohm relay 19 to operate and close circuit from the tip side of the cord through to the calling subscriber's message counter 22. Although the counting takes place over one side of the talking circuit, it will not cause any inconvenience, because the counting is usually done after conversation is finished. If counters are not used the relay 19 is unnecessary and is not installed.

Rules for Use.—The "Aid-System" must be used according to certain simple rules, which are essentially restricted to the following:

(*a*) A call that is to be transferred, must be transferred at once. This rule is not difficult to impress on the operator. Whenever she sees that a calling party will have to wait too long she transfers his call. It is against the rule to make a transfer until both the operator and her two neighbors are engaged and one lamp is lit ahead of the one corresponding to the call to be transferred.

(*b*) A call that has been transferred from another position shall be given preference, even if the operator in order to answer is obliged to transfer one of her own calls.

Results Secured by the Aid-System.—Exhaustive trials as to the working and economy of the "Aid-System" were made in the central office in Copenhagen, called "Obro." There were fifteen "*A*" operators with 90 per cent. out-trunking. At the beginning of these trials (spring of 1909), fourteen of these positions each had 160 working subscribers' lines. The "Aid-System" allowed them in the course of a year to assign 220 jacks to a position, reducing the number of positions in use from fourteen to ten.

Two other improvements are reported, as follows:

Shorter waiting time for subscribers. Vacated operators' positions now available for growth.

Part of the economy secured was the result of close study of conditions, but the "Aid-System" was a large factor. It appealed to the operators and secured their hearty co-operation.

The Stromberg-Carlson Traffic Distributor Installation.—The Stromberg-Carlson Manufacturing Company of Rochester, N. Y., has made two installations of the traffic distributor type, one in one of the telephone offices in Rochester, N. Y., the other in York, Pa. The details of these installations are not available for publication, but the general principles are these:

A number of the busiest lines entering the office are terminated in automatic line switches of the rotary type. The trunks from these line switches are divided among the "*A*" operators. The calls on these busy lines are distributed among the "*A*" operators. By arranging it so that a line switch will seek an operator who is not engaged in handling calls from the lines permanently assigned to her and terminating in line jacks in her position, much can be accomplished in the way of distributing the load and increasing the efficiency of the operators.

The Automatic Electric Company's Traffic Distributor Equipment.—Several years ago the Automatic Electric Company brought out equipment for distributing traffic more completely than by the Christensen or the Stromberg-Carlson method.

In the general scheme of the Automatic Electric Company, all subscribers' lines terminate in line switches of the Keith type. The trunks from the line switches terminate in cords and plugs in the "*A*" operators' positions. If not more than ten operators' positions are required, one of the ten trunks outgoing from each line switch unit will lead to each operator's position. In this way the traffic from each unit will be distributed among all positions. If the office should be sufficiently large, the scheme includes secondary line switches in which the trunks from the primary line switchboards would terminate while the trunks from the secondary line switch groups would lead to the operators' positions.

From the description of these line switches, which has been given in other chapters, it will readily be understood that if a subscriber to an office in which the traffic distributor was installed, should lift his receiver from its switch hook, the line switch in which his line terminated would extend his line to an idle cord circuit. A lamp associated with the cord circuit would immediately light, the operator would throw her listening key, take the subscriber's number and complete the connection by plugging into the multiple in the customary way; or, if the subscriber desired a party connected to another office, she would press her order wire key and secure a trunk to the distant office from the proper "*B*" operator, as in regular manual practice.

The plan embodies circuit arrangements which make it possible for any operator to leave her position, after first making busy the trunks terminating in it, by throwing keys associated with those trunks. During less busy hours, the work to be done is placed immediately in front of the operators remaining at the switchboard so that they never have to reach over the positions on either side of them. This feature is intended to eliminate, so far as is possible, the loss of efficiency due to the first difficulty mentioned in the opening paragraphs of this chapter.

The inventors have worked out theoretically the efficiencies which might be expected to be secured by its use. Apparently their deductions are approximately correct, but at this writing no plant has been in service long enough to determine fully what the results will be in practice.

It is expected that the merging of all traffic into one large group will (as far as possible) even up the load between positions and distribute momentary fluctuations. Greater efficiency certainly should result, because of proportioning the work to each operator's ability and offering rewards for high efficiency.

It has been calculated that the omission of the labor of inserting and later removing the answering plug will reduce the operator's work 22 per cent. (single office, individual line, flat rate). It is expected to increase the actual busy hour working time from two-thirds to five-sixths of the hour. This will make a total increase in efficiency of 60.6 per cent. in the busy hour, requiring 38 per cent. less operators than usual.

Practice shows that an operator's average load is about 75 per cent. of her busy hour load. If traffic distribution will enable the busy hour load to be maintained, it will add 33 1/3 per cent. to the efficiency. This reduces the operator-hours for the day to about 47 per cent. of that required without distribution.

Fewer busy hour operators means a smaller switchboard, with saving in multiple sections, jacks, cable and equipment.

Of course the efficiency estimated above could not be realized where a large percentage of calls is trunked to other offices, or where the operators' work is slowed down by measured service conditions, etc., but doubtless the saving would still be a great one.

Typical Traffic Distributor Circuits Using Keith Line Switch Equipment.—In Fig. 161 is shown the circuit of a simple traffic distributor arrangement using primary Keith line switches. The line switch has associated with it a multiple jack, which is mounted in the manual switchboard. Each subscriber's line terminates in these two pieces of apparatus. The telephones used with this equipment may be of any regular common battery manual type.

When a calling subscriber removes his receiver from the switch hook, the line switch operates in the usual manner and extends the line to a trunk. The grounding of the same bank contact which moves the master switch also energizes the chain relay *C.R.* whose function has been fully described. Current is now supplied to the calling subscriber's loop

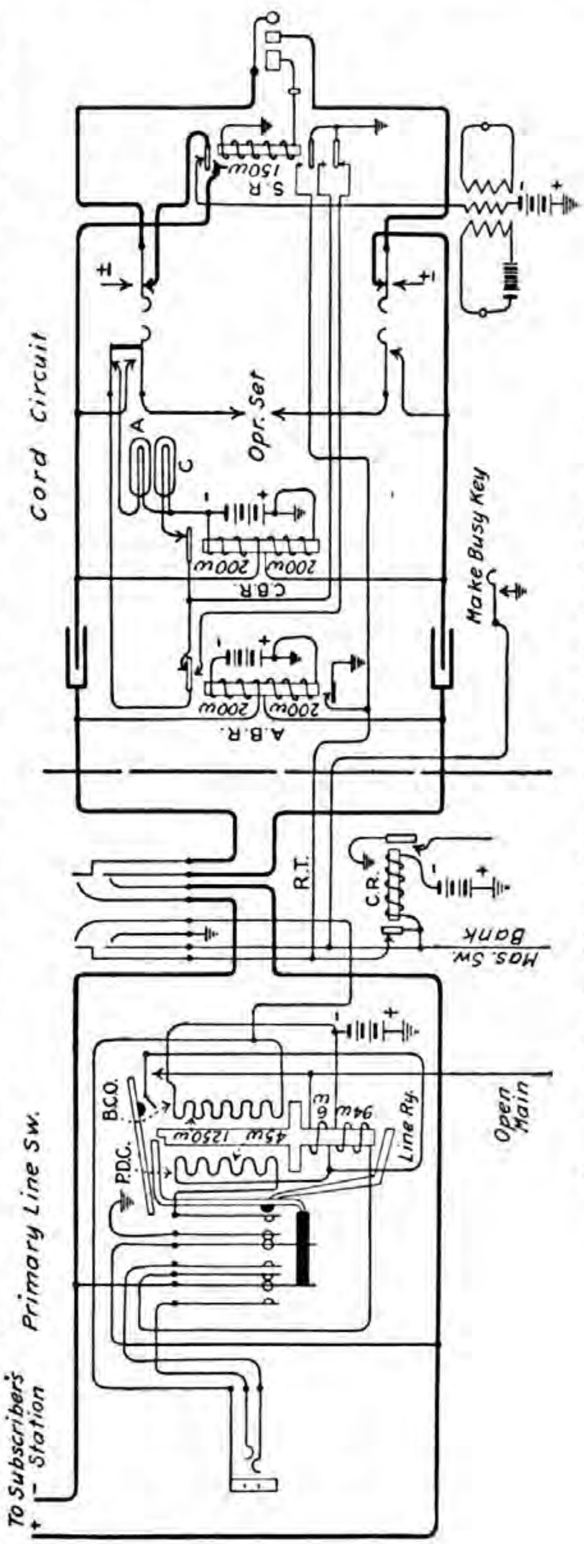


FIG. 161.—Circuit of line switch and cord in a traffic distributor system.

through the windings of the answering bridge-relay (*A.B.R.*) of the cord circuit. *A.B.R.* closes circuit from earth through the release trunk *R.T.*, the primary line-switch bank contacts, and the bridge cut-off winding of the line switch to negative battery. The completion of this circuit causes the line switch to hold its plunger in the bank. At the same time *A.B.R.* closes circuit through the answering signal lamp *A*. The operator responds by throwing the listening key of the cord circuit corresponding to the glowing lamp, thus breaking the circuit through *A* and connecting her operator's set across the line. She takes the subscriber's number in the manner customary in regular manual practice, then picks up the plug of the cord circuit and touches its tip to the sleeve of the jack of the desired subscriber's line. If this line is busy, the sleeve will be connected to earth, because it is connected to the release trunk of the line switch. Therefore, a circuit will be completed from earth through the tip of the plug, contacts of the sleeve relay, *S.R.*, and one winding of the operator's induction coil to negative battery, giving her the customary busy click. If the line is not engaged, she inserts the plug into the jack, whereupon current immediately flows from earth through the winding of the sleeve relay, sleeve of the plug, sleeve of the jack and the bridge cut-off winding of the called party's line switch to negative battery. When that bridge cut-off relay armature operates, it disconnects the line relay winding and extends the connection through to the called party's telephone, as in full automatic practice. At the same time the sleeve relay connects the release trunk to earth, preventing the line switch from being released until the operator disconnects. This relay also closes circuit from earth through the calling signal lamp *C*, which remains lighted until the called party responds, when its circuit is opened by the calling bridge relay *C.B.R.*, through whose windings talking current is supplied to the called party.

The called party is rung manually by means of a ringing key.

When the calling party replaces his receiver on the switch hook, lamp *A* again lights; and when the called party hangs up, lamp *C* lights. Either party may flash the lamp belonging to his end of the circuit at any time. When conversation is completed and the operator withdraws the plug from the jack, the line switch releases.

At any time the operator wishes to make any particular cord circuit busy, because it is in need of repairs, she may do so by throwing the "make busy" key. When she leaves her position she must throw the "make busy" key of each cord circuit terminating in it, thus causing all calls, which might have come to her position, to be automatically distributed among the remaining positions. Since, if line switch plungers of the ordinary type should be used, some plunger poised over a trunk leading to this operator's position might be out of engagement with the master switch shaft, at the time she leaves her position, it is necessary to follow either one of two practices to prevent a calling party being trunked to her position while she is absent.

One practice is to install a key in the chief operator's desk, which the chief operator presses for an instant at any time an operator leaves her

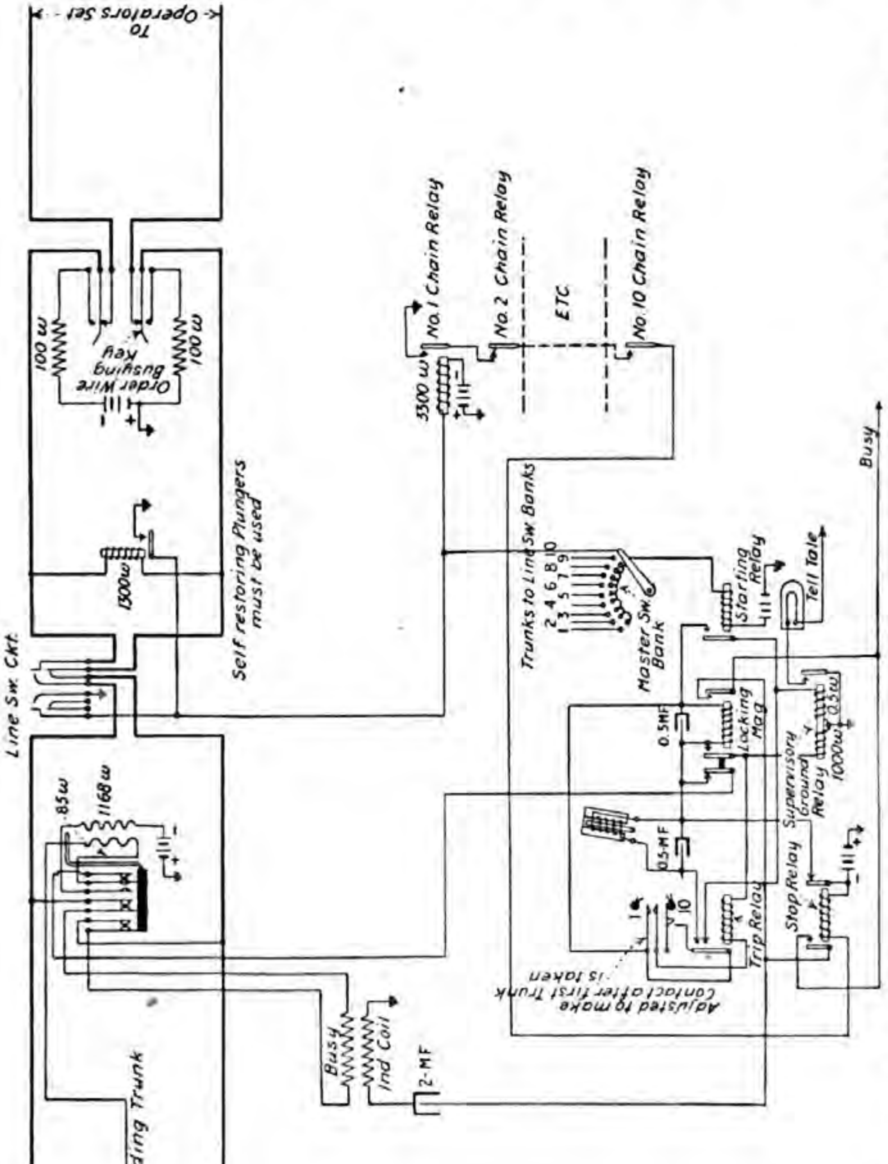


FIG. 162.—Circuit of traffic distributor equipment used on order wires from "A" to "B" operators.

position, and which causes all of the master switches to swing their master shafts through their complete arc, thus picking up any plungers which are out of engagement.

Another practice is to use what is called a self-restoring type of plunger.

The construction of this plunger is such that when it has withdrawn from the bank it instantly lines up with the other idle plungers.

In a traffic distributor arrangement for a much larger office, secondary line switches are required on account of the large number of operators' positions, and where all service is measured so that each call must be registered, by the operator handling it, a meter is associated with each subscriber's line.

Keith Line Switches Used on Order Wires Between "A" and "B" Operators.—A circuit for use in distributing the load among "*B*" operators, who receive their orders over order wires from "*A*" operators, is shown in Fig. 162.

The line switch used is of the "secondary" type, because no bridge cut-off relay is required. The switch is operated and kept in operated condition during the conversation between an "*A*" and "*B*" operator, by means of the holding trunk wire, which is connected to earth when the "*A*" operator depresses her order wire key. This system is intended for use only between branch offices of considerable size. Each "*A*" operator's position would be equipped with one order wire key only for each other office unless it were thought that a second key was necessary for use in case the first key or some of the circuits or apparatus connected with it, should require repairs.

The circuits of the operators' sets and of the order wire key are not shown, because they might be of any ordinary design. The only departure from regular practice would be that already mentioned, that is to arrange the key so that it would connect the holding trunk to earth.

The operation of this system is as follows:

An operator desiring to transmit an order to a "*B*" operator will depress the order wire key for the proper office, whereupon the holding trunk will be connected to earth and the line switch will thrust its plunger into bank contacts corresponding to a trunk to an idle "*B*" operator. The "*A*" operator's talking set will be connected to the order wire at the same time, and without waiting a response from the "*B*" operator she will immediately order up the connection desired, whereupon the "*B*" operator will assign an idle trunk in the usual manner. When the "*A*" operator removes her finger from the order wire key, the line switch restores to normal position.

A "*B*" operator's position may be made busy to all incoming calls when desired by throwing the order wire busy key shown in the diagram, thereby operating the 1300-ohm relay bridged across the circuit. The effect is to connect to earth the master switch bank contact corresponding to the trunk. At any time when the "*B*" operators of a certain group are all busy, all the chain relays of that group will be energized, the circuit of the stop relay will be closed and the busy circuit will be closed through the primary of the busy induction coil. Since the negative battery connection to all line switch pull-down coils is cut off when the stop relay is energized, no line switch can be operated under these conditions, and the busy signal is transmitted through the back contacts of the line-switch relay to any "*A*" operator depressing an order wire key. The instant any chain relay is released, however, the line switch of the operator who has depressed her order wire key seeking a connection will seize the idle order wire trunk. The busy signal is closed during the operation of the master switch mechanism also.

The apparatus may be used either with, or without, what is called the position blocking feature, as desired. That is, it may be arranged to distribute the load evenly among the "*B*" operators, regardless of the relative efficiencies of the operators. With this arrangement two or more "*A*" operators might secure connection to a given "*B*" operator simultaneously,

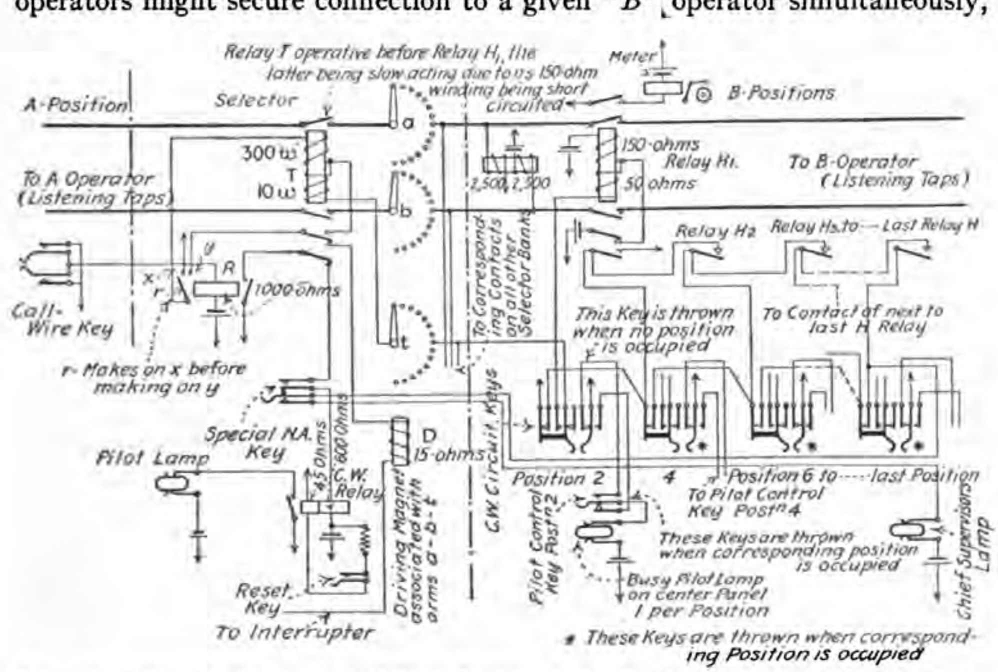


FIG. 163.—Circuit of Siemens-Halske call wire selector installed at the Central exchange in London.

as in straight manual practice, but on the whole the work would be evenly distributed among the "*B*" operators.

Since with the blocking feature any "*B*" operator's position is busy, however, for such a very short period of time, that is during the time only that an "*A*" operator's order wire key is depressed, and since no appreciable period of time need elapse between the release of a trunk by one line switch and the seizure of it by another, it would appear that the position blocking arrangement would not only be the most efficient and systematic one generally, but that even at rush moments it will handle the traffic as well as the other plan, because no matter how great the need for her services may be, a "*B*" operator cannot take two orders and put up two connections at the same time.

Siemens-Halske Co.'s Traffic Distributor Equipment.—An automatic call-wire selecting equipment installed by Siemens Brothers & Company Limited, and of the Siemens-Halske Company's design has recently been put into service on trial in the Central Exchange, London. The following description of it is quoted from a paper presented by Mr. W. Slingo before "The Institution of Electrical Engineers."

An automatic call-wire selecting equipment has been installed at the Central Exchange, London, which has for its object the selection and isolation of a call-wire when one is required by an "*A*" operator. There are ten call-wires in the group affected, and they were, before the introduction of the new conditions, operated from ten call-wire keys, the circuits of which were multipled over 160 "*A*" positions. When the selecting equipment was introduced the ten keys per position were replaced by one key per position.

Each operator is given a selector which rotates when she depresses her call-wire key. (See Fig. 102 for selector which is like that used in London, but has ten bank contact sets instead of fifteen.) The rotation continues until the wipers find an idle "*B*" operator, when the "*A*" operator is able to pass her call. Fig. 163 gives the circuit arrangement.

DETAILS OF SELECTIVE MECHANISM

Each "*A*" position is provided with a selector, and each selector has associated with it two relays, an "*R*" relay and a "*T*" relay. The contact banks of the selectors are multipled together and are connected to the group of "*B*" positions, so that each "*B*" position is represented on each bank by a separate set of contacts. The "*B*" positions have also each associated with them an "*H*" relay and a retardation coil.

The "*a*" and "*b*" arms of the selectors are connected with the "*A*" operator's telephone circuits through contacts of the associated "*T*" relays, and the selector bank contacts are connected with the "*B*" operator's telephone circuits through contacts of the "*H*" relays.

On the depression of a call-wire key by an "*A*" operator, the arms of that selector which corresponds to the particular position concerned commence to seek over the contact bank, and automatically come to rest on the contacts of the first accessible and disengaged "*B*" position. The "*T*" relay associated with the "*A*" position and the "*H*" relay associated with the "*B*" position are now operated, so that the two speaking circuits are connected.

On the release of the call-wire key on the "*A*" position the selector arms do not move from the position occupied. The "*T*" and "*H*" relays are, however, released, and disconnect the "*A*" operator's telephone circuit from the "*B*" operator's circuit.

During the time the call-wire is in use the "*T*" relay remains operated, and this renders the multiple contacts, on the particular "*B*" position, engaged against the other selectors by reducing the potential on the "*t*" contacts from 22 volts to nearly earth potential. The "*T*" relays of other selectors whose arms may pass over these contacts therefore will not be operated.

When a "*B*" position is rendered inaccessible to the selectors by the "*B*" position call-wire key being normal, the battery is disconnected from the "*t*" contacts corresponding to the position, so that in this case also the "*T*" relays of searching selectors will not be operated.

Motor interrupters are used for supplying the interrupted current to drive the selectors. These are provided in duplicate, and there are also two separate sets of supply mains available for driving the motors.

The interrupters themselves have each twenty sets of contact springs (ten of which are at present spare). Each spring set supplies driving current to twenty selectors, these being distributed between four time-fuse mountings, so that only alternate positions at the switchboard are supplied through the same fuse and spring set.

In order to absorb the spark which would otherwise occur at the contacts of the interrupter springs, a circuit consisting of a 0.5 ohm resistance coil and a 4 m.f. condenser in series is bridged across each pair of springs.

The current supplied to the interrupter spring sets is taken from a 30-volt supply.

Operation of Circuits.—On the depression of a call-wire key by an "*A*" operator a circuit is closed through relay *R*.

Relay *R* operating contact *r* is arranged so that the spring *x* makes contact with the spring *r* before contact is made with the spring *y*; *r* therefore first prepares the circuit of the testing relay *T* from earth through *T* 300 and 10 to the "*t*" arm of the selector; and second, completes the circuit of the driving magnet.

The other contact of relay *R* is used to complete the circuit of the night-bell relay and to start the motor interrupter during the period of night working.

The circuit of the selector-driving magnet now being completed, the selector arms "*a*," "*b*," and "*t*" are driven over the bank of contacts representing the "*B*" positions, and when a set of contacts representing a free "*B*" operator is found, the circuit of relays *T* (300 and 10-ohm coils in series) and H_1 (50-ohm coil only) is completed through the arm "*t*" and a "*B*" position call-wire key.

Relays *T* and H_1 are now operated, but relay H_1, since its 150-ohm coil is short-circuited by one of its own contacts, is slow acting, and relay *T* is thus allowed to operate slightly before it.

The line contacts of relay *T* connect the "*A*" operator's instrument circuit to the selector arms "*a*" and "*b*," and current then flows through the 2500 + 2500 ohm coil and the "*A*" operator's instrument circuit. A click is given in the "*A*" operator's receiver, denoting that a free "*B*" operator has been found, and the potential difference between the arms "*a*" and "*b*" falls to a small fraction of 22 volts.

Another contact of relay *T* disconnects the circuit of the driving magnet, preventing further movement on the part of the selector arms, and also engages the "*B*" position against other selectors by short-circuiting the 300-ohm coil of relay *T*. Relay *T* now holds through its 10-ohm coil, and the "*T*" relay of any other selector testing on a multiple of this contact will have its 300-ohm coil shunted by the 10-

ohm coil of the engaging relay T, and will consequently not receive sufficient current to operate.

The line contacts of relay H_1 close, completing the circuit of the speaking leads between the "A" operator's and the "B" operator's instruments. No appreciable click is produced in the "B" operator's receiver when these contacts close, as the potential difference existing between the "a" and "b" wires is by this time reduced to a small value (see above).

Of the further three contacts of relay H_1 one contact closes and operates the meter associated with the "B" position, registering one call; another removes the short-circuit from the 150-ohm coil of relay H_1; and the remaining contact completes the portion of the circuit of the chief supervisor's lamp which belongs to the particular "B" position.

The "A" operator will now pass the call to the "B" operator, and will be assigned a junction in the usual manner; she will then release the call-wire key at the "A" position and disconnect the circuit of relay R.

Relay R releases.

Contact r disconnects the circuit through the relays T and H_1, and here again it will be noted that the circuit of the driving magnet is opened at contacts x and y before the circuit of the "T" relay is disconnected, thus preventing any possibility of the selector stepping forward during the period of release.

Relays T and H_1 release.

Of relay T the line contacts disconnect the "A" operator's telephone circuit from the selector arms, thus preventing interference with other circuits when the arms commence to seek.

Of the other two contacts of relay T one prepares the circuit of the driving magnet for further use, and the other prepares the night-bell circuit and the motor-starting circuit.

Of relay H_1 the line contacts disconnect the "B" operator's telephone circuit from the contact banks of the selector and open the circuit through the retard coil K and the "B" operator's telephone.

Of the further three contacts of relay H_1, one releases the meter associated with the "B" position, another short-circuits the 150-ohm coil of the relay H_1, thus making it again slow-acting; and the remaining contact opens the circuit of the chief supervisor's lamp at this position.

When it is desired to render a "B" position inaccessible to the "A" position selectors, the call-wire circuit key on the "B" position is returned to normal. This disconnects the contacts on the "t" banks of the selector multiple from the "H" relay corresponding to that position. The "T" relays of selectors whose arms may seek over these contacts will therefore not be operated.

When the call-wire circuit key on a "B" position is normal a circuit is closed through: Positive, inside contact of call-wire circuit key, contact of pilot control key, busy pilot lamp, -22 volts. This lights the busy pilot lamp situated above the position. Should it not be necessary for this lamp to remain lighted its circuit can be disconnected by means of the pilot control key and the lamp extinguished. When the call-wire circuit key is not thrown another circuit is closed through: Positive, outside contact of call-wire circuit key, back contact of pilot control key lamp, -22 volts, and the lamp will again light.

The circuit for the chief supervisor's lamp is completed when all the "*B*" positions which have not been rendered inaccessible to the selectors are simultaneously engaged. The circuit will then be from -22 volts, through the pilot relay associated with the desk, the chief supervisor's lamp, contact of the special night-bell key, the contacts of relay *H* on those positions which are engaged, and the call-wire key contacts of those positions which are inaccessible to the selectors, to positive.

If an "*A*" position selector develops a mechanical fault a spare selector can be connected up to the "*A*" position affected as follows:

Take out the "*R*" relay fuse of the faulty "*A*" position, insert the "*R*" relay fuse of the spare selector and connect *a*, *b*, and *t* terminals of the two selectors together on the terminal strips above the selector racks. This procedure applies to other than mechanical faults on a selector, as is obvious from an inspection of Fig. 163.

If the supply to both interrupter motors fails the selectors must be adjusted by hand to distribute the traffic among the "*B*" positions according to the requirements of the exchange manager. The ordinary method of call-wire working will then apply.

CHAPTER IX

AUTOMATIC DISTRICT STATIONS IN CONNECTION WITH MANUAL CENTRAL OFFICES

The purpose of an automatic district station is to save cable and conduit between a district and the central office. Sometimes the outgrown line cable will serve as a trunk cable to the district station.

The same reasons which make district stations desirable in connection with automatic central offices create a demand for them in connection with manual central offices. These reasons are satisfied to better advantage with an automatic district station than with a branch, manually-operated switchboard, because, while the latter may be less expensive to install, it increases the operating cost, slows up the service, increases the chances for wrong connections, premature disconnections, and other troubles which are inherent to the setting up of connections where both "*A*" and "*B*" operators are required.

When an automatic district station is used, the calls from the branch office locality to the main office are handled as speedily as if the lines were connected directly to the central office. Calls going in the opposite direction preferably pass through two operators, but the second operator is located at the central office so that at nights and on Sundays economy may be practised by having one of the few operators on duty attend to the work at this "*B*" position also. With a branch manual switchboard it is always necessary to have some one on duty at all hours of the day and night.

There are other reasons which make district stations in connection with manual plants attractive under certain conditions. Sometimes a company has outgrown its multiple switchboard, or has reached a point in the growth of the switchboard where each additional section added to it is very expensive, because the multiple must be increased throughout the entire board. This expense can be saved by putting one or more district stations in some of the out-lying localities and reserving the line jacks and multiples of the central-office switchboard for the shorter lines. Sometimes the company's equipment has grown to the limit of its switchboard room, so that to enlarge it will require an addition to the building. This difficulty may also be met by the use of an automatic district station.

Again, a company may be expecting to change to some form of automatic equipment in a comparatively few years and may have decided which type of automatic equipment it will use and will, therefore, not wish to invest any more money than necessary in additions to its manual switchboard. Such additions may be avoided to a large extent in cities large enough to warrant the use of district stations, by installing one or more of them to take care of the required growth; and these stations will be available with slight changes, for use with an automatic central office when it is installed.

The average manual switchboard may be used with a large number of different district station arrangements, and such stations have been installed using the equipment manufactured by the Automatic Electric Company, the American Automatic Telephone Company, and the Siemens-Halske Company of Germany; but in order to make this chapter clear and concise, a limited number of typical arrangements will be outlined, and before explaining the details of circuits, several general plans will be discussed.

General Plans.—The first of these plans, which will be called Plan No. 1, requires no appreciable change in any of the circuits or equipment of almost any ordinary common battery multiple switchboard, and therefore may be installed in connection with almost any central office without large expense for changing or adding to the central-office equipment.

Plan No. 2 requires more changes than Plan No. 1 in the central-office switchboard, but is the easier and more economical of operation.

PLAN NO. 1

Incoming Calls.—In this plan the trunks incoming to central from the banks of the line switches or from finder switches installed at the district station terminate at the central office in the regular subscribers' line equipments of the multiple switchboard. The lines may be divided among the various "*A*" operators, or may be assigned to one operator. The former is the preferable plan when a comparatively small number of calls is made between district station subscribers; but where the percentage of local interconnections is large, it is better to have the incoming trunks go to one operator; and, preferably, to the one who also handles the outgoing calls to the district station, so that the interconnections may be made with the least effort.

If a district station subscriber desires a connection to a central-office subscriber, he removes his receiver from the switch hook in the usual manner and places it to his ear, awaiting the answer of the operator. The instant the switch hook rises, the subscriber's line switch or an idle trunk finder switch (of whatever type or manufacture it may be) places his line in connection with an idle trunk with the result that the line lamp corresponding to the trunk selected glows in front of the central-office operator before whom the trunk terminates. She plugs in, takes the subscriber's order, and completes the connection by plugging in to the desired party's multiple jack and ringing in the usual manner. When the subscribers finish talking they hang up their receivers, whereupon the operator receives the customary supervisory signals and pulls down the connection. It may be arranged so that the calling subscriber's line switch will release when he hangs up, or so that the trunk will be kept busy until the operator pulls down the cords, thus preventing any possibility of another subscriber being switched to the same trunk after the first subscriber has disconnected and before the operator has pulled down her cords. Should a subscriber, who has a connection, desire to attract the operator's attention at any time, he can do so in the usual manner by moving his switch hook up and down, thus flashing the operator's supervisory lamp. The talking current for the district station may be fed from the cord circuit at central or from the district station battery, as desired; generally the latter is preferable from the standpoint of transmission efficiency.

Outgoing Calls.—These calls are put up by the use of a calling device, at the manual central office, by means of which connector switches installed at the district station are operated over the outgoing trunks from the central office to the district station. A calling device may be made available to each "*A*" operator, enabling her to complete connections from a central office subscriber to a district station subscriber directly, without the aid of a "*B*" operator, or the plan may be such that all out trunk-connections will be set up by a "*B*" operator, at whose position alone calling devices are installed. The former plan may be made practicable where the percentage of calls to district stations is large. Generally, however, the latter method is preferable because of the comparatively small number of calls from central-office lines to district stations and the difficulty of training "*A*" operators, who are accustomed to go through a regular, set routine on most of their calls, to go quickly and accurately through a different routine on a call to the district station. If all these calls pass through one or more operators, who are especially trained to handle them, the efficiency of those operators may be made quite high.

When a "*B*" operator is used for handling the outgoing trunk calls under Plan No. 1, her position is equipped with cord circuits. When she receives an order from an "*A*" operator over an order wire in the usual way, she picks up the answering plug of an idle cord circuit and inserts it into the multiple jack of the calling subscriber's line, and it is therefore unnecessary for her to assign any trunk to the "*A*" operator. The "*A*" operator's work is now completed. The trunk operator at the same time picks up the calling plug of the idle cord circuit used and inserts it in the jack of an outgoing trunk which terminates in an automatic connector switch in the proper group at the district station. She then throws the calling device key of the cord circuit and makes two motions of her calling device dial to operate the switch and complete the connection. The ringing of the called party's bell may be done by the trunk operator, or may be done automatically by the connector switch, as desired. In either event the relays and lamps in the "*B*" operator's cord circuit give her the customary supervisory signals. When the subscribers finish talking and place their receivers on their switch hooks, the operator is given the signal and pulls down the cords. When she removes the plug from the outgoing trunk jack the connector switch used releases.

If the switchboard is equipped with trunks ending in jacks in the "*A*" operators' sections and in plugs in the "*B*" operators' position, it is better practice than that outlined in the foregoing paragraph to have the "*B*" operator assign an idle trunk when the subscriber's order is received from the "*A*" operator. The "*A*" operator then inserts the calling plug of the cord on which the subscriber is waiting in the jack of the assigned trunk while the "*B*" operator inserts the plug of the cord terminating the transfer trunk into the jack of an idle, outgoing trunk to the district station and calls the desired party. With this method the "*A*" operator usually supervises the connection. This plan of using trunks from "*A*" to "*B*" operators is of course necessary in any system which has more than one manual office.

If party lines are connected to the district station the trunk operator may ring on them selectively or by code, following whatever plan and using whatever apparatus has been adopted for ringing on the regular party lines connected directly to the central office. Talking current may be supplied to the called telephone from the main-office battery through the trunk operator's cord circuit relays, but it is preferable to supply it from the district station battery through the relays of the connector switch.

Interconnections Between District Station Lines.—Where the trunks incoming to the central office from the district station are scattered among the "*A*" operators, an interconnection is handled in the same manner as that described for an outgoing call from the central to the district station. Where the incoming trunks terminate in line jacks before the operator at the special position equipped for handling outgoing calls to the district station, this operator responds to incoming trunk calls by plugging in to the proper line jack, then picks up the other plug of the cord used, inserts it in the jack of an outgoing trunk to a connector switch in the proper group at the district station and from there on handles the call just as she would any outgoing trunk connection.

PLAN NO. 2

The district station equipment for use with this plan may be the same as that used with Plan No. 1. The difference between the two arrangements lies in the equipment in the manual central office.

Incoming Calls to the Central Office.—For this plan the trunks incoming to central from the district station terminate in special cords and plugs before the special "*B*," or trunk operator. An incoming call lights an associated lamp. The operator responds by pressing the answering key associated with this cord circuit, takes the order, at the same time picks up the plug and after the busy test inserts it in the multiple jack of the desired party. The service is sped up appreciably because it is not necessary to use an answering plug and cord.

Outgoing Calls to District Stations.—It is not necessary to have the trunk operator's position equipped with line multiple jacks. Therefore one of the end positions of the board, which is not fully equipped with multiples, or a separate desk may be used, unless this operator handles the incoming trunk calls also. Each outgoing trunk ends in a key in the "*B*" operator's position, and is also connected to a trunk multiple jack in each section of the multiple switchboard so that each "*A*" operator will have access to it.

A call is handled as follows: When the "*A*" operator receives the order of the calling central-office party, she presses a key in her order wire to the trunk operator's set and repeats the number desired, for example "132." The trunk operator says "132 on 7," (No. 7 being an idle outgoing trunk to the No. 1 line switch group at the District Station), and at the same time presses the key of trunk No. 7, thus switching in her calling device, and pulls "3-2" on the calling device dial. She then presses No. 7 ringing key to signal the called party, unless the connector switch is arranged to ring his bell automatically. Meanwhile the "*A*" operator has plugged into jack of trunk No. 7, thus completing the connection. As soon as she does this a guard lamp, associated with trunk No. 7 in the trunk operator's position, lights and remains lit until the "*A*" operator pulls down the connection.

The "*A*" operator's cord circuit lamps give her the usual supervisory and clearing out signals. The "*B*" operator pays no attention to the connection after setting it up, or after ringing the called party once if the ringing is done from central office. If the called party does not answer promptly, where ringing from central office is used, the "*A*" operator may ring him again by pressing the proper ringing key in the usual way. When she receives the clearing out signal she pulls down the connection and when she removes the plug from the trunk multiple jack the guard lamp in "*B*" position is extinguished and at the same time the connector switch used at the district station automatically releases. If the called party should be busy when the trunk operator attempts to call him, the trunk operator does not change her method of handling the connection and the busy signal is given instantly and automatically by the connector switch to the calling subscriber. The circuits may be arranged for feeding talking current to the called party's telephone from the central office battery through the "*A*" operator's cord circuit relays, but it is preferable from a transmission standpoint to have the current supplied through the relays of the connector switch from the district station battery.

Interconnections Between District Station Lines.—For use in such connections the "*B*" operator handling the trunks to the district station should have within her reach jacks associated with outgoing trunks so that she can insert the plug of the cord through which she receives the call into an idle out trunk jack, and then set up the connection in the usual way. The supervisory signals of the incoming trunk cord circuit are watched by her just as on an incoming trunk connection to a central office line.

District Station Battery.—A small storage battery of suitable voltage is generally used to furnish current for operating the district station switches. This battery may be charged by means of a simple automatic arrangement over idle trunks from central office, so that it is not necessary for an attendant to go to the district station and switch the charging current on or off. If desired, the battery may be charged by a small mercury arc rectifier, or by other means, installed at the district station and switched in and out of circuit by an attendant.

Supervision.—A district station apparatus is usually equipped with telltale signals so that it can be supervised quite easily from the central office. It is also supplied with testing switches, such as are generally installed in district stations connected to automatic central offices and by means of which the wire chief at his central-office desk can make any tests he desires on any district station line without the assistance of any one, either at central or the district station. It is not necessary, and it is not customary to keep an attendant on duty in one of these district stations; in fact, the apparatus is often left for several days without any attention. It should receive a short, thorough inspection at regular intervals. The most complex parts of the mechanism are the connector switches terminating the trunks outgoing from central to the district station, and if one of these should be out of order the trunk operator will simply refrain from using it until it is repaired.

Semi-Automatic District Station Using Line Switches and Connectors of the Automatic Electric Company's Manufacture in Connection with Central-office Switchboard Equipment of the Dean Electric Company's Manufacture.

The circuits of this system, which is a representation of Plan No. 1, are shown diagrammatically in Fig. 164. The trunk relay used for closing the circuit for energizing the bridge cut-off relay winding of the switch and controlling its release, also for supplying talking current to the calling party is somewhat different from the repeaters used in full automatic practice.

Incoming Trunk Calls.—When the line switch extends the calling party's line through to the trunk relays, current flows from earth through one winding of the double wound relay through the subscriber's loop and the winding of the 250-ohm relay to negative battery. This negative line relay closes circuit from earth to the release trunk and through the winding of the bridge cut-off relay to negative battery. It also breaks its circuit through the 3100-ohm supervisory relay, which is common to all the trunks of the group, and which serves to open the circuit through the starting relay of the line-switch unit master switch, when all of its outgoing trunks are busy. The object of this is to keep the master switch from searching for an idle trunk when none is to be found. The negative line relay closes circuit also from negative battery through the 500-ohm coil to the inter-office section of the trunk. The positive line relay coil closes circuit from earth through the slow-acting 500-ohm relay to negative battery. This relay it will be noted controls contact between the release trunk and the earth connection. The purpose of this relay is to prevent the line switch from releasing when ringing current is sent over the line to complete a reverting party line call.

At the central office the trunk terminates in the customary jack and line relay equipment used for regular subscribers' lines. The line relay is operated by current flowing through the positive line relay coil, of the district station trunk relays, and the 500-ohm winding of the negative trunk relay. The operator, before whose position this line terminates, responds to the call as if it were from a regular manual subscriber's line. She receives the customary supervisory signals. The line switch does not release when the calling party restores his receiver to the switch hook, unless the operator has withdrawn the answering plug used from its jack.

Outgoing Calls.—When a manual subscriber wishes a connection to an automatic district station subscriber, he removes his receiver from its switch hook and gives his order in the customary manner to the "*A*" operator who responds. She repeats the order over an order wire to the "*B*" operator handling the outgoing trunks to the automatic district station. This procedure is the same whether the "*A*" operator is in the same office as the "*B*" operator or not. The "*B*" operator repeats the number and assigns an idle trunk in the usual manner. At the same time she picks up the trunk plug and inserts it in the jack of an idle outgoing trunk to the proper group of the automatic district station, throws the calling device key and calls the last two digits of the district station subscriber's number.

The connector switch has the customary relays and magnets except that the line relay has a single winding only, one terminal of which is connected to earth and the other to the positive side of the incoming trunk. The negative side of trunk is normally open at side-switch wiper No. 2, and this connector switch is operated through earth over the positive side of the trunk.

The operation of a connector switch has been explained. If the called line is busy, circuit is closed from guarding earth potential on the private bank contact through the private wiper, side-switch wiper No. 1, and one coil of the busy relay to negative battery. This relay closes a circuit from earth through the springs of the 1300-ohm slow relay, its own locking winding and the private magnet, which prevents the private magnet from releasing its armature and allowing the side switch to move to third position. This relay also opens the circuit through the rotary magnet and closes the circuit from the "busy" bus bar to the negative side of the line. The busy signal is transmitted directly through the "*B*" and "*A*" operators' cord circuits to the calling subscriber.

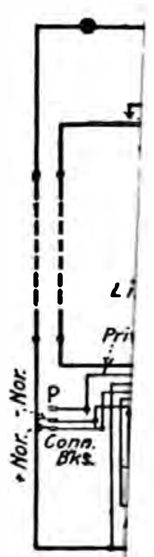
If the called party should not be busy when the connector shaft wipers stop on his bank contacts, the side switch moves to third position, circuits are closed in the usual manner for operating the bridge cut-off relay of the called party's line switch, and the connection is extended through the called party's normals to his line and telephone.

The called party is not signalled automatically by the connector switch, but is signalled by the "*B*" operator using her ringing keys. Since four-party line service is given through this district station, and the "*B*" operator's cord circuits were already equipped with four-party line ringing keys when the district station was installed, it was thought advisable to simplify the district station equipment by having the "*B*" operator do the selective ringing. To make this possible it should be observed that when the side switch of the connector moves to third position, the line is entirely clear through the connector with the exception of the 250-ohm line relay connected from the positive side of the line to earth, and the 250-ohm back-bridge relay connected from the positive side of the called party's loop to negative battery, through side switch No. 4. When the called party responds, this back-bridge relay is energized through the called party's loop, and the tip relay winding of the "*B*" operator's cord circuit. This tip relay operates the supervisory lamp cut-off relay of the cord circuit, while the back-bridge relay of the connector switch closes circuit from the negative side of the line through a 500-ohm coil to earth. The purpose of this coil is to increase the supply of talking current to the called subscriber, and to balance the line during conversation. When the subscriber hangs up his receiver, the "*A*" operator receives the customary disconnect signals and withdraws the plug from the trunk to "*B*" operator, who then receives the disconnect signal and withdraws the plug from the outgoing trunk to the automatic switch. This breaks the circuit through the positive line relay of the connector switch and as its armature falls back, circuit is closed through the release magnet, resulting in the release of the switch.

Interconnections Between District Station Subscribers.—The method of interconnecting one district station subscriber with another, by using a trunk incoming from the district station for receiving the calling subscriber's order and another trunk outgoing to the district station for calling the desired party, is obvious from the preceding circuit drawings and explanations. It should be stated, however, that if a subscriber on a party line wishes to talk to another party on his own line, that a special method of handling the connection is required. It is necessary for the calling party to give the trunk operator his own number and the number of the party he wishes. She then removes the answering plug used, inserts the calling plug of an idle cord in the jack of the trunk on which the party is waiting and tells him to hang up his receiver for a moment while she rings the desired party's bell. His line switch does not release, however, for reasons already explained. The operator then presses the ringing key corresponding to the current frequency required to ring the bell of the desired party, and thus signals him through the trunk used by the calling party. After having hung up his receiver for a moment, as instructed, the calling party removes it and awaits the response of the called party. This is similar to a method of handling reverting calls, which is very common in manual practice.

Modification of Plan No. 2.—A modification of Plan No. 2 is an installation employing the circuits shown in Fig. 165. The line switch equipment is of the Automatic Electric Company's type and the central office equipment of the Stromberg-Carlson Manufacturing Company's make. The line switches and the master switches used are so similar to those already described that the discussion of their circuits is not necessary. The relay used on each trunk incoming to the central office from the district station has coils through which talking current is supplied to a calling subscriber from the district station battery. When a line switch extends a connection to a trunk, current immediately flows through both windings of the double-wound line relay of the trunk relay set and through the subscriber's loop. This relay closes circuit from ground to the release trunk, energizing the bridge cut-off relay winding *B.C.O.* of the line switch. The trunk-line relay also closes circuit from earth through the 1300-ohm slow-acting relay, which also controls a connection between the release trunk and earth. The purpose of this slow-acting relay is to prevent the line switch from releasing in case a calling subscriber moves his switch hook up and down repeatedly, in order to signal the operator. The trunk-line relay closes a circuit also between the two sides of the inter-office portion of the trunk, through the bridge coil, whereupon the central office line relay operates and signals the operator, who responds, takes the subscriber's order and completes the connection in the manner common to regular manual practice.

Outgoing Calls.—When the subscriber's operator receives an order for a district station number, she presses an order wire key and repeats the order to the "*B*" operator in charge of the outgoing trunks to the district station. The "*B*" operator repeats the number and assigns an idle trunk to the "*A*" operator, who immediately inserts the calling plug of the cord used to take the order into the corresponding trunk jack. When she does this, the trunk jack springs close circuit from earth through the 210-ohm trunk super-


+ Nor. - Nor.
P
Conn.
B'ks.


+ Nor. - Nor.
P
Conn.
B'ks.

visory relay, the jack springs, the tip conductor of the plug and the 500-ohm relay of the cord circuit to battery. The result is that the trunk supervisory relay closes a circuit through the guard lamp which remains lit so long as this particular trunk is occupied, thus preventing the "*B*" operator from reassigning it. At the same time that the "*B*" operator assigns the trunk she throws the corresponding calling device key, which connects the calling device between the negative side of the outgoing trunk line and earth, and calls the desired party, making two turns of the calling device dial. The circuits of the connector switch are so similar to those which have already been explained that they will not be discussed in detail. It should be noted, however, that when the connection has been completed the called party is rung automatically by the connector switch, using ringing generator current supplied over an extra cable pair from the main office. These circuits and those of the automatic interrupting device for making and breaking the circuit through the ringing relay *B*, which is connected to negative battery when side switch No. 3 moves to third position, are shown in detail in the diagram.

Party Lines.—It should be noted also that two-party lines are used in this system, but harmonic ringers are not employed. The ringer of one telephone on each line is connected between one side of the line and earth, and the ringer of the other telephone between the other side of the line and earth. To make this practicable, one terminal of the ringing machine at central office must be permanently connected to earth and two groups of connector switches must be employed at the district station, one group being arranged so that its ringing relays will project ringing current on to the positive side of a called line, and the other group to the negative side of the line. The only circuit change that is required to accomplish this is to reverse the line wiper connections on one group of connector switches. The necessary ground connection is secured at the central office, through the other side of the cable pair, one side of which is connected to the ringing generator. The return circuit of the ringing generator is carried back to central to prevent inductive disturbances in the cable.

Supervision.—After the "*B*" operator has set up the connection she pays no further attention to it. If the called line is engaged the busy signal is furnished automatically by the connector switch. When the parties hang up the "*A*" operator receives the necessary disconnect, supervisory signals, pulls down the cord circuit used and thereby causes the release of the connector switch.

District Station of the American Automatic Telephone Company.—The district station made by the American Automatic Telephone Company employs as a rule finder switches and connectors only. The subscribers' lines are divided into groups of fifty each. Each group of fifty has its own set of trunks to and from the manual office which handles the traffic. It is customary to provide six finder switches, each connected to the trunk for carrying traffic to the manual office, and six trunks from the manual office to district station each terminating in a fifty-point connector located at the latter place.

The general operation of the trunk to the manual office is as follows: When a subscriber takes his receiver from the hook, his line relay pulls up and starts a finder switch. This finder rotates, seizes the calling line, pulls up the cut-off relay and extends the connection to the manual office. At the same time that the finder begins its work, the line lamp associated with the trunk in the manual office is lighted so that the operator may begin work promptly. The release is controlled by the manual operator so that the calling subscriber can operate his hook switch to signal the operator without causing premature release.

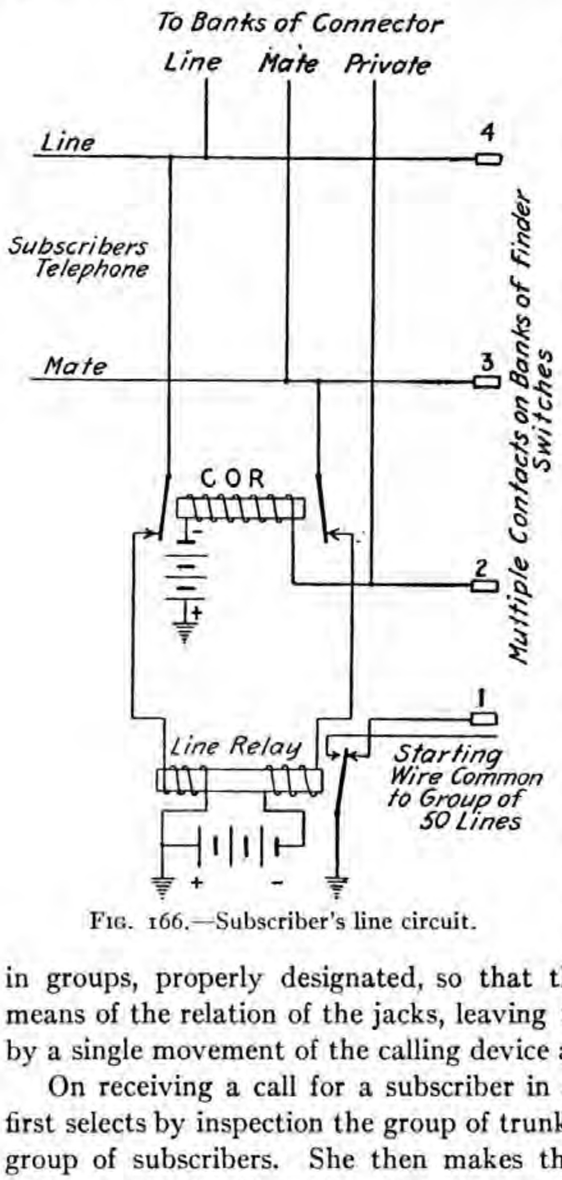


FIG. 166.—Subscriber's line circuit.

The general conditions under which trunking is done from the manual office to the district station are as follows:

Each outgoing trunk at the manual office is multipled before a number of operators. In some installations every "*A*" operator has access to these outgoing trunks. Each operator is also equipped with a calling device which may be cut into any cord circuit by means of a key. The trunks appear before the operators in groups, properly designated, so that the operator selects the group by means of the relation of the jacks, leaving the individual line to be selected by a single movement of the calling device and connector.

On receiving a call for a subscriber in a district exchange, the operator first selects by inspection the group of trunks leading to the desired fifty-line group of subscribers. She then makes the usual busy test to determine which trunk is idle, plugs into it, operates the dial, which by means of the connector extends the line to the desired telephone. The operator is then able to ring this subscriber by her ringing key the same as she would any other subscriber. The called subscriber operates the supervisory lamp in the standard way. The release is controlled by the operator.

The Finder Switch and Trunk—Circuit Details.—The line circuit employed is shown in Fig. 166. A simplified diagram of the finder and trunk circuit is given in Fig. 167. The test wiper No. 1 is normally connected to the testing circuit of the finder, which however is broken at relay 145.

The motor magnet is caused to vibrate by the co-operation of the motor relay. The motor relay is also the testing relay which tests for and finds the

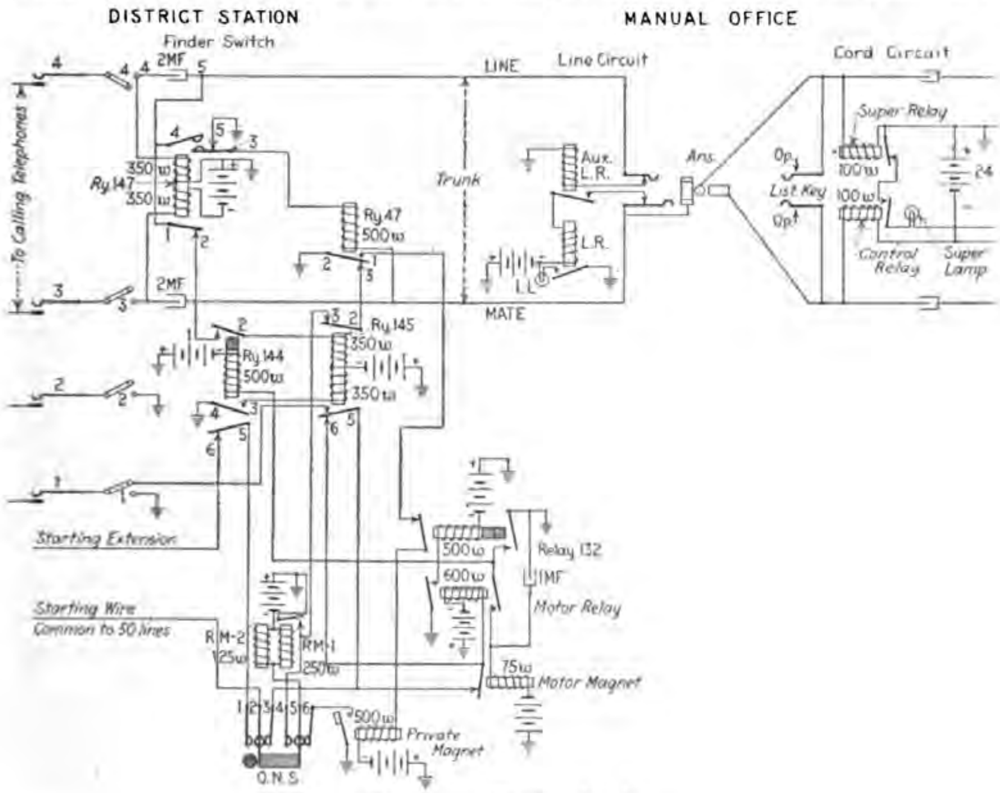


FIG. 167.—Finder circuit.

calling line and stops the motor magnet. There are two release magnets, *RM*-1 for the wipers and *RM*-2 for the side switch; both of them reset their respective members upon being energized. The private magnet operates the side switch when energized, which, it will be noted, is contrary to the action of other private magnets and side switches.

When the subscriber takes his receiver from the hook, the line relay (Fig. 166) is energized, removing the ground from the guard contact No. 1 and grounding the common starting wire. This results in pulling up the motor relay (Fig. 167) in an idle finder switch.

As a result of the pulling up of the motor relay the circuit is prepared for the motor magnet and relay 132 is pulled up. Relay 132 as a precautionary measure breaks the circuit of the private magnet and also energizes relay No. 144.

Relay 144 starts the train of operations which gives the signal to the operator at the manual office. It energizes relay 145 and the auxiliary line relay at the manual office in series with each other and cuts off the starting extension to prevent another finder switch from being started before this finder switch has finished its work.

The energizing of relay 145 breaks the circuit of the release magnet at 3-2, removes the short-circuit from the motor magnet contacts and connects the circuit of the motor relay to the testing wiper 1.

The pulling up of the auxiliary line relay at the manual office has two effects.

First.—Pulls up the line relay, lighting the line lamp.

Second.—Pulls up relay 47 in series with the line relay. The latter opens the circuit of the release magnet at the second point and prepares the circuit for the private magnet (at 2-1).

Relay 132 in addition to the above-described action energizes the motor magnet, which on pulling up catches a tooth on the ratchet wheel and breaks the circuit of the motor relay causing it to fall back.

When the motor relay falls back, relay 132 remains energized because it is slow acting, and therefore keeps energized the other relays which depend upon it.

The motor relay falling back opens the circuit to the motor magnet causing it to fall back and to drive the wipers on to the contacts of the first line in the group of fifty. Wiper 1 is now resting upon a grounded contact, if we assume that the calling line is not line 1. The motor magnet having closed its contact, the motor relay will again be energized and on pulling up give another impulse to relay 132 to keep it energized and will pull up the motor magnet a second time. This mutual action of the motor relay and motor magnet will continue until the wipers have been advanced to a calling line.

When the test wiper 1 reaches the contact of a calling line it will find no earth connection. The motor relay will therefore be unable to pull up, so that the motor magnet will not be pulled up again and the wipers will be left resting at this point. After an instant, relay 132 will fall back because of the failure of the motor relay to pull up again. Relay 132 will perform thereby two circuit functions.

First.—Energize the private magnet.

Second.—De-energize relay 144.

The private magnet will pull up first allowing side switch to escape to the second position. The circuit changes caused by the movement of the side switch are as follows:

The test wiper is disconnected from the test circuit and grounded, thereby guarding this subscriber's line from seizure by another finder switch. Side switch 2 grounds wiper 2 and pulls up the cut-off relay of the calling line, clearing it for conversation. The falling back of the line relay takes the ground off the starting wire and puts a ground on the guard contact 1. Side-switch wipers 3 and 4 connect the subscriber's line to the trunk circuit as well as to relay 147.

When relay 147 pulls up it cuts off the ground on the "mate" of the trunk and bridges relay 47, closing the circuit so as to hold three relays energized in series, the line relay, auxiliary line relay and relay 47. Relay 147 also opens the upper winding of relay 145.

After an instant, relay 144 falls back. This closes the starting wire to the extension so that the next call will be handled by the next finder switch. It also breaks the circuit of the upper winding of relay 145 at the

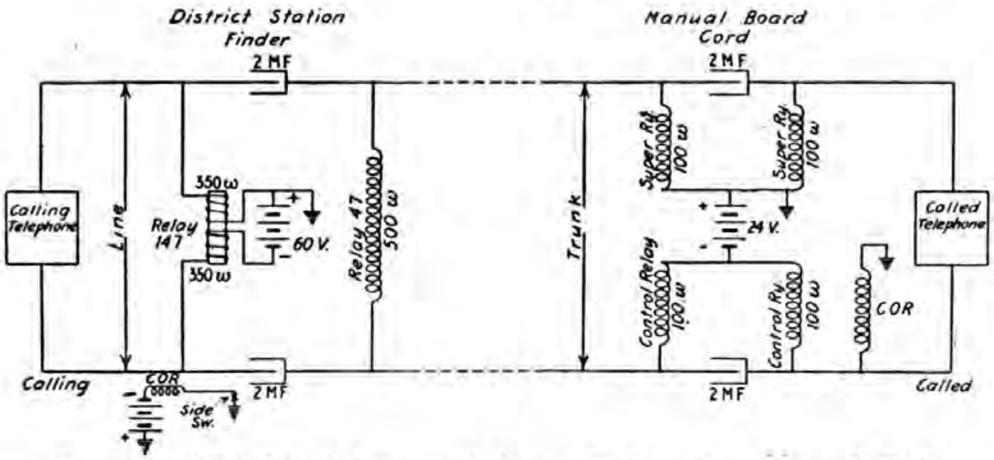


FIG. 168.—Talking circuit between telephones (district station to manual office).

second point and by cutting off the lower winding also causes relay 145 to fall back. Relay 145 falling back prepares the circuit for the release magnet and restores the short-circuit to the motor magnet contacts.

The operator, seeing the line lamp lighted, plugs into the jack with the answering end of the cord circuit. The supervisory relay is substituted for the auxiliary line relay and the control relay takes the place of the line relay. The trunk-holding circuit is now as follows:

From ground at the central office through supervisory relay, tip of plug, tip of jack, line wire of trunk to district station, contact 4-3 of relay 147, winding of relay 47, "mate" wire of trunk to manual office, sleeve of jack, sleeve of plug, winding of control relay to negative battery.

After obtaining the desired number the operator completes the connection according to standard manual practice. Unless the call should be for another subscriber located in the district station, conversation takes place between two subscribers over the circuit shown on Fig. 168.

It will be observed that each subscriber talks through four 2 m.f. condensers in series and that there are four bridged impedances across the line, with one cut-off relay from sleeve of line to earth.

Supervision is given by the subscriber hanging up his receiver. When this occurs, relay 147 falls back, breaking the bridge across the trunk circuit but keeping relay 47 and the control relay energized in series. The supervisory relay of the cord circuit is caused to fall back, lighting the supervisory lamp.

When the operator pulls out the plug the control relay falls back and puts out the supervisory lamp. Relay 47 also falls back releasing the private magnet and pulling up the release magnets over the following circuit, from ground, contact 2-3 of relay 47, contact 2-3 of relay 145, contact 4-5 of off-normal switch *O.N.S.* through the release magnets *R.M.*-1, *R.M.*-2 to negative

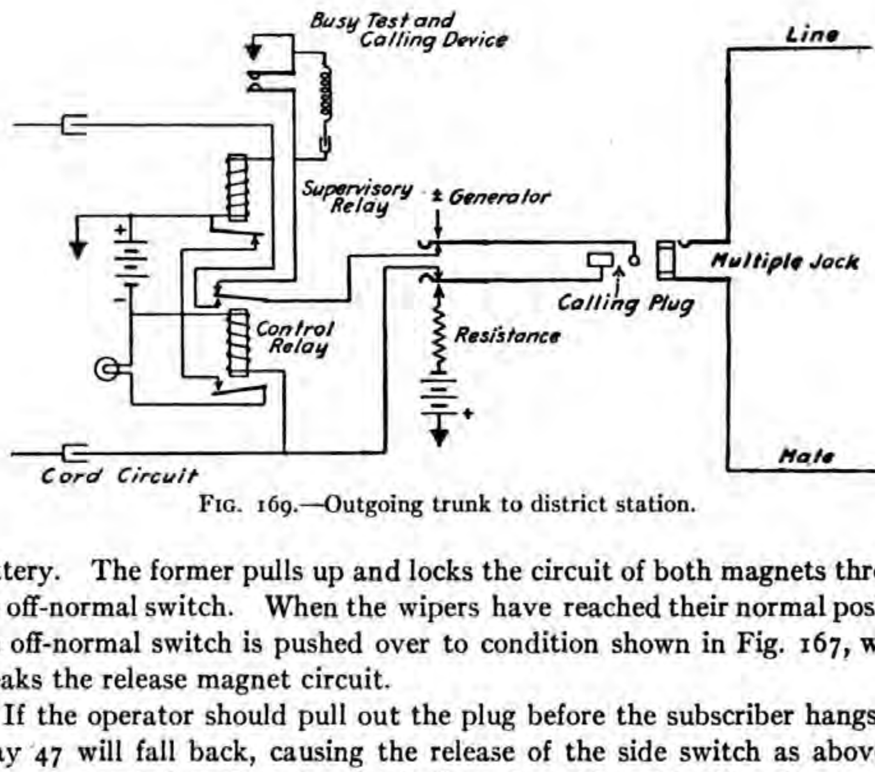


FIG. 169.—Outgoing trunk to district station.

battery. The former pulls up and locks the circuit of both magnets through the off-normal switch. When the wipers have reached their normal position the off-normal switch is pushed over to condition shown in Fig. 167, which breaks the release magnet circuit.

If the operator should pull out the plug before the subscriber hangs up, relay 47 will fall back, causing the release of the side switch as above described except that the subscriber's line relay, Fig. 166, will pull up again, ground the starting wire and cause another finder switch to seize the line, and connect it again to the manual office, just as if a new call had been made.

Connector and Trunk—Circuit Details.—The outgoing trunk, Fig. 169, from the manual office to district exchange is extremely simple having only multiple jacks. The cord circuit is changed only by having a calling device added to the busy test wire from the back contact of the control relay. The springs of this calling device are normally open and do not interfere with the operation of the busy test.

The connector at the distant station embodies several items of interest, being different from circuits commonly used. (See Fig. 170.)

The switch is operated by the operating relay over one side of the trunk circuit. This function employs only three magnets, the operating relay, the auxiliary operating relay and the motor magnet. The called subscriber is rung over the line side to earth. The back-bridge relay does not pull up by the direct action of the subscriber's telephone, but is brought into the circuit

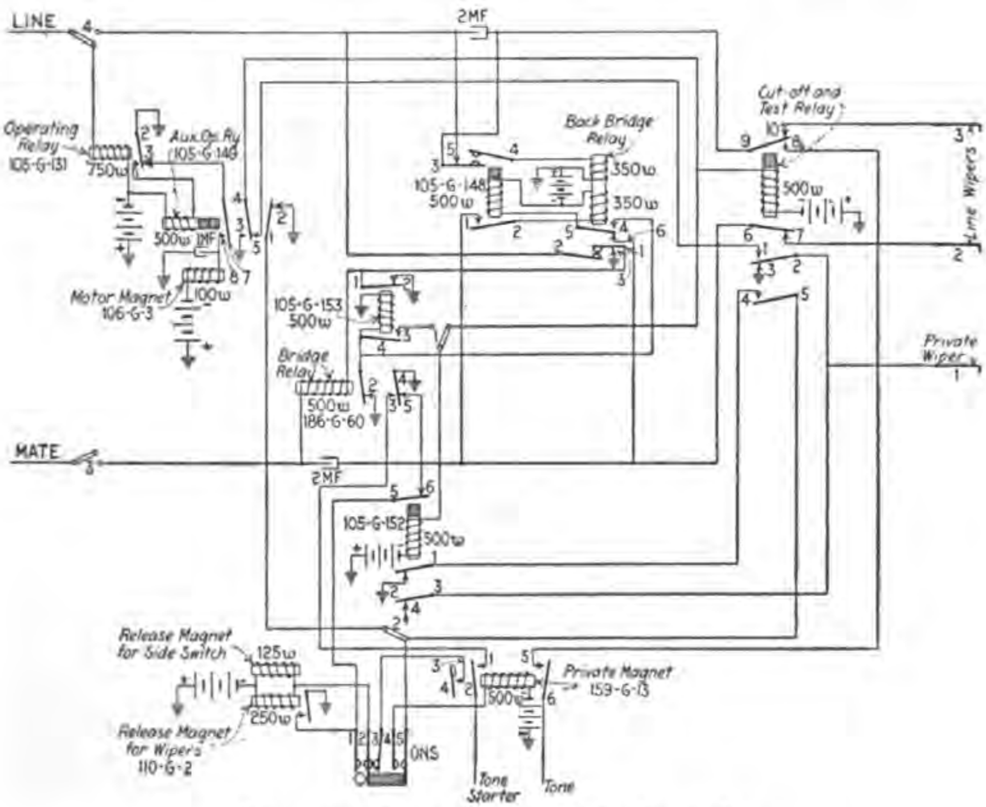


FIG. 170.—Connector circuit at district station.

by another relay 148. The relay which cuts the wipers from the circuit during rotation is also utilized as the busy test relay and, therefore, is termed the cut-off and test relay.

When the operator plugs into the jack of the out-going trunk no action takes place at the connector. When the operator pulls the calling device a number of impulses varying from one to fifty will be sent over the line actuating the operating relay the same number of times.

The auxiliary relay pulls up with the first action of the operating relay and being slow acting, remains energized throughout the series. It performs four actions which are as follows:

Opens the private magnet circuit at 1-2 (cautionary).

Prepares the motor magnet circuit.

Pulls up cut-off and test relay and relay 152 (by closing circuit at 3-4).

The cut-off and test relay cuts off the line wipers, prepares the busy tone circuit (8-9), prepares part of the private magnet circuit (4-5), takes the ground off the private wiper (3-2) and closes part of the test circuit (1-2).

As a cautionary measure only, relay 152 opens the release magnet circuit (5-6), private magnet circuit (1-2) and disconnects the private wiper from ground which will come later through side switch 2.

Every time the operating relay falls back it sends an impulse to the motor magnet, pulls it up, and causes the pawl to engage a tooth of the ratchet wheel. Every time the operating relay pulls up again the motor magnet lets go and

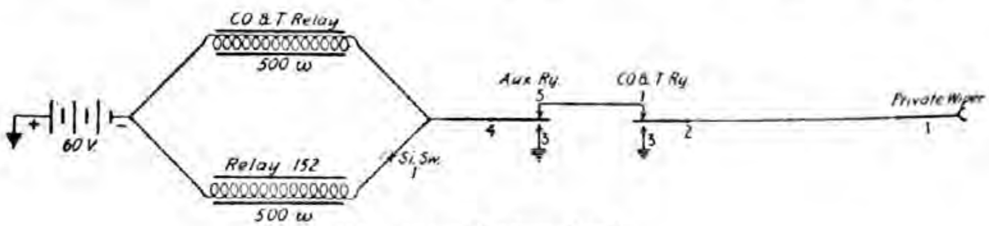


FIG. 171.—Testing circuit.

drives the wipers forward one step. The first rotary step of the wipers causes the operation of the off-normal switch *O.N.S.* which prepares the circuit for the release magnets (1-2) and the private magnet (4-5).

When the series of impulses has come to an end the operating relay comes to rest de-energized, the motor magnet thereby receives its last impulse and pulls up, catching a tooth. An instant later the auxiliary operating relay falls back and disconnects the motor magnet, causing it to let go and drive the wipers to the desired line.

In addition to the above, the falling back of the auxiliary relay pulls up the private magnet (at 1-2) and closes the test circuit. The test circuit is as follows:

From private wiper 1 through contact 2-1 on cut-off and test relay, 5-4 of auxiliary relay, windings of the cut-off and test relay and relay 152 in parallel to negative battery. (See simplified diagram Fig. 171.)

The pulling up of the private magnet lets the side switch escape to its second position and causes a number of changes which are as follows:

At 1, relay 152 is switched to a contact on relay 153, at 2 the private magnet is cut-off and falls back, at 4 the operating relay is cut-off and the line closed. At 3 the "mate" is closed to the connector circuit energizing the bridge relay in the connector and the control relay on the cord in series. The latter lights the supervisory lamp, cuts off the calling device and closes the tip circuit. The bridge relay in the connector opens the circuit of the release magnet at 4-5 (cautionary) prepares the tone-starting circuit at 3-4 and takes the short-circuit from the relay 153 at 1-2.

If according to our first assumption the called line is not busy, relay 152 and the cut-off and test relay will fall back after an instant. Relay 152 will prepare the circuit for the release magnets (at 5-6) and will ground the private wiper through the side switch. The cut-off and test relay will ground the private wiper directly at 3-2 and connect the lines to the wipers. The grounding of the private will result in operating the cut-off relay of the called line and clear that line for ringing and talking.

The operator now rings the called station from the tip of her plug over the line, contact 5-3 of relay 148, through contact 9-10 of cut-off and test relay,

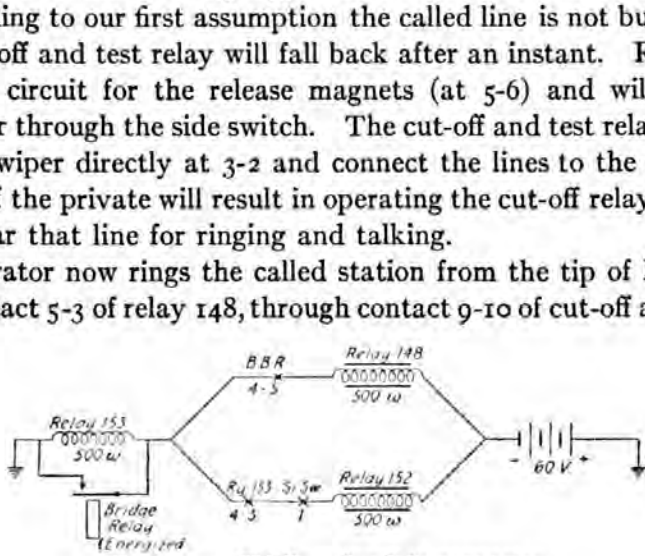


FIG. 172.—Holding circuit in connector.

line wiper 3, subscriber's line, subscriber's bell and condenser to ground and return.

When the called subscriber answers, his telephone draws current through the supervisory relay of the cord circuit of the manual position and the winding of relay 148 of connector. The circuit is as follows:

Positive or grounded terminal of battery, winding of supervisory relay, Fig. 169, front contact of ringing key, tip of calling plug, tip of multiple jack, "line" wire, trunk to district station, side switch 4 of connector, Fig. 170, contact 5-3 of relay 148, contact 9-10 of cut-off and test relay, line wiper 3, subscriber's line and telephone, line wiper 2, contact 7-6 of cut-off and test relay, contact 6-5 of back-bridge relay, winding of relay 148 to negative battery at district station.

Relay 148 in the connector takes the short-circuit from the condenser and connects the positive winding of the back-bridge relay to the line. It also connects the negative winding to the other line. On pulling up, the back-bridge relay switches the winding of relay 148 from the line to the series relation with the winding of relay 153. The latter relay immediately pulls up and connects relay 152 in parallel with relay 148 so that the three are now held energized in circuit as shown in Fig. 172. This circuit will be maintained during conversation.

The back-bridge relay also switches the bridge relay from ground to the other side of the line so that during conversation it is bridged across the circuit. Conversation takes place between the two subscribers over the circuit shown in Fig. 173. If the calling subscriber is served from a manual office there will be four 2 m.f. condensers in series and four bridged impedances across the line, besides the cut-off relay of the calling subscriber which is connected from the sleeve of line to earth.

When the subscribers hang up their receivers the back-bridge relay falls back and practically undoes the work which it performed on pulling up, with the exception that the relays 153 and 152 are left in series with each other. The removal of the bridge relay from this connection clears the circuit, allowing the supervisory relay of the cord to fall back and light the supervisory lamp.

When the operator pulls down the connection the cord relays and supervisory lamp will be restored to their normal condition. The bridge relay in the connector will cause relays 153 and 152 to be unlocked by short-circuiting relay 153 at contact 2 of the bridge relay. Relay 152 on falling

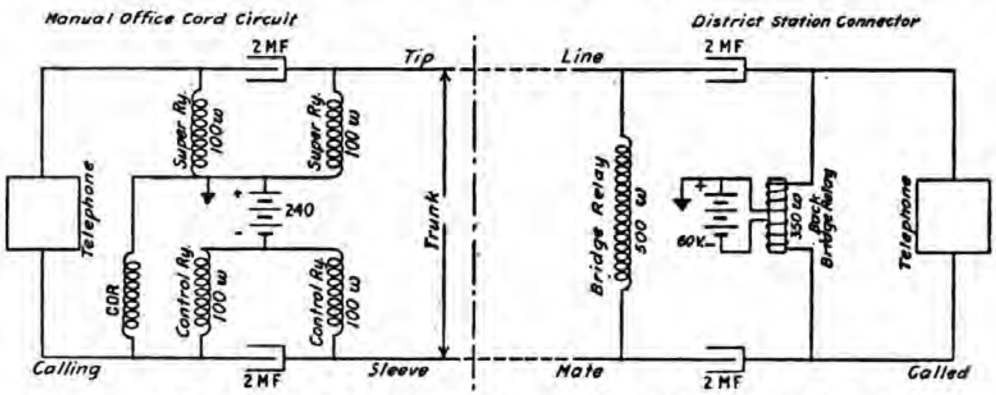


FIG. 173.—Talking circuit between subscribers. (Manual office to district station.)

back will close the circuit of the release magnets. The release magnets will now pull up over the following circuit; ground, contact 4-5 of bridge relay, 6-5 of relay 152, contact 1-2 of off-normal switch, through the windings of the release magnets in parallel, to negative battery. The release magnets will lock their circuits until the wipers have been returned to normal, at which point they will be de-energized by the restoring of the off-normal switch to the condition shown on Fig. 170.

If the operator should pull out the plug before the subscriber hangs up his receiver, the bridge relay will fall back, preparing the circuit for the release magnet and short-circuit relay 153 as above described. The release will follow as before.

If the called line is busy, the cut-off and test relay and relay 152 will be held energized in parallel by the action of the private wiper. The falling back of the auxiliary operating relay places a ground upon wiper No. 2 of the side switch so that the private magnet will be pulled up at once.

The busy tone machine will be started by the ground placed on the tone starter wire. The circuit is as follows: Ground, contact 4-3 of bridge relay, contact 1-2 of private magnet, to starter wire. The busy tone machine will then deliver tone current to the trunk line as follows: Tone wire, contact 6-5 of private magnet, contact 8-9 of cut-off and test relay, contact 3-5 of relay 148, side switch 4 to line.

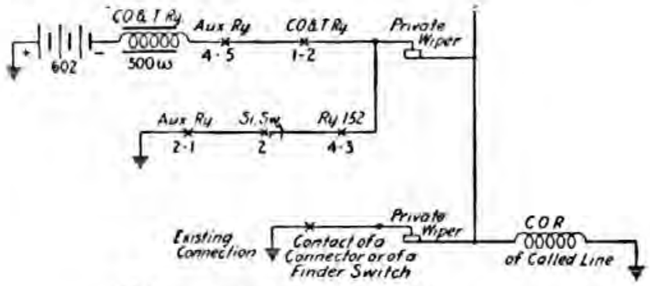


FIG. 174.—Testing a busy line.

The operator can not gain control of a busy line if she waits until the connection is released, because the cut-off and test relay is locked to ground by the action of the private normal of the called line. The circuit is shown in Fig. 174. This will naturally force the operator to a speedy release. If the operator should hold the trunk until the existing connection was released, it would hold the called line in a busy condition, so that no one else could call the line nor could the subscriber make a call until the operator released the connector. After hearing the busy tone the operator will release by pulling out the plug.

CHAPTER X

CLEMENT AUTOMANUAL SYSTEM

The automanual system combines automatic switching with manual operation by interposing the work of an operator between the subscriber and the automatic switches. It consists of a complete automatic switching installation in the central office, ordinary manual common battery subscriber's telephone connected thereto, and operators' apparatus added to enable the operators to control the action of the switches.

The idea of employing an operator to receive instructions from a telephone user and to operate automatic switches for completing the connection is very old in the art of telephony. In the early eighties Connolly proposed it and applied for a patent on a crude arrangement. As early as 1894 Strowger automatic switches were operated by operators in setting up connections from a manual to an automatic exchange. In 1904 Leroy W. Stanton read a paper before the International Electrical Congress at St. Louis, Mo., in which he proposed semi-automatic operation of multi-office exchanges.

In 1906 Edward E. Clement applied for certain patents related to a semi-automatic system, which later developed into the system made by the North Electric Company and sold by the Telephone Improvement Company, under the trade name of "Automanual." It was put upon the market in 1909 since when a number of plants have been installed. Among them may be mentioned Ashtabula, Ohio, Galesburg, Ill., and Greensburg, Ind.

The general layout of the trunking scheme is shown in Fig. 175. The subscribers' lines at the left are multipled to the banks of finder switches, here designated "primary selector" switches. Each primary selector is attached to a trunk leading to a first selector. From the banks of the first selectors, trunks run to second selectors and from the banks of the second selectors, trunks are provided to the connectors in the individual hundreds. Associated with each connector is a ringing selector switch for party-line use. The latter switch delivers to the connector the proper frequency of ringing current for ringing the bell of the desired station on the line.

The gain in the efficiency of operators by the use of traffic distributing apparatus is explained at length in the chapter devoted to equipment of that character. The automanual system includes the traffic distributor idea, but replaces the traffic distributor operator's act of picking up a trunk ending plug and inserting it into a multiple jack, with the act of setting up the called party's number on a set of keys similar to those of an adding machine.

The traffic distributor operator has to make the usual busy test and pull out the plug used when conversation is completed. These things the automanual operator does not do. The traffic distributor system is less expensive than the automanual to install, but which is the more economical to operate and maintain in single-office systems remains to be determined.

The automanual is adapted to multi-office systems where considerable inter-office trunking is done, because the operator's work is the same on a trunked call as on one completed locally. All the switches used in the automanual system, with the exception of a few auxiliary switches, are of the hundred-point two-motion type. The bank contacts are set on edge

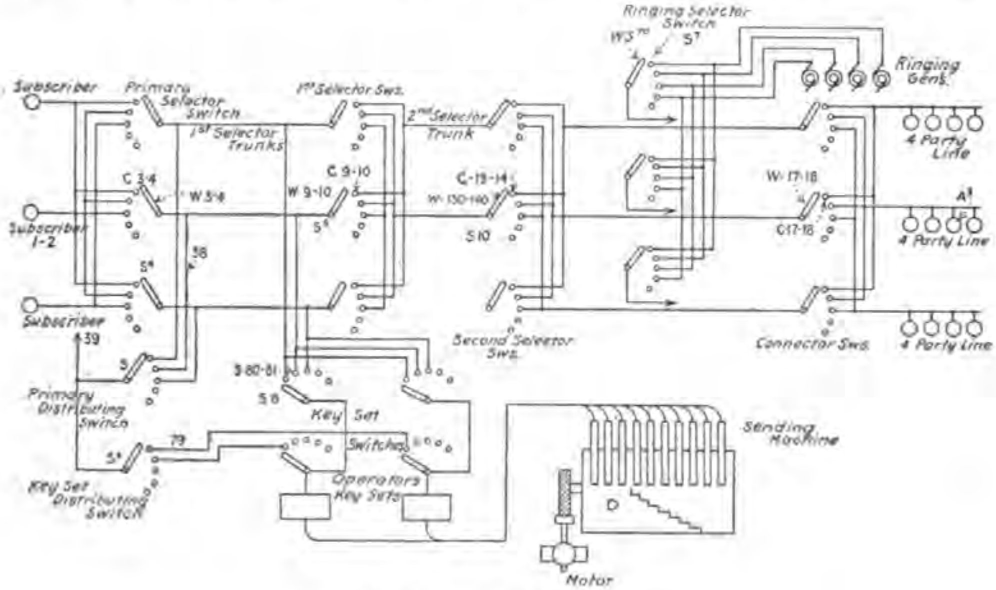


FIG. 175.—Trunking System.

(vertically) and the shaft is arranged first to rotate to a vertical row and then to rise to an individual contact. The auxiliary switches are arranged to be rotated by a ratchet action in one direction, so that their restoration to normal consists in driving them on until the wipers leave the bank.

The subscribers' lines are grouped by hundreds, each hundred lines being served by a number of primary selector switches (usually ten). For each group there is one primary distributing switch and one key-set distributor. The function of the former is to find an idle primary selector and cause it to seek the calling line. The function of the latter is to find an idle operator's position, and to cause the key-set switch to hunt the trunk line attached to the primary selector which has found the calling line. By the combined efforts of these switches, the subscriber's line is connected through a trunk to a first selector and an idle operator's equipment.

The operator is provided with one or more keyboards through which impulses generated by the sending machine can be delivered to the switches in such a manner as to set up the connection. After the connection has been established the operator's apparatus is disconnected so that it may revert to common use.

The order of digits in the called number is as follows: The first digit operates the first selector, the second digit operates the second selector, the third digit operates the ringing selector and the fourth and fifth digits operate the connector.

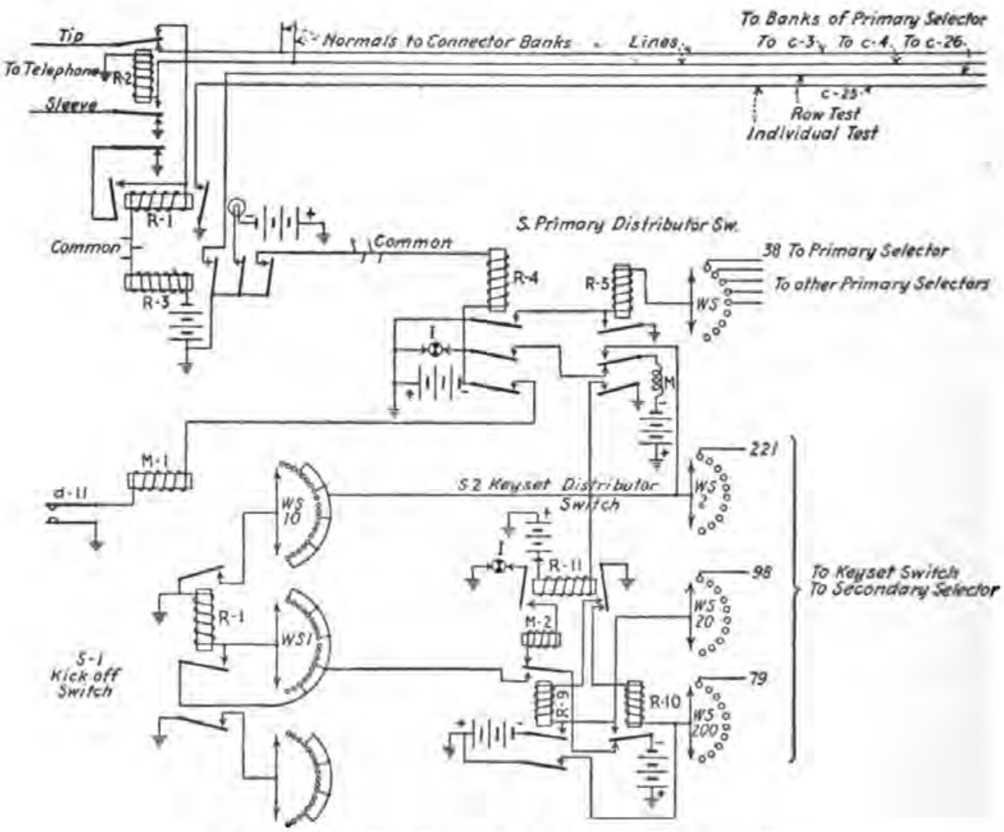


FIG. 176.—Subscriber's line and distributor circuits.

Details of Circuits.—The subscribers' lines, see Fig. 176, have line and cut-off relays. All of the line relays, belonging to lines which are in the same vertical row on the banks of the primary selectors, draw their current through a common line relay, *R*-3. This is for the purpose of enabling the primary selector to stop at the row containing the calling line.

The primary distributor switch *S* is of the flat rotary type, having a starting relay *R*-4, a stopping relay *R*-5 and a magnet *M*. The key-set distributor, *S*-2, is similar except that it has three wipers and possesses a starting relay *R*-11, a stopping relay *R*-10, a magnet *M*-2 and an auxiliary relay *R*-9.

The primary selector, Fig. 178, and the first selector are linked together. Primary selector apparatus is shown at the left and first selector apparatus at the right. The line circuit is broken by two condensers and talking current supplied to the calling subscriber through two relays *R*-14, and relay *R*-15. There are four wipers: the line wipers, *W*-3 and *W*-4; the row wiper, *W*-26. and the individual wiper, *W*-25. The line wipers and the individual wiper are set on edge. The row wiper, *W*-26, is set flatwise so as to engage the

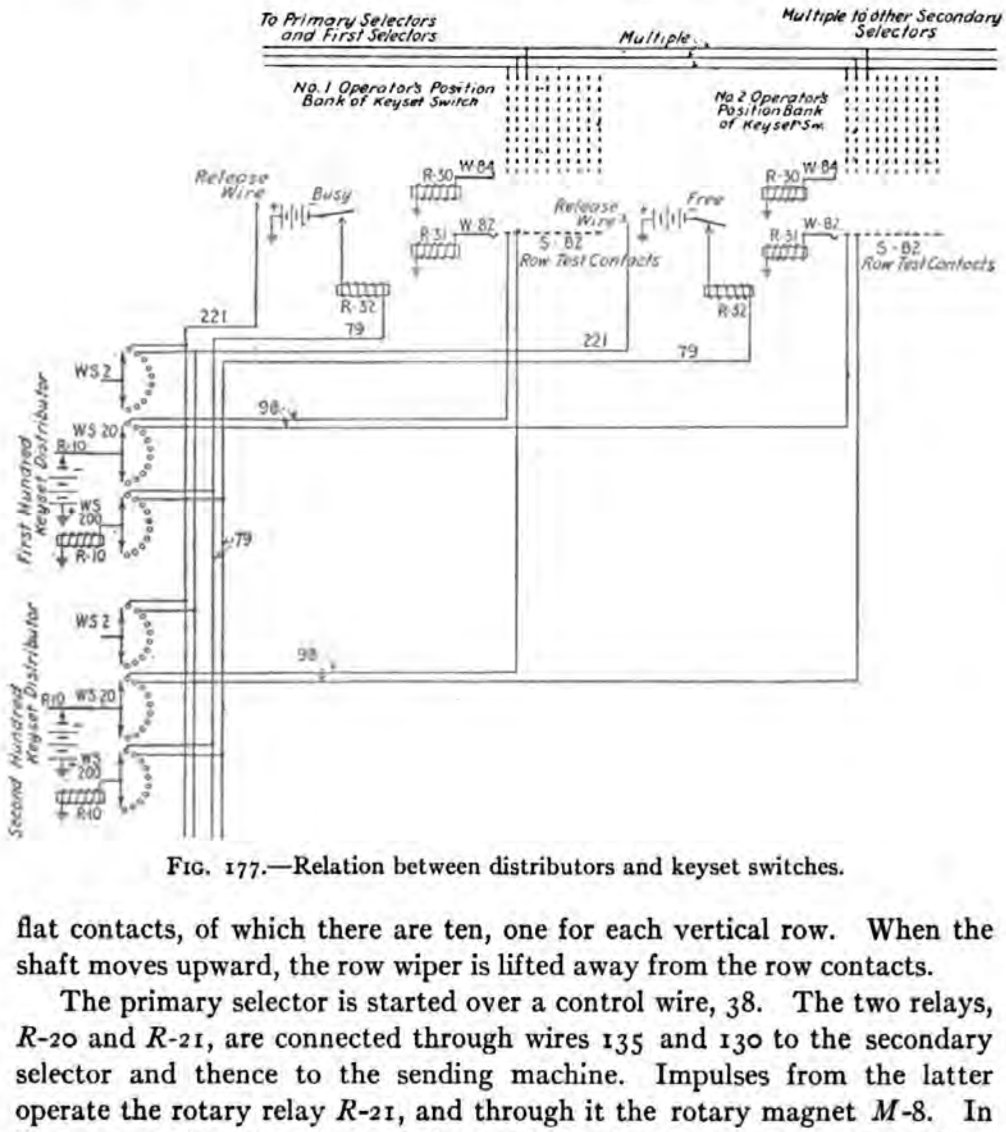


FIG. 177.—Relation between distributors and keyset switches.

flat contacts, of which there are ten, one for each vertical row. When the shaft moves upward, the row wiper is lifted away from the row contacts.

The primary selector is started over a control wire, 38. The two relays, *R*-20 and *R*-21, are connected through wires 135 and 130 to the secondary selector and thence to the sending machine. Impulses from the latter operate the rotary relay *R*-21, and through it the rotary magnet *M*-8. In like manner impulses through the vertical relay *R*-20 actuate the vertical magnet *M*-7.

The selection of a non-busy trunk is accomplished by sending ten impulses over line 135, the foot-step or off-normal switch, 144-145, being open and relay

R-41 closed to the private wiper W-147 at the time. When a non-busy trunk is found relay R-41 falls back and cuts off further impulses.

The key-set switch, see Fig. 179, has line wipers, W-80 and W-81, over which conversation between operator and subscriber will take place and impulses sent to the connectors and selectors. The row wiper is W-82 and the individual test wiper is W-84. The wiper 83 is auxiliary and is used for operating trunk cut-off relay R-42, Fig. 178, as well as other relays.

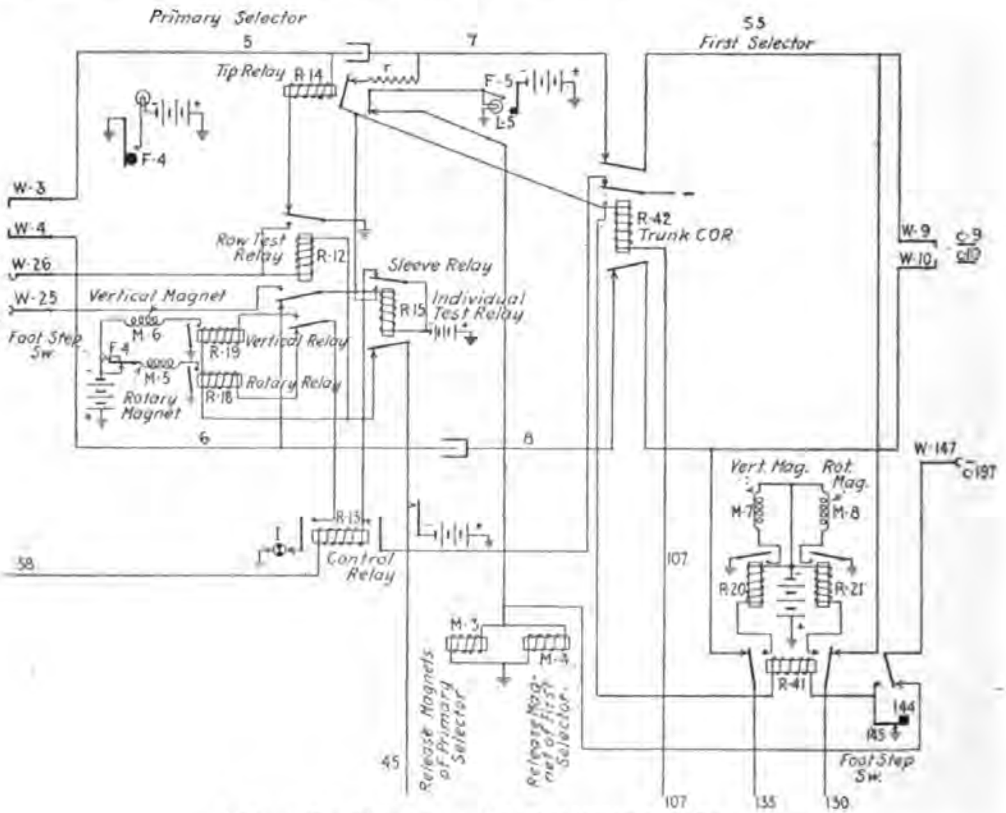


FIG. 178.—Primary and first selector circuits.

The operator's set has a listening relay, 33, which connects it to the circuit. At the right is an auxiliary switch, S-3, which has three wipers driven by the magnet M-15. Its chief function is the delivery of the proper impulses from the sending machine and keyboard to lines 131 and 132, and thence to the selecting switches. In the lower right-hand corner of the diagram are shown a number of relays which co-operate with each other in the control of the impulses. The release magnet for the key-set switch, M-16, belongs properly with the apparatus shown at the left.

The connector switch (see Fig. 183), has two line relays, R-23 and R-22. The lines are transposed before entering the switch circuit. There is a rotary off-normal spring, F-6, and a vertical foot switch 237 and 238. The rotary foot switch, *F*-6, operates on the first rotary step and the vertical foot switch, 237-238, on the first vertical step. The two control relays, *R*-24 and *R*-27, co-operate with the line relays and the foot switches in delivering the impulses, first to the magnet *M*-11 for the frequency selector *S*-7, then to the rotary magnet *M*-9, and lastly to the vertical magnet *M*-10. The busy-test relay is *R*-29. If the called line is busy, *R*-29 will release the connector and supply the busy tone to the calling subscriber. The ringing relay, *R*-28, is wired in

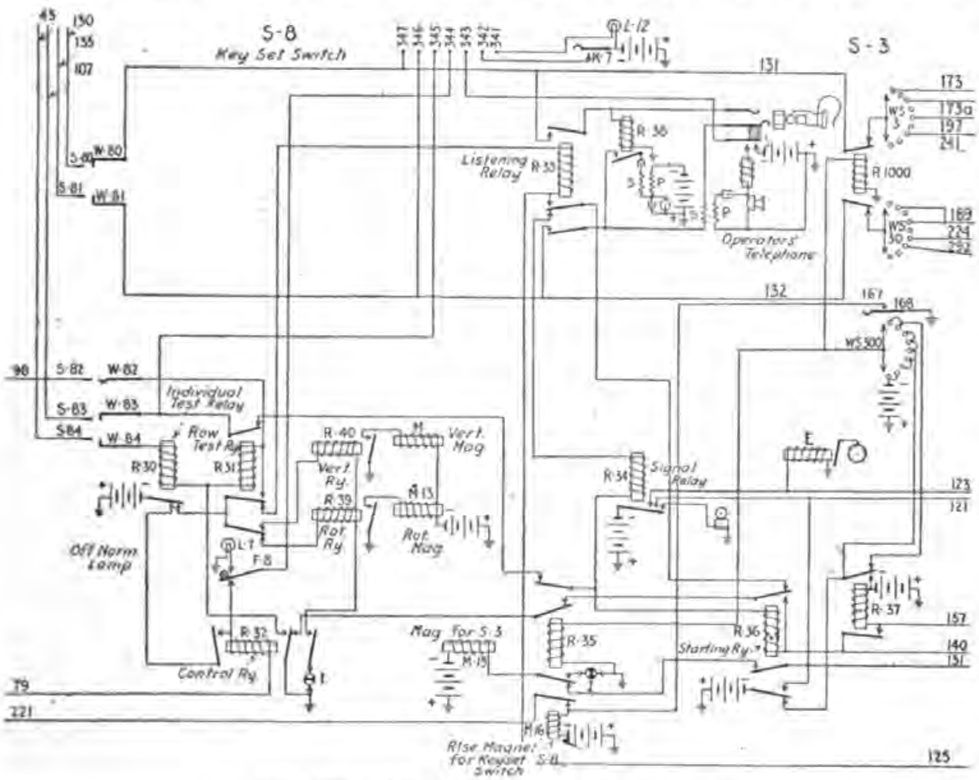


FIG. 179.—Operator's keyset switch circuit.

the usual manner except that its sleeve contact is wired through a resistance *r*-1 to negative battery, to hold up the cut-off relay while ringing.

The frequency selector, S-7, is a flat rotary type switch. The selecting wiper is *W*-*S*-70 but there are two other wipers, *W*-*S*-700, for the purpose of restoring the switch to normal, by propelling it around the circle, and *W*-*S*-7, which has for its object the release of the connector.

The general relation between the secondary distributor and the key-set switches is shown in Fig. 177. At the left are shown the banks of two key-set distributors, one of which is assumed to be for the first hundred subscribers' lines and the other for the second hundred. For 1000 subscribers there would be ten key-set distributors. In the upper part of the figure are shown two banks, each belonging to the key-set switch of an operator. These are hundred point banks and are multipled together. Each operator can, therefore, be connected to any one of one hundred trunks, the same being divided into ten groups of ten each. The groups are by vertical rows.

When a call is initiated in any hundred, the key-set distributor rotates to find an idle operator's position. Wire 79 indicates by the presence or absence of negative battery potential whether the position is free or busy. Position No. 1 is shown as busy and position No. 2 as free. When the primary distributor closes contact *R*-10 the secondary distributor will rotate until wiper *W-S*-200 finds negative battery potential on wire 79. Then the distributor will stop and the control relays *R*-10 and *R*-32 perform their functions. Wires 79 are common starting wires, and are multipled to the banks of all the secondary distributors which have access to these operators. The release wire 221 is also common.

The row test wires 98 are individual to the hundred group. All those proceeding from the key-set distributor for the first hundred will terminate on contact No. 1 *S*-82 of the row test contacts of all the secondary selectors. Similar wires 98, proceeding from the secondary distributor of the second hundred are attached to contact No. 2 on each key-set switch bank. Immediately above each row test contact *S*-82 is the vertical row containing the terminals of the trunks which serve the particular hundred to which the row test contact belongs.

When the key-set switch operates, its wipers rotate until *W*-82 strikes the contact carrying negative battery potential from wiper *W*-20 and contact *R*-10. The wipers will then be lifted until *W*-84 finds the individual contact leading to the trunk which at this moment is busy.

DETAILED CIRCUIT OPERATIONS

Initiation of Call.—When the subscriber takes the receiver from the hook, the line relay *R*-1, Fig. 176, and the row relay *R*-3 both energize. The line relay locks itself and the row relay. The line relay grounds the individual test contact *C*-25 of all the primary selectors in this group. The row relay, *R*-3, grounds the row test contact, *C*-26, lights a supervisory lamp and energizes the starting relay, *R*-4, of the primary distributor switch.

Relay *R*-4 prepares the testing circuit of the primary distributor switch by connecting relay *R*-5 from ground to the wiper. It also connects the interrupter to the magnet *M* so that the wiper of the primary distributor is thereby driven over the bank contacts. The wire 38, leading to an idle trunk, has negative battery potential on it, so that when the idle trunk is found, relay *R*-5 will be energized in series with a relay connected with the trunk. The energizing of relay *R*-5 cuts off the current from the magnet *M* and stops the primary distributor switch.

The same current which stops the primary distributor switch energizes the control relay *R*-13, Fig. 178, of the primary selector, both *R*-5 and *R*-13 being in series.

The control relay on pulling up locks itself to negative battery, through a back contact on the trunk cut-off relay *R*-42. The control relay places negative battery on wire 45, leading to the key-set switch bank, Fig. 179; contact *S*-84, which is the individual contact in a certain vertical row, and is for the purpose of stopping the wiper of the secondary selector at the proper trunk. The control relay also connects ground from the interrupter *I* through a back contact of relay *R*-12 to the rotary relay *R*-18 which also receives its negative battery connection through the control relay.

The pulsations furnished by the interrupter *I* cause the rotary relay to vibrate so that the rotary magnet *N*-5 rotates the wipers. During this time the row test relay *R*-12 lies in a circuit between the row test wiper *W*-26 and negative battery which it receives from the control relay through a contact on relay *R*-15. When the subscriber initiated the call his group relay *R*-3, Fig. 180, placed a ground on the row test contact *C*-26, Fig. 176, of the primary selector, hence when the primary selector wipers have rotated to the row in which the calling subscriber's line terminates, the row test relay *R*-12 will find ground and be energized.

On pulling up, relay *R*-12 will lock itself to ground, connecting individual test relay *R*-15, Fig. 178, to the wiper *W*-25 and shift the pulsations from the rotary relay to the vertical relay *R*-19. The vertical magnet at once steps the shaft upward, while *R*-15 tests each individual contact *C*-25. On arriving at the contact belonging to the calling line, the individual test relay *R*-15 finds ground which has been placed there by the line relay *R*-1. On pulling up, the test relay *R*-15 cuts off the negative battery supplied from the vertical relay *R*-19, and the row test relay *R*-12, so that both of them becomes de-energized, stopping the wipers of the primary selector on the calling line.

The line wipers, *W*-3 and *W*-4, are now in contact with the bank contacts, *C*-3 and *C*-4. The cut-off relay of the calling line is pulled up, owing to the switching of the individual test relay *R*-15 from the wiper *W*-25 to the line 6, so that current will flow from negative battery through the winding of *R*-15 back contact of *R*-12, the line 6, wiper *W*-4, contact *C*-4, winding of cut-off relay *R*-2 to ground. The pulling up of the cut-off relay clears the line of the line relays *R*-1, and *R*-3, unlocks them from ground and connects the tip and sleeve of the subscriber's line through to the primary selector.

The extension of the subscriber's telephone line to the primary selector results in the flow of current through the subscriber's telephone from the two relays *R*-14 and *R*-15, with the cut-off relay *R*-12, tapped off to ground from the negative or sleeve side of the line. The tip relay *R*-14 on pulling up cuts off the tip line 7 from the trunk cut-off relay *R*-42.

Coincident with the stopping of the primary distributor switch, Fig. 176, the key-set distributor is started on its hunt for an idle operator's position. The pulling up of relay *R*-5 energizes starting relay *R*-11. The rotary magnet *M*-2 drives the wipers over the bank. Relay *R*-11 also connects up the testing circuit from ground through relay *R*-10 to the wiper *W*-*S*-200. Wire 79 leads to the control relay *R*-32, Fig. 179, of the key-set switch. If the position is not busy and is ready for the reception of a call, the control relay will be connected to negative battery through back contact of rotary foot switch *F*-8, terminal 344, back contact of relay *R*-49 of special first selector, Fig. 186, terminal 343 key-set switch, Fig. 1 9, contact on operator's receiver jack. If an operator leaves her position she will withdraw the receiver plug cutting off the negative potential from the control relay and wire 79 and making her position busy.

When the wipers of the secondary distributor, Fig. 176, arrive at a line operator's position, the stopping relay *R*-10 will be pulled up in series with the control relay *R*-32, Fig. 179. In the secondary distributor switch this energizes relay *R*-9 and cuts off the rotary magnet *M*-2 so that the switch stops. Relay *R*-9 puts negative battery potential on wiper *W*-*S*-20, wire 98 leading to bank contact *S*-82 which is the row test contact. Relay *R*-9 also grounds *W*-*S*-200, which short-circuits relay *R*-10, allowing the latter to fall back. This, however, does not affect relay *R*-9, since the latter is locked to negative battery through its own contact.

The pulling up of the control relay *R*-32 of the key-set switch, Fig. 179, locks its own winding to negative battery through a back contact of relay *R*-36, prepares the row test circuit from ground through a front contact on relay *R*-32, winding of relay *R*-31 to wiper *W*-82, and closes the interrupter circuit from ground through the interrupter *I*, front contact of relay *R*-32, winding of relay *R*-39, back contact of relay *R*-31, back contact of relay *R*-30 to negative battery.

Pulsations are now delivered through the rotary relay *R*-39 and thence relayed to the rotary magnet *M*-13 so that the wipers of the key-set switch rotate, hunting for the row in which lie the contacts of the trunk seized. When wiper *W*-82 arrives at the live contact *S*-82, relay *R*-31 pulls up, cutting off ground from the rotary relay and giving it to the vertical relay instead. At the same time relay *R*-31 locks itself to negative battery through a back contact of relay *R*-30 and opens a wire leading from wiper *W*-83.

The vertical magnet *M* now lifts the shaft while the individual test relay, being connected between wiper *W*-84 and ground, tests the individual trunk contacts. The control relay of the primary selector seized (see Fig. 178, relay *R*-13) placed negative battery potential on wire 45 which terminates on the bank contact *S*-84 of the secondary selector. Hence, on arriving at this contact, individual test relay *R*-30 of the secondary selector will pull up, cutting negative battery current from the vertical relay *R*-40 and unlocking relay *R*-31. The wipers are thereby stopped and the circuit from wiper *W*-83 closed.

At this moment two wires are extended from the first selector trunk in Fig. 178 to the operator's position. Wire 130 carries the circuit from the tip wiper *W*-9 of the first selector, through a back contact of relay *R*-41, through wire 130, bank *S*-80 of key-set switch, Fig. 179, and wiper *W*-80 to wire 131. The other is from wiper *W*-10 of the first selector, Fig. 178; through a back contact of relay *R*-41; wire 135; bank contact *S*-81 of key-set switch, Fig. 179; wiper *W*-81 to wire 132.

The falling back of relay *R*-31 of the key-set switch closes a circuit which simultaneously energizes the trunk cut-off relay *R*-42 of the first selector and signal relay *R*-34 at the operator's position. This circuit extends as follows:

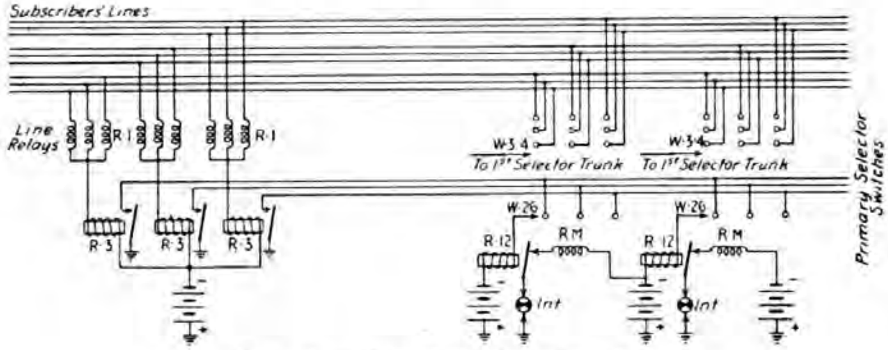


FIG. 180.—Identifying the calling line.

from negative battery, through front contact of sleeve relay *R*-15, primary selector (Fig. 178), winding of trunk cut-off relay *R*-42, wire 107, bank contact *S*-83 of key-set switch (Fig. 179), wiper *W*-83, back contact of relay *R*-31, back contact of relay *R*-35, winding of signal relay *R*-34, back contact of listening relay *R*-33, back contact of starting relay *R*-36, another back contact of relay *R*-35, back contact of relay *R*-32 (this having been de-energized), to ground.

The trunk cut-off relay *R*-42 on pulling up, cuts off the wires 7 and 8, so that the impulses to be sent will not annoy the subscriber. It also unlocks control relay *R*-13, as well as stopping relay *R*-5 of the primary distributor, Fig. 176. When this latter relay falls back, current is cut off from relay *R*-11 of the secondary distributor. This allows relay *R*-9 to fall back and take the negative battery potential from wire 98 and row test contact *S*-82 of the secondary selector. The primary and secondary distributor switches are therefore returned to common use so that any other subscriber in the same hundred may initiate a call.

The unlocking and falling back of the control relay *R*-13 of the primary selector, Fig. 178, takes the negative battery potential from wire 45 so that any other key-set switch will not stop on this trunk. The pulling up of the signal relay *R*-34, Fig. 179, at the operator's position, lights a guard lamp *L*-2, Fig. 181, which attracts the attention of the operator. It also rings a night alarm bell for night service, if desired, and operates a call register, *E*.

The operator now answers the call by pressing the listening key *L-K*, Fig. 181. Current then flows from ground Fig. 181, contact of key *L-K* and wire 125 to Fig. 179, winding of listening relay R-33, back contact of relay *R*-31, back contact of relay *R*-30 to negative battery. The listening relay immediately pulls up and locks itself to ground. It breaks the circuit

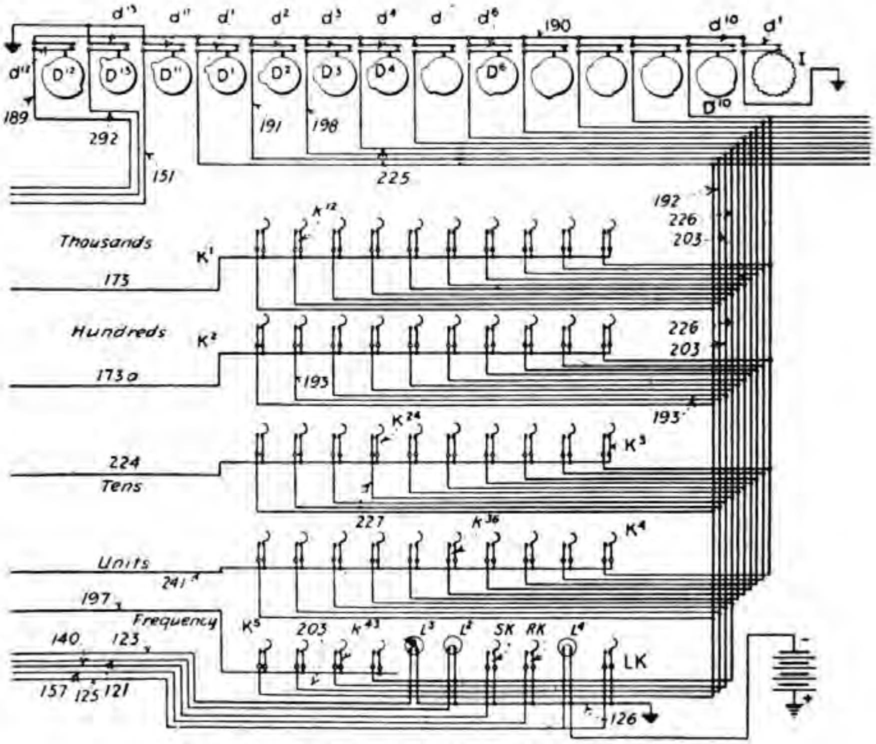


FIG. 181.—Sending machine and keyset circuit.

of the trunk cut-off relay *R*-42, Fig. 178, which falling back connects the talking circuit to the operator's position. The signal relay is also de-energized so that the lamp *L*-2 is extinguished. The listening relay also connects the operators' set to the line.

The operator now speaks to the subscriber and obtains the desired number, which she sets up on the rows of keys shown in Fig. 181. The row of keys marked "*K*-1" indicates the thousands digit, *K*-2 the hundreds digit, *K*-3 the tens digit, *K*-4 the units digit and *K*-5 the station desired upon a party line. Lastly she presses the starting key *S-K* which energizes the starting relay *R*-36, Fig. 179. The circuit over which this is done is as follows: ground, starting key *S-K*, Fig. 181, wire 140, winding of relay *R*-36, Fig. 179 back contact of relay *R*-35, back contact of relay *R*-31, wiper *W*-83, contact

S-83, wire 107 to Fig. 178, winding of relay R-42, front contact of relay R-15 to negative battery. This pulls up the trunk cut-off relay, disconnecting the calling subscriber and connecting negative battery through winding of relay R-41 to ground at foot switch 144-145. Relay R-41, therefore, pulls up and connects the operating wires 135 and 130 to the vertical and rotary relays R-20 and R-21. Relay R-41 will constitute part of the trunk seeking circuit.

The pulling up of relay R-36 of the key-set switch, Fig. 179, unlocks the listening relay R-33, and disconnects the operator's telephone. The same main spring now locks the starting relay in an energized condition, using the same ground as formerly held the listening relay R-33. The starting relay puts negative battery on wire 121 which relights the guard lamp L-2. It will remain lighted until the sending machine has completed its work.

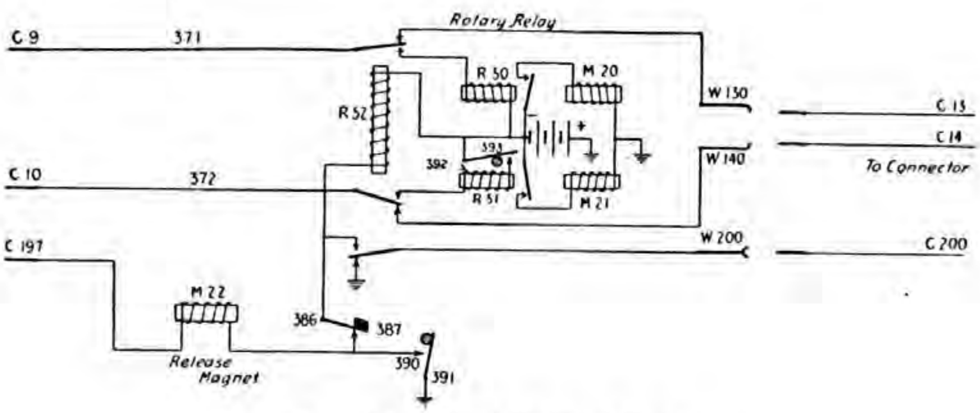


FIG. 182.—Second selector circuit.

R-36 also closes a circuit from the magnet M-15 which operates the auxiliary switch S-3, through a back contact of relay R-35, front contact of relay R-36, wire 151 to the sending machine, Fig. 181, to the pair of springs marked d-11. Since the shaft upon which all these cams are mounted is in constant rotation, presently cam D-11, will close the springs d-11, sending one impulse to the magnet M-15, rotating the wipers of the auxiliary switch S-3 to the first contact.

The auxiliary switch prepares the circuit for the "thousands" impulses as follows: from the common wire of the key K-1, Fig. 181, through wire 173, wiper W-S-3, Fig. 179, back contact of relay R-1000, wire 131, the wiper W-80, contact S-80, wire 130, front contact of relay R-41, winding of relay R-21 to negative battery.

As soon as cam D-11 has broken the contact, the number cams from D-1 to D-10 inclusive pass under their contact springs d-1 to d-10 inclusive. These cams are of graded length, D-1 maintaining contact during only one impulse of the interrupter I. Cam D-2 holds its contact closed through two impulses, interrupter cam D-3 through three impulses, and so forth. The result is that the key in row K-1 which is closed will cause to be delivered to wire 173 as many impulses generated by the interrupter I as correspond to the thousands digit. This will cause the rotary relay R-21 of the first selector Fig. 178 to attract its armature the same number of times, and thereby to operate the rotary magnet and rotate the shaft to the desired vertical row. At the first rotary step of the first selector the rotary foot switch F-5 is closed, lighting the off normal lamp L-5 and preparing the circuit for the release magnets M-3 and M-4, which, however, can not pull up on account of the circuit being broken by the tip relay R-14.

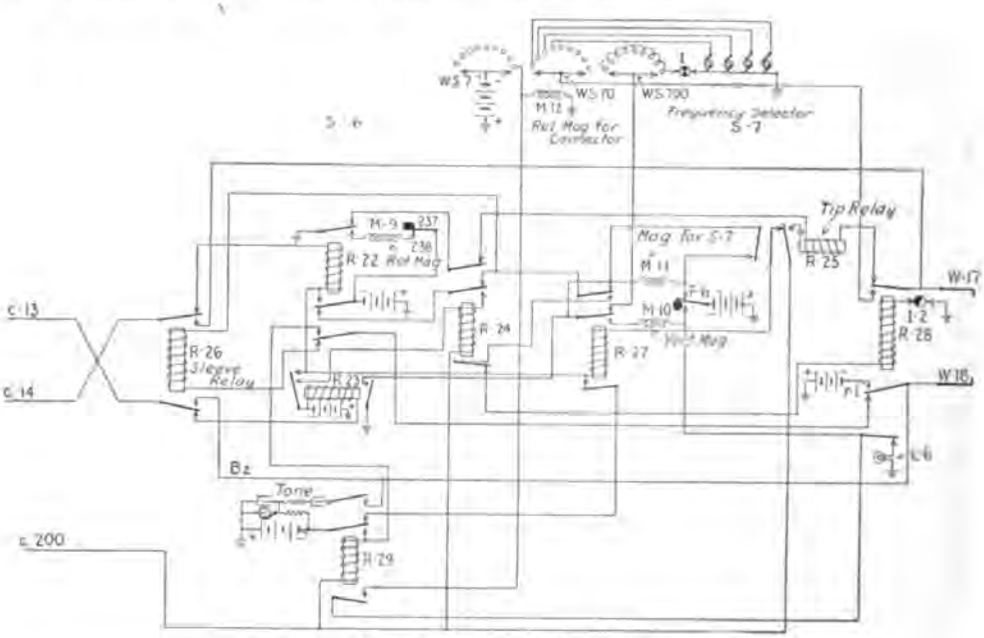


FIG. 183.—Connector circuit.

The selection of an idle trunk is as follows:

After the number cams have caused the rotation of the first selector wiper shaft, contact d-11 is again closed, stepping the auxiliary switch S-3 to its second position which connects wire 189 to wire 132. Wire 189, it will be observed, leads to the sending machine, Fig. 181, where it terminates in spring contacts d-12. This is actuated by a long cam which keeps the circuit closed during ten impulses from the interrupter I. Ten pulsations are, therefore, delivered by the impulse machine over wire 189, wire 132, wiper W-81, contact S-81, wire 135, front contact of relay R-41, vertical relay R-20 to negative battery. This actuates the vertical magnet, lifting the wipers on the first selector in the desired vertical row. The first step of the shaft upward opens the foot switch 144-145 so as to give relay R-41 the opportunity of testing the contacts C-197 for an idle trunk. As long as busy trunks are encountered current will flow through the testing relay. When private wiper *W*-147 of the first selector finds no ground, relay *R*-41 will release, cutting off further pulsations from the vertical magnet, stopping the selector upon a free trunk.

The circuits of the second selector are now prepared. By falling back, relay *R*-41 grounds the private wiper *W*-147 and pulls up the control relay *R*-52 of the second selector over the following circuit: Ground, release magnets *M*-3 and *M*-4 in parallel, back contact of relay *R*-41, private wiper *W*-147, contact *C*-197, low resistance release magnet *M*-22 of second selector, Fig. 182, foot switch 386-387, winding of relay *R*-52 to negative battery. The latter relay on pulling up prepares the line circuits 371 and 372 for delivering impulses to the rotary and vertical relays *R*-50 and *R*-51, with the exception that the latter relay is cut off by the rotary foot switch 392-393.

The switches are now ready for the "hundreds" impulses. Springs *d*-11 of the sending machine close again, causing the auxiliary switch *S*-3 to move to its third position. This connects up wire 173-a, Fig. 179 to wire 131, which now delivers the hundreds impulses to rotary relay *R*-50 of the second selector which repeats them to the rotary magnet *M*-20, rotating the second selector to the desired row of trunk contacts.

The second selector finds an idle trunk as the first selector did. Cam *D*-11 causes the moving of auxiliary switch *S*-3 to contact 4 and follows with ten trunk testing impulses from spring *d*-12. This lifts the wipers of the second selector. The testing circuit includes relay *R*-52, which must depend for ground upon the private contacts C-200 over which the private wiper is moving. When an idle trunk is found, relay *R*-52 will fall back, cutting off further vertical impulses and connecting the line wires through to the seized connector. It grounds the private wire leading to the connector, which protects the trunk from being seized by another second selector.

The frequency selector is next operated. The auxiliary switch, *S*-3, Fig. 179, is moved one step as before, so that its wipers rest upon contact 5. This connects the frequency impulses, wire 197, Fig. 181, to the wire 131 of the secondary selector, Fig. 179. By this means the number of impulses corresponding to the station number of the called telephone will be delivered over the wire 131, wire 130, wiper *W*-9 of first selector, wire 371 to second selector, wiper *W*-130, contact *C*-13 to connector, Fig. 183, back contact relay *R*-26, through the winding of relay *R*-23, to negative battery. The impulses delivered to this relay are repeated by its grounded main spring to the magnet *M*-11 which actuates the frequency selector *S*-7.

The first impulse of relay *R*-23 closes the control circuit of the connectors by causing relays *R*-24 and *R*-27, to lock themselves to the release trunk, which has just been grounded by relay *R*-52 of the second selector. Relay *R*-24 locks itself through a back contact on relay *R*-22, relay *R*-27 energizes through front contact of relay *R*-23, and back contact of relay *R*-25, to release trunk and ground. It locks through the back contact of relay *R*-29.

The connector switch is the next to be operated. The sending machine moves the auxiliary switch *S*-3, Fig. 179, to contact 6, in which position wire 224, which furnishes the tens impulses, is connected to wire 132 for actuating the connector switch. The impulses are sent from the impulse machine, through wiper *W*-*S*-30, wiper *W*-10, wiper *W*-140, back contact of relay *R*-26, winding of relay *R*-22, front contact of relay *R*-27 (locked), back contact of relay *R*-29, to negative battery. The vibrations of relay *R*-22 deliver impulses to the rotary magnet *M*-9, which rotate the shaft to the desired vertical row. The first movement of relay *R*-22 unlocks relay *R*-24

The auxiliary switch *S*-3 is now moved to position 7 for the purpose of stepping the connector wipers up to the called line. The units impulses are furnished from the sending machine, Fig. 181, wire 241 through wiper *W*-*S*-3, wiper *W*-80, wiper *W*-9, wiper *W*-130, back contact of relay *R*-26, through relay *R*-23, to negative battery. The first movement of relay *R*-23 again locks relay *R*-24. Since relay *R*-27 is still locked energized and the rotary foot switch *F*-6 has been moved from its normal position, the impulses now generated by relay *R*-23 will be sent to the vertical magnet through front contact of relay *R*-27. The vertical magnet will lift the shaft to the desired line in response to the definite impulses from the sending machine. During the journey of the wipers upward they are cut off from the tip and sleeve relays *R*-25 and *R*-26, respectively, by relay *R*-24. The called line is tested by relay *R*-29, which is brought into use by relay *R*-22. After the number cams have finished giving impulses and before cam *D*-11 closes its springs, cam *D*-13 closes springs *d*-13 sending a single test impulse to pull up relay *R*-22. It connects the test relay *R*-29 to the wiper *W*-18 as follows: beginning at wiper *W*-18, back contact of relay *R*-28, front contact of relay *R*-22, winding of relay *R*-29, release trunk back to second selector, contact *C*-200, wiper *W*-200, back contact of relay *R*-52, to ground. The sleeve side of the subscriber's line is grounded through the cut-off relay *R*-2, Fig. 176. If the line is not busy no current will be flowing through the cut-off relay, and therefore the sleeve contact at the banks of the connectors will have ground potential. If, however, the line is in use, the sleeve contact will be raised above ground potential.

If the called line is busy relay *R*-29 will be energized and lock itself directly to negative battery. It will close the circuit of the release magnet *M*-12, and cause the connector to release quickly. The same relay, *R*-29, will also unlock relay *R*-27, so that it will fall back, disconnecting the vertical magnet *M*-10 and reconnecting the circuit of the magnet *M*-11 which belongs to the frequency selector *S*-7. Since the rotary foot switch has been reset to normal, the circuit of the magnet for *S*-7 is now completed as follows: negative battery, foot switch *F*-6 in the normal position, winding of magnet *M*-11, back contact of relay *R*-27, wiper *W*-*S*-700, of the frequency selector through its contacts, to the interrupter I to ground. The interrupter will send pulsations to magnet M-11 and cause the rotation of the frequency selector wipers until they again reach their normal position. At the same time relay R-29 connects the busy tone to the sleeve line so that calling subscriber is notified that the line is busy.

When the calling subscriber hangs up, his tip relay R-14 falls back, connecting battery to the release magnets of the primary and first selectors in parallel with the release magnet, of the second selector. This releases the primary first and second selectors.

If the called line in this particular system is not busy, relay R-29 will receive no current, and after the transitory impulse to R-22 is past, the latter will fall back and connect up the sleeve relay R-26 to wiper W-18 which is now resting upon the sleeve contact C-4 of the called line. Current will, therefore, flow through the sleeve relay and cut-off relay of the called line, energizing both. The cut-off relay will clear the called line except for its

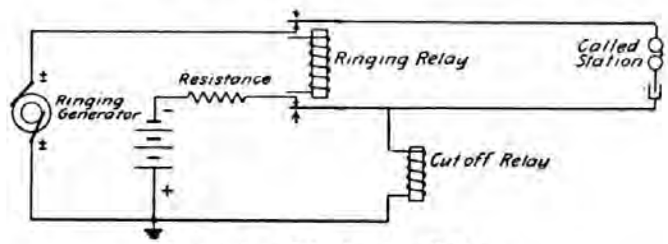


FIG. 184.—Ringing conditions.

own winding. The sleeve relay of the connector cuts off both of the relays R-22 and R-23 and connects the talking circuit through the wipers W-17 and W-18.

The ringing relay now receives impulses from the interrupter I-2 through the back contact of relay R-24, front contact of relay R-27 (still locked), back contact of relay R-24, back contact of relay R-22 to negative battery. Each time relay R-28 pulls up it gives the conditions of Fig. 184.

When the called station answers (during the de-energization of the ringing relay R-28) current will flow to the called telephone by way of the tip relay R-25 returning through the sleeve relay R-26. The pulling up of the tip relay cuts off the ringing current by unlocking relay R-27 which breaks the circuit of the ringing relay R-28.

In order to guard the connector switch from being seized in case the calling subscriber should release before the called subscriber hangs up, the tip relay R-25 places a ground upon the release trunk which terminates in contacts C-200 on the banks of the second selectors. In this case the calling subscriber would cause the release of all the switches except the connector, but the ground held on the release trunk by tip relay R-25 would protect the connector circuit.

During conversation the existing circuits are as shown in Fig. 185. The calling subscriber draws current through two relays in the primary selector. The called subscriber is supplied with current from two relays in the connector. The cut-off relay of each line is energized by current from the sleeve line.

The release magnets of the primary selector, first selector and second selector, are in one common circuit, broken only at contact of the relay *R*-14, which will be closed whenever the calling subscriber hangs up his receiver.

The release circuit of the connector is complicated by being linked in with the release of the frequency selector to secure slow release. If the called

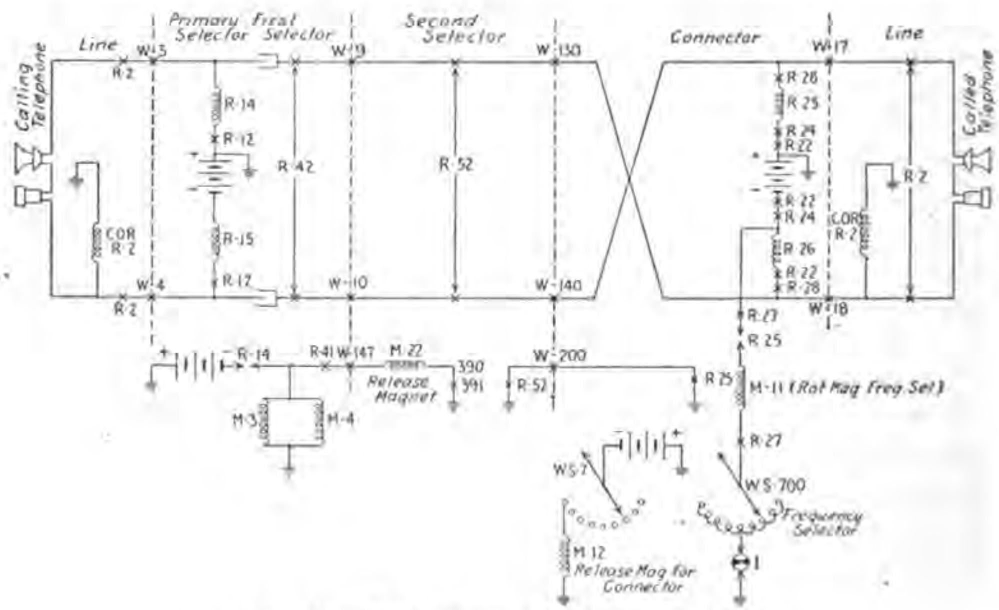


FIG. 185.—Talking connection between stations.

subscriber accidentally opens the circuit of his telephone by unintentional movements of the hook switch, his tip relay *R*-25 will momentarily close the contact marked *R*-25 in the circuit of the rotary magnet *M*-11 of the frequency selector. This connects the impulse machine *I* to the rotary magnet *M*-11 and, if the circuit should be closed long enough, would drive the wipers of the frequency selector on around the circle to normal. Momentary movements of the hook switch will not advance the wipers of the frequency selector very far. When the called subscriber hangs up his receiver for a sufficient time the frequency selector will reach normal. On the last contact the circuit of the release magnet *M*-12 of the selector is closed by wiper *W*-*S*-7 (see Fig. 183 as well as Fig. 185).

When the subscribers release, each controls only a part of the complete connection. The calling subscriber releases primary, first, and second selectors. The called subscriber releases the connector as above described.

Reverting Calls.—When a subscriber desires another subscriber who is on the same party line, the operator will tell him to hang up his receiver for a

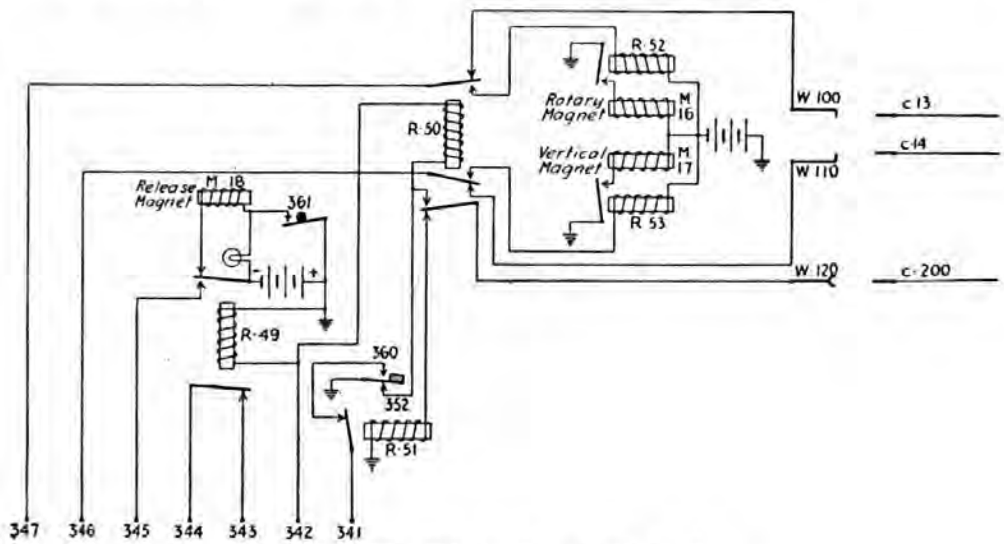


FIG. 186.—Selector for reverting calls.

moment. This will clear his line. The operator will then call the desired subscriber by using a special first selector. When the called subscriber answers, a guard lamp will indicate the fact to the operator, who will then release the special first selector leaving the subscribers to hold conversation on

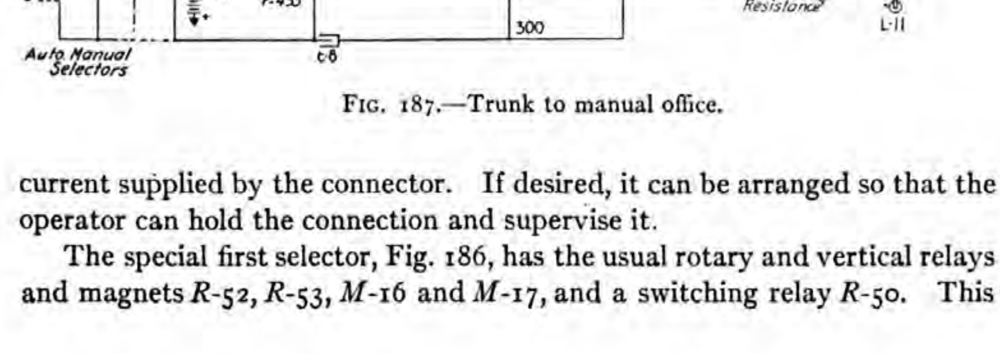


FIG. 187.—Trunk to manual office.

current supplied by the connector. If desired, it can be arranged so that the operator can hold the connection and supervise it.

The special first selector, Fig. 186, has the usual rotary and vertical relays and magnets R-52, R-53, M-16 and M-17, and a switching relay R-50. This arrangement is almost exactly the same as found in the first and second selectors. Relay R-50 also controls the circuit of the private wiper W-120.

The terminals numbered 341 to 347, inclusive, are connected directly to the similarly numbered terminals in Fig. 179 at the operator's position. "346" and "347" are the operating and talking wires. "343" and "344" constitute the loop to make the position busy by the removal of negative battery potential from wire 79 which leads to a bank contact on the key-set distributor switch. "342" is the control wire.

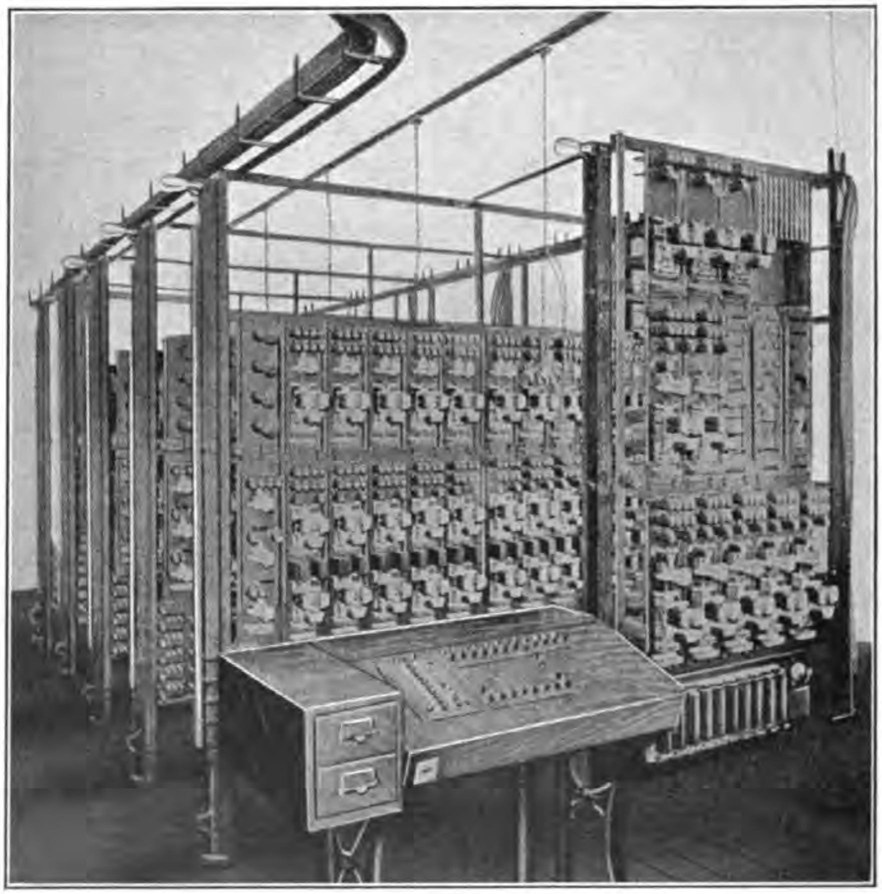


FIG. 188.—500-line installation.

To use the special first selector, the operator presses key K-7. This pulls up relays R-49 and R-50. Relay R-50 on energizing connects the operating wires 346-347 to the vertical and rotary relays and connects the winding of relay R-50 to the private wiper to be used as a trunk-finding circuit. Relay R-49 opens the protective loop 343-344 making the position busy, cuts off the circuit of the release magnet M-15 and connects negative battery to the controlling circuit at the operator's position. The current flow in this circuit is as follows: negative battery, front contact of relay *R*-49, wire 345 to Fig. 179, wiper *W*-83, back contact of relay *R*-31, back contact of relay *R*-35, winding of relay *R*-36, wire 140, to the impulse machine Fig. 181, where it terminates on one of the springs of the starting key *S-K*. It will be noted that this circuit, so far as the key-set switch is concerned, is the same as was previously traced. The operator sets up the number by pressing the buttons, and finally the starting key *S-K*. This energizes the starting relay *R*-36 over the circuit just described which locks and causes the transmission of the impulses, exactly as was described for the regular connection, the only difference being that the impulses, instead of going out over the wipers *W*-80 and *W*-81, pass over the wires 346 and 347, to the special first selector.

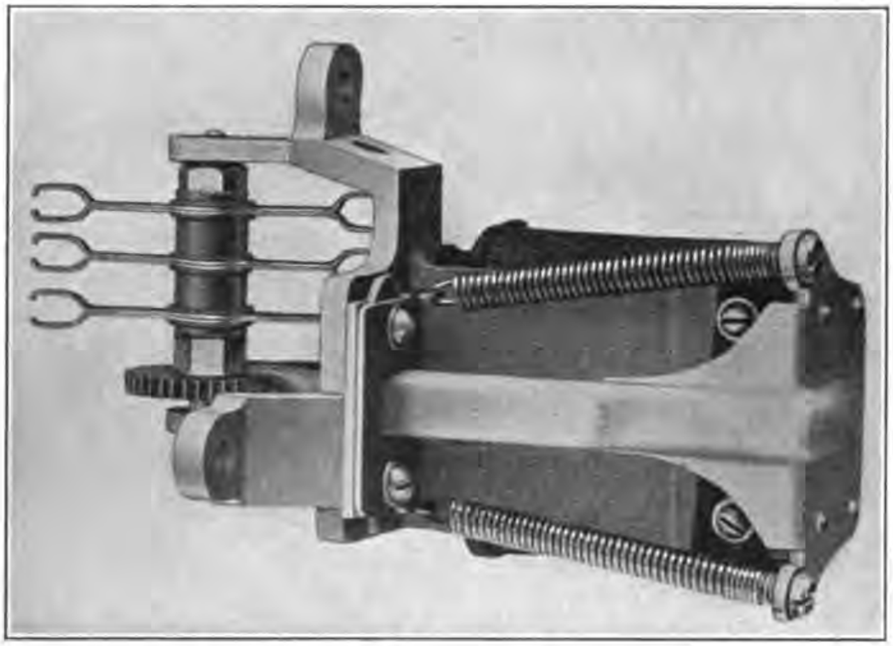


FIG. 189.—Wipers and magnet of rotary switch.

Trunking from Automanual to Manual.—A trunking circuit for handling calls from an automanual to a manual office is shown in Fig. 187. At the left are seen the banks of first selectors, it being assumed that the trunks between offices are handled by the first selector, requiring only a single call figure to establish the connection. The trunk terminates as usual at the "*B*" board in the manual office, under the charge of a "*B*" operator, who is expected to receive her instructions over the trunk line. For the latter purpose she is provided with the usual listening key *K*-6, with which is associated a manual ringing key. The subscriber's line circuit shown at the right is of the simplest type, merely to indicate the possession of line and cut-off relays. It is, however, shown for a three-conductor jack and plug.

When the operator receives a call for the manual office, she causes a first selector to seize a trunk line. Upon the seizure of the line, current flows from the private wiper of the selector through the contacts *C*-200 to the center of a bridge coil whose two windings are indicated by "*r*-2" and "*r*-3." The current thus divides and passes over both sides of the trunk circuit to the cord apparatus in the manual office and passing through the back contacts of relay *R*-45, goes through the two windings of relay *R*-44 in parallel to negative battery. Relay *R*-44 immediately pulls up and by means of its own main springs *r*-442 and *r*-443, connects its windings directly to the line, independent of relay *R*-45. The movement of main spring *r*-441 causes the lighting of the lamp *L*-10.

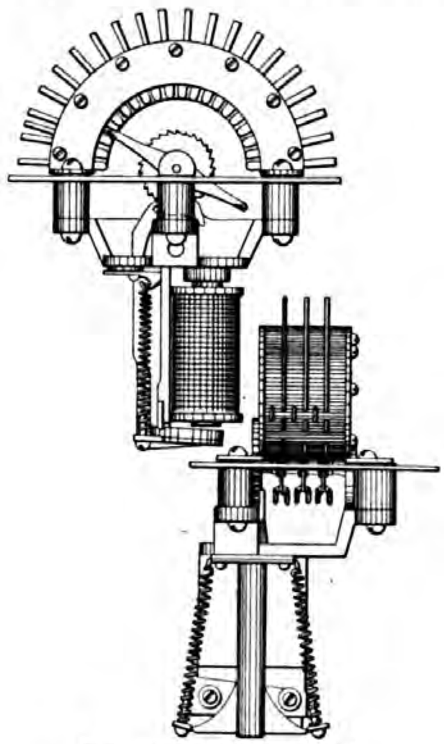


FIG. 190.—Rotary switch.

The "*B*" operator in the manual office, on receiving the number, makes the busy test in the usual way and if the line is free inserts the plug in the jack. This closes the sleeve circuit through cut-off relay *R*-48, sleeve of jack and plug, and lamp *L*-9 and winding of relay *R*-45 in parallel. The lamp lights as a guard for ringing purposes. Relay *R*-45 cuts off the lamp *L*-10. The "*B*" operator now rings with the ordinary ringing key.

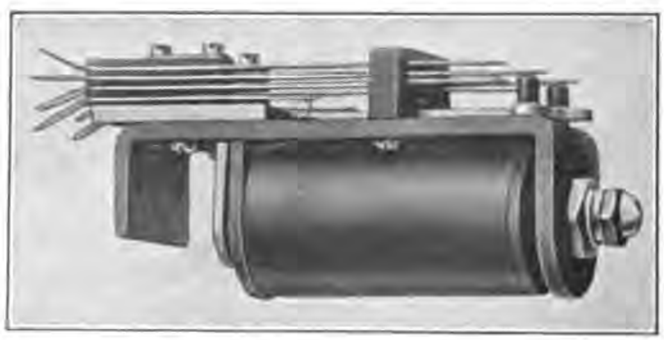


FIG. 191.—Relay.

When the called subscriber answers he will draw current through relay *R*-46 which, on pulling up, will put out the lamp *L*-9, thus notifying the

"*B*" operator that conversation has begun. The two lamps *L*-9 and *L*-10 are the individual supervisory signals for the two subscribers.

When the called subscriber hangs up, relay *R*-46 will fall back and light the lamp *L*-9. When the calling subscriber hangs up it causes the release of the first selector. This allows relay *R*-44 to fall back, whereupon the circuit of the lamp *L*-10 is closed through main spring *r*-441, back contact, to the front contact of relay *R*-45 main spring *r*-452, through the sleeve side

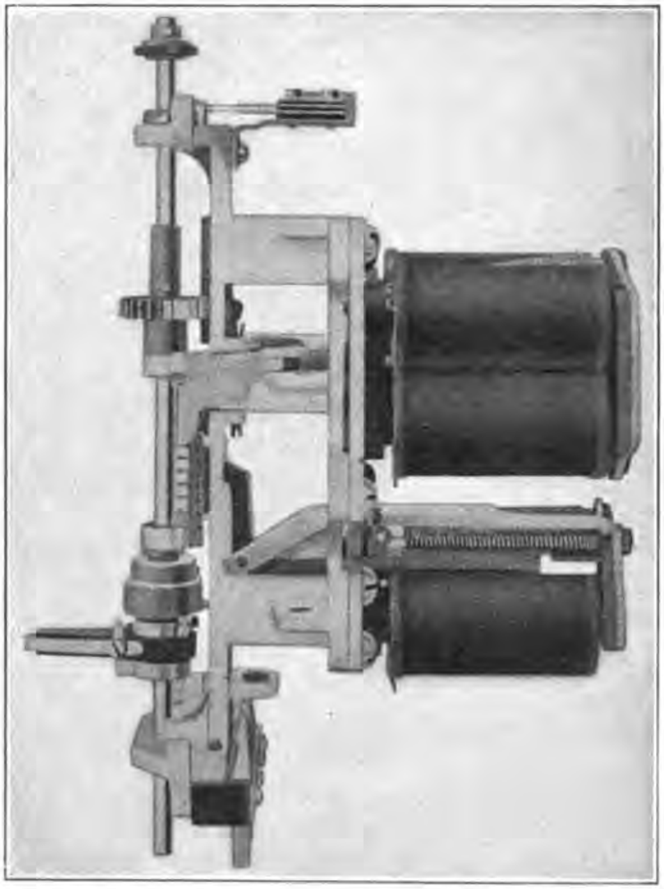


FIG. 192.—Wipers and magnets of switch unit.

of the trunk circuit to main spring *r*-442, through its back contact, through the front contact of main spring *r*-453. Upon seeing both the lamps *L*-9 and *L*-10 lighted, the "*B*" operator will pull down the connection, which will allow the cut-off relay *R*-48 and the trunk relay *R*-45 to fall back.

If desired, the number of the called subscriber in the manual office can be transmitted by impulses and set up before the "*B*" operator, who then needs only to read off the number and make the connection accordingly.

A small installation of five hundred lines is shown in Fig. 188. The operator's desk may be seen in the center foreground. It is equipped with one key set, having three digits (rows of keys) and an additional row of five keys for party lines.

A rotary switch such as used for the distributor switches and the frequency selector, is shown in Figs. 189 and 190. The magnet has a knife edge pivoted armature, retained by coiled springs, adjusted by screws in the armature. The bank has twenty points.

The line relay (Fig. 191) has a heelpiece which makes two bends, one end carrying the core and the other used for mounting. The armature is pivoted

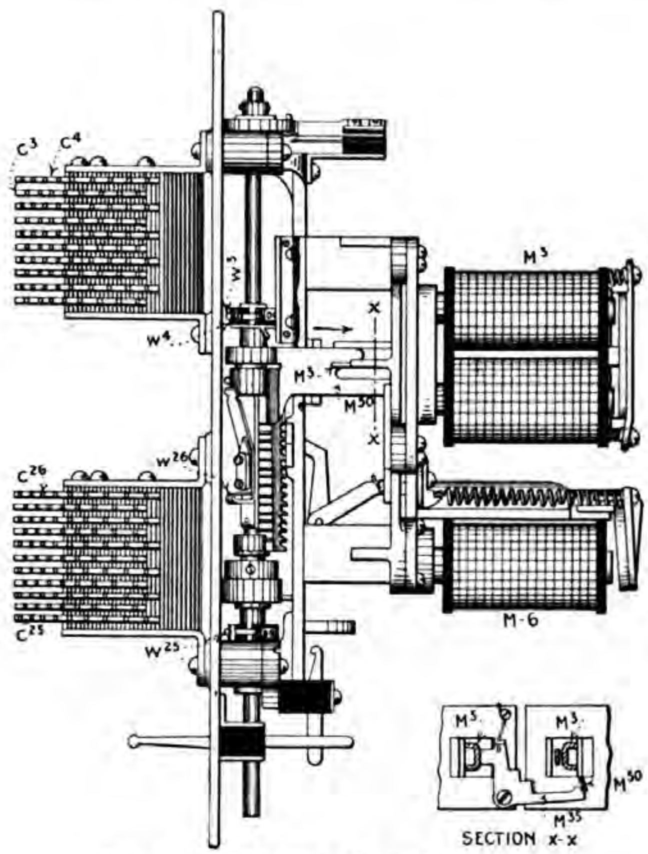


Fig. 193.—Side view of 2-motion switch.

to the back end of the magnet, through a hole in the heel piece. Its finger projects forward to operate the springs.

In the view of a switch unit, Fig. 192, the wiper shaft is at the left. The rotary ratchet wheel is pinned to the shaft and rotates and rises with it. The rotary detent is in the form of a long plate which holds the wheel no matter how high the shaft rises. The vertical ratchet rack is attached to the shaft by collars. It rises with the shaft, but does not rotate. The rack for the vertical detent is at right angles to the rack for the vertical magnet.

The magnet coils are shown at the right. The release magnet, at the top, hides the rotary magnet. Below them is the vertical magnet.

Further details of the switch are shown in the drawings of Figs. 193 and 194. In these the banks are attached. The upper is the line bank, through which the telephone lines are connected. The lower bank carries the

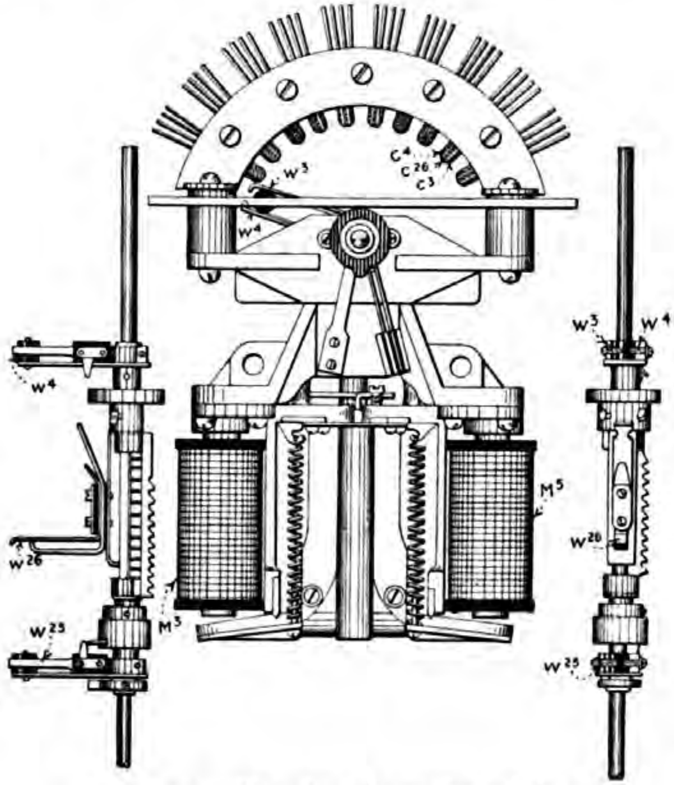


FIG. 194.—Plan-view of 2-motion switch.

auxiliary circuits, which have been described. All bank contacts are set vertically (on edge) with the exception of the top row of the bottom bank. It is the "row test" set, which is engaged by row test wiper, *w*-26. When the switch has rotated and found a certain row, the vertical motion of the shaft lifts the row test wiper, *w*-26, clear of the bank.

CHAPTER XI

THE SYSTEM OF THE WESTERN ELECTRIC COMPANY

The Western Electric Company began work on an automatic system in 1899. It was developed to a commercial point in 1910, and for test a semi-automatic system of 450 lines was installed in the general offices of the Western Electric Company in New York City. This is maintained and operated by the New York Telephone Company as one of its offices in the metropolitan area. Small systems are now being installed in several French and English cities.

This system is designed for use either as a straight automatic or as a semi-automatic system.

Semi-automatic System.—In the semi-automatic arrangement the subscribers' stations may have any common battery telephone and the calls are given to operators who set up the desired numbers and push-button calling

FIG. 195.—Operator's Desk.

device keys. The subscriber removes his receiver from its switch hook, whereupon a finder switch at the central office establishes connection with the terminals of the line. Another finder connects the particular trunk used with an idle cord circuit in an operator's position.

The line signal lamp in the upper row of the operator's position (see Fig. 195) is lighted and when ready for attention will flutter.

Without pressing any key the operator secures the number desired by the calling subscriber and then presses in succession keys bearing the name of the office wanted and the number of the desired line. These keys are shown in the middle of the operator's key shelf in Fig. 195, and are arranged like the keys of an adding machine. The keys are provided with a locking magnet, which holds them depressed until the registers are placed. As the last register takes its position, the sequence switch of the cord circuit disconnects the operator's telephone and breaks the connection of the registers with the operator's numerical keys, retaining, however, the connection of the registers with the cord circuit.

The sequence switch of the first or "group" selector now passes into position to close the circuit between the register and the operating magnet of the selector switch. The register then transmits the proper impulses to the various switches used, with the result that connection is automatically completed from the calling line through the cord circuit of the operator's position and the automatic switchboard to the line of the called party, provided that line is not busy. The ringing current is then automatically and intermittently applied to the called line until the called party responds.

Each cord circuit is equipped with supervisory lamps. If the called line is busy, a lamp flashes. (At the same time the calling party hears an intermittent tone in his receiver.) Either the calling or called party may secure the operator's attention during conversation by flashing a supervisory lamp and when both parties hang up their receivers the display of two supervisory lamps gives the disconnect signal, whereupon the operator presses the button key of the cord circuit displaying the signals. This key closes circuits which cause the various automatic switches used in setting up the connection to return to normal; and, if a meter is used, it causes the meter to register, provided the called party had responded; or, if the calling station should be equipped with a coin collector for taking or refunding coins, it likewise collects or returns the deposited coin automatically.

Where supervision is not desired, a slight change in the cord circuit results in the release of each connection through the automatic operation of the sequence switch, when the connected parties replace their receivers on their switch hooks.

Team Work.—The equipment in Fig. 195 gives thirty cord circuits to each operator, but allows operators to aid each other.

The thirty cord circuits collect calls from so large a number of lines, through the agency of the primary and secondary finder switches, that the calling becomes nearly uniform on each position. It is possible to arrange the apparatus so that a call will never be trunked to the position of an operator other than an idle one, but this is not recommended by the manufacturers for use under ordinary conditions.

The transfer or helping keys need not necessarily be on the operators' positions, but may be placed in the chief operator's desk, or elsewhere.

This assisting service is ordinarily established between three consecutive positions, the middle one being called the "normal" position and the two adjacent positions on either side "assisting" positions. Each position occupies, relatively to its two immediate neighbors, the rôle of normal position. The call terminating normally at any position can be transferred only to one of the two positions immediately adjacent to the position considered.

Whenever any calls have been transferred from one position to another, a pilot lamp burns so that an operator cannot shirk work unobserved. No operator can extinguish the calling lamp of the cord circuit on which a subscriber is waiting until the call is completed. If an assisting operator is not busy, and she sees one of her neighbors very busy she should pull the proper

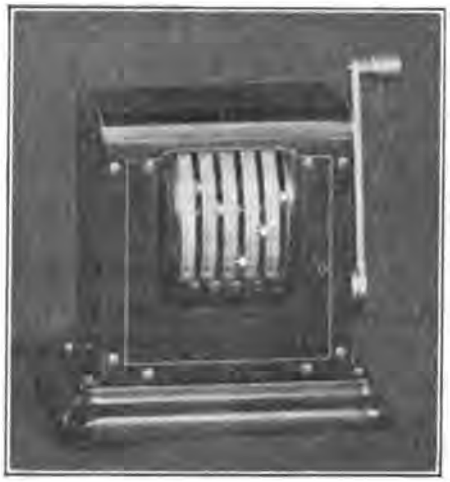


FIG. 196.—Calling Device.

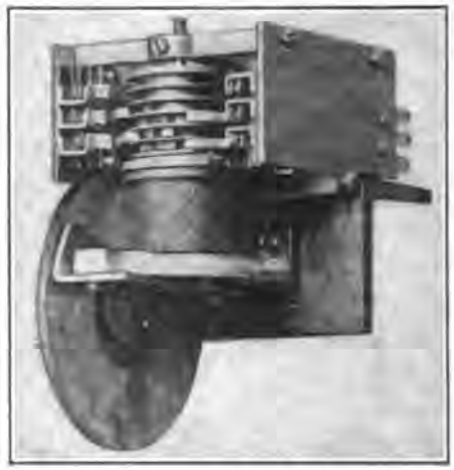


FIG. 197.—Number register (full automatic).

key and cut in to answer calls on the overloaded position; but the calling lamp, the supervisory lamps and the disconnecting key remain on the first position so that the assistance consists only in receiving the call and in setting it up on the register of the neighboring position. The disconnection must be made on the normal position where the call originated.

Number of Calls Handled per Operator.—It is believed that a skilled operator may handle 500 calls during the busy hour. During light load this may drop down to 400.

Automatic System.—If a line is to be given full automatic service, then the station is equipped with a calling device of the type shown in Fig. 196, which is so designed that the number is set up by moving the pointers between the numbered segments to correspond with the respective digits of the wanted party's number. The subscriber must listen for a tone or "office sign" to indicate that the apparatus is ready. The calling device commences sending in the impulses to central when the calling subscriber pulls the lever at the right of the calling device. The necessary changes are made in the central office by replacing the register adapted for operation by the operator's keys with one, Fig. 197, adapted to receiving and recording the impulses from the subscriber's station calling device, and arranging it so that a sequence switch connects an idle set of these registers with the trunk connected to the calling line by the primary and secondary finder switches. The registers receive the impulses sent in from the subscriber's station and then perform their functions of governing the selectors in the same way as before. This change arranges the equipment so that when the calling party replaces his receiver on the switch hook, the automatic disconnection takes place.

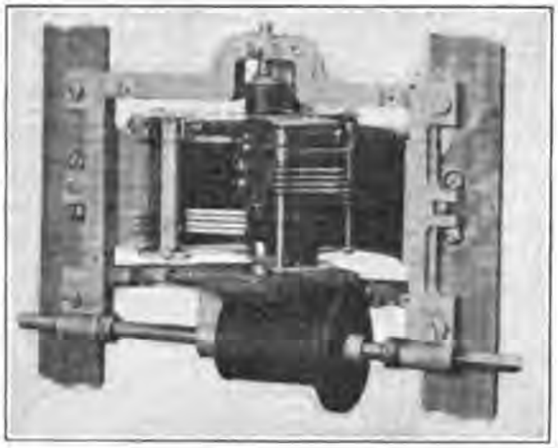


Fig. 198.—Finder switch.

Automatic Switchboard.—Whether the system be semi-automatic or full automatic, there is required in the central office, a complete automatic switchboard. This switchboard possesses three main points of interest, the switch mechanism, the trunking system, and the electrical circuits. These are described in the order named.

The finders, selectors and connectors, and sequence switches are characterized by power drive and single motion (rotary).

The finder switch is attached to a trunk and has for its function the finding of a calling line or trunk and attaching to it its own trunk. It consists (see Fig. 198) of a semi-circular bank of contacts, over which three sets of brushes may be driven. Each line occupies a set of four terminals or contacts in a vertical row. There are twenty such sets of contacts in a horizontal row, while the entire bank is made up of three such rows. Thus the finder serves sixty lines.

There are three sets of brushes, Fig. 199 (four per set) held by a carriage mounted on a vertical shaft. The bottom set may trail over the first level or row, the next set over the second row and the top set over the third or top row of contacts. The brush sets are 120 degrees apart so that only one set will be on the bank at a time. Since the corresponding brushes of all three sets are wired together, the finder may by appropriate rotation connect to any one of the sixty sets of bank terminals.

To rotate the shaft and brushes, the former is connected to the power shaft by a magnetic clutch. The power shaft may be seen in Fig. 198 where it lies horizontally between two bearings. Approximately half way between the bearings is the clutch magnet coil surrounding the shaft. The lower end of the vertical brush shaft carries a flexible bronze disc, whose iron edge barely clears the edge of an iron disc on the power shaft. When the clutch magnet

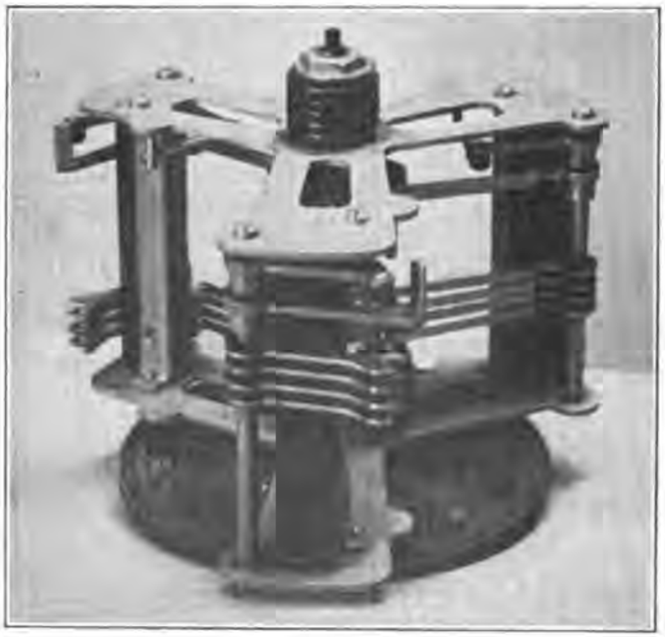


FIG. 199.—Finder brush carriage.

is energized, the magnetic attraction draws the two discs together, so that the brush shaft is driven by the friction between them.

The Selector.—The selector, Fig. 200, resembles the finder in its construction except that it has ten sets of bank terminals (three rows each), ten sets of brushes, and a brush choosing device called the "tripping spindle." There are twenty bank contacts in each row.

Essentially, the function of this selector is to pick out a certain group of trunks fixed by the call number, and to select any idle trunk in that group. It first chooses a set of brushes (by means of the tripping spindle) and then rotates all the brushes. Only the tripped brushes will trail over contacts and thus select a trunk in the chosen group.

The selectors are mounted on vertical frames of angle iron; each forming a self-contained unit or bay, Fig. 201. They are arranged in panels, the number depending upon the volume of traffic. The banks, Fig. 202, are mounted in frames on the back of the bay.

The terminals are moulded in plates of electrose with end lugs for support. The terminals are of phosphor bronze with the grain presented on end. They are assembled in a frame, Fig. 202, the lugs at the ends of the plates entering notches in steel segment plates at the top and bottom of the frame.

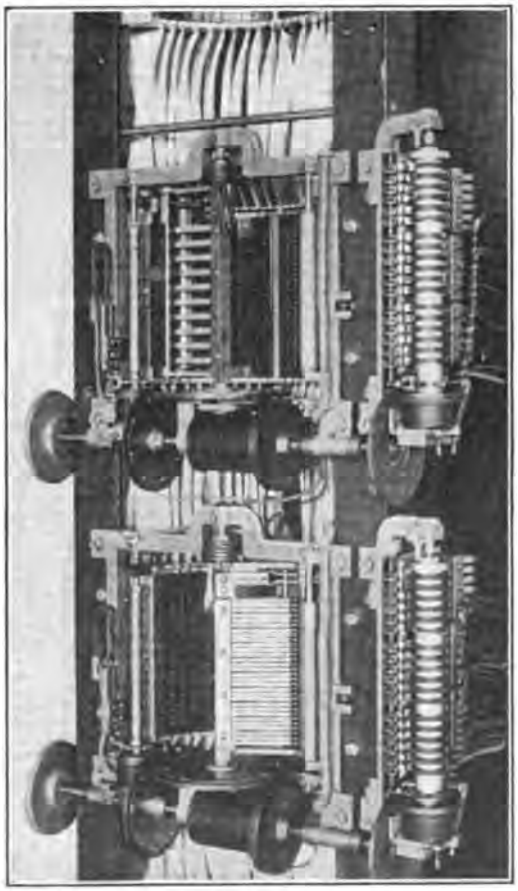


FIG. 200.—Selector.

The brushes and accessories are assembled in a frame known as "the brush carriage," Fig. 203. This frame is mounted on the front of the frame-bars by four screws, aligned by dowel pins.

The contact brushes are shown in Fig. 204. Thirty bronze punchings are carried on insulating hubs on a steel rod attached to the shaft by brackets. Three adjacent brushes form the line and local terminals of a trunk. The thirty brushes thus constitute ten sets. Three spring plates are secured to the shaft, each of which has ten springs which press upon the short arms of ten corresponding brushes and tend to thrust the brushes outward, into position as shown at the fourth set, Fig. 204. The top brushes in each set of three are thus connected in multiple by means of the springs and plate, which are in turn

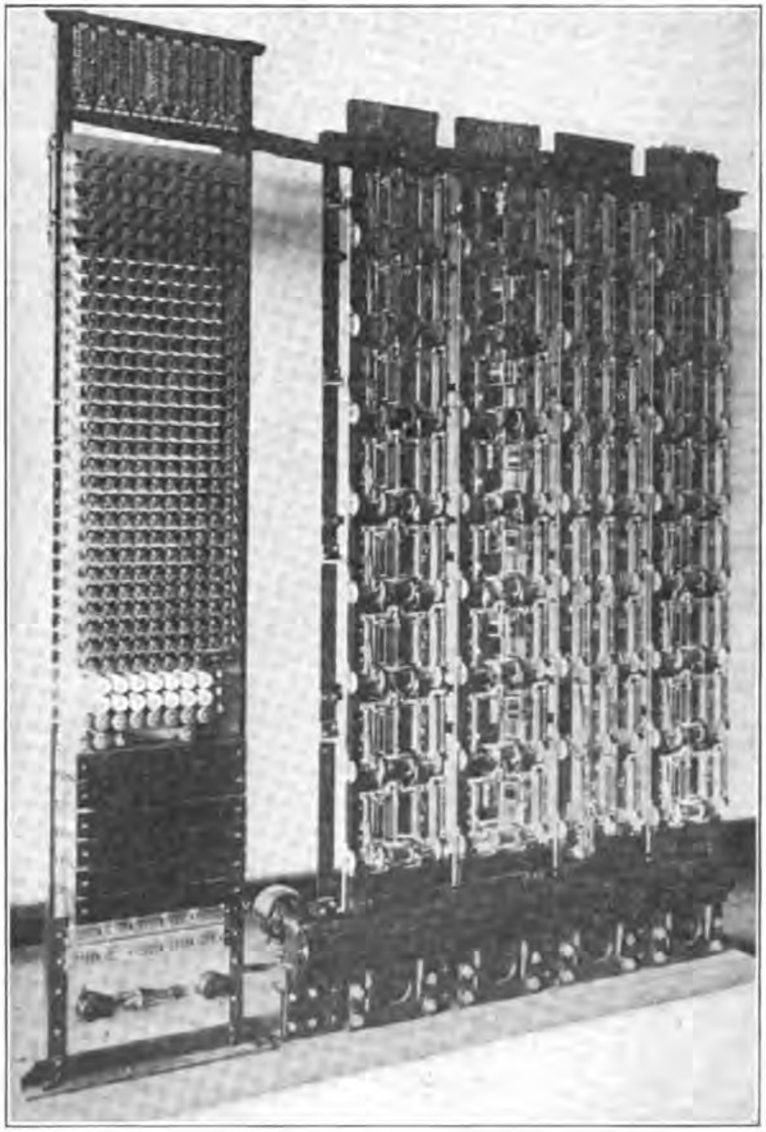


FIG. 201.—Switches mounted on frame.

connected by internal wires with the collector ring upon the shaft. Likewise the second brushes and the third brushes of the different sets are connected together in multiple respectively and with commutator rings.

The free ends of the brushes engage latches (see Fig. 203), by which the brushes are held in such position that they can be moved around inside the

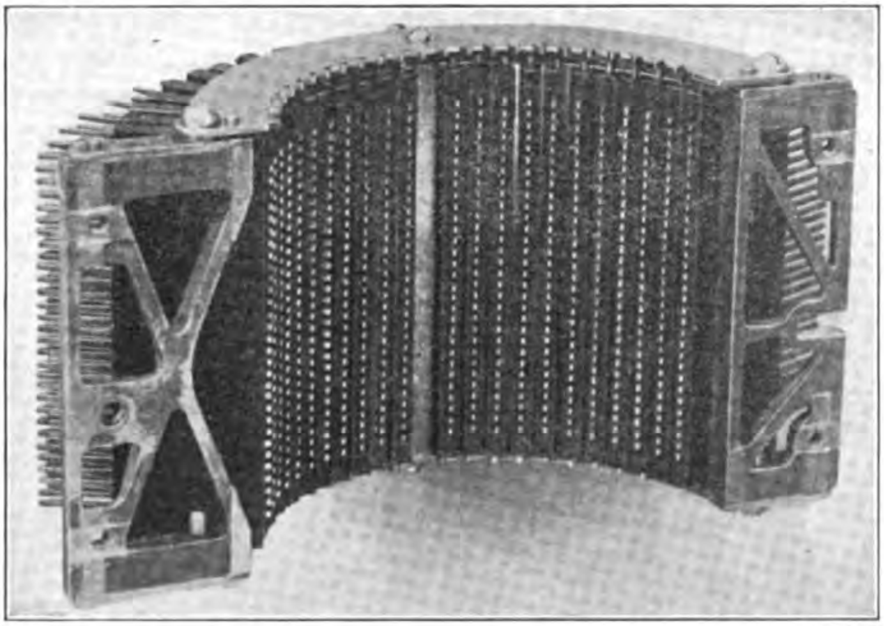


FIG. 202.—Switch bank.

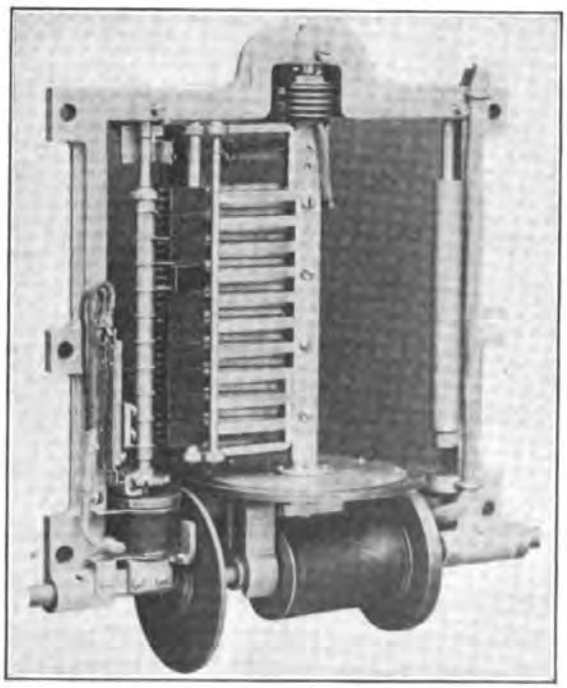


FIG. 203.—Selector brushes and mechanism.

arc without touching terminals. The latches are pressed into engagement with the brushes by a similar comb spring, and hold them firmly. By pulling any of the latches outward, as shown at fourth latch in Fig. 203, a set of brushes can be released and thrust out into position to sweep over the terminals and make contact with them. The peculiar form of the contacting portion of the brush permits it to pass from one terminal to the adjacent with-

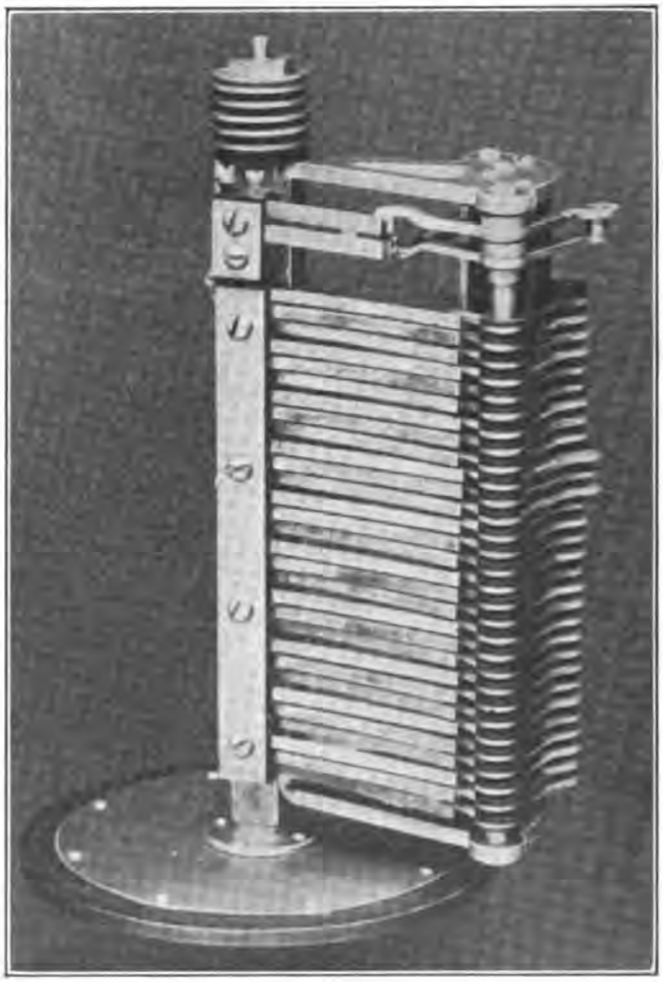


FIG. 204.—Selector brush carriage.

out crossing the two together and so producing interferences with lines which are in use.

The brush-choosing mechanism, Figs. 203 and 205, shows a spindle carrying a series of ten teeth in a spiral, projecting so far that one of them may be brought into position to engage one of the latches of the brush carriage while the other latches will pass without touching. The spindle is driven from the power shaft by a magnetic clutch. Above the iron wheel is a star wheel whose periphery bears a roller which governs circuit contacts, seen at the left. Each tooth of the wheel corresponds to a position of the spindle suited for releasing one of the sets of brushes, the contacts being the means for transmitting impulses of current to the governing registers by which the spindle is stopped in position to release the chosen set of brushes. The brushes are driven over the terminals by a magnetic clutch.

The brush carriage bears at the upper end a pair of contact levers which ride over a toothed rack on the arc seen in Fig. 200, with a notch for each row of

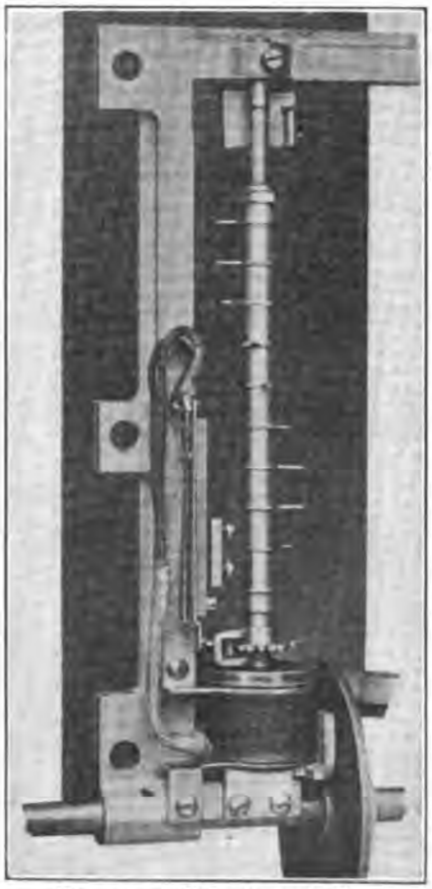


FIG. 205.—Tripping spindle.

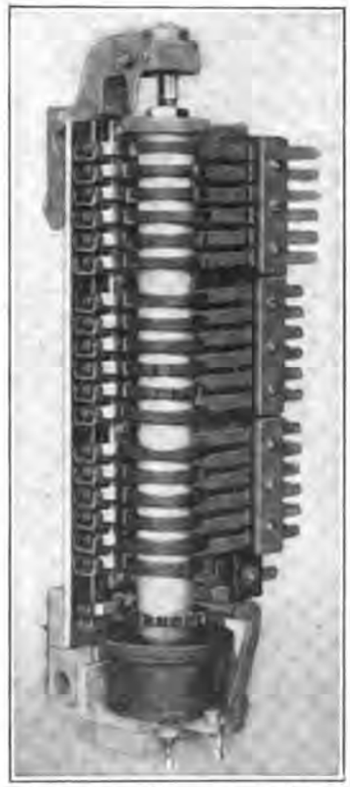


FIG. 206.—Sequence switch.

terminals, and used in a way similar to that for choosing the brushes. The stopping of the brushes on the chosen set of terminals is determined by the number of impulses produced by these contact levers as the brushes pass successively over the rows of terminals. The brushes, after traveling over the terminals, are restored to the latched position by passing over a roller, seen at the right in Fig. 203.

The Sequence Switch.—This appliance may be described as a power-driven relay, Fig. 206. The driven member of the magnetic clutch is fixed to a rotating spindle which carries a series of cams operating upon spring levers vibrating between platinum contact points. The cams are cut to three different depths; for holding the spring lever out, midway, or in. Just above the iron friction wheel there is a special cam or star wheel, with teeth corresponding to the positions in which the sequence switch spindle is to rest; the contacts controlled by this wheel are so connected with the motor magnet that the spindle can come to rest only in its correct position. The cut of the cams fixes the circuit combinations.

Trunking System (200,000 Lines).—The 200,000 line system here described employs first selectors, second selectors, third selectors and connectors.

The reader should disabuse his mind of any connection between the directory or call number, and the number of steps required in the setting up of a connection through any of the switches. The trunking must be discussed as trunking pure and simple, without any regard whatever to the steps or electrical impulses required in establishing the connection. There is

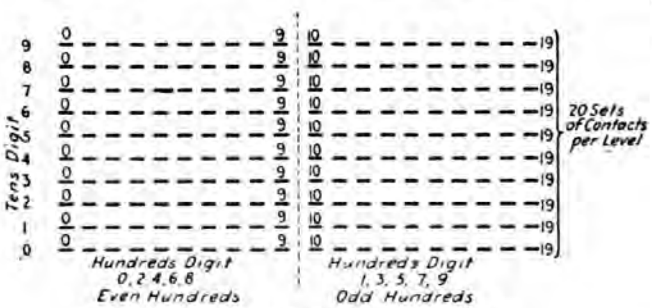


FIG. 207.—Numbering of switch bank.

a definite relation between call number and switch movement, but it will be described at the proper place.

The fundamental unit is two hundred subscribers' lines, Fig. 208. There are several connectors which deliver traffic into each pair of hundreds. The sets of contacts corresponding to subscribers' lines are arranged on the connector bank with twenty sets of contacts per level. There are ten levels.

On each connector bank the first ten contacts of each level belong to one hundred, the last ten sets to another hundred. The hundreds are numbered 0-1-2-3-4-5-6-7-8-9 in each thousand. In any particular connector an even hundred occupies the first half of each level, and the next higher odd hundred the second half. This is illustrated in Fig. 207.

It requires only five groups of connectors to deliver traffic into one thousand subscribers' lines. One group of connectors, Fig. 208, will serve the "0" and the "1" hundred, the next group the "2" and "3" hundreds, and lastly the fifth group of connectors will serve the "8" and "9" hundreds.

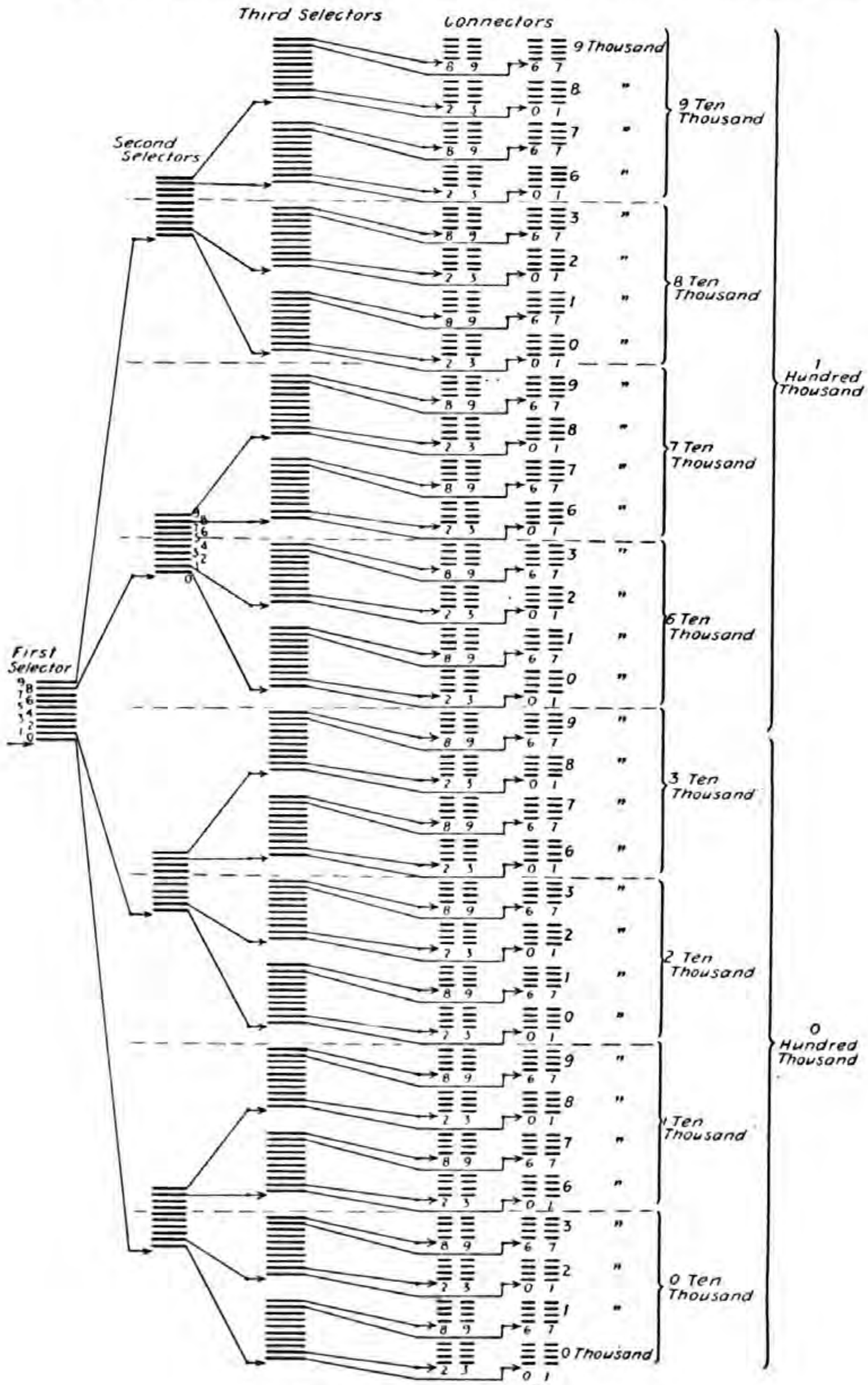


FIG. 208.—Trunking scheme.

From the banks of the third selectors the trunks run in groups of twenty each to the connectors. It thus follows that there are twenty connectors in a group, each capable of distributing calls into two hundred subscribers' lines. This preserves the 10 per cent. ratio of trunks.

Every selector has ten levels with twenty trunks per level. Since it requires only five groups of trunks (five groups of connector switches) to deliver the traffic into one thousand lines, only five levels are required on the bank of a third selector to distribute the calls among the different hundreds of a given thousand. Hence the first five levels in a third selector run to all the connectors for the "0" thousand, and the second five levels to connectors for the "1" thousand.

The various groups of thousand lines are re-grouped into larger divisions called ten thousands.

The distribution to the third selectors is made from the banks of second selectors. From the banks of the second selectors run ten groups of trunks, one group of twenty trunks from each level. The lower five levels deliver traffic into a certain ten thousand division, the upper five levels to a different ten thousand division.

Consider the bank of any given second selector. From its bottom level twenty trunks will run to twenty third selectors, all of which can equally well connect with two different thousands in the given ten thousand division. From the second level of the second selectors trunks will run to third selectors capable of delivering traffic into two more thousands of the same ten thousand division. This will continue up to and including the fifth level.

The sixth level of the same second selector will contain trunks to third selectors capable of delivering traffic into the first two thousands of a different ten thousand division. The remaining four levels above the sixth will similarly care for the remaining thousands of this ten thousand division.

The traffic is distributed to the second selectors from the banks of first selectors. All of the ten-thousand divisions are grouped into two great sections, each having one hundred thousand lines. We call them the "0" hundred thousand and the "1" hundred thousand. The lower five levels of each first selector will deliver traffic into the "0" hundred thousand section, the upper five levels into the "1" hundred thousand section.

The foregoing description takes care merely of the purely numerical switches in the automatic exchange. To this must be added certain non-numerical switches, which connect the subscribers' lines to the first selectors, Fig. 209. The subscribers' lines are attached to the banks of finder switches. When a subscriber originates a call, several finders will rotate to pick up the calling line. The first switch to engage the terminals of the calling line will sieze the same. All remaining finder switches in the same group will stop and remain wherever they happen to be.

The trunk from any finder switch runs to the banks of secondary finder switches. The primary finder switches may be located in the main or controlling office or in a sub-office, or satellite. The secondary finders are always located in a controlling office. Each is directly connected to the jacks of a first selector, the two forming a connecting unit which may be likened to a cord circuit.

A number of these connecting units, or trunks, which extend from a secondary finder to its first selector, are placed under the care of a manual operator. Whenever a subscriber initiates a call, the same will be extended through the primary and secondary line finders and will stop at the operator's position.

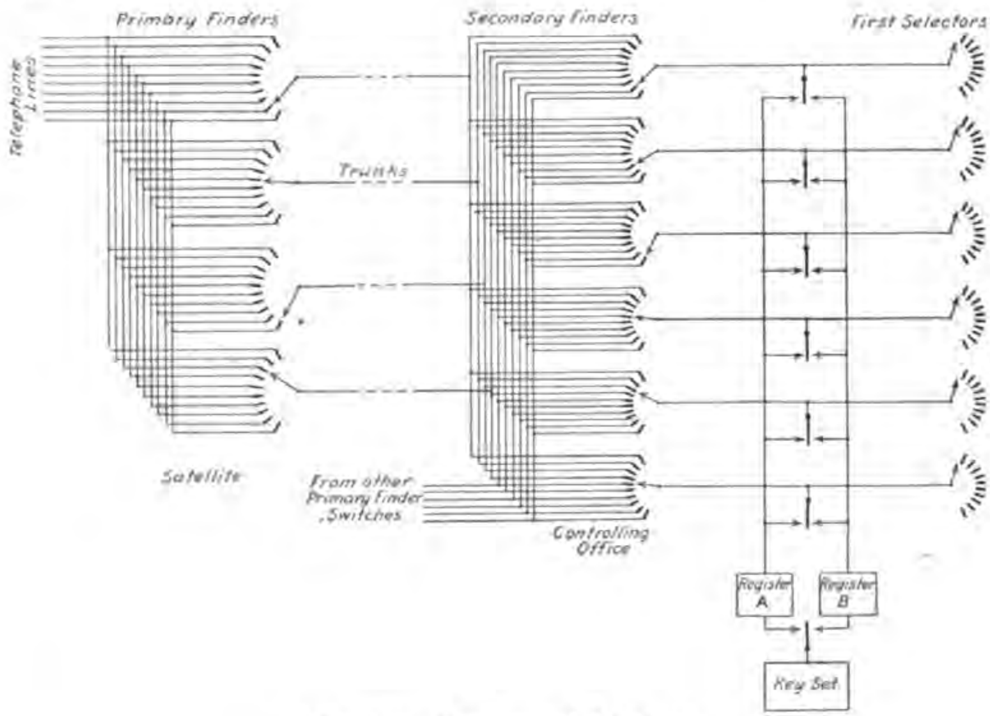


FIG. 209.—Arrangement of finders.

The operator is equipped with one key set, having six rows of ten keys each, numbered from "0" to "9." The first row corresponds to the first figure of the call number, the hundred thousand digit. The second row corresponds to the second figure in the call number, the ten thousand digit. The other rows corresponding to the succeeding figures of the call number ending in the last or sixth row, which corresponds to the units digit of the call number. Upon this array of buttons the operator sets up the number given by the calling subscriber.

Associated with each operator's key set are two registers, each being a duplicate of the other and capable of being connected to any of the trunks, or connecting units, which are cared for by one operator. As soon as the operator has set up a call upon her key set, the number is transferred automatically to an idle register and the key set immediately freed for other calls. The register, which has received a call, proceeds to govern the generation of impulses which control the motion of the switches.

If an operator becomes overloaded with work, relief is provided for by a helping out key. By throwing this key an adjacent operator can answer a call and set up the connection. The connection so set up by an adjacent operator will remain under the control of the home operator, who will supervise and disconnect.

Circuits of Western Electric Semi-automatic System.—In general the circuits may be divided into three groups: finder switches, operators circuits and selector and connector circuits.

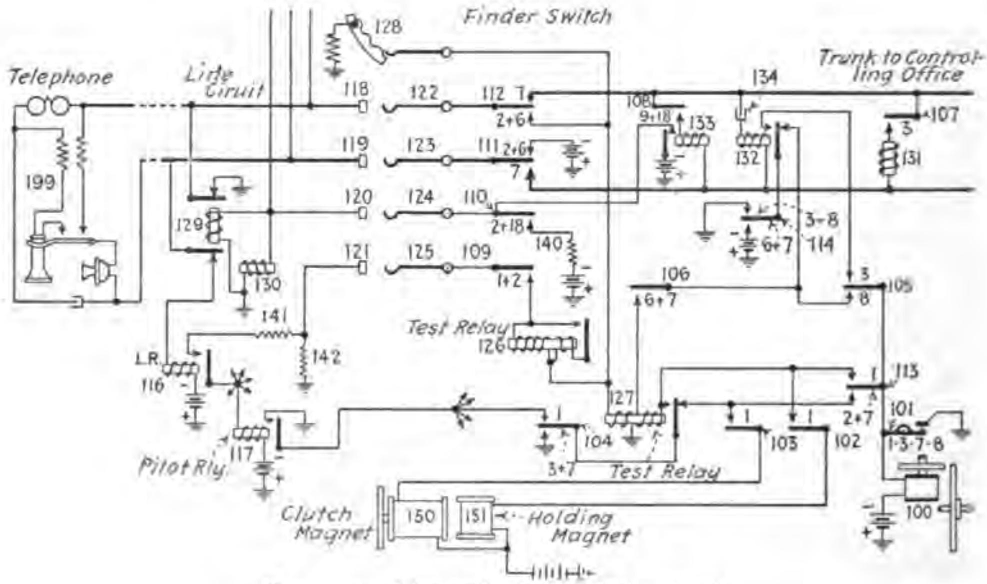


FIG. 210.—Line and primary finder circuit.

Subscriber's Line Circuit.—This consists of a line relay (116, Fig. 210) a cut-off relay (129) and two resistances (141 and 142) individual to a line. There is a pilot relay (117), common to all the subscriber's lines which are served by a group of finder switches.

Primary Finder Switches.—This circuit (Fig. 210) is characterized by having an alternating-current relay (132) in series with a condenser permanently bridged across the trunk circuit. There is another relay (133) which is bridged across the circuit at certain times beside the impedance (131) used for holding purposes.

Two wipers handle the trunk circuit, one energizes the cut-off relay (129) and the other is used to find the calling line. A sequence switch (100) having four stop positions controls most of the circuits.

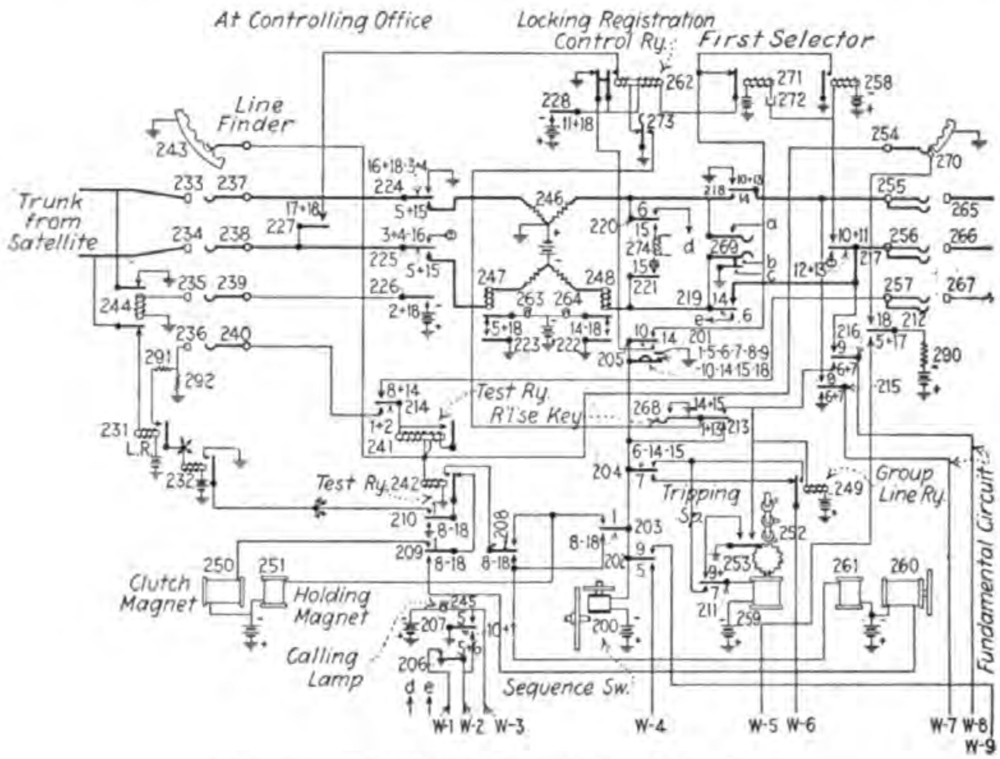


FIG. 211.—Secondary finder and first selector circuit.

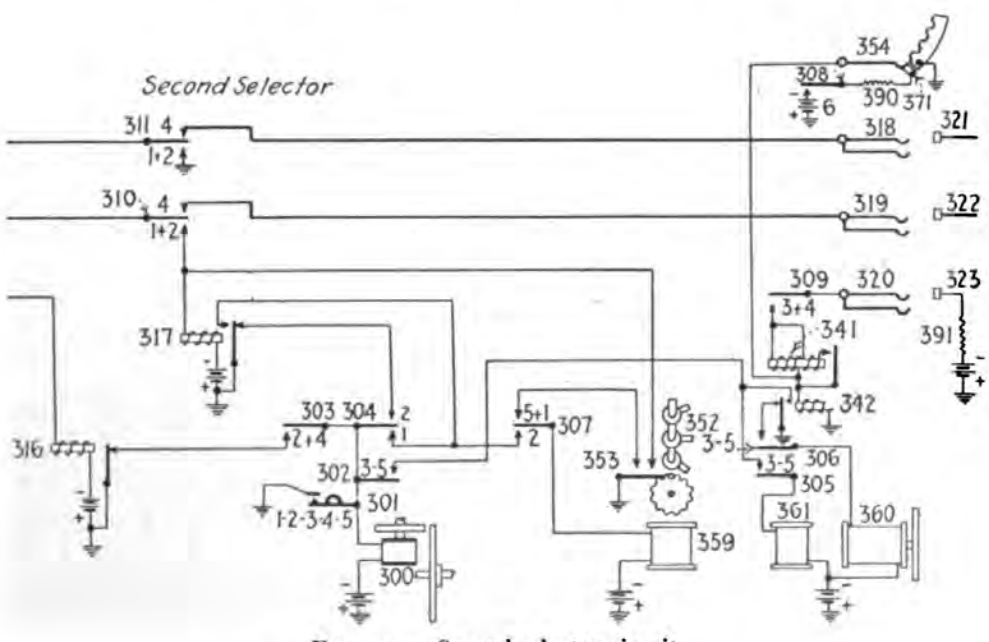


FIG. 212.—Second selector circuit.

Secondary Line Finders.—The line apparatus (Fig. 211) of a trunk coming from a satellite is almost exactly like the subscriber's line equipment and acts in the same way. The line finder and the first selector are permanently attached to each other both as to trunk and auxiliary circuits. The trunk lines extend through the repeating coil (246) to the brushes of the first selector. The usual supervisory lamps 263-264 are provided. There is one sequence switch (200) serving both finder and selector. The same is true of the test relay (242) by which a line finder picks up a calling trunk and the selector an idle trunk in a predetermined group. The sequence switch (200) has ten stop positions.

Second Selector.—The sequence switch (300) Fig. 212 has five stop positions. The control of the second selector is secured through impulses sent over both wires of the trunk circuit in series.

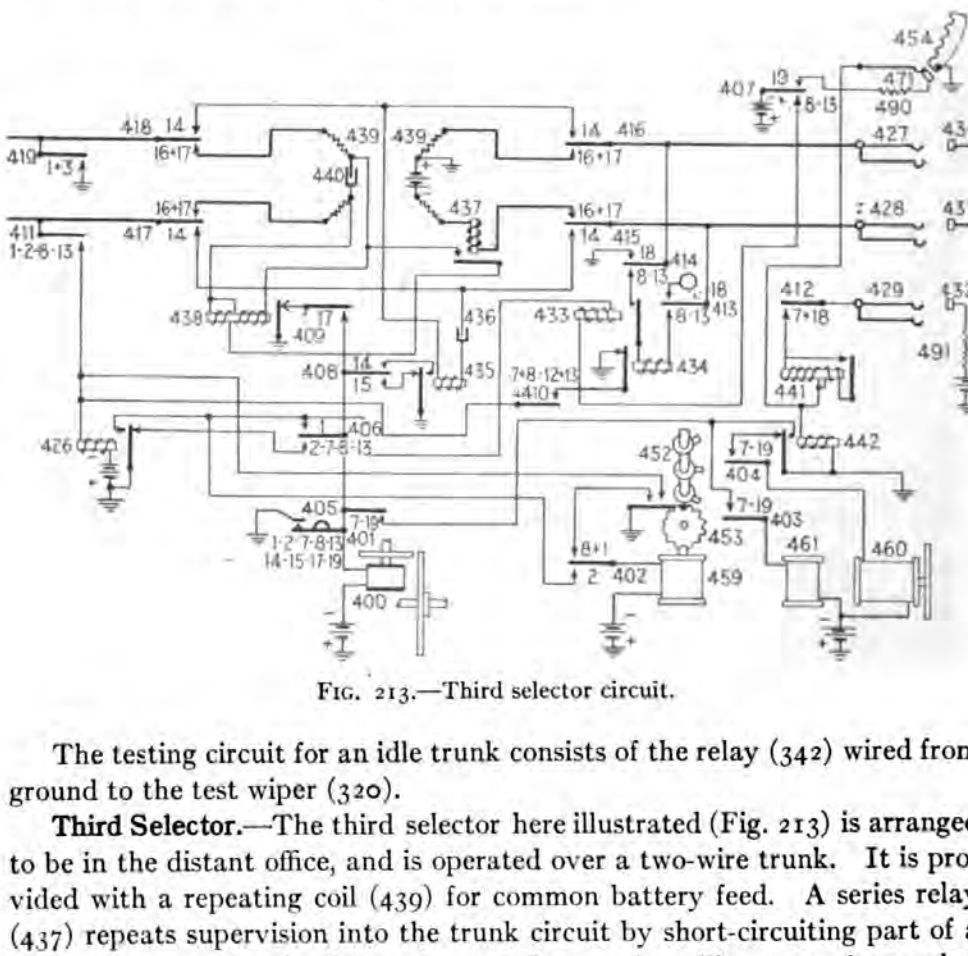


FIG. 213.—Third selector circuit.

The testing circuit for an idle trunk consists of the relay (342) wired from ground to the test wiper (320).

Third Selector.—The third selector here illustrated (Fig. 213) is arranged to be in the distant office, and is operated over a two-wire trunk. It is provided with a repeating coil (439) for common battery feed. A series relay (437) repeats supervision into the trunk circuit by short-circuiting part of a high-resistance relay (438) in order to influence the calling supervisory relay (248, Fig. 211) located at the first selector.

The sequence switch (400) Fig. 213 has nine stop positions.

Connector.—The connector switch (Fig. 214) illustrated is installed at a satellite. It is provided with a sequence switch (500) having nine stop posi-

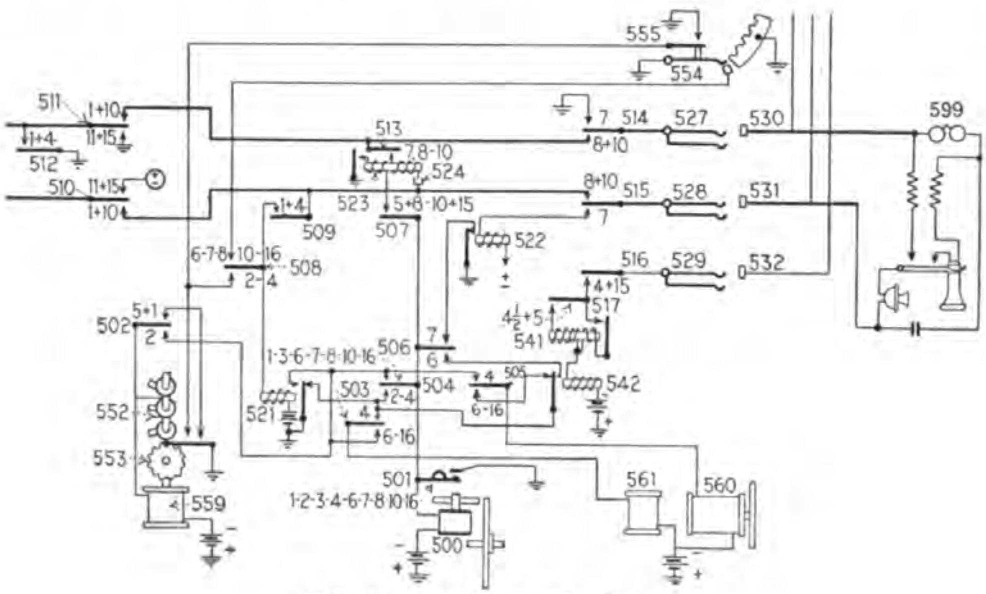


FIG. 214.—Connector circuit.

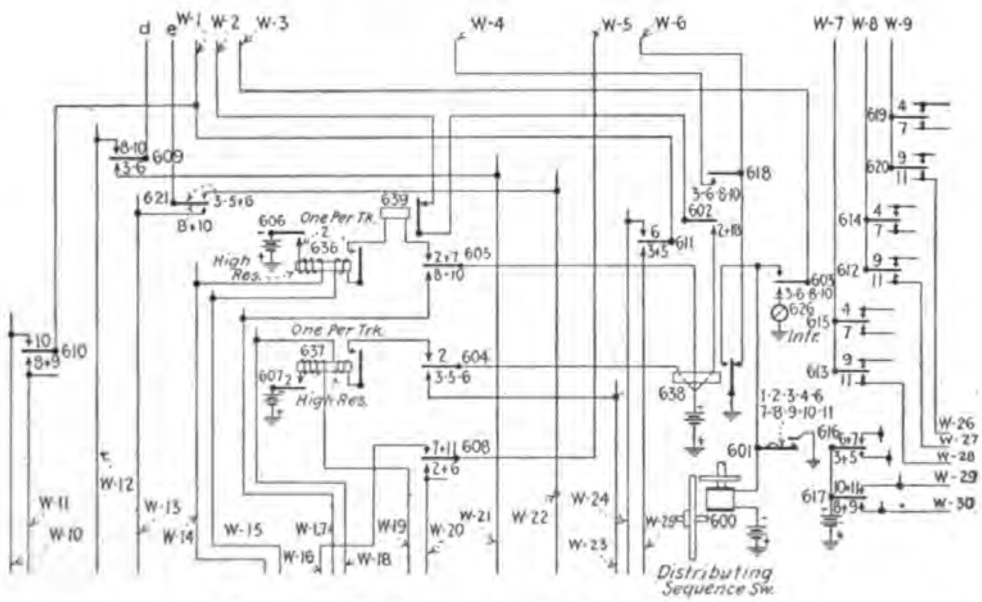


FIG. 215.—Distributing sequence switch circuit.

tions. There are three wipers or brushes, two for the line circuit and one (529) for the third wire sometimes called a private normal, which operates a cut-off relay (129, Fig. 210) to clear the line and protect it from intrusion.

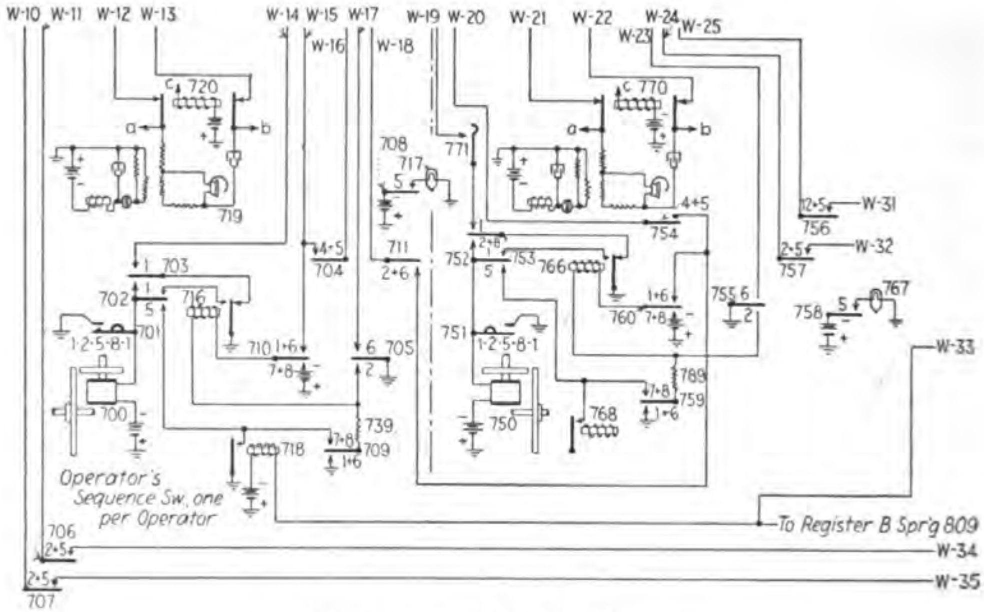


FIG. 216.—Operators' circuit.

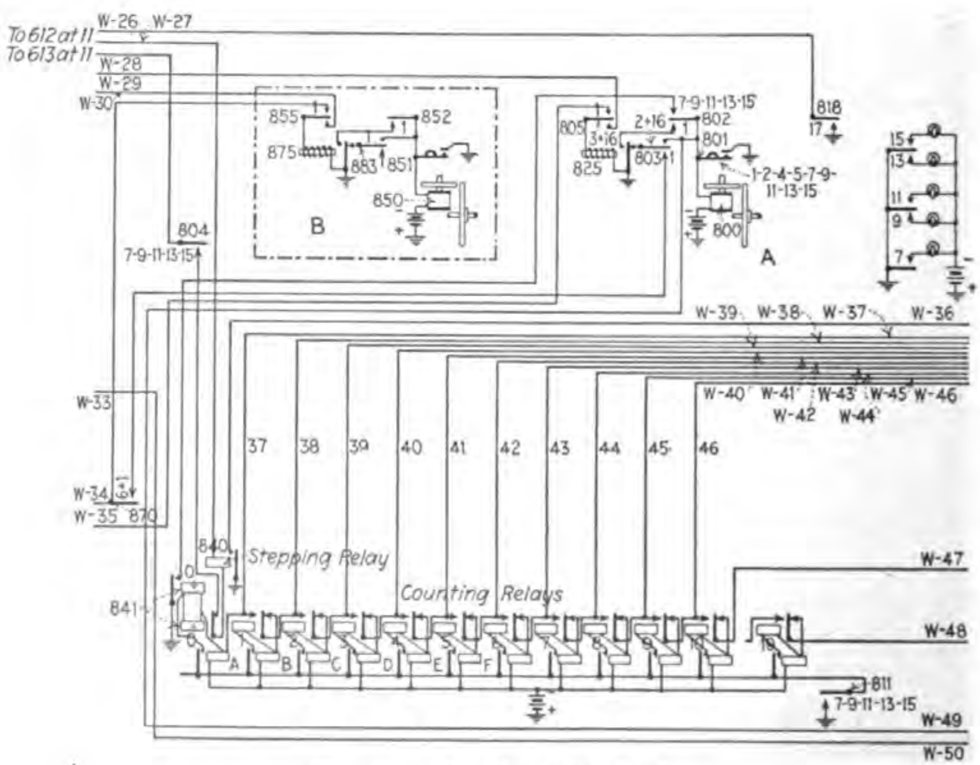


FIG. 217.—Counting relay circuit.

Operators' Circuits.—Each trunk between secondary finder and first selector is equipped with two sequence switches. One (200) is the regular sequence switch devoted to controlling the circuits from step to step. The other (600) is called the distributing sequence switch and has for its function the finding of an idle register for either the regular operator or the helping out operator. Each trunk has also two relays, one (636, Fig. 215) for the purpose of connecting with the home operator and the other (637) for connecting with the helping out operator. If either operator is not in a position to receive a call, the corresponding relay can not energize.

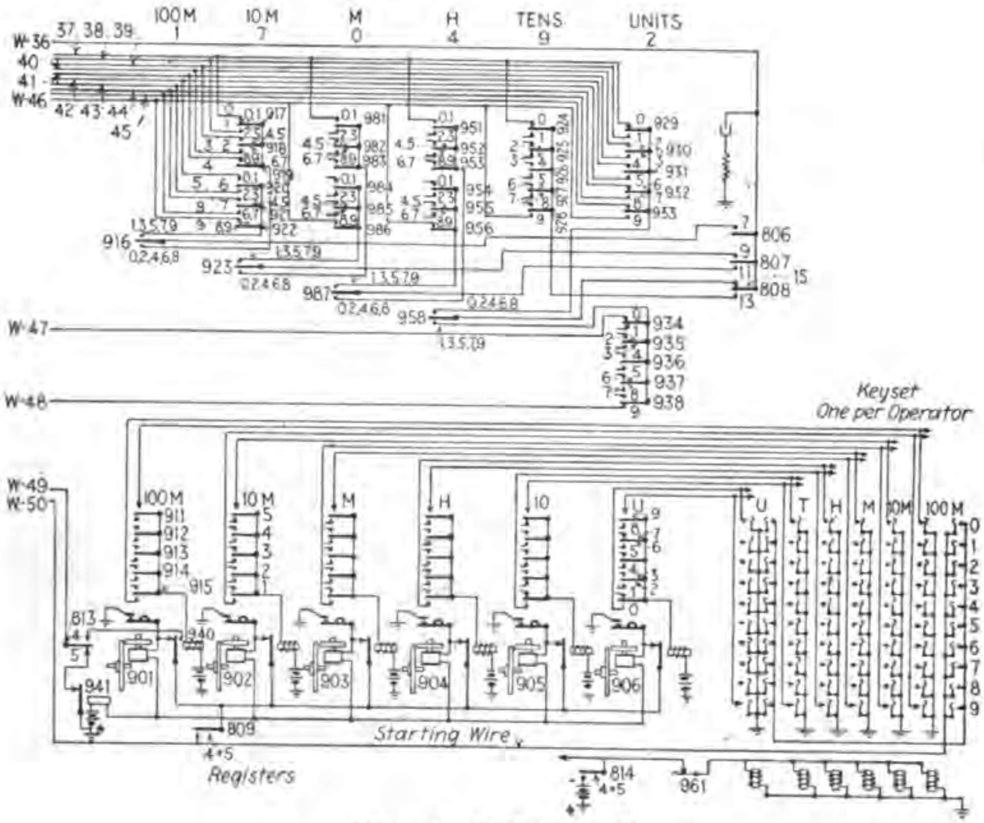


FIG. 218.—Register circuit.

Lamp (245) Fig. 211 is to attract the attention of the operator when the call is initiated.

Each operator is provided with a sequence switch (700) (Fig. 216) having four stop positions. It controls the connection of the subscriber to the operator and co-operates with the other sequence switches and the register in putting a call through.

Each register (Fig. 217) has its own sequence switch (800 or 850) together with a stepping relay (840) and a series of twenty counting relays (0 to 19). Each register has six auxiliary or recording sequence switches (Fig. 218) 901, 902, 903, 904, 905, and 906 whose duty it is to take the numbers set up on the keys set by the operator and record them on certain springs. No. 901 controls the first or one-hundred-thousand digit, No. 902 the second or ten-thousand digit, etc., to the last or sixth, No. 906, which records the units. The sequence switch (800) then connects the controlling circuit successively to the various spring combinations set up on the register and thereby drives the various numerical switches (selectors and connectors).

Nomenclature.—Each sequence switch spring is designated by a number, consisting of three figures. In order to show the position in which a contact is closed, other figures are placed on either side of the spring. For example, spring 105, Fig. 210, is marked to indicate that it is open at all times except when the sequence switch is in position 3 and in position 8. When in position 3 the spring is pressed against its upper contact. In position 8 it is pressed against the lower contact.

If a spring is pressed against one of its contacts continuously from one position of the sequence switch to another, that fact is indicated by a plus sign placed between the two limiting positions. For example, spring 113 is pressed against the upper contact when the sequence switch is in position 1. When, however, the sequence switch moves to position 2 spring 113 is pressed over against the lower contact and remains in that position until the switch leaves position 7.

On the other hand if a spring is in contact at two positions but is not in contact between, the fact is indicated by a minus sign. Thus spring 114 is pressed against its upper contact when the sequence switch is in position 3. When sequence switch leaves position 3 it breaks away from the upper contact and does not return to it until position 8 is reached. When sequence switch leaves position 8 the contact is broken.

A single exception is made in the case of the spring which fixes the rotation of the sequence switch. In the case of switch 100 it is spring 101. All such springs may be recognized by a curved lug on one side. This spring is shown in its normal position and the figures placed alongside and separated by minus signs indicate the position at which this spring causes the sequence switch to stop. For example, when sequence switch leaves position 1 the governor spring 101 drops into contact and maintains the clutch magnet energized until the sequence switch arrives at position 3 when its contact is broken. If now the sequence switch leaves position 3, spring 101 will again drop into contact with the ground and maintain the clutch magnet 100 energized until the shaft arrives at position 7.

If the figure 1 is shown near a spring, the spring is normally touching this contact, because position 1 is the normal or home position for sequence switches.

Springs belonging to a given apparatus have the same hundreds digit. Thus, the numbers of all springs operated by the trunk sequence switch

(200, Fig. 211) begin with 2, as 201, 202, 203, etc. All springs on the operator's sequence switch (700, Fig 21) are numbered 701, 702, 703, etc.

Corresponding springs in duplicate apparatus of the same kind are numbered 50 higher than those in the original. Thus in the operator's apparatus, Fig. 216, 751 corresponds to 701, 752 to 702, etc.

Operation of Circuits in Setting up Connection.—When the subscriber, Fig. 210, takes his receiver from the hook his line relay is energized also the pilot relay for the group. The flow of current through the resistances raises the potential of the test contact so that a finder switch may have means for stopping. The energizing of the pilot relay starts all the idle finder switches to rotating. The first finder switch whose wipers come in contact with the calling line will stop, energize the cut-off relay of the calling line and stop the remaining finder switches. If more than one subscriber is calling, the remaining finder switches will continue to rotate until all of the subscribers' lines are connected. The energization of the pilot relay closes the common starting circuit which goes into each finder switch on spring 104, back contact of relay 127, spring 103 through winding of clutch magnet 150 to negative battery. The clutch magnet causes the wipers of the finder switch to revolve. When wiper 125 finds the test contact 121, test relay 127 will pull up, cutting the current off from the clutch magnet 150, energizing the holding magnet 151 and stopping the switch. The brush associated with sector 128 short-circuits relay 127 until the brushes come into the exact center of the contacts; then the short-circuit is taken off. Relay 127 responding quickly will bring the brush carriage to rest.

After the finder switch has come to rest on the calling line, current is supplied to the calling telephone by the test relay of the finder switch. The trunk circuit is also closed through the holding coil to attract the attention of a finder in the controlling office.

The pulling up of test relay 127 sends current through spring 113 position 1 to the sequence switch 100. This causes it to move from position 1 to position 3. The cut-off relay 129 is energized through contact 120, wiper 124, spring 110, position 2 and resistance 140. Should the calling subscriber hang up his receiver before the calling office had picked up the trunk, test relay 127 will fall back. This would drive the sequence switch to position 8, where the clutch magnet would find another circuit through spring 105, back contact of relay 132, spring 114 driving it to position 1.

Secondary Line Finder Picks up Calling Trunk.—The impedance coil 131 across the trunk energizes the line relay 231 at the controlling office, Fig. 211. This starts all the secondary line finders in the group. The first finder to arrive at the calling trunk will stop, clear the line and cause the stopping of the remainder of the secondary line finders. The pilot relay grounds a common starting wire which action causes current to flow through the spring 210, back contact of the test relay 242, the spring 209, the clutch magnet

250 of line finder. This causes the wipers to rotate. When the test wiper 240 finds the contact 236, test relay 242 energizes, breaking the circuit of the clutch magnet and closing the circuit of the holding magnet 251 through spring 208. The same arrangement of sector 243 and wiper is employed to insure the centering of the brushes on the bank contacts.

When the secondary finder has found and seized the calling trunk, the sequence switch 200 sends ringing current over the trunk line so as to move the sequence switch of the primary finder from position 3 to position 7 and extends the calling telephone line to the repeating coil. The sequence switch 200 also lights the calling lamp 245 and places the operator's selecting relays 636 and 637 in a position to choose an idle operator.

Test relay 242 sends current to the sequence switch clutch magnet 200 through spring 208 and spring 203. The sequence switch now revolves to position 5. Here the cut-off relay 244 is energized, clearing the trunk line and de-energizing the pilot relay. Springs 224 and 225 swing into ground and generator lead while in positions 3 and 4, sending alternating current over the trunk line to primary finder at the satellite, through condenser 134 (Fig. 210) and relay 132. Relay 132 energizes clutch magnet 100 through spring 114 position 3, and spring 105 position 3. The sequence switch moves to position 7. Moving away from position 3 it cuts off the bridged impedance 131 and clears spring 105. When the sequence switch arrives at position 6 it connects negative battery through spring 114 to the main spring of relay 132 and thence through spring 106 to the second winding on test relay 127. Up to and including this time the test relay is energized. Hence the closure of springs 106 and 114 will energize the second winding of the test relay through spring 104 on its bottom contact. As the sequence switch goes on to position 7 the calling line is switched to the trunk circuit by springs 111 and 112. By this time the ringing current has ceased and the sequence switch at the controlling office has connected the trunk to the repeating coil. Sequence switch 100 remains in position 7 during conversation. When sequence switch 200 (Fig. 211) arrives in position 5, it lights the calling lamp 245 and moves the distributing sequence switch (600) from position 1 to position 2, by current through wire *W*-3 and spring 603 (Fig. 215) upper contact.

Choosing an Idle Operator.—In position 2 the distributing sequence switch Figs. 215, 216 and 219 closes the circuits of the two relays which choose the idle operator. Relay 636 is for the home operator and 637 for the helping operator. If the home operator is idle, relay 636 will be energized and lock itself through a second winding on the same core. This will move the operator's sequence switch 700 from normal to position 2, rendering the operator busy. If the home operator is busy, relay 636 will be unable to energize because *W*-14 is open at spring 703. If the helping operator is idle and the helping key 771 closed, relay 637 will respond and lock itself through its second winding and move the helping operator's sequence switch 750 from normal. When the operator's sequence switch moves from position 1 to position 2, it makes the home operator's position busy, switches the control of the operator's sequence switch 700 from the front contact of relay 716 to the back contact of the same relay and drives the distributing sequence switch 600 from position 2 to position 8.

Arriving at position 2, spring 705 short-circuits the high resistance 739. The increased current energizes relay 638 through its middle winding. It therefore responds and energizes clutch magnet 600 of the distributing sequence switch until position 7 has been passed. The sequence switch will stop at position 8. If the helping operator had been chosen, the distributing sequence switch 600 would have been stopped at position 2, because the

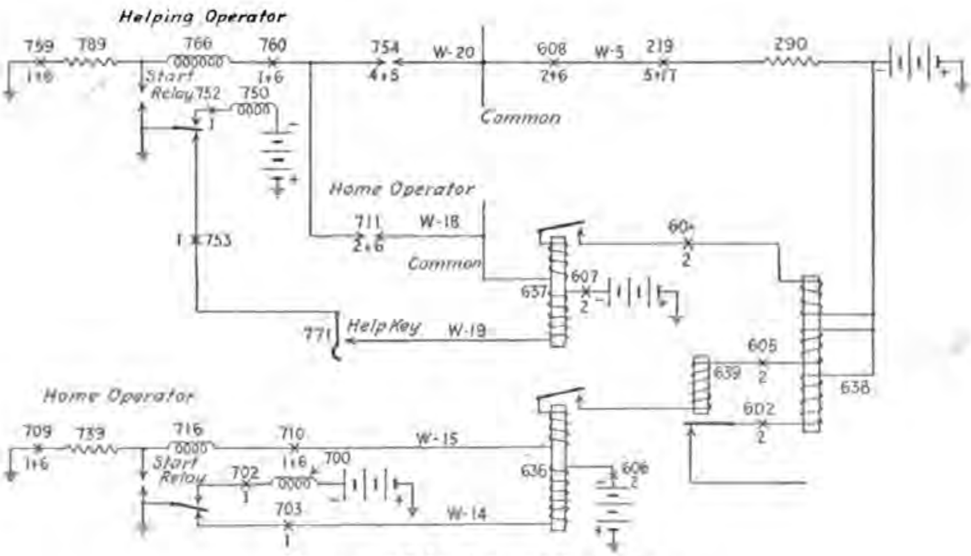


FIG. 219.—Selecting an idle operator.

holding circuit for relay 638 passes through spring 604 which breaks contact and swings over to another circuit between positions 2 and 3.

Choosing an Idle Register.—The distributing sequence switch now proceeds to choose an idle register from between the two registers "A" and "B" belonging to the home operator. When the sequence switch arrives at position 8 (Figs. 215, 216 and 217 or Fig. 220), it closes spring 610 downward. If *A* is idle, "638" will energize through "803-1" and back contact of relay 825. The switch, therefore, goes on through position 9, arriving at position 10. Spring 610 swings over to the upper contact and causes the winding of relay 638 to draw its current through the winding of relay 825 whose high resistance makes 638 de-energize and stops the switch.

Elimination of Simultaneous Calls.—If it should happen that more than one trunk attempts to seize an operator at the same time, all but one of the relays 636 will be eliminated. This is done by causing them to pull up in parallel with each other, and by having their locking circuits in parallel with each other but in series with a relatively high resistance, so high that only one relay can remain energized. In Fig. 221 are represented the relays belonging to three trunks. We will suppose that all three attempt to seize the home operator at once; that is, if springs 606 on each of the three distributing

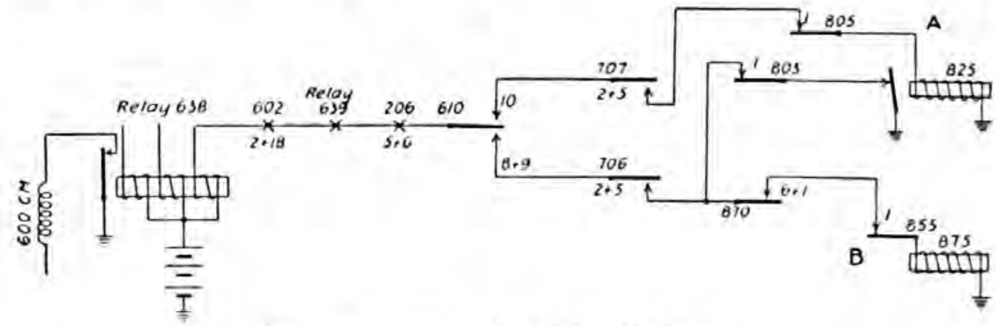


FIG. 220.—Principle of register selection.

sequence switches close at the same time, relays 636 on all three trunks will energize together. Relay 716 will pull up opening the energizing circuit (high winding) of relays 636, leaving each to hold by its low resistance winding. All but one will fall back. Some relays are quicker than others, and the slowest relay to fall back will not fall back at all. When the distributing sequence switch 600 has found an idle register, relay 638 falls back and sends

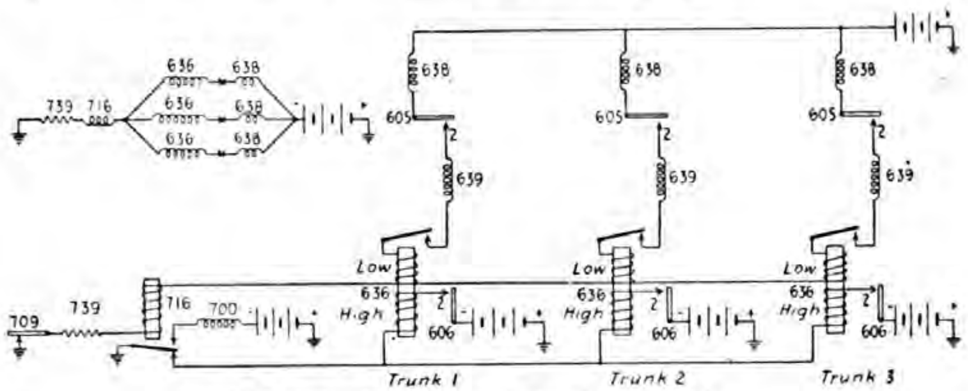


FIG. 221.—Elimination of simultaneous calls.

the distributing switch 200 of the trunk from position 5 to 6 (spring 618, position 8 or 10, wire *w*-4, spring 202, position 5, clutch magnet 200).

The same condition (relays 638 and 825 in series) which stopped switch 600 moves the seized register (*A*) from position 1 to position 4, to prepare it to receive the call number after it has been set up on the keys.

Operator Connected to Trunk.—The trunk sequence switch 200 moving from position 5 to position 6 flashes the calling lamp 245 (by interrupter 626), connects the operator's set to the trunk circuit at *d* and *e*, prepares the fundamental circuit (*w*-7 and *w*-8) for the control of the first selector and transfers the control of its own clutch magnet 200 from the distributing sequence switch to the group line relay 249. The fundamental circuit may be traced as follows: From ground on spring 215, position 6, through wire *w*-7 to spring 613 of the distributing sequence switch. The other side of the circuit extends from negative battery, through the winding of the group line relay 249, spring 216, position 6, wire *w*-8 to spring 612 of the distributing sequence switch. From this point the circuit will be extended at the proper time.

Setting up the Number.—The operator now receives the number from the subscriber and presses the corresponding keys on her key set (see Fig. 218). Each key when depressed grounds a wire leading to a certain controlling spring associated with the auxiliary registers 901 to 906 inclusive, which will fix the limit for the rotation of each of the register shafts. The first and last of the keys close the "starting wire," which will cause the six registers to revolve, each rotating as far as indicated by the corresponding button of the key set and thereby making the proper combinations of springs shown at the top of Fig. 218, which constitutes a transfer of the number from the key set to said springs. The starting wire also returns the operator's switch 700 to normal by current through "*w*-50," "*w*-33" and relay 718.

At position 8, relay 716 has fallen back, so that the switch goes on to the number 1 or home position.

While the operator's sequence switch 700 is returning to normal, it sends the distributing switch 600 from position 10 to 11 by spring 705 and wire *w*-17.

The operator's telephone set is cut off the trunk circuit by the act of the distributing sequence switch in moving from position 10 to 11. Springs 609 and 621 effect the separation.

Each key is locked in its position by a magnet which draws its current through spring 814, positions 4 and 5, and key 961. Key 961 enables the operator to unlock all the depressed keys for the purpose of correcting an error.

Transferring the Number to the Register.—Each auxiliary register will now rotate until stopped by the condition imposed by the key which is depressed in the column of the key set to which it belongs. To do this, the stopping relay (940) is connected successively with each of the keys in the corresponding row, until a ground is found. For instance, the hundred thousands digit is "1" in the number assumed. Hence, a ground is placed upon the No. 1 or second contact of register 100 *M*. As the shaft of "901" rotates, the bottom spring (915) will be pressed against the lower contact leading to the "0" key of the "100 *M*" row of the key set. Then it will be swung up to the upper contact leading to the "1" key of the "100 *M*" row.

Here it will find a ground. Relay 940 will therefore energize and cut off the current from the clutch magnet 901, stopping the register in the "1" position.

The whole plan is shown schematically in Fig. 222.

The stopping circuit for each register runs through the winding of relay 940 to a point which may be connected successively to each of ten contacts. The latter represent the ten keys of a given row or column on the key set. Grounds are placed to indicate the number 176,292. When the key set closes the starting circuit, relay 941, and all the clutch magnets 901-906 pull up. The registers start testing the keys. As fast as they find grounded keys, they stop regardless of the others. When "901" finds a ground and stops, relay 940 sends the main shaft of the register *A* from position 4 to position 5.

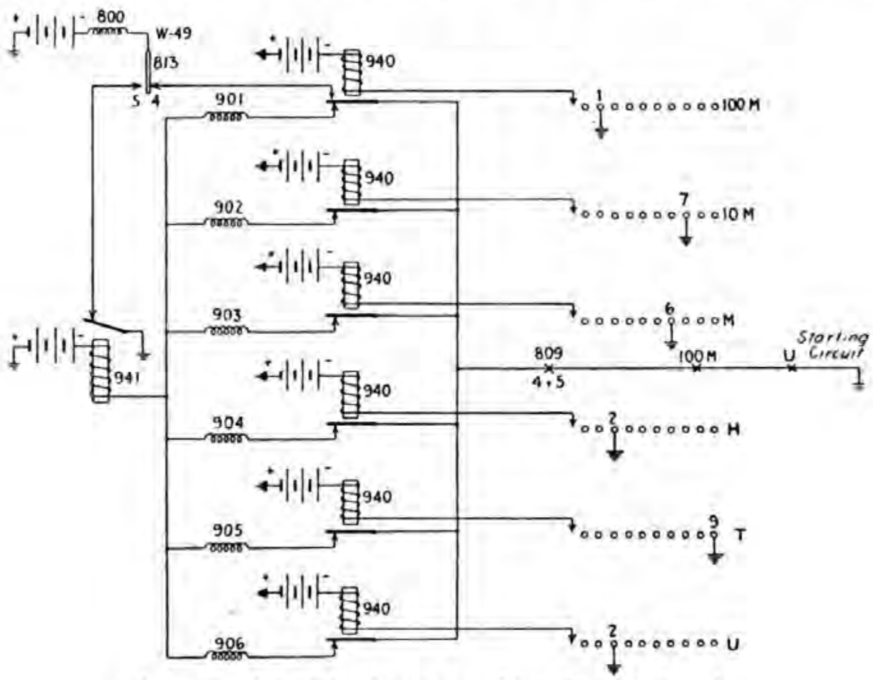


Fig. 222.—Principle of setting registers from keyboard.

The register *A* on arriving at position 5, gives the control of its clutch magnet 800 to the charge of relay 941. When the last of the auxiliary registers has found its position and stopped, relay 941 falls back and drives register *A* into position 7. In this position the first of the impulses start to the first selector.

Translating the Number into Impulses.—The manner of translating the directory or call number into the number of impulses required for setting a switch is worthy of special attention. As it is rather difficult to characterize the plan in a single sentence, the attention of the reader is directed to Fig. 208, which was used in the explanation of trunking.

The following table gives the group numbers handled by each level in all the selectors, showing how two digits of the call number are required to fix the level required to reach a given group.

No. of level	First selector Ten thousands	Second selector Thousands	Third selector Hundreds
9	18 and 19	18 and 19	18 and 19
8	16 and 17	16 and 17	16 and 17
7	14 and 15	14 and 15	14 and 15
6	12 and 13	12 and 13	12 and 13
5	10 and 11	10 and 11	10 and 11
4	08 and 09	08 and 09	08 and 09
3	06 and 07	06 and 07	06 and 07
2	04 and 05	04 and 05	04 and 05
1	02 and 03	02 and 03	02 and 03
0	00 and 01	00 and 01	00 and 01

We will suppose that a subscriber is attempting to call 176,292. This number lies in the first hundred thousand and, therefore, the trunks will be found somewhere among the upper five levels of the first selector bank. Since it is the "7" ten thousand in the first hundred thousand, it will be found on the No. 8 level. Consequently, nine impulses which must be sent to the first selector for setting the tripping spindle, so that the brushes corresponding to the No. 8 level will be brought into action.

The second selector will have its level chosen in accordance with similar principles. The desired number lies in the "6" thousand of the "7" ten thousand. All the trunks leading to the "7" ten thousand come from the upper five levels of the second selector. The trunks leading to the "6" thousand of the "7" ten thousand come from No. 8 level which requires nine impulses to reach. Hence nine impulses must be sent to the second selector for setting its tripping spindle.

The third selector is set similarly in obedience to the third and fourth digits of the call number, that is, "6" and "2". The "6" thousand is supplied by the trunks from the lower five levels of the third selector. The "2" hundred is reached by trunks from the No. 1 level. Therefore, two impulses must be sent to the third selector.

In a connector switch we require that the setting of the spindle and the rotation of the wipers shall both be under the control of the directory number. The spindle is first set in accordance with the tens digit and in this case the correspondence of the number of impulses with the directory number is exact, except for the allowance which must be made because "0" takes one step, "1" takes two steps, "2" takes three steps, etc. Consequently, for the particular number which is being illustrated (176,292) ten impulses will be sent to the tripping spindle of the connector.

Since each connector switch serves 200 subscribers' lines, the hundreds digit, as well as the unit digit, will be required to fix the number of rotary steps which the brushes must take to reach the desired line. If the line lies in the hundred occupying the first portion of the bank, the number of rotary steps will correspond to the directory number plus one; but if it lies in the next odd hundred higher, ten steps must be added. Since the number under consideration is "292," the desired line will lie in the first half of the bank so that only three steps need be taken to reach the line.

	Directory number 176,292 Figures affecting each switch	Level required	Impulses delivered
First selector.......	17	8	9
Second selector.....	76	8	9
Third selector......	62	1	2
Connector			
Spindle............	9	9	10
		contact in level	
Brushes............	2 2	2	3

The combination of springs (see Figs. 218 and 226), by which the above results are secured, are operated by the six auxiliary registers. The hundred thousands register 100 *M* has but one spring, with two contacts normally clear. The spring 916 will be thrown downward for all even numbers and upward for all odd numbers. The ten thousands register 10 *M* has six springs, 917 to 922 inclusive, for acting on the first selector in conjunction with the one hundred thousands register 916, and one spring 923 for acting upon the second selector.

Likewise, the thousands register *M* has six springs 981 to 986 which co-operate with spring 923 in acting upon the second selector and a single spring 987 for acting on the third selector. The hundreds register has six springs 951 to 956 for acting on the third selector, and the single spring 958 for acting on the connector switch. The tens register has five springs only, which are effective on the spindle of the connector switch. The units register has ten springs, 929 to 938, which co-operate with the hundreds register 958 for setting brushes of the connector switch.

At the lower left-hand corner of the diagram are shown twenty wires coming from the counting relays whose structure and function will be explained later. For the present let it suffice to know that the wire marked "0" will secure one impulse, the wire marked "1" will secure two impulses, the wire marked "2" will secure three impulses, and the last wire marked "19" will secure twenty impulses. This is further indicated by the small numbers placed to the left of the register springs.

The fundamental circuit is briefly indicated as passing through the stepping relay 840. This fundamental circuit will be successively switched into connection with the first selector, second selector, third selector and the connector switch. During the time that the fundamental circuit is acting on the first selector, spring 806 will connect the contact of the stepping relay 840 with the spring combination indicated by the hundred thousands register spring 916. When the fundamental circuit is switched to the second selector, spring 806 will be cleared and spring 807 will extend the circuit of the stepping relay contact to spring 923 in order to control the movements of the second selector. Likewise, the change of spring 807 to its lower contact will occur at a time when the fundamental circuit is operating on the third selector and spring 808 will successively control the spindle of the connector by the tens register and the brushes of the connector by the hundreds and units registers.

The details of the connections for setting up the number 176,292 are as follows: The first selector switch will receive nine impulses over the following circuit: From the counting relay wire marked 8, through spring 921, upper contact, spring 916 upper contact, spring 806 upper contact, wire *w*-36 to the stepping relay. The second selector will receive nine impulses over the following circuit: From the counting relay wire marked 8, through spring 985 upper contact, spring 923 upper contact, 807 upper contact, wire *w*-36 as before. The third selector will receive two impulses as follows: From the counting relay wire marked "1," through spring 951 upper contact, spring 987 lower contact, spring 807 lower contact to wire *w*-36 as before. The tripping spindle of the connector will be controlled by ten impulses, over the following circuit: From the counting relay wire marked "9," through spring 928 upper contact, 808 upper contact to wire *w*-36 as before. The brushes of the connector will be set by three impulses over the following circuit; counting relay wire 2, spring 930 lower contact, spring 958 lower contact to wire *w*-36 as before. Further details regarding the action of the fundamental circuit and its control over the selectors and connectors will be given later.

The Control of the Switches.—The object now is to set the tripping spindle on each switch and rotate the shaft so as to bring the wipers to certain contacts. In the case of a selector switch, we will pick out the group by means of the tripping spindle and then allow the shaft to rotate automatically until the wipers which were released have found an idle trunk. The former is fixed by the call number, the latter has nothing to do with the call number. In the case of the connector switch, both the setting of the spindle and the rotation of the wiper shaft are fixed by the call number.

The Counting Relays.—The counting relays (twenty pairs) are best illustrated in Fig. 223, which shows in schematic form the relationship existing between them. Only five of the impulse relays (*A* to *E*) are shown, each in series with its locking relay, numbered from 0 to 4.

Contact *a* is operated by relay *A*.

Contact *b* is operated by relay *B*.

The register is represented by a five-point switch.

If the register be placed in any position and the key operated an indefinite number of times, the stepping relay will execute as many impulses as are indicated by the position of the register and will then stop no matter how many more impulses be made by the key. When the key is closed for the first time, the stepping relay 840 energizes relay *D*, supposing the register to be on contact 3. Relay *D* upon pulling up will close contact *d*, but relay 3 will not act because it is short-circuited by the contact of the stepping relay. When the key is released and the stepping relay falls back, relay 3 will at once pull up and switch the contact of the stepping relay from the point between relays *D* and 3 to the point between relays *C* and 2. When the key is depressed the second time, the stepping relay will then respond and send current through relay *C*. When relay *O* pulls up, it opens the impulse circuit

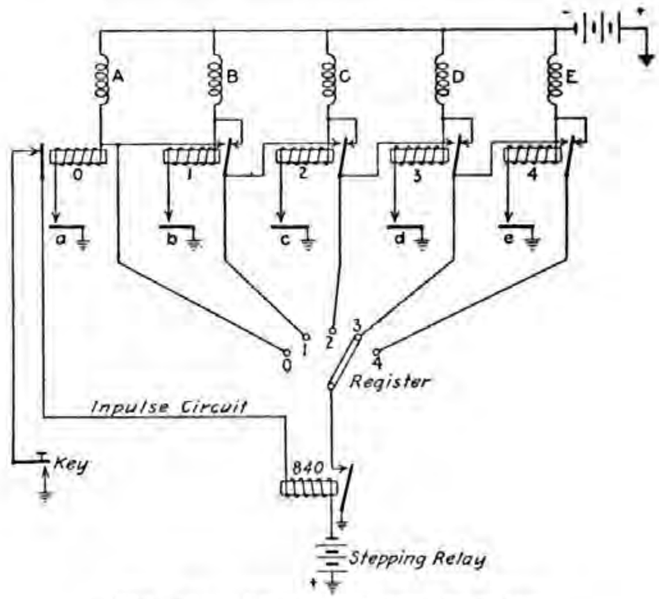


FIG. 223.—Principle of counting relays.

so that any further operation of the key will have no effect. Thus the net result of the circuit is to allow the stepping relay to perform a fixed number of movements, which number is conditioned by the position of the register.

The Fundamental Circuit and First Selector.—The impulse circuit above described is termed the fundamental circuit when used in the apparatus. See Fig. 224 which is a schematic representation of the fundamental circuit linked with the counting relays, showing the manner of extending the control of the counting relays from the first selector, to the second selector, third selector, and finally to the connector. See also Figs. 211 to 218.

The fundamental circuit possesses within itself the means for starting the magnet of the tripping spindle to rotating, and of automatically stopping this rotation when it has rotated as many steps as are fixed by the register spring acting through the counting relays. In general, this is done by causing the tripping spindle to operate the stepping relay once for each angular step of the tripping spindle; the stepping relay in turn operates the counting relays so that when the last counting relay has been energized it opens the fundamental circuit and prevents the further rotation of the tripping spindle.

When the main spindle of the register *A* arrives at position 7, the fundamental circuit is closed through the line relay of the first selector as follows: From ground, through spring 215, position 6, wire *w*-7, spring 613, position 11, wire *w*-28, spring 804, position 7, back contact of relay 841, winding of stepping relay 840, wire *w*-27, spring 612, position 11, wire *w*-8, spring 216, position 6,

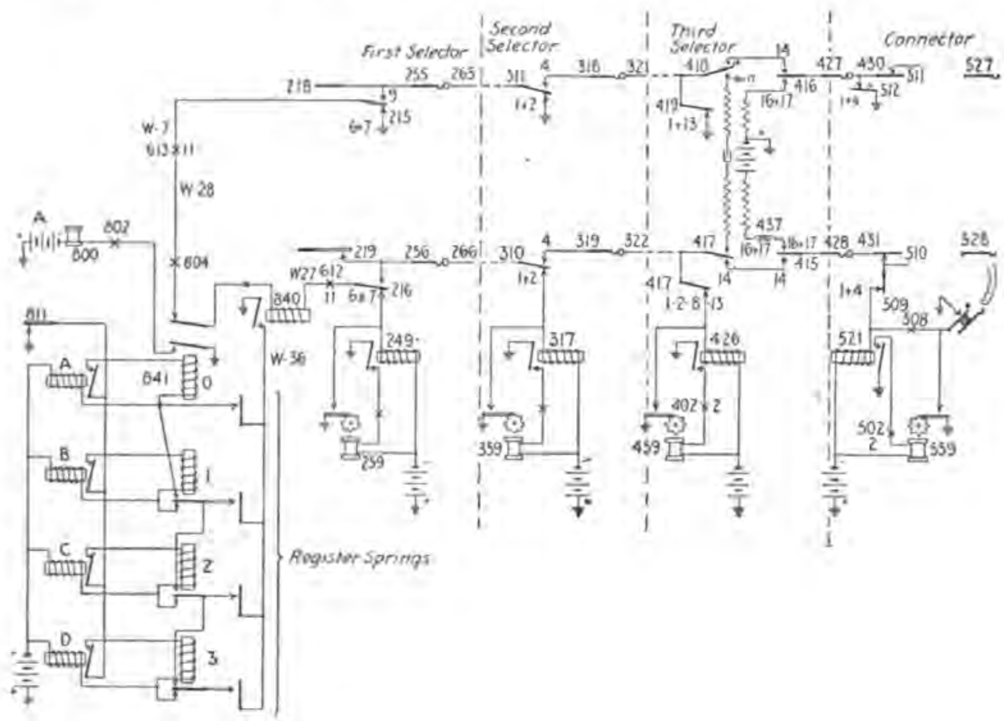


FIG. 224.—Fundamental circuit.

winding of relay 249, to negative battery. Simultaneously, the line relay and the stepping relay energize. The former energizes the tripping spindle clutch magnet 259 of the first selector. The stepping relay 840 closes the circuit to the first of the counting relays as follows: From ground, through contact of relay 840, wire *w*-36, to spring 806, position 7, spring 916, position 1, spring 921, position 7, through wire 45, through relay 1 to negative battery. This is the first of the counting relays to be energized (for the number 176,292).

The contact maker of the spindle will give intermittent ground connections to the fundamental circuit between the line relay 249 and the stepping relay 840. The line relay will be unaffected, but the stepping relay will be short-circuited. Each time the latter falls back, it allows the locking relay of a pair of counting relays to pull up, and each time it pulls up another counting relay is energized. When the last counting relay 841 opens the fundamental circuit, it causes the line relay 249 to de-energize and stop the tripping spindle. Relay 841, also moves the main shaft of register *A* from position 7 to position 9. At the same time the falling back of the line relay 249 of the first selector causes the sequence switch 200 to move from position 7 to position 8.

The counting relays are unlocked by the temporary opening of spring 811, so that all the counting relays will become de-energized. On arriving at position 9, spring 811 closes to provide a new holding circuit for the counting relays, and spring 802 closes to provide the circuit over which relay 841 will control the register *A* when the next series of impulses has been completed.

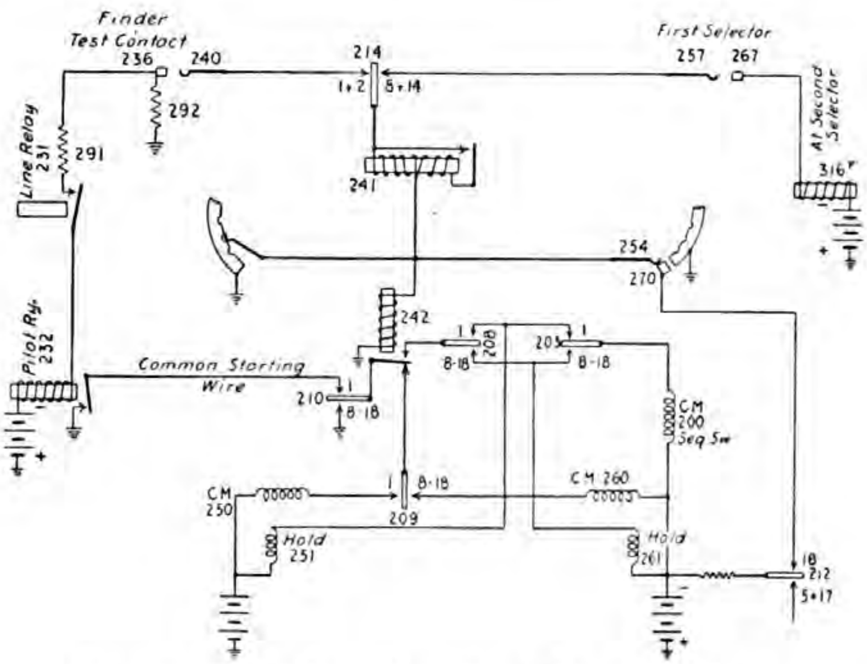


FIG. 225.—Testing circuit of secondary finder and first selector.

Hunting an Idle Trunk.—The first selector now proceeds to hunt an idle trunk, which it does by energizing its clutch magnet 260 (Figs. 211 and 225, position 8), while a test circuit extending from the wiper 257 hunts for an ungrounded contact 267. The test relay 242 will be energized when a contact possessing negative battery potential is found, and will break the circuit of the clutch magnet so that the wipers will stop on the idle trunk, and move the sequence switch to position 9. When the wiper 257 finds an idle trunk, current flows through the winding of relay 242, relay 241, spring 214, position 8, wiper 257, contact 267, release trunk to second selector through

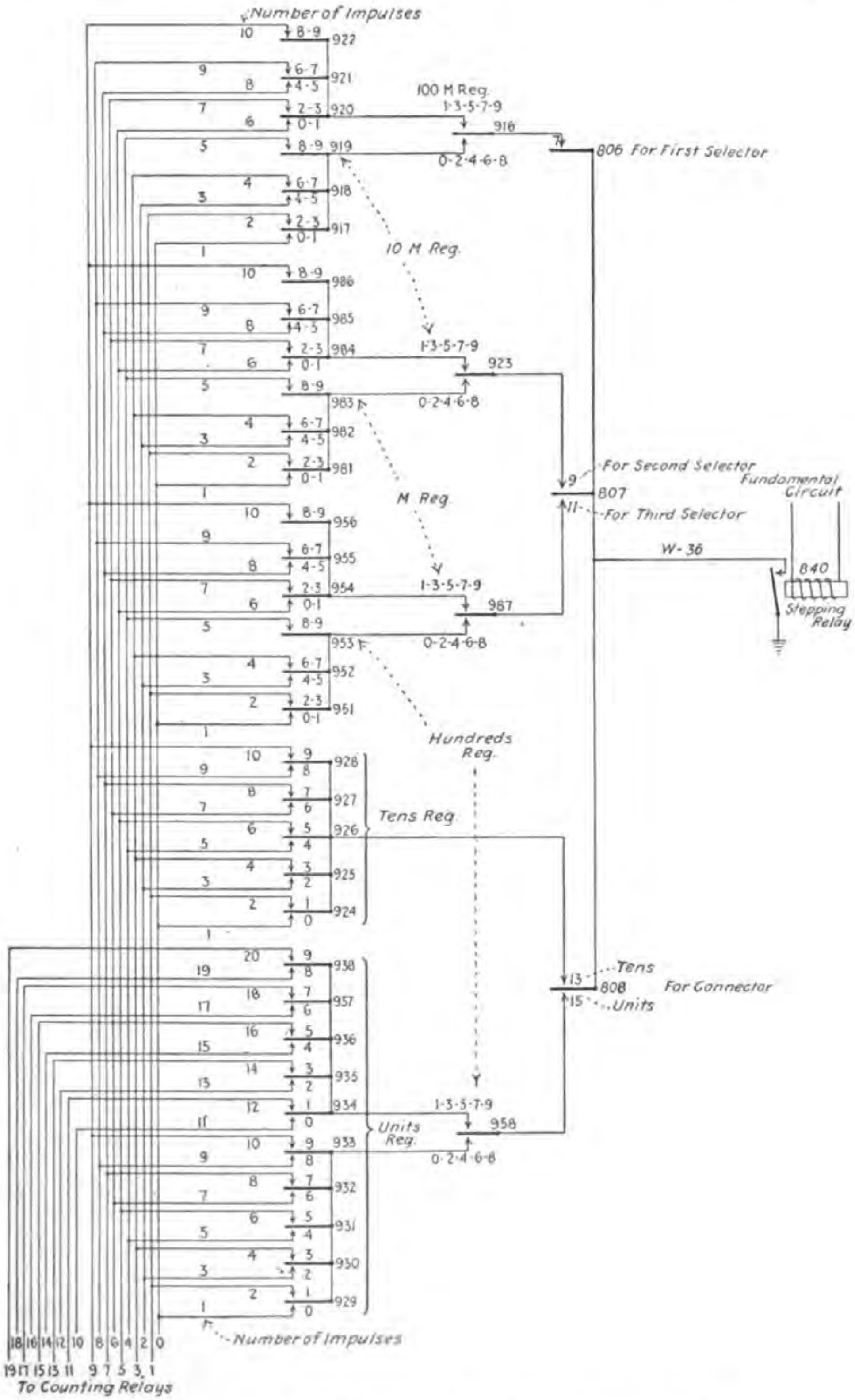


FIG. 226.—Transformation of call number into impulses.

the winding of relay 316 to negative battery. Relay 242 cuts off the current from the clutch magnet 260 and energizes the holding magnet 261. It also sends the sequence switch from position 8 to 9.

The movement of the sequence switch from position 8 to 9 cuts off magnets 200 and 261 and switches the fundamental circuit, Figs. 211 and 224, on to the trunk leading to the second selector (springs 215 and 216).

Second Selector Acts.—Immediately upon the closure of the fundamental circuit through the second selector, the line relay 317 in the second selector energizes and drives the sequence switch 300 from position 1 to position 2. In this position the release circuit is prepared, and the spindle started into rotation as was described for the first selector. During the rotation of the spindle, intermittent grounds are placed upon the circuit between the line relay 317 and the trunk circuit, thereby causing the stepping relay 840 to

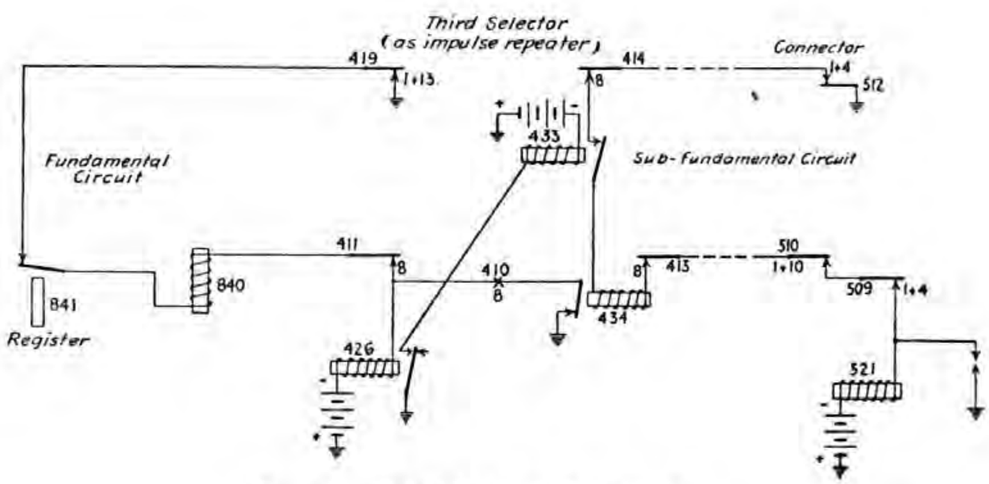


FIG. 227.—Principle of impulse repeater.

vibrate, and by this means to actuate the counting relays. When the proper number of impulses have been sent, the fundamental circuit is broken by the cut-off relay 841, which allows the line relay 317 at the second selector to fall back. This not only stops the spindle from rotating further, but drives the sequence switch 300 from position 2 to position 3.

While the sequence switch 300 of the second selector is in position 3, two simultaneous operations are carried on. First, the register *A* is rotating to shift the springs so that a new series of impulses may be sent, restoring the counting relays to their original position; second, the second selector is hunting an idle trunk. Two circuits have been prepared to act in parallel, the holding magnet 361 and the sequence switch 300.

The fundamental circuit is held open independently by the second selector and the register *A*, until each is ready. No matter which one gets ready first, no other impulses can be sent until both have closed their part of the fundamental circuit.

When the wipers of the second selector strike an idle trunk (full voltage on 323) relays 341 and 342 will become energized. The latter will simultaneously cut off the current from clutch magnet 360 and energize the holding magnet 361 and the clutch magnet of the sequence switch in parallel. The sequence switch moves from position 3 to position 4, where it remains during conversation.

Third Selector.—The third selector is operated by means very similar to those employed in the case of the second selector, but with this exception, that after the third selector has found and seized its trunk, which it does with its sequence switch in position 7, the latter is moved to position 8 and certain relays used to repeat impulses from the connector at a satellite. While in position 8, the spindle of the connector switch is set; in position 13 the brushes are set.

Impulse Repeater.—The scheme of this repeater is shown in Fig. 227. When the register closes the fundamental circuit, relay 426 in the third selector will repeat this closure into the subfundamental circuit by the energization of relay 433. When the connector switch is ready for the reception of impulses, it completes the closure of the subfundamental circuit by contacts on its own sequence switch. As the rotation of the spindle or of the brush carriage proceeds, ground impulses are placed on the subfundamental circuit between the line relay 521 of the connector and the trunk. This causes relay 434 at the third selector to be shunted out and therefore to fall back and shunt out the stepping relay 840 in the fundamental circuit at the register. When finally the register opens the fundamental circuit, relay 426 will de-energize and allow relay 433 to fall back to open the subfundamental circuit.

During the time that the spindle of the connector is being set, the sequence switch 400 of the third selector is in position 8. The breaking of the fundamental circuit drives sequence switch to position 13, where it remains during the repeating of impulses for setting the wipers of the connector. When both series of impulses have been completed, the final breaking of the fundamental circuit causes the sequence switch 400 to be driven to position 14. This closes the trunk circuit through the third selector by means of springs 415, 416, 417 and 418, with relay 435 and condenser 436 bridged across the circuit. This places the connector switch in direct connection with the first selector.

Connector.—The seizure of the connector switch by the closure of the fundamental circuit energizes relay 521, which drives the sequence switch 500 from position 1 to position 2. This starts the tripping spindle which is stopped at the proper position by the action of the register as has been described. When the spindle arrives at the desired position and the fundamental circuit opens, relay 521 will fall back and drive the sequence switch from position 2 to position 3. When the register is ready to proceed with the next operation, it will close the fundamental circuit. This pulls up relay 521, which sends the sequence switch to position 4. The brushes are set while the sequence switch is in position 4. The impulses sent back over the trunk are made by the contact 555, which closes and opens once for each contact past which the brushes rotate. By this control, the register acts as before, finally opening the fundamental circuit for the last time.

Busy Test.—When the subfundamental circuit is opened for the last time, line relay 521 falls back, driving the sequence switch from position 4 to position 6. During this time, a test is made as to the condition of the called line. Springs 516 and 517 close the testing circuit from negative battery, through test relays 542,541 to the private wiper 529 which is now resting upon the private bank contact 532. If the line is not busy, earth potential will be found and the full battery voltage will drive current through the testing relays just mentioned and the cut-off relay 129 of the called line. The latter will clear the called line of ground and battery connection. The test relay 542 in the connector switch will immediately energize and drive the sequence switch 500 from position 6 to position 7.

Ringing.—Position 7 is the ringing position, and in it ringing current will be applied to the called line by means of springs 514 and 515. The ringing current is supplied through a marginal relay 522.

Answering.—When the subscriber removes his receiver from the hook, the increased flow of current, due to the low impedance of the talking apparatus, will cause relay 522 to energize and drive the sequence switch 500 to position 8. In this position ringing current is cut off and the subscriber's line connected up by means of springs 514 and 515. At the same time, relay 523 is connected across the circuit by spring 513, in order to receive a ringing impulse from the first selector when that switch is ready for conversation to begin. When such ringing impulse arrives, it will pull up relay 523 and thereby drive the sequence switch 500 into position 10, where it will remain during conversation.

At this moment, the circuit is completed from the first selector through the second selector, third selector and connector to the called telephone. In the third selector a single relay 435 is bridged across the circuit, and in the connector the same condition prevails, each relay being open to direct current because of a condenser.

When its work is done the register *A* returns to normal, there being no stop position from "15" to "1". At position 17 it sends current through spring 818, *w*-26, spring 620, *w*-9 spring 202 to move the sequence switch 200 of the trunk from position 9 to position 10. This connects the battery to the trunk wiper 256, through the relay 258, and grounds the wiper 255 through the agency of spring 218, position 10. When the third selector and connector complete the circuit of the called telephone with the receiver of the latter off the hook, relay 258 will supply current to the telephone. In so doing it will energize and by sending current from its contact through spring 205, position 10 will drive the sequence switch 200 from position 10 to position 14. During this transition, relay 258 will be cut off and there will be a momentary application of ringing current to the trunk line by means of spring 217. The alternating current will actuate relay 435 in the third selector and relay 523 in the connector. This will cause the third selector to be driven from position 14 to position 15. Here the falling back of relay 435 will again start the sequence switch and drive it to position 17 in which it will remain during conversation. In the connector the sequence switch will go to position 10.

Current Supply.—In this position the direct connection through the third selector is broken and the repeating coil 439 inserted, by means of springs 415, 416, 417 and 418. This causes the current supplied by the repeating coil at the first selector to flow through a high resistance relay 438 at the third selector. This relay will energize, but on account of its high resistance will not allow the supervisory relay 248 at the first selector to operate. Spring 409, by closing, prepares a release circuit which, however, is not closed at present because of the energization of relay 438, as described. Through the right-hand windings of the repeating coil current is supplied to the called station.

As soon as the called station begins to draw current from the repeating coil at the third selector, supervisory relay 437 will energize and by closure of this contact places a low resistance of winding on relay 438 in parallel with the high resistance winding. This action so greatly lowers the resistance of the trunk circuit and increases the flow of current that the supervisory relay 248 at the first selector will pull up and extinguish the supervisory lamp 264.

Supervision.—During the conversation, the operator may supervise the connection by the use of a key 269, which will connect her telephone set directly from points *a* and *b* in Fig. 211 to points *a* and *b* in Fig. 216. An additional contact on the listening key 269 places a ground upon wire *c* which, by operating relay 720, Fig. 216 cuts off the operators' set from wires *w*-12 and *w*-13, so as not to interfere with any call which may come in on another trunk.

Measured Service.—Provision for measuring the service by recording effective calls is made in a locking registration control relay 262 at the first selector. When relay 258 energized, it not only actuated the sequence switch but also pulled up and locked the relay 262.

Disconnection.—When the calling subscriber hangs up his receiver it will de-energize supervisory relay 247, lighting the lamp 263. The action of the called subscriber is relayed through the third selector which, by removing the low resistance winding of the relay 438, raises the resistance of the trunk circuit so that supervisory relay 248 at the first selector will be unable to hold up and on falling back will light the lamp 264.

The operator upon seeing both supervisory lamps lighted will press release key 268 which, by energizing the line relay 249, will move the sequence switch from position 14 to position 15. Holding the key a little longer allows the sequence switch to pass on away from position 15, after which it will continue in rotation until position 18 has been reached. Here the brushes will be reset to normal by the energization of clutch magnet 260, which will drive the brush carriage on around the circle until wiper 254 arrives at normal. A circuit will be closed through the test relay 242 which will stop the brush carriage by cutting off the current from the clutch magnet 260 and simultaneously drive the sequence switch from position 18 to its normal, or position 1.

Since the tripping spindle is no longer needed after the brushes have rotated on to the bank, it will have been reset to normal, by means of its left spring, acting through spring 211 in time after the sequence switch has arrived at position 9. When the notched wheel 253 has gone around to normal, this left spring will break contact, because the home notch is deeper than the rest.

During the passage of the sequence switch from position 14 around to normal, there is a momentary application of ringing current to the line leading back to the satellite by means of springs 224 and 225 in position 16. This energizes relay 132, Fig. 210 which, by pulling up, unlocks the test relay 127, which, in turn, falling back energizes the clutch magnet 100 of the sequence switch. In obedience to this, the sequence switch moves from position 7 to position 8. In this position that the subscriber's telephone has been disconnected and relay 133 connected across the trunk. A moment later the further rotation of the sequence switch 200, at the first selector, removes the ringing current and substitutes therefore direct battery potential through springs 228 and 227. If the locked registration control relay 262 is energized by reason of a successful call, this flow of direct current will pull up relay 133, at the satellite and by applying stronger flow of battery current to the service meter 130, will cause it to energize and record one call.

The falling back of relay 132, after the end of the ringing impulse, starts the sequence switch 100 away from position 8 and it is thus moving, during the time that the call is being registered on the service meter 130. Since the finder switch has no normal position, its clutch magnet will not be energized and the brushes will remain where they are.

When the release trunk between the first and second selectors is broken, relay 316 de-energizes and closes the clutch magnet (300) circuit moving it to position 5. In position 5, the sequence switch clutch magnet 300 and the holding magnet 361 are placed in parallel with each other, from battery to the front contact of relay 342. At the same time the clutch magnet 360 is energized through the back contact of relay 342. Therefore the brushes of the second selector will be rotated over the bank. When they arrive at normal, spring 354 and spring 308 position 5 will energize relay 342 cutting off the current from the clutch magnet 360, energizing the holding magnet 361 and during the sequence switch 300 from position 5 around to position 1. The spindle is reset to normal immediately upon the arrival of the sequence switch at position 5. The release of the third selector is secured by the de-energization of relay 438 due to the opening of the trunk circuit leading back toward the second and first selectors. The sequence switch 400 immediately moves away from position 17 and stops on position 19. Here the circuits of the sequence switch 400, the holding magnet 461, and the clutch magnet 460 are given into the control of the test relay 442. When the brushes have been revolved around to normal, current through the brush and contact 471 causes relay 442 to pull up and stop the brushes and drive the sequence switch 400 from position 19 to position 1, normal. When the sequence switch arrived at position 8, the tripping spindle was reset to normal, in a manner before described.

The connector switch is released by alternating current sent from the third selector over the trunk line to relay 523. This current is secured through springs 413 and 414 in position 18. When relay 523 of the connector pulls up in response to this alternating current, a circuit is closed through its front contact and other winding, through spring 507 to the clutch magnet 500 of the sequence switch, driving it to position 16. In position 16, the resetting of the brushes takes place, at the conclusion of which the sequence switch is driven forward from position 16 to position 1, normal.

Called Line Busy.—If the called line is busy, there will not be sufficient potential upon the private contact 532, Fig. 214 to cause relay 542 to energize. Consequently, the clutch magnet 560 will derive current through back contact of said relay, spring 505 position 6, and the back contact of relay 521 and drive the brushes around to normal. When the brushes arrive in their normal position, brush 554 touches contact 571 so as to send current through relay 521. The pulling up of this relay sends the sequence switch 500 until it arrives in position 16. This is because spring 508 closes its upper contact whenever the sequence switch goes to rest.

In position 16, the brushes of the connector will be restored to normal as was described before. The sequence switch is also restored to normal by the action of relay 521.

While the sequence switch 500 of the connector is passing through positions 11 to 15, ringing current is sent back over the trunk by means of springs 510 and 511. This alternating current releases the third selector by means of relay 435, and energizes simultaneously relays 258 and 271 at the first selector. Relay 258 will attempt to energize the locking restoration control relay 262 as well as to operate the sequence switch 200; but, because of the action of relay 271, it will succeed in the latter action only. This function hinges entirely upon the nature of the current passing over the trunk. If direct current be sent, as is the case if the called line is not busy, only relay 258 would respond. But if the line being busy alternating current is sent over the trunk, both relays energize so that no call will be registered on the subscriber's service meter.

The sequence switch 200 will now travel to its fourteenth position, from which it will promptly move to the fifteenth position, because of a circuit extending from the back contact of relay 262, spring 205, position 14, leading to the clutch magnet 200. In this position, springs 220 and 221 will close, connecting a busy back induction coil 274, on to the trunk circuit. This passes through an interrupter which, besides interrupting the tone, will cause the relay 248 to pull up and fall back, flashing the supervisory lamp 264. The subscriber on hearing this busy tone should hang up his receiver. If he does not do so, the operator seeing the flashing lamp may operate the listening key 269 and inform the subscriber of the state of affairs.

The operator will now release the connection by pressing the release key 268, which will energize the group line relay 249 which, in turn, will energize the sequence switch. The sequence switch will move from position 15 to 18, during which it will restore the apparatus at the satellite by sending alternating current over the trunk just as it did in the case of a normal release. It will, however, be unaccompanied by any operation of the service meter, because relay 262 is not energized and, therefore, no battery current will be sent over the trunk when spring 227 closes.

Free Calls.—If the operator should desire, for any reason, to keep the service meter from registering a call, she can unlock the relay 262 by releasing with key 273 instead of 268.

Called Station does not Answer.—If the desired subscriber does not answer or for any reason it is desired to release the connection before the called station has responded, the operator can release by pressing key 268 as before. When releasing under these conditions, we will remember that in the connector the sequence switch is in the seventh position, the sequence of the third selector and that in the second selector in the fourth position, and that in the first selector in the tenth position. The pressure upon the disconnect key 268 will now act directly upon the sequence switch 200 through spring 213 and its lower contact. While moving thorough its eleventh position, no call will be charged to the subscriber because relay 262 has not been operated. While passing through its twelfth and thirteenth positions alternating current will be supplied to the trunk leading through second selector, third selector and connector. This will actuate relays 435 and 523, and will cause the restoration to normal of those two switches, while the opening of the release trunk by the restoration of the first selector will cause the second selector to release as has been described.

CHAPTER XII

LONG DISTANCE, SUBURBAN AND RURAL LINE EQUIPMENT

Connections between long distance lines and automatic switchboard telephone systems are set up by operators, following quite closely the methods current in good manual telephone practice. The services of these operators are required for switching the long distance lines for "through" or "toll-to-toll" connections, putting up the connections between toll and local lines, checking conversation lengths and for recording names of parties to each conversation, the amount of the fee charged, etc. Where a long distance board is large enough to require the services of a number of operators, the circuits are usually so arranged that the operators are divided into classes; that is, recording, line, pay station, suburban and rural line operators are used as in manual practice.

Since it is impossible, within the confines of this volume, to describe in detail the circuits and apparatus used for long distance and rural line service in connection with automatic switchboards of each of the makes treated within these pages, it has been thought best to limit the chapter to an exposition of some of the Automatic Electric Company's typical equipments, circuits and practices. It is felt that general methods and fundamental principles are fully illustrated by limiting the chapter to one system.

Variations in the circuits and equipment are largely due to variations in the means used for furnishing supervision to operators setting up connections through the automatic switchboards. The following means have been employed to indicate when a called party answers.

1. Talking current started to flow in the calling party's loop.
2. Direction of talking current flow reversed in the calling party's loop.
3. Strength of current is changed in calling party's loop.
4. Current is caused to flow, stopped flowing, reversed or varied in strength over a third wire used for supervisory purposes only between the connector switch and the toll board.

Recording Methods.—It is almost universal practice in the exchanges employing Automatic Electric Company's apparatus for an automatic subscriber to secure a connection to the long distance switchboard for the purpose of recording his order, by turning his dial from the finger hole, which is labeled "Long Distance" as mentioned in the description of the telephones. These words are usually printed in connection with the naught (tenth) finger hole. When the calling-device operates after the dial is turned from the long distance finger hole, the impulses transmitted raise the shaft wipers of the first selector switch secured to the naught (or tenth) bank level, where they are automatically rotated by the switch and stopped on an idle trunk to a recording position of the long distance board. The trunks usually terminate in the recording position in relay and lamp signals and are generally arranged so that the operator may respond by simply throwing a key. Sometimes jacks are used instead of keys. Details of a typical recording operator's circuit will be discussed later. These circuits are arranged so that when the operator responds they do not reverse the direction of current flow through the calling party's telephone, so that if he is calling from a measured service line, he does not have to pay.

In most modern systems it is customary to use what are called "Discriminating tone tests" in connection with recording operator's circuits. The purpose of this feature is automatically to supply to the recording operator a tone signal which will warn her that the request for a long distance connection comes from a line belonging to a subscriber whose credit is so poor that he is not allowed long distance connections. When thus warned the operator will refuse to set up the connection, or will refer him to the proper company official. A different tone is used for warning her, if the call comes from a subscriber's station, whose proprietor insists that all orders for long distance connections must be approved by him personally. Another tone may be used, to inform the recording operator when a call comes from a pay station, so that she may make note of this fact on the ticket, which she passes to the line operator, who sets up the connection.

After having made out this ticket the recording operator tells the calling subscriber to hang up his receiver and that he will be called when the party he desires has been secured. When the line operator has secured the desired party she calls the local subscriber and puts the two into connection with each other.

The methods followed in setting up the long distance connection may be the same as those used in handling long distance lines in connection with manual telephone systems or, if the order is for a subscriber in another city, which is equipped with an automatic telephone system, it generally promotes efficiency to have the line operator's position equipped with a calling device and to have the long distance line terminate in the automatic switchboard as well as in the toll board at the distant end, so that the line operator can set up the connection by manipulating her calling device and without the aid of the operator at the other end. It has been found that in this way many more connections can be handled than by the ordinary double checking method. Of course the economy is not so great in comparison with a line operated by the single checking method.

Toll Line Connecting Methods.—Three different arrangements are use for enabling toll line operators to complete connections to local lines.

1. A calling device and a trunk like a subscriber's line.

2. A calling device, special selectors, and a toll connector (one per 100 lines).

3. A "*B*" operator's switchboard to which all subscriber's lines are multipled.

The first of the three methods is the cheapest to install and furnishes much more liberal trunking facilities than method 2; in fact, where 2 is used it is necessary to resort on occasions to method 1 to take care of overflows.

Method 2 is preferable to 1 because connections are set up more quickly and better transmission is secured. When this method is used in a multi-office system, it improves transmission by eliminating one or more repeaters. A third advantage of this plan is that it is practicable to arrange the special toll connector switch so that the ringing is under the control of the operator. This feature is quite helpful in setting up toll connections, because it enables the line operator (without ringing) to hold a connection against a possible call from some local subscriber, while the operator finishes setting up the long distance connection.

The third method mentioned has been used in but a few plants in which automatic switchboards of the old local battery type are installed. It has the advantage in connection with automatic equipment of that old type of affording a better transmission circuit than could be secured through the automatic switchboard, and of reducing the difficulty of giving the operators adequate supervision over the long distance connections. The equipment for this method is so expensive to install and so much more expensive than the other methods to operate that it is not likely that it will be used in connection with modern automatic switchboards except under one peculiar condition; that is, where an automatic switchboard supersedes a manual switchboard, and it is not thought advisable to replace the long distance board, or to remodel it in order to adapt it for use in handling connections directly through the automatic switchboard. Where this condition arises the "*B*" board, or some of the "*A*" operators' sections of the old manual board may be used to make up a toll switching multiple board for setting up connections in accordance with method 3, thus making it possible to leave the old long distance board unchanged and eliminating the expense of installing special toll connectors on the automatic switchboard.

Pay-station Lines.—In automatic systems public pay stations which are used to a considerable extent for long-distance talking are generally equipped with ordinary manual common battery telephones and three-slot coin collectors. Lines from pay stations of this type run directly to the long-distance board and, if there are enough of them to warrant it, they all terminate in the position of a pay-station operator. In any event they are multipled through the board so that any long-distance line operator has access to them.

Rural Lines.—Rural lines connected to an automatic telephone system are not as a rule equipped with automatic telephones, but with telephones of any of the types which are in accord with good practice in connection with manual systems. The reasons are as follows:

First.—The construction used on rural lines is often not of a high character, so that poor insulation is common.

Second.—Rural lines are often quite heavily loaded. It is not uncommon to bridge eight, ten or twelve telephones on one line. It is difficult to call automatically through the combined capacity of the condensers which are in series with the ringers of the telephones.

These lines are generally run to the long distance switchboard, and where there are enough of them, they terminate in the position of a special rural-line operator. Sometimes it is necessary to have several of these operators. These lines, like the pay-station lines, are multipled throughout the switchboard so that each toll-line operator will have access to them, when necessary to set up a toll to rural connection. Rural lines may be called by the local subscribers directly and automatically when proper arrangements are made, or they may be called through the rural-line operator. The latter is generally the plan adopted and the rural-line operator is usually secured by one or two movements of the dial.

To call rural lines automatically in modern two-wire systems, the most practicable plan is to put not more than eight telephones on each line, and to equip the telephones with harmonic ringers of the same type as those used in automatic party line telephones, connecting four telephones between each side of the line and earth. Each telephone may then be given its own individual number and eight groups of connector switches may be installed for the use of the automatic subscribers in establishing connections and selectively ringing the rural lines. The method is the same as that explained in Chapter II for giving local four-party line service, except that eight groups of connector switches are used instead of four. Of course where the number of lines is not sufficient to warrant the use of eight groups of connector switches, four may be used by multipling together in pairs the connector bank contacts in adjacent rows, that is, by multipling together rows one and two, three and four, five and six, seven and eight, and nine and ten. This multipling must be done in such a way that the upper line bank contacts in one row will be connected to the lower-line bank contacts in the other row. It is apparent that after this multipling has been completed, a subscriber using a connector switch in a group supplied with 16-cycle ringing current will ring on one side of a rural line if he calls a number which places his connector wipers on row 1; for example, if he calls 12; whereas if he calls 22 he will secure the same line, but will ring the 16-cycle telephone on the other side of the line. Likewise if he calls 12 using the 33-cycle group of connectors, he will project 33-cycle current out on one side of the line;

whereas, if he calls 22 he will project current of the same frequency out on the other side of the line and ring the other 33-cycle telephone. Where rural lines are called automatically it is necessary to multiple the connector-switch banks with the rural line jacks of the long-distance board, so that when a connection is set up at either point it will establish a guarding potential for giving the busy test at the other point.

Suburban or "Rapid Fire" Toll Service.—The method for handling calls from an automatic central office to a suburban or neighboring office when a special fee is to be charged for each connection depends upon whether one of the offices is a manual office or not.

Calls from an Automatic Office to a Suburban Manual Office.—If one office is equipped with a manual switchboard, the preferable method is to have the automatic subscribers connect to, and signal an operator at the manual switchboard, by calling some short, predetermined and generally known number. For example, if naught is used for connection to the regular long-distance board, 9 or 91 might be used for connections to the manual office under discussion. At the manual office these trunks may terminate in regular subscribers' line-jack equipments, in front of one or more "*A*" operators, who will respond to a subscriber's signal, take his order, make a record of his number and the number of the party desired, complete and supervise the connection in the usual way; but it is preferable to have them terminate in cords and plugs in a "*B*" operator's position, where they may to better advantage receive the rather special attention that they deserve.

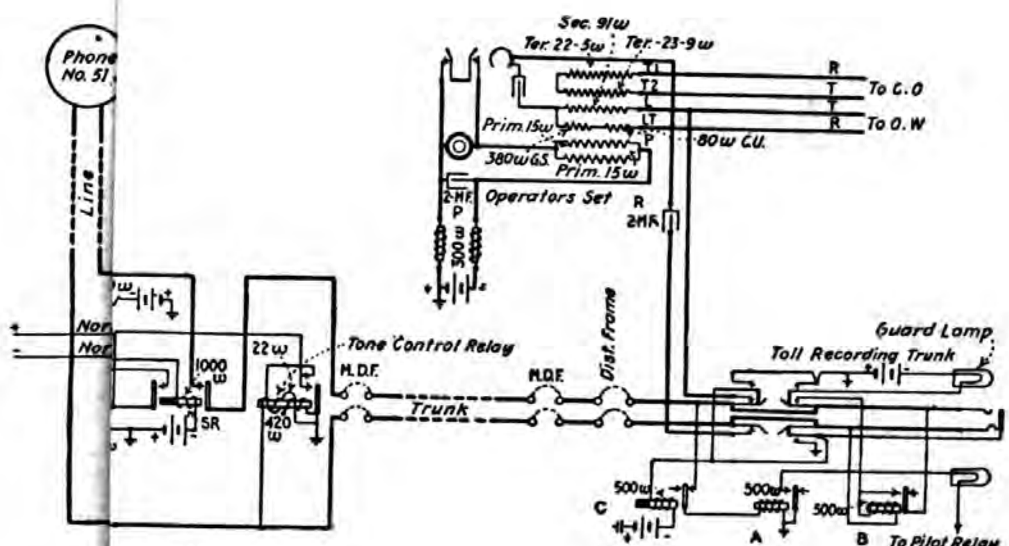
It might appear that since this method makes it necessary for the operator to depend upon the calling subscriber to give her his correct náme and telephone number in order that the fee may be charged to the proper subscriber's account, that some subscribers would endeavor to secure free service by giving the operator the name and number of some other subscriber. It has been found, however, that if a percentage of the calls are checked, by not putting them through directly, but by telling the calling party to hang up and that he will be called when his desired party is secured, the knowledge that this may be done at any time almost entirely prevents cheating.

Calls from the Manual to the Automatic Office.—These may be handled either by means of calling devices placed on the "*A*" operator's positions of the manual switchboard, by means of calling devices on a special "*B*" operator's position on the manual switchboard, or through a "*B*" operators' switchboard located in the automatic office. A "*B*" board in an automatic office may be either equipped with calling devices, or it may be a multiple board in which jacks are multipled with the connector-switch banks of the automatic switchboard. Generally, the most economical and efficient method is to have the calls set up by the operators in the manual central office. If an office is a small one it is preferable to install a calling device in each "*A*" operator's position. If it is a large one, where the "*A*" operators are worked at high pressure in handling local manual calls, and the number of calls dialed out to the automatic office is comparatively small, it is preferable to have the calls to the automatic office handled by a special "*B*" operator to whom calling manual subscribers will be switched by means of *transfer* trunks. The "*B*" operator will respond to each such call by securing the number of the calling party, the number of the automatic subscriber desired, and the name of each, and will then complete the connection.

Suburban Calls between Two Automatic Offices.[1]—It should be obvious that where subscribers' lines are equipped with measured service devices, such as meters or coin collectors for registering or collecting a fee for each local call, that if the same fee is charged for the suburban call—and it is practicable from an engineering standpoint to allow the subscribers to set up their own suburban calls automatically (as it would be under almost any conceivable condition) that the registering or collecting of fees for the suburban connections may be done automatically without the aid of operators. Where the fee for the suburban call is different from that charged for local service, or where local service is not furnished on a measured plan a switchboard for the use of the operators required may be placed in either one of the automatic offices, or a switchboard may be placed in each of them; that is, a switchboard may be placed in one office for calls outgoing from "*A*" office to "*B*" office and a switchboard in "the other" office may be used for setting up and recording the calls outgoing from "*B*" office to "*A*" office. In either event a subscriber desiring a suburban connection would secure the operator by calling some short, well understood number, as already mentioned, and she would complete the connection by means of a calling device. The operators' positions may be equipped with cords and plugs, but it speeds up the service to have them equipped with keys only, and the arrangements may be such that when a calling subscriber secures an idle trunk to an operator, he thereby secures a corresponding idle trunk to the distant office so that when the operator responds to his signal lamp and takes his order, she may then throw her calling device key, set up the balance of the connection desired by the subscriber and restore her key to normal. It can be arranged, if desired, that when a calling party hangs up, he will release the whole connection and at the same time furnish the operator the necessary supervisory signal, showing the termination of conversation. She has no work to do at the time of disconnection, except to press a key to break the circuit through the disconnect signal lamp. The trunks will be much more efficient if the subscribers do the disconnecting.

A Typical Recording Trunk Circuit.—A connection from a calling telephone through a line switch, secondary line switch, first selector and toll trunk

[1] See the paper entitled "The Automatic Telephone in City Service" by Arthur Bessey Smith, to be found in Vol. II (pages 1371 to 1378) of the *Transactions of the American Institute of Electrical Engineers*, 1910.



ll Repeater

criminating tone signals.

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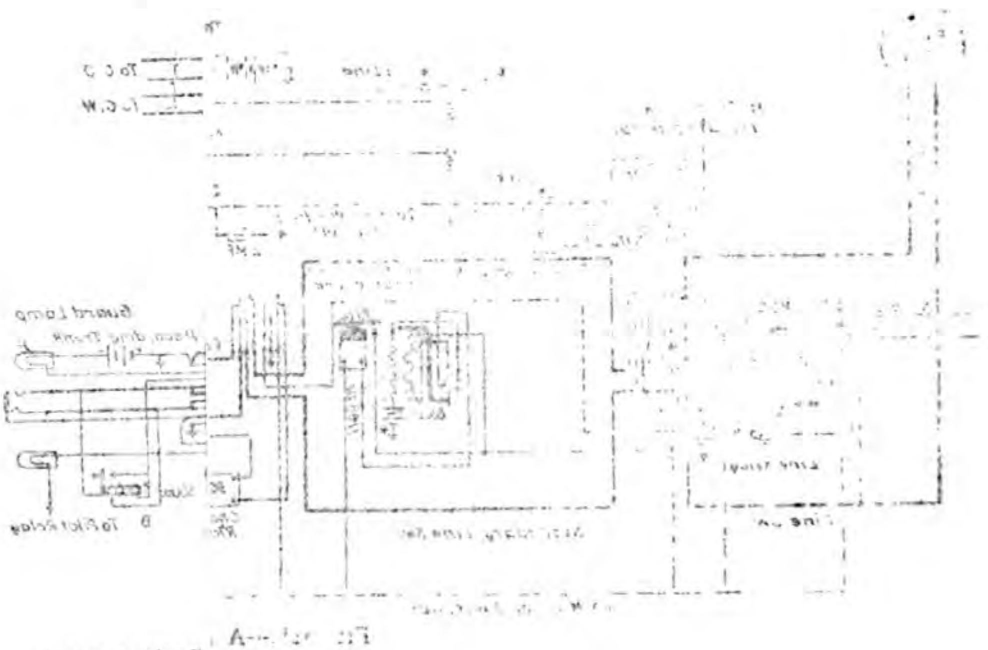


repeater to a typical recording trunk circuit is shown in Fig. 228. The circuits of the primary line switch, secondary line switch and first selector are the same as, or very similar to, those shown heretofore, and will therefore not be described. Attention is called, however, to the tap of the private normal and release trunk of the line switch which is connected through a condenser to the tone circuits of the tone machines which supply four distinct interruptions or tones for use on the recording trunks to identify the classes of service, as already mentioned. When a tone is desired on any line, a wire is run from the terminal of the busbar furnishing the particular tone desired through the condenser to the trunk as shown. Completion of the circuit from this point through the toll recording operator's circuit will be described farther on.

As already explained the calling party may secure connection to the repeater of an idle trunk by turning his dial from the long-distance finger hole thus raising his first selector shaft wipers to the naught bank level, where they rotate until they find an idle trunk. When connection to this trunk is established circuit is completed from either pole of battery through the windings of the double wound line relay *L.R.* of the repeater and the subscriber's loop. *L.R.* closes circuit from earth to negative battery through the 1000-ohm slow relay *S.R.* and continues the release trunk through to the 420-ohm winding of the double-wound tone-control relay to earth. The 1000-ohm relay closes the negative side of the line through to the toll recording trunk. As soon as this occurs circuit is closed from negative battery through the 420-ohm resistance coil, negative side of the line, negative side of the trunk and the line relay *A* of the recording trunk to earth. Relay *A* closes circuit through the line lamp, signalling the recording operator, who responds by throwing her key in the direction to switch her circuit on to the trunk. The tone-test circuit has already been closed from tone terminal in line switch unit through condenser, release trunk, release trunk of secondary line switch, the release trunk of the first selector, the first selector private wiper, private bank contact, contacts of relays *L.R.* and *S.R.* of the repeater, the make before break contact of the tone-control relay and the 420-ohm winding of this relay to earth. The tone-control relay is not operated at this time by the battery flow through the *B.C.O.* relay of the line switch via the release trunk. A corresponding current is induced in the 22-ohm winding of this relay which transmits the tone to the operator through a circuit completed from earth, through the 22-ohm winding, positive side of the trunk line, the trunk listening key, the operator's head phone. At the same time a circuit is closed from earth through a make contact of operator's listening key, the cut-off relay *C* of the trunk to negative battery. This relay breaks circuit through line relay *A* which in turn breaks the circuit through the line-signal lamp. To cut off the tone the operator throws the key in the opposite direction, that is, into holding position and then back to listening position. When the key is in holding position a circuit is closed from battery through the 420-ohm resistance coil of the repeater, the negative side of line, winding of 500-ohm relay *B* in the trunk circuit, the positive side of the trunk line, the 22-ohm winding of the tone-control relay to earth. The tone-control relay thus energized attracts its armature and shunts the tone circuit from its 420-ohm winding through its make contact to earth. Relay *B* in the trunk circuit locks up through its make contact and holds the tone cut-off relay of the repeater, when the operator's key is restored to the listening position. Thus the tone is kept off the talking circuit until the calling subscriber releases. If, after talking to the calling subscriber, the recording operator should wish to hold him on the trunk, but disconnect her head phone while talking to another party or looking up some desired information, she does so by throwing the key into holding position. This leaves relay *B* across the line and at the same time the key closes circuit through the guard supervisory lamp. The jack shown as a part of this trunk is not essential, but is very convenient for connecting parties through to the chief operator's desk and for other similar purposes.

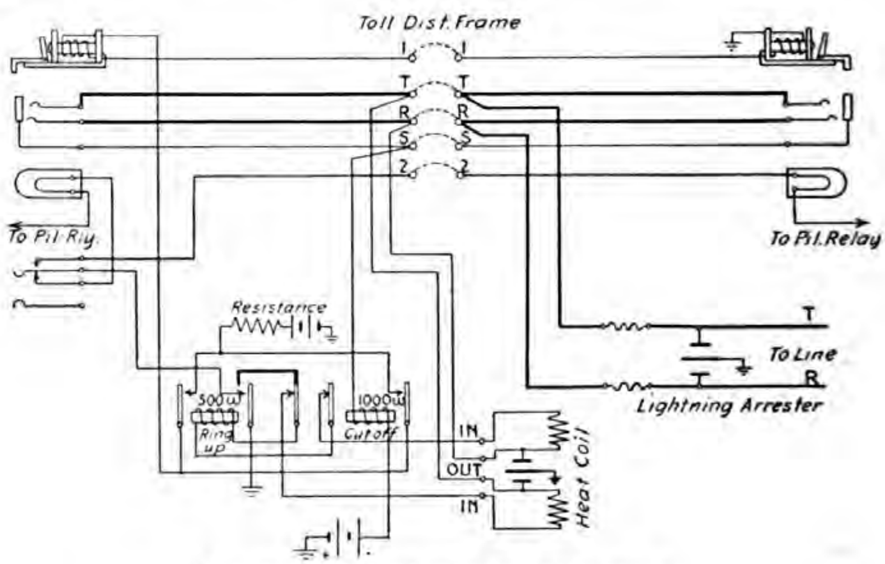


FIG. 229.—A typical toll or rural-line circuit.

Toll or Rural-line Circuit.—A typical toll or rural-line circuit with its multiple connection and supervisory signals is shown in Fig. 229. The ring-up relay on this circuit locks itself mechanically when its armature is pulled up, and closes circuit from earth through the line signal lamp. At the same time it closes circuit from the negative end of battery, through a resistance and in series through the visual signal associated with the multiple jack corresponding to the line in each section of the toll board to earth.

When the operator responds by inserting the answering plug of an idle toll cord circuit in the line jack, a circuit is closed from earth to which the sleeve of the plug is connected by the third strand of the cord, through the sleeve of the jack and the cut-off relay to negative battery. The cut-off relay unlocks the line relay and at the same time disconnects it from the line. When it does so it closes a contact which keeps the circuit established from negative battery through the visual signals guarding the multiples of the line.

Where the rural lines are called by the automatic subscribers directly, this line circuit and the connector banks would be multipled together by connecting the two sides of the line to the terminals of the line contacts of the connector banks, and the sleeve of the jack to the terminal of the private contact multiple of the connector bank. With this arrangement, whenever a plug was inserted in the jack, the earth connection that pulled up the cut-off relay would put a guarding potential on the corresponding private multiple of the bank, and vice versa, whenever a connector switch was connected to this line the guarding earth potential established on the private bank contact and its multiple would pull up the cut-off relay of the line, which would close the circuit through the visual busy signals.

Toll Cord Circuit.—The toll cord circuit used with this line is shown in Fig. 230. The plug of this circuit, which is marked "Toll," must always be used in toll line jacks, regardless of whether the operator is answering or calling; and the plug marked "Auto" must always be used in the trunks to the automatic switchboard or in pay-station lines. When a line operator has received an order for a connection to one of her toll lines, she picks up the toll plug of an idle cord circuit and inserts it into the jack of the line on which the desired party is to be called. As already mentioned, current immediately flows from earth through the third conductor of the cord, the sleeve of the plug, sleeve of the jack, and the cut-off relay of the line which cuts off the ring-up relay and leaves the line clear for the operator to ring. It will be noted that when she throws her ringing key the tip and ring of the plug are disconnected from the cord circuit and connected directly to the ringing generator busbars. She then restores her ringing key to normal, throws her listening key and awaits the answer of the operator at the distant end of the line.

Should the operator at the other end desire at any time to secure the operator at the local end, she does so by sending generator current over the line which causes the 3100-ohm ring-up relay to attract momentarily its armature and open the shunt around the 200-ohm supervisory relay to earth. The supervisory relay immediately acts and closes the circuit through the lamp, giving the required signal to the operator. When the operator responds, by throwing her listening key, it closes a circuit to earth, which again shunts out the supervisory relay causing it to release its armature and break the circuit through the lamp.

The automatic end of this cord circuit is separated from the toll end by a condenser of 4 m.f. capacity inserted in each side of the cord. Supervision in the automatic end is provided by two relays, *A* and *B*, operated through the third strand of the cord, the sleeve of the plug and the sleeve of the jack, and by the double wound polarized relay which sometimes is bridged across the line; but when relay *A* is energized sufficiently to attract its armature, one winding of the polarized relay is connected to earth and the other winding is connected to negative battery through the 30-ohm German silver resistance coil which is wound, for convenience, on the spool of relay *B*. The purpose of this coil is to prevent danger from accidental short-circuiting of the two poles of the battery through the springs of relay *A*, by inserting the 30-ohm resistance between the springs and the negative pole of the battery.

The automatic end of this cord circuit is designed so that it may be used

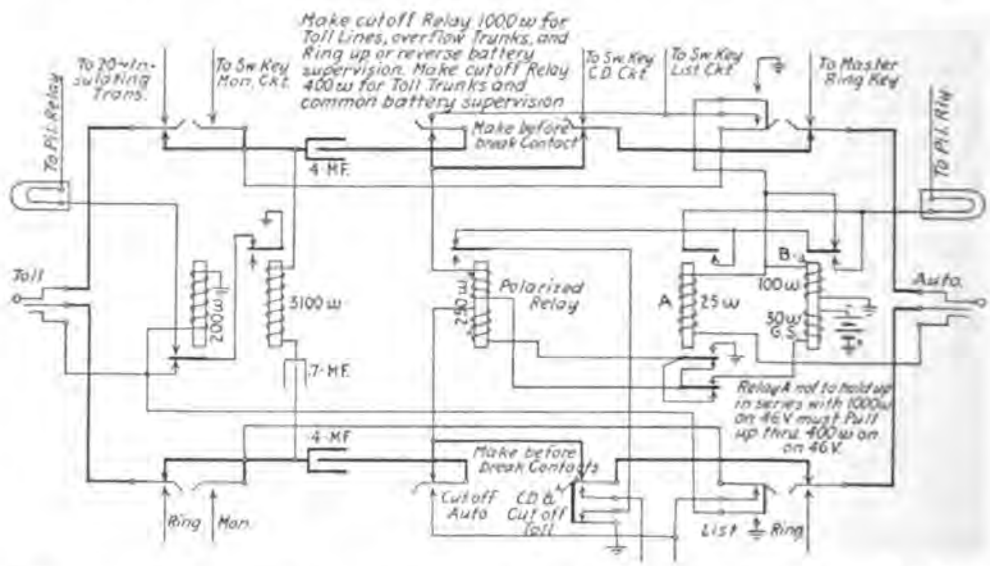


FIG. 230.—A typical cord circuit for connecting toll lines to local automatic switchboard lines.

with at least four different types of circuits: First, with common battery pay-station lines; second with overflow trunks; third, with regular toll service trunks terminating in special connector switches and, fourth, with local battery, magneto signalling, pay-station lines.

Before describing in detail the various circuits with which this cord circuit is used, an indication will be given of the method by which it differentiates between the various circuits.

Relay "*A*" (Fig. 230) will not pull up in series with 1000 ohms on 46-volt battery, but will pull up through 400 ohms. Therefore, on the circuits where it is desired to have the polarized relay remain bridged across the line (overflow trunks and local battery pay stations), the sleeve relay of the line circuit has a resistance of 1000 ohms or more; but on the service trunks and common battery pay-station lines, where it is desired that the polarized relay supply talking current to the line, relay *A* is energized through a 400-ohm sleeve relay. Supervision is therefore obtained as explained in the following descriptions of the respective line and trunk circuits.

Overflow Trunks.—One end of an overflow trunk is shown in Fig. 231. The other end terminates in selectors and reversing battery connectors, the circuits of which have been explained in a previous chapter. When the automatic plug of the toll cord circuit is inserted in the jack of an overflow trunk, the third strand of the cord is connected to negative battery, through the 1300-ohm busy-control relay of the trunk. Relay *A* of the cord circuit therefore does not operate but the busy control relay of the trunk does so, closes the positive side of the trunk, and operates the visual busy signal associated with this trunk, and with each of its multiples in the various positions. When the operator throws her calling device key to call the desired

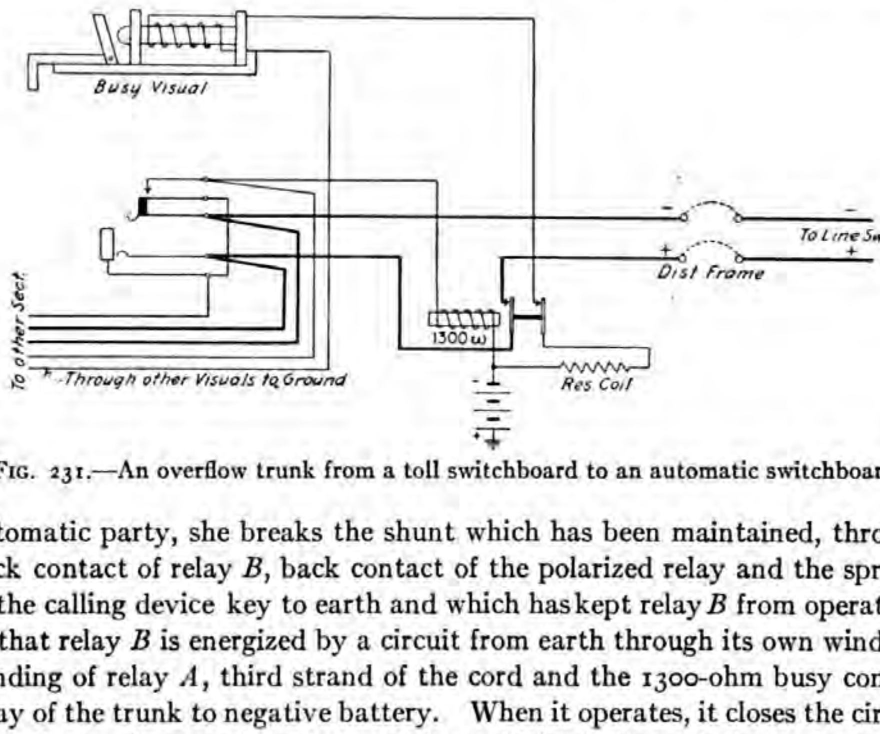


FIG. 231.—An overflow trunk from a toll switchboard to an automatic switchboard.

automatic party, she breaks the shunt which has been maintained, through back contact of relay *B*, back contact of the polarized relay and the springs of the calling device key to earth and which has kept relay *B* from operating, so that relay *B* is energized by a circuit from earth through its own winding, winding of relay *A*, third strand of the cord and the 1300-ohm busy control relay of the trunk to negative battery. When it operates, it closes the circuit from the trunk supervisory lamp of the cord circuit through the back contact of the polarized relay to the springs of the calling device key, so that so soon as the calling device key is restored to normal the supervisory lamp circuit is completed to earth and the lamp glows. When the automatic subscriber responds, the direction of the current through the polarized relay is reversed by the connector switch used and it swings its armature away from normal position thus breaking the circuit through the lamp. Relay *B*, however, remains energized during conversation, and when a subscriber replaces his receiver on the switch hook, thus reversing the direction of current flow back to normal through the polarized relay, the armature of which swings back to normal position, the circuit through the supervisory lamp is again immediately established giving the operator the disconnect signal.

Local Battery Magneto Signalling Pay Station or Line.—The circuit of a local battery magneto signalling pay station or line for use with this cord circuit should be practically the same as the toll and farmer line circuit, Fig. 229, already described. As the diagram indicates, this circuit is provided with a 1000-ohm cut-off relay, so that relay *A* of the cord circuit will not be operated when the plug enters the jack and consequently the polarized relay will be left bridged across the line to act as a ring-up relay for supervisory purposes.

Pay-station Lines.—On a common battery pay-station line (Fig. 232) when a plug is inserted in the jack, current flows from negative battery through

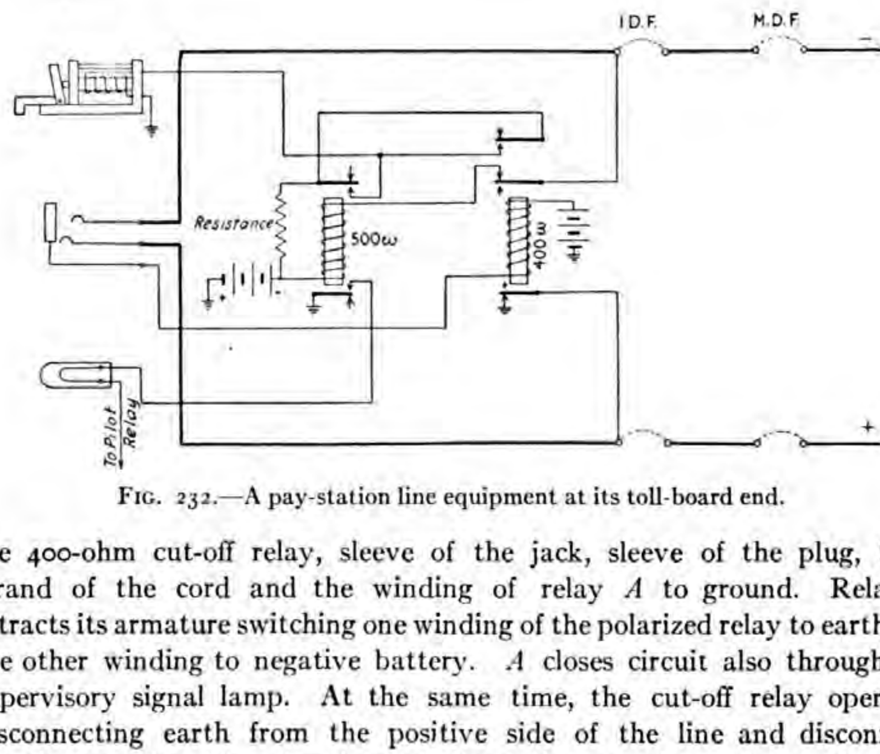


FIG. 232.—A pay-station line equipment at its toll-board end.

the 400-ohm cut-off relay, sleeve of the jack, sleeve of the plug, third strand of the cord and the winding of relay *A* to ground. Relay *A* attracts its armature switching one winding of the polarized relay to earth and the other winding to negative battery. *A* closes circuit also through the supervisory signal lamp. At the same time, the cut-off relay operates, disconnecting earth from the positive side of the line and disconnecting the 500-ohm line signal relay from the negative side of the line. It also closes a circuit from negative battery through a resistance coil to the visual, busy signal associated with the jack of this line and in series through each of its multiples in the various sections to earth; so that a guarding signal shows wherever a multiple of this line appears.

The operator rings on the line by throwing her ringing key, which she then restores to normal. When the pay-station party responds, current flows from earth through one winding of the polarized relay and the subscriber's loop, back through the other winding of the polarized relay to negative battery. The polarized relay swings its armature away from normal and in doing so breaks the circuit through the supervisory lamp of the cord.

When the subscriber finishes conversation and places his receiver on the switch hook, the armature of the polarized relay returns to normal position and the supervisory lamp lights, giving the operator the required disconnect signal.

Toll Service Trunk Circuit.—In an exchange using toll service trunks, when the operator has secured the party desired by an automatic subscriber, she picks up the automatic plug of the cord circuit, and if the busy visual which is associated with the proper toll service trunk circuit, is not operated (Fig. 233) she inserts the plug into the jack of this trunk. When she does this, circuit is closed from earth through the winding of relay A, the third conductor of the cord, sleeve of the plug, sleeve of the jack, and

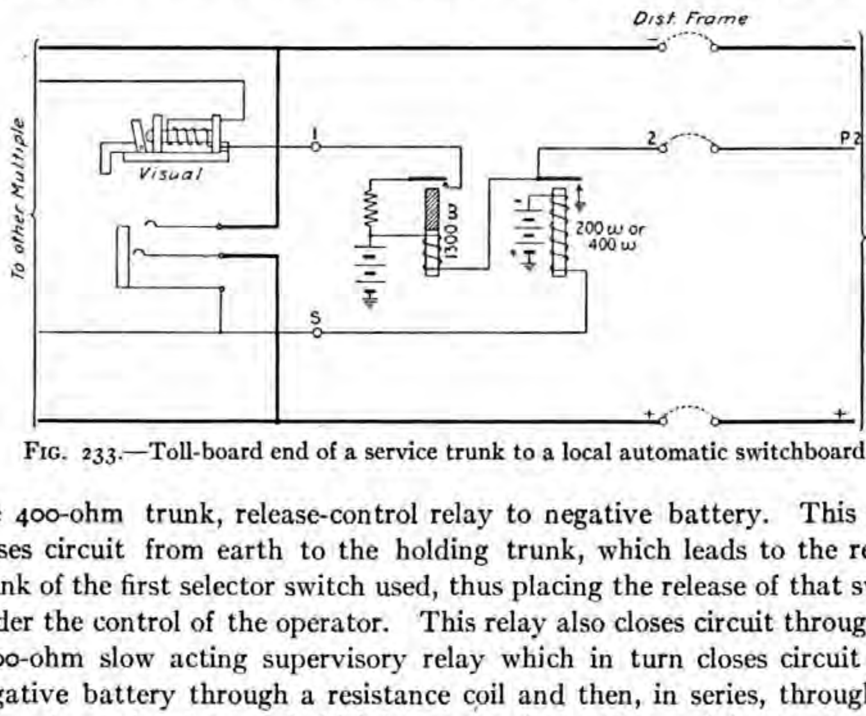


FIG. 233.—Toll-board end of a service trunk to a local automatic switchboard.

the 400-ohm trunk, release-control relay to negative battery. This relay closes circuit from earth to the holding trunk, which leads to the release trunk of the first selector switch used, thus placing the release of that switch under the control of the operator. This relay also closes circuit through the 1300-ohm slow acting supervisory relay which in turn closes circuit from negative battery through a resistance coil and then, in series, through the busy visual signals, one of which is associated with the trunk jack and each of its multiples in other sections.

While the first switch is called a first selector, it is generally used as a second selector in a multi-office system by arranging trunks to lead from the long distance board directly to each of the main offices.

In such a system, the first selectors are generally used to select main offices. Therefore, if the operator manually selects an idle trunk to the proper main office, no first selector switch is required and the first digit of each party's number is omitted by the operator when calling him.

When the operator has inserted the plug in the trunk jack, she throws her calling device key and calls the local party's number. If she then does not hear a tick-tick signal indicating that another operator or the wire chief is using one of the switches required to complete the connection, or the regular busy signal indicating that the called line is busy, she restores the calling device key and throws her ringing key, which projects ringing current out on the automatic trunk through the connector switch to the line of the called party. When the called party responds, talking current flows through the trunk from the toll-board battery busbars through the windings of the double-wound polarized relay in the cord circuit and the called subscriber's line and telephone. The polarized relay breaks the circuit through the guard lamp.

It will be noted later on that talking current is also supplied to the called subscriber through the 250-ohm relay windings of the connector switch. The consequence of supplying this current through two sets of relays in multiple is, that the telephone is furnished with considerably more current for long distance calls than is supplied to it, or is needed for local connections. When the parties finish their conversation, the operator secures the disconnect signal from the automatic subscriber, when he places his receiver on the switch hook and the polarized relay armature drops back and recloses the circuit through the trunk supervisory lamp. The operator or subscriber on the long distance line rings off sending generator current over the line, which pulls up the 3100-ohm relay in the toll end of the cord circuit, breaking the shunt of the 200-ohm supervisory relay, which closes the circuit through the toll supervisory lamp. After this relay is once pulled up it keeps the lamp lighted until the operator withdraws the plug from the toll line jack, or throws her listening key as already mentioned.

Toll Selectors and Connector Switch Circuits.—The circuits of the toll first selector, second selector and connector, used in connection with the service trunk circuit and toll cord circuit described, are shown in Fig. 234. These selectors are of the side switchless type, and differ little from the regular side switchless selectors, with the exception that the wiring of the release trunk is such that it gives the control of the release to the operator at the long distance board, and with the further exception of a provision for supplying a busy signal to the operator in case all of the trunks to which either the first selector or the second selector has access should be busy. In this case the private relay E will remain energized and close the circuit from the primary winding of the busy signal induction coil through the winding of line relay A, springs of the line switching relay C to the positive side of the line, through the operator's set, back on the negative side of the line and through the other winding of line relay A to negative battery. The circuits of the second selector are practically the same, with the omission of the release control relay F, as those of the first selector and they will therefore not be explained.

To understand the circuits of the connector switch, one should realize that this switch is designed to be used by the long distance operators for setting

to retain its armature and prevent the side switch from moving to third position.

calling device key and calls the local party's number. If she then does not hear a tick-tick signal indicating that another operator or the wire chief is

plained.

To understand the circuits of the connector switch, one should realize that this switch is designed to be used by the long distance operators for setting up toll connections and also by the wire chief for testing subscriber's lines.

The double-wound, quick-acting line relay and 1300-ohm slow acting relay combination for operating the vertical, rotary and other magnets is not used on this connector switch. An impedance coil, as the diagram indicates, is substituted for the positive winding of the line relay, and a single coil relay is used on the negative side of the line. A 3100-ohm ordinary relay is used in place of the customary 1300-ohm slow acting relay, the release is controlled over the release trunk and as soon as this 3100-ohm relay once attracts its armature, it locks itself to the release trunk until the operator withdraws the plug from the trunk jack. Calls are set up through this switch by means of the following circuit operations:

When the operator rotates her calling device dial for the next to the last digit of the number called, the loop through the line relay coils is broken and the armature of the negative line relay *A* drops back a corresponding number of times. Each time it falls back it closes circuit from earth through side switch 2, springs of the 3100-ohm relay *B*, private control relay *E*, the vertical magnet and side switch 3 to negative battery, with the result that the vertical magnet gives the shaft a corresponding number of vertical steps. At the same time, the private control relay closes the circuit from earth on the release trunk to the private magnet *H*, causing it to hold down its armature until the vertical movement of the shaft has been completed. While the operator is pulling round the dial from the finger hole corresponding to the last digit of the number she is calling, private control relay *E* releases its armature and in turn the armature of the private magnet falls back and allows the side switch to move to second position, switching the vertical magnet out of circuit and the rotary magnet in, so that when the circuit through the negative line relay is broken a number of times, corresponding to the last digit called, the rotary magnet is operated and the shaft wipers are rotated on to the bank contacts corresponding to the called subscriber's line. Then the private control relay *E* again releases its armature and the private magnet allows the side switch to move to third position, unless the called party's line is busy, in which case circuit is closed from earth on the private contact corresponding to the busy line, through the private wiper, side-switch wiper 1, one winding of the busy relay *D* to negative battery. When *D* operates, it breaks the circuit through the rotary magnet so that if the operator should by mistake make another turn of the calling device dial, the wipers will not be rotated off the called subscriber's bank contacts. *D* also closes contact from the busy busbar to the positive side of the line, giving the busy signal to the operator. It also closes circuit from the release trunk through the private magnet, causing it to retain its armature and prevent the side switch from moving to third position.

If the called party's line should not be busy when the private control relay falls back, the private magnet armature falls back also and the side-switch wipers step to third position. Guarding potential is placed on the called line from earth through side-switch wiper 1 to the private wiper. The line is closed through to the line wipers and the normals of the called party, by the action of the 1300-ohm line switching relay C, which is energized from the earth connection on the release trunk, through the winding of C and side-switch wiper 3 to negative battery.

The line is now left clear from the jack at the long distance board through to the called subscriber's line, with the exception of the positive line impedance coil and the negative line relay coil, so that the operator rings directly through the switch to signal the called party. When he responds current flows through the winding of the impedance coil G and the line relay coil A in multiple with the windings of the polarized relay in the operator's cord circuit to supply him with talking current.

When the operator withdraws the plug from the trunk jack, the circuit through the release control relay B is broken. When its armature falls back, circuit is closed from earth, through side switch 2, back contact of B, the shaft normal springs *O.N.S.* and the release magnet to battery. When the release magnet attracts its armature, the double dog is kicked out of engagement with the shaft which returns to its normal position, and breaks the circuit through the release magnet, by breaking contact between the normal springs.

When this switch is used by the wire chief, he operates it, in the manner just described, to call any number desired. If he wishes, as he frequently does, he may call the first pair of contacts in any row and then, after testing that line, step the wipers on to the next pair of bank contacts, test them, move to the next, etc., without releasing the switch. He does this by connecting the wire marked Pr. 1 to earth, by means of a key located at his position, and thus operating relay F which closes the circuit from Pr. 1 through side switch 1 and the busy relay D to negative battery so that the private magnet is energized and keeps the side switch from moving to third position. F also closes the circuit from the rotary magnet through to the contacts of relay E, which enables the wire chief by connecting the negative side of the line to earth for the fraction of a second, by pressing a key at his position, to operate the negative-line relay and thus, in turn, operate the rotary magnet, causing the shaft wipers to pass to the next pair of bank contacts.

After testing these he may again ground the negative line for a second and thus cause the switch to step the shaft wipers on to the next pair of bank contacts, etc. The detailed circuits of the wire chief's desk, together with the test distributor and other testing equipment used by him, are explained at greater length in Chapter XIV.

Rural-line Switchboard Incoming Trunk Circuit.—An incoming trunk circuit for use in receiving orders for rural-line connections from automatic subscribers is shown in Fig. 235. This circuit terminates in a jack in the rural-line position and in selector banks on the automatic switchboard. As previously mentioned, it is common practice to arrange the numbering and trunking plan so that automatic subscribers may place orders for rural-line connections by calling not to exceed two digits. When a two digit number is used in a multi-office system, the first digit is used in operating a first selector in the automatic subscriber's own office, which selects an idle trunk to the office in which the rural-line board is located. The second digit is used in operating a second selector switch in that office to extend the subscriber's connection over an idle trunk circuit, similar to that

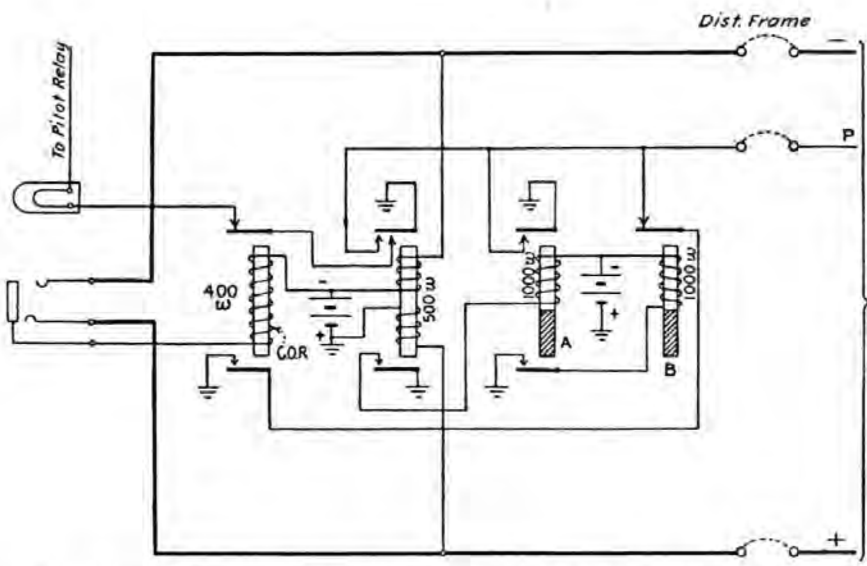


FIG. 235.—Circuit of trunk incoming to a rural-line switchboard from an automatic switchboard.

shown in the above diagram, to the rural-line board. As soon as the second selector switch has completed the connection, current flows from earth through one winding of the double-wound relay of the line circuit, through the calling subscriber's loop, back through the other winding of the line relay to negative battery. This relay closes a circuit from earth to the release trunk *P* of the second selector. It also closes circuit from earth through the line lamp, signalling the operator, and circuit from earth through the 1000-ohm slow-acting relay *A* to negative battery. Relay *A* closes circuit from earth through relay *B* to negative battery. In case the operator does not respond promptly, or a subscriber should wish to attract her attention at any time, he may flash the line lamp by moving his receiver switch hook up and down rapidly, or by making another turn of his dial. This will cause the double-wound line relay to make and break the circuit through the lamp, but the slow-acting relay *A* will keep the release trunk connected to earth, preventing the second selector switch from releasing.

When the operator answers, using the automatic plug of the cord shown in Fig. 230, the 400-ohm cut-off relay, *C.O.R.*, of the trunk is energized in series with relay *A* of the cord circuit and breaks the circuit through the line lamp. The operator throws the listening key in her cord circuit, and after ascertaining the rural-line party desired by the automatic subscriber used, inserts the toll plug in the jack of the proper rural line, circuit of which is similar to that shown in Fig. 229, and sends out the proper signal. The supervisory features have already been explained.

When the calling automatic subscriber disconnects before the operator withdraws her plug from the trunk jack, the cut-off relay closes circuit from earth through the back contact of the slow-acting relay *B*, to the release trunk so soon as the armature of *B* falls back. Since the circuit through *B* is not broken, however, until the armature of the slow-acting relay *A* falls back, *B* does not complete the circuit to the release trunk until the selector switches have had time to release. The purpose of connecting the release trunk to earth after the switches have released, is to prevent the trunk being seized by another subscriber before the operator has withdrawn the plug from the jack.

Since the circuits, of chief operator's and monitor's desks, through switching toll cord circuits, toll test panels, etc., may be the same as any efficient circuits used in manual practice, space will not be occupied by a description of them.

Long Distance Automatic Calling.—As already stated, long distance lines of moderate length, terminating at one end in a central office in which an automatic switchboard is installed, may be made considerably more efficient by connecting them up so that an operator at the distant end of the line may use a dial to call directly, any subscriber to the automatic central office.

Simplex Calling.—A method of connecting up the calling circuit which is now coming into vogue, and which is less liable than some others to disorders due to line conditions, is illustrated in Fig. 236, which shows a circuit in use between several cities in the state of Indiana.

The automatic switchboard is located at *A*. *B* is a switching station 45 miles from *A*, and *C* is a large manual plant 45 miles from *B*, and 90 miles from *A*. *B* and *C* are both provided with calling devices for doing automatic calling into *A*. Between *A* and *B* is another toll station, of one telephone only, which is bridged across the line in the usual way for manual calling and is not shown in the diagram. Each calling device (indicated by *CD*) is connected between earth and the middle point of a repeating coil, bridged across the line, following the practice used in connecting up simplex telegraph circuits to telephone lines.

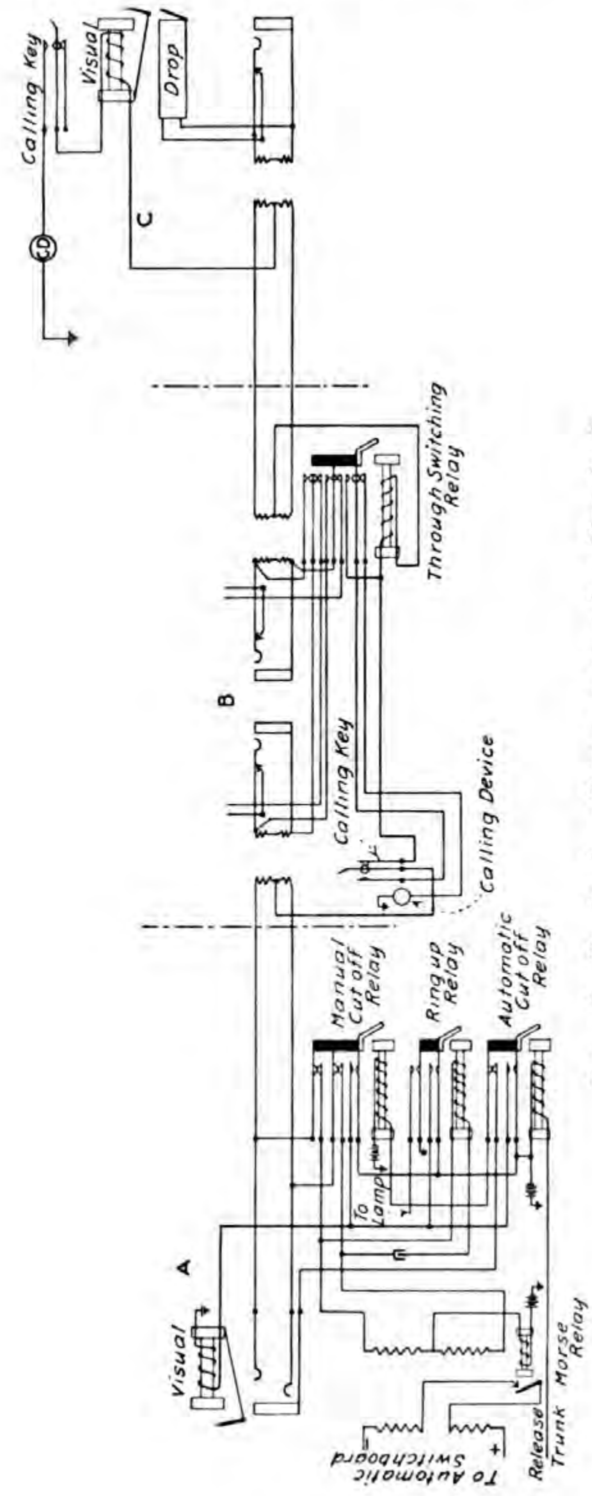


FIG. 236.—Simplex, long distance, automatic, calling circuit.

When *B* wishes to call some subscriber at *A* she throws her calling key and operates her calling device in the usual way. The calling device opens and closes the circuit between the two sides of the line and ground thus operating the Morse telegraph relay connected between the line and battery at *A*. This relay makes and breaks the circuit to the two-wire automatic switchboards at *A* so that the automatic switches set up the number desired. All adjusting of impulses due to line leakages is readily taken care of by the switchboard attendant at *A*, by adjusting the Morse relay to suit the amount of leakage on the line at the time.

When *C* wishes to call a party at *A*, she throws her calling device key and if the line from *B* to *A* is not busy, *C*'s visual signal will operate and thus indicate that the line is clear, but if the line from *B* to *A* is in use the visual signal circuit will be open in one of two places.

1. If *B* is calling *A*, the simplex tie at *B* will be open at *B*'s calling key.

2. If *A* has called *B*, or if *B* has called *A* manually, so that there is a plug inserted in the line jack at *A*, the ring of the jack will be connected to earth through the third conductor of the cord circuit and consequently the "manual cut-off relay" will be operated opening the connection between each side of the line and the repeating coil installed in the circuit to the automatic switchboard.

If *C* finds the line from *B* to *A* in use, she leaves her calling device key in operated position. This does not interfere with operations between *B* and *A*, and as soon as that section of the line is clear the visual at *C* operates.

At the same time the through switching relay at *B* operates, cutting off both of the taps at *B*, switching both sides of the line straight through to *A*, and bridging out *B*'s calling device key so that *B* can not break the connection from *B* to *A* by throwing her calling device key. It should be noted that if such a station as *B* should be connected in through a cable of considerable length, that a transmission loss in the through circuit can be eliminated by installing the through switching relay and repeating coil at *B* on the pole where the cable connects to the through line.

When *C*'s visual signal indicates that the line is clear, she operates her calling device in the usual way and the Morse relay at *A* operates the automatic switches as already described.

Whenever *C* or *B* calls automatically into *A*, the "automatic cut-off relay" at *A* operates, due to the grounding of the release trunk of the automatic switches, and cuts off the man -al cut-off relay, while at the same time it closes the circuit through the visual signal at *A*, which operates and indicates that the line is in use.

On leaky lines better operation can be secured following telegraph practice by installing a battery at the sending end of the line and connecting the Morse relay at the receiving end to earth. With this arrangement a leak on the line will shunt off some of the current intended for the Morse relay—a difficulty which can generally be overcome by adjusting the relay to suit the weakened current reaching it; but with the battery at the receiving end, a moderate leak makes the relay act sluggishly and a greater leak renders it inoperative.

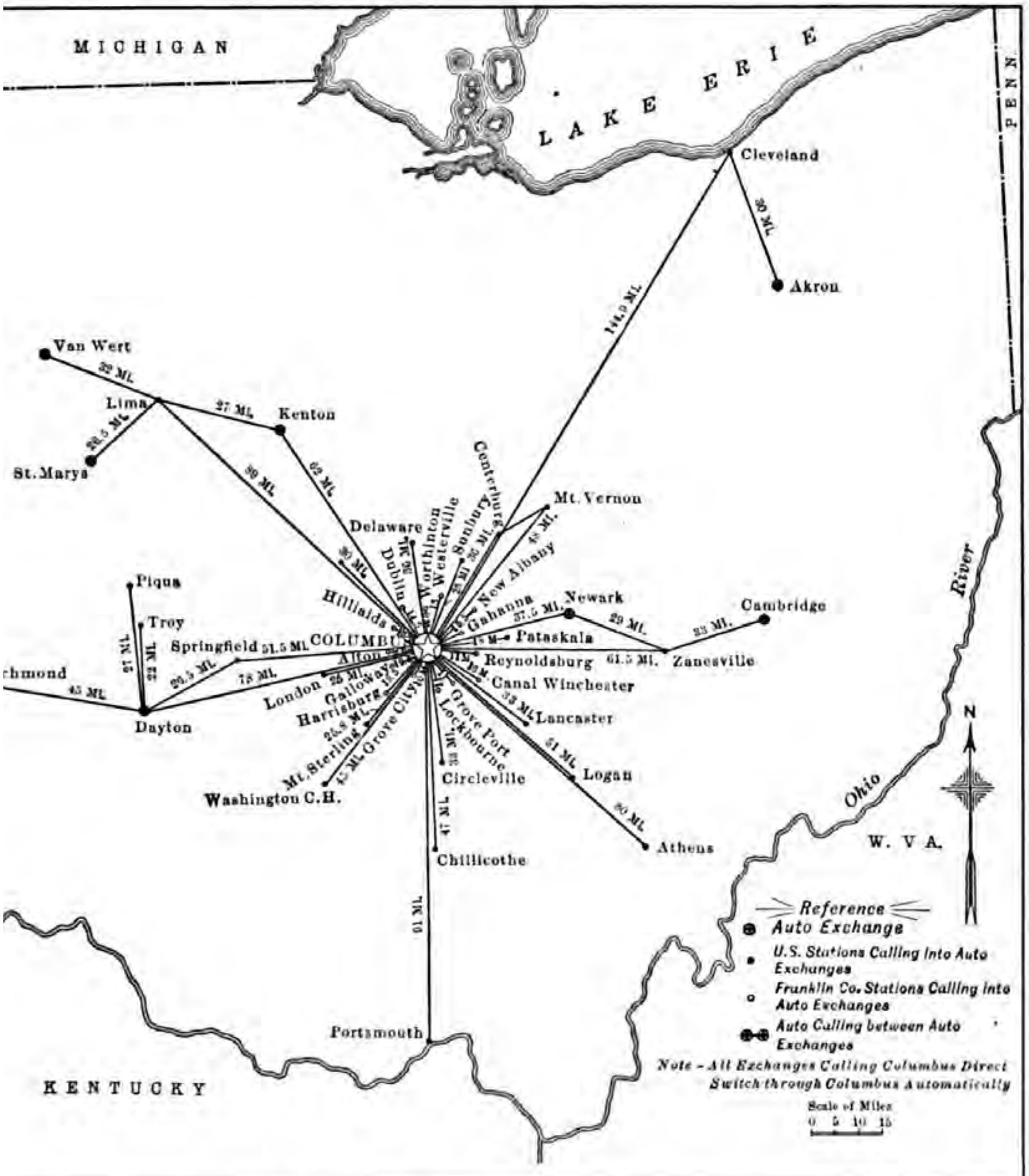


FIG. 237.—Map showing long distance automatic lines centering at Columbus, Ohio.

Automatic Long Distance Calling into Columbus, O.—Fig. 237 is a skeleton map of Franklin County, Ohio, in which Columbus is situated, and of the counties immediately adjoining it, showing the various towns and cities which use automatically operated toll lines into the Columbus, Ohio, automatic system. The longest line is one to Cleveland, which is 145 miles distant from Columbus. While on this map but one line is indicated from each outlying point to the capital, in reality a number of these cities are connected to Columbus by several automatic toll lines. For example Dayton is connected to Columbus by three lines.

Automatic Through Switching.—All of these lines terminating in the Columbus automatic switchboard have numbers by which they can be called automatically by any other toll station equipped with a calling device in the long distance line system. The lines to Cleveland are numbered 023 and 024, and a toll-board operator in Indianapolis, for example, can dial either of these numbers and secure a through connection to Cleveland, provided the line called is not busy. If it is busy the Indianapolis operator is automatically given a busy signal. Several of the large hotels in Columbus have in their lobbies switchboards connected into this long-distance system and equipped with dials, so that the attendants call the various cities in the system without the aid of the operators at the toll board in the Columbus Central Office. All lines are connected into the Columbus, manually-operated, toll board, so that they may be switched either manually or automatically.

NOTE.—It is suggested that the student of long distance automatic calling refer to the very interesting paper discussing some other phases of the subject which was presented before the *American Institute of Electrical Engineers* by Messrs. H. M. Friendly and A. E. Burns, printed in the *Proceedings* for July, 1912.

CHAPTER XIII

CUTOVERS AND INTERCONNECTIONS OF MANUAL AND AUTOMATIC OFFICES

Cutover from a One-office Common Battery Manual Plant to a Common Battery Automatic Plant.—The arrangements required for giving service during the process of cutting subscribers over from a single, common battery, Manual, Central Office to a single, common battery, Automatic, Central Office are very simple. Since all makes of automatic telephone instruments, either of the two-wire or three-wire, common battery type, are essentially the same as common battery manual instruments, with the exception of the automatic calling device which is connected in the circuit at the time of calling only, one of these instruments may at any time be substituted for the regular manual instrument on a line to a common battery, manual switchboard. Therefore, subscribers' stations using wall or desk telephones only are prepared for a cutover by simply taking out the manual instruments and replacing them with the automatic instruments, one at a time. Until the cutover takes place, each subscriber uses his automatic instrument just as he had hitherto used his manual instrument.

This being the case the automatic central office equipment may be installed in the building provided for it, and the subscribers' cables multipled into the main distributing frame of the automatic office, where each circuit should be kept open, until the hour for the cutover arrives, at the protector springs on the main distributing frame or at the bridge cut-off relay springs. This may be easily done by inserting small insulators, such as wooden toothpicks, between the springs.

Pending the cutover each subscriber's line should be temporarily switched from the manual to the automatic switchboard by inserting insulators at the main frame in the manual central office and removing the insulators at the automatic central office, and the operation of the telephone should be tested by having an employe operate the subscriber's station equipment while another supervises the central office apparatus. After this test has been made, the line should be cut back to the manual switchboard to operate manually until the hour for the cutover is reached.

It is customary to notify the subscribers through the daily papers and by special notices that the cutover will take place at a certain hour. Preparatory to this time each subscriber must be supplied with a directory, showing what the various subscribers' numbers will be when automatic service is inaugurated, and be instructed in the use of the dial, so that after the hour on which he is informed that the cutover is to take place, he will understand that he is to use the calling device for securing his connections and will be in possession of the information which will enable him to do so properly.

At the Central Office the process of cutting over consists in removing the insulators from the protector or bridge cut-off relay springs, and in cutting the lines or inserting similar insulators in the Manual Central Office.

Sometimes subscribers' lines, which have been served from one manual central office, are distributed among several offices, for example, a Main Central Office and one or more district stations, when the cutover to automatic equipment is made. A quick and satisfactory cutover may be made under these conditions, however, just as when the change is made to one automatic central office only. In fact, the course of procedure is the same, with the exception that each subscriber's line must be multipled, prior to the cutover, into the particular automatic office to which it is to be eventually connected permanently, and there be temporarily kept open until the hour for cutover arrives. Furthermore, the trunks for automatic calling between offices must be prepared and thoroughly tested out prior to the cutover along with the equipment installed in each office.

Changing Subscriber's Station Apparatus. — Subscribers' stations equipped with private branch exchange switchboards should be prepared for the cutover by remodeling them so that they may be used in connection with trunks to either a manual or automatic switchboard up to the time of the cutover. After the cutover it is generally desirable to make further changes in order to furnish better supervision to the *P.B.X.* operators, and generally to simplify the operation of the equipment. It is apparent that if the incoming trunks to the private branch exchange are equipped with ring up signals of any kind, as they usually are, whether the *P.B.X.* has been used in connection with a magneto or common battery manual system, that the same signal may be operated when the trunks are connected to the banks of the automatic connector switches, which also signal called stations by the use of alternating ringing current. It is necessary however to see that a condenser is installed in series with each ring-up signal, for otherwise the ring cut-off relay of a connector switch which connected to a trunk would operate as soon as connection was established, and calls from desks, metered lines or pay stations would operate supervisory or registering devices prematurely, i.e., previous to the actual answering of the call. Also in two-way two-wire trunks it is necessary that the loop be normally open.

For calls going in the other direction, a calling device must be supplied to the *P.B.X.* operator and be connected up so that after the hour for the cutover has arrived she can call parties by using it. In almost every instance this can be done very easily by connecting the calling device to the ringing busbars of the calling side of the operator's cord circuits, and by inserting a master key which will enable the operator to switch either the calling device or the ringing machine onto the busbars. It must, of course, be remembered that as an automatic two-wire call proceeds and after its completion, it is necessary to keep the calling subscriber's loop closed in order to prevent the connection from releasing. No special provision is required for this, however, in some ordinary common battery manual *P.B.X.*'s, using 22-volt batteries, because the regular cord circuit relays arranged for supplying battery to a calling plug furnish the bridge required. Another and perhaps a better way, to arrange one of these stations for a cutover where conditions will permit, is to install trunk jacks with the associated supervisory relays, as shown in Fig. 73 in the chapter on subscriber's station equipment for automatic exchanges. As a rule the equipment of this trunk will serve on a straight manual trunk and the cord circuits used in this *P.B.X.* are similar to many that are used in straight manual systems.

Changing Service Desks and Toll Board.—The wire chiefs' desks, complaint desks, and information clerks' desks are generally not remodeled when a cutover is made from manual to automatic equipment, but as a rule new desks, especially designed for use with the automatic apparatus, are installed and the old desks are abandoned.

This is generally the practice in connection with long distance switchboards also, although long distance switchboards are sometimes remodeled for use in connection with the new automatic equipment. As a rule, when the manual switchboard in connection with which the wire chief's information and long distance switchboards have been operated, has reached a condition where a new switchboard is required, all of the boards used in connection with it are ready for the scrap heap also; or, are so outgrown or out of date that it would not pay to remodel them for use in the new central office. When it is decided to use any of these boards, it requires a special study in each case to determine the best means of bridging the cutover period.

Cutting over from a Magneto Manual System to a Common Battery Automatic System.—The procedure in cutting over a magneto system is generally the same as that outlined in the foregoing portion of this chapter, with the exception that at each subscriber's station equipped with a desk or wall instrument only, it is preferable to install a new automatic instrument beside the old magneto instrument. The latter should not be removed until after the cutover, because it is necessary to have the magneto for signalling, and the local battery of the instrument for furnishing talking current until after the cutover takes place. Prior to the cutover the automatic instrument should be bridged across the line and the ringer of the magneto instrument should be disconnected so that calls incoming will ring the bell of the automatic instrument, while the subscriber should be instructed to respond at the magneto instrument. After the hour for the cutover has passed, the subscriber simply stops using the magneto telephone and uses the automatic instrument for all of his calls. The telephone company removes the old magneto instruments as rapidly as possible.

Changing a Multi-office Manual System to Automatic Equipment.— When all of the subscribers' lines connected to the various offices in a multi-office manual system are to be cut over to new automatic switchboards at one time, the problems encountered are the same as those mentiond in the preceding portion of this chapter. In other words, the task is increased in magnitude, but not in complexity. If, however, some of the offices are to be operated manually after one or more offices have been changed to automatic equipment, new problems arise.

Taking a comparatively simple case, for example, suppose that a given city contains two large central offices; that the switchboard in one of these has reached the end of its life, while the switchboard in the other is in comparatively good condition and may be operated for some years longer; that the company owning the system has not the financial means to change both offices at once to full'automatic equipment, and that it has therefore decided to immediately install automatic apparatus in place of the worn-out switchboard, but to continue to operate the good manual switchboard for some years longer. So far as switching over the lines of the subscribers connected to the office which is to be abandoned and so far as arranging for intercommunications between them are concerned, the matter may be handled just as if that office were the only one in the system; but arrangements must be made for handling calls from the new automatic office to the manual office which is to be retained, and vice versa, from the manual office to the automatic office. These arrangments must be such that it will not be difficult for the subscribers to either office to understand how to secure subscribers to the other, and such that the service in either direction will be rapid, otherwise satisfactory and economical. Under these conditions the calls to be trunked in either direction may be, and have been in practice, handled in any one of several different ways.

Plan 1, Calls Going From the Automatic to the Manual Office.— One of the simplest methods for handling the calls from the automatic to the manual office, and one which has been used with success in a number of different places, is to arrange the trunks so that in the automatic office they will terminate in one level of the first selector banks, enabling any automatic subscriber to secure a trunk to the manual office, by making one turn of his calling device dial; while in the manual office, they will terminate either in regular subscribers' line jacks, or preferably, in cords and plugs before "*B*" operators. If these trunks terminate in regular line-jack equipments they may be distributed among the "*A*" operators' positions, but if this will overload the "*A*" operators, the positions which were formerly used as "*B*" positions, before the old manual switchboard was abandoned, should be continued as "*B*" positions, and the trunks be terminated in the cords and plugs of these positions. It may be necessary to remodel these cords, either before or just after the cutover, to provide all supervisory features desired. For example, if the automatic switchboard is of the Automatic Electric Company's type and uses reversing battery connectors, then either the "*B*" operators' cord circuits, or repeaters used on the trunks from the automatic office to the manual office, should be arranged so that when a manual party responds to a call, he will reverse the direction of current flow in the calling subscriber's loop.

The foregoing description should make the method of operation apparent, when it is said that each subscriber is instructed in his directory, and also, if possible, by a notice printed on the number disk of his calling device, that by turning his dial from a certain finger hole (for example, finger hole 1) he will secure an operator in the manual office.

In the directory the word "Automatic" should be printed in front of all numbers belonging to automatic telephones, and the word "Operator," or "Manual," or the name of the manual office or nothing at all, may be printed in front of the numbers belonging to manual telephones. It is found that it is a comparatively easy matter to teach subscribers that when one wishes connection to any number beside which the word "Automatic" is printed, that he makes the connection by means of his automatic calling device in the usual way; while, if he wishes connection to any number connected to the manual switchboard, he turns his dial from finger hole 1 and gives the number desired to the operator who responds, and who then completes the connection and rings the desired party just as in regular manual practice.

Plan 2.—A plan which is more economical of operation, because it eliminates the "*B*" operators at the manual switchboard, is to install in the manual office enough automatic selector and connector switches with the banks of the connector switches multipled to the multiple of the manual switchboard, to enable the automatic subscribers to call all manual numbers automatically. This plan is generally warranted where a large percentage, 33 1/3 per cent. or more, of the connections completed in the manual office originate in the automatic office, and where the manual office is to be retained for more than two or three years.

An arrangement of this kind has been worked very successfully in several large American offices during a number of years, pending a change of the manual office to full automatic. With this plan the trunks from the automatic to the manual office should terminate in first selector banks in the automatic office as in Plan 1, and as in regular multi-office automatic practice;

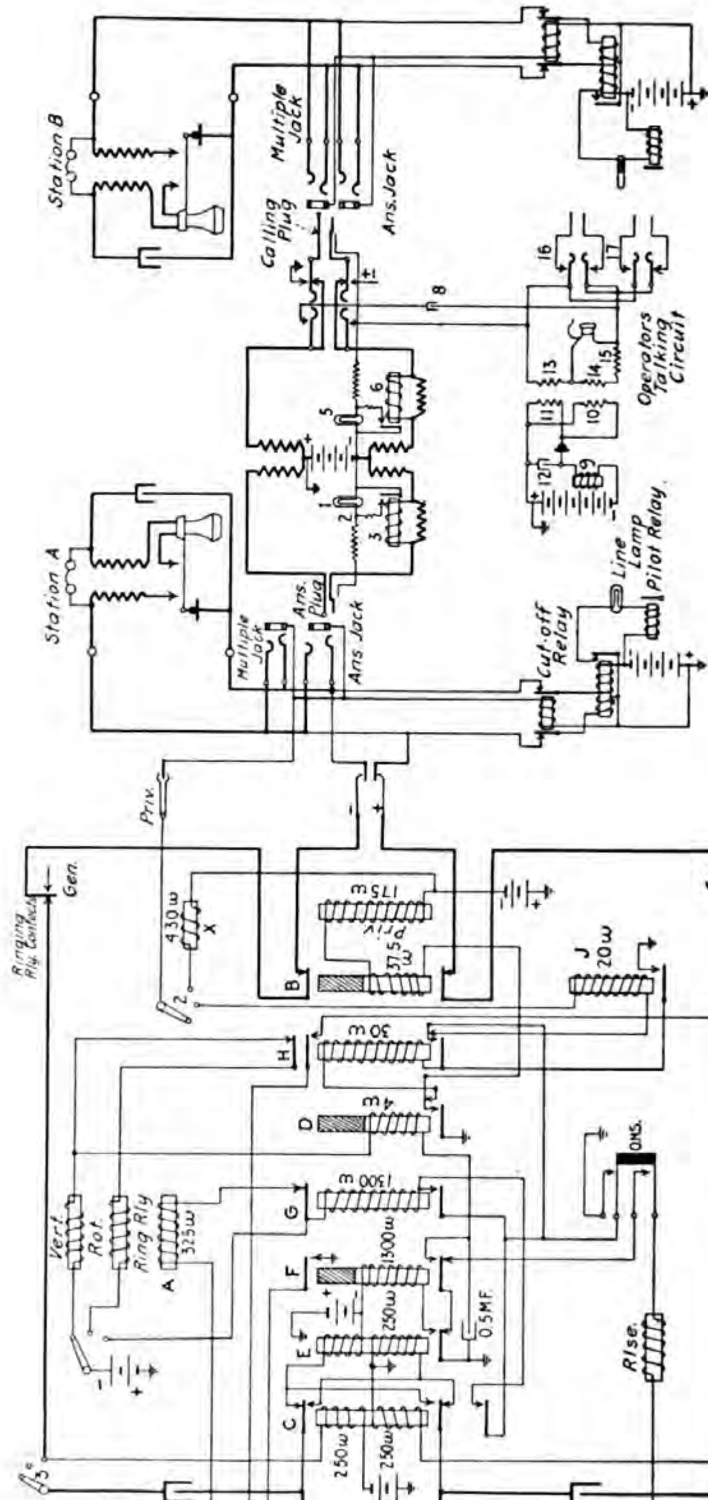


FIG. 238.—Interconnection of a manual and an automatic switchboard by the multiple method.

while in the manual office they should terminate in second selector switches. Generally a system of the character under discussion would be of such size that third selectors also would be installed in each office and five-figure automatic numbers would be used. To make this system practicable it will be necessary, of course, to change some of the numbers in the manual office, because the numbering of manual switchboard lines generally starts with No. 1; whereas, in automatic practice each number has the same number of digits as each other number. Consequently all manual numbers having less than four digits, that is numbers from 1 to 999, must be changed to at least four-digit numbers. If the system is such that third selectors are used, requiring five-digit numbers, either a figure or a letter must be prefixed to all of the four-figure manual numbers. As a rule matters are simplified, and subscribers are mollified, by using a letter prefix and leaving the balance of the number unchanged. It is advisable to consider using the first letter of the manual office name as the prefix. With this arrangement it is unnecessary for an automatic subscriber to know whether the party he wishes to call is connected to the automatic switchboard, or to the manual switchboard. He makes the call and secures his party automatically in either case.

The connector banks and the manual multiple jacks are connected together in such a way that if a line is made busy at either place, it will be guarded at the other. As a typical example of a practical interconnection of connector switch circuits and banks with a multiple manual switchboard. Fig. 238 shows circuits for multipling together connector switches of the Automatic Electric Company's type, and switchboard circuits of the Western Electric Company's No. 1 type board. There is no change in the circuits of the Western Electric board, and the only change from standard, full automatic practice in the circuits of the connector switch, is due to the fact that in the Western Electric board, as in some other manual switchboards, a busy line is guarded by connecting the sleeve of the jack to negative battery; whereas, in regular automatic practice, the private contact of the guarded line is always connected to earth, that is, to the positive terminal of the battery. It therefore becomes necessary to add the 430-ohm resistance coil *X* and the extra 20-ohm private wiper relay *J* to the connector switch and to make some slight alterations in the circuit. Since, otherwise, it is practically the same as that shown and described in Chapter II, only the operation of the private magnet and wiper circuit in connection with the manual switchboard will be explained here.

It will be noted that the positive side of the connector bank multiple is connected directly to the tip side of the manual board multiple, the negative side of the connector bank is connected to the ring side of the manual switchboard multiple, and the corresponding private contacts of the connector bank are connected to the sleeve multiple of the manual switchboard. The result is that whenever the connector switch completes connection to any line, the sleeves of all the corresponding jacks, and the private bank contacts are connected to negative battery, through the private wiper, side-switch wiper 2 and resistance coil *X*. On the other hand whenever a connector switch finds a line made busy, because a plug is inserted in one of its jacks in the manual switchboard, the private magnet, the private relay *B*, and the busy relay *H* are locked, and the busy signal is given to the calling subscriber, because current flows from negative battery of the manual switchboard, through the lamp and contact of cord relay 3, resistance coil 2, the sleeve of the plug, the sleeve of the jack, the private bank multiple, private wiper, side-switch wiper 2, relay *J*, and the off-normal springs *ONS* to earth. Relay *J* closes circuit from earth through busy relay *H*, private relay *B* and the private magnet in series, to negative battery. The result is that the private magnet retains its armature and keeps the side switch from moving to third position. Private relay *B* retains its armature and prevents the line from being closed through to the line wipers, and busy relay *H* attracts its armature, closing circuit from the busy busbar through side-switch wiper 1 to the positive side of the calling subscriber's loop, and at the same time breaking the circuit through relay *J* and closing its own locking circuit, which extends through the off-normal springs to earth.

When the calling subscriber hears the busy signal, he replaces the receiver on the switch hook and all connections are restored to normal condition, as usual.

Calls Going from the Manual Office to the Automatic Office.—Calls originating in the manual office for subscribers in the automatic office may be handled in either one of several different ways, which have been found by experience to be good practice.

Plan 1.—One of the simplest methods, where conditions warrant it, is to use the "*B*" operators' sections, and as much of the balance of the old abandoned manual switchboard as may be necessary to make a "*B*" switchboard to be installed along side of the automatic switchboard for handling these calls. To carry out this plan, the multiple jacks of the switching section are interconnected with the connector banks of the automatic switchboard, in accordance with circuits in Fig. 238 just described, or according to any similar scheme. The old order wires from the "*A*" operators in the retained manual office, to the *B* positions of the abandoned switchboard are used for ordering up connections, which the "*B*" operators complete by plugging into the multiple jacks in the usual manner. It is apparent that one difficulty with this scheme is to make such arrangements that the "*B*" positions may be used in handling calls between the two manual switchboards up to the moment of the cutover, and may be available for use as a switching section in multiple with the automatic switchboard, immediately after the cutover. The problem may be a comparatively easy one, however, if the new automatic switchboard is in the same room, or in the same building, as the manual switchboard which is to be abandoned. The details of the plan must, of course, depend upon the conditions peculiar to each case.

Plan 2.—A second plan for completing the calls trunked to the automatic central office is to use a "*B*" operator's switchboard which is not equipped with any multiple jacks, but is supplied with automatic calling devices.

The trunks entering the "*B*" positions do not terminate in cords and plugs, but pass through the "*B*" operators' positions and terminate in line switches, or first selector switches in the automatic switchboard. Each trunk is equipped in the position of the "*B*" operator, through which it passes, with keys necessary for switching calling devices into connection with it. This plan is operated by the "*A*" operators at the manual office, ordering up connections over order wires just as in Plan 1. The "*B*" operator secured, assigns a trunk, as in regular manual practice, and instantly throws a key which switches one of her calling devices, which is idle, onto the trunk, and proceeds to call the number of the desired party.

When the call has been completed, if the desired line should be busy, the busy signal will be transmitted automatically, by the connector switch used, back to the calling subscriber. If the called party should not be busy, the connector switch will automatically signal him, and the "*B*" operator need pay no further attention to the connection. The supervisory arrangements should be such that when the "*A*" operator plugs into the jack of the trunk assigned, a lamp, corresponding to the trunk, will glow in the "*B*" operator's position and the regular calling cord supervisory lamp should light at the "*A*" operator's position. When the "*B*" operator throws her calling device key, the signal lamp should go out, and a guard lamp associated with the trunk should light and remain lit, so long as the connection is up, to prevent the "*B*" operator from re-assigning the trunk while it is engaged.

When the called party responds, the calling cord lamp in the "*A*" operator's position should go out. Either party should be able to flash the corresponding cord lamp in the "*A*" operator's position at any time, by moving his receiver switch hook up and down slowly. When either party hangs up the receiver, the corresponding disconnect lamp should glow in the "*A*" operator's position, and when she pulls down the connection the guard lamp, associated with the trunk used in the "*B*" operator's position, should be extinguished. All of these features are easily arranged.

If the calling device used by the "*B*" operator is of the push-button type, so that she simply presses keys, corresponding to the number of the desired subscriber, and the impulses are transmitted by a motor-driven machine, which must complete its work several seconds after the operator finishes pressing the buttons, a guard lamp or some other visual signal should be used in connection with the calling device keys, which will prevent the operator from attempting to set up a second call on the calling device before the machine has finished transmitting the previous call.

The "*B*" operator's switchboard may be situated either in the manual office or in the automatic office. If, as in the case under discussion, there is but one manual office, there is an advantage in having the switchboard placed in it, because by so doing all operators will be confined to that office, and no rest rooms or other provision need be made for them at the automatic office. Furthermore, it will be easier to supply reliefs and to enforce good discipline if all the operators are kept in one office.

Quite often when a manual office is changed to automatic equipment the subscribers' lines are distributed among an automatic main office and several district stations surrounding it. Under such conditions Plan 1 for handling the calls from the manual office will be at a decided disadvantage, in comparison with Plan 2; because, while it is entirely practicable to use the multiple switching section for completing connections to the lines in the main automatic office, it is impracticable to complete connections in that manner to the lines terminating in the district stations.

If Plan 2 is used, however, the "*B*" operators, by means of their calling devices, will complete connections to district station subscribers just as easily as to the lines connected to the automatic main office. In fact, a "*B*" operator need not know to which office a line she is calling is connected. If the traffic between the "*A*" operators and the "*B*" operators is sufficiently great to warrant it, the use of an automatic order wire distribution system, such as described in the chapter on automatic traffic distributer equipment, between the "*A*" operators and the "*B*" operators should be considered.

Changing a Manual System of More than Two Offices to an Automatic System.—If a manual system including more than two offices, say twenty for example, is to be changed over to full automatic equipment, and it is not considered wise to attempt to change all of it at one time, the most practical plan is to take the first step by dividing the system into not to exceed nine districts. In full automatic practice it is not practicable to have more than nine offices of the first magnitude, since but nine levels of first selector banks are available for trunks to such offices, the "*O*" level being reserved for trunks to the long distance switchboard. Therefore, if there are more than nine offices, the remaining ones must be, in a sense, subsidiary to the nine main offices. While at first this might appear to be a disadvantage, it is really an advantage, because it simplifies the trunking scheme and economizes in trunk mileage, as explained more fully in the chapter on "Development Studies."

Having divided up the system under discussion so that there are nine main offices, some of which have one or more satellites, suppose that it is decided to change over one of these main offices, which is to be called the "*A*" office and which is to have three district stations about it; suppose that the remaining eight offices are to be called *B*, *F*, *L*, *N*, *U*, *W*, *X* and *Y*, respectively.

These letters are chosen because they are least likely to be confused one with another when spoken through the telephone. Office *A* with its satellites may be switched to full automatic equipment so far as intercalling between the various subscribers in the "*A*" district are concerned, at one time, just as if there were no other offices in the system, following the methods described in the opening paragraphs of this chapter; but the plans for handling calls outgoing from this district to the eight other districts require further consideration.

Plan 1-A.—It should be remembered that all of the outgoing calls originating in the automatic district will be handled by trunks which terminate in the district main office, because the subsidiary offices are district stations only. One plan for trunking calls outgoing from "*A*", would be an enlargement of the scheme explained as Plan 1 in the discussion of methods for changing over one office in the hypothetical system of two manual offices only. To make this scheme practicable, subscribers' numbers would have to be arranged and would have to be printed in the directory in such a way that the subscribers would be able not only to distinguish manual numbers from automatic, but be able to tell to which district any desired manual number belonged. This could be done by printing the word "Manual" in front of all manual numbers.

These designations would, of course, have no significance to subscribers to manual service; but to subscribers to automatic service they would mean that automatic numbers would be called in the usual automatic manner, but that manual numbers must be secured through an operator. In every case the present exchange names should be replaced by a prefix made up of a combination of two letters, such as *A-B*, *A-F*, etc., in which the first letter indicates the district and the second letter the office.

For carrying out this plan trunks should run from the automatic main office to each of the eight manual district centrals, and it is recommended that all automatic subscribers be instructed, when a manual number is desired, to call the first letter of the prefix only, and then give the number including the prefix to an operator who would thus be secured. These orders would be taken by "*A*" operators located at each of the half-dozen central district offices. When such a call was received by one of these "*A*" operators, she would handle it in the usual manner; that is, if the party desired were connected to her own office, she would complete the connection in the multiple in front of her without further trunking. If the party desired were connected to one of the subsidiary offices in her district she would handle the connection over an order wire to one of the regular "*B*" operators in the subsidiary office.

While Plan 1-A would be more economical of trunk mileage, it will entail a greater expense for operators' wages and will give slower service to the subsidiary offices, than will Plan 1-B.

Plan 1-B.—The only object in having the calls from the automatic district to the various subsidiary manual offices pass through the main offices, instead of going direct to the subsidiary offices is to simplify the trunking plan and save trunk mileage. Over against the saving of trunk mileage, however, must be placed the increased cost of operator's hire. In Plan 1-A each such call must pass through an "*A*" operator at the district central office to a "*B*" operator at the subsidiary office.

It is possible to eliminate the work of one operator, by having the trunks run direct from the automatic district main office second selector banks to each of the subsidiary manual offices, and there terminate in "*A*" operator's positions. They might terminate in regular line jacks, or in cords and plugs. The latter would be preferable probably in the larger manual offices.

Following this plan, automatic subscribers would be instructed, when calling manual numbers, to call both letters of the prefix; and any automatic subscriber doing so would secure an idle trunk direct from the automatic main office to an operator in the particular manual office to which the party he desired was connected. He would then give the desired party's number to the operator, either including or omitting the prefix, and she would complete the connection by plugging into the proper jack in the multiple in front of her. This arrangement will give faster service than that which is secured in regular manual practice, because it will not require more than two seconds for an automatic subscriber to signal an operator in the particular office to which his desired party belongs.

Plan 1-C.—It would be possible to have outgoing trunks from the "*A*" district main office terminate in first selector banks, as under Plan 1-A, and to have second selector switches installed at each of the eight other main offices so that switching of calls to the satellites in each district would be done in the main central office of the district, but this would scatter the automatic equipment about so much and require such an expensive outlay for power plants to operate the automatic switches in the various main offices, that it might not be practicable.

Generally, Plan 1-B would be the preferable one, but some offices may be so small, or be situated at such great distances from other offices, that to save trunk mileage it would be advisable to handle the calls to them under Plan 1-A. Of course, if Plan 1-A and Plan 1-B were both used, it would be necessary for the automatic subscribers always to call both letters of the prefixes instead of calling one letter only as suggested in Plan 1-A.

Plan 2-A.—This plan is a further development of the Plan 2 explained, for cutting over one office of the hypothetical manual system, which had two offices only. It will be remembered that the plan contemplated the installation in the manual office of sufficient selector and connector switches, with the banks of the connector switches multipled to the manual switchboard, to enable the automatic subscribers to call the manual subscribers automatically. While the installation of this equipment might be warranted in some of the larger of the eight main offices, which are to be continued as manual offices for a considerable length of time, it is not likely that it would be in the sub-offices of the various districts; consequently, calls to sub-offices would have to be handled in accordance with Plan 1-C, the switching being done to the "*A*" operators at any sub-office by means of first selectors at the automatic main office, and second selectors at the main central office of the district to which the sub-office belonged.

In considering this plan it should be remembered that a district which is operated manually, until several, or a majority, of the other seven districts are changed over to full automatic equipment, will receive a continually growing percentage of incoming calls from automatic offices, consequently, if the way in which the various districts will be changed over can be decided upon at the start, the installation of automatic switching equipment should be very seriously considered for the district main offices, which will be changed over at the latter end of the schedule; but less seriously considered for those which will be changed over earlier in the schedule. Very little of the automatic equipment installed in one of these manual offices would be wasted, because it would generally be the same as that used in a full automatic office, so that when it was no longer required in the manual office it could be removed and used for additions to some full automatic switchboard.

Plan 3, Semi-automatic Operation During the Cutover Period.—A third plan for changing over a multi-office metropolitan area embodies the use of semi-automatic or "Auto-manual" equipment during the cutover period. While this increases the operating cost during the time of the cutover, it simplifies the method of calling from the subscribers' standpoint. The only difference between this plan and any one of the plans already explained, would be the omission of calling devices from the subscribers' instruments, the installation of operators' keyboards with special, motor-driven, calling devices for their use at the automatic central office, and a change in the wiring of that office, so that the outgoing trunks from the line switches to the first selectors would pass through or be automatically connected with the positions of the operators.

If any subscriber to the semi-automatic office should desire to call, he would lift his receiver from the switch hook and secure an idle operator, who, if he wished another automatic subscriber, would set up the connection for him automatically by operating the push-buttons belonging to one of her machine calling devices. If the calling party should wish a subscriber connected to one of the manual offices, then the operator would have to do just what a subscriber would have to do if trunking schemes like Plans 1-A, 1-B, or 2-A were used. In other words, if no automatic switches were installed in any of the manual offices and Plan 1-A were used, the operator would secure another operator in the main central office of the manual district to which a desired party belonged, by calling one digit only. If Plan 1-B were used, the operator would call two digits to secure another operator. If Plan 2-A were used, she would set up the connection automatically, where it was possible to do so and where arrangements were not made for automatic calling, she would secure an operator.

One objection to this, from a traffic engineer's viewpoint is, that a subscriber would be required to give his order twice on connections requiring the services of a second operator, because under the plan explained, no order wires are included between the semi-automatic operators and the operators in the manual offices.

It should be apparent that when all of the offices in the various districts had been changed over to semi-automatic service, it would be a simple matter to change the subscribers' stations, one at a time, to full automatic service, by installing a calling device on each telephone, and when calling devices were installed on all of the telephones connected to a given line switch group, the outgoing trunks from that group might be cut out of the operator's switchboard and connected straight through to secondary line switches, or first selectors switches, if secondary line switches were not used. At the same time the subscribers should be provided with the proper instructions for full automatic calling, and be informed that thereafter they were to call all parties without the aid of operators.

Plan 4.—This plan contemplates proceeding (as under Plan 1-A or 1-B), by providing automatic calling from the beginning for interconnections between subscribers in the automatic district, but to arrange it so that to secure manual subscribers the automatic subscribers would call the same number in every instance; for example, finger hole 1, on every dial might be labelled "Manual," and the subscribers' directories be arranged so that the word "Manual" would be printed at the side of the numbers of all manual telephones. The subscribers would be instructed to make one turn of the dial from finger hole 1 whenever any manual number was desired, and then to give the number of the desired party to the operator who would respond. It is apparent that the trunks would connect to the first level of the first selector banks in the main automatic office. The operators would be situated at a special trunking switchboard, either in the automatic office or, preferably, in some centrally located manual office. These operators would be provided with order wires and trunks to each of the various manual offices, excepting small outlying offices, to which tandem trunking might be practised. With this method of operating, the objection mentioned in plan 3 of having the automatic subscribers give their orders twice when wishing manual numbers would be eliminated, and at the same time the method of securing connections would be so simple, that no subscriber should have difficulty in understanding how to proceed. Furthermore, if the centrally located manual office, in which the special trunking operators were placed, should be the principal office, or one of the principal offices in the business district of the city, considerable economy would be secured by making the multiple of the manual switchboard, in that office, available to these special operators. It is apparent that if these special trunking operators are installed in a centrally located manual office, that as additional outlying offices are cut over to automatic equipment, the connections from them to the remaining manual offices may be very satisfactorily handled at this central point. Some additions to the force and equipment might be required on account of the increased traffic, but the economy and general satisfaction which the plan would give would be greater than if the trunking operators were scattered among the different automatic offices.

After the number of automatic offices changed over reached a certain point, the number of trunking operators required would commence to decrease, because of the large number of connections completed automatically between the various automatic districts.

In considering this plan for any city, it should be determined whether it may not be made a very economical one from an equipment standpoint, by using portions of one, or more, of the abandoned switchboards for constructing, or adding to the trunking operator's equipment.

Calls from Manual to Automatic.—Connections from the various manual offices to an "*A*" automatic district should be made by means of the requisite number of "*B*" operators working at a special semi-automatic switchboard as explained in the outline of methods for cutting over one office in the hypothetical system of two manual offices only. It is stated, however, in that explanation, that it might be a question whether the "*B*" operator's switchboard should be located in the new automatic office or in the remaining manual office.

In the example, now under discussion, the "*B*" switchboard could be put either in the automatic main office, or in a centrally located manual office. Which plan would be preferable would depend upon circumstances. If the first automatic district cutover should be an outlying one, a "*B*" board installed there would probably be of no use in cutting over succeeding districts; whereas if it should be placed in a centrally located office, it could be used with necessary additions for handling all of the trunks from manual offices to automatic offices until the entire cutover was completed.

Doubtless under some conditions the plan of putting semi-automatic operators' switchboards in each of the main automatic offices might be the most economical of trunk mileage, and in some cases be the best from a transmission standpoint; but it would seem that in any instance, the plan of using one centrally located switchboard would be the most economical from the equipment and operating standpoints.

Another attractive feature of the combined centrally located board is, that it makes possible the introduction of traffic distributer equipment, on either the order wires or the trunks incoming to the semi-automatic "*B*" operators from the "*A*" operators in the various manual offices, if first selector switches should be installed either in the building with the semi-automatic switchboard, or in a nearby automatic office, making it unnecessary for the "*B*" operators to have direct trunks to the different automatic main offices. In other words, if first selector switches were available to them, any "*B*" operator would be able to call any automatic subscriber, in any office, by using her push-button calling device. This makes it practicable to introduce traffic distributor equipment of a character similar to that described in the chapter especially devoted to apparatus of that kind for distributing the load among the "*B*" operators.

Line Switch District Stations in Connection with the Manual Offices.—It would not be necessary to wait until the main office in each manual district was changed over to automatic equipment before changing over one or more of that main office's satellites to line switch district station apparatus, such as described in the chapter on semi-auto district stations. In fact not only might some of the existing outlying manual offices be changed over to equipment of that character, but if a congestion should occur at any point which would appear to require the installation of additional equipment or cable, for relief, a lines witch district station should be very seriously considered before any other means is decided upon.

Branch Offices.—To make the discussions of various methods for cutting over as clear as possible, the use of "branch" automatic offices has not been considered. Such offices have their place, as explained at considerable length in the chapter on "Development Studies."

CHAPTER XIV

POWER PLANT, SUPERVISORY AND TESTING EQUIPMENT, AND CIRCUITS

Power Plants.—A power plant of an up-to-date automatic switchboard central office generally consists of one storage battery, two ringing equipments, two battery charging equipments, one power switchboard, and one supervisory cabinet.

Storage Battery.—If the equipment is designed to operate on a normal difference of potential of 46 volts, the battery consists of twenty-five cells with seven counter electromotive force cells. The latter are used to keep the pressure between 46 and 50 volts at the busbars. Except in small offices, it is the practice to install each cell in a lead-lined wooden tank because glass cracks too easily. The cells are mounted on battery racks from which each is insulated by four glass insulators. The racks are insulated from the flood by glass insulators resting on vitrified brick.

Since a number of standard books and other publications are available which give full instructions concerning the installation and care of storage batteries, space will not be occupied here by an attempt to cover those subjects.

Charging Machines.—Two charging equipments are usually installed; one consisting of a motor-generator set, or rectifier, and the reserve or emergency set being either a gas or gasoline engine direct connected to a charging generator. A mercury arc rectifier has a higher efficiency than any other type of charging outfit for use in deriving power from an alternating-current supply, and is, therefore, generally used for offices which will not require an ultimate charging rate to exceed 50 amp. Two mercury arc rectifiers may be used in multiple to supply 100 amp., but it is the general practice to use motor-generator charging machines for offices requiring a charging rate higher than the output of one rectifier.

The rectifier apparatus is mounted on a slate, or marble, panel to match the balance of the power switchboard of which it becomes a part. Fig. 239 is a front view of such a switchboard on which the second panel from the right is the rectifier panel. The circuits will be described further on in this chapter.

Where direct current of 110 volts is available, charging may be done directly from the supply mains through a suitable resistance, but on account of danger of making the talking circuits noisy, this method is rarely practised, except for small private exchanges.

Motor generators for charging sets are preferably of special design, in that the generator commutators have an extra large number of bars, and the armature is generally of a "smooth core" type in order to reduce the danger of noise on talking circuits. If a smooth core armature is not used, the charging circuit is passed through an impedance coil to "smooth out" the current.

The generator is generally compound-wound, but arranged so that it may be changed to a shunt-wound machine by switching one of the armature lead fuses to another clip on the terminal block, which is mounted on the frame of the machine. It is ordinarily used as a shunt machine and the compounding is only used in case of emergency, when the battery is disabled and the

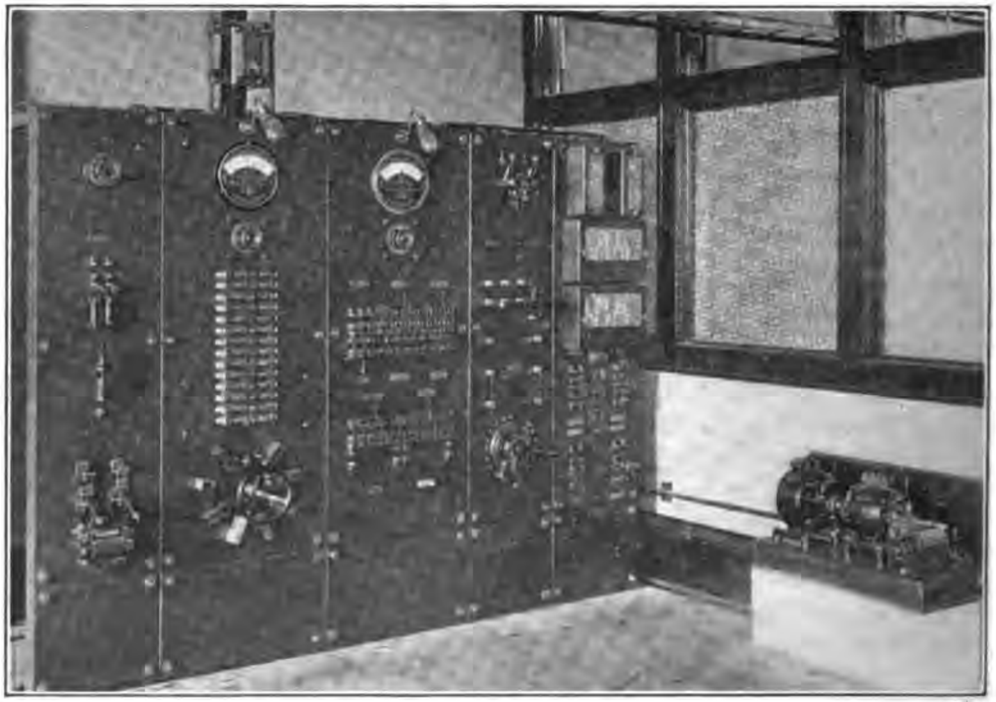


FIG. 239.—Typical power and battery switchboard.

dynamo must take the switchboard load direct. A common specification for the compound winding requires that it shall be such that under operating conditions it will automatically regulate the voltage, so that it will not drop lower than 46, nor rise higher than 52, while the current delivered by the machine varies from its full-rated amount to 1/15 of the full-rated amount.

The motor and dynamo of motor-generators are direct connected and mounted on a common sub-base. The motor may be of any standard design.

Ringing Machines.—Harmonic converters (pole-changer sets) and motor generators are used for ringing. Some of the latter are shown in the foreground in Fig. 240 and one such machine is shown in the right-hand portion of Fig. 239. In two-wire plants, where automatic ringing is practised, the motor-generator machine is frequently equipped with sets of springs (seen in the views referred to above) designed to furnish the make and break contacts for the group ringing relays and to distribute the switchboard load in such a way that the generator will supply ringing current to the various switchboard sections in succession, and not be required to furnish the ringing current needed throughout the entire switchboard at one time. In addition to the ringing springs these motor-generator outfits carry busy and howler attachments.

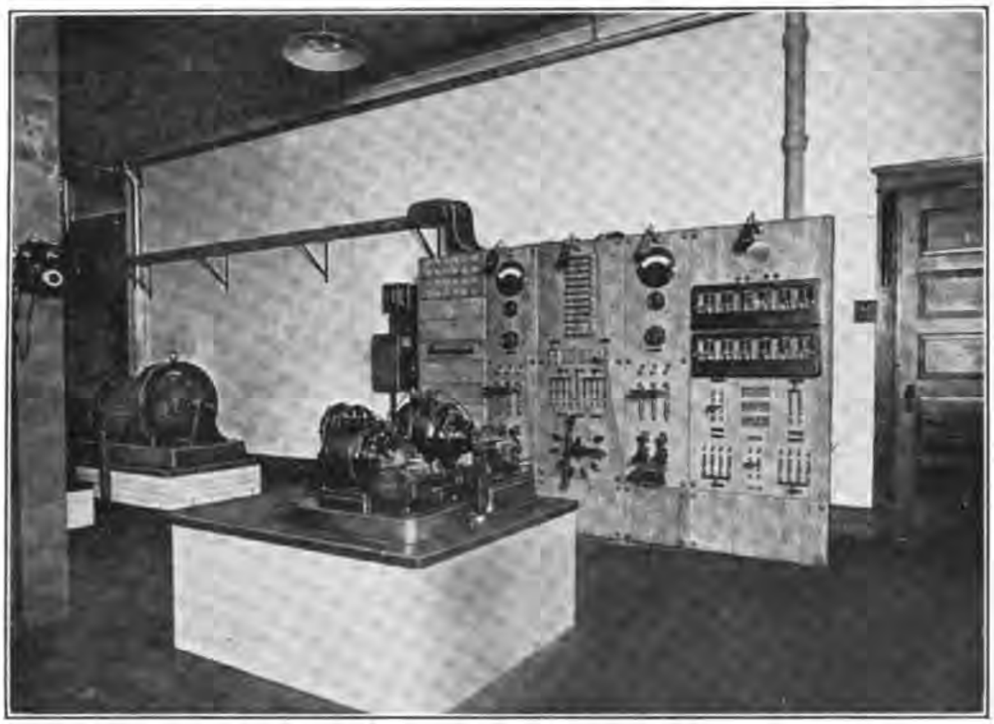


FIG. 240.—View of power plant.

Sometimes the ringing machine used regularly is operated on the commercial power circuit, while the reserve machine is a dynamotor driven from the exchange storage battery. With this arrangement, a failure of the commercial source of power supply for a few hours would not disable the telephone plant. Such a reserve machine is shown mounted on the same pier with the regular machine in Fig. 240. The reserve ringing apparatus, in the plant in which the photograph reproduced in Fig. 239 was taken, is a harmonic converter outfit; in fact, two harmonic converter ringing outfits are installed, each consisting of a pole changer, a suitable transformer, for furnishing 33.3-cycle ringing current, a ringing interrupter mechanism, and another device for furnishing the interrupted buzz, used as a busy signal. This apparatus together with its knife switches, is mounted on the panel at the extreme right-hand end of the power board. In Fig. 240, two complete harmonic converter outfits for furnishing the four frequencies, namely, 16.6, 33.3, 50 and 60.6 cycles of ringing current required for the Automatic Electric Co's four-party line equipment, are mounted on the right-hand panel. In addition to the four pole-changers, each of these outfits includes a pendulum and buzzer for furnishing the busy signal. Since the power plant shown in this illustration was installed, the solenoid ringing interrupting device (shown in Fig. 241) has been developed, to make it possible to supply all the ringing current required in a 10,000-line system by means of the harmonic converters alone. This ringing interrupter consists of a solenoid which, by means of its plunger, controls a rod carrying a pair of wipers, which are arranged to move back and forth over two rows of seven contacts each. When the solenoid has drawn in its plunger, thereby raising each wiper to the top contact in its row, the circuits are such that the plunger is then allowed to return to normal position by the force of gravity. The speed at which it returns is controlled by a piston, mounted on the lower end of the rod, which moves through a cylinder filled with oil. The circuits of this device will be explained in detail further on. The purpose of it is to operate the relays which supply ringing current from the harmonic converters to the automatic switchboard, a section at a time. A switchboard may be divided into five sections, and as the wipers, when descending, pass over the second pair of contacts from the top, ringing current is supplied to the first section and the ringing relays of the connectors in ringing position in that section are operated. When the wipers pass to the third pair of contacts, ringing current is supplied to the second section and the ringing relays of the connectors in ringing position in that section are operated, etc. This device may be used for doing the interrupting, where dynamotors or motor generators supply the ringing current also. It costs less, and is less expensive to install, maintain and operate than the spring and cam equipment operated by the rotary machines.

FIG. 241.—Solenoid ringing current interrupter.

Power Switchboard.—A power switchboard consists of the required number of slate or marble panels, mounted upon suitable angle iron frames.

On these panels are mounted the necessary instruments for operating and controlling the various battery charge and discharge circuits, the circuits of the ringing machines, etc. A voltmeter is provided, which ordinarily has a scale reading from 0 to 75 volts. If district stations are used, which are to be charged by using the 120-volt circuit of a rectifier installed at the central office, the voltmeter should read up to 120 volts.

An ammeter with center zero is also installed. Circuits, to be explained later on, will show the ammeter so connected that when the charging machine is in operation it will show the net amount of current which the battery is receiving; and when the charging is not in operation, it will show the amount of current which the battery is delivering to the switchboard. Furthermore, shunts are provided so that when either charging machine is in operation the current delivered by it may be measured.

Instrument switches are used for switching the volt and ammeters in connection with the various circuits. The hand wheels of these instruments are shown directly underneath the meters in each of the views of a power board. (See Figs. 239 and 240.)

A "Reversite" and overload circuit breaker is installed for controlling each charging circuit. One of these is shown at the bottom of the left-hand panel in Fig. 239.

At the bottom of the second panel from the left is seen an eight-point counter-e.m.f. cell switch, which is provided on each power board for regulating the voltage on the main discharge busbars, by switching in and out the counter-e.m.f. cells already referred to. Each power board is generally equipped with a high- and low-voltage alarm relay, which rings a bell when the voltage on the main switchboard feeders drops below 46, or rises higher than 50.

Typ cal Power-board Circuits.—In Fig. 242 is shown a typical power-plant wiring diagram. In the lower left-hand corner are the connections of the storage battery, the counter-e.m.f. cells and the counter-e.m.f. cell switch. It will be noted that from the battery one pair of feeders leads to the power distribution panel, from which go the power supply circuits to the various sections of apparatus. This pair of busbars supplies current also to one of the two rotary ringing machines. The other pair of busbars leads to the two charging outfits, one of which consists of a motor generator operated on a 220-volt, 60-cycle, single-phase, commercial power circuit.

The reserve set is a four-cylinder gas engine (1, 2, 3, 4) direct connected to a charging machine (No. 2). The mains from the charging generator pass through a "Reversite" and overload circuit-breaker. A voltmeter and its switch are shown in the upper left-hand corner of the diagram, but for simplicity's sake the wiring is not given in full. At various points of the power-board wiring, however, are seen arrowheads, with such designations as *V.S.*-3, *V.S.*-4, etc., which indicate the points at which the various volt-

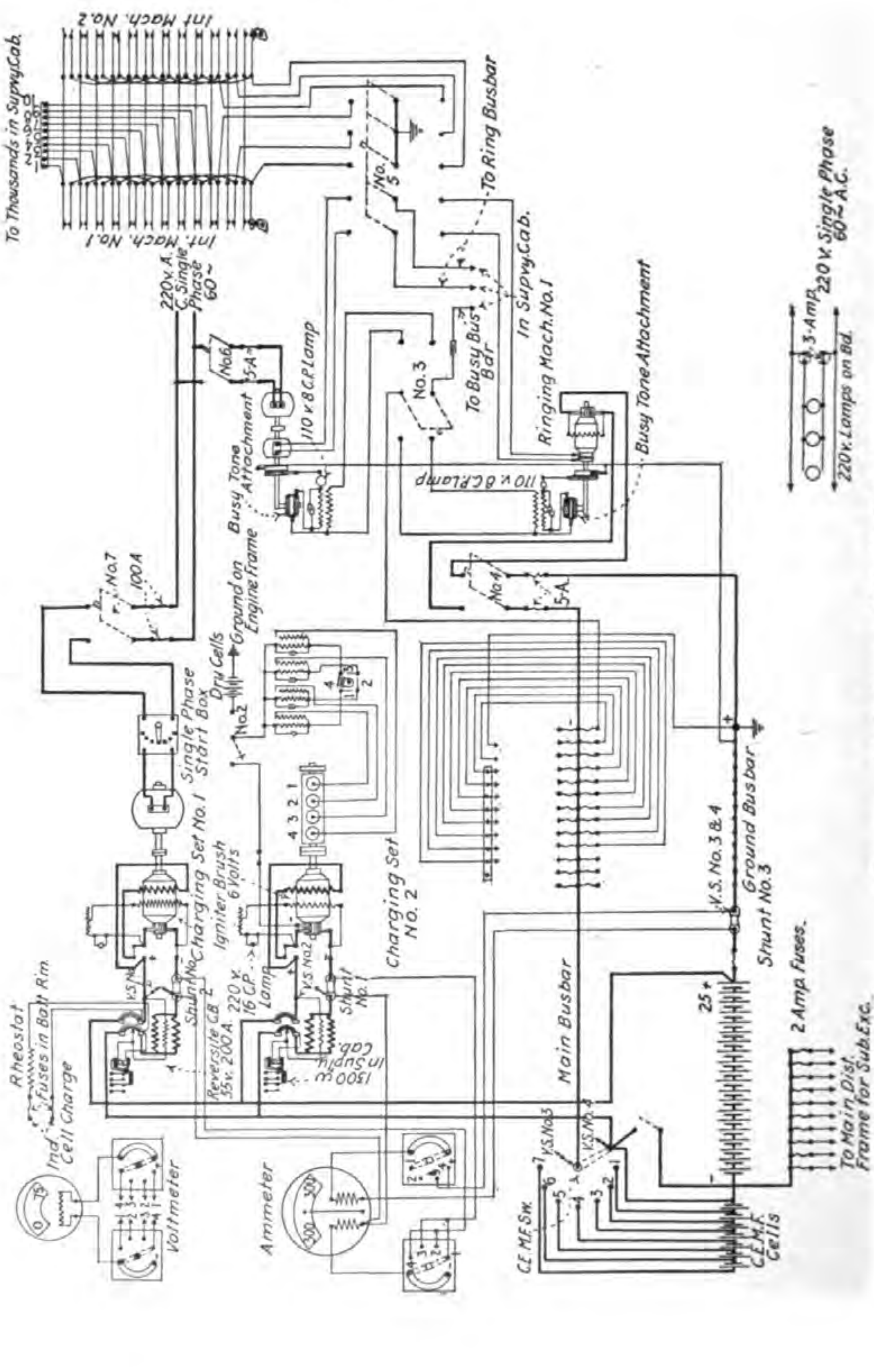


FIG. 242.—Typical power-plant circuit diagram.

meter switch connections are made. Beneath the voltmeter are the ammeter circuits. One of the ammeter shunts is used for measuring the current of each

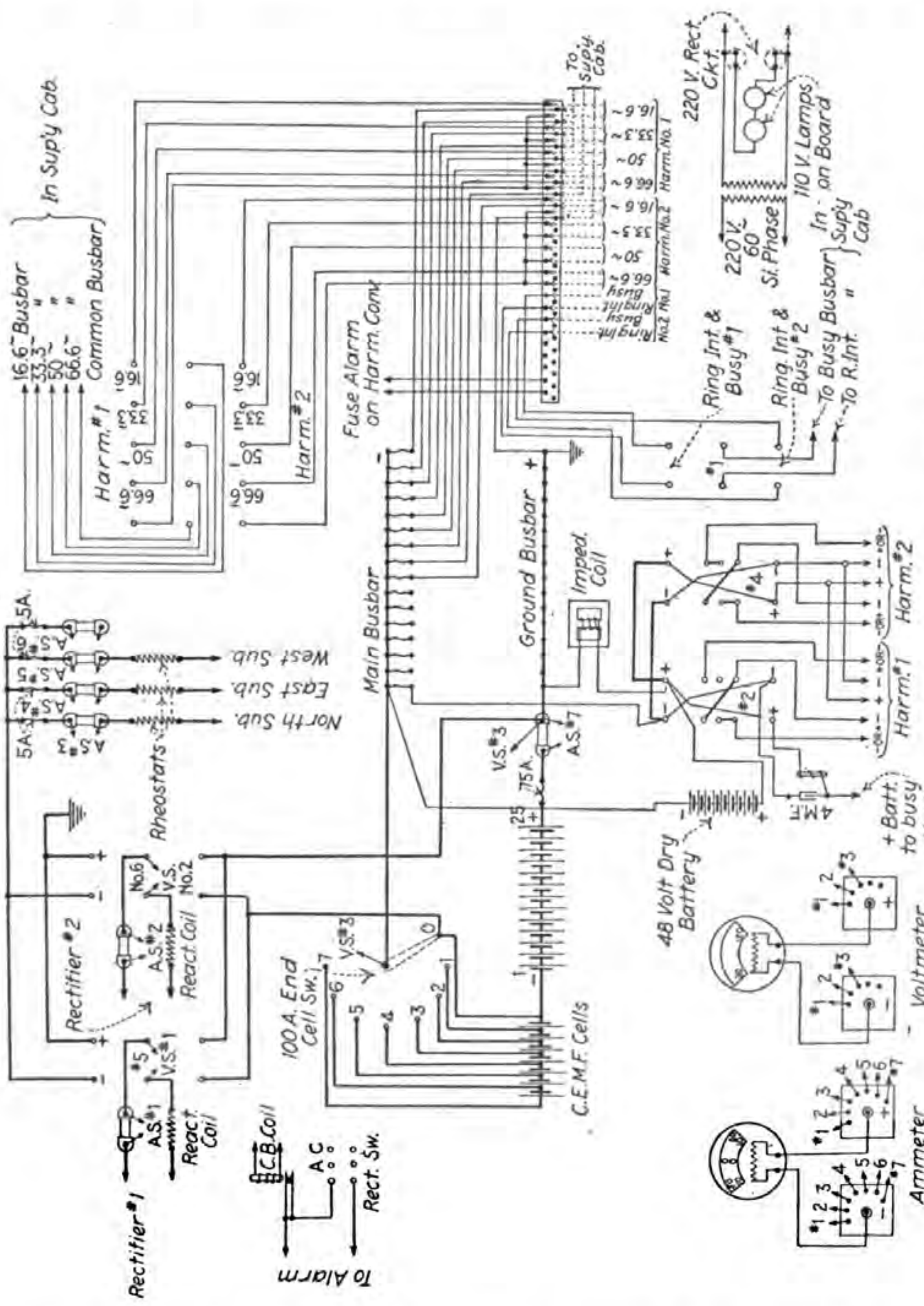


FIG. 243.—Typical circuit diagram of power plant for an office with district stations.

charging machine, and the third is used for measuring the current flow from the battery to the automatic switchboard.

In Fig. 243 is shown the power switchboard wiring diagram of a main office with three sub-offices or district stations. In these offices the ringing current and busy signal current are furnished by harmonic converters. The charging is done by means of rectifiers. As indicated in the lower right-hand corner of the diagram, each rectifier is connected to a 220-volt, 60-cycle, single-phase commercial power circuit, by means of an insulating transformer. The use of such a transformer is common practice, to avoid danger from a punctured transformer on the commercial power circuit. A reactance coil is connected between the rectifier and the charging mains to eliminate any noise on talking circuits.

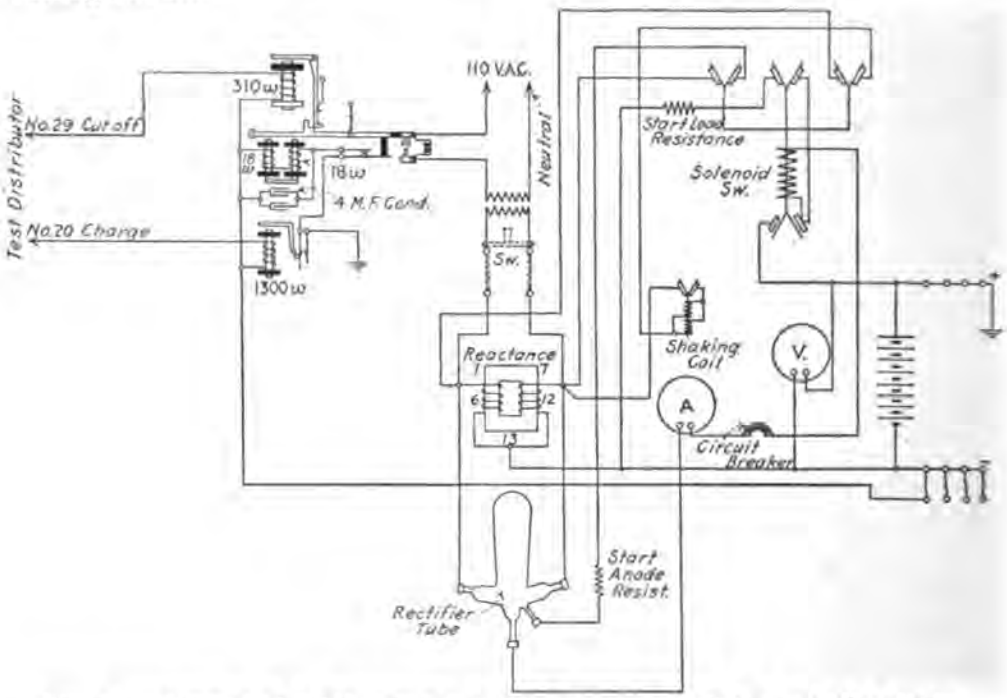


Fig. 244.—Circuits of a Mercury arc rectifier charging outfit for a district station.

As indicated, the batteries at each of the sub-offices may be charged by means of the rectifiers at the main office through a rheostat placed in the negative battery feeder of each sub-office. No positive battery feeder is provided, because the connection for the positive side is made through the earth, reinforced, quite often, by the sheath of the cable supplying the trunks to each district station.

District Station Power Equipment and Circuits.—The battery of a district station not more than a mile from its main exchange, may be floated on the main exchange battery of twenty-five cells through cable pairs. If the distance to the district station is too great, or the spare cable conductors not low enough in resistance a 120-volt rectifier installed at the central office, as indicated in Fig. 243, may be used. Where this plan is not practicable, it is common practice to charge the district station batteries by means of connections to the commercial source of power supply, tapped into the district station for the purpose. If 110-volt direct current is available, the district station battery may be charged directly through a rheostat. If alternating current is available, it is customary to use a mercury arc rectifier.

The circuit of a typical district station rectifier equipment is shown in Fig. 244. Relays are arranged to enable the wire chief at the central office automatically to switch the district station charging apparatus on or off, as desired, by calling certain numbers on his test distributer switch, using a

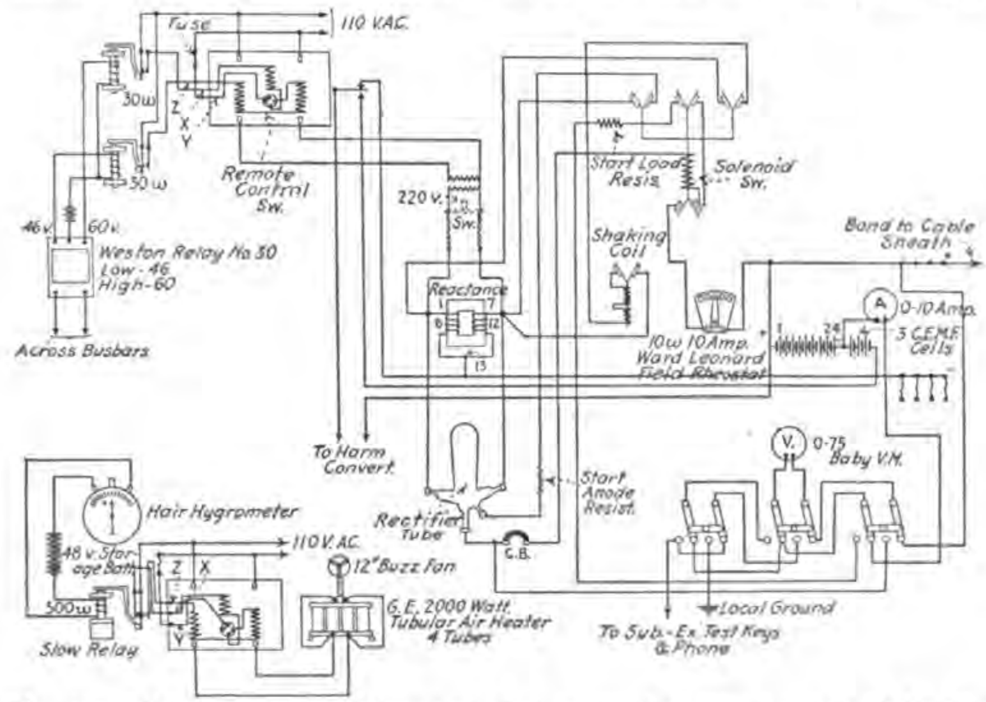


FIG. 245.—Circuit of district station power plant arranged for remote control of charging apparatus and automatic control of heating apparatus.

calling device on his desk. Circuits of these relays are indicated in Fig. 244. To charge, for example, the wire chief calls 20, whereupon the private wiper of the test distributor switch connects the wire marked "charge" to earth. This operates the 1300-ohm relay, which closes circuit from earth through the two 18-ohm coils of the electromagnet to negative battery. This electromagnet attracts its armature which closes the power supply circuit, as shown. At the same time that the electromagnet closes the switch, it breaks its own circuit and the switch lever is locked mechanically by the armature of the 310-ohm relay. When the circuit through the primary of the transformer is closed, the secondary potential is brought to bear upon the rectifier tube, and at the same time the shaking coil shakes the tube, starting the mercury vapor arc, between the starting anode and the cathode. The arc is taken up by one or other of the regular anodes and the solenoid switch is then actuated, which closes the circuit from the cathode, through the ammeter A, circuit-breaker, the solenoid switch coil and the storage battery direct to the middle point of the reactance coil. At the same time, the solenoid switch opens the circuit through the shaking coil, through the starting load resistance and through the starting anode resistance.

When the wire chief wishes to stop the charge, he calls 29, which closes the circuit that operates the 310-ohm relay and unlocks the switch lever, whereupon a spring draws it up, opening the switch. The leads to the automatic switchboard are taken off from the positive and negative busbars, shown at the right-hand end of the diagram. Each negative lead is fused as indicated.

Fig. 245 shows the circuits of a district station power plant, arranged so that a mercury arc rectifier installed at the station will be automatically started up and commence charging the battery whenever the battery voltage falls to 46, and the charge will be stopped whenever the battery voltage reaches 60. The circuit of the rectifier is practically the same as that shown in Fig. 244. The starting and stopping relay are actuated by a Weston high- and low-voltage alarm relay. When the voltage drops to 46, the 30-ohm starting relay energizes the solenoid controlled automatic switch which connects the 110-volt alternating-current power mains with the leads to the rectifier transformer. When the voltage reaches 60, the 30-ohm stop relay operates the unlocking coil of the automatic switch, whereupon the switch flies open and stops the charge.

Three counter-e.m.f. cells are provided and connected to a switch shown at the right of the charging control switch, so that while charging is going on, the counter-e.m.f. cells are switched into the battery supply circuit of the harmonic converter. A rheostat is provided in the charging circuit to regulate the current when desired.

In the lower left-hand corner of this diagram, circuits are shown of apparatus controlled by a hair hygrometer for regulating the humidity of this district station which is one of a number installed in the southern portion of the United States where no heating facilities are required, except those necessary to keep the relative humidity of the station below 70 per cent. When the needle reaches the 70 per cent. mark, it energizes the 500-ohm slow relay. This relay controls the automatic switch which in turn closes circuit through an electric heater and a 12-inch electric fan. This combination circulates heated air which absorbs the surplus moisture through the room. When the humidity has been sufficiently reduced, the needle of the hygrometer retires below the 70 per cent. mark, and as it does so, it breaks the circuit through the slow relay. Since the needle vibrates somewhat as it retires from the contact at the 70 deg. mark and does not immediately make a clean break, the slow relay is used, as it will not release its armature until the hygrometer needle permanently breaks the circuit.

Ringing Interrupter, Supervisory and Fuse Alarm Circuits.—In Fig. 246 is shown a typical wiring diagram for the solenoid ringing interrupter, supervisory and fuse alarm circuits of an automatic central office. As indicated by

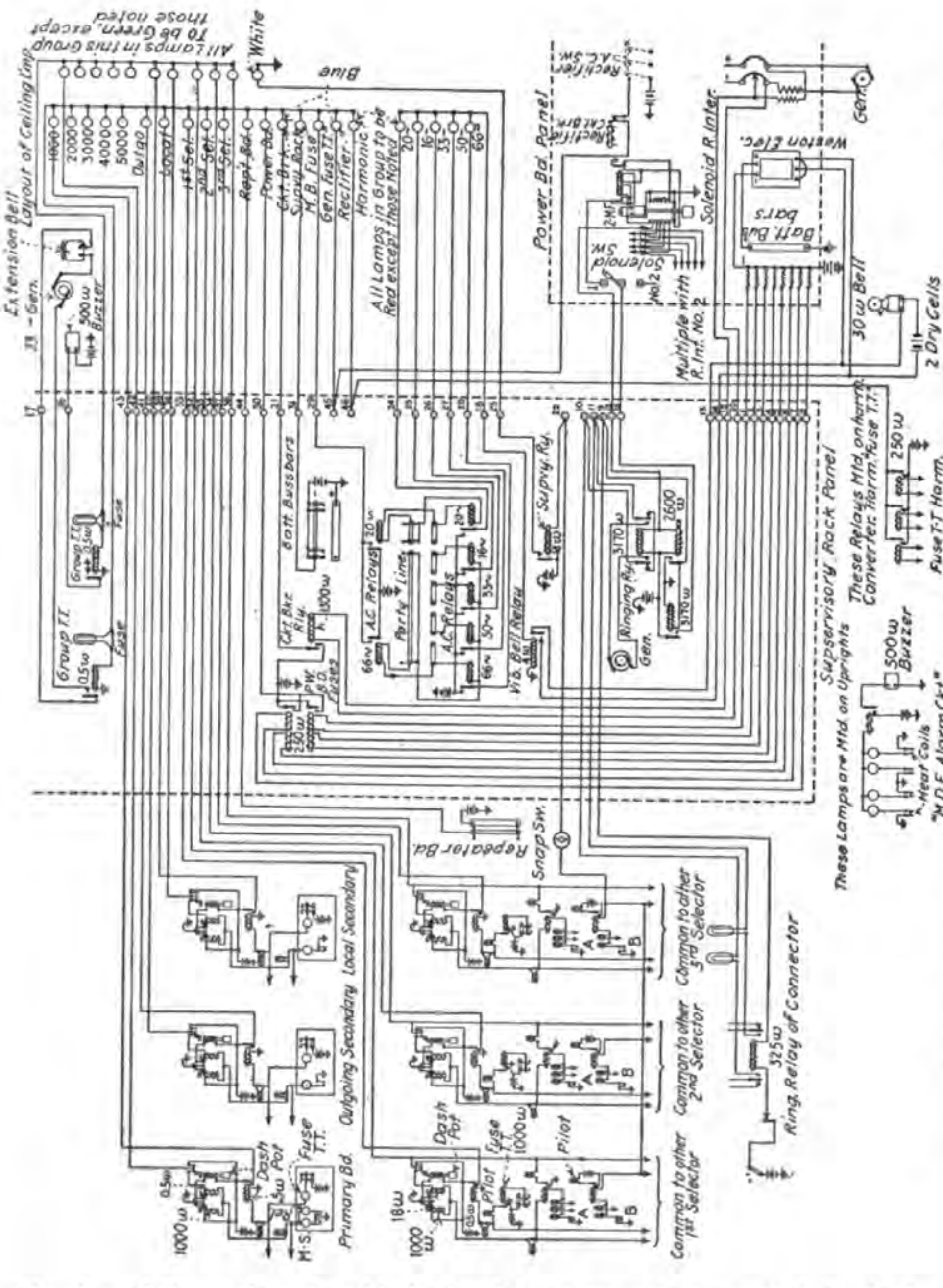


FIG. 246.—Typical wiring diagram of supervisory and alarm circuits for an automatic central office.

the dotted lines, the solenoid ringing interrupters (represented in the lower right-hand portion of this diagram) are mounted and interconnected upon one of the power board panels; while the various signal lamps just above them are mounted upon the ceiling, or in some place where they are visible from any point in the exchange. The central portion of the diagram represents equipment which is mounted upon the supervisory rack panel. Other equipment is mounted in other places, as indicated.

Solenoid Ringing Interrupter.—The circuit is so arranged that the interrupter operates only when a party is calling.

The description of the circuit is as follows:

When a connector is in ringing position, main battery is furnished by its side switch through its 325-ohm ringing relay (see lower left-hand corner of the figure) to a 3170-ohm relay, mounted on the supervisory rack. This 3170-ohm starting relay only will pull up and will connect to negative pole of battery one of the 1000-ohm windings on the double-wound coil of the relay controlling the ringing interrupter, the other terminal of which is connected to ground by means of the double wiper of the interrupter. This relay will furnish a negative battery connection to the solenoid coil, one end of which is connected to ground, and will also close a locking circuit for itself. The solenoid pulls its plunger up to the end of its stroke and when the wiper reaches the top contacts, a ground connection is furnished to the control relay's other 1000-ohm winding, one end of which is connected to negative battery. Since these two windings are so arranged that they neutralize each other, the relay armature will fall away thereby disconnecting negative battery from the solenoid coil and also furnishing ground connection to the five multipled contacts on one side of the interrupter.

As the plunger with its rod drops by force of gravity, retarded in its movement by means of the dashpot, the double wiper furnishes earth connection successively to each of the five contacts on the left-hand side. As the wiper is passing over each of these contacts the respective group ringing relays will be energized. As these relays pull up, the 2600-ohm slow-acting relay, mounted on the supervisory rack, will furnish a direct ground connection to the ringing relays of the connector switches in ringing position in that group (thereby shunting out the 3170-ohm starting relay). The ringing relays will pull up their armatures closing their ringing circuits, and at the same time the 3170-ohm group ringing relay will furnish ringing current. When the Solenoid *R.I.* wiper passes from the contact the group ringing relays will fall away, the 3170-ohm instantly, and the 2600-ohm later. The former temporarily short-circuits the line through its back contacts allowing the condensers in each line to discharge after the ringing period. If the called party has not answered, the ringing interrupter will repeat its cycle of operation as long as any connector in the exchange is in ringing position. The cycle of operation requires about three seconds' time—1/2 second for ringing and 2 1/2 seconds interval between rings.

Automatic Supervisory and Alarm Circuits. General.—Current supply failures, blown fuses, etc., are no more frequent in automatic exchanges than in manual ones, but because there is less supervision, some indication is advisable. This is especially true of small unattended offices.

Battery Circuit Alarms.—A Weston high- and low-voltage alarm relay (represented in the lower right-hand corner of Fig. 246) is arranged so that if one of the main battery fuses should blow, it will instantly close circuit through a battery of two dry cells and an alarm bell. Furthermore, practically all of the fuses used in an exchange on the taps from the main battery busbars are of the "alarm signal" or tell-tale type. (See Fig. 247.) The tell-tale spring of each fuse is so arranged that when a fuse blows it will close a circuit from one pole of the battery through a lamp, relay, or alarm bell to the other pole of battery.

Each of the negative battery taps, shown in the lower right-hand corner of Fig. 246 is connected through one winding of a double-wound 250-ohm relay, shown on the supervisory rack panel, to an adjacent negative battery

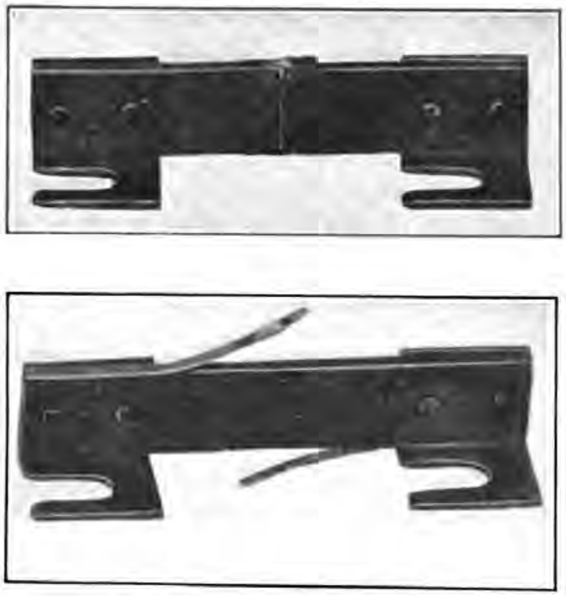


FIG. 247.—Above, tell-tale fuse set. Below, tell-tale fuse operated.

feeder. With this arrangement, if any negative battery fuse (enclosed type) should blow its feeder will draw current through one of the windings of a double-wound relay and the adjacent fuse, causing the relay to close circuit from negative battery through the corresponding ceiling lamp, shown in the upper right-hand corner of Fig. 246, and labeled "Power-board." The circuit through this ceiling lamp passes on through the 1/2-ohm group tell-tale relay, shown in the center of the diagram at the top. This relay closes circuit through an extension bell and the ringing generator of the exchange.

Just to the right of the double-wound 250-ohm power-board fuse relays is shown a 1300-ohm circuit-breaker relay, which is connected in series with the shunt winding of the circuit breaker in the generator circuit, and if the circuit breaker disconnects the battery from this charging machine, this relay will light the ceiling lamp marked "Ckt. Brk." The circuit through this lamp, and through the other lamps in the same row with it, pass through the 1/2-ohm group tell-tale relay, already mentioned, which closes circuit through the alarm extension bell and ringing generator.

When the rectifier circuit breaker opens, it closes contact between a pair of springs, shown just to the right of the solenoid ringing interrupter circuits, which lights the ceiling lamp marked "rectifier," and operates the group tell-tale relay.

There are three of these group tell-tale relays: one furnishes earth connection to all fuse lamps, and operates the extension bell for an audible signal; another 1/2-ohm group tell-tale relay furnishes earth connection to all release signal lamps and closes circuit through a 500-ohm direct-current buzzer for an audible signal; a third, of 4 ohms, labeled "Vib. bell relay" (shown in the lower central portion of the supervisory rack panel) furnishes ground connection to all supervisory lamps on ringing generator leads and when it operates, closes circuit through the same dry cell battery and vibrating bell that has already been mentioned in connection with the Weston high- and low-voltage alarm relay.

The various negative battery supply wires of the supervisory rack are also equipped with tell-tale fuses, as shown in the diagram, arranged so that if one of them blows, a ceiling lamp marked "Supvy. Rack M.B. Fuse" will glow and the group tell-tale relay will give the usual alarm.

Harmonic Converter and Generator Circuit Alarms.—Each of the harmonic converter fuses is supervised by a 250-ohm relay, as described for other enclosed fuses. They operate the ceiling lamp labeled "harmonic" and the group tell-tale relay. An alternating-current relay is bridged across each of the four circuits, supplying the four different frequencies of ringing current from the harmonic converters. These relays are shown in the center of the diagram of the supervisory rack panel. The one across the 16-cycle current is of 1780 ohms, each of the others is of 658-ohm resistance. These relays are arranged so that when the ringing current, across which any one of them is connected, fails, the relay armature falls back, the corresponding ceiling lamp lights and the "Vib. Bell Relay" operates.

If a fuse blows in any of the generator circuits, one of the 400-ohm relays, shown just above the A.C. relays already referred to, operates and closes circuit through the ceiling lamp labeled "Gen. Fuse T.T.," and the fuse group tell-tale relay.

First, Second and Third Selector Supervision.—On each shelf of a selector board two supervisory relays are mounted. One of these is a 1/2-ohm relay through which passes negative current to the release magnets of all selectors on that particular shelf. Consequently, when any one of the selectors releases, one of these relays is operated, and if the circuit through it closes longer than the normal length of time, it will in turn close a signal circuit which will bring the matter to the notice of the switchboard attendant. The springs controlled by this relay are indicated by the letter *A* in each of the three diagrams (shown in the left-hand portion of Fig. 246), which represents the tell-tale circuits for the selector boards. When the "A" relay on any selector shelf closes its springs, circuit is completed from earth through the shelf supervisory lamp, its pilot relay, and the 1000-ohm relay to negative battery. The 1000-ohm relay closes circuit from earth through a slow acting switch operated by a solenoid, the plunger speed of which is controlled by an oil dash pot. The speed at which the plunger piston moves through the dash pot may be regulated by a needle valve. The purpose of this is to provide an arrangement which will not close the alarm circuit, controlled by the dash pot, unless the supervisory circuit through the solenoid is closed for a considerable period of time; for example, 30 seconds. If it should be closed for a long enough time to allow the solenoid plunger to make its full movement, circuit will be completed through the 18-ohm relay shown just beside the 1000-ohm relay, which will shunt out the 1000-ohm relay and supply a holding earth connection to the solenoid. The solenoid will also close circuit through the pilot lamp of the particular switchboard section on which the shelf is mounted and through the corresponding ceiling lamp and the group tell-tale alarm relay, which in turn closes circuit through its 500-ohm buzzer.

The other supervisory relay on each shelf has a coil of 18.6-ohm resistance, and is used to indicate when a selector switch fails to operate or when a connection has been extended through to one of the selectors of the shelf on which the relay is mounted but does not proceed any further. This relay is energized whenever current flows through the slow relay of any selector switch on the shelf on which it is mounted. As explained in the description of the two-wire systems, the slow relay of any selector is energized from the instant at which a calling line is extended through to it, until the selector has selected a trunk to the next switch in the connection. When this supervisory relay attracts its armature, it closes one of the pairs of springs marked *B* in each of the diagrams in the left-hand portion of Fig. 246, and completes circuit through a supervisory lamp, associated with the shelf on which the relay is mounted, a 30-ohm relay, a snap switch and a 4-ohm supervisory relay to negative battery. The 30-ohm relay lights a pilot lamp, which indicates the particular trunking switchboard on which the operated shelf relay is mounted, while the 4-ohm relay closes circuit through a ceiling lamp.

If a fuse blows on any selector board, circuit is thereby completed from negative battery to earth through the 1000-ohm relay, marked "Fuse T.T.," and represented in the center of each of the selector supervisory circuit diagrams now under discussion. This 1000-ohm relay closes circuit through a pilot lamp, indicating the switchboard section, and through a 1/2-ohm relay shown just above it. The 1/2-ohm relay closes circuit through the corresponding ceiling lamp and through the fuse group tell-tale relay, which causes the extension bell to give an audible alarm.

Line Switchboard Supervision.—In the upper left-hand corner of Fig. 246 are three diagrams of supervisory circuits for line switchboards. One of these is for a primary switchboard, one for an outgoing trunk secondary line switchboard, and the third for a local trunk secondary line switchboard. The master switch and release supervisory signals operate a time limit switch like that described for the selectors. The supervisory circuits for the outgoing secondary and the local secondary boards are the same as that just described, except that no release supervision is provided.

If a fuse blows on any line switchboard, circuit is closed, as indicated in each of these diagrams, from negative battery through the pilot lamp on the board, and through a 1/2-ohm relay. This relay closes circuit through a ceiling lamp in the fuse supervisory group and thence through the fuse group tell-tale relay, which closes the circuit through the extension bell.

TESTING EQUIPMENT

Standard Impulse Lengths and Speeds.—One of the essentials of the proper operation of automatic switchboard telephone equipment is the adjustment of the central office switches to a standard calling device impulse, and then the corresponding adjustment of all calling devices so that they will furnish this standard impulse to the switches. In the end, the vital point is the performance of the vertical and rotary magnets to which impulses must be delivered, which are within certain limits as to frequency and character.

To accomplish this a calling device is used in modern two-wire systems which can be adjusted, so that no change in impulse adjustment will be required after it is installed at a subscriber's station, provided the central office switches have been adjusted to a corresponding standard impulse. A calling device of the type referred to has a fiber cam, which passes between a pair of floating contact springs. The only points to be observed in the adjustment of the cam and springs are as follows:

First.—All impulse springs should be adjusted so that the ratio between the open period and the closed period will be the same and according to standard.

Second.—The speed at which each calling device runs should either be adjusted to suit an experienced eye and ear, or, better, be standardized by using a speed indicator.

Calling Device Speed Indicator.—This little piece of apparatus (see Fig. 248) is used to compare the speed of a calling device connected to it with a standard. The essential parts of the indicator are two indicating fingers, each of which is fastened to a small wheel, arranged so that it may be rotated from left to right through an arc of approximately 90 deg.

The power for rotating each of the finger wheels consists of a clock spring. The escapement, which allows the standard finger to move step by step, is controlled by a small weighted pawl adjusted to ten steps per second. The escapement of the other ratchet wheel is controlled by an electromagnet, linked with the line of the calling device to be tested. The ratchet wheel and finger escapes one step for each calling device impulse. If the speed of the calling device is slower than the standard, its pointer will lag behind the standard pointer. A speed indicator of the tuned reed variety is used in the Siemens-Halske exchanges, instead of the type just described.

SWITCH TESTING MACHINES

Standard impulse machines used in adjusting the central office switches are furnished in portable form with carrying case, in which are mounted all necessary resistances and capacities and means for making all changes in conditions required to "vary" any switch so that it will be tested under variations of resistance, capacity and speed greater than those ever experienced in receiving impulses from a subscriber's station.

FIG. 248.—Calling device speed indicator.

A very convenient and commonly used type of machine consists of a small (0.1 h.p.) direct-current motor designed to run at a speed of approximately 400 revolutions per minute. On the shaft of this machine is mounted a large fiber cam, similar to that used on a telephone calling device, arranged to break contact twice at every revolution of the shaft, between a pair of floating contact springs, mounted on a bracket secured to the base of the machine. It is readily apparent that this cam and pair of springs may be adjusted to give an impulse of the same character as that given by the calling device.

The set has flexible cords ending in a clip and terminals. The clip is attached to the negative battery pole. The terminals are inserted in the test jack of the switch to be tested. The motor at once runs so as to give about thirteen impulses per second and the line relay of the switch becomes energized. Pressing certain buttons causes the impulse machine to give ten impulses followed by a rest, succeeded by another set of ten, indefinitely. One button operates the switch through zero loop resistance with 2 m.f. across the line, the other through 1200 ohms without capacity. A release button opens the line to release the switch. Another button cuts 130 ohms in series with the motor armature, slowing it down to five impulses per second.

Wire Chief's Desks.—A typical wire chief's desk (See Fig. 249) for an automatic central office contains one or more of each of the following circuits:

Operator's telephone circuit
Wire chief's test circuit

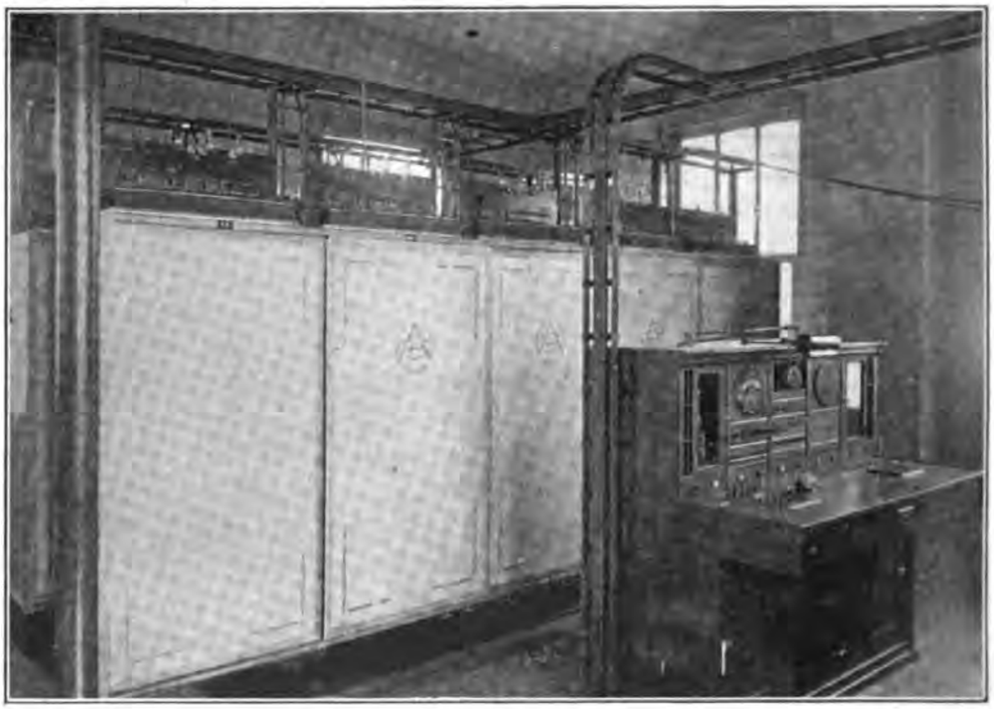


FIG. 249.—A view showing the wire chief's desk in an automatic central office.

Trunks to test jacks on main frame
Toll test plug circuit
Impulse testing switch and calling device speed indicator circuit
Trunks to test distributors
In-and-out trunk circuits
Circuit of incoming trunks from extra cable pairs and inspectors' trunks
Cord circuits for hospital trunks
Hospital trunks
Howler circuit
Out order wire circuit

In order wire circuit
Master ringing circuit
Panel pilot circuit, one per panel
Supervisory pilot circuit, one per position
Fuse alarm circuit
Lamp circuits for supervisory tell-tale lamps in main exchange

Sometimes one or more of these circuits are omitted, sometimes others are added, but as a rule a list similar to the foregoing is used. Testing is usually done through test connectors (one per 100 lines) reached through a test distributor switch.

Description of Circuits.—In Fig. 250 are shown a typical operator's circuit and wire chief's test circuit.

The test circuit consists of keys, a high-resistance voltmeter, and the necessary plugs, as shown in the upper left-hand corner of the figure, for connecting the test circuit, either to the main distributing frame, or to test distributor and test connector switches.

Besides a reversing key and a ringing key there are keys for connecting the line to the voltmeter for the usual line tests. A foreign battery key is installed for testing foreign potentials on the line.

The impulse test switch key is used for connecting a line to a special automatic switch mounted in the wire chief's switchboard, for the purpose of receiving impulses from a telephone and line to determine whether the line and telephone are in good operating condition or not. The wire chief may also supply current to the telephone on the line for talking purposes.

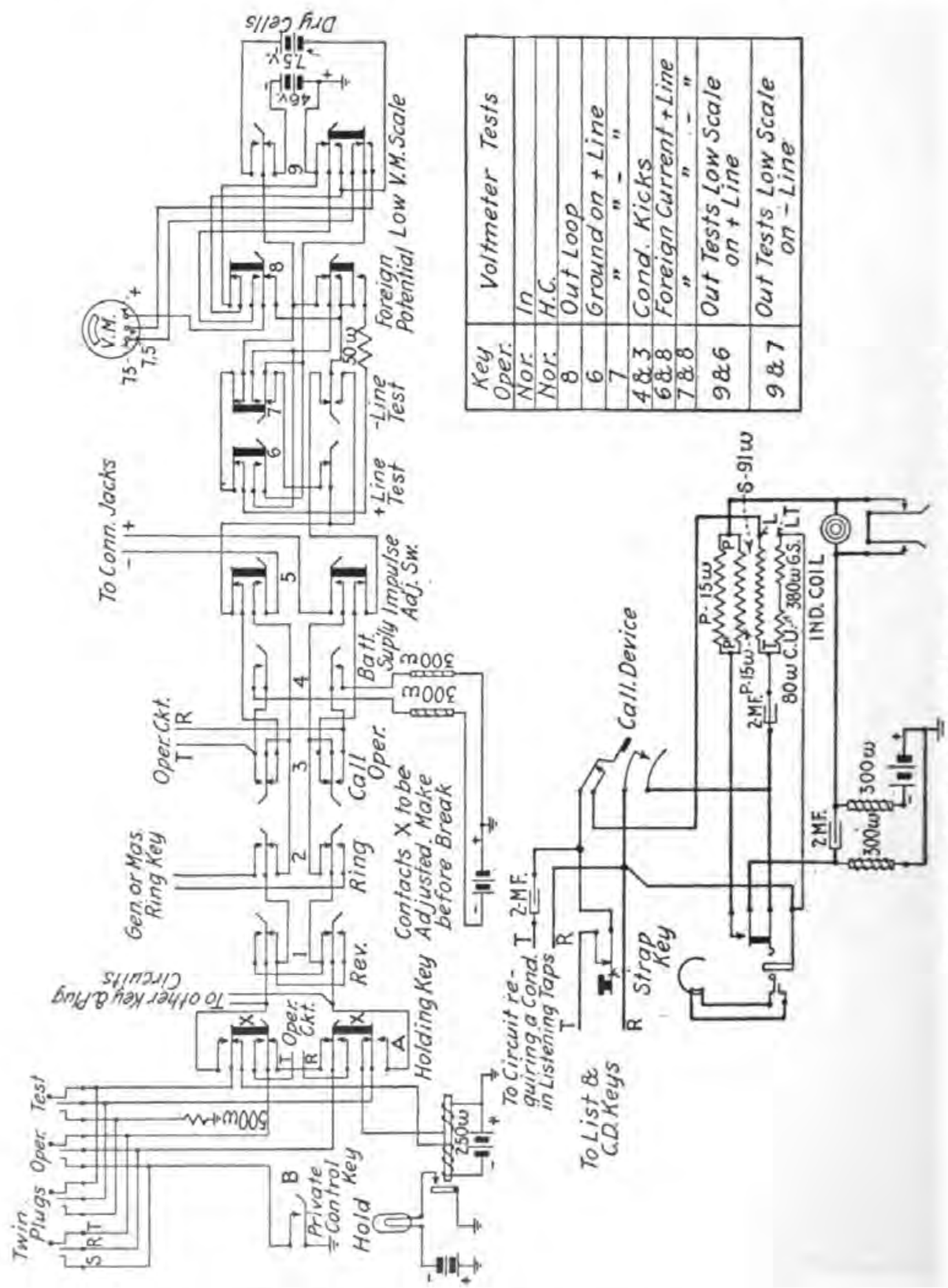
In the lower right-hand corner of Fig. 250 the various key arrangements for the different meter tests, which may be made, are indicated.

Trunks to Test Distributors and Test Connectors.—These trunks enable the wire chief to test lines without assistance and without leaving his desk. The test distributors are useful in other ways, however, especially where district stations are used. A test distributor switch installed at a district station may start or stop the charging of the district station storage battery. These switches are also used for supervising alarm circuits, etc. The test distributor trunk, test distributor switch and test connector switch circuits, shown in Fig. 251, are typical of those in common use in two-wire plants using equipment of the Automatic Electric Company's manufacture.

The wire chief prepares to use the test distributor and test connector by inserting the plugs, marked "*OPER.*" and "Test" in Fig. 250, in the call and test jacks respectively of the test distributor trunks in Fig. 251, and he operates the test distributor switch by making two turns of the calling device dial associated with his test circuits, thus placing the test distributor in connection with the test connector mounted on the particular line switch unit in which the line which he wishes to test terminates.

The test distributor circuit differs from others in the following details:

A pair of positive and negative test wires pass through contacts controlled by the private armature to a special pair of wipers mounted on the switch



Key Oper.	Voltmeter Tests
Nor.	In
Nor.	H.C.
8	Out Loop
6	Ground on + Line
7	" " - "
4 & 3	Cond. Kicks
6 & 8	Foreign Current + Line
7 & 8	" " - "
9 & 6	Out Tests Low Scale on + Line
9 & 7	Out Tests Low Scale on - Line

FIG. 250.—A typical circuit diagram for a wire chief's desk.

shaft. The private wiper and bank contact rows are double like the line wiper and banks. The wiper marked *P-2* takes the place of the ordinary

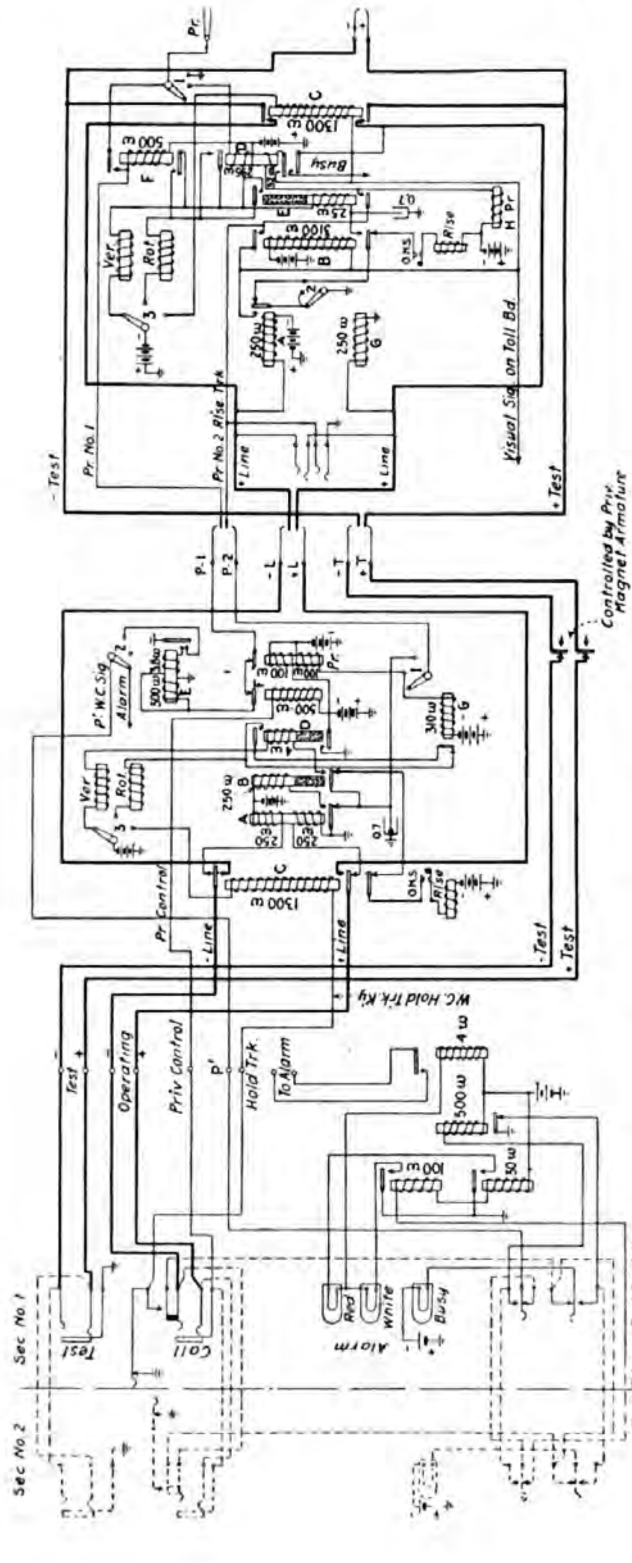


FIG. 251.—Circuits of a wire chief's test trunk, test distributor and test connector switch.

private wiper, while that marked P-1 is for the special use of the wire chief in supervisory work.

If the called test connector be busy, current flows from guarding earth potential on the busy private bank contact, through wiper P-2 and side-switch wiper 1 (second position), and through one winding of the private magnet Pr to negative battery. Pr retains its armature and prevents the side switch from moving to third position. It also holds open the test circuit P-1. Current also flows through P-2 and the 310-ohm relay G, which opens the rotary magnet circuit to prevent further rotation of the wipers.

The operation of the test connector switch has already been explained in the chapter on long distance equipment.

When the test distributor is in normal position, side-switch wiper 2 will be connected to the alarm circuit. This circuit is not used on test distributors installed in central offices, but is very useful on test distributors installed in district stations or small branch offices, because it is employed to transmit a signal to the wire chief's desk in the central office whenever a fuse or heat-coil blows at the district station. It is also common practice to install arrangements which will give a signal to the wire chief over this circuit when a master switch or trunking switch in the district station fails to operate. The blowing of an alarm fuse, or the operation of one of the other tell-tale circuits, will connect the alarm circuit to earth, and the alarm lamp, corresponding to the district station in which the trouble occurs, will then light on the wire chief's desk.

If the alarm lead is grounded through less than 100 ohms, both relays (100ω and 30ω in lower left-hand corner of Fig. 251) will pull up and both the white and red lamps will light. This occurs if an important fuse blows, and is what is called a "danger signal"; but if a heat coil blows, the alarm lead is connected to earth through 500 ohms, and the 30-ohm relay at the central office does not operate, consequently only the white alarm lamp lights.

Upon receiving an alarm signal, the wire chief throws the key, which cuts off the alarm lamps, and with his calling device operates the test distributor switch, causing it to step its wipers over the various local alarm circuits in the district station. Each of these alarm circuits is connected to a pair of bank contacts of the distributor switch. As the test distributor wipers stop on each alarm circuit contact, the wire chief makes a quick test and in this way is enabled to find speedily which circuit is out of order.

Information and Complaint Operators' Desks.—Sometimes a desk is installed for the information clerks, separate from that for complaint clerks, in automatic central offices; sometimes both are placed at one desk, so arranged that information and complaint circuits are common to all positions of the desk; sometimes in small offices the complaint trunks terminate in the wire chief's position, or in a second position in the wire chief's desk. In small offices the information trunks often terminate in a position on the long distance switchboard, so arranged that during the day it is presided over by a clerk, especially assigned for the purpose, but at night and on holidays, or Sundays, the information trunks are attended to by a toll operator.

It is not good practice, as a rule, to have the switchboard attendant spend time answering information and complaint calls, although in an office up to 1000 lines, he is generally able to attend to the wire chief's desk. At night and during Sundays and holidays one employee can generally attend to the automatic switchboard, the wire chief's desk, and the combined long distance information and complaint desk, where all of this equipment is on the same floor and in adjacent rooms. If it is necessary to put the long distance switchboard on the ground floor of a central office building, in which the automatic switchboards are on the second or third floor, and where the switchboard is for 1000 lines or less, it may be advisable to have the complaint trunks terminate in one position of the wire chief's desk; and if the office is quite small, that is, 500 lines or less, they may be attended to by the regular switchboard attendant; but if it is larger, so that the switchboard attendant does not have sufficient time, a boy or a woman clerk may be employed to receive the complaints, make simple tests from the wire chief's position, and generally assist the switchboard attendant during the busy hours of the day.

In larger offices of 2000 lines or more, the information and complaint trunks usually terminate in a desk through the positions of which both classes of trunks are multipled, and which is located in the same room as the long distance switchboard. In fact, it is quite desirable to use the same style of cabinet for the information and complaint desk as for the long distance switchboard, and to place them in a continuous line, arranged so that the information and complaint desk may grow in one direction, while the long distance and rural positions grow in the other direction. It is especially desirable to have them in the same room, however, so that one chief operator can look after all of the operators, and they can all use the same retiring room.

In multi-office systems, information trunks generally terminate at one central office, the business headquarters of the telephone company. Sometimes separate complaint desks are installed at each of the main offices in such a system, but it is preferable to have them all terminate in the same office as the information trunks, and to have the complaints distributed to the wire chiefs' desks in the various main offices by means of telephones or telautographs.

If the long distance switchboard is not situated in the building with the business headquarters of the telephone company, it is generally preferable to keep the information and complaint desk with the long-distance switchboard. This simplifies the supervision and arranging of reliefs, promotes economy in the provision of rest-room facilities, etc.

For all systems, the following circuits generally terminate in the information desk, when it is installed separately from the complaint desk:

Incoming information trunks.

Incoming dead-number trunks.

Where party lines are used and reverting calls are handled by means of an operator, who rings the party desired on a reverting call, trunks for this work also usually terminate in the information desk.

When the complaint desk is separate from the information desk, the following circuits terminate in it:

Incoming complaint trunks.

Incoming trunks from dead-bank levels or contacts.

The following circuits are used in desks of both types:

Trunks between desks.

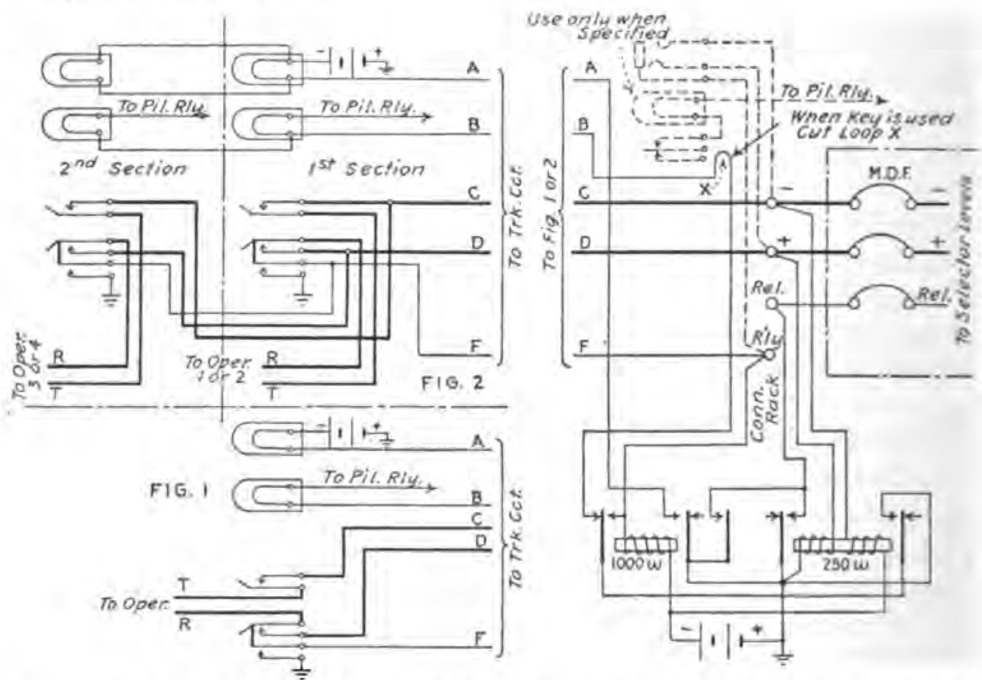


FIG. 252.—Trunk incoming to an information operator's position from selector switch banks.

In- and out-trunk circuits.

Out-order wire circuits.

In-order wire circuits.

Outgoing trunks to the automatic switchboard.

Operators' telephone circuits.

Position switching circuits, for desks of more than one position.

Pilot and night-alarm circuits.

Incoming Information Trunks.—Circuits of a typical incoming information trunk from a level of selector banks to an information clerk's position are shown in Fig. 252. In this diagram detail "Fig. 1" shows the circuit connections for a one-position desk, while "Fig. 2" shows the circuit connections for a desk of two or more positions, through which the incoming trunk is multipled. It is customary to wire these trunks to a level of the automatic switchboard selector banks in such a manner that a subscriber desiring to call the information operator does so by making one, two, or at the most, three turns of his dial. This is determined by whether the trunks terminate in first-, second- or third-selector banks. In small one-office systems, they usually terminate in first-selector banks; in larger systems, in second-selector banks; in large multi-office systems, they sometimes terminate in third-selector banks.

Upon calling the number designated, as that of the information clerk, the selector switch operated by the subscriber, in accordance with the last digit of the number, selects an idle trunk to the information operator and then extends the subscriber's line through to it. When this occurs, current flows from battery through the windings of the double-wound 250-ohm line relay, shown in Fig. 252, and through the subscriber's loop. When this relay attracts its armature, it lights the line signal lamp or lamps, and grounds the release trunk.

The operator responds by throwing a key associated with the trunk in her position, thus connecting her transmitter and receiver across the trunk, and operating the 1000-ohm cut-off relay. When this relay operates, it cuts off the signal lamp and grounds the release trunk to prevent release by the subscriber. It closes also a locking circuit from earth through the springs of the line relay and its own winding to negative battery, so that after once attracting its armature, it will not release it until both the subscriber and the operator are off the circuit. The cut-off relay lights the holding lamps shown just above the line signal lamps, so that so long as the subscriber remains on the trunk these holding lamps will glow to prevent the call from being forgotten.

Occasionally information boards are arranged with the trunks ending in jacks instead of keys. The circuits of a jack ending trunk are shown by the dotted lines in Fig. 252.

Dead Number Trunks.—These trunks are used to connect the connector bank contacts, corresponding to numbers which appear in the directory, but which are not in use, to the information switchboard, so that a subscriber calling such a number will be automatically switched to an information clerk, who will give him attention. Generally the connections from the dead lines to the dead number trunks are made at the main distributing frame, but another practice is to make them at the connector bank cable terminals.

Where party lines are used the latter method is decidedly preferable, because it will not be desired to connect an entire party-line to the dead number trunk. It is, therefore, customary to arrange the connector switch banks on party line boards, with the banks of each group of connector switches connected to a separate terminal strip. This makes it possible to disconnect the bank multiple of any particular group of connector switches from its line, and to connect that multiple to a dead number trunk.

Another method of handling dead number trunk connections for party lines, but one which is considerably more complicated and expensive, is to substitute for the telephone removed from any line a special relay connected to the line at the central office and designed to operate only on ringing current of the same frequency to which the ringer of the removed telephone

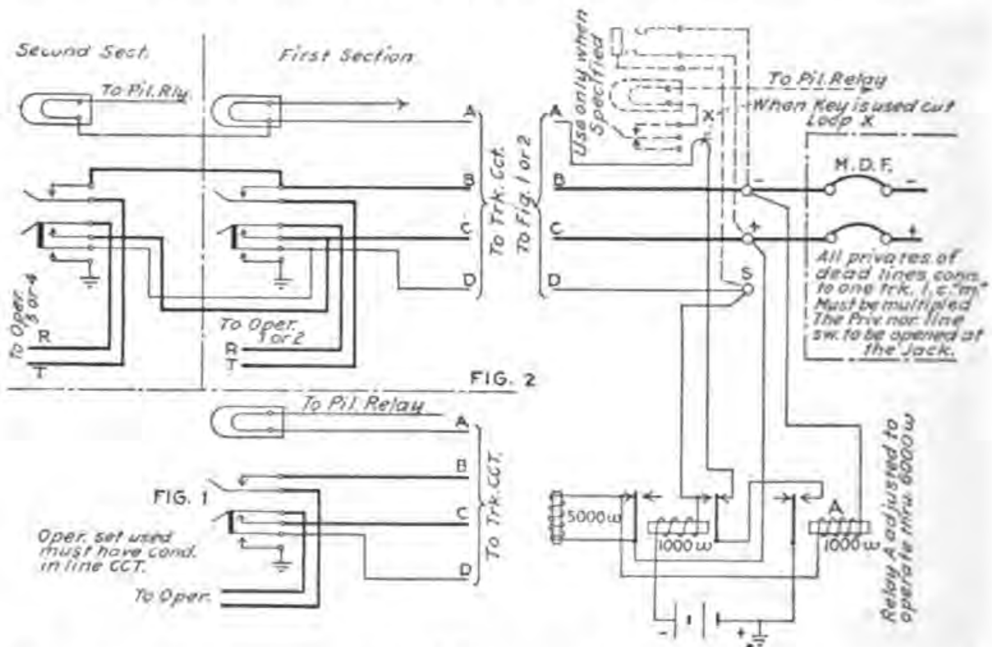


Fig. 253.—Trunk for connecting dead lines or numbers to an information operator's position.

would respond. When a subscriber calls the number corresponding to the removed telephone this relay serves to connect the line temporarily to the dead number trunk. This method of handling dead number trunks must be used on party lines where the design of the switchboard is such that it is not possible to isolate the connector bank multiple corresponding to the dead number.

A dead number trunk for use where the disconnecting of connector bank multiples is the scheme followed for connecting up dead numbers is shown in Fig. 253. In this figure the detail "Fig. 1" shows the method of connecting to a key in a one-position desk, while detail "Fig. 2" shows the method of multipling the trunk through keys in two or more positions.

When a subscriber connects to one of these dead trunks, the current flowing through the back-bridge relay windings of the connector switch used by him energizes the 1000-ohm relay *A*. This relay lights the signal lamp through conductor *A*. The operator responds by throwing a key in her position which bridges her transmitter and receiver across the line and energizes the cut-off relay. The cut-off relay opens the circuit through the lamp and closes a locking circuit through its own winding. It also opens the shunt across the 5000-ohm resistance coil, thus placing that coil in series with the coil of relay *A*. The purpose of this is to prevent sufficient current flowing through the back-bridge relay windings of the connector switch to operate them. If the party has called from a pay-station telephone, equipped with a coin collector using a polarized relay, this relay will not be operated, and the subscriber is not required to deposit a coin.

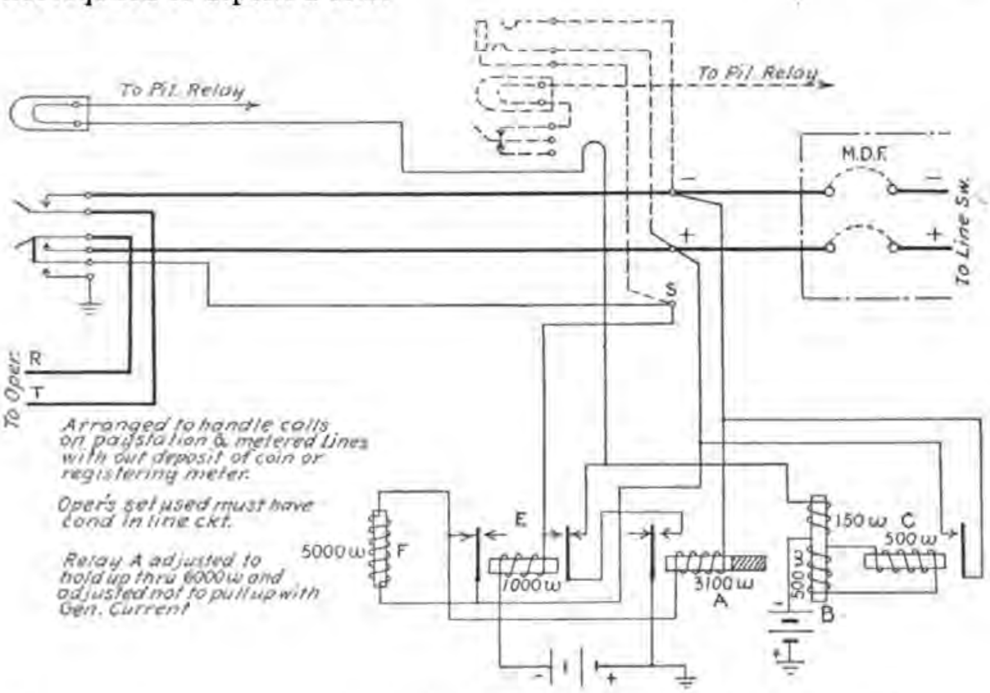


FIG. 254.—Dead number trunk circuit for use in an exchange having metered lines or sub-station coin collectors actuated by "reversing battery" connector switches.

Another type of dead number trunk circuit is that shown in Fig. 254, which is designed especially for use where meters are employed, which register as soon as the current in a calling subscriber's loop reverses at the instant the called party responds. This circuit is provided with a 3100-ohm slow-acting relay *A* bridged across the line and operated by the talking current of the connector switch. *A* being slow, will not respond to ringing current. *A* closes circuit from earth through its own springs, the back contact of the 1000-ohm relay and the signal lamp to the pilot relay and negative battery. It also closes circuit by means of the same spring contact through the 150-ohm winding of the induction coil *B*. The induced current which is generated for an instant, as the circuit through this winding of *B* is closed, in the 500-ohm winding of B and the 500-ohm winding of C, causes C to attract its armature for an instant. This short-circuits the line long enough for the ring cut-off relay of the connector switch to operate and switch the ringing relay out of circuit; but it does not cause the back-bridge relay of the connector switch to reverse the direction of current flow in the calling party's loop for a sufficient period of time to operate the meter associated with the calling party's line switch. It is therefore seen that by the use of this circuit a subscriber, whose line is equipped with a meter, may call the information operator on a dead number trunk without having the call registered.

Trunks for Reverting Calls on Party Lines.—Fig. 255 is a diagram of a trunk circuit from a selector bank level to an operator's position for use in

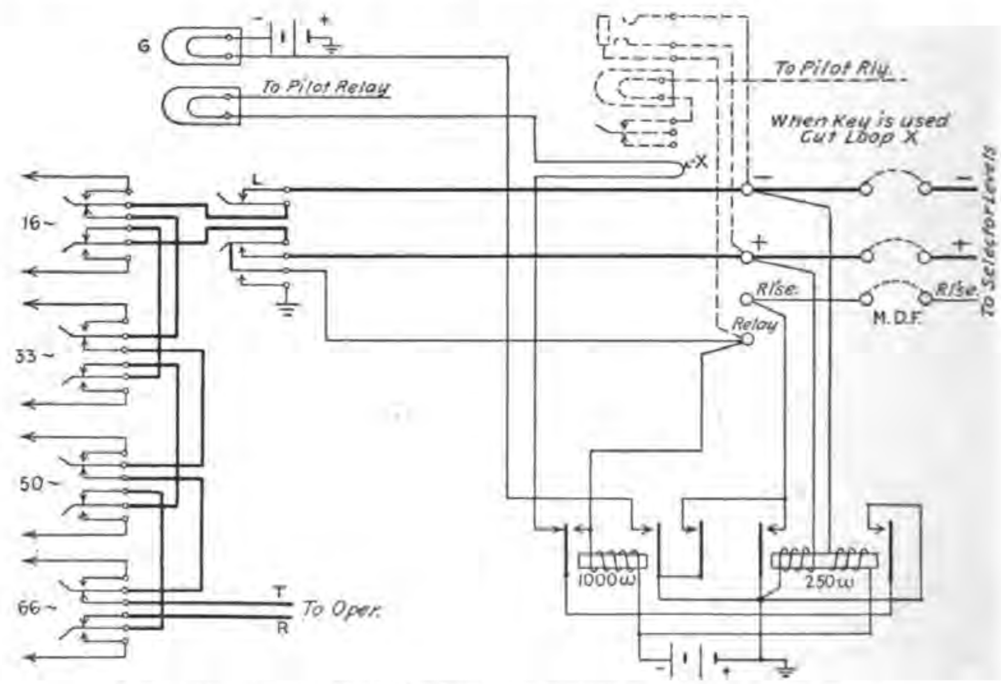


FIG. 255.—Trunk circuit for handling reverting calls on 4-party lines.

making reverting calls on party lines. Where this circuit is employed, each party line subscriber is instructed, by means of a suitable direction card mounted on his telephone, or by a notation in his directory, that when he wishes to call another party on his own line, he must signal the information operator who will ring the bell of the desired party for him. The number of these reverting calls is comparatively small, especially where the customary amount of care is exercised in not putting parties, who call each other frequently, on the same line.

When a party line subscriber calls the number assigned to this circuit to the information operator, the instant the selector wipers stop on the contacts corresponding to an idle trunk, current flows between the two poles of battery, through the two 250-ohm windings of the line relay and the calling party's loop. This relay grounds the release trunk and lights the line signal lamp. When the operator responds, by throwing the listening key *L*, this key completes circuit from earth through the cut-off relay to negative battery. This relay cuts off the line lamp and closes circuit through the guard lamp *G*. The cut-off relay also closes another circuit from earth to the release trunk, arranging it so that the selector cannot release until both the subscriber and the operator are off the circuit. When the operator learns the number desired by the subscriber, she tells him to replace his receiver on the switch hook for a moment while she rings the party desired. As soon as he

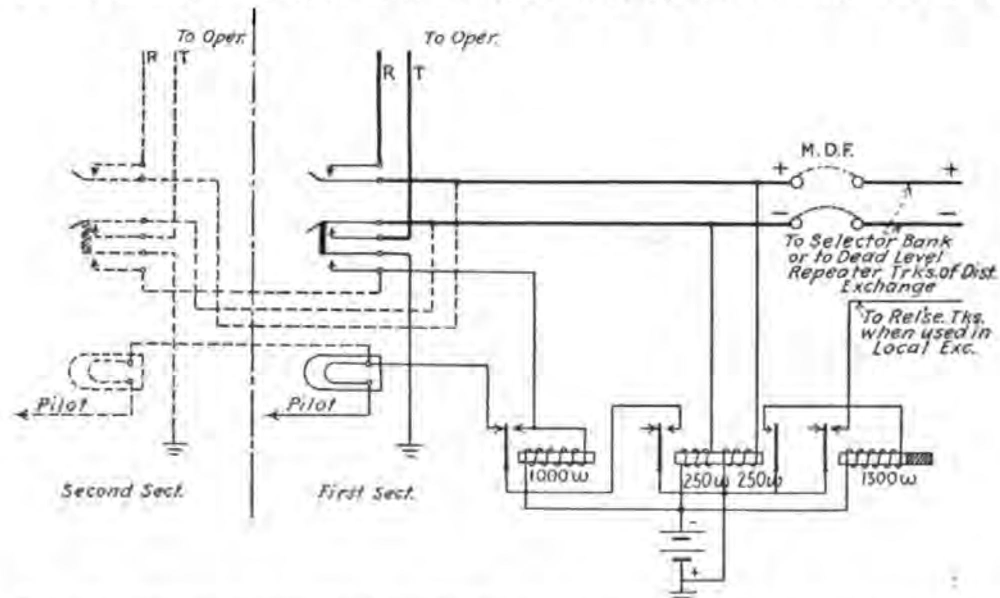


FIG. 256.—Trunk for connecting dead levels or pairs of selector bank contacts to an operator's position.

does so, she throws the ringing key corresponding to ringing current of the frequency required to operate the bell of the number wanted, and thus secures the response of the desired party. When he answers, if the calling party has has not again removed his receiver, she cautions the called party to await his return on the circuit and thus puts the two parties into conversation with each other.

Incoming Complaint Trunks.—These trunks usually terminate at one end in the banks of selector switches, and at the other end in keys in the complaint or information clerk's position, and are in every way similar to the incoming information trunks already shown in Fig. 252 and described in the preceding paragraphs.

Dead Level Trunks.—It is customary in automatic switchboard central offices to connect levels and even contact pairs of the selector banks, which are not in use, to what are called "dead level trunks." These trunks generally lead to keys with relays and lamp signals in a trouble clerk's position. It is not essential that dead bank levels and contacts should be connected up in this way, but the practice enables the complaint operators to give needed instructions to subscribers who may be calling numbers which are not in existence; or who may be using their calling devices improperly. Also the use of these trunks sometimes enables the complaint operator to detect the need for a repair or readjustment of some telephone instrument or part of the switchboard mechanism, and to make a report of it to the proper repairman, resulting in the prompt application of the remedy.

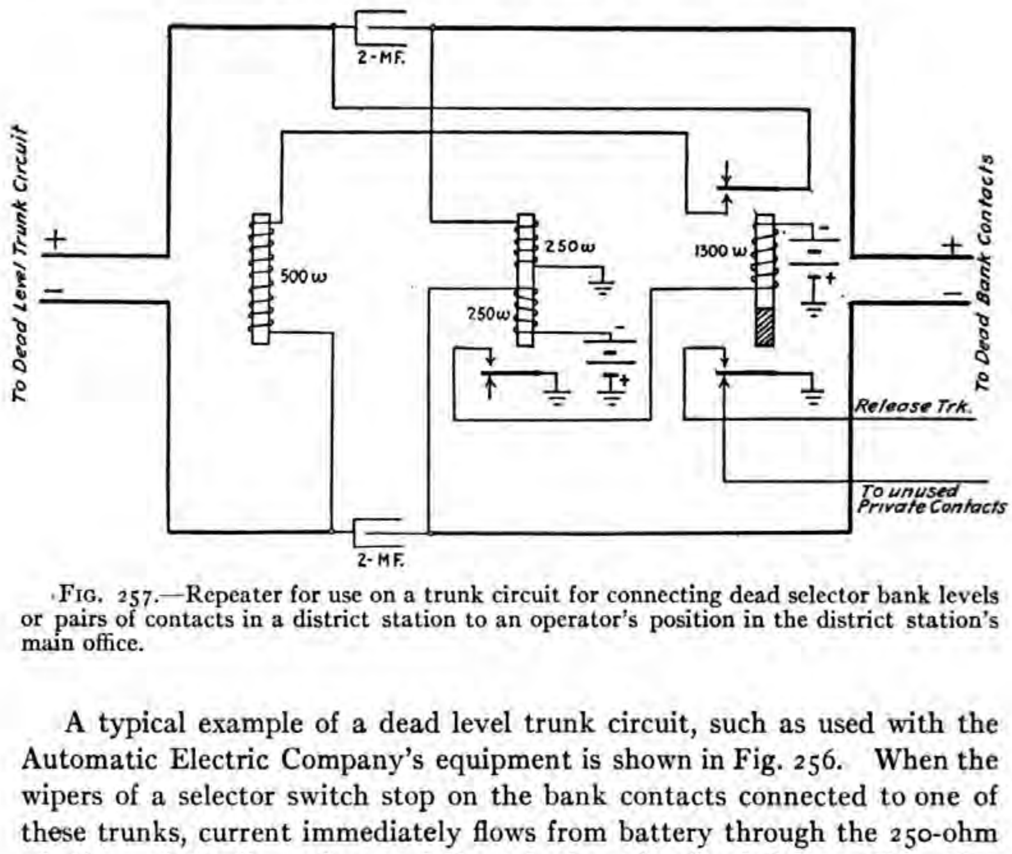


FIG. 257.—Repeater for use on a trunk circuit for connecting dead selector bank levels or pairs of contacts in a district station to an operator's position in the district station's main office.

A typical example of a dead level trunk circuit, such as used with the Automatic Electric Company's equipment is shown in Fig. 256. When the wipers of a selector switch stop on the bank contacts connected to one of these trunks, current immediately flows from battery through the 250-ohm windings of the line relay, and through the subscriber's loop. This relay energizes the 1300-ohm slow-acting relay and lights the lamp. The slow-acting relay grounds the release trunk, thus holding the selector switch on the circuit. When the operator responds, by throwing the key, the 1000-ohm relay cuts off the line signal lamp.

In the event that dead selector levels of bank contacts in a district station, or in a small branch office in which there is no regular attendant, are to be supervised by means of the dead level trunk circuit, it is necessary to connect them to a desk in the nearest main office. To avoid the use of a third wire for the release trunk, each such inter-office dead level trunk circuit must be equipped with a repeater. A circuit for a repeater of this type is shown in Fig. 257.

When occupied, the repeater connects its 500-ohm impedance coil across the trunk, to attract the attention of the information clerk. In a small office only one or two trunks from a dead level are attached to dead level trunks. The rest have their private contacts grounded through the back contact of the slow relay of the repeater. If the available repeaters are in use, and other subscribers call this same level, they will find the private contacts open, and be able to release.

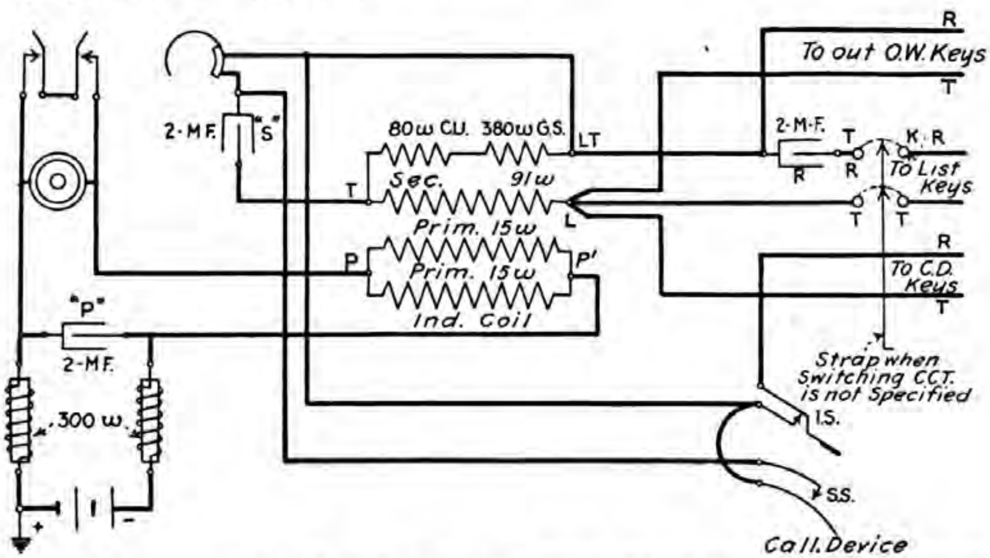


FIG. 258.—Operator's circuit, including calling device, for an information or complaint desk.

Operator's and Calling Device Circuit.—A typical operator's talking, listening, and calling device circuit for an information or complaint switchboard, is shown in Fig. 258. The transmitter of this circuit is equipped with anti-side tone features; leads are provided to out order wire keys, to listening keys on incoming trunks, and to calling device keys. A calling device is wired into the circuit in such a way that connection leads labeled—"To C.D. Keys"—to an outgoing trunk will close the calling loop through circuit leading from the lead marked *R*, through the calling device impulse springs *IS*, the 380- and 80-ohm windings of the induction coil, the 91-ohm secondary induction coil winding, to the other side *T* of the line. At the same time the operator's receiver is bridged across the trunk by a circuit leading from *R* through *IS*, the receiver, the condenser *S*, the secondary winding of the induction coil, and the other side *T* of the trunk. Whenever the calling device dial is turned it shunts out the receiver by closing together the springs *SS* while impulses are being sent.

Outgoing Trunks to the Automatic Switchboard.—A key ending outgoing trunk to a line switch on the automatic switchboard for use by an information operator in calling subscribers, by means of the calling device installed in her position, is shown in Fig. 259. To make a call the operator throws the key, which switches her set onto the outgoing trunk, and operates the calling device in the usual manner. If, after securing the connection, she should

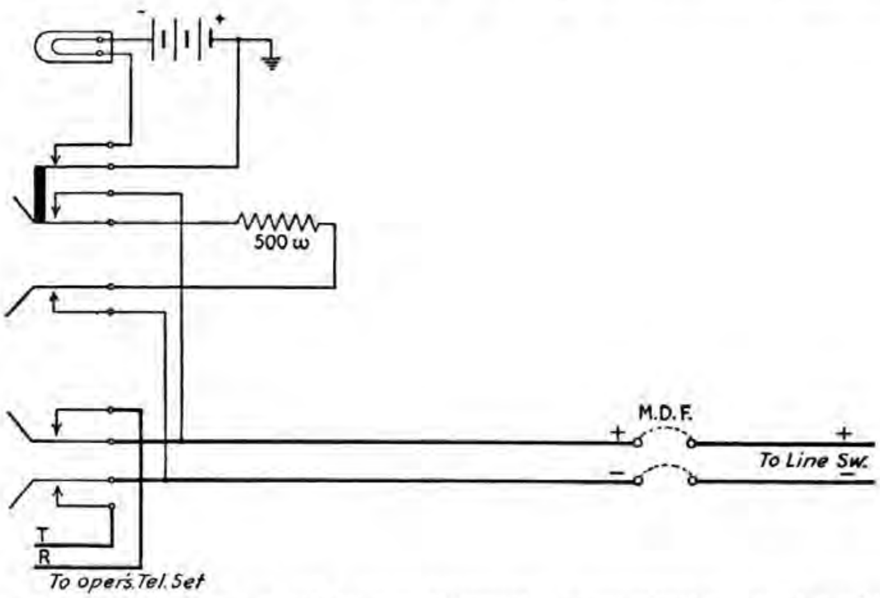


FIG. 259.—Outgoing trunk circuit from an information or complaint operator's position to an automatic switchboard.

wish to switch her set off the trunk without releasing the connection, she throws the other key, shown in the diagram, which bridges a 500-ohm resistance across the trunk and also closes circuit through the holding signal lamp and battery. If, when she is ready to leave the trunk, she does not wish to hold the connection, she simply restores her talking set key to normal, and since this opens the line, the automatic switches used instantly release.

CHAPTER XV

TRAFFIC

Definitions.—The word traffic as used in telephone practice applies to the volume of calls which a system handles. The measure of traffic is commonly the individual call, but for some purposes it is necessary to take the average duration of each connection or call into consideration also. A knowledge of traffic and its laws is essential to the proper design or operation of either an automatic or a manual system. In a discussion of traffic the following terms are used and their meanings should therefore be understood.

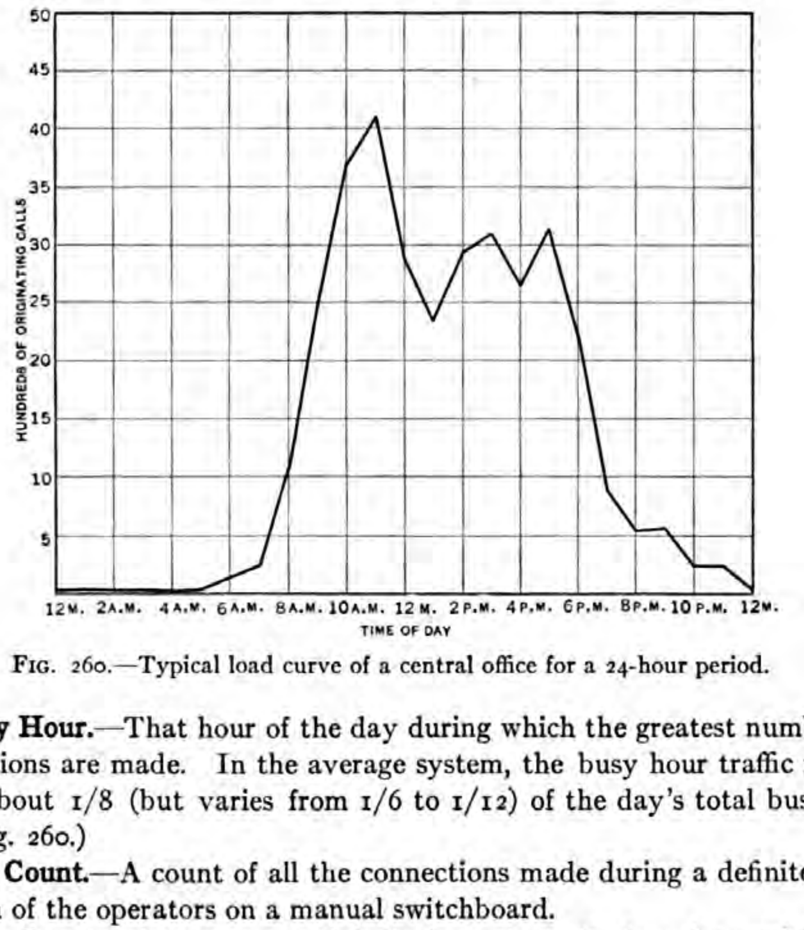


FIG. 260.—Typical load curve of a central office for a 24-hour period.

Busy Hour.—That hour of the day during which the greatest number of connections are made. In the average system, the busy hour traffic represents about 1/8 (but varies from 1/6 to 1/12) of the day's total business. (See Fig. 260.)

Peg Count.—A count of all the connections made during a definite time by each of the operators on a manual switchboard.

Plug Count.—A count at a definite instant of all plugs inserted in the jacks of a manual switchboard.

Traffic Measurements.—In automatic central offices, counts corresponding to peg counts are occasionally taken by the attendants by counting the machines as they complete connections. Calls are also counted by the use of meters. These are generally installed by connecting the release magnets of second and third selector switches on each section of the switchboard to a separate busbar, in series with which is a 1/2-ohm relay which, each time a switch releases, operates and closes a circuit through a meter. Counts similar to plug counts have been taken by counting all of the like machines in operated condition at given times.

The easiest way that has been used to ascertain the maximum traffic through a common battery manual switchboard is to insert a recording ammeter in the leads supplying talking and operating current. By taking the peak of the ammeter curve and dividing it by the current used per connection an accurate idea of the maximum number of simultaneous connections may be secured. This is much more accurate than a plug count because pairs of plugs up do not in a considerable per cent. of cases represent uncompleted conversations, especially during the rush hours.

Average Traffic Requirements.—When an automatic switchboard is designed for a city where it does not displace a previous switchboard, it is not customary to make careful calculations on the amount of traffic which may be placed upon the board. Trunk groups are generally made no larger and sometimes 10 per cent. to 20 per cent. smaller than experience has found necessary in an average central office of corresponding size. If these groups prove to be too small as subscribers are added, they can be increased readily and gradually to meet requirements.

The standard practice is approximately as follows:

For exchanges of 1000 individual lines or less, where no secondary line switches are employed, groups are made large enough to give a trunking capacity of 8 per cent.; i.e., each unit of 100 line switches has trunks to eight first selectors and has eight connector switches mounted upon it, with banks for ten. Each unit for 100 two-party lines is provided with ten trunks to first selectors and has twelve connectors mounted upon it in two groups of six switches each with fourteen banks in two groups of seven each. Each unit for 100 four-party lines is provided with trunks to fourteen first selectors by dividing the line switches into two groups of fifty each, and giving each group seven trunks to first selectors. Sixteen connector switches are installed in four groups of four each with banks for twenty in four groups of five each.

In large offices, when no secondary line switches are employed, the trunking capacity is generally made 10 per cent. instead of 8 per cent. for the individual lines and on the party line boards enough connector switches are installed to fill up the banks given in the preceding paragraph.

In large offices, when secondary line switches are employed, each line switch unit is generally divided into two groups of fifty line switches each, and each group is given seven or eight trunks to secondary line switches. One hundred first selectors are installed for 2000 line switches. The 280 or more secondary line switches in which terminate the trunks from the twenty line switch units are arranged in ten groups of twenty-eight or more each and each provided with ten trunks to first selectors. Connector switches are installed on a 10 per cent. basis. In a very large city, fifteen connector banks are generally provided on each unit.

The total number of trunks, incoming to and outgoing from an office in a multi-office system, is generally made equal to about 8 per cent. of the number of subscribers' lines terminating in the office. Half of these are connected up as outgoing trunks and half as incoming. If there are but two offices in the system, one large one in the center of the city and a smaller one away from the center, the number of trunks is about 8 per cent. of the number of lines terminating in the smaller office. When secondary line switches are used on the trunks, the number is reduced to approximately 5 per cent.

When an automatic system is to displace a previous manual system, the traffic passing through the manual system should be taken as a guide in deciding upon the requisite number of trunks for the automatic.

EFFICIENCY OF TRUNK GROUPS

In making a study of the carrying capacity of automatic and manual trunk groups of various sizes, several truths become apparent.

1. A large trunk group has a greater carrying capacity per trunk than a smaller group.

2. Storage of calls for a few seconds at a time is common practice among manual operators and enables them to slightly smooth out the trunk load curve, but such storage is impossible in an automatic system.

3. An automatic trunk group will carry more calls than a manual group of the same size.

The first truth is strikingly illustrated by the following facts: It has already been stated that it is common practice in automatic systems to provide 8 to 10 per cent. of trunking for outgoing calls from a group of 100 line switches, because experience has shown that this number is required. It has sometimes been necessary to install ten trunks for a group of fifty line switches, but if all the calls being made in a large office could be handled through one group of trunks, a very much smaller percentage would be required. To show how small this might be, counts were made of all the connections up at various moments during the busy hour of every day in a week in a number of automatic offices. From the numbers counted at each office, the largest was selected and placed in the following table:

The average call rate was from ten to twelve per line per day.

This list indicates that if the trunks could be brought up to full efficiency

Office	Number of lines in service	Number of telephones in service	Max. no. of connections up at one time	Ratio of max. no. of connections up to no. of lines in service in per cent.
A	9,300	10,300	258	2.7%
B	7,950	9,914	283	3.6%
C	1,884	2,091	40	2.1%
D	1,870	1,943	38	2.0%
E	1,075	1,150	25	2.3%
F	969	1,008	34	3.5%
G	921	1,199	42	4.5%

a number equal to not more than $3\frac{1}{2}$ per cent. of subscribers lines would be required in the average office.

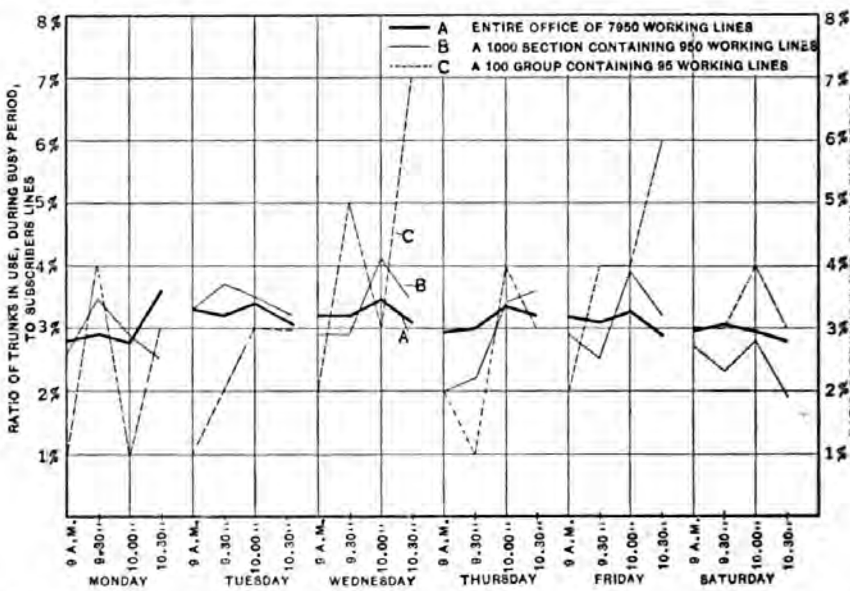


FIG. 261.—Curves showing ratios of trunks in use to susbcribers' lines during the busy hour of each day of a week.

It has already been found possible to reduce the per cent. of first selector switches to 5 in offices carrying an average load by the use of secondary line switches, which combine 100 trunks into one group, serving about 2000 lines.

The great lack of efficiency in small trunk groups is due to the erratic fluctuations in the traffic from moment to moment. It is not unusual for every trunk in one group of ten to be busy at a moment when in a neighboring group all or nearly all trunks are idle, and, five minutes later, to find the conditions just reversed.

The great variations in the traffic of small trunk groups as compared with larger groups is illustrated by the curves in Fig. 261 in which curves *A* show the ratio, in per cent., between the number of trunks in use and the subscribers' lines in service at half-hour intervals during the busy period of each working day of a week in the office designated as *B* in the preceding list.

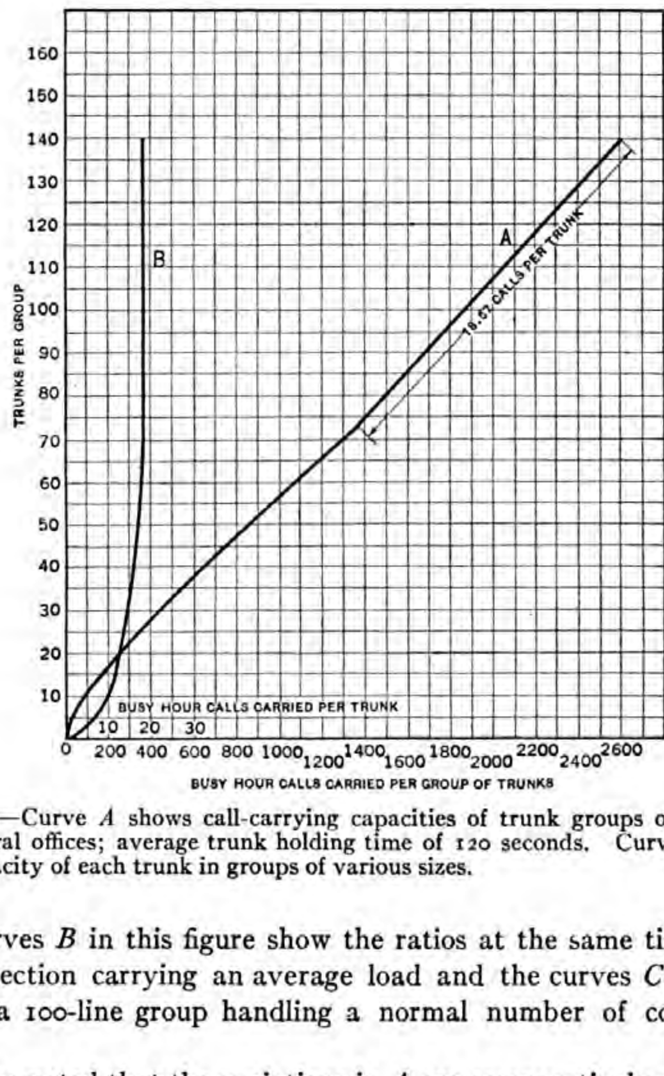


FIG. 262.—Curve *A* shows call-carrying capacities of trunk groups of various sizes, manual central offices; average trunk holding time of 120 seconds. Curve *B* shows call-carrying capacity of each trunk in groups of various sizes.

The curves *B* in this figure show the ratios at the same time for a one thousand section carrying an average load and the curves *C* show similar ratios for a 100-line group handling a normal number of connections in this office.

It will be noted that the variations in *A* are comparatively much smaller than those in *B* while *C* varies very widely.

The second truth on page 369 is readily understood. If two calls come to a manual operator at the same time, one must wait until she cares for the other. In this way each operator slightly smooths out the smaller and quicker variations in the load curve. On an automatic switchboard, this has not been found practicable. Every call must be handled without a delay of even a fraction of a second.

In spite of this fact, the third truth is apparent to any one who has made a study of the matter, viz., that an automatic trunk group will carry more calls than a manually operated group of the same size. Therefore, if an automatic system is to displace a manual system, the busy hour peg counts and plug counts of the operators may be used to ascertain the number of automatic trunks required but the number of cords installed or found in use at the busiest moment on the manual board should not be taken as the number of automatic trunks necessary.

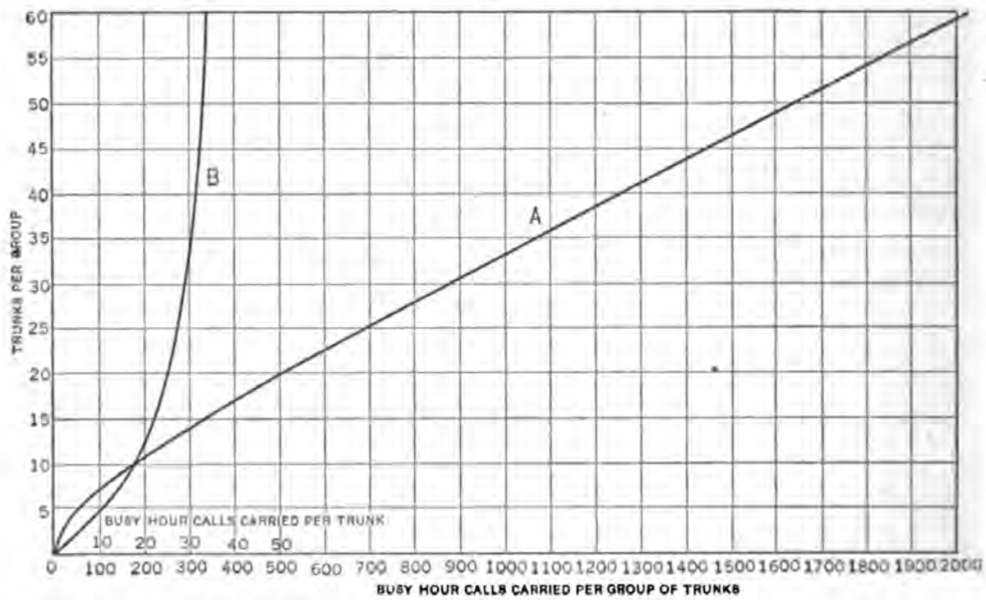


FIG. 263.—Curve A shows call-carrying capacities of trunk groups of various sizes between automatic central offices; average trunk holding time of 83 seconds. Curve B shows call-carrying capacity of each trunk in groups of various sizes.

Curve A Fig. 262 shows the call-carrying capacities of the trunks in the average modern manual telephone system. This curve follows the formula:

$$\text{Trunks} = TC + 4.2\sqrt{(1-T)CT},$$

in which C is the number of calls and T is the average holding time in hours. As a rule a trunk should not be expected to carry over fifteen or eighteen calls during the busy hour even between large, well-managed manual offices, while between smaller offices from ten to twelve is all that can be expected.

Reference to Fig. 263 shows that with automatic trunk groups a much higher carrying capacity is experienced. This curve, which is the result of thousands of observations made in automatic offices, follows the empirical formula:

$$\text{Trunks} = TC + 3.785\ (1-T)\ \sqrt[3]{CT}.$$

For call lengths of less than 130 seconds this formula may be written in the simplified form

$$\text{Trunks} = CT + 3.7\sqrt[3]{TC}.$$

Reasons for High Efficiency of Automatic Trunks.—One reason for the increased efficiency of automatic trunks is found in the shorter time per connection. It is generally considered in manual practice that the average length of connection is two minutes where the *B* operator uses key ringing; whereas many thousands of observations made in automatic plants show an average length of connection not exceeding 83 seconds. It is difficult to account for all of the difference between a holding time of 120 seconds and one of 83 seconds.

The differences in the times required for setting up connections, conversation and disconnecting are shown graphically in Fig. 264. It will be noted that the average subscriber to automatic service answers his telephone quicker than the average manual subscriber. This is especially noticeable when key ringing is used on the manual switchboard. It is conceivable that the average length of conversation in automatic plants is somewhat shorter,

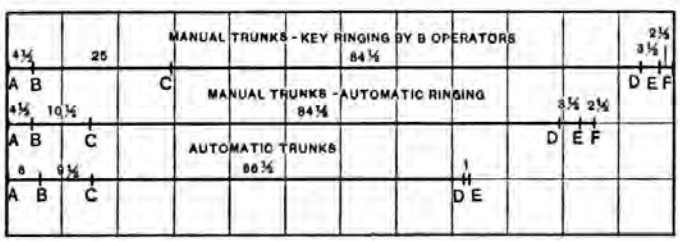


FIG. 264.—Graphical analysis of trunk holding times: *A*, is instant at which a trunk is assigned by a "*B*" operator or taken by an automatic selector switch; *B*, connection completed and ringing started; *C*, subscriber answers; *D*, Conversation completed—disconnect signals given to "*A*" operator; *E*, "*A*" operator or automatic selector disconnects from the trunk; *F*, "*B*" operator releases the trunk.

because of the comparative ease with which a connection may be reestablished, but the actual difference would doubtless be small in the same city and for the same class of subscribers.

Part of the time designated as the conversation period on manual trunks elapses after conversation has really ceased and before the disconnect signals of both subcribers have reached the *A* operator. An automatic connection releases when the calling party or operator disconnects. If a called manual subscriber is connected to a private branch exchange, which is frequently the case in the business districts of cities, there is always more or less loss of time between the instant at which the called party hangs up his receiver and that at which the P. B. X. operator pulls down the connection and thereby gives the disconnect signal to the *A* operator.

Quite a large percentage of calls result in the calling party securing the busy signal or no response from the called party. In fact about 12 per cent. of the former and 16 per cent. of the latter are included in the general average. Consequently since the busy signal is secured more promptly in automatic systems, especially in multi-office areas, and since an automatic subscriber doesn't wait on a "don't answer" call until an operator tells him that the wanted party doesn't respond, but hangs up his receiver of his own initiative both of these types of ineffective calls help to reduce the holding time of the average call.

Calls to "Long Distance," "Information," "Complaint," etc., are all shorter in automatic systems because the calling party secures a direct connection (very often by one turn of the dial) to the desired official, instead of waiting for an "*A*" operator to give him the connection.

The disconnection is accomplished much more quickly in the automatic system and this feature is especially helpful during the busy moments when manual operators are rushed and consequently comparatively slow in pulling down connections. The interval of time that elapses between release of a trunk by one automatic selector and seizure of it by another need be, and often is, but a fraction of a second. This too increases the efficiency of the trunks.

Variations in Holding Times.—The average holding time per connection may be quite different in one city from what it is in another and it is generally shorter in a business office than in a residence office.

In comparison with the average call length of 83 seconds, the following results, of observations made on the private automatic exchange of a busy factory, are interesting.

Time required to complete connection	3.5 secs.
Time required for called party to answer	8.1 secs.
Time spent in conversation	30.1 secs.
Time required for disconnection	1.0 secs.
Total average time	42.7 secs.

In this system a group of ten trunks handled a traffic that sometimes ran up to 300 busy-hour calls, without being overloaded, while Fig. 263 shows that where the length of connection is 83 seconds, a group of ten trunks should not be expected to carry over 180 busy-hour connections. This variation emphasizes the need of a knowledge of the average length of connections in determining trunk group capacities.

Two-way Trunks.—Another point that has been observed in traffic studies and which should be considered here, is that the peak of the load on the trunks outgoing from one office *A* to another office *B* may not occur at the same hour of the day as the peak of the load on the trunks incoming from *B* to *A*. This is sure to be true if A is a business office and B is a residence office. It is readily understood, therefore, that if the same trunks carried connections in either direction, as required, that greater trunk efficiency would be secured. Two-way trunks are now used to a very limited extent in automatic practice and it is probable that they will eventually be used much more, although they are not considered practicable in common battery manual systems between central offices.

Need of Traffic Studies.—It has not been customary in automatic central offices to keep up the constant detailed study of traffic that is made in well-regulated manual offices, where frequent peg counts and plug counts are taken for several reasons:

1. To secure intimate knowledge of traffic not only during the busy hour but throughout the entire day from 5 A.M. to 11 P.M. so that at all times the number of operators may be kept adjusted as closely to the load curve as practicable. Failure to do this would usually result either in slow service on part or all of the positions at times or in a decided loss in wages paid to unnecessary operators.

2. To distribute the load evenly among the operators, thus requiring each to do her share of the work, and ensuring every subscriber attention as prompt as that received by others.

With automatic switchboard equipment the conditions are different. The first reason for traffic study in a manual exchange does not apply to an automatic at all, because, since the connections are made by machines, it is impracticable to eliminate idle machines during the less busy hours or to secure any economy by doing so. The second reason does not apply either. All calls passing over a group of trunks are distributed among them automatically. It is impossible for any machine to shirk its share of the load. It, therefore, is necessary only to be sure that the proper number of machines are installed in each section of the switchboard to carry the peak load safely. This can be most readily determined without a call count by having the switchboard attendants watch for overloaded and underloaded sections.

Distributing the Load.—A lack of trunks may be remedied in either one of two ways.

By shifting subscribers' lines from an overloaded unit to an underloaded one.

By increasing the number of trunks from or to the overloaded unit.

The first method is one not generally followed, because since no intermediate distributing frame is employed between the connector switch banks and subscribers' lines, and since the connector switches for receiving calls for each group of 100 lines are installed on the same unit as the line switches which make their outgoing connections, a line can not readily be shifted from one line switch unit to another without changing the subscriber's number, an annoyance to which he would object.

While it would be entirely practicable to install an intermediate frame that would make it possible to shift a line easily without changing its number, the benefit which it would be in a properly installed office would be generally more than offset by its disadvantages, among which are the following:

1. Increased first cost of equipment and of space required.

2. Increased opportunity for troubles from poor connections at the ends of the intermediate frame jumpers.

3. A departure from an arrangement of all subscribers' line switches, which is so simple and systematic that all switchboard attendants can readily memorize it, to a more complicated arrangement which would require them to refer to guides of some sort and which therefore would delay them in supervising connections and attending to subscribers' complaints.

A variation of this method, which has been used satisfactorily and economically in several plants, is to install a special unit or upright to which very busy lines may be transferred from all overloaded units. This plan leaves practically all lines connected in regular order, because the removal of a very few of the busiest lines will generally afford an overloaded unit all the relief it requires. The number of a subscriber is not changed when his line is transferred to the supplementary unit.

A more common method is to increase the number of outgoing trunks where necessary.

Whether the trunks outgoing from any line switch unit lead to secondary line switches or to first selectors it is good practice to pass them through an intermediate distributing frame which will enable their number or distribution to be readily changed. It is not a very difficult matter, however to increase the number of these trunks without an intermediate frame. To prepare for a proper redistribution of the trunks busy-hour observations should be made on less busy sections of the switchboard to determine where the number of trunks may be reduced safely. For example, if there are ten selector switches in a given group and an attendant who has made frequent busy-hour observations personally or by means of meters, has never found more than six in use at any one time it may be assumed that no more than seven or eight are needed. Some managers advise removing the extra switches from service, whether they are needed elsewhere or not, in order to reduce the number of machines to be kept in good working order as much as possible. They contend that while the switches might be used sometimes when there is a great rush of calls due to a large fire or other events of great public interest, it is impossible to care for all calls in such an emergency anyway, whether the switchboard is manual or automatic. Of course if it is impracticable to reduce the number of trunking switches in any section, the overburdened section must be relieved by the addition of new trunking switches. Since automatic switchboards are built in small sections it is generally a very simple matter to install additional facilities.

Distributing the Load at Time of Installation.—An uneven distribution of the load among the primary line switch units can be avoided to a large extent by a proper system of distributing the lines to the units at the time the switchboard is first put into service, and as additional lines are added to it. The subscribers should be divided first into two classes, namely, business and residence. The residence lines should then be distributed equally among the line switch units. The business lines should be further subdivided into classes indicated by the kinds of business for which they are used. Lines to grocers and markets should be put into one class; lines to stock brokers, banks, etc., in another; lines to wholesale and commission merchants in another; lines to railroad offices in another, etc. The lines in these subclasses should then be distributed among the line switch units. Of course the houses which have more than one line under the same number must be assigned to the units especially equipped with trunking connector switches for handling multiple lines and private-branch-exchange trunks.

Each class of lines has its rush hour. For example, housekeepers are calling their grocers and markets in the early forenoon but are not doing so to any extent in the middle of the day, consequently the distribution of each class of calls among the line switch units is an excellent preventative of unevenly loaded units, at any hour of the day.

NOTE.—The reader who wishes to pursue this subject further is referred to the paper by Mr. W. Lee Campbell entitled "Traffic studies in Automatic Switchboard Telephone Systems," published in the *Proceedings* of the American Institute of Electrical Engineers, March, 1914.

CHAPTER XVI

DEVELOPMENT STUDIES

Definition and Object.—The term "Development Study" is applied to the study that should be made in any city in which it is proposed to establish a telephone system, or in any city where extensive additions or betterments to the existing system are contemplated. The object of the study is to determine the probable requirements for telephone service of the city, and the approximate location of such requirements, for both the present and the future, so that all work executed for extensions and betterments will be planned to provide telephonic facilities at the minimum cost, consistent with good engineering, and all material entering into the providing of facilities will be properly located and of a character to serve during its normal efficient life.

The Fundamental Plan.—The result of such a study is a comprehensive plan for all initial and future work. The result is customarily referred to as the "Fundamental Plan" of the city.

In order to provide telephonic facilities to a city line, a pair of wires is required from the subscriber's station to the central office. A main line subscriber obviously requires one pair for his exclusive use, while a party line subscriber shares a pair of wires with others, the number of subscribers being determined by the number of stations that class of service will permit to be connected to a single pair, and also by the number that can be attached in actual practice. Under average conditions a four-party line will serve 2.8 subscribers and a two-party line 1.3 subscribers. It will be seen, therefore, that in making a development study the number of lines is the important factor, and the number of telephones merely an aid in learning the number and approximate location of the required lines.

The following are, therefore, the main points to be determined by a development study:

1. The present and ultimate number of lines necessary to take care of the present and ultimate possibilities.

2. The most economical location of offices for the present and ultimate requirements.

3. The ultimate underground conduit plan.

Inasmuch as the average life of material entering into the construction of a telephone system is approximately fifteen years, the ultimate requirements are usually referred to as the requirements fifteen years later than the date of the development study. It must be borne in mind that a development study is, in reality, a study for a given number of lines in a designated community and the results of the study, or the fundamental plan, will hold if the estimated ultimate is reached a few years prior or subsequent to the fifteen-year period.

The practical method of determining the present and ultimate possibilities is by an actual count of the present possibilities in each block of the city. The possibilities should be classified according to the kinds of service furnished and translated into the required number of lines or pairs.

While a study of the present number of lines in use and their location may be of value in making a development study of a city with an existing system, it should not be taken for granted that this satisfies the requirements unless there is at least one telephone for every eight inhabitants in an average American city, in which practically everybody is white. Where a large portion of the population belongs to the negro race, or a considerable portion of the white population is made up of very poor workers in factories, the requirements will be less. In some cities one telephone to fifteen inhabitants is all that can be expected.

The number of possibilities in each city block is usually determined by what is termed a "house count" and is taken by making a block-by-block study of the city and determining from the classes of the buildings and their uses, the probable telephone requirements of the occupants. The detailed methods for taking such a count for either an automatic or a manual system have been repeatedly discussed in various publications and will not be repeated here.

After these data have been gathered they should be transferred to a good-sized map of the city. On each block of this map should be indicated the number of lines necessary to provide service for prospective patrons. When the map showing the immediate lines is completed, then a study should be made of the probable growth of the city both in numbers and in area during the next fifteen years.

If there is a well-defined tendency for the city to grow in some particular direction, this should be discovered and a map should be made showing the expected number and locations of the necessary lines at the end of the fifteen-year period.

When this map has been completed and all data on the existing plant are at hand, the determination of the central office location or locations may be undertaken.

First, the study of the best central office locations at the end of a fifteen-year period should be made, and then the best arrangement for immediate needs should be compared with it and a plan thus worked out which will not only satisfy present needs, but which may be extended and enlarged year by year without wasteful rearrangement. When making this plan, the equipment already installed, if any, should be fully considered, and those portions of it which are worth while should be incorporated in the new plan.

DEVELOPMENT STUDIES FOR AUTOMATIC TELEPHONE SYSTEMS

What has been said in the foregoing portion of this chapter is as applicable to a manual system as to an automatic, and it therefore will not be enlarged upon, but we have now come to the parting of the ways, because automatic equipment practice may indicate that a multi-office system should be installed where manual practice would justify nothing but a single-office system. The planning of a multi-office automatic system not only differs from the planning of a multi-office manual system, but the task should be approached with an entirely different attitude of mind.

While in manual practice, systems serving large cities are divided up to save cable and conduit, division of a system of less than 10,000 lines is generally regarded as undesirable and to be avoided, if it is practicable to do so. It is therefore the general practice in the smaller cities to carry all or the bulk of the traffic on one large switchboard, branch offices being installed under sufferance and only for the most urgent reasons. An engineer laying out an automatic plant should realize that while this antipathy toward dividing offices of 10,000 lines or less is reasonable in manual practice, it is not reasonable in automatic practice.[1]

The first cost of any telephone plant may be divided readily into three principal items:

1. Cost of the apparatus (both central office and subscriber's station).
2. Cost of the central office buildings and furnishings.
3. Cost of the wire, cable and conduit plant.

The last of the items named is the largest of the three. It is a variable quantity affected by the number of lines and offices in the system, the kind of soil, character of pavements, the density of population, form of the city, obstructions such as lakes, rivers, etc. Generally, however, it will amount to more than the other two items combined and it is not rare for it to be two-thirds of the entire first cost.

ECONOMIC WASTE IN TELEPHONE SYSTEMS AND ITS REMEDIES

Considering this, it is hard to realize that in the face of all the progress which has been made in the development of the telephone art the efficiency

[1] See paper entitled "A Study of Multi-office Automatic Switchboard Telephone Systems" presented by Mr. W. Lee Campbell before the American Institute of Electrical Engineers at the Annual Convention, June 29—July 2, 1908.

of the cable and conduit is still so small that in most systems at least nine-tenths of the subscribers' lines are idle even at the peak of the load. In the chapter on Traffic is shown a list of results of observations which indicate that in automatic offices of 8000 to 10,000 lines, handling a heavy load, the maximum number of conversations taking place at the busiest moment does not equal 4 per cent. of the number of lines in service. Since each conversation requires two lines these figures show less than 8 per cent. of the lines in actual use for conversation, operating or signalling at the peak of the load.

To reduce the great economic waste represented by the 90 per cent. of the costly cable and conduit equipment which is idle even at the busiest moment, two remedies have been applied to some extent, viz., partly lines and multiplication of offices.

The first is but a poor and inadequate remedy at best and not applicable to the lines of busy subscribers.

Just how much saving can be effected by the second remedy depends upon the local conditions in each city, but we have yet to realize through the medium of automatic switching the full benefits of it. Automatic telephone engineers believe that in the system of the future small district stations, each serving a comparatively small territory, will be distributed over each city and that these district stations will be interconnected by trunks only through one or more central offices. Automatic telephone experience and development are yearly bringing such a system nearer realization, for at the present time a number of automatic district stations are operating successfully and more are being installed to advantage in various cities using full automatic or semi-automatic equipment.

The increase in the cost of operating labor caused by the division of a manual system is a very serious obstacle. In fact, while there are conditions under which the saving in the annual charges on cable and conduit will more than offset the increase in operating labor, experience shows that where the ultimate number of subscribers that may be expected in an office district within fifteen years does not exceed the usual capacity of a single multiple board (about 10,000 lines), and there is no concentrated group of subscribers at a considerable distance from the best location for a single office, that a one-office system will generally be the most economical when manual equipment is used. Furthermore, in a larger system where division is necessary experience shows that the saving in the annual charges on cable conductors of No. 22 B. & S. gauge copper are generally not sufficient when compared with the increased operating expense to warrant placing central offices nearer than two miles apart.

Division of automatic systems may be carried profitably much further on account of the very slow increase in central office expenses resulting from adding to the number of offices.

There is still another point to be considered however, namely, the effect of plant division on service. Therein lies a very serious objection to multi-office manual systems, because slower service, more wrong connections and more premature disconnections are the inevitable results of having calls handled by two operators instead of by one. There is therefore strong opposition, where competition is keen, to dividing up manual systems, on account of the depreciation of the service.

The service in a multi-office automatic system is practically the same as in a single-office system. All calls are trunked anyhow, whether one office is used or more. The time required for calling, the method of calling, and the number of switches employed in setting up a connection are each the same whether the system employs a single office or a number of them.

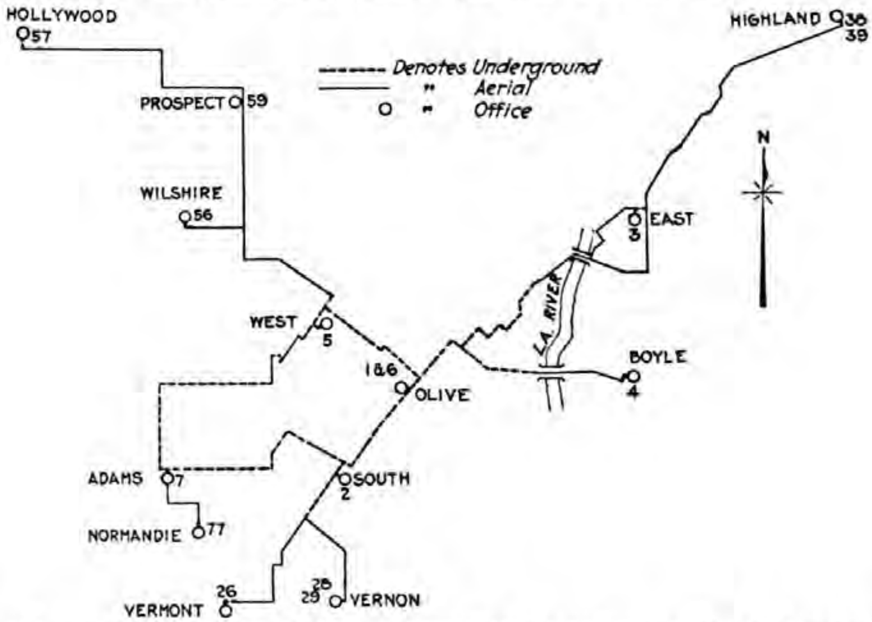


FIG. 265.—Skeleton diagram of the automatic telephone system of Los Angeles, Cal.

Not only do the reasons which make the division of manual systems undesirable apply with but little force to automatic systems, but the saving in cable and conduit realized by division is much greater in a multi-office automatic system for two reasons: First, because division may be carried much farther without greatly increasing operating expenses, and second because trunks between automatic offices are more efficient than trunks between manual offices and a less number is therefore required. The greater efficiency of automatic trunks is more fully explained in the chapter on Traffic.

Types of Automatic Offices.—There are three types of automatic switchboard offices:

1. Main offices.
2. Branch offices.
3. District stations.

A main office is one such as that used in a single office system. In a multi-office system there may be several main offices, but each will rank with the others and in no way be subsidiary to them.

A branch office is subsidiary to a main office which may have several branches but acts as a receiving and distributing office for the trunk calls incoming to all of them from other main offices or the branches of other main offices.

The Los Angeles, Cal. System.—A typical system showing the use of main and branch offices is that in Los Angeles, Cal. This system is illustrated in Fig. 265. There are six main offices, viz., Olive, West, Adams, South, Boyle and East, each with an ultimate capacity of 10,000 lines except Olive which has an ultimate capacity of 20,000 lines.

The character of each of the other offices and the subscriber's numbers used in each are shown in the following list:

Olive office (Main)........	Numbered from 10,000 to 19,999, also 60,000 to 69,999.
South office (Main).......	Numbered from 21,000 to 25,999.
Vermont District station...	Numbered from 26,100 to 26,999.
Vernon Branch office.....	Numbered from 28,100 to 29,999.
East office (Main)........	Numbered from 31,000 to 31,999.
Highland Branch office....	Numbered from 38,100 to 39,999.
Boyle office (Main).......	Numbered from 41,000 to 41,999.
West office (Main)........	Numbered from 51,000 to 55,999.
Wilshire District station...	Numbered from 56,100 to 56,999.
Hollywood Branch office...	Numbered from 57,100 to 57,999.
Prospect Branch office.....	Numbered from 59,100 to 59,999.
Adams office (Main)......	Numbered from 71,000 to 73,999.
Normandie District Station	Numbered from 77,100 to 77,999.

South office has one branch, Vernon and a district station, Vermont; West office has two branches, Prospect Park and Hollywood and a district station, Wilshire; East office has a branch, Highland Park, and Adams has a district station, Normandie. The numbers in each branch office necessarily commence with the same digit as the numbers in the main office to which it connects; that is, one or more of the sections of 1000 numbers is taken from the main office and is set aside for use in the branch. For example: the lines now equipped in South office are numbered from 21,000 to 25,999 and the numbers in its branch Vernon, run from 28,000 to 29,999. It is, of course, unnecessary for a calling subscriber to know to which office he is connected or to which office the party he desires to call is connected.

The trunking between offices is all automatic. A subscriber for instance, in the East office, who, on the first move of his dial turns it from the number

2, will automatically select a local trunk line to a second selector in South office, and if he makes the second turn from the number 8, the second selector at South office will automatically connect him to a trunk line terminating in an idle third selector in the "28,000" group at Vernon branch office. Similarly, any call incoming to the Vernon branch from other main-office districts must pass through South office, because any telephone connected to any other main office will be automatically trunked through to South office so soon as its dial is operated from No. 2 finger hole.

Suppose a subscriber connected to the Vernon office wishes to call 62,138, which is an Olive Street office number. The first movement of the dial operates a first selector at Vernon office, and extends the connection over an idle trunk to a second selector switch in the Olive Street office. The second digit (2) will operate the second selector at Olive Street office, and extend the connection to a third selector in the "2000" section of the Olive Street switchboard. The third digit 1 will extend the connection to an idle connector switch in the "100" group of the "2000" section. The last two digits will operate this connector switch and complete the connection to "38" in this particular 100. Thus, it is shown that outgoing calls from a branch office do not go through its Main office when destined for another main office.

Suppose, again, that a Vernon office subscriber is calling 23,257 which is in the South office. The first movement of the dial operates a first selector in the Vernon office and selects a trunk to a second selector in the Vernon office. The second movement of the dial raises the shaft of this second selector three steps, and selects an idle trunk to a third selector in the "3000" group of the South office. The third movement extends the connection through a local trunk in the South office, to an idle connector in the "200" group, and the last two motions of the dial result in the completion of the connection to "57" in that particular hundred.

It should therefore be noted, as indicated in this paragraph, that when a branch-office subscriber calls a number in his own main-office district, that he does not secure a trunk to his main office by operating a first selector switch, because if it should develop later, when he made the third movement of his calling device dial, that the desired number also was connected to the branch office it would then be necessary to extend the connection back to the branch office over another trunk. To avoid this the trunks for outgoing calls from a branch to its main office terminate in second selector banks at the branch and in third selector switches at its main office. With this practice a connection from one subscriber to another in the Vernon branch office is completed entirely in the branch, because the trunks from the eighth and ninth levels of the Vernon second selector banks terminate in third selectors in the same office, while the trunks from the first level lead to third selectors in the "1000" group in South office; the trunks from the second level lead to third selectors in the "2000" group at South office, etc., there being an outgoing trunk group from Vernon to South for each thousand section of the South office switchboard.

District Stations.—A district station is installed by placing one or more line-switch units complete with connector switches in a small building at the telephonic center of a district, generally 1 mile or more distant from the nearest central office. The lines of all telephones in the district are brought to the district station and are there connected to the line switches. The first selectors to which these line switches are trunked remain at the nearest large central office, consequently when a district station subscriber removes his receiver from his switch hook preparatory to making a call, his line switch instantly puts him into connection by means of a trunk with a first-selector switch at central office. The connectors for handling the calls to the district station telephones are mounted in their usual places on the backs of the line-switch units, and are connected by trunks to the banks of second, or third selectors, also located at the nearest central office, unless the station is a comparatively large one (500 lines or over) in which event the third selectors may be installed at the district station instead of at the central office. Thus all calls from and to the district are handled over trunks instead of over subscribers' lines.

Since there are usually but ten first selectors and ten connectors for each 100 lines, and since but three pairs are needed for testing and supervisory circuits to the district station, a total of twenty-three trunk pairs is sufficient between a station of 100 lines and the central office. This leaves a net saving of seventy-seven pairs of wires per 100 lines. In district-station practice stations of less than 500 subscribers are generally unattended and supervised entirely from the central office to which they connect. This is so thoroughly worked out (see Chapter XIV) that the wire chief can test every line entering each district station without leaving his desk at central. Stations of 500 lines or more are generally put into a combination residence and office building so that one attendant living in the building gives the equipment all the attention that it may require, although he may spend much of his time elsewhere.

The Columbus, O. System.—A typical system employing district stations is that at Columbus, Ohio, which, as indicated in Fig. 266 employs one large main central office and nine district stations varying in size from fifty to 625 working lines.

To illustrate how connections between district station subscribers are made, some imaginary calls will be followed through the Columbus system.

Suppose that 14,625 connected to the Blake office in the extreme northern part of the city is calling 13,578, who is connected to the Hanford station in the southern part of the city. When the Blake subscriber turns his dial from finger hole 1 his line switch plunges into its bank and connects his line to an idle trunk terminating in a first selector switch at the main office. This first selector is operated as the dial rotates back to normal and extends the connection to an idle second selector, also in the main office. When the calling party's dial is operated from finger hole 3 this second selector extends the connection to a third selector in the "13,000" group of switches at Main.

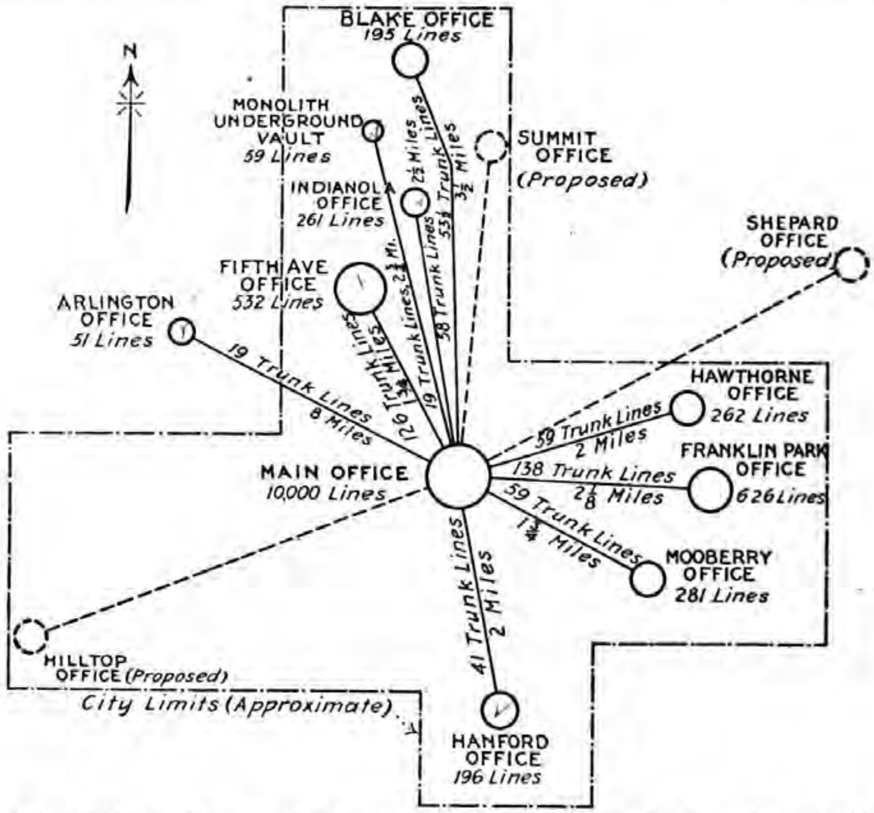


FIG. 266.—Skeleton diagram of automatic telephone system of one main central office surrounded by district stations in Columbus, O.

The next turning of the dial from finger hole 5 results in the operation of this third selector, which extends the connection to an idle trunk terminating in a connector switch on the "500" board at the Hanford station. This connector switch responds to the last two motions of the dial and completes the connection to "78" in that group, thus ending the operation of connecting the Blake subscriber to Hanford subscriber 13,578. This connection is illustrated diagrammatically in Fig. 267.

Trunks for Reverting District Station Calls.—Since, as stated, a district station line is instantly connected to a trunk to main office so soon as a calling subscriber lifts his receiver from his switch hook (or makes the first turn of his dial if a three-wire system is used), it is evident that even if he should wish to call another subscriber connected to his own district station that the connection will pass through the main office and will then be extended back to the district station, in which the call originated, when the connector switch trunk is occupied. Therefore, as

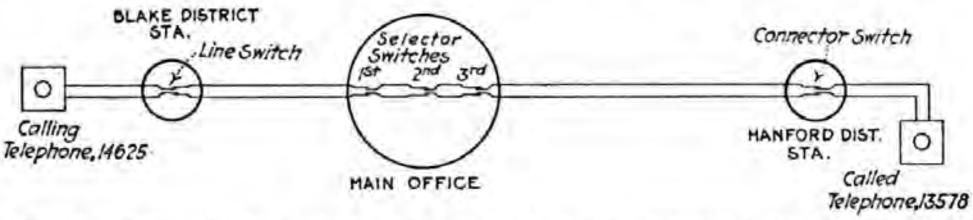


FIG. 267.—Diagram illustrating steps in setting up a connection from a subscriber connected to Blake to one connected to Hanford district station.

indicated in Fig. 268, such a connection occupies two trunks between the district station and its main office.

Where conditions warrant the use of somewhat more complicated and expensive district station apparatus, equipment may be installed at a district station which will avoid the necessity of using any trunk between

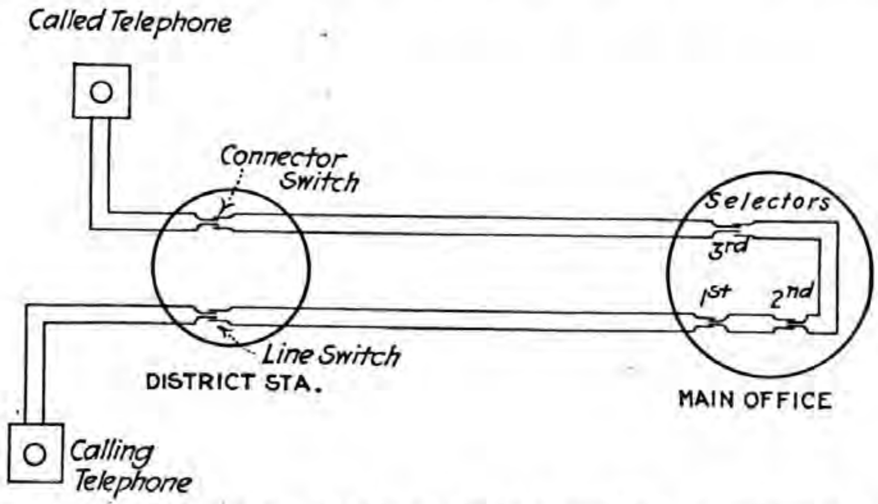


FIG. 268.—Showing switches and inter-office trunks used for a reverting district-station call.

a district station and its main office during a local conversation. When this apparatus is used the trunk from the district station to the main office is occupied until by the selection of the desired "1000" or "100" group the calling subscriber indicates that the connection is to revert to his own district station, whereupon the entire connection is automatically released and a local connection made to an idle third selector or connector in the district station.

Such apparatus is especially adapted to stations having a preponderance of the following characteristics.

1. A comparatively large percentage of local calls.

2. Comparatively expensive trunks to main office.

3. Comparatively constant local supervision, such as generally obtains in a district station of more than 500 lines.

While this apparatus is entirely practicable it should only be installed where a study of local conditions leads to the conclusion that it is warranted. Therefore, to simplify the following discussion no further reference will be made to it.

Utility Trunks to District Stations.—To the talking trunks for each district station must be added a few utility trunks. These trunks are no more "incoming" than they are "outgoing," but it is immaterial which they are called as they can not be grouped with any of the other trunks. They are used for furnishing ringing and busy signal currents, to the district station from its main office and for supplying the main office attendants with supervisory signals, which enable them to supervise the district station from Main. The wire chief at main also uses some of these utility wires for operating a "test distributor" at each district station which enables him to connect to a test connector on any line switch-board and thus test all district station lines from the main office. Five utility trunks are generally specified for the smaller offices and three for the larger. The reason for this is that district stations of over 500 lines are generally equipped with ringing and busy signalling machines of their own so that trunks from the main office are not required for these purposes.

Relative Advantages of District Stations and Branch Offices or Small Main Offices.—Generally, a branch office or a small main office is best suited to a district in which there is a large "community-of-interest," also where enough equipment is to be installed to warrant the expense of a constant attendant, at least during the hours from 6 A.M. to 10 P.M.

A district station is best suited to a territory where the community-of-interest is comparatively small and where not more than 1000 lines are to be served. It is also especially suited to an isolated district which would require a heavy investment in cable to connect it to the nearest main office and where the expense of a constant local attendant would be unwarranted. A district station uses the simplest known automatic apparatus and all calls to or from it can be supervised at its main office.

A district station may often be installed as an excellent expedient for relieving a district in which all cable pairs have been exhausted. To accomplish this the present line cable may be converted into a trunk cable, so that a 100-pair line cable, for example, may be made to carry all trunks to a 400-line district station.

A strong objection to a small main or a branch office, as compared with a district station is that it requires its own individual group of outgoing trunks to every main office in the system. Trunking studies which have been made indicate that in systems with an ultimate capacity of less than 10,000 lines the total trunk mileage is generally the least where only district stations are employed, with the exception that a second main office is sometimes found advisable in a comparatively isolated suburb, with a business center of its own, or in a district requiring a comparatively large office; i.e., one of more than 100 lines.

Ultimate Capacities.—When an area is likely to grow beyond 10,000 subscribers' stations within a fifteen-year period, and especially if more than

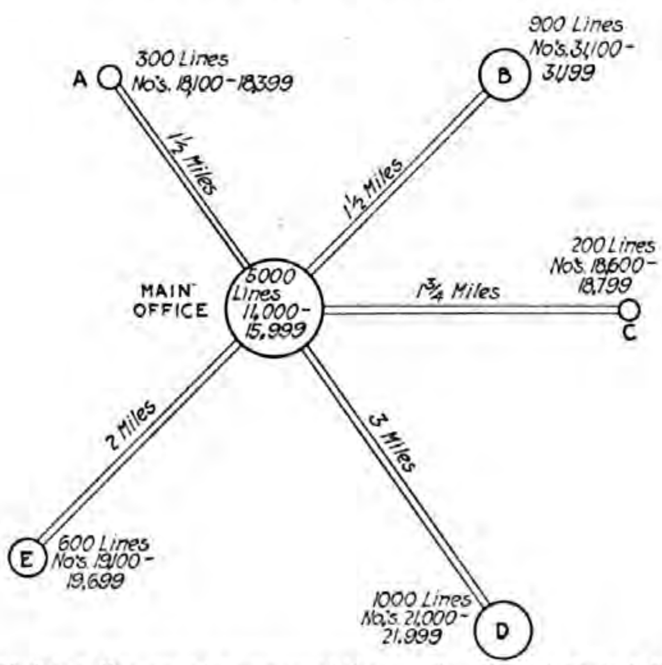


FIG. 269.—Skeleton diagram of a system of three main offices, "Main," B and D, and three district stations A, C, and E.

one main office or if a branch office will be required it generally would be unwise to attempt to serve it with four digit numbers. Instead, five figure numbers should be used; i. e., the system should have an ultimate capacity of 100,000 lines rather than 10,000. There would be two disadvantages to the 100,000 line capacity system.

1. Third selectors would be added, increasing the first cost and slightly increasing operating expenses.

2. Five motions of the dial instead of four would be required to call each number.

Neither of these are very serious disadvantages, and are outbalanced by the two advantages which would be:

1. Room in the numbering system for a large growth in all offices.

2. A reduction in the trunk mileage.

In explanation of the second advantage, reference is made to Fig. 269, which shows a hypothetical system, which if of 10,000 capacity, would require six groups of trunks from each outlying main office to central office, but if changed to one of 100,000 capacity with the numbering arranged approximately as shown in Fig. 269, would require but one group of trunks for calls from each outlying main office to the central main office. *B* and *D* are treated as main offices because it is probable that they would require the least trunk mileage when so arranged.

This being the case, the size and relative importance of each make its treatment as a main advisable, so that an accident to its trunk cables will not throw it entirely out of service.

A, *C* and *E* are shown as district stations and, therefore, their line numbers commence with the same digit that those in the central main office do, i.e., with 1.

Main Office Locations.—The proper theoretical location for a main office for a given district is the point to which all telephones may be connected with the smallest total wire mileage. This point is at the intersection of two lines at right angles to each other and each of which divides the subscribers' lines into two groups equal in number. When two or more main offices are used, each should be at the telephonic center of its district and the boundary line between two adjacent offices should be equidistant from each and perpendicular to a line joining the two offices which it separates.

Location of a Single Central Office.—When the fifteen-year map does not show a concentrated group of subscribers at a distance of 1 mile or more from the telephonic center of the entire city it may be taken for granted that a single office is the most economical arrangement. When the theoretical site for the office has been determined it may be advisable to depart from it somewhat in order to use existing conduit leads or an existing building or to secure new property at a more reasonable price. An engineering study will be necessary to decide how far the office may be moved economically in order to allow for any of these factors.

Central Office Locations in a Multi-office Automatic System.—To take up the matter in its simplest form first, a system in which there is but one main central office, together with a number of district stations, will be given primary consideration.

The location of this central office will be affected by the number of district stations installed, unless the same number of subscribers should perchance be put into district stations on each of the four sides of the office; but take, for example, a case in which the business houses are concentrated at one side of the city on account of a lake, river or other obstruction. Then the number of district stations installed in the residence section, directly opposite the obstruction will move the telephonic center toward the obstruction and toward the actual center of the business district. It is, therefore, necessary in order to locate the central office properly to arrive at a fairly accurate idea as to which subscribers will be connected into district stations, and, consequently, trunk their calls into the main office.

District Station Locations.—Installing line switches for serving a given group of subscribers in a district station instead of in the central office affects the following items of first cost:

1. Increases cost of switchboard and power equipment.
2. Increases or decreases cost of buildings and lots.
3. Decreases cost of cable and conduit.

A careful study should be made of each proposed location for a district station to determine the effect upon each of these items. After these results have been determined, the effect upon annual charges and operating expenses should be calculated.

Effect on the Cost of Switchboard and Power Equipment.—The cost of switchboard and power equipment for serving a given number of subscribers from a district station is greater than that of the equipment necessary to serve the same number of subscribers from the central office, because while the same type of equipment is used, the cost of the trunking, power and supervisory apparatus is increased.

Each trunk from the main office to a district station must be provided, in addition to the usual second or third selector, with cross connecting frame terminals at each end, with a repeater at the main office end and with certain test and supervisory equipment. Each trunk from the district station to the main office requires, in addition to the usual first selector, cross connecting frame terminals at each end, and a repeater at the district station. When secondary line switches are used between the line switches and first selectors at the central office the number of first selectors is increased by the use of district stations. For example, when secondary line switches are used the number of first selectors required to handle calls for 5000 lines all connected to one central office would be less than if the same system were built with 3000 lines connected direct to the central office, and the remaining 2000 lines connected to four different stations of 500 lines each.

The cost of the power equipment is greater in a multi-office system than in a single-office system, because, as is readily apparent, it is more expensive to install apparatus for furnishing the necessary amount of power from a number of small units than from one large plant.

Generally in district stations of from 100 to 500 lines, the battery charging will be done from the main office and in district stations of 500 lines and up, the charging and ringing equipment will be located at the district station.

In district stations of 500 lines or over, and especially when situated at a considerable distance from the main office, it is generally advisable to use secondary line switches on the trunks in order to reduce the cost of cable pairs, but that should be a matter of special study for each district station.

Effect on Cost of Central Office Building and Lots.—The total number of cubic feet of space required for switchboard and power equipment is practically unaffected by the use of district stations, because it is customary in district stations to make aisles smaller, ceilings lower, and generally to economize in space more than in the main central offices, so that, although a little more equipment is to be taken care of when district stations are used, experience shows that the total number of cubic feet of space required is about the same. The cost of the space in a main office fire-proof building, may be taken at the rate of 19 cents per cubic foot, for purposes of comparison; while experience would indicate that in district stations the cost per cubic foot of space may be taken at not to exceed 10 cents, because the buildings are of rough finish, and not provided with plumbing or elaborate heating systems. Since the total number of cubic feet of space required in a district station system is practically the same as in a one-office system, and the cost of the space in district stations is cheaper than in the main office, it follows that the total cost of all office buildings may be reduced by the use of district stations.

It will generally be found that the land on which a district station building may be installed is decidedly cheaper than that on which the main central office building is placed. It is suggested that when an operating company purchases a lot, puts up a small district station on the rear of it, and then sells the rest for residence purposes that the cost of the land occupied by the district station building may generally be reduced to a very nominal figure. Some operating companies have made the cost of building space and lot that can properly be charged against the district station, a comparatively small figure by purchasing, or renting a residence, installing the district station equipment in one room of it and then renting the rest of it to an employe of the company. A point to be considered in this connection is that the heating of the substation equipment during damp, rainy weather or the cold winter months becomes a very simple matter when it occupies one room of a residence.

No general rules can be laid down for determining whether or not the total cost of office buildings and lots will be increased or decreased by the use of district stations. The necessary data must be secured by a study of local conditions. Generally if the use of district stations is decided upon before an unnecessarily large central office building is erected, the tendency will be to lessen rather than to increase the total real estate investment.

Annual Charges and Operating Expenses.—While the study of the first cost of each office arrangement as compared with the first cost of other suggested office arrangements is necessary and interesting, it should only be a step in making up a comparison of the annual charges and operating expenses of the different arrangements.

Annual Charges on Central Office Equipment.—At an average figure, taxes on central office equipment may be taken at the rate of 1-1/2 per cent. per annum, and interest at the rate of 6 per cent. per annum. Depreciation and obsolescence on automatic equipment should be calculated on a life of not less than fifteen years and it would not be unreasonable to consider the life twenty years. The amount which must be set aside annually at 6 per cent. compound interest to equal 100 per cent. in fifteen years is 4.3 per cent. of first cost; therefore, this percentage may be used in calculating depreciation and obsolescence, although the life of automatic apparatus is full twenty years. The actual cost of maintenance material, or renewals, for automatic central office equipment, it has been found from experience, will be covered by a charge of 1/2 per cent. per annum. Insurance in fire-proof buildings is taken at 1 per cent. per annum. Adding together the percentages indicated for taxes, interest, depreciation, maintenance and insurance, makes a total of 13.3 per cent.

When estimating the annual charges on district station equipment, the figures might be taken at 14.3 per cent. instead of 13.3 per cent.—the extra 1 per cent. being added to cover any additional cost of furnishing power and heat for the equipment at the district station.

Central Office Operating and Maintenance Labor.—The average operating and maintenance labor cost in branch offices or district stations as small as 500 lines is not more than 10 per cent. to 20 per cent. greater than in the larger offices. For offices below that size there is usually a greater increase, although this depends considerably on local conditions. Our investigations lead us to believe that the annual labor cost allotted to the average district station of the smallest size—that is, 100 lines—will rarely be increased more than 25 per cent. over what would be the operating and labor maintenance cost for the same amount of equipment installed in a central office.

As already mentioned the wire chief in a city using district stations can test all lines from his desk at central without the aid of an assistant at the district station. All trouble and information calls come to central office just as in a one-office system, and all records, supervision and management remain centralized at the main office so that the only labor cost affected is that necessary to take care of the switchboard, power and cross-connecting frame apparatus.

Annual Charges on Lines and Trunks.—The annual charge per working pair mile for subscribers' circuits in No. 22 gauge cable is commonly taken at $2.55. In the case of a smaller office, say one with 2000 lines or less the charge should be somewhat higher, about $2.65.

The higher charge is due to the smaller number of cables, and consequently, greater loss of efficiency in the smaller office. In No. 19 gauge cable, the charge per working pair per mile is generally taken at $4.25. The annual charges on local trunk circuits are generally taken to be somewhat less than on the subscribers' lines. The charge per working pair mile on No. 22 gauge circuits should be taken at about $2.40 per annum, and on No. 19 gauge cable at $3.60 per annum.

If more accurate figures than these are desired, the cost of the conduit manholes and underground cable, poles with wire, cable and suspension may be carefully computed, and the annual charges calculated from the following figures:

Annual charge on underground conduit and manholes.	9 per cent.
Annual charge on underground cable................	11 1/2 per cent.
Annual charge on pole lines........................	21 1/2 per cent.
Annual charge on aerial cable and suspension.........	14 1/2 per cent.

Additional Main Offices.—In a very large city system covering many square miles and including not only a number of suburbs or former suburbs with their own business centers, but also business districts which have a very large number of intercommunications, more than one main office will be very clearly indicated. As a rule the best way to lay out such a city is to make studies with the main offices at the points which appear to be the most likely locations for them, and then as far as possible to take care of the rest of the territory with district stations surrounding each main office and connected with it.

While it is generally advisable to make a separate engineering study for a subsidiary office, which is expected to have an ultimate capacity of 1000 lines or more, it will be found that the trunking plan becomes more complicated and the trunk mileage is likely to be greater in a large system where branch offices are used, than it is where district stations are used. For illustration, refer to Fig. 270 which outlines a hypothetical system in which there are four main offices *A*, *B*, *C*, and *D*, each serving 5000 lines. *C* has two subsidiary offices *C*-6 and *C*-7 serving 1000 and 500 lines respectively. *A* has two subsidiary offices *A*-6 and *A*-7 serving 500 and 1000 lines respectively.

Suppose the subsidiary offices to be branch offices; then *C*-6, for example, will require nine groups of outgoing trunks, five to "*C*" office and one group to each of the other offices, except *A*-6 and *A*-7. Suppose, also, that the number of busy-hour calls is two per line. The total number of outgoing busy hour calls from each of the offices to any other office may be calculated by the well known formula $\frac{C(S \times R)}{T}$ = outgoing calls. In this formula S represents the number of rush hour calls originating in the sending office, R the number originating in the receiving office, T the number of busy hour calls in the entire system, and C is a corrective factor proportional to the "community-of-interest" at the sending office. Suppose that the community-of-interest factor C for each of the branch offices is 1 when its own main office is being considered, and is 0.75 when one of the other main offices is being considered.

Suppose that the holding time of connections in this system to be such that the trunk-carrying capacities are represented by the curve in Fig. 271.

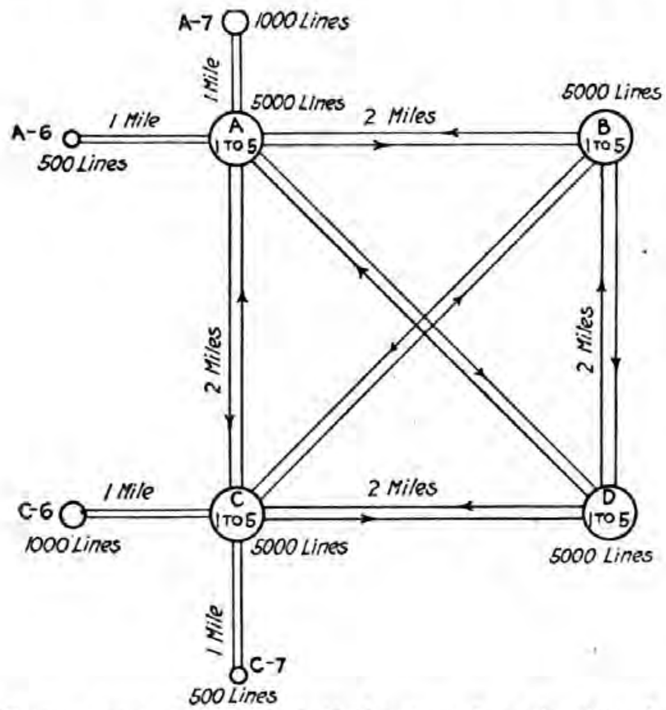


FIG. 270.—Diagram representing hypothetical system of 4 main offices A, B, C, and D and 4 subsidiary offices, A-6, A-7, C-6, and C-7.

Calculations with these hypotheses give the results for the calls and trunks from and to *C*-6 shown in the following tables:

BRANCH OFFICE ARRANGEMENT

(Outgoing from *C*-6)				(Incoming to *C*-6)			
To Office	Busy Hour Calls	Trunks Required	Trunk Mileage	From Office	Busy Hour Calls	Trunks Required	Trunk Mileage
C	435	30	30	*C*	1511	70	70
C-7	44	4	8	*C*-7	44	4	8
A	424	20	60	....	....	....	....
B	326	17	85	....	....	....	....
D	326	17	51	....	....	....	....
Total.......	1555	88	234	....	1555	74	78

The trunks are figured for a system without secondary line switches and in which the largest group of trunks is ten. It is noted that the total trunk mileage required for handling the incoming and outgoing traffic of *C*-6, when it is considered as a branch office, is 234 plus 78 or 312.

Now consider *C*-6 as a district station containing line switches, connectors and third selectors only. In this event, all of its trunks will terminate in its main office *C*, in fact all of its connections will be made through *C*. Without secondary line switches it will have ten groups of outgoing trunks, one group for each line-switch unit of 100 switches; and its incoming trunks will be divided into as many groups of ten as may be necessary to carry the traffic. No other factors are to be taken into account because third selectors are installed at *C*-6.

While all outgoing trunks from *C*-6 terminate in *C*, its traffic will make necessary more outgoing trunks from *C* to other offices than would be necessary if it did not exist and these must be taken into account in a comparison. The following table shows the trunks required from *C*-6 to *C*, also the additional trunks from *C* to other offices.

DISTRICT STATION ARRANGEMENT.

Trunks Into and Out of *C*-6

To Office	Busy Hour Calls	Trunks Required	Trunk Mileage	From Office	Busy Hour Calls	Trunks Required	Trunk Mileage
C	2000	100	100	*C*	2000	90	90
C	For Supervision, etc.	3	3	....	....	....	....
Additional Outgoing Trunks Required from *C* to other offices on account of *C*-6							
C-7	44	4	4	....	....	....	....
A	424	19	38	....	....	....	....
B	326	16	64	....	....	....	....
D	326	16	32	....	....	....	....
Total........	....	....	241	....	....	....	90

Comparing this table with the previous one we note that the total trunk mileage is 331 as against 312, so that the branch office is the most efficient arrangement by 19 trunk miles. The introduction of secondary line switches on the trunks from the district station *C*-6 to *C* would reverse the conditions, however. Such switches would reduce these trunks to seventy and thus make a saving of 30 trunk miles and a total saving of 11 miles as compared with the branch office plan. There would be practically no economy in the use of secondary line switches on the outgoing trunks from *C*-7 if it were a branch office because the trunks would be divided into so many small groups.

A further saving can be made with the district station arrangement by using secondary line switches on the outgoing trunks from *C* to other main offices. All out traffic, not only from *C* but also from *C*-7 and *C*-6 to the other main offices, would pass through these secondaries; but with the branch office arrangement where the outgoing traffic is handled by the small groups of trunks terminating direct in *C*-6 there would be very little saving in *C*-6's trunks by the use of such switches.

The district station plan will appear more favorably still in any plant where long-distance connections are afforded to the subscribers and where a subscriber places his order for such a connection by the common method of calling "*O*" and thus securing an idle trunk to the recording operator. These trunks would be separate and distinct from a branch office's first

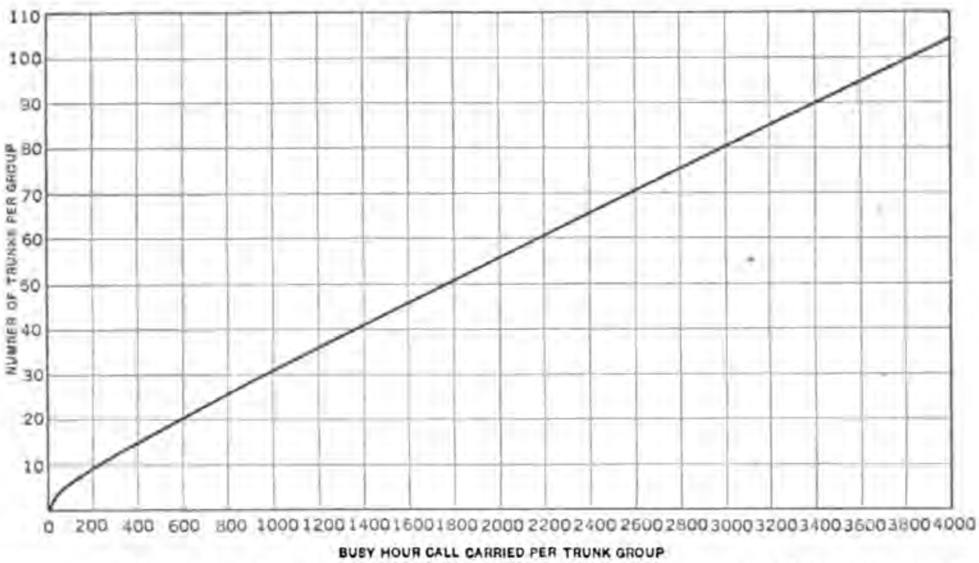


Fig. 271.—Curve showing carrying capacities of trunk groups of hypothetical system in Fig. 270.

selector banks direct to the toll board, but would not be taken into account in arranging for the trunking facilities of a district station, whose first selectors are in its main office. In many exchanges a one-figure number is used for some other purpose besides calling the long-distance board. Wherever this practice occurs it requires a separate trunk group from any branch office that may be installed, but does not affect the trunks from a district station. Of course a separate engineering study should generally be made of each case to determine whether a branch office or a district station is most practical, but the foregoing illustrates in a general way the factors that would effect the result, and as a general rule a branch office, or even a second main office should not be installed unless its advantage as against the use of a district station is very clearly indicated.

By employing district stations only the trunking system is kept as simple as possible, regardless of the number of offices used.

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ABBREVIATIONS USED

Automanual—Telephone Improvement Co., and North Electric Co.

A. A. T. Co.—American Automatic Telephone Co.
A. E. Co.—Automatic Electric Company.
S. & H.—Siemens-Halske Company.
W. E. Co.—Western Electric Company.
P.A.X.—Private Automatic Exchange.
P.B.X.—Private Branch Exchange.

A

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K

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M

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