# AUTOMATIC TELEPHONY

# AUTOMATIC TELEPHONY

*A COMPREHENSIVE TREATISE ON AUTOMATIC AND SEMI-AUTOMATIC SYSTEMS*


BY

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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-SEVEN YEARS THE LEADER IN THE
DEVELOPMENT OF AUTOMATIC TELEPHONY,
THIS VOLUME IS RESPECTFULLY DEDICATED.

# PREFACE TO SECOND EDITION

Prior to the year 1908, the use of automatic and semi-automatic telephone apparatus was confined almost entirely to the "Independent" telephone companies of the United States of America.

Since that year, its adoption, first, by the Governments of various Canadian cities and provinces, then by the Governments of Germany, Austria and France, and, latterly, by the Governments of England, Italy, Australia and New Zealand; and its introduction into Denmark, the Argentine Republic, Cuba, the Hawaiian Islands and the lands of the far East, has created a world-wide interest in this system and a general demand among telephone engineers for a more extensive knowledge of it.

An endeavor to meet this demand has resulted in the preparation of this volume, which is the first to be devoted exclusively to automatic and semi-automatic telephony, or which has attempted to treat the art in the manner which its importance requires.

Even within the pages of this book the authors have found it impracticable to narrate the full details of the practice of all the manufacturers. They therefore have described fully, typical circuits and apparatus of the Strowger type, with brief outlines of other important systems. The authors feel that the principles and methods brought out in these chapters are sufficiently applicable to other makes of equipment to supply the wants of students of the general art.

Radical changes have been made in revising this book from the first edition. As far as possible, only live matter has been retained, live subjects introduced, and old things re-cast into such form as will be more readily understood. The writers do not believe in coddling those who are too lazy to work. Much of the thorough knowledge which people need is to be obtained only by patient, persistent, consistent study. But there is no need of hiding those fundamental principles which are simple behind the customary mass of physical material which is used in putting those principles into practice. For this reason most of the electrical diagrams have been rearranged from the stand-point of the requirements of teaching.

The authors wish to express their thanks to Mr. Fred L. Baer, of Chicago, for his assistance on traffic and trunking, to Mr. P. V. Christensen, of Copenhagen, Denmark, for information concerning his traffic distributer system, to Mr. E. L. Grauel, of Rochester, New York, for information on the practical uses of the private automatic exchange, to Dr. Frank B. Jewett, chief engineer of the Western Electric Company, New York City, for information concerning the system of that company, and to Mr. Harry E. Hershey, of Chicago, for his assistance in the preparation of technical matter and copy.

They also wish to acknowledge the assistance and co-operation of a number of the members of the engineering staff of the Automatic Electric Company, and thus publicly to express to them their appreciation and thanks.

THE AUTHORS.

CHICAGO, ILL.,
*January*, 1921.

# PREFACE TO FIRST EDITION

Prior to the year 1908, the use of automatic and semi-automatic telephone apparatus was confined almost entirely to the "Independent" telephone companies of the United States of America.

Since that year, its adoption, first, by the Governments of various Canadian cities and provinces, then by the Governments of Germany, Austria and France, and, latterly, by the Governments of England, Italy, Australia and New Zealand; and its introduction into Denmark, the Argentine Republic, Cuba, the Hawaiian Islands and the lands of the far East, has created a world-wide interest in this system and a general demand among telephone engineers for a more extensive knowledge of it.

An endeavor to meet this demand has resulted in the preparation of this volume, which is the first to be devoted exclusively to automatic and semi-automatic telephony, or which has attempted to treat the art in the manner which its importance requires.

Even within the pages of this book the authors have found it impracticable to narrate the full details of the practice of all the manufacturers. They therefore have described fully, typical circuits and apparatus of each of the more important or instructive types on the market, but have found it necessary to confine their discussion of such subjects as "Traffic," "Development Studies," "Central Office Building Design," "Long Distance Line Equipment," etc., to the practice of some one manufacturer Wherever this has been found necessary, the practice of the Automatic Electric Company has been followed, and the authors feel that the principles and methods brought out in these chapters are sufficiently applicable to other makes of equipment to supply the wants of students of the general art.

The authors wish to express their thanks to Mr. P. V. Christensen, of Copenhagen, Denmark, for information concerning his traffic distributer system; to Mr. David S. Hulfish, of the Canadian Machine Telephone Company, Brantford, Canada, for information concerning the Lorimer system; to Dr. A. Rapp, Berlin, Germany, for information on the system of the Siemens-Halske Company; and to Mr. Gerard Swope, New York, for his assistance in the preparation of the description of the system of the Western Electric Company. They also wish to acknowledge the assistance and co-operation of a number of the members of the engineering staff of the Automatic Electric Company, and thus publicly to express to them their appreciation and thanks.

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*October*, 1914.

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# AUTOMATIC TELEPHONY

## CHAPTER I

### INTRODUCTION

The telephone was invented in 1876 and exhibited at the Centennial Exhibition at Philadelphia.

The first automatic telephone switching apparatus, that of Connolly and McTighe, was invented not long after and a patent applied for in 1879. Thus the idea of remote controlled electrical switches for connecting telephone lines is almost as old as the telephone itself.

The Strowger automatic system originated about 1887, and its first patent was applied for in 1889.

The commercial development began with the La Porte, Indiana, exchange in 1893, and has continued steadily ever since.

The conditions of labor became more difficult with every passing year. The world war rendered the situation acute. These conditions led the largest operating companies in America publicly to adopt the automatic on a comprehensive scale. Foreign governments also started similar measures of relief for a condition which was almost intolerable to the public.

Today (1921) the automatic switching of telephone lines is the foremost subject in telephony.

"Automatic" telephony is the term applied to the use of machinery to perform those parts of the work of switching which were formerly done by hand. See definitions of "automatic" in Webster's New International Dictionary (1915), Standard Dictionary (1913), and Worcester's Dictionary (1897).

The requirements of a telephone subscriber must be stated in terms which are independent of apparatus and methods. Much error will be avoided if we divest our minds of the conditions imposed by any one means of rendering service.

The subscriber requires, without unnecessary delay, without undue stress on himself, to be connected to the telephone which he desires (and to no other), to talk to the called subscriber with ease and without interruption or eavesdropping, and to have this service available continuously. Stated concisely, the requirements are:

1. Speed of connection and disconnection.
2. Ease of obtaining connection and disconnection.
3. Accuracy of connection.
4. Voice transmission.
5. Secrecy.
6. Continuous service.

The manual switching of telephone lines involves the following inherent features:

1. One or more human intermediaries between the subscribers. This leads to:
2. Translation of calling subscriber's desires from sound into ideas;
3. Translation of these ideas into action;
4. Common spoken language between subscriber and operator;
5. Crowding many operators together in a place difficult to ventilate;
6. Fluctuations in service due to personality and health of operator and the amount of traffic;
7. Immediate impairment of service by strikes, epidemics, etc.;
8. Co-operation of operator with subscriber in securing his desires largely negatived by the machine-like conditions of the work.

Automatic switching involves the following inherent features:

1. Nothing but automatic switches between the subscribers. This leads to:
2. The definite control of the automatic switches by the subscriber (by electrical impulses);
3. The accurate response of the switches to the control, over lines of varying properties;
4. Uniform service, almost independent of traffic, public health, and personnel;
5. Absence of human co-operation, except when desired and requested.

Automatic telephony may be divided for study into (1) trunking, (2) mechanism, and (3) electrical circuits. These will be treated separately with such cross-references as are helpful.

## CHAPTER II

### TRUNKING

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 sub-groups. 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 50-line groups (practised by the late American Automatic Telephone Company) and into 200-line groups (installed by the Western Electric Company in Europe). 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 sub-groups 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. 1, 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.

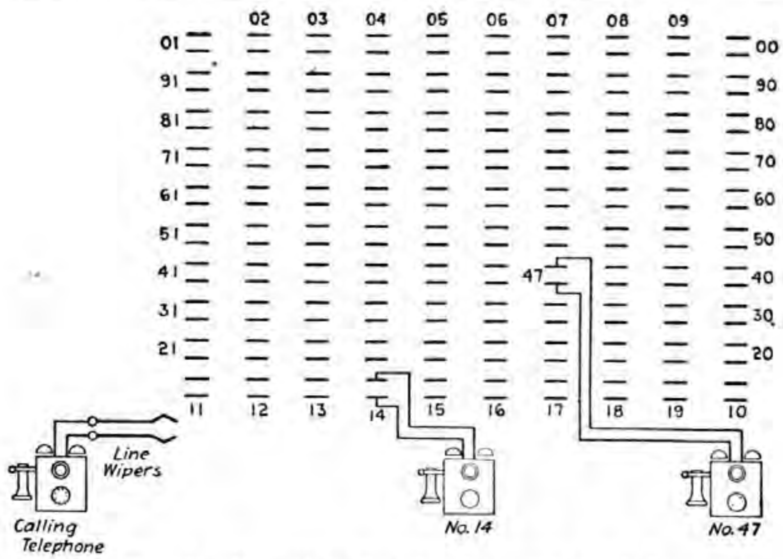



FIG. 1.—Essential principle of connector switch.

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.

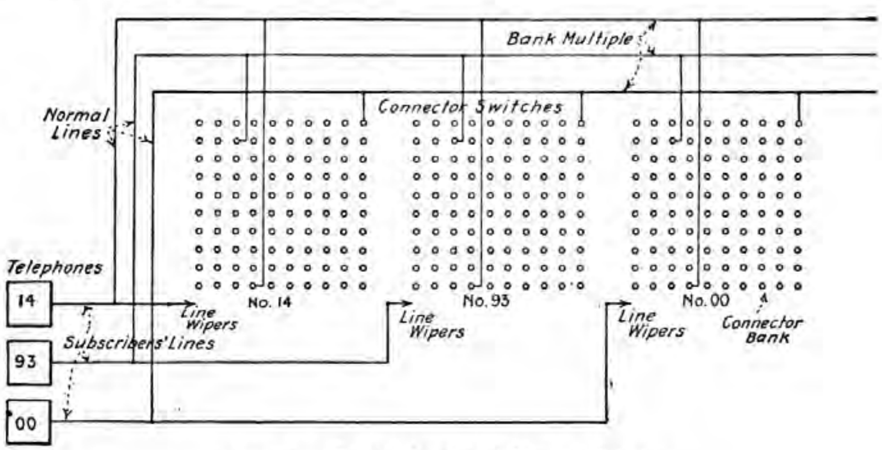



FIG. 2.—Principle of 100-line exchange.

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. 2.) Three telephones are here used to show the 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 multiplied to a contact pair in every bank. For example, the

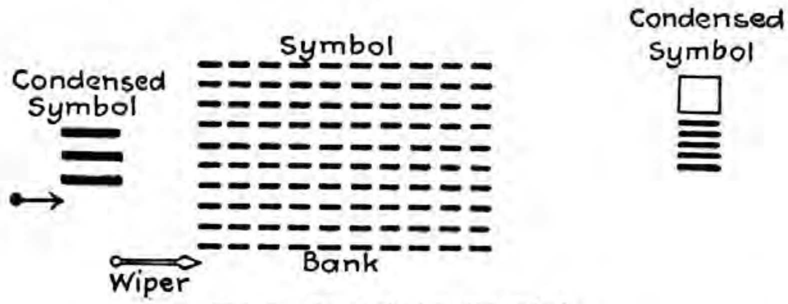



FIG. 3.—Symbol of major switch.

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 wiring," 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.

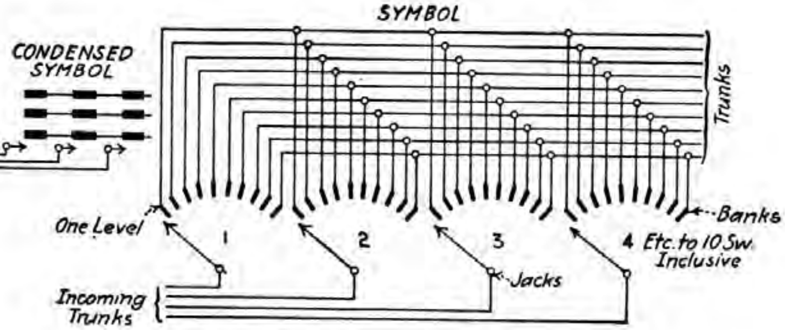



FIG. 4.—Connectors multipled.

**Symbols.**—From time to time symbols peculiar to automatic telephony will be introduced. The connector-switch symbol (Fig. 1) is reduced to the two symbols shown in Fig. 3. The multipled connectors of Fig. 2 are reduced to the symbol of Fig. 4.

A "major switch" is one which performs a major act in switching. A "minor switch" is one which has purely auxiliary functions.

**Non-numerical Switches.**—When each subscriber has one connector, there is considerable waste of apparatus, because not very many of them are in use at the same time.

If a residence telephone originates ten calls per day (each lasting two minutes) and receives the same number of calls, these 20 calls occupy the telephone 40 minutes per day, which is a liberal allowance for this class of service. This is only 2.8 per cent of the day. A calculation for a business telephone, allowing 40 calls (20 in and 20 out) at one and one-half minutes each, shows an actual occupancy of the apparatus of scarcely more than 4 per cent of the time. Yet the telephone company must maintain all the apparatus which is individual to the line and pay interest and depreciation on it 24 hours per day in order that it may be used 3 or 4 per cent of the time.

It is therefore standard practice to interpose non-numerical switches between the subscriber lines and a reduced number of connectors (usually ten per hundred lines). A non-numerical switch is one which will enable the subscriber (without his knowledge) to get the use of an idle connector switch.

**Lineswitches.**—A lineswitch is a non-numerical switch, attached to the subscriber line, which can connect the line to a trunk leading to an idle connector (or other switch in the larger systems).

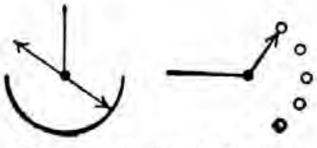


Fig. 5.—Symbol of rotary lineswitch.

A rotary lineswitch (Fig. 5) is one whose subscriber line comes to the wipers and whose bank contains the trunk terminals. It usually has one motion (in one plane).

A Keith lineswitch, plunger type, Fig. 6, accomplishes the same result with both the subscriber line terminals and the trunk terminals built into a bank, and employs a moveable plunger to cause the connection. There is a master switch to select idle trunks for each group of lineswitches. (See page 45.)

**Finder Switches.**—A finder switch, Fig. 7, is a non-numerical switch, attached to a trunk leading to a connector (or other switch in the larger systems). On its banks are subscriber lines, multipled also to other finder banks in the same group. The finder of an idle connector can move its wipers into contact with a calling line. It may have one or two motions, rotary only, or vertical and rotary.

**One-hundred-line System.**—The effect of lineswitches on a 100-line system of lineswitches of either type is to reduce the connectors from one hundred to an average of ten. Figure 8 shows such an exchange with rotary lineswitches. Each subscriber line is multipled to its own set of contacts on the bank of each connector; it also runs to the wipers of its own rotary lineswitch. The individual apparatus in the central office consists of a lineswitch and a set of contacts on each connector bank. The connector mechanisms and wipers are common to all—they may be used by any subscriber.

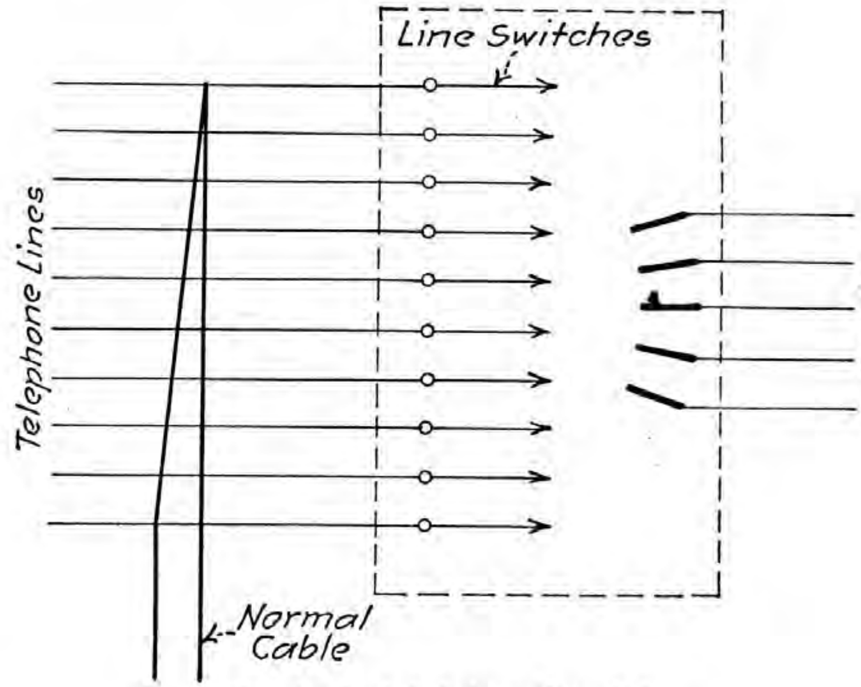



FIG. 6.—Symbol of plunger lineswitch.

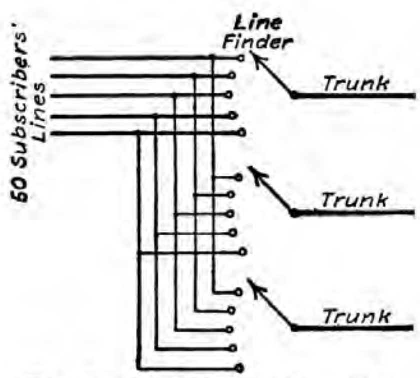



FIG. 7.—Symbol of finder switch.

The normal cable, starting from the multipled banks of the connectors, runs to the plunger side of the lineswitches, 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 lineswitches.

When a subscriber takes his receiver from the hook, his lineswitch 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 lineswitch of the called line and thence to the called telephone. The lineswitch of the called telephone is merely a meeting point: the line does not go through it. The same exchange equipped with Keith lineswitches is shown in Fig. 9.

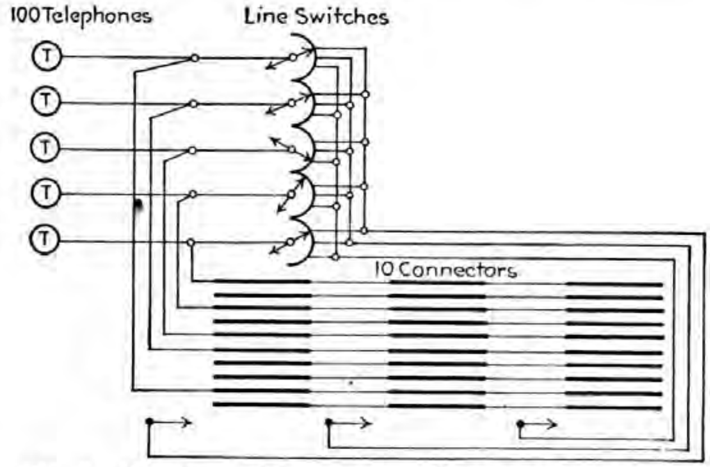



FIG. 8.—One-hundred-line system with rotary lineswitches.

**Thousand-line System.**—The 1000-line system is built up out of ten 100-line groups. The selection is based on first choosing the unit or group in which the called line is located and then picking out the particular line in that group. (See Fig. 10.)

The telephone lines come into the central office to lineswitch wipers and connector banks as before. The lineswitch banks have trunks

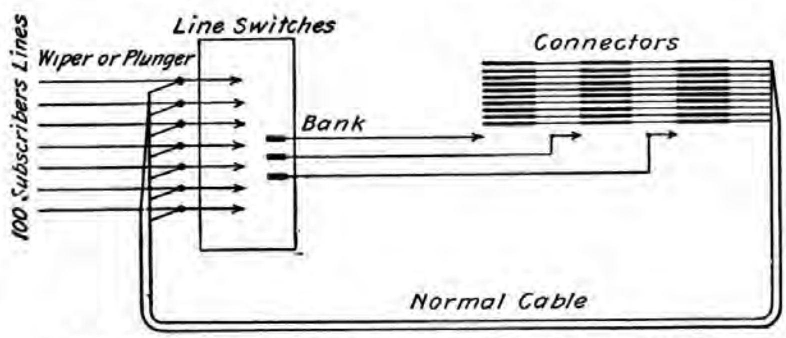



FIG. 9.—One-hundred-line system with Keith lineswitches.

running to the wipers of selectors. The selector banks are multipled together throughout the exchange.

The connector wipers receive trunks from selector bank levels according to groups. All the trunks from the first level run to connectors in the first hundred, from the second level to the second hundred, etc.

Though only the first, second, and eighth hundreds are represented, the others are easily imagined.

The first function of the selector (to select the level) must be completely under the control of the subscriber. The second (to hunt an idle trunk) should be completely self-acting, for it is of no interest to the subscriber which trunk or connector he gets.

Let us suppose that subscriber No. 261 desires a connection with telephone No. 805. The calling subscriber first removes his receiver from the hook. This enables the lineswitch to connect his line to an

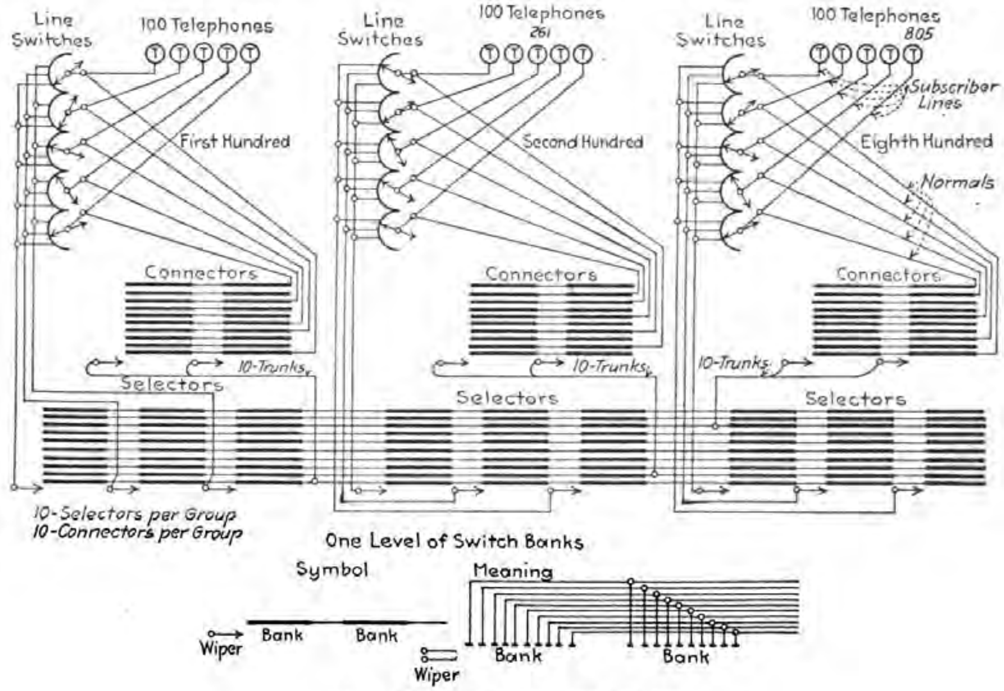



FIG. 10.—Thousand-line system.

idle selector. He then pulls "8" on his calling device, in response to which the selector lifts its wipers to the eighth level. Then, in a very brief time, the selector rotates its wipers until they touch the contacts of an idle trunk line (leading to an idle connector). This extends the calling line to a connector in the eighth hundred group. The subscriber then dials "0" which lifts the connector wipers to the "0" or tenth level. He now dials "5" which causes the connector wipers to rotate to the fifth set of contacts on the "0" level. If the line is busy, the connector will refuse to complete the connection, and will send back a busy tone to the calling telephone. If the line is free, the connector will complete the connection, ring the bell of the called telephone (No. 805) and permit conversation. When the subscribers hang up their receivers, the selector and connector return to normal, and the lineswitch frees the trunk for use by others.

The wires which multiple together the banks of adjacent switches are termed collectively "bank wiring." Thus we have "lineswitch bank wires," "selector bank wires," and "connector bank wires."

The wires which multiple together different groups of selector banks are called "selector bank multiple."

The wires which lead from a switch to a different kind of switch ahead are called "trunks." Thus we have "lineswitch trunks," from lineswitch banks to selector jacks (leading to wipers), and "selector trunks" from selector banks to jacks of connectors.

Wires from connector banks to subscriber lines are called "normals."

## SYSTEMS LARGER THAN ONE THOUSAND LINES

It is useful to view an automatic exchange as a network of trunks which connect switching junctions. It makes easier the explanation of the larger systems.

In its simplest form we may consider a 100-line exchange (Fig. 11) as a single switching junction *C* between a number of telephone lines, *T*. The actual junction is the multipled banks of the connectors of Fig. 2. We will call this a "junction" because it is a point where the various subscriber lines are connected to each other.

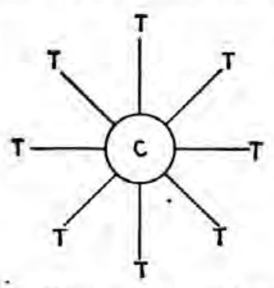



FIG. 11.—Hundred-line exchange (one junction).

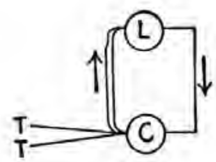



FIG. 12.—Hundred-line exchange with lineswitches (two junctions).

A 100-line exchange with lineswitches (Fig. 12) is composed of two switching junctions with suitable connecting links. The banks of the connectors *C* are the junctions for the subscriber lines *TT* and the wires leading to the lineswitches *L*. (Compare Fig. 8.) The link which carries the calls to the lineswitches is composed of as many circuits as there are subscriber lines *TT*. The link which ties the lineswitches to the connectors has in it as many circuits and connectors as are necessary to carry the traffic. Each part of this link must be thought of as including the lineswitch trunk and its connector switch clear to the tips of its wipers.

The lineswitch is a switching junction which resembles a reducer in a pipe line. It merely reduces a large number of circuits to a smaller number of circuits.

The 1000-line exchange of Fig. 13 has three kinds of switching junctions. Each group of subscriber lines *TT* comes in to its own connector junction *C*, so that *C* is able to distribute calls to its own subscribers. There is another switching junction, *S*, which is able to distribute traffic to all of the 100-line groups, that is, to all of the junctions *C*. Only three *C* junctions are shown, but ten must be imagined.

The junction *S* is the multipled banks of all the selectors. (Compare with Fig. 10.) The links which connect *S* to the various junctions *C* are selector trunks, including each connector to its wipers.

The junction *S* receives calls from all the junctions *L* (lineswitches). Each link between one *L* and *S* is composed of lineswitch trunks and selectors to their wipers.

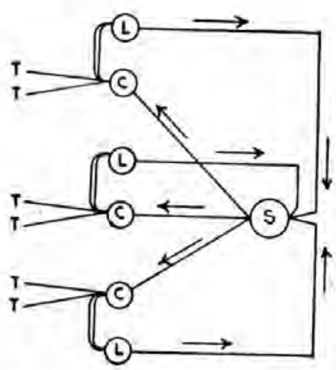



FIG. 13.—Thousand-line exchange (three kinds of junctions).

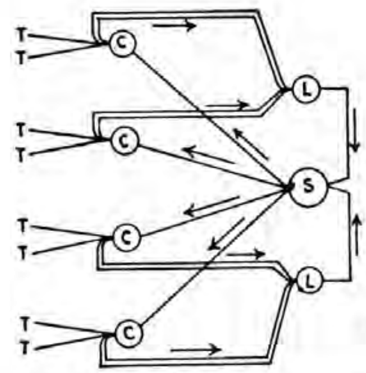



FIG. 14.—Thousand-line exchange (re-arrangement).

One group of lineswitches and their trunks may serve more than 100 subscriber lines. (Fig. 14.) In this illustration, one lineswitch junction *L* handles all the traffic originated by 200 lines. The rotary lineswitch with 25 trunks on its bank can handle such cases. It may even take care of 300 or more lines.

**Ten Thousand-line System.**—A 10,000-line exchange is made up of groups of groups. Ten 100-line groups or switchboards make up a 1000-line groups. Ten of these 1000-line groups make up the entire exchange. (See Fig. 15.) Only three 100-line boards in each thousand and only three thousands are shown, but the reader will remember that the full size is ten of each.

Each 100-line unit has its own connector junction *C* as in smaller systems. It consists of as many connectors as are necessary to distribute the traffic going to the 100 subscribers *TT*.

Each thousand has its own switching junctions 2-*S* which distributes traffic to each of the 100-line boards. It consists of the bank multiple of "second selectors." These second selectors perform the same functions as the first selectors in the 1000-line system (Fig. 10 and Fig. 13) in that they trunk to all the hundreds of a given thousand. Usually there are as many second selectors for a 1000-line group as there are connectors in that group. Ten 100-line boards, each having ten connectors, require 100 second selectors, whose banks form the "2-$S$" for the thousand.

Each junction 2-$S$ must receive traffic from all the thousands in the exchange. Hence on the one side the links (composed of first selector trunks) converge from all the thousands, and on the other side they diverge to the separate 100-line boards within the one thousand.

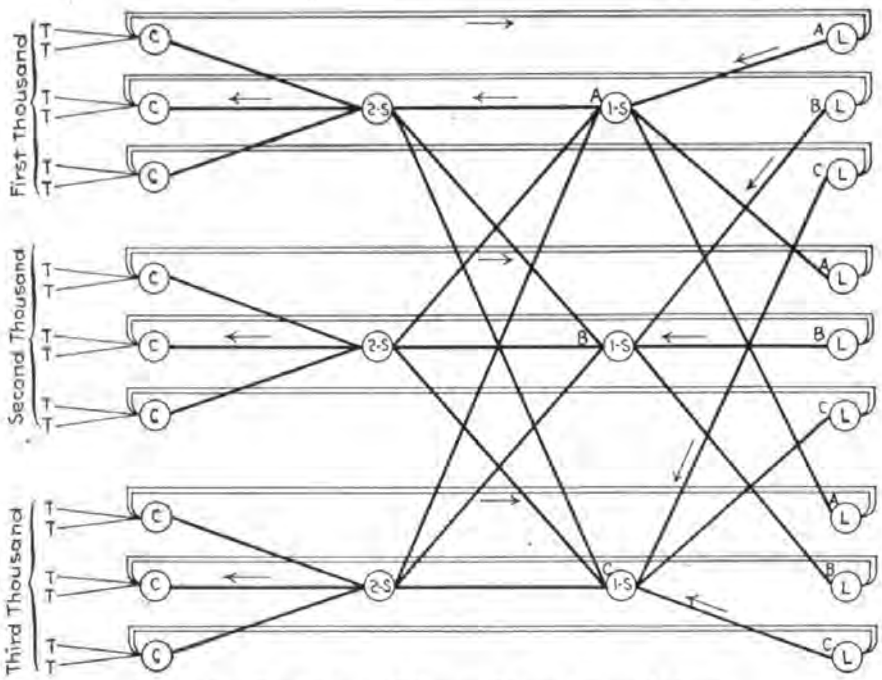



FIG. 15.—Ten-thousand-line exchange (network form).

There are as many first-selector junctions (1-$S$) as there are junctions (2-$S$). Each junction (1-$S$) consists of the banks of first selectors which are multipled together.

It is necessary that the traffic coming from the various thousands shall be distributed so as not to overload any one junction (1-$S$). To secure this, each one of them receives traffic from all the thousands. Thus, the junction marked $A$(1-$S$) receives traffic from all the lineswitch units marked $A(L)$. The junction $B$(1-$S$) receives calls from all the junctions $B(L)$. This arrangement is continued throughout all the ten thousands.

Each 100-line unit $C$ is shown as having its own group of lineswitches $L$. This may or may not be the case in practice. Several hundreds may use the same group of lineswitches, especially if they are of the rotary type. A given hundred may be served by two or more groups of lineswitches, as is often done with Keith lineswitches, if the traffic is heavy. Finally, the lineswitches may be grouped without any relation to the groups of subscriber lines.

The trunking described above is shown in more detail in Fig. 16. The actual apparatus and trunks are indicated instead of the junctions and links which represent them. Three out of the ten different thousands are shown, also three out of the ten hundreds in each thousand.

All of the lineswitches are in a row at the left. The first selectors and connectors in groups or "sections" of ten each alternate with each other in the second column. The second selectors are at the right, arranged in sections of ten switches each.

In the banks of each section of ten connectors we recognize a junction *C* of the network. These connectors deliver calls to the 100 lines to which they belong.

In the banks of the second selectors of a 1000-line group we can recognize a junction 2-*S* of the network. All ten sections (100 second selectors) are multipled together. They are usually lettered *A* to *J* inclusive. This bank multiple binds together the different hundreds in a given thousand.

The banks of the first selectors are also multipled together so as to form switching junctions 1-*S*. One section in each thousand goes into the making up of a given junction 1-*S*.

The ten sections of first selectors in a given thousand are lettered from *A* to *J* inclusive. Since there are ten thousands in the exchange, there are ten *A* sections, ten *B* sections, etc.

In order to distribute the traffic, all the *A* sections of first selector banks are multipled together to form one junction. This appeared as *A*(1-*S*) in Fig. 15. All the *B* first-selector banks likewise are multipled to form another junction. It appeared as *B*(1-*S*) in Fig. 15. In this way ten bonds are formed which tie together all the ten thousands.

As illustrated in Fig. 16, each first-selector section (ten switches) receives its traffic from a lineswitch board which belongs to a given hundred. In a certain sense that particular 100 lines, its lineswitches, first selectors, and connectors, may be said to belong together. But this relationship is binding only for the connectors. The lineswitches and the first selectors may be grouped quite differently.

The first selector banks are trunked to the second selectors according to levels and thousands, and according to like sections.

The first level of all first selector banks must trunk to second selectors in the first thousand, second level to second selectors in the second thousand, third level to the third thousand, etc.

The trunks from *A* first selector banks are trunked to *A* second selectors in all the thousands. *B* first selector banks trunk to *B* second selectors in all the thousands. This grouping applies to all the sections.

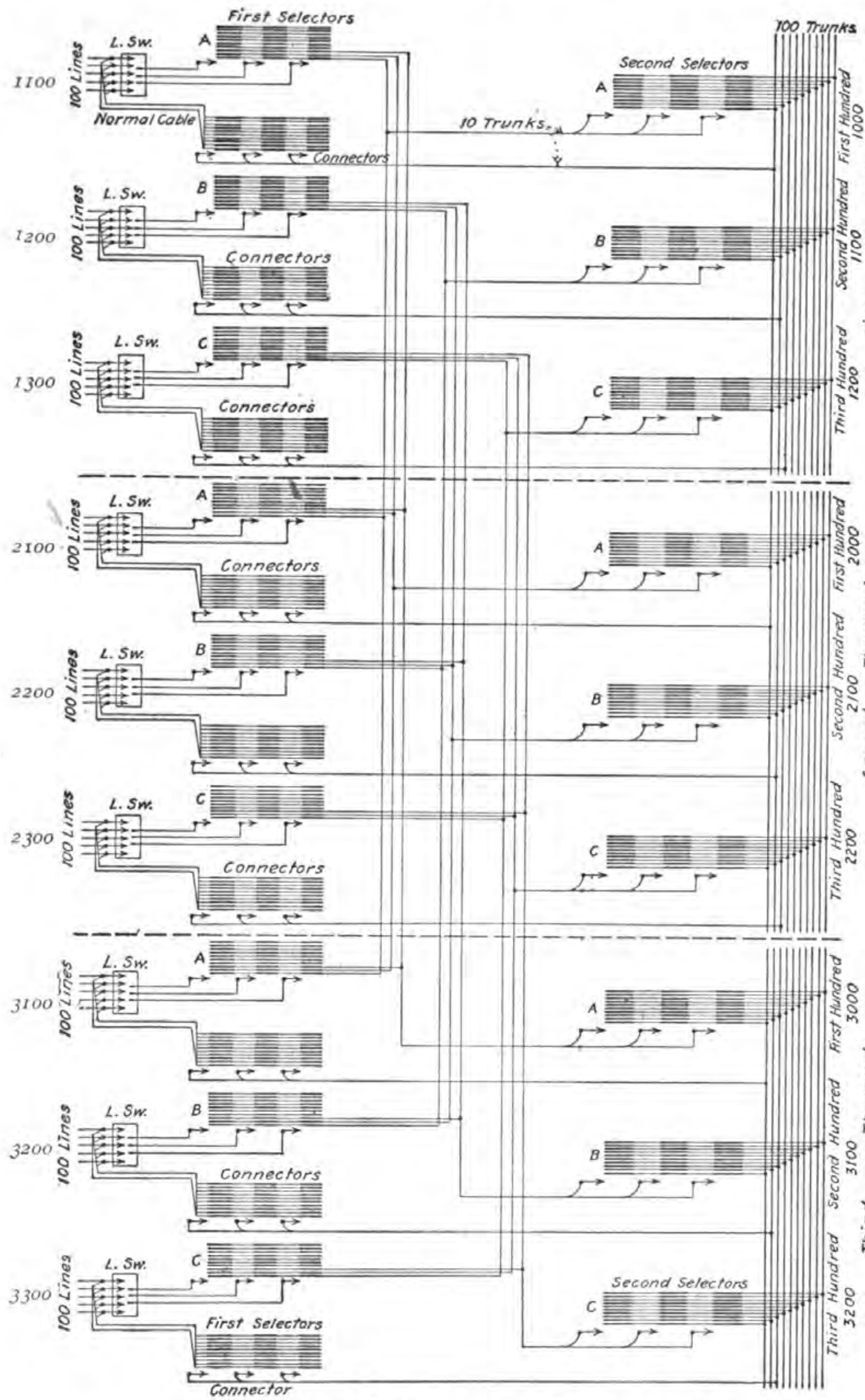



FIG. 16.—Ten-thousand-line exchange with lineswitches.

The combination of the above two schemes results in the arrangement of trunks shown. Consider the *A* first selectors. From the first level of their banks run ten trunks to the *A* section of second selectors in the first thousand. From the second level of *A* first selector banks run ten trunks to the *A* second selectors in the second thousand. Likewise the third level trunks to *A* second selectors in the third thousand. This is continued throughout all the levels.

Consider the *B* first selectors. Their first bank level trunks to the *B* section of second selectors in the first thousand. The second level trunks to *B* second selectors in the second thousand. The third level leads to *B* second selectors in the third thousand. This is continued to all levels and thousands.

In this way all first selector sections of a given letter trunk to all thousands to second selector sections bearing the same letter. Also each second selector section of a given letter receives traffic from all thousands from first selector sections bearing the same letter. The traffic is effectively mingled.

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 section *A*. 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 section *A* 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 connector 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 lineswitch 70 and out to the called telephone.

Let telephone No. 2130 call No. 2241. The call will extend from lineswitch 30 on the 2100 board to an idle first selector on the "*A*" section. Thence it is trunked through the second bank level to a second selector on section *A* in the same thousand. From here it goes through the second bank level to a connector attached to the "2200" board, and from the forty-first set of contacts, through the normal cable to lineswitch jacks, 41 and out to the telephone No. 2241.

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

**The Secondary Lineswitch.**—The object of the secondary lineswitch 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 secondary lineswitch is introduced in two places, (1, local) between subscriber lineswitches and first selectors to reduce the number of selectors required, and (2, outgoing) between selector banks and outgoing trunks to other offices of a multi-office exchange to reduce the number of inter-office trunks, the incoming selectors in the distant office, and the impulse repeaters associated with each trunk in the sending office.

The general principle of trunking by primary and secondary lineswitches is shown by Fig. 17. The subscribers' lines are attached to the primary lineswitches. The secondary lineswitch 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 lineswitches run to the secondary lineswitches, indicated by the arrows marked "plungers." From the banks of the secondary lineswitches the trunks run to first selectors, ten for each section of secondaries. They are lettered from *A* to *J* as usual, and their multipling is done in accordance with the practices already described.

It should be observed that not more than one trunk from a primary board runs to a given secondary section. Examining primary board 1, notice that trunk 1 (beginning at the top) runs to secondary section 1, trunk 2 to secondary section 2, etc. This is one of the prime facts of the arrangement, and upon it depends the effectiveness of the large trunk group. By giving each primary board a trunk into each of the ten secondary sections, we render all the first selectors, 100 of them, available to all the subscribers; also, if all the first selectors of a given secondary shelf become busy it renders useless not more than one trunk from each primary board or section.

This arrangement may be seen in both kinds of lineswitches. If we consider any primary lineswitch, we shall see that it has a choice of ten trunks, any one of which will serve equally well. It has to share this choice with from 49 to 99 other lines. When the subscriber's line,

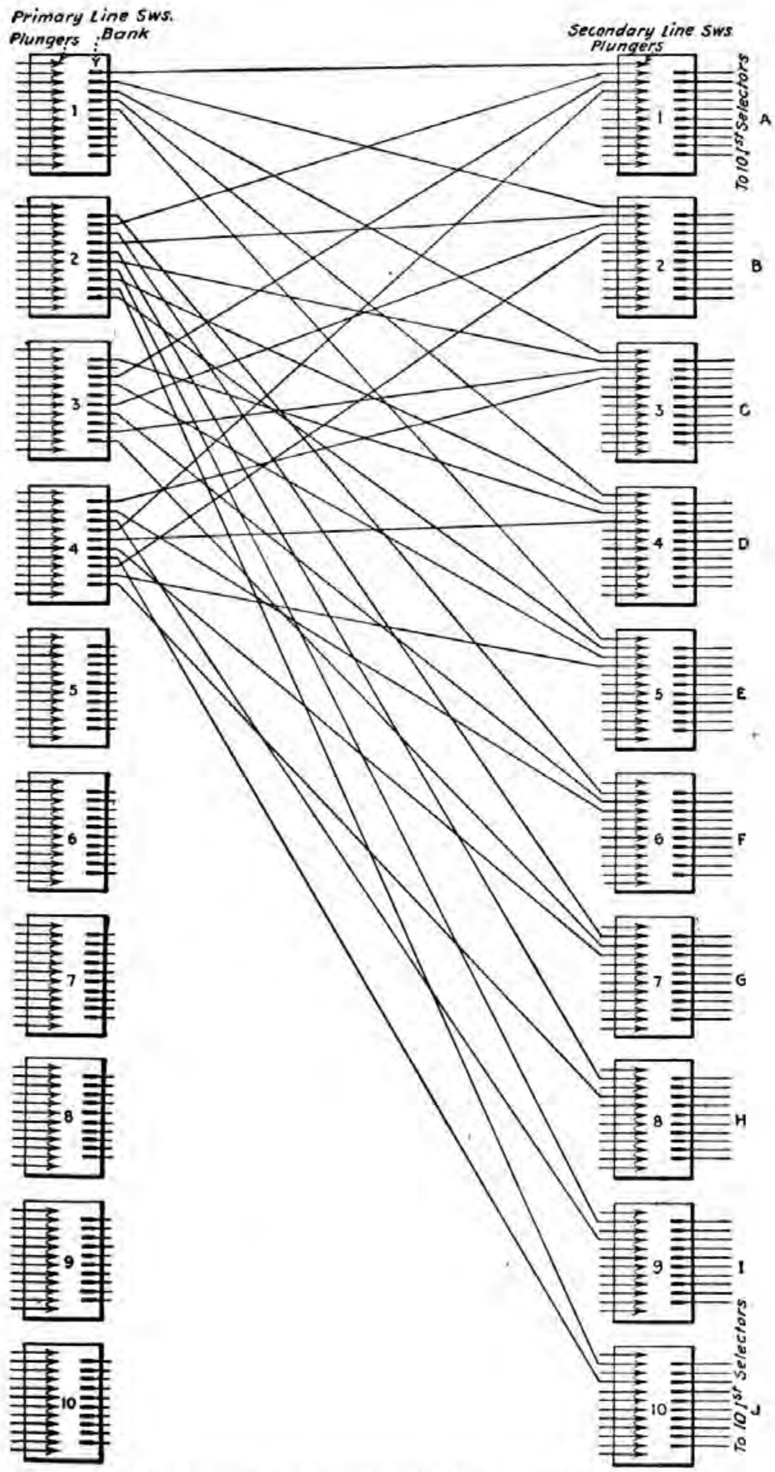



FIG. 17.—Primary and secondary trunking (distributive).

through its primary lineswitch, has seized one of the ten trunks, it is thus extended to a lineswitch on one of the secondary boards. Here again it has a choice of ten trunks any one of which will serve equally well. It has to share this choice with a number of other secondary lineswitches. But by the double choice of ten trunks each we secure the ability to seize any one of 100 trunks, each leading to first a selector.

If the traffic from 100 subscribers' lines is too great to be carried by ten trunks, it is customary to divide a primary lineswitch board into two parts of 50 lines each, and to give each part from seven to ten trunks.

### MULTI-OFFICE EXCHANGE

The automatic system is easily divided into a number of offices without increasing the number of digits in the call number. This may be illustrated by dividing a 1000-line exchange into two parts. We can put the first, second, third, fourth and fifth hundreds in one office, and the rest of them in another office. For simplicity assume only four hundreds, placing the first and second hundreds in the first office and the fourth and fifth hundreds in the second office. (See Fig. 18.)

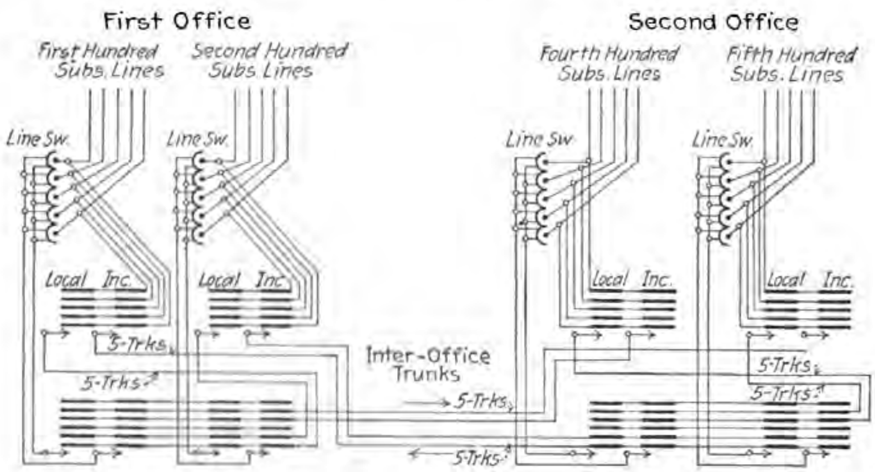



FIG. 18.—Thousand-line, 2-office exchange.

We will assume that the traffic division is ideal, *i.e.*, that there is no community factor and therefore half of the originating traffic in each office goes to lines in the same office and the other half to the other office. This is necessary in opening up the subject.

In each office the first-selector banks are multipled to each other, but there is no common multiple between the two offices. In the first office, levels 1 and 2 run to local connectors in the corresponding hundreds. Trunks from the fourth and fifth levels run to incoming connectors in the second office, terminating in the fourth and fifth hundreds. In the second office, the reverse is the case. The first and second levels run to the distant office to incoming connectors, while the fourthand fifth levels carry the local traffic to local connectors in the fourth and fifth hundreds. This is one way of handling such a case.

The 10,000-line system may also be divided into two offices of 5000 lines each, placing the first, second, third, fourth and fifth thousands in

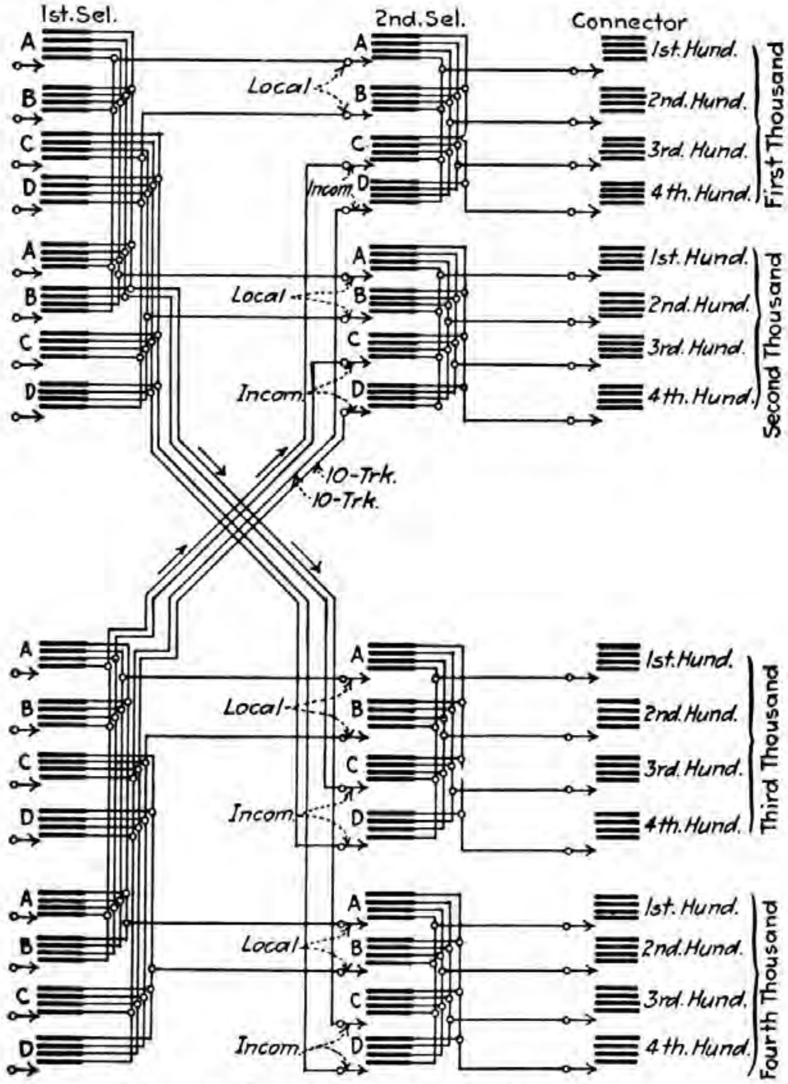



FIG. 19.—Ten-thousand-line, 2-office exchange.

one office, and the rest in the other office. It is however, not essential that consecutive thousands be placed in one office. We could just as well put the second, fifth, ninth and any other thousands in one office, and the rest in the other.

The 10,000-line system has no one first selector bank multiple. As was described before, all the "*A*" sections of first selectors are multipled together, all the "*B*" sections are multipled in another group, etc. For this reason, the division into two offices can not be handled exactly as was done in the case of the 1000-line exchange.

We will illustrate by taking 4000 lines and dividing them into two offices. (Fig. 19.) The first office has the first and second thousands, and the second office the third and fourth thousands.

Each switch symbol represents a section of ten switches. The first thousand has ten hundreds, of which only four are represented, and each hundred has ten connectors. The second selector banks are multipled in common within the thousand to which they belong. The various levels are trunked to connectors as usual.

We will assume an ideal traffic, *i.e.*, that the division of originated traffic is proportional to the number of lines in the two offices. In this case, half the traffic originating in the first office will be trunked out to the other office, and half will remain as local traffic. Accordingly, as one means of grouping, we may multiple together the banks of all the *A* and *B* sections of first selectors so that they will trunk together. In the same way, we will place the *C* and *D* sections together, etc.

In the first office, levels one and two are local, and go to local second selectors in the thousands to which they belong. The third and fourth levels lead to outgoing trunks to the second office where they terminate in incoming second selectors, whose banks are multipled to the local second selectors in the appropriate thousands. In every case, the local and incoming second-selector banks are multipled together.

The traffic may go to the first selectors in any way whatever. It is not material to the scheme of inter-office trunking whether the traffic goes directly, through lineswitches, or through primary and secondary lineswitches. The multipling of the banks of first selectors would in every case be carried out in such a manner as to secure as thorough a mixing up of the traffic as possible.

In a fully equipped 10,000-line system, divided ideally into two offices of 5000 lines each, there would be 500 first selectors on the 10 per cent basis. The first selector bank group (five *A* sections and five *B* sections) would comprise 100 selectors, trunking into ten trunks from a given level, or 50 trunks from the five levels which go to the other office. Each of these ten-trunk groups go to a particular thousand in the other office. There will be five such first selector bank groups of 50 trunks each, making a total of 250 trunks one way from one office to the other.

The outgoing traffic is apportioned among the thousands before it leaves the originating office; it is the work of the first selectors We may regard the 250 trunks referred to above as really being in five groups, one going to each of the thousands in the distant office.

**Outgoing Trunk Secondary Lineswitches.**—The efficiency of inter-office trunks is increased if the ten-trunk groups can be merged. The secondary lineswitch is used for this purpose.

The two-office system of Fig. 19 would require 50 trunks from the first office to each of the thousands in the second office. Each group of 50 is divided into five groups of ten trunks each. Thus all of the $A$ and $B$ first selectors in the first office, trunk through ten trunks to the $C$ section of second selectors in the third thousand (second office). The $C$ and $D$ first selectors in the first office have a different group of ten trunks to the same third thousand (section $D$ of second selectors). If the two offices have five complete thousands each, it takes five such groups of ten trunks to carry the traffic from the first office to the third thousand alone.

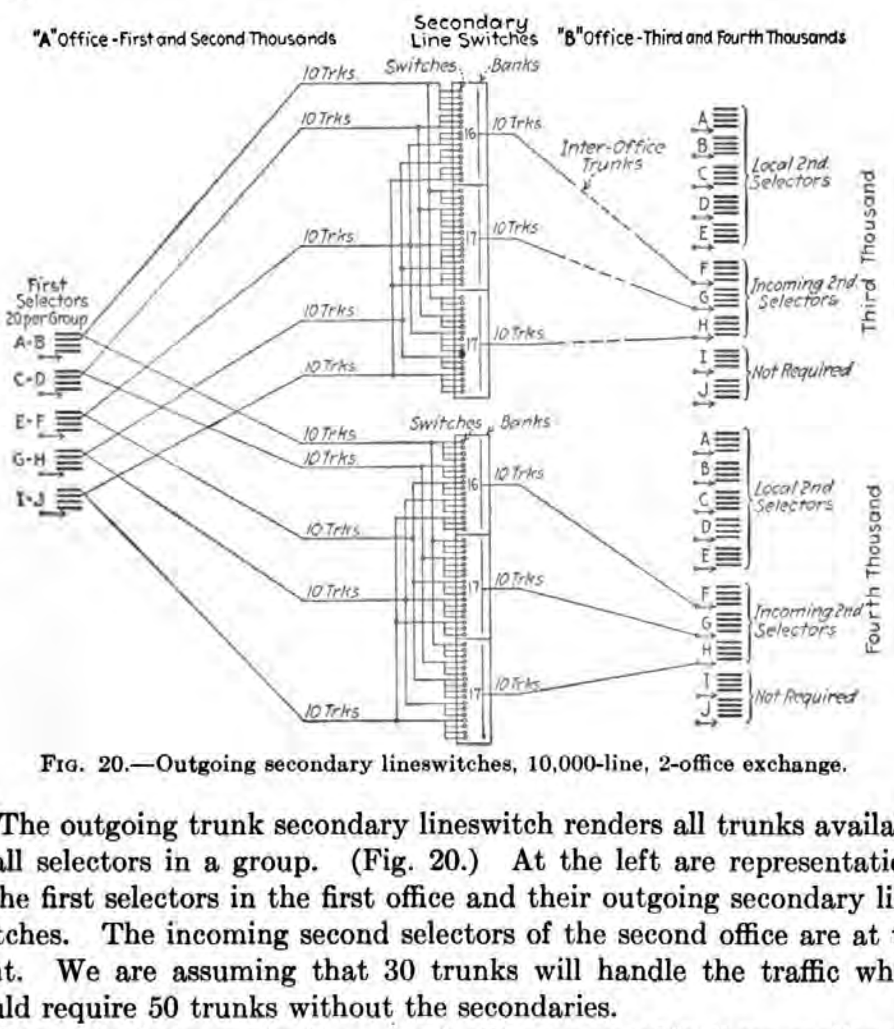



FIG. 20.—Outgoing secondary lineswitches, 10,000-line, 2-office exchange.

The outgoing trunk secondary lineswitch renders all trunks available to all selectors in a group. (Fig. 20.) At the left are representations of the first selectors in the first office and their outgoing secondary lineswitches. The incoming second selectors of the second office are at the right. We are assuming that 30 trunks will handle the traffic which would require 50 trunks without the secondaries.

For each thousand in the second office we provide three sections of secondary lineswitches in the first office. To them we distribute the trunks from first selectors by levels.

Each ten-trunk group is divided as evenly as possible among the three sections of secondaries. This means three lineswitches in one section, three in another section, and four in another section.

This is not the only way to connect selectors to outgoing secondaries, but in general it illustrates the method.

**One Hundred Thousand-line System.**—It is usual in a system of this size to assign one digit of the call number to an office. This results in the ideal arrangement of ten offices, each having a capacity of 10,000 lines. Variations will be discussed later.

The essentials of the inter-office trunking are shown in Fig. 21. 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 lineswitches directly to first selectors arranged in sections *A*, *B*, etc. Since inter-office trunking begins at the first-selector banks, we need not bother ourselves as to whether there are primary and secondary line-switches.

It is assumed that the student is familiar with the ordinary inter-office network in which there is a group of direct trunks from each office to every other office in the exchange. This gives a total of $N(N\text{-}1)$ groups. Automatic switching in the ideal exchange which we are describing links the offices together by such a network.

Since the first selectors are the office-choosing switches, the first-selector bank 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 lead 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.

The "first selector" in this system did not exist in the smaller systems just described. The name was there but the function was not. The first selector in a 10,000-line system selects "thousands." This same function in the 100,000-line system is performed by the second selector. It is the position of any switch in the chain of selections that gives to it the name. The first to be used is called "first selector," the second to be used is a "second selector," and so on.

The first selector banks are multipled together so as to mingle the traffic and prevent any one group of ten trunks from being over loaded. All *A* sections may be multipled together, all *B* sections together, etc.; or the *A* and *B* sections may be tied together, the *C* and *D*, etc. Sometimes the multipling is *A* to *F*, *B* to *G*, etc. It is not necessary for the outgoing levels to be multipled in the same way as the local banks, nor

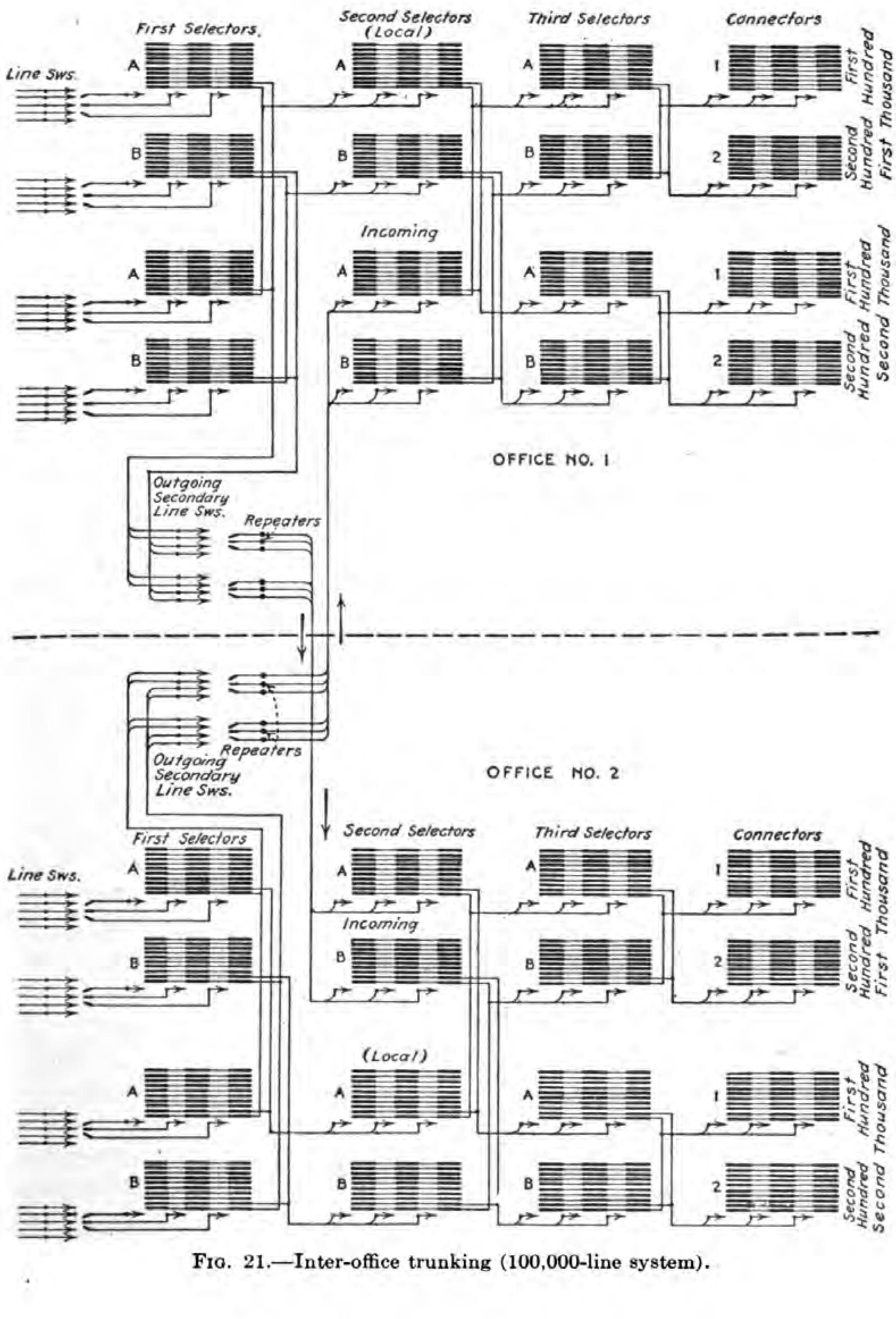



FIG. 21.—Inter-office trunking (100,000-line system).

all the local banks in the same way. It is entirely a matter of traffic requirements.

Economies can be secured by bringing into one group all the trunks from one office to another. To secure this end outgoing secondary lineswitches are interposed between the first selector banks and the outgoing trunks in the originating office. The trunks from any given section of first selectors are distributed among several sections of secondary line switches in order that each section of first selectors may have access to all the trunks leaving the office. In this way the several groups of trunks leaving the secondary lineswitches become in fact a common group. In case any one section becomes busy, the traffic will be carried by the remaining sections and each section 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 each 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 sections having the same letter, the traffic from outside offices coming through incoming second selectors is mingled with the local traffic.

**Large Trunk Groups.**—In the network of a large multi-office exchange it often occurs that the traffic between two offices requires a large number of trunks. Theoretically at least the number of calls which each trunk will carry increases with the size of the group to a very large number. As many as 1000 trunks in one group have been considered. It is possible to put together apparatus to secure this large a group. But it is doubtful if it is advisable. Indeed, there are many who think that a practical limit is reached at 250 trunks.

The usual selector switch, having ten trunks in each level of its bank may have access to 100 trunks by connecting each selector-bank point to a Keith secondary lineswitch. This was illustrated in Fig. 20. In this case the selectors of one group would have but one secondary lineswitch in each section of secondaries, and there would be ten sections of secondaries, each feeding traffic into ten trunks.

By using a selector which has 20 trunks on each level of its bank, the outgoing trunk group is increased to 200. There is no loss of speed in trunk selection by this method.

The ten-trunks-per-level selector used in connection with the rotary lineswitch (25 trunks on the bank) gives a maximum of 250 trunks in one group. The distribution of trunks from the selector banks to the lineswitches is made as described for the Keith switches.

The selector whose bank has 20 trunks per level together with the rotary lineswitch gives a group of 500 trunks.

The 20-trunk selector with a rotary lineswitch having 50 trunks on its bank give a maximum of 1000 trunks in a group.

All the combinations mentioned involve no new principles of structure, mechanically or electrically.

**Exchanges Having More Than Nine or Ten Offices.**—In an exchange which has more than nine or ten central offices, we can not take the first selectors for office selectors alone. This is because we can not set aside one first-selector level for one office, for there are more offices than levels. It is necessary to increase the availability in one of two ways.

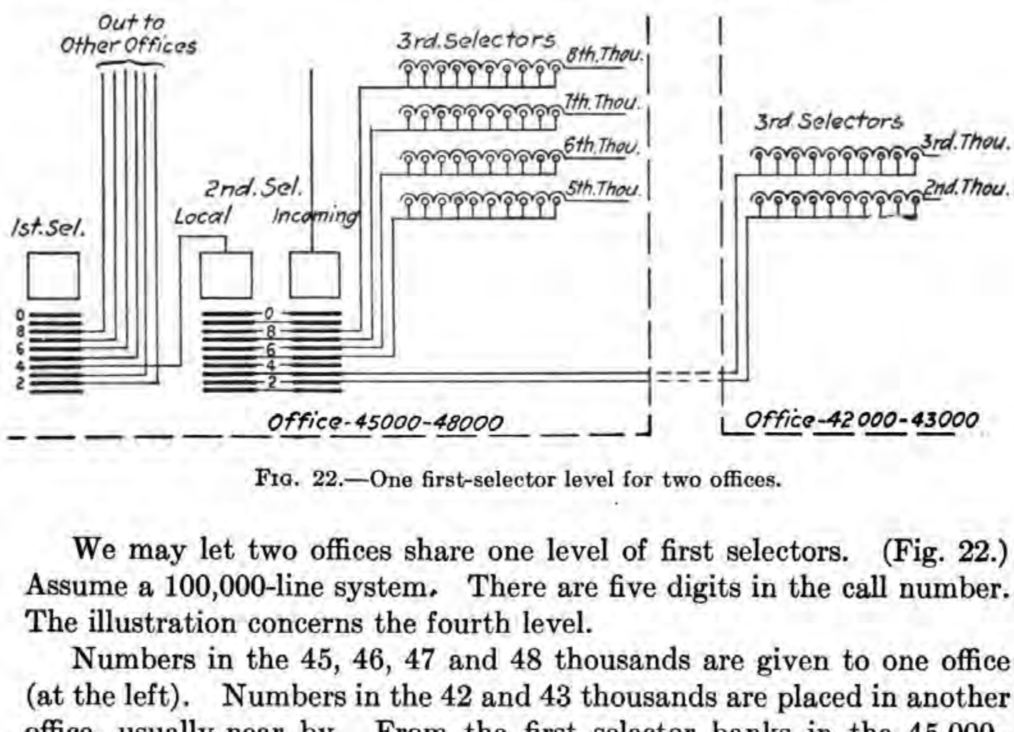



FIG. 22.—One first-selector level for two offices.

We may let two offices share one level of first selectors. (Fig. 22.) Assume a 100,000-line system. There are five digits in the call number. The illustration concerns the fourth level.

Numbers in the 45, 46, 47 and 48 thousands are given to one office (at the left). Numbers in the 42 and 43 thousands are placed in another office, usually near by. From the first selector banks in the 45,000–48,000 office the trunks run to other offices, except that the fourth level is local. These fourth-level trunks run to local second selectors.

Levels five to eight on the second selectors run to third selectors which are grouped according to thousands. Their banks in turn lead to connectors by hundreds. Incoming trunks from other offices in the exchange terminate on incoming second selectors whose banks are multipled with the local second selectors.

Levels two and three are trunked out to the associated office. There they terminate in third selectors for the second and third thousands.

The second selectors at whose banks occur the division between offices may be located anywhere, the question being one of local conditions. They may be in one of the two offices, as illustrated. They may be in a third office. (Fig. 23.) In this case the traffic from the four offices at the left divides at office $A$ for the 42–43 thousand office and the 45–48 thousand office. When any subscriber dials "4," his first selector trunks the call to a second selector at $A$. If now he pulls "2" or "3" that selector will trunk the call to the lower office at the right. But if

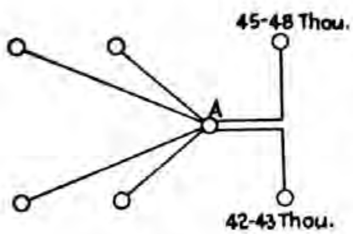



FIG. 23.—Traffic divided at intermediate office.

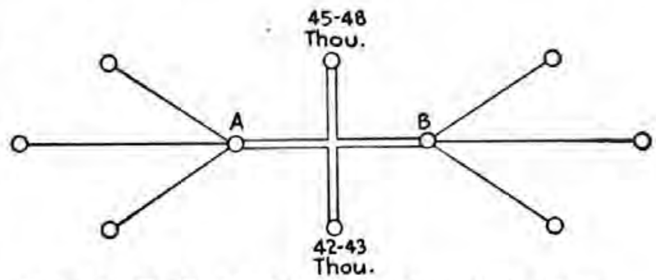



FIG. 24.—Traffic divided at two intermediate offices.

he pulls any digit from "5" to "8" inclusive, that selector will trunk the call to the upper office.

Again, the traffic may be divided at two intermediate offices. (Fig. 24.) In this case the traffic from offices at the left is most conveniently gathered together and separated at office $A$ while that coming from the offices at the right can be handled better at office $B$. The exact routing of inter-office cables is not indicated.

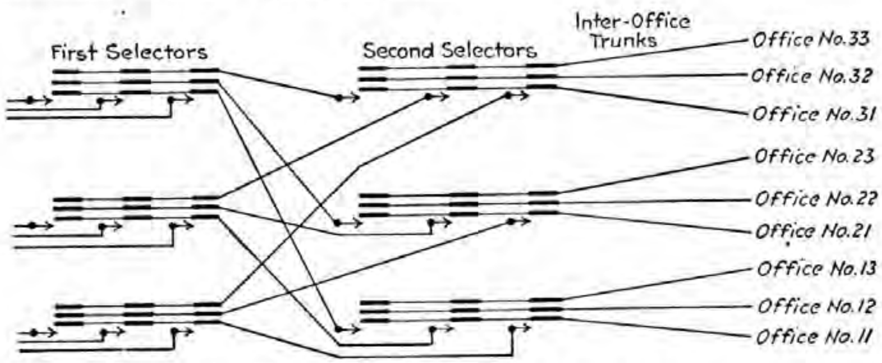



FIG. 25.—Direct trunks with first and second selectors.

Another way of handling the large exchange is to provide first selectors and second selectors in each office, with direct trunks between offices in most cases. (Fig. 25.) This permits the manual trunks to be used for automatic without rearrangement. Direct trunking is not always the most economical, but in changing from manual to automatic the existing trunk links must often be used until the more economical arrangement possible with automatic can be secured.

A better way is to divide the exchange into districts, each with a number of offices. (Fig. 26.) Theoretically there may be ten districts each having ten offices, or 100 offices in all. In the illustration, three districts are shown, each having three offices. For convenience, calls are assumed to originate in office No. 11, and one first selector shows how any number of first selectors will act. The first selectors choose the districts. If "1" is the first digit of the call number, the first selector will take the first digit of the call number, the first selector will take the first level, which leads to a second selector whose bank trunks to third selectors in other offices in the same district (offices 12 and 13, etc.) If the first digit

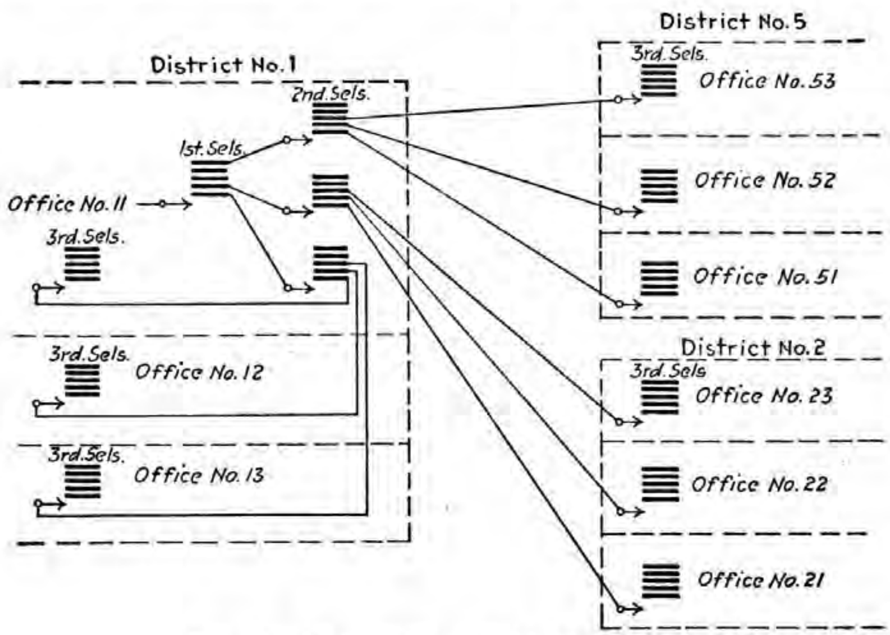



FIG. 26.—Large exchange divided into districts.

is "2," the first selector will secure a trunk to a second selector in another group, whose bank is trunked to third selectors in district 2. The second pull of the dial lifts the wipers of this second selector to the level corresponding to the office in the district.

The fundamental principle underlying the selection of offices in districts is the same as the selection of a 100-line group out of 1000 lines.

Having the exchange divided into districts, it is more economical to locate the second selectors of a district in the district which they serve. (Fig. 27.) In this case the trunks from first selectors to second selectors are long and those from second selectors to third selectors are short. The former are common, the latter are individual to the office.

If a subscriber of office 11 calls 13, he will lift the wipers of his first selector to the first level, secure a trunk to a second selector in the same district, so that on pulling "3," he will get a trunk to office 13. These second selectors may be located in office 11, or in any convenient place in district 1.

If the subscriber calls "22" the first selector will go to its second level, and the second selector in district 2 will be lifted to its second level, delivering the connection to office 22. These second selectors may be located anywhere in district 2, the place depending on economy of trunks.

It is usual to locate these second selectors in the most convenient of the offices of the district. But if the conditions warrant, they may be put in a building by themselves, with no local subscriber lines at all. In this case it is a "switching office," pure and simple. When the second selectors are located in an office which serves subscriber lines, the office has a double function, one of which is switching office.

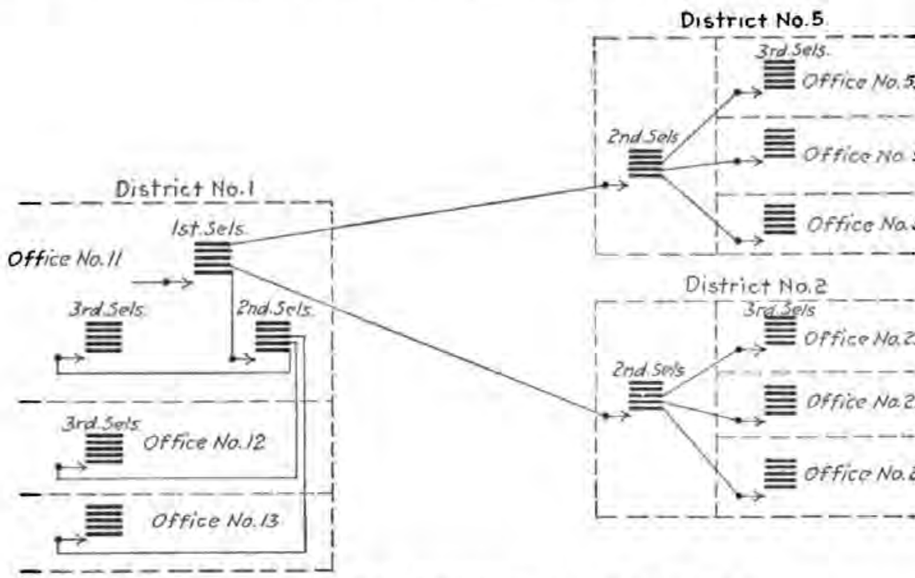



FIG. 27.—Large exchange, second selectors in their own districts.

Tandem trunking is the term applied to the idea of selectors located at an intermediate office to switch calls between other offices. The term holds in both the cases described above.

The outgoing trunks from an office need not be arranged the same as the incoming trunks. There is much freedom as to their arrangement. One may be direct trunks, the other may be tandem trunks.

The outgoing traffic from a district may often be combined to advantage by grouping the second selectors at one place in the district. (Fig. 28.) Here they are shown as located in office 11, it being assumed that this office is where it can best gather the traffic from all the other offices of the district. This renders each trunk available to all the offices of the district. It is a form of tandem trunking.

The switching-office idea and tandem trunking may be carried out regardless of districts. (Fig. 29.) As long as we are gathering together originating traffic, we may combine at any suitable place the trunks which come from any offices by using second selectors to function as a switching office. It gives great flexibility to the system.

Offices and districts may be rearranged, if the development of a city does not follow the lines which were apparent when the exchange was installed. Suppose (Fig. 30) that when the exchange was laid out it was

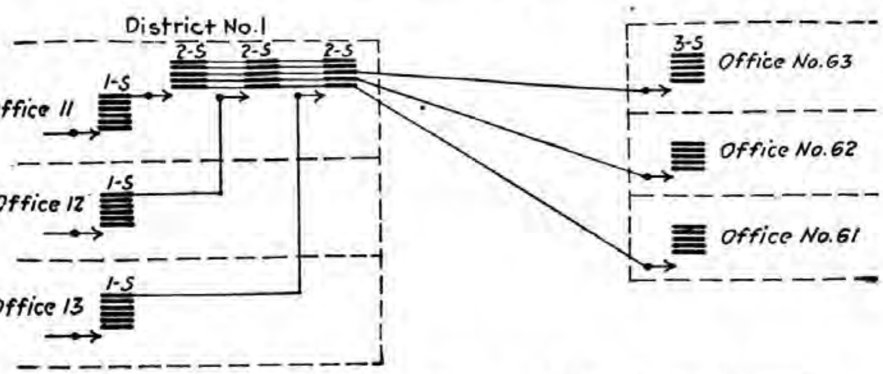



FIG. 28.—Combining traffic from one group of offices to another group.

thought that districts 2 and 3 would ultimately need ten 10,000-line offices each. Accordingly, offices 21, 22, 23, etc. to 29 and 20 were set aside for district 2 and offices 31, 32, 33, etc. to 39 and 30 were set aside for district 3. The upper part of the illustration shows trunks from the west offices coming to second selectors in the switching office of district 3 and similarly to district 2. The switching office of district 2 has also second selectors for traffic from the offices which lie to the south of district 2.

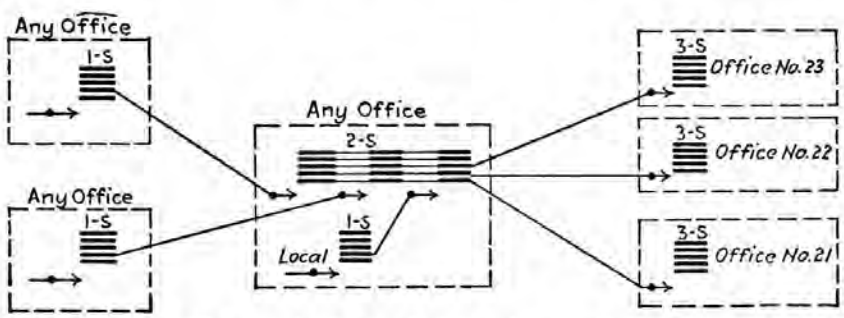



FIG. 29.—Combining traffic at an intermediate office.

But suppose that district 2 fails to develop, and that district 3 grows telephonically beyond the ten offices which were assigned to it. This can be corrected without changing the numbers of any telephones.

Move part of the switching office of district 2 into district 3 either in its switching office or elsewhere. The former is shown. The second selectors which are moved are marked "$x$" in the two sketches.

The selectors "$x$," lower part of Fig. 30, which were moved from district 2 to district 3, have ten levels, part of which are occupied by trunks for the existing offices of district 2. Levels 1, 2, and 3 are shown. They are now trunked separately to the offices which they serve. The vacant levels (4 and 5 are shown) are now trunked to new offices (24 and 25) which are opened to help take care of the growth in district 3. Thus district 3 has annexed part of the offices which were set aside for district 2.

Traffic for district 2 which comes from south offices will be handled by second selectors in the switching office as before the change. The

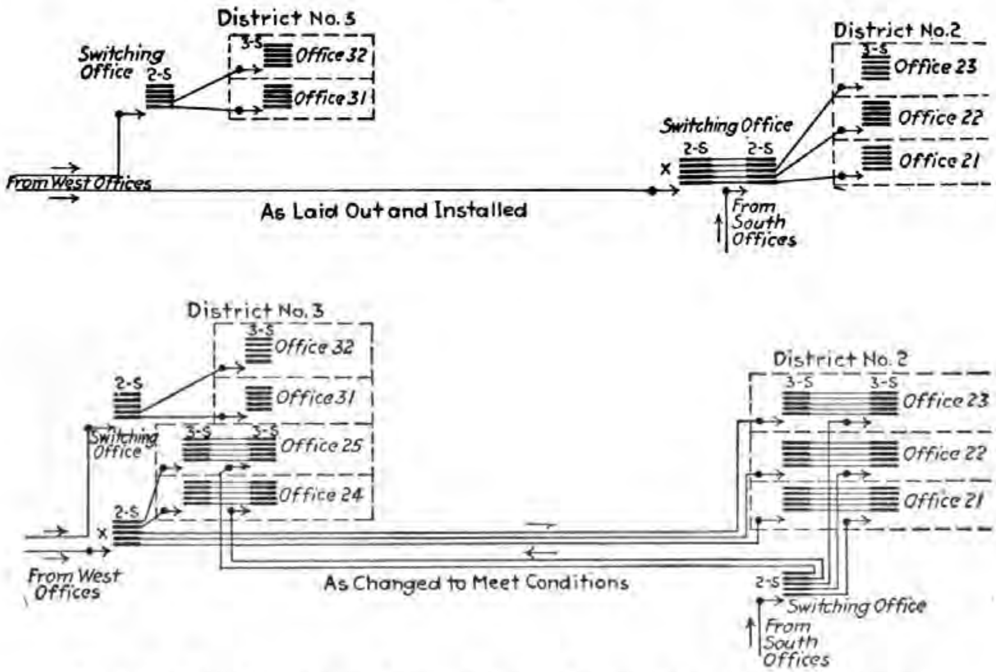



FIG. 30.—Trunking, inter-office, switching office moved to re-arrange districts.

three levels which were in service are trunked to third selectors in the offices 21, 22 and 23 whose banks are multipled with the existing third selectors. The formerly vacant levels (4 and 5) are trunked to third selectors in the newly opened offices (24 and 25).

**Sub-offices.**—The sub-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 lineswitch 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 sub-office. (Fig. 31.) There will be two kinds of trunks, outgoing trunks from the sub-office and incoming trunks to it. The outgoing trunks run from the banks of the lineswitches 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 sub-office.

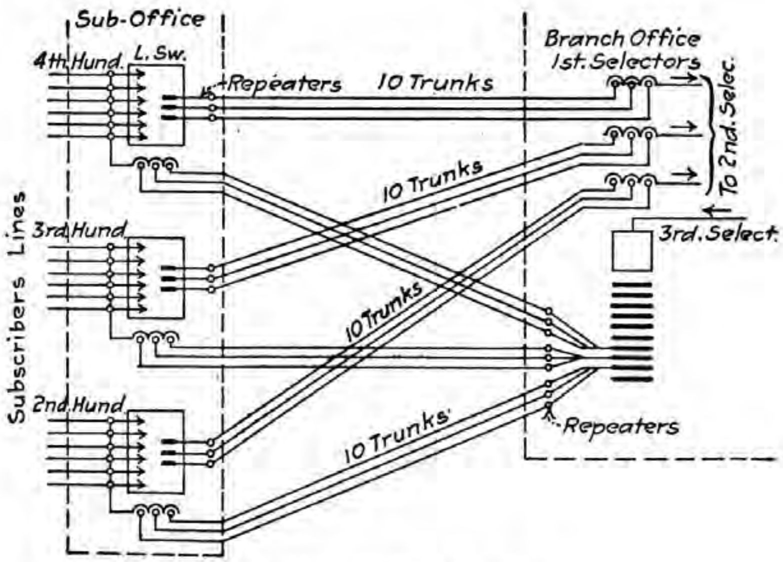



FIG. 31.—Sub-office trunking.

In order to reduce the number of trunk wires required between the banks of the lineswitches or the finder switches and the first selectors in the main office, it has been customary to install a repeater in the sub-office between the lineswitch 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 sub-office to the main office is short enough to warrant depending upon battery supplied from the main office, the "series" type of repeater or trunk holder may be used. This trunk holder has the simple function of grounding the release trunk and preventing the premature release of the lineswitch.

**Sub-office with Switching Repeater.**—In the ordinary sub-office, every local connection holds two trunks, the trunk from lineswitch bank to the selector in the main office, and the trunk from the third selector bank in the main office to the connector in the sub-office.

This can be avoided by using the switching repeater. (Fig. 32.) This repeater is built in the form of a selector, having wipers, banks, magnets, and relays. There is one of these per trunk from the lineswitch banks. Each such trunk also terminates in a secondary lineswitch. The trunks to the main office start at these secondary lineswitch banks.

The levels of the switching repeater lead nowhere, except those which correspond to the division in which the sub-office is located. A "local" level leads to local connectors in the sub-office.

When a subscriber in the sub-office initiates a call, the primary and secondary lineswitches extend the connection to a first selector in the larger office.

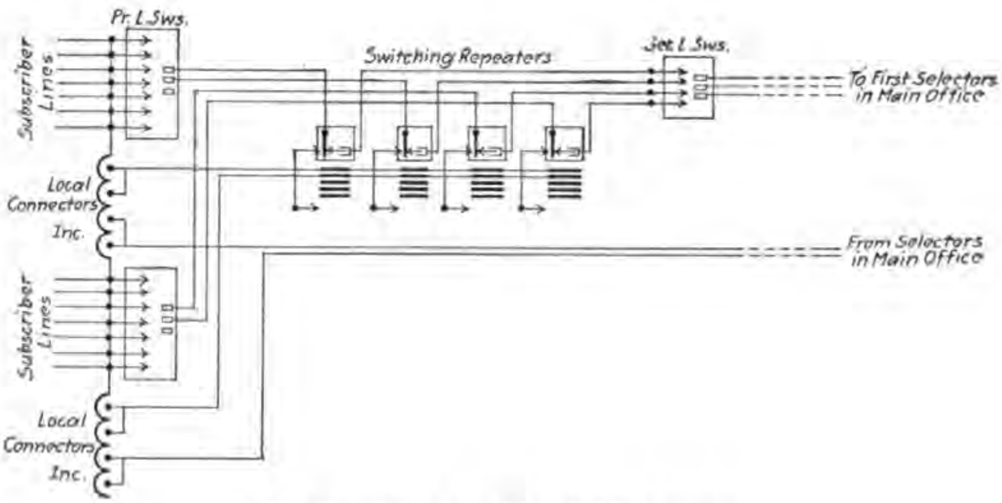



FIG. 32.—Sub-office with switching repeater.

When the subscriber dials the first digit, both the switching repeater and the first selector lift their wipers in synchronism. If the level called leads to other offices, the connection is completed as usual, the repeater acting only as a repeater.

If the subscriber dials the first digit of his own office, both repeater and selector lift their wipers in synchronism, when the repeater rotates into its bank, the secondary lineswitch is released and the trunk between offices freed to be used by others. Succeeding pulls of the dial complete the connection locally in an obvious manner. A 1000-line exchange is assumed. Any number of hundreds may be placed in the sub-office.

In a 10,000-line system, the repeater which switches on the first digit may be used, but second selectors must be interposed between the banks of the repeaters and the jacks of the connectors. (Fig. 33.) This sets aside one entire block of 1,000 numbers for the sub-office, none of which may be used elsewhere. When a subscriber in the sub-office dials a number in that office, the first selector in the main office goes so far as to seize an incoming second selector in the sub-office, but both first and second selectors are released when the repeater switches from outgoing trunk to wipers and local second selector.

In the 10,000-line system we may use a repeater which switches on the second digit, and thus do away with local second selectors, also permitting some of the hundreds in this thousand to be used in the main office. Figure 34 may be used to explain this trunking. When a sub-

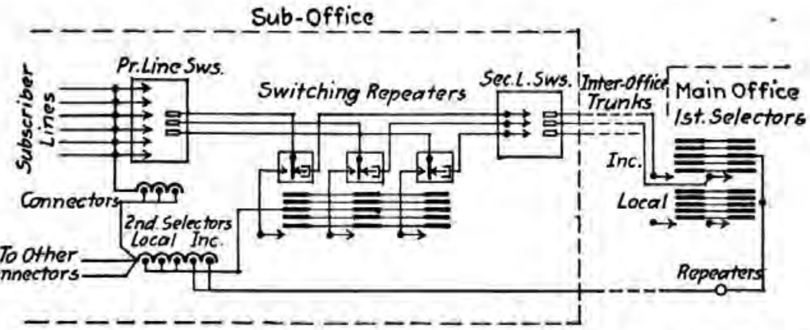



FIG. 33.—Sub-office with switching repeater, 10,000-line system switch on first digit.

office subscriber calls a number not in his own office, the wipers of the repeater are released after each digit and no local connection is made. If he calls a number in the sub-office, the wipers are released after the first digit, but a condition is created in the repeater so that when the second pull of the dial lifts the wipers to a level leading to local connectors, the repeater rotates the wipers to hunt an idle connector. When the connector is seized, the lines are switched from the outgoing trunk

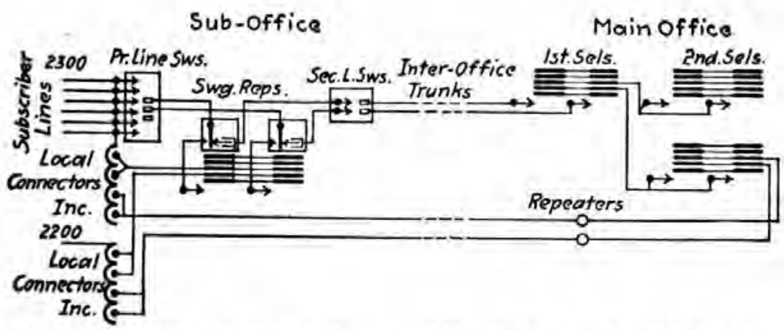



FIG. 34.—Sub-office with switching repeater, 10,000-line system switch on second digit.

to the wipers and the local connector, so that the switches in the main office release.

The switching depends upon both of the first two digits. Either one being wrong will cause the repeater to fail to switch to local.

The sub-office may be increased to 1000 lines, maximum.

The same switching repeater may be used in a 100,000-line exchange by inserting third selectors between the repeater banks and the local connectors. The sub-office must be made up of one or more thousands, each thousand being completely set aside for this sub-office. But other thousands in the same 10,000 may be used elsewhere. The trunking limit of the sub-office is 10,000 lines, but this is never reached, because it would long before that have become a main office itself, and need to be equipped with first selectors.

In the 100,000-line system, sub-offices may have less than 1000 lines each by using a switching repeater which switches on the third digit. It requires no third selectors in the sub-office, because the bank of the repeater is connected by levels to the connectors. The limit is 1000 lines for any one sub-office. Any hundred-line unit which is not used in a sub-office may be assigned elsewhere.

Two-way trunks between a sub-office and its main office are sometimes used, if the traffic is light, or has its busy-hour load one way at a different time from the busy-hour load in the other direction. (Fig. 35.)

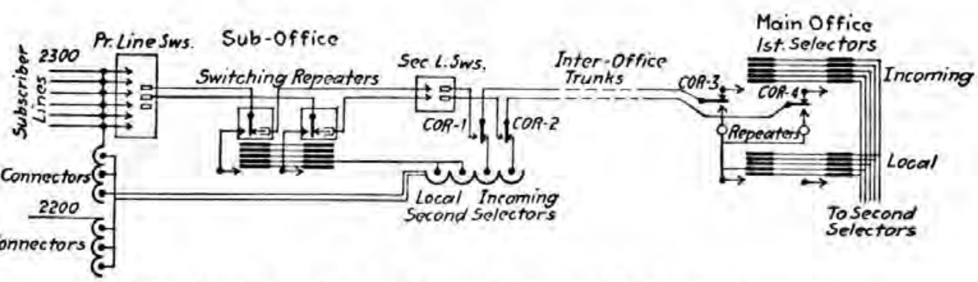



FIG. 35.—Sub-office with 2-way trunks and switching repeater.

In this illustration second selectors are used in the sub-office. The incoming second selectors differ from the local ones in having a switching or cut-off relay to switch the inter-office trunk from the selector to the secondary lineswitch for an outgoing call. The incoming first selectors in the main office are similarly equipped.

Normally each inter-office trunk ends in a first selector in the main office and in a second selector in the sub-office. When a sub-office subscriber initiates a call, the secondary lineswitch takes a trunk and, over an auxiliary wire, operates the cut-off relay (*COR*-1) extending the connection to the first selector in the main office. Cut-off relay 3 (*COR*-3) is prevented from operating, but the first selector grounds the release trunk through the repeater, so that any call from a local first selector will find the trunk busy.

When a main office subscriber calls the sub-office, the first selector (local) takes a trunk leading through a repeater. This repeater, over an auxiliary wire, operates the cut-off relay (*COR*-3) which switches the inter-office trunk onto the repeater. At the sub-office, the cut-off relay

(*COR*-1) does not operate, but the incoming selector makes the trunk busy so that no secondary lineswitch can take it.

If two-way trunks are used with a sub-office which has no selectors but has more than 100 lines, the inter-office trunks are divided into groups, one for each group of connectors (100-line unit). For traffic from main to sub-office they operate by groups, for traffic in the other direction they operate as one group.

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 only rotary lineswitches. The primary and secondary lineswitches used by the Siemens & Halske Company in full automatic systems have a capacity of ten trunks each, while in its traffic-distributor system a similar lineswitch having a capacity of 25 trunks is used.

In the American Automatic Telephone Company systems finder switches are used instead of lineswitches. Each finder switch has a capacity of 50 lines. The multiple wiring of the finder-switch banks is "slipped" to reduce the amount of wiper movement and the loss of time required to find a calling line. The wipers of each finder switch are the terminals of a first selector switch.

The wipers of these first selector switches do not have both a vertical and a rotary movement as in the Strowger design, but have a rotary movement only. The capacity of the bank is 50 trunks in ten groups of five each, and the rotary movement is divided into two actions. The first action is controlled by the subscribers' calling device and rotates the wipers to the group of five trunks leading to the section of the switchboard in which is terminated the line of the party being called. The second action is entirely automatic and places the wipers on the terminals of an idle one of the five trunks.

The second selectors act the same as the first selectors and the banks of the connectors are the same as those of the first selectors. Of course all movements of the connector wipers are controlled by the subscribers' calling device. Ordinarily, five connectors are put in one group but by the use of "individuals" more are sometimes employed. The trunking scheme of this company is more fully described in the chapter devoted to its apparatus.

The Clement "Auto-manual" system uses linefinder switches of 100 lines capacity. These switches have their bank contacts arranged similarly to those of Strowger switches, but the contacts are set on edge and placed in vertical rows instead of horizontal rows. The wiper rotates to the proper row and then moves upward to the proper contact. The contacts are set on edge to reduce the opportunity for dust to settle on them.

The assignment of a finder switch to search for each calling line is controlled by a master or distributing switch.

As in the American Automatic system, each finder switch is tied "tail to tail" to a first selector switch.

The first selector, second selector and connector switches each have 100 capacity banks and each use the rotary movement first and vertical movement second as the finder switches do.

When a calling subscriber's line is connected to an idle first selector, another idle finder switch is set in motion and bridges a second trunk on the trunk already connecting the calling party to a first selector switch. This bridged trunk leads to a key-set switch which operates automatically and extends the bridged trunk to an idle set of calling keys in some operator's position. After the number has been set up by the operator and the connection has been completed, the key-set switch and its finder switch automatically release and await another call. The methods employed for multipling the 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 European system, primary and secondary finder switches are used. These switches have a capacity of 60 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 American 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 were used which have access to 100 lines each. These were single-motion switches as in the Western Electric system. Each switch had ten sets of wipers which were selectively chosen. Each finder was tied to a first selector and each first selector had as many second selectors, or "interconnectors" as they are called, as there are thousands. The connectors had a capacity of 100 lines each. All switches had a rotary wiper movement only.

## CHAPTER III

## AUTOMATIC ELECTRIC COMPANY'S APPARATUS

The systems of the Automatic Electric Company are divided into the two general classes—"three-wire" and "two-wire." The term "three-wire is commonly applied to systems which require, in addition to the regular metallic circuit from a telephone to its central office, a connection from each telephone to ground. This term is used to distinguish these systems from what are called "two-wire systems" and which require no ground connection at a subscriber's station.

While there are in operation a large number of three-wire systems of the Automatic Electric Company's manufacture, which are either of the earlier local battery type (using cells of battery at each telephone for supplying current for talking purposes) or else of the later common battery type and which are giving excellent and economical service, they are thought to be of especial interest only to those connected with the companies operating them and they will, therefore, not be described in this chapter. It may be said, however, that the practice, mechanisms and principles employed in these systems are not greatly different from those used in the two-wire common battery systems herein described.

**The Telephone Instrument.**—The discussion of the apparatus will open with a description of the telephone instrument, with special reference to the automatic-calling or impulse-sending device used.

Prior to the year 1896, an automatic telephone subscriber called any number which he might desire by pressing push-buttons on his telephone. There were generally three push-buttons arranged and labeled as shown in Fig. 36. If the subscriber wished to call No. 143, for example, he would first push the "hundreds" button once, then the "tens" button four times, and finally the "units" button three times. While this arrangement gave passable service, the subscribers made many mistakes in counting the pushes and sometimes did not press a button in far enough, or hold it long enough. Consequently, in 1896 a contact-making machine or a "calling device," as it is commonly named, was substituted for the push-buttons. A wall telephone equipped with a modern calling device is shown in Fig. 37, and a desk telephone in Fig. 38.

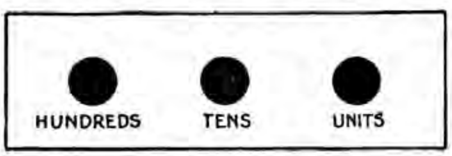



FIG. 36.—Calling push-buttons.

As shown in these figures the visible portion of the calling device consists 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, 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, "0" appears. In the Automatic Electric Company's practice "0" always represents "10."

Fig. 37.—Wall telephone instrument.

To call "143," for example, a subscriber will first remove his receiver from its switch hook, then put his finger into the hole through which "1" is seen and pull the dial around until his finger strikes the stop. He will then take out his finger, allowing the dial to return to normal, and place it in the hole through which "4" is seen, and again pull the dial round until his finger strikes the stop. Finally, he places his finger in the hole showing "3," and turns the dial until his finger again strikes the stop. He then places the receiver to his ear and awaits the answer of the party called. Each turn of the dial requires approximately one second. By the time he has placed the receiver to his ear, the automatic machines at the central office will have completed the connection to the desired line and will have commenced to ring intermittently the bell of the desired telephone. If the number called by a subscriber is busy, his receiver will give forth an intermittent buzzing sound, the same as that used for a busy signal in large manual systems. When through talking he hangs the receiver on the switch hook and the circuit changes thus made cause the central office apparatus to return to normal condition.

Fig. 38.—Desk telephone instrument.

There is contained within the calling device, but not seen, a revolving cam, arranged to make and break the contact between a pair of springs.

A small governor, which is geared to the cam shaft, controls the speed at which it revolves. The power is furnished by a piano-wire spring which is rewound each time the subscriber turns the dial. The cam does its work after the subscriber's finger strikes the stop and as the dial returns to normal position.

A photograph of the calling-device mechanism which is ordinarily hidden within the telephone instrument is shown in Fig. 39, and a drawing showing the functions of some of the parts more clearly is given in Fig. 40.

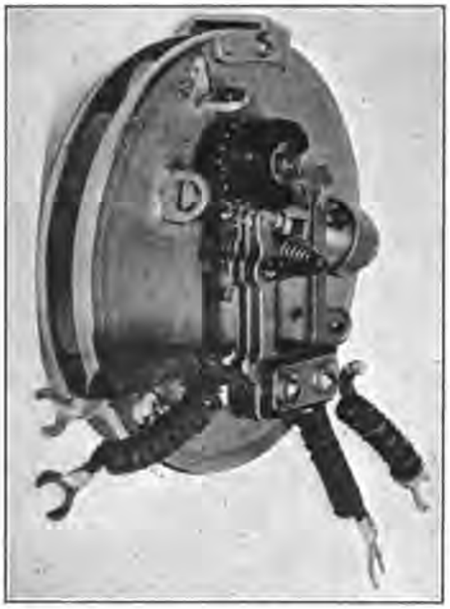


Fig. 39.—Automatic telephone calling device.

As the dial is turned, the ratchet spring snaps from tooth to tooth of the ratchet wheel and at the same time the spring coiled around the dial shaft (projecting from the rear of the calling device) is wound up. When the dial is released the ratchet spring at once engages a tooth of the ratchet wheel and under the influence of the shaft spring the dial returns to its normal position, carrying the ratchet wheel with it. The governor and impulse cam are 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 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.

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. 41. When the receiver is removed and the switch-hook rises, the

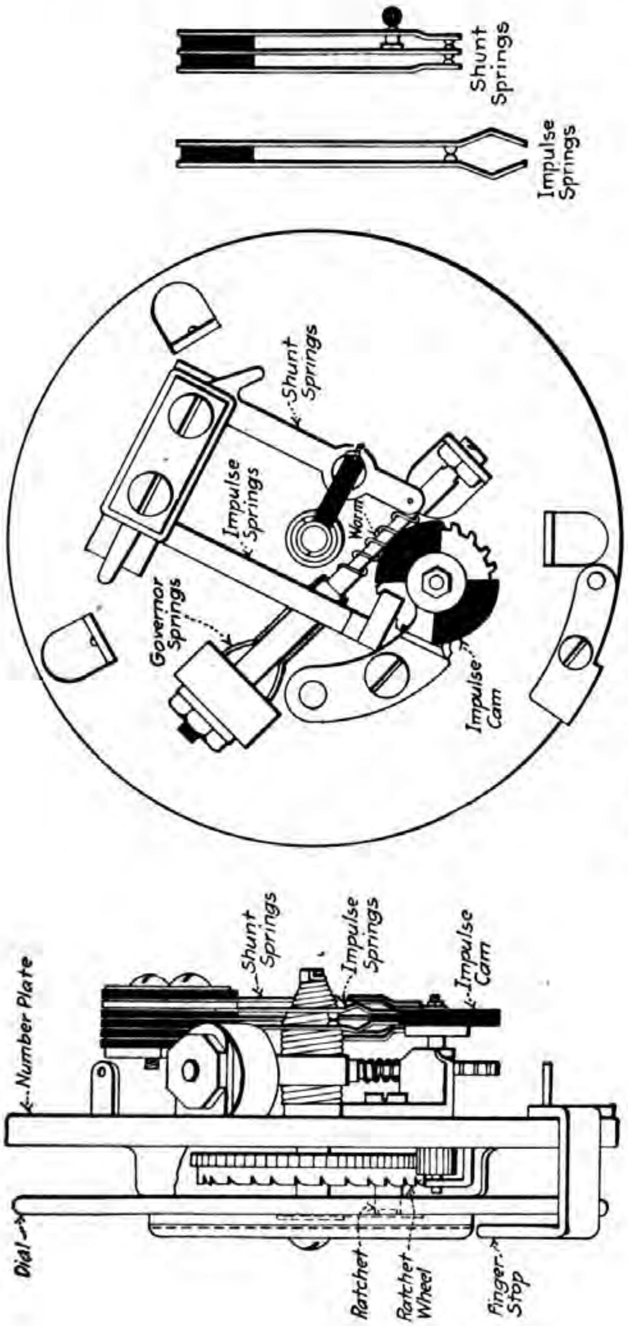



Fig. 40.—Details of calling device.

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 springs, it opens the line for an instant, thus causing one "impulse" to be sent. During the time of sending impulses the receiver and transmitter are both shunted out of the circuit by the action of the shunt springs, between which contact is closed whenever the dial is turned away from its normal position. This contact is opened, when the dial returns to normal, by the bushing at the end of the arm carried by the dial shaft.

The object of shunting out the transmitter and receiver during impulse transmission is to keep the resistance of the subscriber's loop constant and prevent undue noise in the receiver. Very often it would not remain constant, especially on a desk telephone, if the transmitter were in circuit, because it is not uncommon for a subscriber to pick up a telephone and hold it at various angles so that the carbon in the transmitter

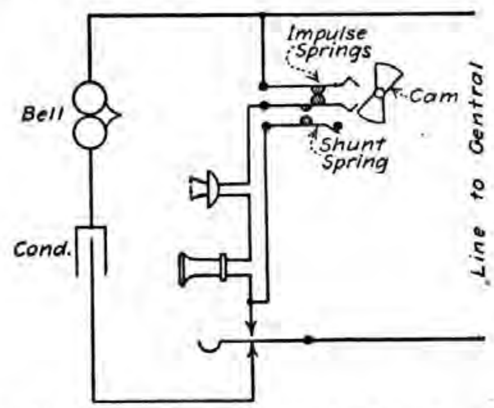



FIG. 41.—Automatic telephone circuit, series type.

shifts about, causing wide variations of the transmitter resistance during the time the dial is being used. Although in most cases the operation would be satisfactory, even with the handicap of this varied resistance, it is safer and requires less careful adjustment of the mechanism to use the shunt springs. Fully to comprehend the diagram it should be understood that the receiver used with this circuit is what is called a non-polarized direct-current or series receiver, *i.e.*, it has no permanent magnet, but uses an electromagnet and is connected in series with the line and the trasmitter during conversation.

The direct-current type of receiver is not essential to the operation of the two-wire system, but was perfected and put on the market by the Automatic Electric Company at about the time their two-wire system was. Since it is especially applicable to that system but is not applicable to three-wire systems, it has become identified with the two-wire systems. Several of the first two-wire plants installed, however, use induction coils and receivers with permanent magnets at the subscribers' stations.

Varieties of telephone instrument circuits will be found in Chapter on "Subscribers' Station Equipment."

In Fig. 42 is shown an ordinary common-battery manual desk telephone which has been converted into an automatic instrument by mounting a calling device upon it in a suitable cup clamped to the handle tube of the instrument. This indicates one of the attractive features of this system, which is that almost any common-battery telephone may be readily converted into one suitable for use on an automatic system by mounting a calling device on it and connecting the calling device in series with the transmitter of the instrument.

FIG. 42.—Manual telephone instrument converted into an automatic instrument.

**Switchboard Apparatus.**—The automatic switchboards used in systems of the Automatic Electric Company employ the following principal pieces of apparatus:

1. Lineswitches (primary and secondary) with their master switches.
2. Selector switches (first, second and third).
3. Connector switches.
4. Repeaters and trunk holders.

Whether or not all of these pieces of apparatus are used in any system depends upon the size of the system and the number of offices in it.

Many of our readers are more familiar with manual switchboard apparatus than with the principles of automatic switchboards. Therefore, this explanation of automatic switchboard apparatus will begin with a description of the two pieces of equipment whose functions are most nearly analogous to the subscribers' line equipment and to the cord circuits manipulated by an operator in a common-battery manual office.

The subscribers' line equipment of the manual is resembled by the lineswitch associated with each line of the automatic switchboard; and the cord circuit manipulated by the operator is resembled by the connector switch of the automatic switchboard. By means of these two pieces of apparatus, only, a system of not more than 100-lines capacity may be built up. After such a system has been discussed, the equipment used for enlarging it into a system of almost unlimited capacity, as explained in the chapter on "Trunking," will be described.

A switchboard for 100 lines consists of 100 lineswitches with their master switch and other associated apparatus and about ten connector switches for making interconnections between the lines.

**The Keith Lineswitch.**—The Keith lineswitch, used by the Automatic Electric Company, was invented by Alexander E. Keith, vice-president of the company. It is distinct from those of the rotary type. Essential parts of each lineswitch are its line relay and its cut-off relay. The duties of the latter are practically the same as those of the relay of the same name associated with each common-battery manual line, while those of the former differ in one important respect, viz., in manual practice the line relay operates a signal to attract the attention of an operator who connects an idle cord circuit to the calling line, but in automatic practice the line relay causes the lineswitch to perform the reverse function of connecting the calling line to an idle cord circuit mechanism, *i.e.*, to an idle connector switch.

The duties and operation of Keith lineswitches have been explained at length in the chapter on trunking, but a further reference to them may be helpful here. Each subscriber is equipped with a lineswitch, consisting of a magnet and a lever, carrying on its end a plunger. These plungers are maintained in alignment by means of the guide shaft, whose edge fits into a notch in the tail of the plunger. Immediately in front of each plunger is a group of contacts arranged on the arc of a circle. Half of these contacts are attached to trunk lines, the other half to the subscriber's line to which this lineswitch belongs. If the magnet of the lineswitch be energized, the plunger will be driven into the bank and by pressing together certain springs will connect the subscriber's line to a certain one of the trunk lines. These trunk lines in a 100-line system lead to connector switches through which the subscriber obtains access to the entire exchange.

The master switch is responsible for the control of the guide shaft, as indicated in Fig. 43. The means of connection is not shown in this illustration. The duty of the master switch may be divided into two parts:

*First.*—The duty of keeping the shaft and plungers in such a position that all the plungers will be pointing toward the contacts of an idle trunk line.

*Second.*—The duty of preventing any lineswitch from operating during the time that the master switch is hunting an idle trunk.

There are two types of lineswitches used in two-wire systems, the "single spool" and the "two spool." Because the single spool switch has not been made for a long time, only the two-spool switch will be described.

A photograph of a lineswitch and bank is reproduced in Fig. 44. The line relay is at the left. It has a copper collar to make it slow to release. The plunger is carried by the plunger arm, under which is pivoted the cut-off relay armature. The plunger has a notch in its fan-shaped tail to engage the guide shaft. The point of the plunger carries two little hard rubber rollers to press the bank springs.

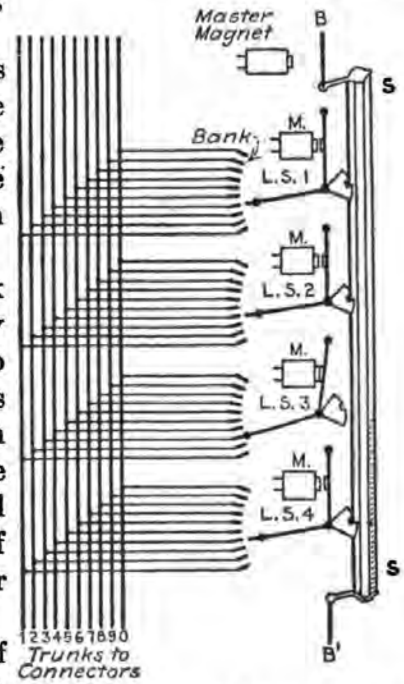



FIG. 43.—Scheme of master-switch control of Keith lineswitches.

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

These lineswitches are mounted in four sets of 25 each on an "upright" or "unit" as shown in Fig. 86, Chapter 4. Each set of 25 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 lineswitches are divided into two sets of 50 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 lineswitches 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 25 lineswitches each.

The lineswitch 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 lineswitch 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. 44.

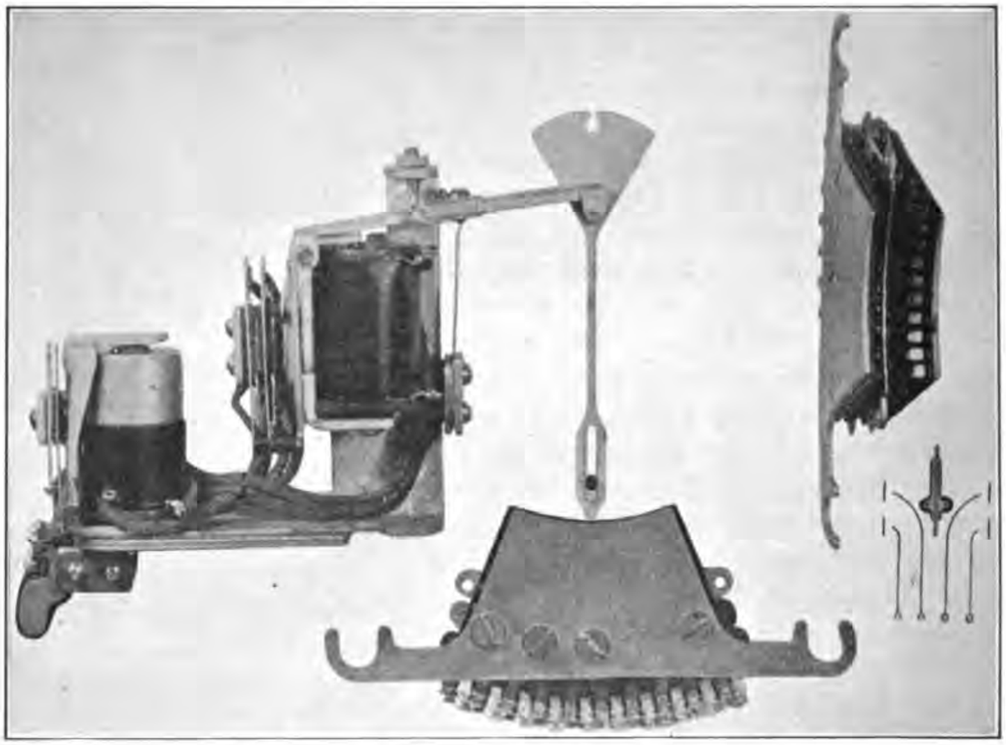


FIG. 44.—Keith lineswitch with an unwired bank.

The switch jacks engage corresponding shelf-jack springs as shown in Fig. 45, which gives a clearer view of a master switch and a few mounted lineswitches. The lineswitches in this illustration are of the two-spool type.

**Lineswitch Circuits.**—The circuit of the lineswitch 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 lineswitch 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.

The operation of the lineswitch circuit (Fig. 46) proceeds as follows: When a subscriber lifts his receiver from the switch hook the circuit is closed from earth at the lineswitch through spring (*a*) to the positive side of line to the telephone, through the telephone receiver and transmitter, back on the negative side of line through spring (*b*) and the line relay winding, *L.R.*, of the lineswitch, to the negative pole of battery.

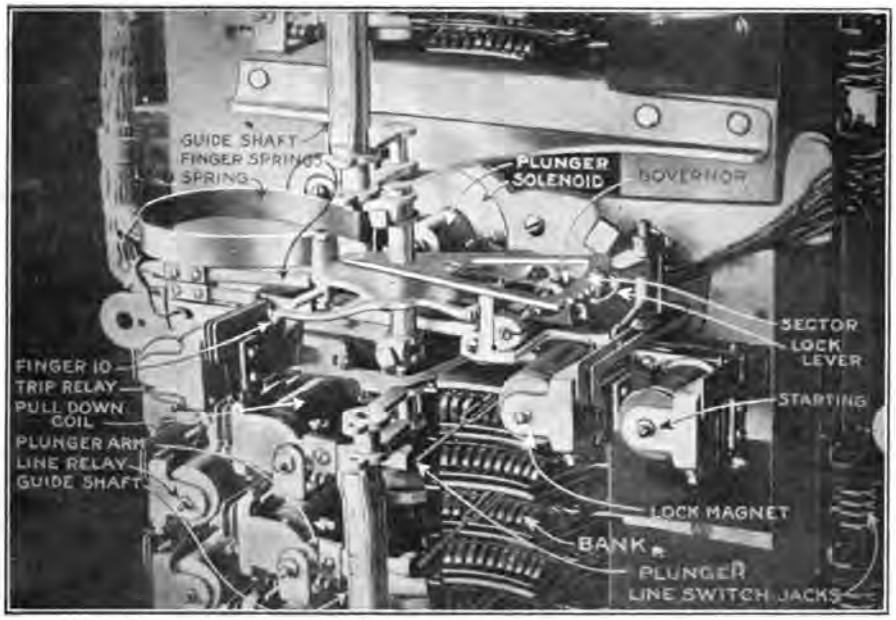



FIG. 45.—Master switch mounted on shelf of Keith lineswitch unit.

As soon as this circuit is established the line relay attracts its armature, closing the circuit from ground through the "pull-down" coil, *P.D.C.*, to "open-main" battery bus bar, which is always connected to the negative pole of battery except when the master switch is moving the lineswitch plungers from one trunk to another.

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 eddy current in the copper collar. 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.

When the plunger is thrust into the bank, circuit is closed from telephone to the line relay of the connector, causing it indirectly to ground the release trunk. This energizes the *B.C.O.*, which holds down the bridge cut-off armature and also holds the plunger after the line-relay armature has dropped back and opened the circuit through the pull-down coil.

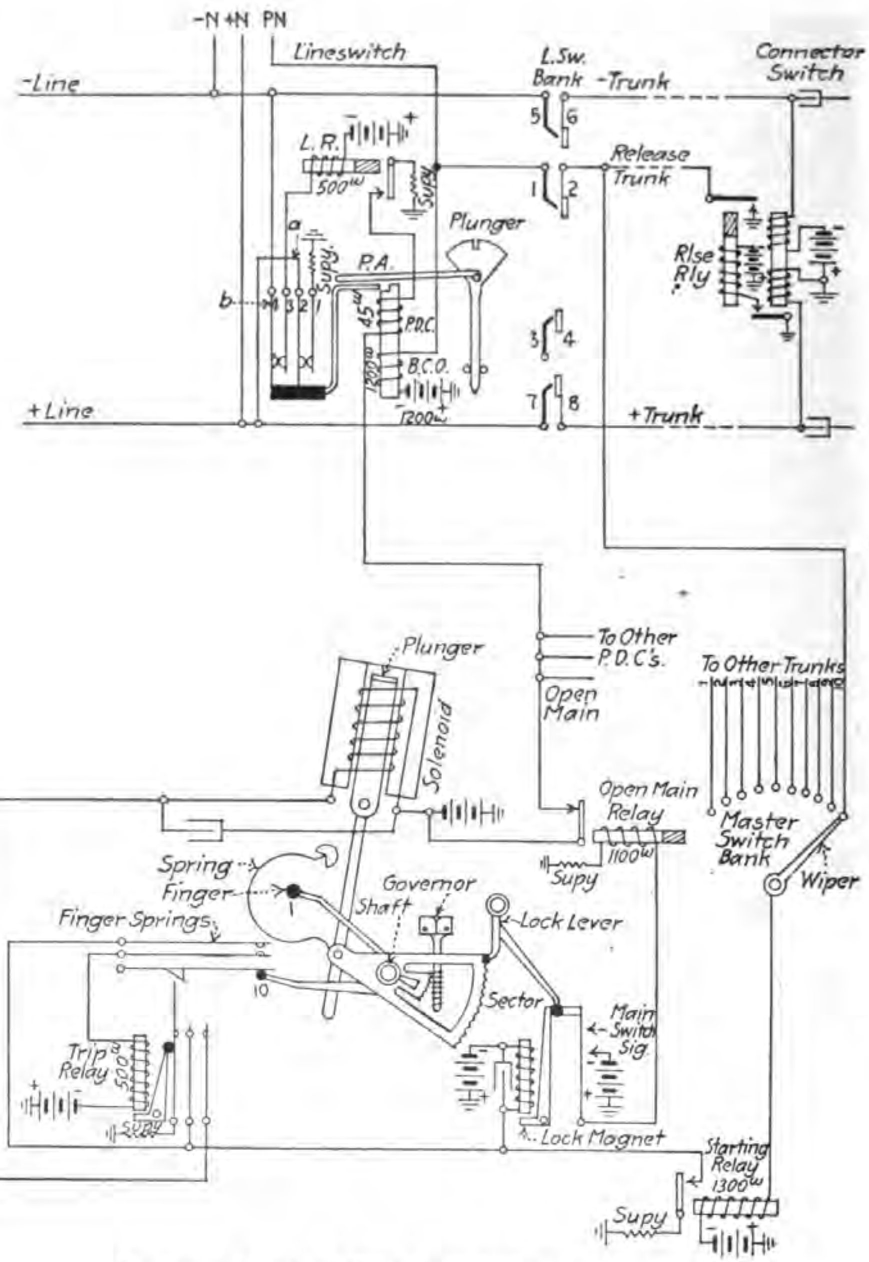


FIG. 46.—Circuit of Keith lineswitch and master switch.

The release of the switch is, therefore, controlled through the release trunk so that whenever the connection between the release trunk and ground is broken by the action of the switch ahead, which has this connection under control, the bridge cut-off winding of the lineswitch will release the plunger. While the plunger remains in the bank the positive side of the line is extended through to the trunk by contact between bank springs 7 and 8, and the negative line by contact between bank springs 5 and 6. The earth connection of the release trunk serves also to establish a guarding potential on the private normal *P.N.* of the lineswitch, protecting it from seizure by a connector switch while it is in use. The release trunk also grounds the master switch-bank contact. This causes the master switch to operate and swing the plungers, still under the control of its shaft, to a point where they are poised over the bank springs of an idle trunk.

The springs controlled by the armature of the bridge cut-off winding are also used when the line to which the lineswitch is attached is called. At such a time the bridge cut-off winding is energized through a circuit that will be explained in the description of the connector-switch circuits, and the operation of these springs disconnects the line relay winding and ground of the lineswitch but does not affect the plunger arm.

**Master Switches.**—The master switch used in the two-wire system is shown in Fig. 47, and its circuits are given in Fig. 46.

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

When the lineswitch whose action we are discussing seizes a trunk, the ground placed on the corresponding master-bank contact energizes the starting relay of the master switch. The illustration shows the master switch as holding the guide shaft so as to point the plungers at the tenth trunk. The starting relay causes the lock magnet to pull up, withdrawing the lock lever so that the escapement releases the sector. The force of the U-shaped spring moves the guide shaft with the idle plungers. The governor restrains the speed. During this time the lock magnet has energized the open main relay, which cuts negative battery from the pull-down coils so that no subscriber can plunge in his switch.

When the master-switch wiper strikes an ungrounded contact, indicating a free trunk, the starting relay falls back and releases the lock magnet. Instantly the lock lever drops the roller into a notch in the sector, stopping the guide shaft with the idle plungers poised opposite the idle trunk. The open main relay now releases and closes the negative battery wire to the pull-down coils.

When the guide shaft has reached trunk No. 1, the U-spring has done all that it can do. As soon as a subscriber takes this trunk, the solenoid magnet pulls the shaft back to trunk No. 10, ready to start all over again. The way that it is done is this:

When the guide shaft is opposite trunk No. 1, finger No. 1 is pressing together the two-finger springs. When the starting relay operates, the trip relay is pulled up as well as the lock magnet. The springs of the trip relay are caught by the latch and held together. These springs keep the lock magnet energized regardless of the starting relay. They also energize the solenoid magnet. The latter pulls the guide shaft to trunk

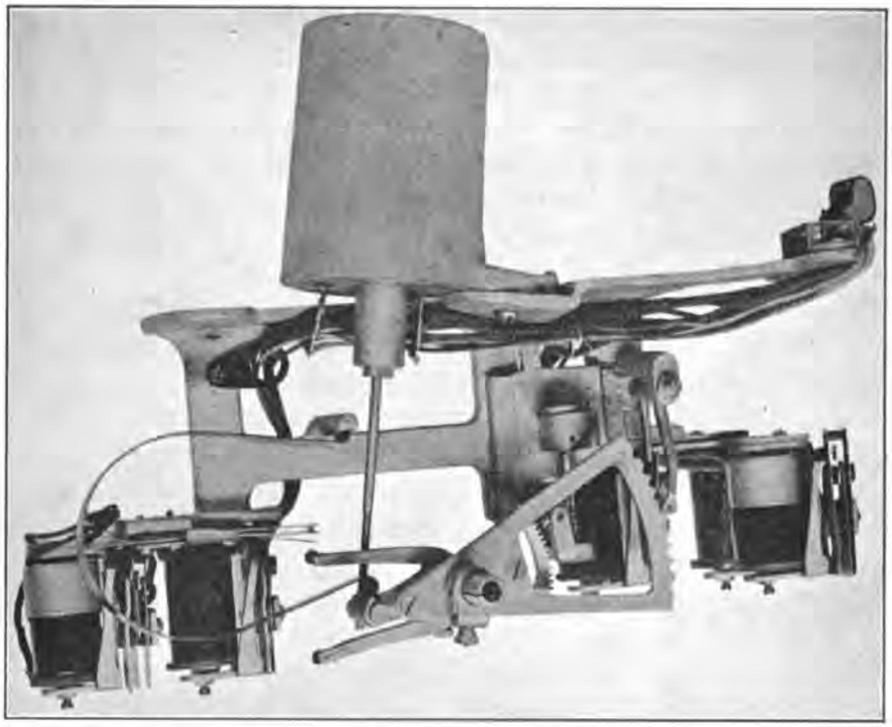


FIG. 47.—Unmounted master switch.

No. 10, where the finger No. 10 trips open the springs of the trip relay. This cuts off the current from the solenoid magnet, and returns the lock magnet to the control of the starting relay. From then on, the action is as has been described. If the tenth trunk is free, the shaft will stay there. If it is busy, the starting relay will cause the hunt to begin, the shaft being moved by the U-spring.

The several symbols marked "*Supy*" refer to a common relay which gives switchroom supervision. The details of this will be described in the chapter on Power Plant.

The condenser placed in parallel with the solenoid is to reduce the arc at the contacts of the trip relay. A similar condenser is provided for the lock magnet.

**Rotary Lineswitch.**—This is a later development which avoids common mechanism (master switch) and permits much larger trunk groups and greater flexibility of arrangement. While rotary lineswitches with ten trunks (Siemens and Halske) have been made, the Automatic Electric Company made its bank with 25 sets of contacts. It was also arranged so that 50 sets of contacts can be used by the same mechanism. The advantages of large trunk groups are discussed elsewhere.

The rotary lineswitch, Fig. 48, has a bank and four double-ended wipers, so that each rotation through a half circle runs a wiper over all trunks. The current is carried to each wiper by two springs. The private wiper, by means of which the trunks are hunted, has a longer trailing tip than the rest.

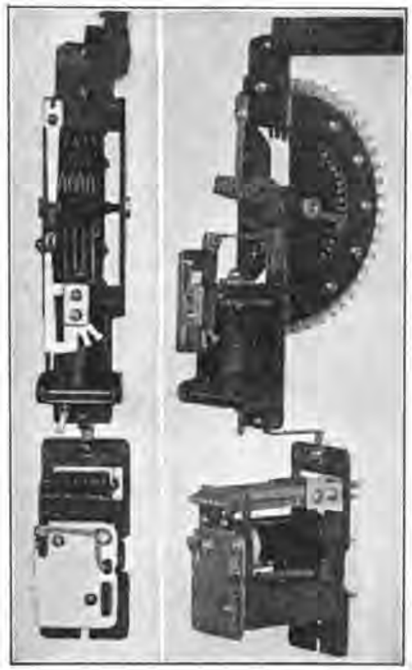


Fig. 48.—Rotary lineswitch with bank.

The motor magnet drives the wipers on its return stroke. The pawl rests normally between the toothed wheel and a stationary lug, locking the wipers in position. The wipers rest wherever they were when last used, and never move unless it is necessary to hunt an idle trunk.

There is a line relay and a cut-off relay with each lineswitch. The former is slow-releasing, the latter is quick-acting. There is a mechanical interlocking device which permits the cut-off relay to move its armature only part way if the line relay is normal. This breaks all back contacts, but does not close any front contacts. If the line relay is energized, the cut-off relay can move its armature a full stroke.

The circuits of the rotary lineswitch, Fig. 49, are very simple. The line relay is normally connected to the subscriber line with the usual polarity of battery. The cut-off relay is in series with the motor magnet and the lead to the private normal *PN*. The line relay initially protects the calling line from intrusion and connects the trunk-hunting circuit. The cut-off relay siezes the free trunk and extends the connection.

When the subscriber takes his receiver from the hook, the line relay energizes, grounds the private normal *PN* for protection, connects the motor magnet *MM* to the private wiper to test the trunk, and removes the mechanical lock from the cut-off relay armature. In the large majority of cases the trunk is free. The magnet, finding no direct ground, will not act through the high resistance of the cut-off relay *COR*. The cut-off relay, drawing current through the magnet and springs 3–4 of the line relay, pulls up, switching both subscriber lines $-L + L$ from ground, line relay and battery to the wipers $-W + W$. It also switches the private wiper $PW$ from the test circuit of springs 1–2 of the line relay $LR$ to the private normal and the cut-off relay.

The extension of the subscriber lines to the connector causes its line relay and release relay *Rlse Ry* to ground the release trunk. This holds the cut-off relay of the lineswitch energized and keeps the private normal grounded. The line relay of the lineswitch, being slow to release, only now falls back.

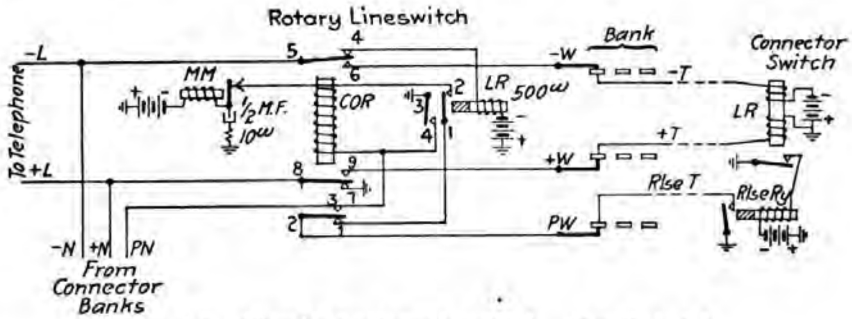



FIG. 49.—Circuit of rotary lineswitch. Pencil sketch.

During conversation the line circuit runs through the lineswitch without attachments of any kind. The cut-off relay is the only energized coil, drawing its weak current through the motor magnet.

Release is accomplished by removing ground from the release trunk. The cut-off relay simply releases and re-establishes normal conditions.

If the trunk on which the wipers were resting at the start is busy, there is a ground on the private contact and hence on the private wiper $PW$. This permits the motor magnet to get a direct ground. The cut-off relay is also short circuited because there is a ground at both ends of its winding. The magnet pulls up and its pawl catches the next tooth on the wheel. Near the end of its stroke the magnet opens its own circuit (like a door bell) so that the spring can drive the pawl back, rotating the wipers to the next trunk contacts. If this trunk also is busy, the performance is repeated. The cut-off relay can not energize because of the short-circuit.

When the private wiper strikes an ungrounded contact, the magnet receives current only through the cut-off relay, which is too little to actuate the magnet. But the cut-off relay promptly acts, siezing the trunk as was described above.

The condenser and small resistance attached to the magnet are to reduce the arc at its own interrupter contact.

When this line is called by some other line, the call comes through a connector switch and the normal wires. The connector first tests the private normal *PN* to see if the line is busy or free. If busy, the private normal is grounded, and the connector can not sieze the line. If the private normal is not grounded, the connector first puts a ground on it. This is to keep other connectors away and to operate the cut-off relay to clear the line of attachments. Since the line relay is normal, the cut-off relay can pull its armature up only part way. It is enough to break all back contacts, cutting off the ground, line relay and battery, and to disconnect the private wiper. The connector delays ringing until this has been accomplished.

**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 supplies the current for energizing the transmitters. When conversation is completed it controls circuits which cause all of the switches used in setting up the connection to return to normal.

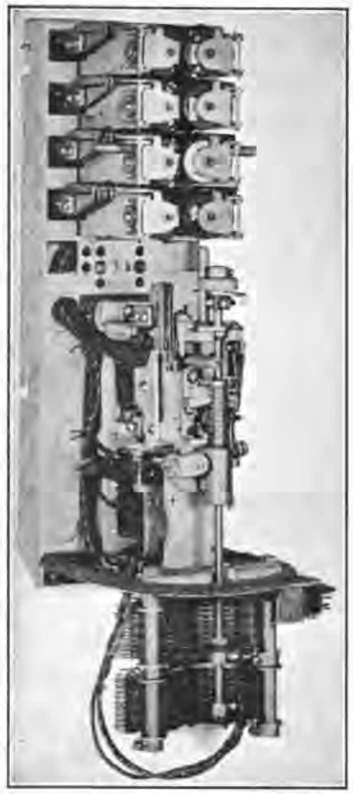


FIG. 50.—Connector switch.

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 manipulates. The wiper cords take the place of the switchboard cord. In other words, this switch is an automatically operated and controlled cord circuit.

Figure 59 may be used as the basis of the following discussion:

**Mechanism.**—Figure 50 is from a photograph of one type of two-wire connector switch with a set of unwired banks. In the front of the switch is seen the shaft which carries the contact arms or wipers, and which can be raised step-by-step by a pawl and ratchet movement operated by the vertical magnet, and can be rotated step-by-step through about 120 degrees by another pawl and ratchet movement operated by the rotary magnet. The vertical movement is opposed by gravity and the rotary movement by a clock spring carried in a small box or cup at the top of the shaft. At the completion of each vertical or rotary step, the shaft is locked in position by the "double dog." When the release of a connection occurs, the release armature pushes the double dog out of engagement with the shaft and into engagement with a catch called the "release link," which holds it until another call is initiated. When the double dog disengages it, the shaft rotates back to its original angle, under the influence of the clock spring and there drops down to its normal position by the force of gravity. The drawing in Fig. 54 of the shaft with its wipers shows more clearly the method of insulating each of the wipers from the shaft, and the springs of the line wipers from each other.

At the upper end of the shaft is a set of springs known as the off-normal springs and indicated

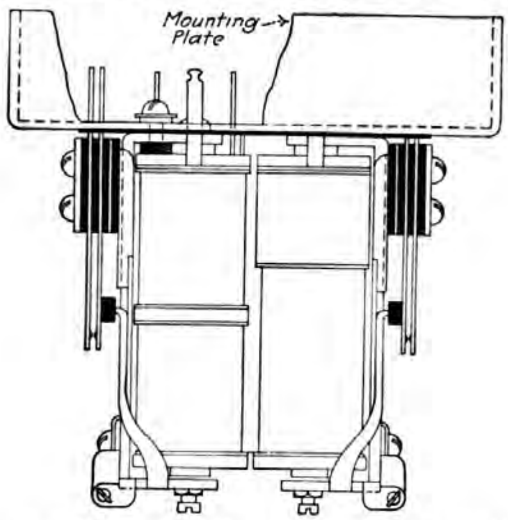



FIG. 51.—Automatic relay mounting, top view.

FIG. 52.—Back of connector switch.

by the designation $O.N.S.$ When the shaft is in its normal position the springs are in one condition. When the shaft is lifted one step, the finger connected to the shaft releases its pressure on the off-normal springs and allows them to perform whatever switching action they are designed to do.

FIG. 53.—Switch shelf, showing jacks.

In Fig. 50, the upper bank is the private bank, while the lower one is the line bank. In each bank the rows number "1" to "9" then "0," in regular order counting from the bottom row to the top. Each wiper is so placed on the shaft that when it is raised one step, it will be on a level with row 1 of its bank and the next step will place it on a level with row 2, etc.

For convenience all of the relays forming a part of the connector-switch circuit are mounted on the connector-switch frame, although they are not a part of its mechanism and could be mounted elsewhere. A top view of two relays is given in Fig. 51.

All the wiring leading from the switch magnets or the relays terminates the spring of the "jack," shown at the rear of the switch (Fig. 52). When the switch is hung on its shelf these jack springs engage those of the shelf jack (Fig. 53).

In Fig. 55 is shown an unwired private bank, while Fig. 56 is a sectional view showing how the brass contact pieces are laid between strips of insulation to form the assembly. Figure 57 illustrates the looping of the wires from bank to bank in a set of line banks. The twisted pair of wires that is soldered to pair 01 on the bank at the left loops over and is soldered on the corresponding pair in each of the other banks. In this way all pairs of the same number are multipled together.

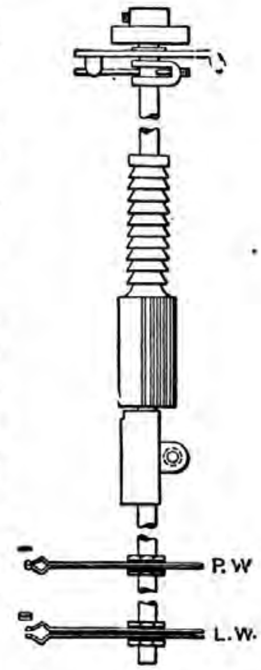


Fig. 54.—Switch shaft and wipers.

A feature of the connector relays, which should be understood, before discussing the circuit, is the use of slow-acting coils. Such a coil is contrived by placing a heavy ring or cylinder of very pure copper over one end of the core of the spool, occupying a portion of the space used for the

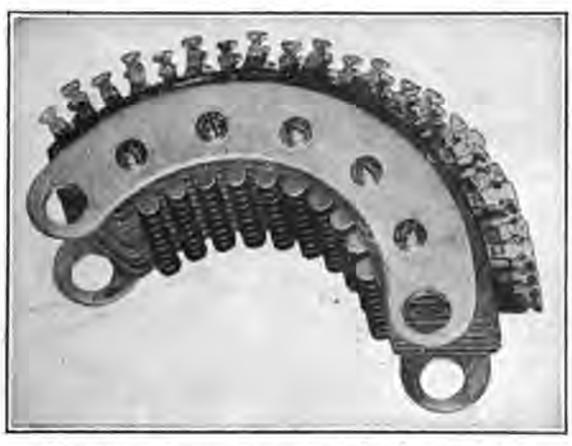


Fig. 55.—Connector-switch bank, unwired.

winding on an ordinary spool. The outside diameter of this ring, which has a rectangular cross section, is the same as that of the spool head, and the inside diameter is just large enough to allow the ring to fit snugly over the core. (See Fig. 58.) A relay of this type attracts its armature nearly as quickly as an ordinary relay, but when the circuit through its winding is broken the current induced in the heavy copper ring retains

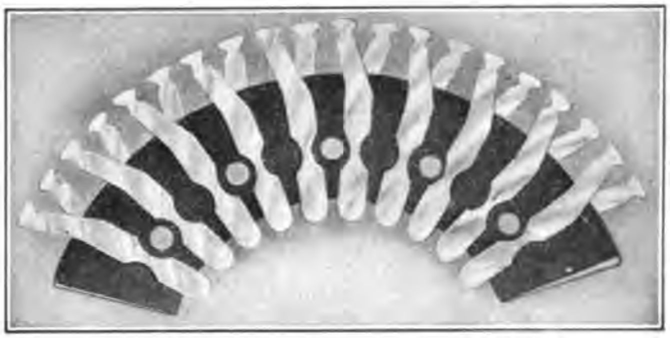


Fig. 56.—Detail of connector-switch bank.

the armature for the fraction of a second, giving it a very noticeable lag. As explained more fully in the description of the circuits of this system,

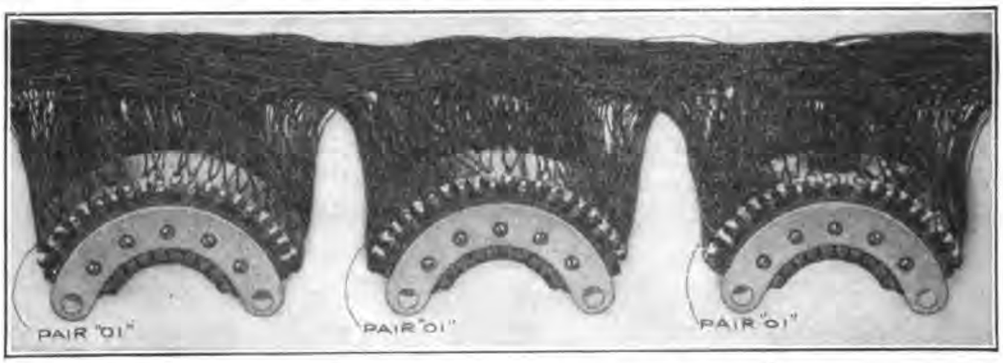



Fig. 57.—Wiring of connector-switch banks.

the introduction of these slow-acting relays makes possible the operation of the switches by simply making and breaking the calling party's loop,

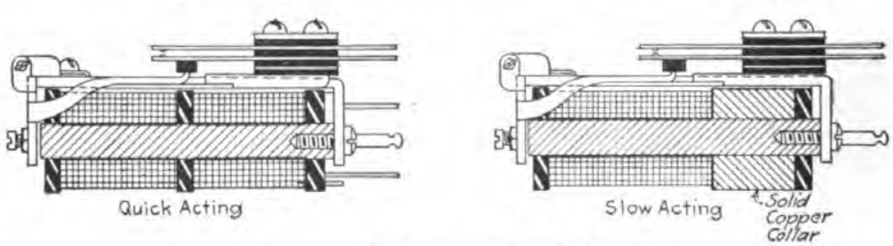



Fig. 58.—Relays, quick and slow.

and the consequent elimination of the ground required at each subscriber's station in the three-wire system

**Circuits of Switches.**—While describing the electrical circuits of the connectors and other switches, the reader is asked to keep in mind that circuits like machines are made up of elementary parts, each of which is exceedingly simple. These elementary parts may be termed "circuit devices." Upon the uses to which a switch is put depends the choice of circuit devices and the manner in which they are combined. We will, therefore, first consider the duties which devolve upon each switch and then explain the circuit devices and combinations by which the desired results are obtained.

**Connector Circuits.**—In order that the reader may have already in mind the functions of the connector circuits, the duties of the switch are recapitulated as follows:

1. Execute the vertical and rotary movement of the shaft under the control of the calling device.
2. Keep the wipers disconnected during rotation so as not to interfere with lines past which they rotate.
3. Test the called line to see if it is busy. This busy test consists of two parts: (*a*) A lock to prevent intrusion on to the busy line, (*b*) a signal to notify the calling station that the line is busy.
4. Protect the called line from intrusion.
5. Clear the called line of attachments.
6. Ring the bell at the called station.
7. Supply battery current to both stations for conversation.
8. Release itself without interfering with other lines.
9. Release other switches (selectors, etc.).

In Fig. 59 is shown a skeleton drawing of the mechanism. This will help to make clear the operation of the switch as the circuits are discussed.

The calling-line circuit (Fig. 60) leads from negative line $-L$ and positive line $+L$ through the line relay *LR* to battery, 48 volts. The normal polarity is as drawn, but it is reversed by the back-bridge relay *BBR* which feeds the called line. Condensers connect the two current supplies.

The line relay *LR* controls the release relay *RlRy* and repeats line impulses to the magnets, *VM* and *RM*. The release relay grounds the release trunk, holds open the release magnet circuit *Rlse*, prepares the impulse circuit for the magnets, and furnishes ground for the locking of the ring cut-off relay *RCOR* and the wiper-closing relay *WCRy*.

The series relay *Se* co-operates with the vertical magnet as the rotary relay *RotRy* does with the rotary magnet *RM*. The busy-test relay *ByRy* tests the called line, furnishing busy tone and preventing the wiper-closing relay from connecting the wipers. The wiper-closing relay *WCRy* connects the line circuit to the wipers, starts the ringing interrupter, *Ri. Int.*, grounds the private wiper *PW*, prevents further rotation, and cuts off the busy-test relay. The ring cut-off relay *RCOR* cuts off the ringing current when the called station answers, and furnishes positive battery to the back-bridge relay *BBR*.

When the lineswitch connects a calling subscriber line to a connector, the line relay of the connector immediately pulls up and energizes the release relay. The latter grounds the release trunk so that the lineswitch will not release. This also makes the connector busy so that no other lineswitch will seize it.

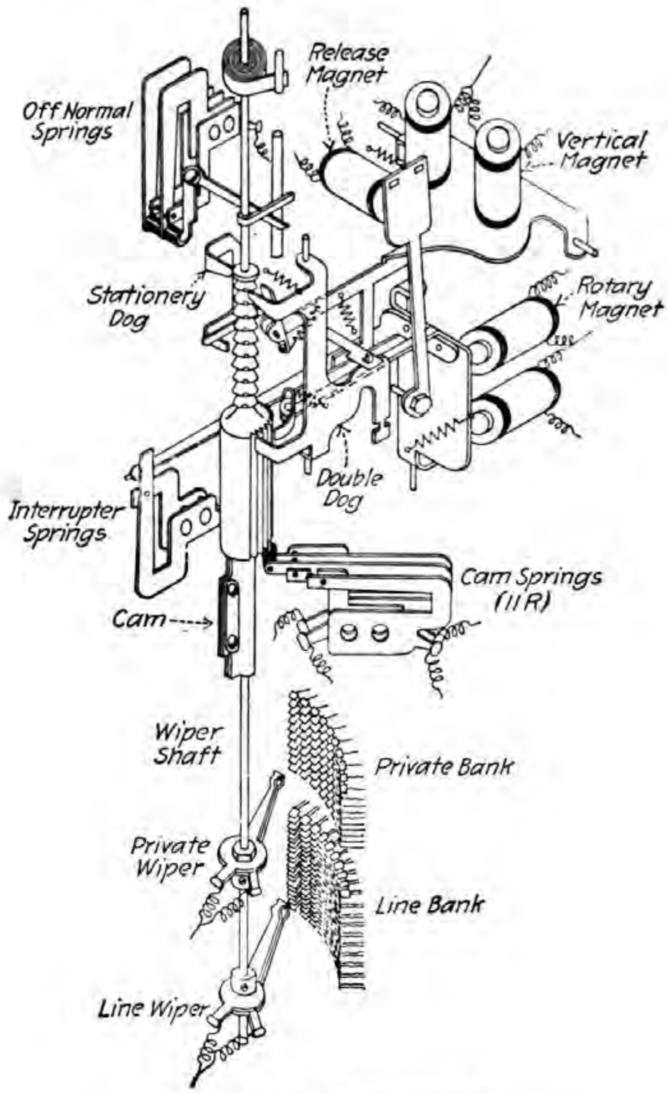



FIG. 59.—Switch mechanism.

When the subscriber dials the first digit of the call number, the line-relay armature vibrates one complete cycle for each unit in the digit. Thus it feeds current alternately to the release relay and to the vertical magnet. The former is slow release, and remains energized throughout the series of pulsations which it receives. The vertical magnet is quick-acting, follows the impulses and lifts the wiper shaft. The series relay *Se* energizes with the first impulse and remains energized to the end of the series of pulsations fed to the vertical magnet.

The first upward step of the wiper shaft operates the off-normal springs *ONS*. These springs prepare the release circuit (for the release magnet *Rlse*), but action is prevented by the release relay (back contact open). The off-normal springs also switch the impulse circuit of the vertical magnet from the winding of the series relay to the main spring of the same. But since this relay is energized, the vertical magnet continues to get the impulses.

When the impulses cease, the series relay falls back and switches the impulse circuit to the rotary magnet *RM* and rotary relay *RotRy*. A pause of a little less than a second is sufficient for the change to take place.

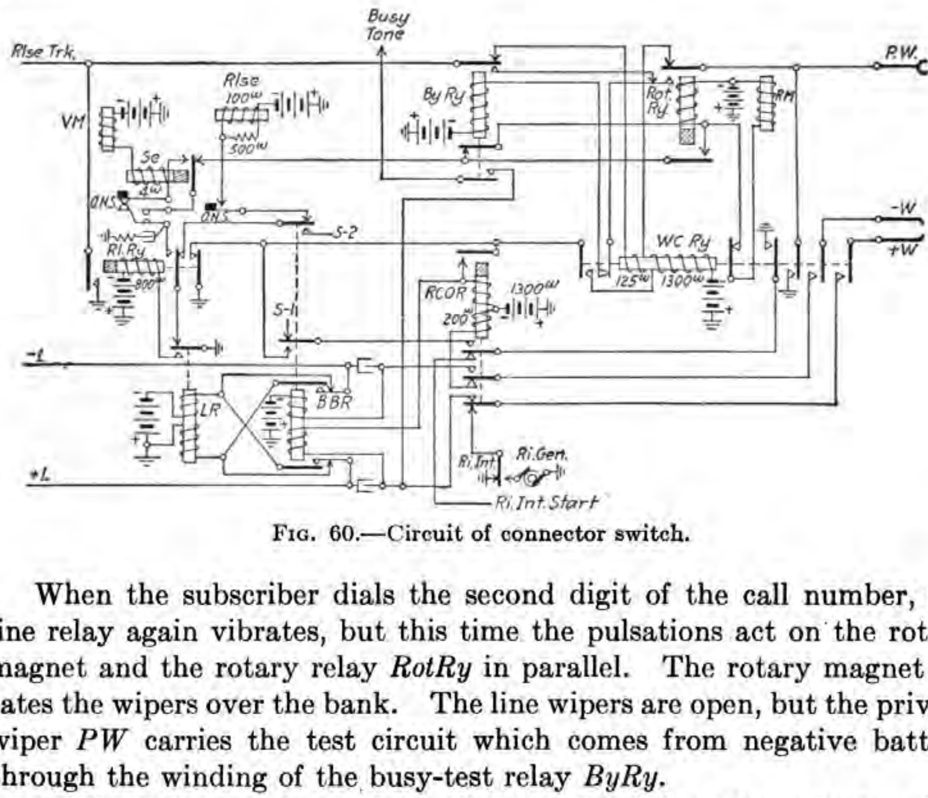



FIG. 60.—Circuit of connector switch.

When the subscriber dials the second digit of the call number, the line relay again vibrates, but this time the pulsations act on the rotary magnet and the rotary relay *RotRy* in parallel. The rotary magnet rotates the wipers over the bank. The line wipers are open, but the private wiper *PW* carries the test circuit which comes from negative battery through the winding of the busy-test relay *ByRy*.

As the wipers progress toward the desired line, the private wiper may pass over one or more busy lines. Their private contacts are grounded. Hence the busy relay will be energized while passing over such contacts. This would cut off the rotary magnet, if it were not for the rotary relay, which maintains the circuit for the rotary magnet until the group of pulsations has ceased.

When the group of impulses ceases, the rotary relay de-energizes. Assume that the line is not busy. The busy-test relay reveals this condition by being de-energized. There is therefore a circuit from ground at the release relay, through a back contact on the busy relay, 125-ohm winding of the wiper-closing relay, back contact of the rotary relay, to the private wiper. This circuit is completed through the cut-off relay winding of the lineswitch of the called line to negative battery. Simultaneously the latter relay clears the called line while the former closes the line wipers to the source of ringing current, which is controlled by the ring cut off relay. The wiper-closing relay also grounds the private wiper with a direct ground and starts the ringing interrupter *Ri. Int.* It is itself locked by its 1300-ohm winding to a ground at the release relay. This contact is the first to close.

Ringing takes place intermittently, by the action of the ringing interrupter. The wire through which ringing current is delivered is switched alternately between the ringing generator and ground (positive battery). The complete circuit of the ringing current includes the 200-ohm winding of the ring cut-off relay and the main battery, 48 volts. During the ringing period, the battery is unable to affect the ring cut-off relay because of the condenser in series with the bell in the telephone set. The ringing current can not operate the relay, because it is equipped with a copper collar and a copper sleeve, the latter under the winding. Dependence is placed upon the battery alone to operate the relay.

If the called subscriber answers during the ringing period or between rings, the battery current energizes the 200-ohm winding of the ring cut-off relay. The contact for the locking winding, 1300 ohms, closes first. The relay switches the line wipers from the ringing generator to the talking circuit and opens the ringing interrupter start wire. The locking contact also supplies positive battery to the back-bridge relay *BBR*.

The switching of the lines to the talking circuit causes the called station to draw battery current through the back-bridge relay, which energizes and reverses the polarity of current supplied to the calling subscriber.

The subscribers may now talk, under the conditions shown in Fig. 61. The reversal of battery current is used to operate service meters, give supervision to a manual operator, etc. These uses will be described later.

The release of the connection is controlled by the calling party. Suppose that the called party hangs up his receiver first. The back-bridge relay de-energizes, but nothing else happens, because the line relay and the release relay hold the release-magnet circuit open. When the calling subscriber hangs up, the line relay falls back, followed by the release relay. The latter takes the ground off the release trunk, permits the lineswitch to release, and also takes the locking ground off the ring cut-off relay and the wiper-closing relay. The latter releases quickly, to open the line wipers and to take the ground off the private wiper. The release magnet gets current through the back contact of the line relay, back contact of release relay, back contact of back-bridge relay, and the off-normal springs. It pulls the double dog from the shaft, which now restores to normal. When the shaft finishes its drop, the off-normal springs return to normal, opening the release-magnet circuit.

The ring cut-off relay is slower to release than the wiper-closing relay, so that the line wipers may have no ringing current on them while they are rotating back off the bank. It would annoy other lines which might be in use.

If the calling subscriber hangs up first, the lineswitch will release, but the connector will not. The line relay falls back and energizes the rotary relay before the release relay has time to let go. Then the release relay falls back, so that for a brief time there is no ground on the release trunk. Yet the release-magnet circuit of the connector is open, being held so by the back-bridge relay. Then the rotary relay releases and replaces the ground on the release trunk, so that another lineswitch may not seize this connector. This ground is through 125 ohms, but it is effective.

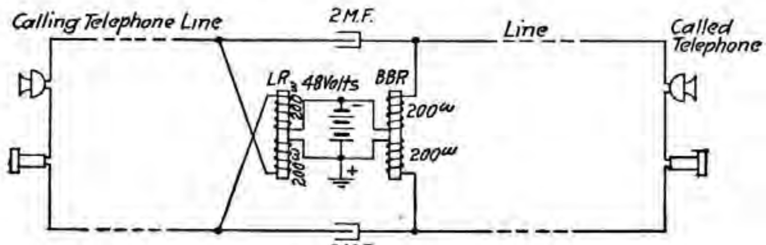



FIG. 61.—Talking conditions in single-office exchange.

When the called subscriber hangs up, the back-bridge relay closes the release-magnet circuit and takes the locking ground off the ring cut-off relay and the wiper-closing relay. The release of the connector proceeds as described above.

The holding of the connector until the last party has hung up prevents undue noise in the ear of the called party when the calling party hangs up first. It also keeps the called subscriber from seizing another switch, which will happen if he stays on the line after the connector has been released.

The contact on the back-bridge relay marked "*S*-2" is provided to give switch-room supervision. A lamp connected to it will glow if the called station holds on after the calling subscriber has released. The contact marked "*S*-1" is not often provided. It may be used to give switch-room supervision by a lamp if the calling subscriber hangs onto the line after the called subscriber has hung up.

The condenser and small resistance attached to the front contact of the release relay is to reduce the spark at the back contact of the line relay during dialing. The inductance of the vertical magnet and later of the rotary magnet causes the arc.

The energy from the magnetic field of the release magnet is absorbed by the 500-ohm non-inductive resistance in parallel with the 100-ohm winding. It greatly relieves the contact of the off-normal springs.

**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. A photograph of a selector switch with a set of unwired banks mounted upon it is reproduced in Fig. 62. It employs the same type of shaft, 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.

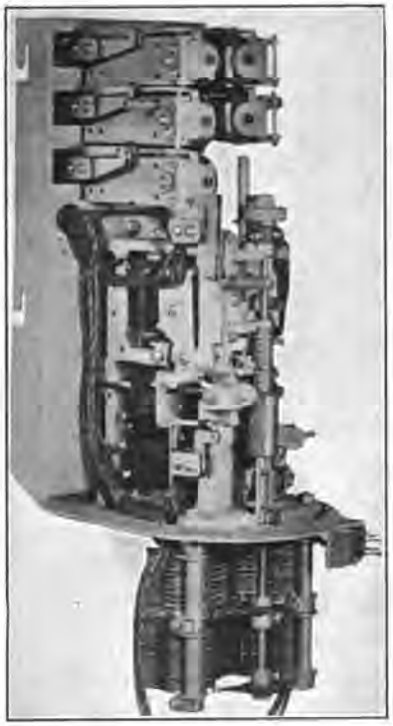


Fig. 62.—Selector switch.

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

1. To perform the vertical motion under the control of the calling device.
2. To hunt and seize an idle trunk.
   (*a*) Rotate automatically without regard to the calling device.
   (*b*) Keep line wipers clear.
   (*c*) Test each trunk.
   (*d*) Stop rotary motion at first idle trunk.
   (*e*) Protect seized trunk.
   (*f*) Extend line circuit through to next switch without attachments.
3. Release itself without interfering with other trunks.

A diagram of a circuit of a first selector is shown in Fig. 63. The two line wires normally run to the line relay *LR*, but are capable of being switched to the line wipers, $-W$ and $+W$. The functions of the line relay are to energize the release relay *RlRy*, to repeat impulses to the vertical magnet *VM*, and to control the circuit of the release magnet *Rlse* if it is desired to release the selector before it has completed its work.

The release relay places a ground on the release trunk and holds it there during the operation of the switch and until the next switch ahead can take up that duty. The release trunk will be connected straight through the selector when the lines are extended. The release relay helps to control the release-magnet circuit and prepares the impulsing circuit from the line relay to the vertical magnet.

The series relay *Se* co-operates with the off-normal springs *ONS* to initiate the rotary magnet *RM* action when the vertical magnet has done its work.

The rotary-interrupter relay *RIR* tests the trunks and helps the rotary magnet to vibrate in driving the wiper shaft around.

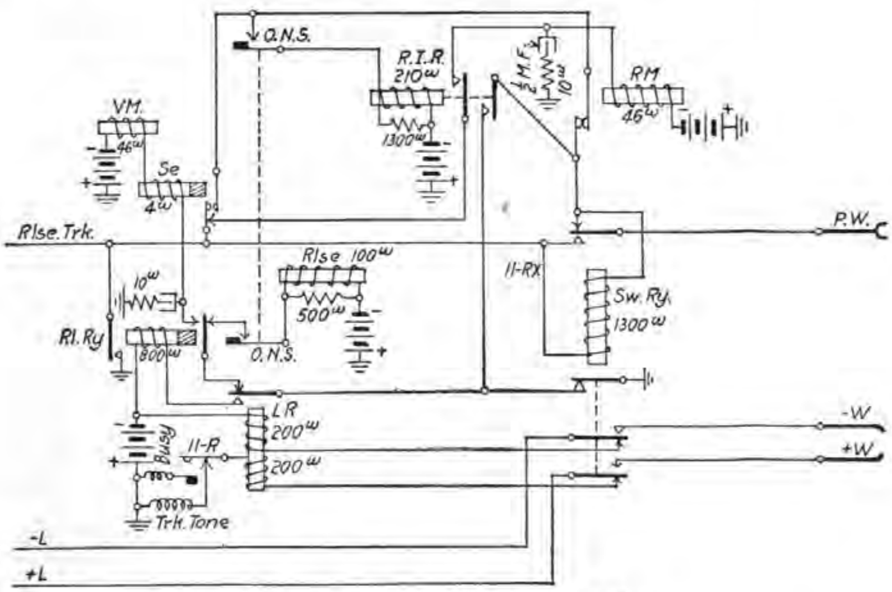



FIG. 63.—Circuit of selector switch.

The switching relay *SwRy* switches the lines from the line relay to the line wipers $-W$ and $+W$, extends the release trunk to the next switch ahead and controls the ground connection of the line relay so as to take charge of the release of the switch.

Normally the positive battery connection of the line relay has in it a coil which furnishes a tone to indicate to a subscriber that a selector is ready for use. It is called the "trunk tone" or "dial tone."

There is an auxiliary set of springs marked "11–*R*" which come into play when the entire ten trunks of a level are busy and the wipers therefore rotate off the bank. These springs open the circuit of the switching relay to prevent its action and substitute the regular busy tone on the line relay, so that the subscriber will be induced to hang up and release.

The action of the switch is as follows. When a selector is seized by a lineswitch or by another selector, the subscriber line or its equivalent is connected to the line wires, $-L$ and $+L$, so that the line relay at once energizes and causes the release relay to pull up. The latter places a ground on the release trunk, so that all switches back of it will be held up. At the same time it prepares the impulse circuit to the vertical magnet.

When the subscriber pulls the dial for the digit which is to operate this switch, the line relay vibrates in unison with the line impulses. This keeps the slow-releasing release relay energized and at the same time sends pulsations to the vertical magnet and the series relay. The latter pulls up and remains energized, the former follows the impulses and lifts the wiper shaft.

The first upward step of the shaft operates the off-normal springs. One pair of springs prepares the release-magnet circuit. The other pair connects the rotary-interrupter relay to the front contact of the series relay. As the series relay is energized, the rotary-interrupter relay also pulls up by reason of the ground on the release trunk. It locks itself energized by a circuit which runs through the contact of the rotary magnet to the ground on a spring of the switching relay.

When the series of impulses end, the line relay comes to rest energized, holding the release relay. The series relay falls back, closing the circuit of the rotary magnet from the release trunk ground through a front contact on the rotary-interrupter relay. The rotary-interrupter relay now depends upon the ground at the switching relay, while the rotary magnet depends on the release trunk.

The rotary magnet now pulls up, moving the wipers onto the first set of trunk contacts. If this trunk is free, there will be no ground on its private contact. If it is busy, there will be a ground there. Assume the latter to be the case. This ground on the private bank contact is in effect on the private wiper and passes through a back contact on the switching relay to the spring of the rotary magnet and of the interrupter relay.

Near the end of its stroke, the rotary magnet opens its springs, cutting off the interrupter relay. The latter falls away, opening the rotary-magnet circuit. The rotary magnet falls back, closing the circuit of the interrupter relay to the private wiper. At this time the interrupter relay depends solely upon the private wiper for a circuit, because its own circuit to the ground at the switching relay is open. If the private wiper again rests on a grounded contact, the interrupter relay will pull up again and give current to the rotary magnet, causing it to rotate the wipers to the next trunk. As long as the private wiper finds ground, the interrupter relay and the rotary magnet will vibrate.

During this time the switching relay has had a ground at each end of its winding, therefore it could not act.

When the private wiper strikes an ungrounded contact, the rotary-interrupter relay fails to pull up. The switching relay immediately energizes, getting its positive battery from the release trunk ground at the release relay and its negative battery from the circuit through the rotary-magnet contact and the interrupter relay winding.

The pulling up of the switching relay cuts off the line relay and extends the lines to the next switch ahead. It removes the ground from the line-relay main spring so that when that relay de-energizes it will not actuate the vertical magnet. This same contact also controls the release magnet. The switching relay also closes the release trunk through to the private wiper.

Before the release relay of this selector can fall back, the line relay and release relay of the next switch ahead has grounded its release trunk, so that the private wiper of this selector now has ground on it. Then the release relay in this selector lets go, but the continuity of ground on the release trunk is maintained.

The switching relay alone remains energized. It is the holding relay for this selector.

Release from a completed connection is accomplished by removing the ground from the release trunk. The switching relay falls back, opens the line wipers, and closes the release-magnet circuit. The release magnet presses the double dog out of engagement with the shaft, allowing the latter to rotate and drop to normal. As it reaches the bottom, it operates the off-normal springs, opening the release-magnet circuit and that of the interrupter relay.

If all trunks on the level are busy, the private wiper will be unable to find absence of ground. The wipers will therefore rotate off the bank. This is called the eleventh position. Here the $11\text{–}R$ springs act, cutting off the switching relay and putting on the busy tone. The subscriber, hearing the tone, will release. The line relay falls back and gives a momentary pulsation to the vertical magnet, after which the release relay falls back and energizes the release magnet. The rest is as before. This case does not occur very often and is not detrimental.

**Ten-Level 20-Trunk Selector.**—The trunking capacity of this type of selector has been increased by equipping it with two line banks, making its private bank with the contacts in pairs, and arranging the circuit so that as the wipers rotate over both line banks at the same time they hunt idle trunks and seize the first one found, whether it be in the upper bank or the lower one. If the two sets of wipers find an idle trunk at the same time, one only is seized, with the certainty that the other is not touched.

The circuit (Fig. 64) has the usual line relay, release relay, series relay, release magnet, vertical magnet, etc., as in other selectors.

There are two switching relays, *SR*-1 and *SR*-2. The former switches the lines from the line relay to line wipers $-W1$ and $+W1$. The latter switches the lines from the line relay to the line wipers $-W2$ and $+W2$.

Each of the switching relays also takes part in the trunk seizure in almost the same way as does the switching relay of the ordinary selector.

The rotary trunk-hunting action consists of mutual vibration between the rotary magnet *RM* and the rotary-interrupter relay *RIR*. The latter is double-wound and is so adjusted that it will not move its armature unless both windings are energized, and if while energized one of the windings fails, the armature will be released.

The switch is seized in the usual way, the line relay and the release relay pulling up and grounding the release trunk. The group of line impulses cause the line relay to vibrate, during which time the vertical magnet lifts the shaft and the series relay *Se* is continuously energized. The latter pulls up the rotary-interrupter relay *RIR*, which locks itself by two contacts on to the ground furnished by the two switching relays.

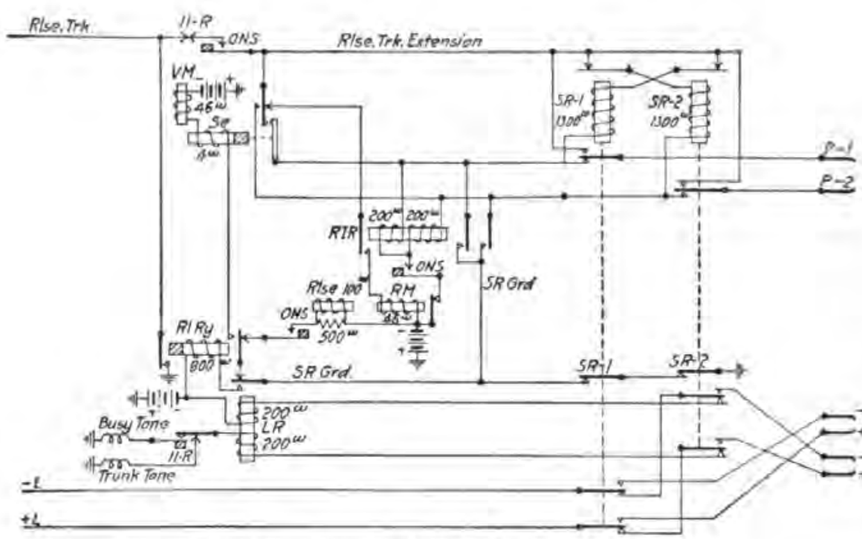



Fig. 64.—Circuit of 10-level 20-trunk selector.

The rotary-interrupter relay prepares a circuit for the rotary magnet, which is yet open at the contacts of the series relay.

When the group of impulses comes to an end, the line relay stops in an energized condition, the release relay as well. Then the series relay falls back, closing the circuit for the rotary magnet to the release trunk extension. The rotary magnet now rotates the wipers onto the first set of contacts of the level selected. Assume that the first few trunks are busy on both line banks.

Since both private wipers are resting on ground, the switching relays can not pull up. Near the end of its stroke, the rotary magnet opens the circuit of the rotary-interrupter relay *RIR*, which falls back. As it releases, it opens its locking circuits and cuts off the rotary magnet. The rotary magnet falls back and closes the circuit of the interrupter relay. If both private wipers rest on ground, the interrupter relay will energize, lock itself, and energize the rotary magnet. In this way the mutual vibration of magnet and relay continue as long as both private wipers can find ground.

When one of the private wipers finds a free trunk, there will be no ground between a winding of the interrupter relay and the corresponding switching relay. Assume that it is *P*-1 which finds no ground. At the moment that the rotary magnet closes the circuit by falling back, there is no ground between the left-hand winding of *RIR* and the winding of *SR*-1. The former can not energize through the latter. But the *SR*-1 will pull up at once, switch *P*-1 from *RIR* so as to extend the release trunk through to the bank, switch the lines from line relay to the line wipers on line bank No. 1 and cut off the ground from *LR* and *RIR* so that it can do no harm. It also cuts off the other relay *SR*-2, so that it can not operate. Soon the line relay and release relay of the next switch ahead will ground the extended release trunk and hold the connection.

If both private wipers find a free trunk at the same time, there is a tendency for *SR*-1 and *SR*-2 to operate together. But each is wired so as to cut off the other. Therefore that relay which acts more quickly will cut off the other and take the trunk. It is impossible for both to act together. This circuit device has been known for many years and is a very delicate test for the speed of two relays.

This switch circuit shows the dial tone normally on the line relay with the busy tone ready to be substituted if all trunks on the level are busy and the wipers rotate off the bank and operate the springs "11-*R*." The same springs open the release trunk extension to prevent the switching relays from operating.

**Multi-Level Group Selector.**—It sometimes happens that a small exchange or a small office in a multi-office exchange has need for more than one level of trunks to a certain destination and can spare the call numbers which the additional levels represent. In this case a selector may be arranged to treat several levels as in one group.

The multi-level group selector responds to the calling device, lifting the wipers to the desired level in the same way as is done by an ordinary selector. If there is an idle trunk on the first or bottom level of the group, the wipers will rotate onto that level and hunt an idle trunk. But if the first level is busy, the wipers will be lifted to the next level, its condition tested, and the wipers rotated into the bank or lifted to the next level as the test may direct.

A selector of this type requires horizontal-chain relays, one for each trunk in a level, vertical chain relays, one for each level, and a vertical wiper and bank. (See Fig. 65 and 66.)

When a trunk is occupied, its horizontal-chain relay pulls up. When all the trunks in the same level are busy, the chain of contacts is completed and the corresponding vertical-chain relay is energized. This relay places a ground on the corresponding contact in the vertical bank, which contact the vertical wiper will engage when the line wipers stand opposite the level which is busy.

The vertical bank contact for the upper level of a group is open.

The vertical wiper has connected to it a testing circuit which runs to negative battery through the vertical relay which controls the vertical runk hunting.

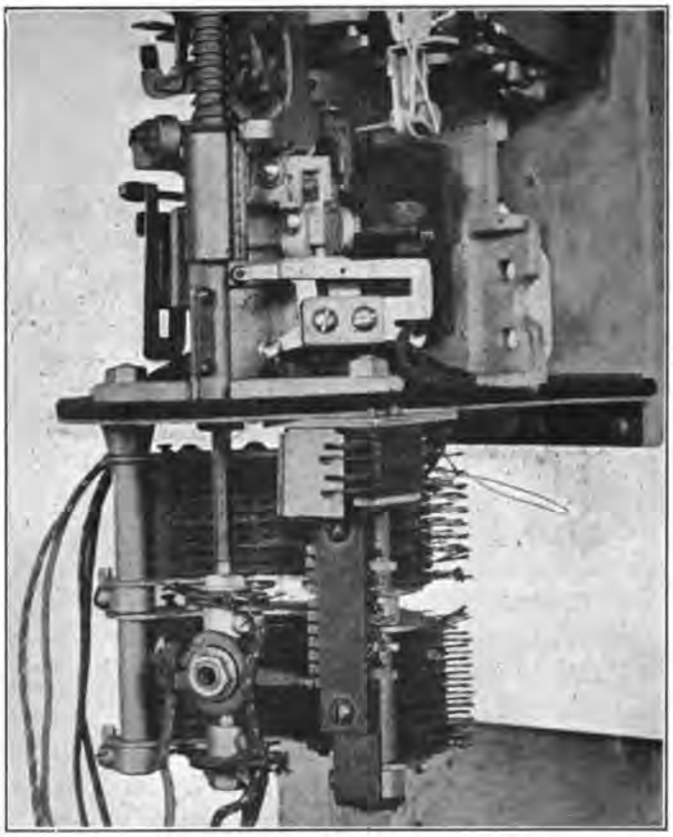


FIG. 65.—Vertical wiper and bank, normal.

When the switch is seized, the line relay and release relay operate as usual, grounding the release trunk and preparing the vertical-magnet circuit.

The calling device of the telephone makes the line relay vibrate and thus to cause the vertical magnet to lift the shaft to the selected level.

If the calling device stops the vertical motion with the vertical wiper resting on a grounded contact, the vertical relay will energize.

The vertical magnet at once operates again, and will continue to do so as long as the vertical magnet finds ground, this operation results in the lifting the wiper shaft while the levels are tested one by one.

When the vertical relay finds no ground it will fall back, at this moment, the interrupter relay is de-energized and the vertical motion ceases. Following this the wipers are moved onto the first trunk of the selected level.

As long as the private wiper finds grounded contacts, the mutual vibration of the rotary magnet and the interrupter relay will cause continued rotation of the wipers.

When an idle trunk is found, the absence of ground on the private wiper will prevent the interrupter from acting again. The switching relay will now operate in the usual manner.

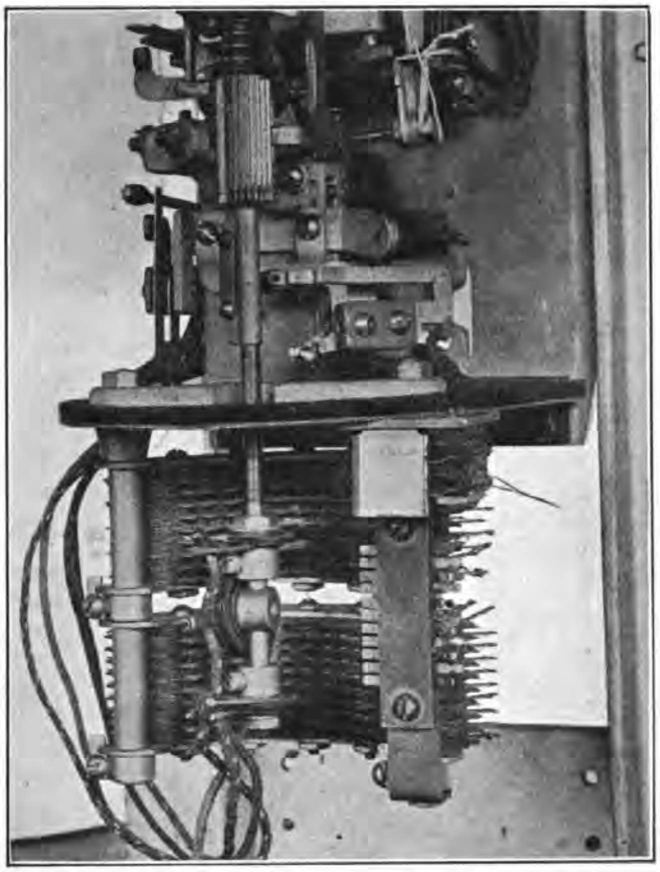


FIG. 66.—Vertical wiper and bank, operated.

The next switch ahead soon grounds the release trunk, so that when the line relay and release relay of this selector fall back, the switching relay will be held energized.

If there is a free trunk in the first level of the group, the rotary action starts at once.

If all levels are busy, the switch will rotate on the upper level of the group anyway, because the corresponding vertical-bank contact is open. Since the upper level is busy, the same as the rest, the usual rotary action will carry the wipers off the bank and operate a set of cam springs. They open the switching relay winding so as to prevent its action, and

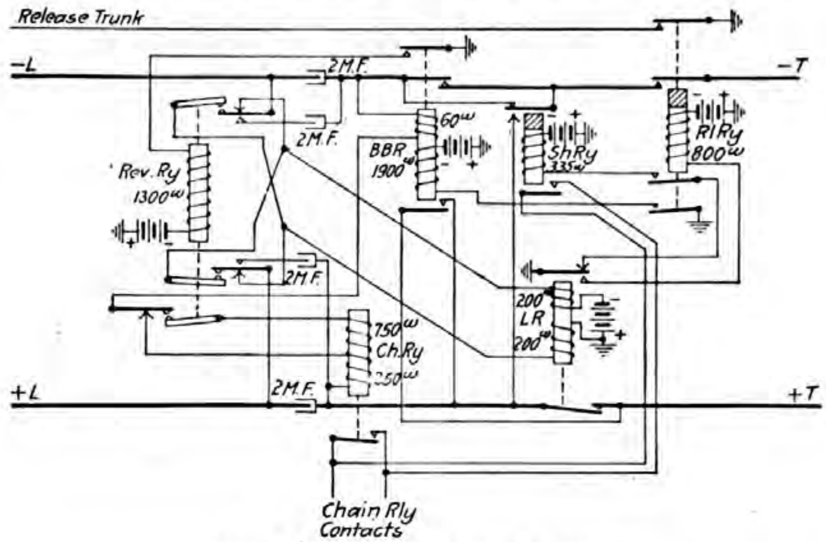



FIG. 67.—Circuit of impulse repeater.

switch the ground connection of the line relay from dial tone to busy tone.

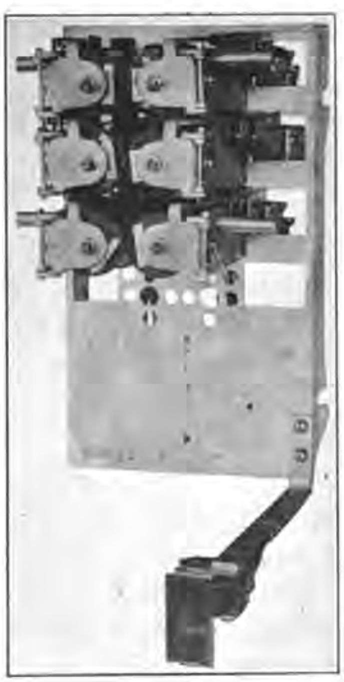


FIG. 68.—Impulse repeater.

**Repeater Circuits.**—Automatic impulse repeaters are introduced in outgoing trunks from one office to another. (See Fig. 68.) The purposes of a repeater are as follows:

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

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

3. Repeat impulses to the distant office.

A typical repeater circuit is given in Fig. 67.

Three wires arrive from the left, release trunk, negative line $-L$ and positive line $+L$. Two wires depart to the right, negative trunk $-T$ and positive trunk $+T$. The line circuit has the line relay *LR* with battery to supply current, and the trunk circuit has the back-bridge relay *BBR* and the chain relay *ChRy* as a bridge. The two are connected by condensers which are normally 2 *MF*.

The line relay *LR* repeats the impulses from the line to the trunk. It also controls the release relay *RlRy* and the shunting relay *ShRy*. The release relay grounds the release trunk, prepares the circuit for the shunting relay, and polarizes the back-bridge relay. These two relays (*LR* and *RlRy*) have in general the same duties and relationships which they will be found to have in very many pieces of apparatus.

The shunting relay *ShRy* cuts out the back-bridge circuit during dialing and assists the chain relay *ChRy* in its duties. The latter is chiefly an impedance, but also acts as a relay in co-operation with similar relays of other repeaters to indicate when all trunks in a group are busy. Details will be given later.

The back-bridge relay *BBR* causes the reversal of the current fed to the calling line, so as to repeat the supervision sent back by the connector in the distant office. Since the load of springs is great, the work itself is not put on the back-bridge relay, but on the reversing relay *RevRy*, which the former merely controls. The back-bridge relay is electrically polarized by its 1900-ohm winding, so that it will not operate when the trunk current is normal, but will pull up and remain energized thereafter. The polarizing winding is not able to operate it alone.

The reversing relay, in addition to reversing the current, increases the impedance of the chain relay by cutting in additional turns.

When a selector seizes a trunk in which is this repeater, the extension of the subscriber line causes the line relay of the repeater to pull up. The release relay therefore also energizes. These two relays close the trunk circuit, so that the line relay of the selector in the distant office will come into action. The chain relay in the repeater will close its contacts. The release relay grounds the release trunk so that the selector and the lineswitch will be held up.

When the subscriber dials a digit, the line relay of the repeater vibrates as described in connection with other apparatus. The first time that it falls back, it energizes the shunting relay, which opens the negative trunk $-T$ to the back bridge and connects it directly across the line to the main spring of the line relay. The rest of the impulses travel over this short circuit without having to overcome the impedance of the relays in the back bridge. The line relay keeps both the release relay and the shunting relay energized during the group of impulses.

At the end of the group of impulses, the line relay comes to rest energized. The release relay remains up, but the shunting relay falls back, restoring the back bridge to the trunk circuit. This action is repeated every time a digit is pulled.

When the called station in the distant office answers, the connector reverses the battery current as was described. The change of direction of current through the 60-ohm winding of the back-bridge relay causes it to assist the polarizing winding, and operates the contacts. One pair of springs shunts the impulse springs of the line relay, so that this contact shall be assured even if the calling loop is long. It also operates the reversing relay to reverse the current flow in the calling line and increase the impedance of the chain relay.

Release is controlled by the calling subscriber. When he hangs up, the line relay falls away, allowing the release relay to de-energize and remove the ground from the release trunk. Both line relay and release relay open the trunk circuit. Thus the switches ahead and behind are released.

The contacts of the chain relays of all trunks in the same group are connected in series. This chain or series circuit is carried to a suitable device which renders it impossible for selector switches to attempt to send calls through this busy group. As long as there is one free trunk in the group, this chain circuit is open and calls may be received. But when all trunks are busy, the circuit is complete and the stopping device comes into play. A meter may also be attached to indicate how many times this occurs, or a supervisory signal may be used.

The talking circuit of a connection between offices is shown in Fig. 69. An important thing from the standpoint of voice transmission is that the current for the transmitter of the calling telephone is supplied

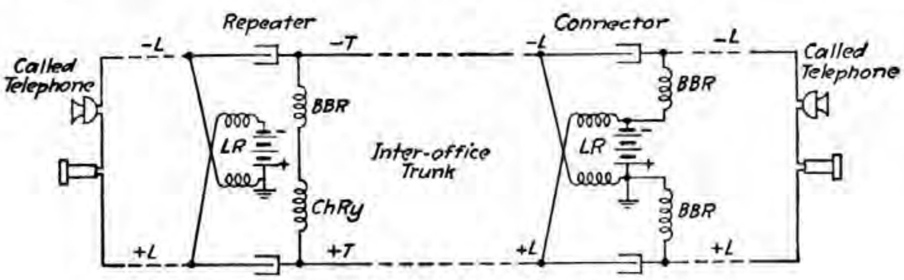



FIG. 69.—Talking circuit of an inter-office connection.

from the originating office, and for the called telephone from its own office. It results in a high standard of transmission efficiency.

**Switching Repeaters.**—The desire for economy of inter-office trunks between a sub-office and its main office led to the production of the switching repeater which was mentioned in the chapter on trunking.

Strictly speaking, there were at one time two kinds, the switching repeater and the switching-selector repeater. The former was a repeater only, and for its complete functioning required selectors in the sub-office in which it was located. The latter combines in itself the functions of repeater and of selector, from which it takes its name. It is not to be confused with the "selector-repeater," which functions first as a selector and afterwards as a repeater. The old switching repeater is no longer used. For the purpose of simplicity as well as of clearness, we will use the term "switching repeater" in describing the present form of apparatus, which is primarily a repeater which acts as a selector under part of the conditions of use and switches the inter-office trunk out of use.

At the left of Fig. 70 is shown a diagram of trunking utilizing switching-selector repeaters. The apparatus inclosed within the dotted lines

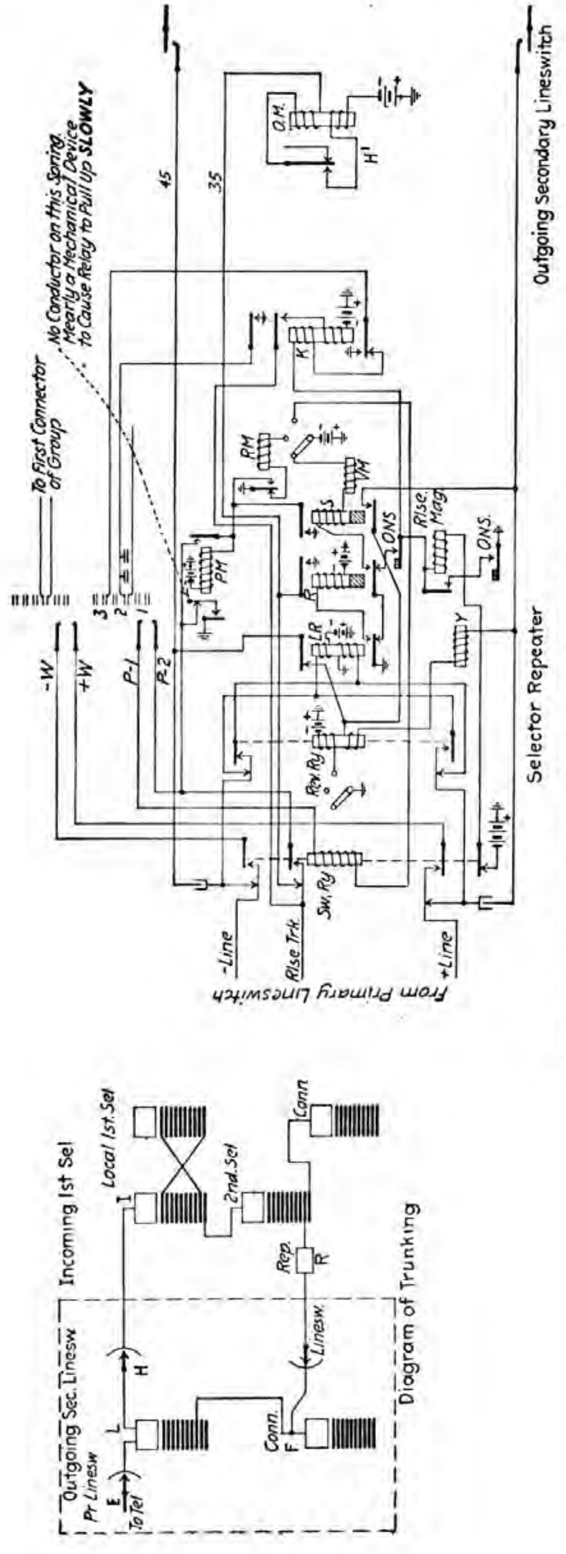



FIG. 70.—Switching repeater, switches on one digit.

represents the apparatus of a sub-office, while the remaining apparatus is assumed to be local to the main office At the left of the figure a telephone line is shown terminating on a primary lineswitch. These lineswitches have access to trunks passing through a switching-selector repeater and terminating upon outgoing secondary lineswitches. These switches in turn have access to trunks terminating upon incoming first selectors in the main office. A certain level in the banks of the switching-selector repeater contains trunks which terminate upon connectors which have access to the lines in the branch office. At the main office a certain level in the banks of the second selectors contains trunks which pass through a repeater and terminate on primary lineswitches at the branch office. These lineswitches having access to trunks which are a multiple of those appearing in the banks of the switching-selector repeater. In the figure the sub-office is represented as containing only 100 lines; it will readily be apparent, however, that the scheme is not necessarily limited to an office of this size.

In general, the operation of the system is as follows:

Upon the removal of the receiver from the switch-hook by the subscriber of one of the sub-office groups, his individual line-switch $E$ operates to select a trunk line leading to a secondary switch $H$, which in turn operates to select an idle first selector $I$. The subscriber operates his calling device to cause the selected first selector to extend connection to an idle second selector in the section or division of the exchange to which the called subscriber belongs. The selected second selector is then operated to extend the connection to an idle connector switch which has access to the group of subscribers to which the called subscriber belongs, which connector is then operated to establish connection with the called subscriber's line. Assuming now that the called subscriber is in the same sub-office as the calling subscriber. Under these conditions, when the calling subscriber operates his calling device to cause the second selector to establish connection with a connector switch, the switching apparatus $I$, in the trunk line which has been seized by the calling subscriber's lineswitch operates to extend the connection directly to one of the connectors in the sub-office. In other words, when the trunking has progressed to the stage of eliminating all the sections except the section to which the call is to revert, then the switching apparatus $L$ disconnects the call from the trunk line leading to the switch $H$ and switches the call over to the local connectors $F$. When the apparatus $L$ thus operates to extend the connection to a local connector, it causes the secondary switch $H$ which was previously selected, as well as all the selectors which have been operated in the main office, to be released and the connection is therefore confined solely to the sub-office.

In Fig. 70 is shown the circuit of a switching-selector repeater. Numerous circuits have been developed—the one used here is a reproduction of the circuit appearing in the United States Patent disclosing this type of switch (Patent 1283182 issued to Harry E. Hershey.)

This device performs two functions. In a call from the sub-office to the main office, it operates as a repeater to repeat the impulses from the calling sub-station to the trunk extending to the central station. In a local connection this device operates to free the trunk line leading to the main office and to divert the call to the proper local switches for completing the desired connection. This switching repeater comprises a vertically- and rotably-movable switch shaft which carries the wipers $P$-1, $P$-2, $-W+W$ and is controlled by the vertical magnet *V.M.* and the rotary magnet *R.M.* These operations are controlled through the medium of a double-wound line relay *L.R.*, which is connected with the line conductors through the springs of a reversing relay *REV. R.Y.* The relay is double-wound and is so adjusted that it is operatively energized only when both windings are energized in the same direction. The line relay controls a second bridge across the trunk conductors for the purpose of repeating impulses to the main exchange in a manner to be soon more fully explained. The *RLSE MAG.* is the usual release magnet for restoring the switch shaft and side switch to normal position upon the release of the connection. This release magnet is connected in series with a double-wound relay *K*. The switching-selector repeater is also provided with a so-called side switch similar to that shown in connection with the test-distributor circuit.

There are ten rows or levels of bank contacts for each of the wipers $P1$, $P2$, $-W$ and $+W$. The bank contacts accessible to the wipers $P$-2, $-W$ and $+W$ of the level corresponding to the sub-office in which the repeater is located are multiples between bank, while the contacts in each level of the banks accessible to the wiper $P1$ are connected together, and the level which corresponds to the group of connectors in the sub-office is connected to the spring of the relay *K* of each repeater. Also in the bank associated with the wiper $P2$ the first contact in the level corresponding to the main office with which the sub-office is connected with the spring of the relay *K*. For example, if the numbers in the branch office begin with the digit 5, whenever the dial is operated for the first digit 5, the wipers will be raised to the fifth level, and upon cutting in upon the first contact in said level will close a circuit which will cause the release of this switch, at the same time causing a ground to be placed upon all the contacts accessible to the wiper $P1$ which are connected with the spring of relay *K*. If the first digit called by the first operation of the dial is other than 5, the switch will not be released but will come to rest upon the first contact in the level to which it has been raised, but should this level be one which leads to the local connectors, the switching relay *SW·RY.* will not be operated for the reason that at this time there is no ground on the spring of relay *K*, as the relay $K$ has not yet been energized by the switch releasing from the fifth level. It may be noted here that should the switch be resting upon a bank contact leading to a connector, and the switching relay $SW \cdot RY.$ is not energized, the contact in question is not made busy, for the switch does not place a ground upon its private wiper when said wiper is in third position. After the first digit 5 has been called, should the next digit called be that of a group of connectors at the branch office, the switch, upon coming to rest upon the first idle contact in that level, will have its switching relay $SW \cdot RY.$ energized, due to the ground now upon the springs of relay $K$.

The outgoing secondary lineswitch $H'$ which corresponds to one of the switches $H$, is the same in principle as the ordinary lineswitch, being somewhat simplified, however, in that it is not provided with line or cut-off relay armatures. This switch belongs to a group controlled by a master switch (not shown).

When the connection is extended to the switching repeater, a circuit is closed to the line relay. The relay, upon energizing, closes a circuit through the relay $R$ to battery. One result of the energization of the relay $R$ is the closure of a circuit extending from ground to the release trunk. A further result of this action is the closure of a circuit extending from ground through the winding of the secondary switch $H'$ to battery. The switch $H'$ thereupon operates to extend the connection to a first selector at the main office. A further result of the energization of the line relay, when the connection is extended thereto is the closure of a bridge across the trunk conductors, whereby, as soon as the connection is extended to the first selector, as above described, an energizing circuit is closed for its line relay. The relay $REV \cdot RY.$ is not energized at this time because only one winding has current flowing through it.

The foregoing operation takes place immediately upon the removal of the receiver from the switch-hook at the calling sub-station. The calling subscriber now operates his calling device in the usual manner for the first digit 5 of the called number. Each time the sub-station impulse springs are separated, the line relay of the switching repeater is momentarily de-energized, thus opening the bridge across the trunk conductors thereby momentarily breaking the energizing circuit of the line relay of the first selector. The relay $R$ in the switching repeater being slow acting does not de-energize during the momentary interruptions of its circuits by the relay $LR$, and therefore at each operation an impulse is transmitted over a circuit extending from ground through relay $S$ vertical magnet and the side switch wiper (in first position) to battery. The vertical magnet receives five impulses over this circuit and operates to raise the shaft wipers opposite the fifth level of bank contact. The slow-acting relay $S$ is energized by the first impulse which is transmitted through it and remains in its operated position until after the last impulse is delivered for the digit. In its operated position the relay *S* short circuits the coil *Y* and the lower winding of the relay *REV·RY.*, so as to remove their resistances from the circuit of the line relay of the selecter while impulses are being transmitted through it. The operation of relay *S* completes an energizing circuit for the private magnet *PM*. Upon the breaking of this latter circuit, when the relay *S* de-energizes after the last impulse for the digit is delivered from the sub-station, the private magnet de-energizes and permits the side switch to pass to second position. The side switch, upon passing to second position, closes a circuit through the rotary magnet, which thereupon energizes and rotates the shaft wipers one step, upon the first contact in the fifth level and energizes the private magnet. The wiper *P2* will meet with no guarding potential upon the first contact of the fifth level, as hereinbefore described, whereupon the private magnet will deenergize. At the time that the springs of the private magnet are in engagement, a circuit may be traced from ground through the bank contact, upper winding of the relay *K*, release magnet, to battery. The release magnet will energize over this circuit and operate to restore the shaft of the switching repeater to normal, without in any way affecting the first selector. The relay *K* will be energized in series with the release magnet and, upon operating, will close a locking circuit for itself. The energization of the relay *K* places ground upon all the bank contacts accessible to the wiper *P1* which corresponds to the group of connectors in the branch office. Also, places ground upon the first contact in the fifth level which is accessible by the wiper *P2*. The five impulses which are transmitted to the first selector by the relay *LR* of the switching repeater caused five impulses to be transmitted through the vertical magnet in the usual manner, lifting its wipers to the fifth level.

The calling subscriber now operates his calling device for the second digit 2 of the called number, in response to which the shaft wipers of the switching repeater come to rest upon the first contact of the second level in the bank. The second level being dead in the sub-office, its first contact will always be idle. When the side switch of the selector repeater passes to third position, a circuit is closed through the lower winding of the relay *REV RY.*, but the relay will not pull up at this time, for the current in its two windings oppose each other. In response to the impulses sent over the trunk by the relay *LR* the second selector operates to place its shaft wipers upon the first idle contact of the second level in its banks and to extend the lines to a connector in the same manner as explained for the first selector.

The sub-station calling device is now operated for the tens digit 0, whereby the switching repeater by means of the line relay *LR* causes the vertical movement of the connector in the usual manner.

The calling subscriber now operates his calling device for the last digit 0, whereby the switching repeater by means of the line relay *LR* causes the rotary movement of the connector in the usual manner.

Upon the response of the called subscriber his line is provided with talking current through the windings of the back-bridge relay of the connector, which, upon energizing, reverses the flow of curent in the trunk from the switching repeater. Since the current in the lower winding of the relay *REV RY* is now reversed, the two windings help each other and the relay becomes operatively energized, and in so doing reverses the current in the lines of the sub-station.

After the conversation is completed, the connection is released by the hanging up of the receiver at the calling sub-station in the following manner: When the receiver at the sub-station is restored to the switch-hook, the separation of the switch-hook springs destroys the energizing circuit of the switching-repeater line relay. The relay *LR* upon de-energizing, opens the circuit of the relay *R* which in turn, upon de-energizing, closes a circuit through the release magnet. The release magnet, upon energizing, withdraws the retaining pawls from the shaft and its own circuit is broken at the off-normal springs when the shaft reaches its lowest position. The de-energization of the relay *R* also removes ground from the release trunk which allows the secondary switch *H′* to return to normal position. The de-energization of the relay *LR* opens the energizing circuit of the line relay of the connector.

It will now be explained how a connection is extended from the telephone station of a sub-office to a telephone of the same sub-office. The number of the called telephone will be assumed to be 5300.

Upon the removal of the receiver at the sub-station, the action of the lineswitch, the switching repeater, the secondary switch *H′* and the first selector is the same as previously described.

Upon the operation of the calling device for the first digit 5, the switching repeater operates to raise the shaft wipers to the fifth level and to then release therefrom thus locking up the relay *K*, as previously explained. The action of the selector is the same as previously explained.

The calling subscriber now operates his calling device for the second digit 3 of the called number. As a result the switching repeater raises its shaft wipers to a position opposite the third level, from which point it seeks the first idle contact in said level of banks in the following manner: As soon as the side-switch wiper passes to second position, a circuit is closed through the rotary magnet, which, upon energizing, rotates the shaft wiper one step and closes the circuit through the private magnet. Should the contact upon which the wiper *P2* is rotated have a guarding potential upon it, a circuit will be closed extending from ground at the bank contact through the private magnet to battery. In this way the private magnet will be energized so long as the wiper *P2* is passing over busy contacts. At the first idle contact, the circuit through the private magnet will be broken and the private magnet, upon de-energizing, will allow the side switch to pass to third position, thereby opening the circuit of the rotary magnet. The operation of the first selector for this digit is the same as previously explained. When the side switch of the switching repeater passes to third position, a circuit may be traced from ground through the bank contact wiper *P*-1, switching relay *SW RY* and the side switch wiper in third position to battery. The springs of the relay *SW RY* are adjusted to make contact with their front contacts before they break contact with their back contact. The relay *SW RY*, upon becoming energized over the above traced circuit, operates to shift calling line from the line relay of the switching selector to the line relay of the local connector. The line relay, upon being disconnected from the line, de-energizes and opens the circuit of the relay *R*, which in turn, upon de-energizing, allows the secondary switch *H'* to return to normal position. At the same time the selectors in the main office release.

Upon the subscriber at the sub-station calling the last two digits of the called number, the action of the local connector is the same as usual.

Upon the completion of the conversation, the restoring of the receiver to the switch-hook at the sub-station causes the release of the apparatus in the usual manner.

In the foregoing description it has been assumed that the switching repeater is used in the 10,000-line system, and that the branch office is not over 100 lines. For this reason the switching repeater must be capable of operating upon the second digit called. When used in a hundred thousand-line system, and the branch office is not above 1000 lines, it is necessary for the switching repeater to be capable of operating upon the third digit called. A slight modification of the circuit will bring about this result.

**Trunk Holders.**—In some cases two central offices are so close together that it is not necessary to have a separate battery feed. The connector feed is ample, even to the calling station. But it is desired to have only two-wire trunks. In this case it is not worth while to use the repeater, but only a trunk holder. (See Fig. 71.)

This simplest form of trunk holder has only a series relay *LR* to energize a release relay *RlRy* to ground the release trunk and to close the chain contact. Both relays are made slow-release in order to insure the release trunk of a ground during dialing.

There are conditions under which the addition of parallel battery feed is advantageous. (See Fig. 72.) This is secured by adding a differential line relay *DLR*, which is in reality electrically polarized. This controls an auxiliary relay *AR* which connects the current supply through a double-wound impedance coil.

When the trunk is seized, the line relay *LR* energizes the release relay

*RlRy* which grounds the release trunk and polarizes the differential line relay *DLR*.

During the sending of impulses over the line, the line relay and the release relay do not vibrate. The current flowing from the distant office over the positive trunk $+T$ is in the wrong direction to actuate the differential line relay.

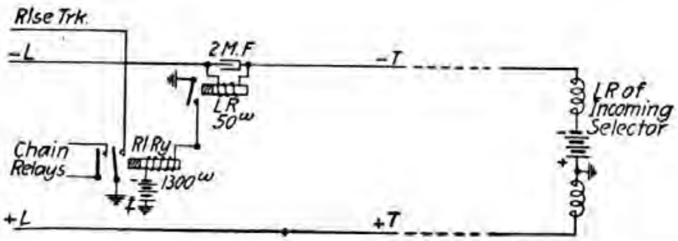



Fig. 71.—Trunk holder.

When the called station answers, the line current is reversed in direction. This causes the line winding, 60-ohms, to assist the polarizing winding, 860-ohms, and the differential line relay pulls up. This energizes the auxiliary relay *AR* which connects the battery feed in parallel with that of the connector in the distant office and with the same polarity. The line relay *LR* holds up with the reversed current. Though it may fall back momentarily during reversal, the release relay is so slow that it is not affected.

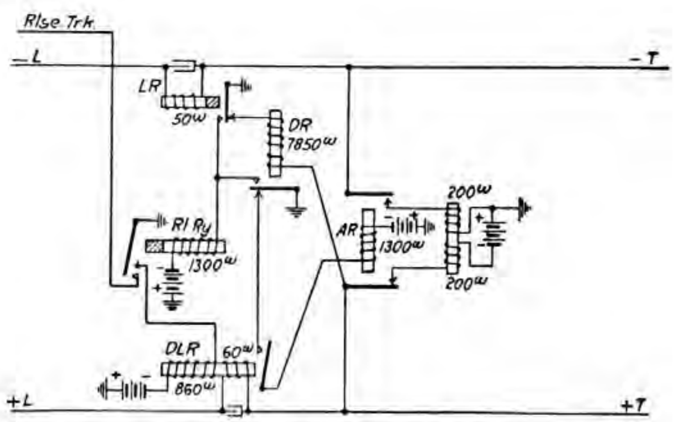



Fig. 72.—Trunk holder with parallel battery feed.

When the subscribers release, the failure of current in the line relay *LR* permits it to fall back and to release the release relay. The latter removes the ground from the release trunk and depolarizes the differential line relay.

If the calling subscriber hangs up first, relay *DR* will pull up, cut-off relay *AR* and the parallel battery feed, and hold *RlRy* so as to keep the trunk busy.

While a trunk holder is useful, the inter-office trunks are often so long and their resistance so high that in the interest of good impulsing the regular form of repeater is used.

**Quad-Level Trunks.**—Sometimes the trunking between certain offices is light. There may not be enough traffic to fill a ten-trunk group. These partial groups are not very efficient. Whenever they can be combined, it should be done, if it is possible to separate the traffic at the distant end of the link of trunks.

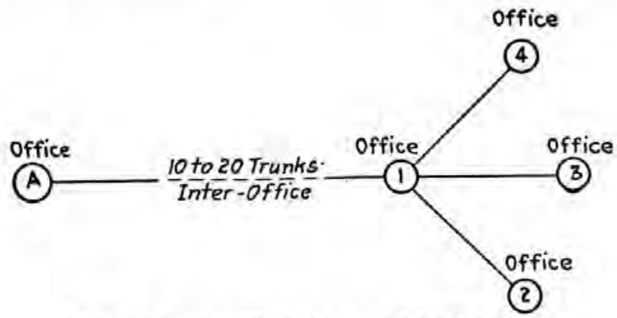



FIG. 73.—Conditions for quad-level trunks.

Suppose (Fig. 73) that the total busy-hour traffic from office $A$ to the four offices numbered 1, 2, 3, and 4 is such that from ten to 20 trunks will carry it. But because each office is called from a different level on the selectors at $A$, it is ordinarily impossible to combine them into one group.

The plan of quad-level trunks (Fig. 74) permits this desired grouping. The outgoing trunks are multipled to four levels on the banks of selectors,

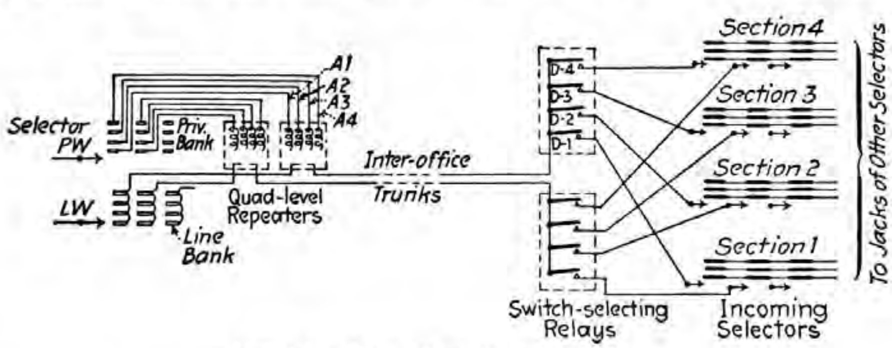



FIG. 74.—Plan of quad-level trunks.

but the release trunks are separately attached to the private bank contacts. Each trunk passes through a repeater which has four relays ($A$-1, $A$-2, $A$-3, $A$-4) affected by the level selected. Otherwise the repeater is of the usual type.

At the distant office where the division takes place (Office 1, in this case) each trunk arrives at a group of switch selecting relays $D$-1, $D$-2, $D$-3, and $D$-4.

6

If the subscriber calls the first level on the selector, its wipers will rotate in on the first level and seize the first idle trunk. Relay *A*-1 in the repeater will be pulled up. This causes relay *D*-1 in the distant office to pull up, switching the trunk to a selector in section 1, leading to office No. 1.

If the subscriber calls the second level on the selector in the originating office, its wipers will rotate in on the second level and seize the first idle trunk. Relay *A*-2 in the repeater will be pulled up. This causes relay *D*-2 in the distant office to pull up, switching the trunk to a selector in section 2, which represents office No. 2.

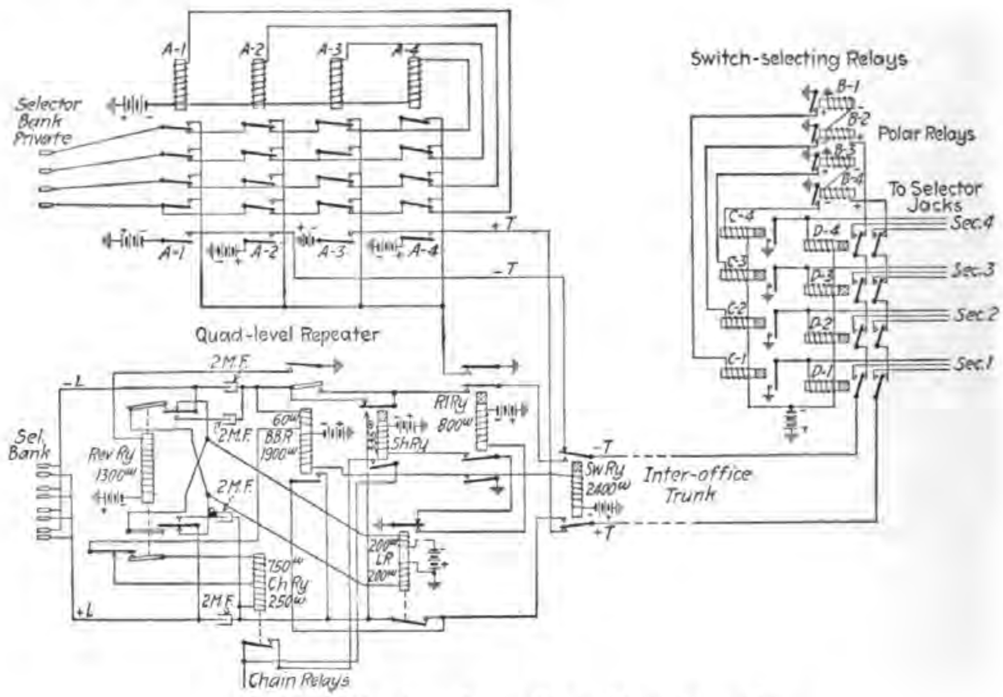



FIG. 75.—Quad-level repeater and trunk circuits.

The other levels cause the direction of calls to sections 3 and 4 in a similar manner.

It is not necessary to use four groups—three or two can be arranged just as well.

By using the ten-level 20-trunk selector, 20 trunks in one group may be used.

The circuits of the quad-level trunk system (Fig. 75) involve four relays added to the usual repeater and switch-selecting relays in the distant office.

The essential principle is found in the four polar relays in the distant office (*B*-1, *B*-2, *B*-3, *B*-4) and the battery polarity put on the two-line wires by the relays *A*-1, etc., in the originating office.

When the subscriber dials "one" the wipers of the selector are lifted to the first level. Then the switch rotates and seizes the first idle trunk.

The private wiper grounds the corresponding private contact on the first level of the private bank. This pulls up relay *A*-1, which cuts off the circuits of the other three relays but not itself. It also puts negative battery on the negative trunk $-T$.

The negative battery on the negative trunk operates relay *B*-1 in the distant office, but not *B*-2, because the latter is poled in the opposite direction.

Relay *B*-1 energizes relay *C*-1, which makes busy the trunk to section 1 and operates relay *D*-1. The latter switches the trunk lines to section 1. Relay *C*-1 holds the ground on the release trunk until the switch ahead can pull up its line and release relays. The action of relays *B*-1 and *C*-1 is momentary, for *B*-1 is cut off by the switching action. *D*-1 is held by the switch ahead.

At the same time that the above has been taking place, the calling subscriber line has been acting on the repeater proper. The line relay pulls up and actuates the release relay as usual. The latter, in addition to other duties, grounds a wire leading to the "*A*" relays. This is the ground which holds relay *A*-1 and the switches back of the repeater and makes busy the other private contacts. The release relay also pulls up the switching relay *SwRy*, which cuts off the selecting circuit and extends the lines through to the distant office, ready for dialing and talking. The rest of the operations have already been described in connection with Fig. 67.

**Secondary Lineswitches.**—Mention has already been made of secondary lineswitches in the chapter on "Trunking." 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 but having more than 10 per cent trunking, and on trunks between comparatively large automatic offices.

Both Keith type and rotary lineswitches are used as secondaries, the former for local and for out-going trunks, the latter only for the out-going trunks. A photograph of a Keith secondary lineswitch is reproduced in Fig. 76. The rotary switch is like Fig. 48 except the relays.

As this illustration indicates, the mechanical features of the secondary lineswitch are the same as those of the primary lineswitch. It uses banks of the same construction and is mounted on an upright similar to those used by the primary lineswitch. In fact, the only difference between the uprights is that lineswitches are mounted on one side only of an upright, the back of which is reserved for connector switches, but switches are mounted on both sides of a secondary lineswitch upright, *i.e.*, each such upright, when filled, carries four shelves, each having a capacity of 50 lineswitches. These lineswitches may be divided into four sections each employing a master switch, or they may be divided into eight sections, each having a master switch. In the latter event, one master switch is mounted at the customary place in the middle of each shelf, and the extra switch is mounted at the top of each shelf. A photograph of a secondary lineswitches installed is reproduced in Fig. 95.

FIG. 76.—Secondary lineswitch, Keith.

As stated in the chapter on "Trunking," when the secondary lineswitches are inserted between the primary lineswitches and the first selectors, they are used to reduce the number of first selectors required, by placing the first selector switches in groups of 100 instead of in groups

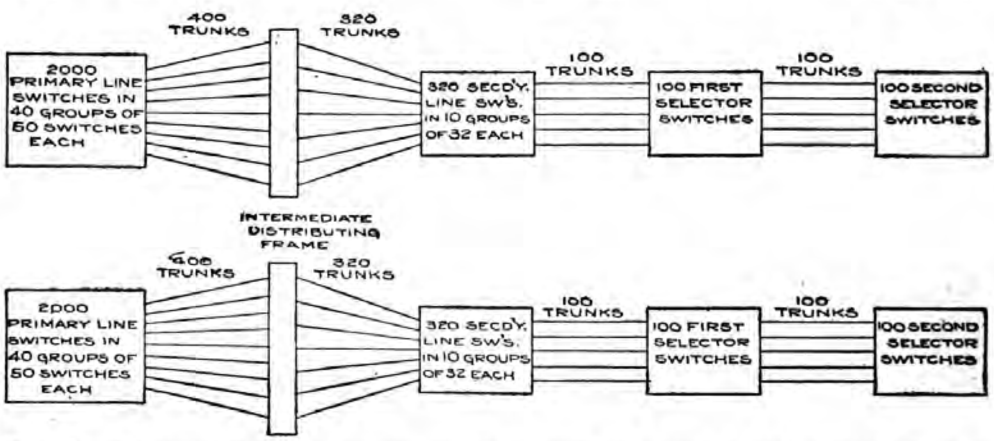



FIG. 77.—Diagram illustrating scheme of using secondary lineswitches to reduce first and second selectors.

of ten. The application of this mechanism makes it possible to give a large number of primary lineswitches (say 2000) access to a group of 100 first selectors.

The drawing in Fig. 77 shows the number of primary lineswitches, the number of primary lineswitch groups, the number of trunks from primary

**lineswitches to secondary lineswitches, the number of secondary lineswitch sections, the number of trunks from secondary lineswitches to first selectors, and from first to second selectors, that might be used in a typical office of 4000 lines, using third selector switches.**

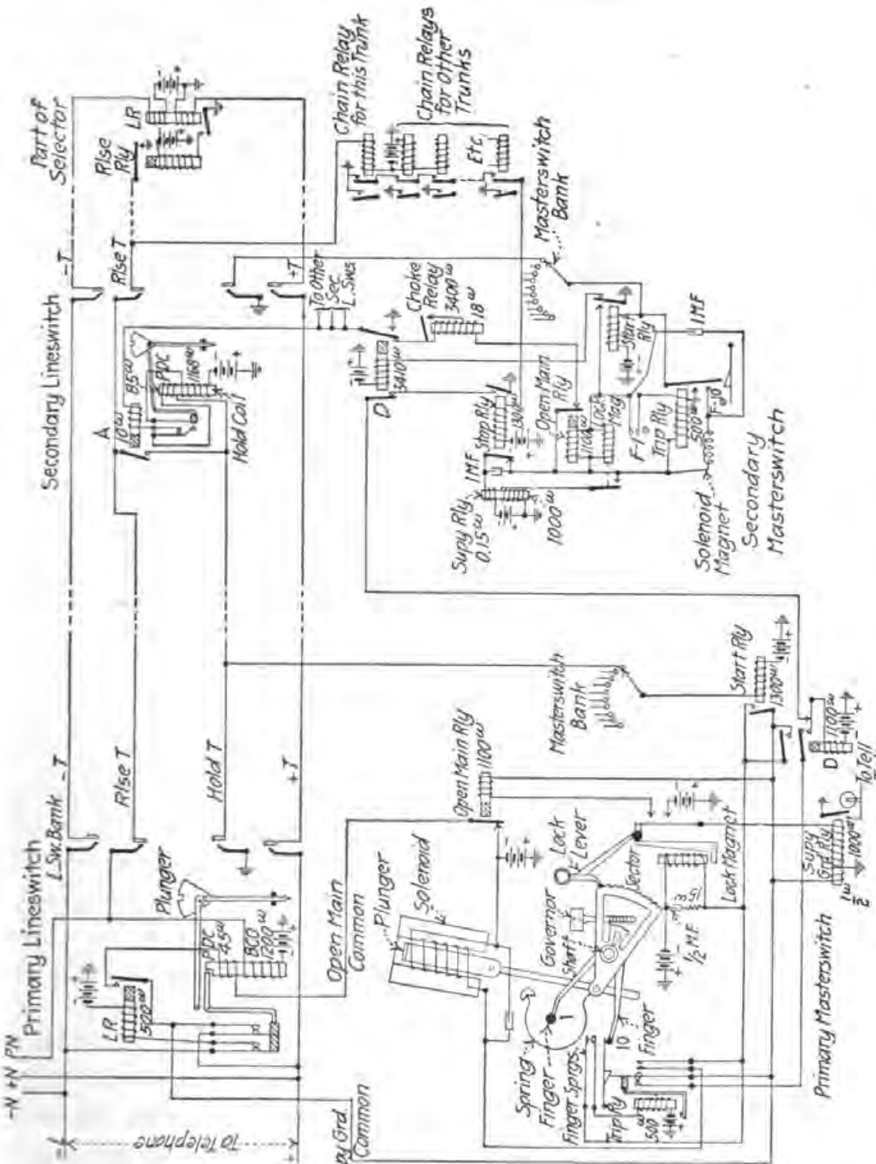



FIG. 78.—Circuit from telephone through secondary lineswitch.

Sometimes secondary lineswitches 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 lineswitches and the first selectors, the circuit is such that when a subscriber lifts his receiver from the switchhook, preparatory to making a call, his primary lineswitch and the secondary lineswitch 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.

Figure 78 shows a circuit from a calling telephone through a primary and secondary lineswitch to a first selector trunk.

The circuits of the secondary lineswitch may be divided into the following parts: secondary lineswitch proper, master switch, and relay equipment. The trunk from the primary to the secondary lineswitch consists of four wires, the added wire being called the "holding trunk." The release trunk is arranged to be extended clear through from the primary lineswitch to the selector and later on to other switches as far as it is needed. The secondary lineswitch is operated and held by means of the holding trunk.

The secondary lineswitch has a pull down-coil of 85 ohms which is powerful enough to pull in the plunger, and a holding coil of 1168 ohms which, in series with the pull-down coil, is able to hold the plunger in the bank with reduced current.

In order to furnish current promptly to the *BCO* winding of the primary switch, there is a slow releasing relay *A* of 10 ohms resistance which is normally in series with the pull-down coil. This relay connects the holding trunk ground onto the release trunk and holds it there only until the selector has had time to ground the release trunk directly. The secondary master-switch bank is grounded by means of a contact in the secondary lineswitch bank.

When the subscriber takes his receiver from the hook, the primary lineswitch plunges into the bank, extending the line wires to the trunks, $+T$ and $-T$. The *BCO* is connected to the release trunk and the holding trunk is grounded. This ground simultaneously actuates the primary master switch and operates the pull-down coil of the secondary lineswitch, causing the plunger to be driven into the bank. At the same time the 10-ohm relay *A* receives current enough to pull up and ground the release trunk, so that the *BCO* of the primary lineswitch will hold the plunger in the bank, although its pull-down coil is cut off.

The action of the secondary lineswitch cuts out the relay *A* and substitutes in its place the holding coil of 1168 ohms, by means of which the plunger is retained. The secondary lineswitch extends the trunks $+T$ and $-T$ and release trunk to the first selector. It also grounds the secondary master bank so as to cause the idle plungers to be moved to another trunk.

The selector line relay at once pulls up and operates the release relay, placing a ground upon the release trunk so that when the relay *A* falls back the connection will still be retained.

During a conversation, both lines are clear from attachments all the way from the telephone to the switches beyond the lineswitches. The release trunk runs through from *BCO* of primary switch without attachments. The holding trunk is local to the primary and secondary switches.

**Chain Relays.**—The purpose of the chain relays and their accompanying circuits, which are installed where secondary lineswitches are used, is to prevent calls being lost when all of the outgoing trunks from any group of secondary lineswitches are busy. When a primary lineswitch releases its plunger arm, after having occupied a trunk to a sedondary lineswitch group, the plunger does not engage the master-switch shaft at once but remains out of engagement with the shaft and still poised over the trunk recently used by it, until the master shaft in the regular course of events "picks it up," *i.e.*, moves into a position where the plunger slips into engagement.

Meanwhile, if the subscriber to whose line the plunger under discussion belongs should lift his receiver from the switch-hook, the plunger will again connect him to the trunk used in his last call. It therefore sometimes happens that a busy subscriber, who is making a number of calls in succession, will use the same trunk repeatedly. No difficulty could possibly arise from this unless secondary lineswitches are used. Where secondaries are used, the trunks to each secondary lineswitch unit do not come from any one primary lineswitch group but are distributed as widely and as evenly as possible among the lineswitch groups or shelves.

The loss of a call may occur as follows:

Suppose that a subscriber's line which has been extended from his primary lineswitch through secondary section No. 3 to a selector releases, and the primary master switch does not immediately pick up his plunger. Suppose that secondary section No. 3 now becomes fully occupied by calls from other primary sections. If now our subscriber calls again, his primary lineswitch will have but one outlet, viz., to the busy secondary section No. 3, into which it can not connect because the "open-main" wire is open. There is no danger of double connection. Our subscriber will lose his call.

The chain relays prevent this condition by closing a circuit whenever all of the trunks outgoing from any secondary lineswitch group are busy, which causes the master switches of all of the primary lineswitch groups having trunks to the busy secondary group to sweep their shafts through the entire arc and thereby pick up any plunger which may be released but out of engagement with the master-switch shaft. For this purpose a number of relays co-operate.

When the last one of ten trunks becomes busy, its chain relay simultaneously grounds the only remaining master-switch bank contact and closes the chain circuit of the stop relay. The latter prevents the master switch from vainly hunting for the idle trunk which does not exist. It also grounds the "kick-off" wire, which ground is very soon removed by the falling back of the *D* relay. The latter was cut off by the start relay, because the latter pulled up at the same time as the stop relay.

The momentary pulsation over the kick-off wire operates all the kick-off relays *D* in the master switches whose trunks run to the secondary section which now is busy. Each relay *D* locks itself through the back contact of the trip relay of the primary master switch. It at the same time closes contacts in parallel with the start relay, so as to cause the master switch to let its guide shaft rotate to trunk No. 1. Here the trip relay is brought into play and locked as was described before. The solenoid pulls the shaft to trunk No. 10, on the way picking up all the idle plungers. The operation of the trip relay unlocked the relay *D*, so that on arriving at trunk 10 the master switch will be free to choose trunks as before.

During the time that the secondary section is busy, the open main wire is grounded by relay *D*. The total resistance from primary master switch bank contact through secondary lineswitch to ground is not much over 95 ohms, consisting of relay *A* and *PDC*. This prevents any primary master switch from stopping on this trunk.

The circuit of the secondary master switch has been rearranged for compactness and clearness of current-flow. The mechanical relations and functions of the various parts are like those of the primary master switch. "*F*-1" is the finger which operates at trunk 1 while "*F*-10" is the finger which operates at trunk 10. The supervisory relay for the master switch has to be in the negative lead, because the mainspring of the start relay furnishes ground normally to relay *D*. The latter is normally energized, and the current drawn by it would interfere with the proper operation of the supervisory relay.

During the time that the secondary master switch is hunting for an idle trunk, none of its lineswitches must be allowed to plunge into the bank. This is taken care of by the open main. But if the hunting time should be a little too long, one or more calls might be stored up, so that when the idle trunk is found and battery connection restored to the open main, more than one secondary lineswitch might be plunged in on the same trunk and a double connection result.

Double connection in the above case is prevented by relay *D*. During brief operations of the master switch it will remain energized. But if the hunting period be longer than is safe, relay *D* falls back, grounds the holding trunk, and prevents any primary master switch from sending calls over this trunk.

The choke relay performs a function which is not obvious. It prevents the primary master switch from running past a single idle trunk, which easily occurs if the holding trunk and open main of secondary are connected to negative battery through a low resistance. While the primary master switch is sweeping over its bank, its wiper may pass over a succession of grounded contacts, followed by a single one which is not grounded. The start relay is energized When it arrives at the single ungrounded contact, the start relay is supposed to fall back promptly and stop the guide shaft. But if the master bank has on the idle contact a low resistance path to negative battery, the latter acts like a shunt on the start relay, making it temporarily slow to release. It will not fall back quickly enough, thus permitting the shaft to pass on beyond.

The choke relay has normally a high impedance, so that under the above conditions, it does not affect the start relay of the primary switch. But when the primary switch places a ground on the holding trunk,

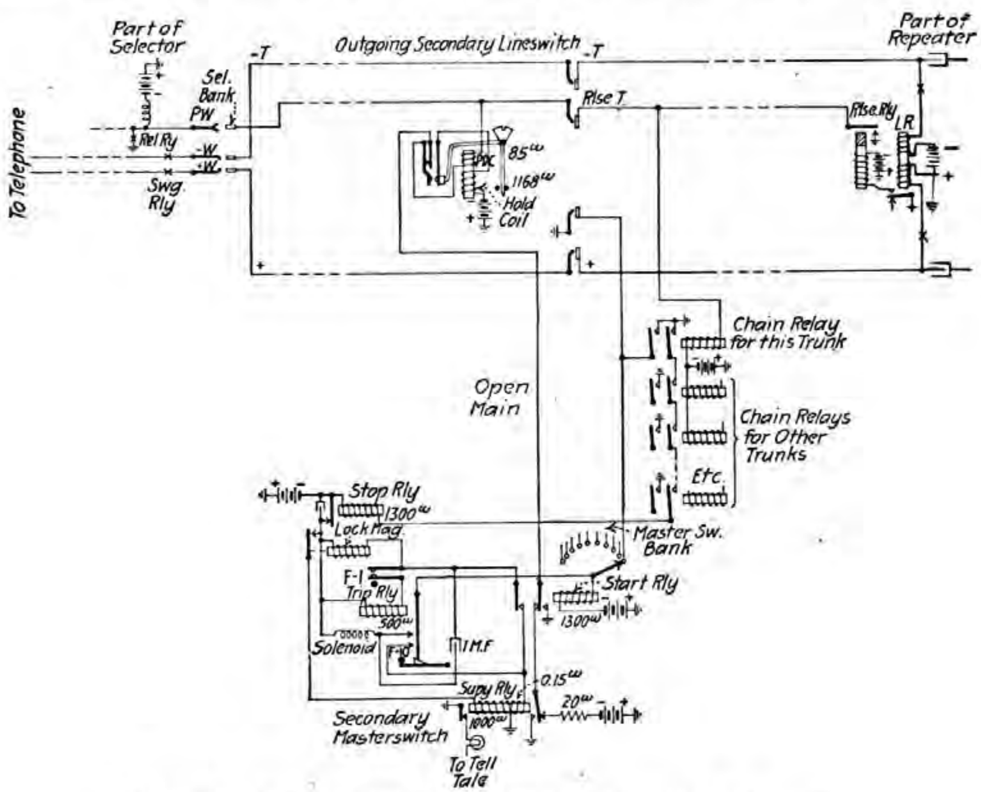



FIG. 79.—Circuit of outgoing secondary lineswitch, Keith type.

the choke relay pulls up and short-circuits all of its w nding except 18 ohms, becoming little more than a conductor.

**Outgoing Trunk Secondary Lineswitches.**—Both types of lineswitches, Keith and rotary, have been used on outgoing trunks from one office to another. They are located between the banks of the selectors and the repeaters.

Figure 79 shows the circuits of a Keith outgoing secondary lineswitch with its master switch and associated relays. The circuits are much simpler than those for the local secondaries, because no pick-up device is needed and the selectors now used are not affected by low resistance connections to negative battery. There is also no danger of premature release, because the release trunk is grounded amply long by the selector.

The lineswitch proper has only the pull-down coil, *PDC*, and the holding coil. The chain relays perform the same functions as before. The stop relay of the master switch needs only to stop the master switch by cutting off the battery, for the start relay switches the open main from negative battery to ground to busy the trunks while hunting for an idle trunk.

The skeleton of the circuits arriving from the left through the selector shows the selector in the act of seizing the trunk. The ground on the release trunk has not yet been removed. Here we begin.

The ground on the release trunk in the selector operates the pull-down coil *PDC* and drives the plunger into the bank. This extends the lines and release trunk clear through to the repeater, which, by its line relay

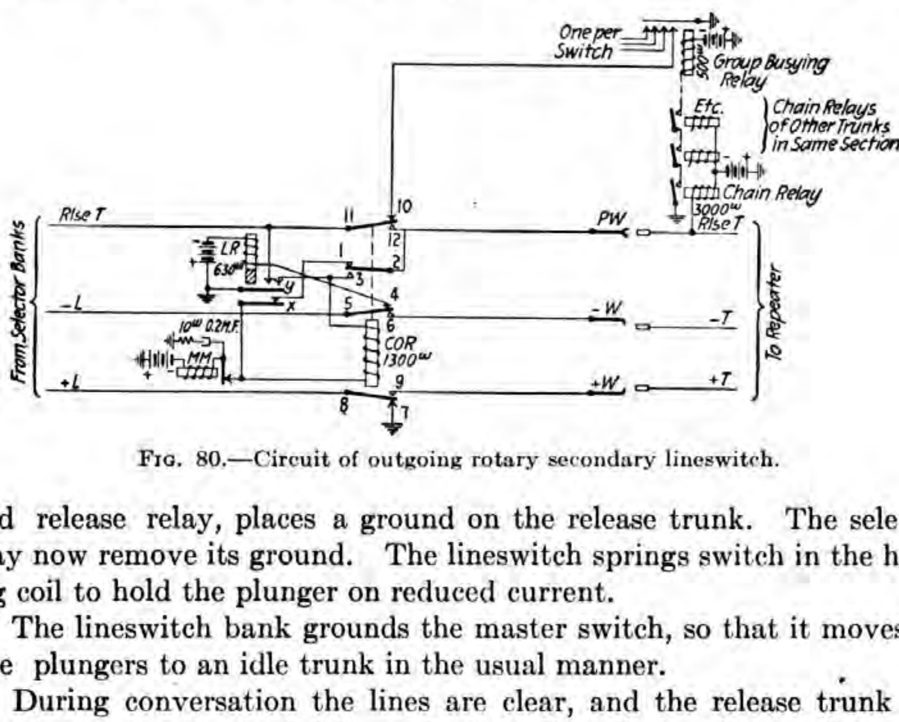



FIG. 80.—Circuit of outgoing rotary secondary lineswitch.

and release relay, places a ground on the release trunk. The selector may now remove its ground. The lineswitch springs switch in the holding coil to hold the plunger on reduced current.

The lineswitch bank grounds the master switch, so that it moves its idle plungers to an idle trunk in the usual manner.

During conversation the lines are clear, and the release trunk has attached to it only the holding coil of the lineswitch. Release is accomplished by merely removing the ground from the release trunk and letting the plunger withdraw from the bank.

If the mechanism of the master switch stops between positions, the lock magnet will be unable to return to normal. This leaves the lock-magnet contact closed, and the 1000-ohm winding of the supervisory relay therefore energized. In addition to lighting the supervisory lamp, it switches the open main from negative battery to ground, so that as long as the master switch is out of order no calls will be received. The trunk will test busy.

The rotary outgoing secondary lineswitch (Fig. 80) has circuits which are still more simple. Each switch has a motor magnet $MM$, line relay $LR$, and a cut-off relay $COR$. But the only common apparatus is the chain relays and the group busying relay.

When a selector seizes this trunk, it extends the lines so that the telephone draws current from the line relay and battery connections in the rotary lineswitch as shown. The line relay pulls up and grounds the release trunk, so that the selector ground may be taken off. It also connects the magnet $MM$ to the private wiper $PW$ through contacts 1-2 of the cut-off relay. This is to test the trunk. Contact $Y$ closes a little later than contact $X$, grounding the cut-off relay winding. Since the cut-off relay and the magnet are in series, it is essential that the contact $X$ shall close first, so that if the trunk is busy (grounded) the cut-off relay will not pull up, but will give the magnet time to rotate the wipers to the next trunk.

If the trunk is idle, the magnet will find no ground. This leaves the cut-off relay free to energize. It switches the lines from line relay and ground to the line wipers $+W$ and $-W$, cuts the release trunk through to the private wiper $PW$, and connects the winding of the relay to the release trunk so as to hold the cut-off relay energized during the holding time. The repeater immediately places a ground on the release trunk, so that the line relay of the rotary lineswitch may fall back without harm.

If the trunk is busy and the private wiper therefore grounded, the action of the line relay will result in there being a ground at both ends of the cut-off relay winding, so that it can not act. The private wiper ground permits the magnet $MM$ to act, driving the wipers to the next trunk. Since the magnet drives the wipers on the back stroke, the magnet is de-energized when the wipers strike the next set of contacts. If they also are grounded, the cut-off relay is again short-circuited, and the magnet performs again. If they are not grounded, the magnet can not pull up, but the cut-off relay will act as before described.

During conversation the lines are free, and the release trunk has only the cut-off relay attached. At release, the cut-off relay merely falls back, the wipers remaining where they are.

**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, four or five-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.

Two systems of frequencies have come into use, the first of which had its origin in the limitations of motor-generators. The multiple harmonic system employs the frequencies 16.7, 25, 33.3, 50.0, and 66.7 cycles per second. The non-multiple harmonic system employs the frequencies 20, 30, 42, 54, and 66 cycles per second. 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.**—Two arrangements for ringing harmonic party lines are in use. The first employs a group of connectors for each frequency. The second uses connectors, each of which is equipped with a frequency selector. The latter is operated by one of the latter digits of the call number.

**Groups of Connectors.**—On a five-party line each telephone has its own individual number. These numbers are generally assigned so that to 100 five-party lines a consecutive series of 500 numbers will be assigned; for example, a series like 4100, 4200, 4300, 4400 and 4500. With this particular series the numbers given to the individual telephones on line 24 of this one hundred lines would be "4124," "4224," "4324," "4424" and "4524;" while the numbers assigned to the telephones on line 36 would be "4136," "4236," 4336," 4436" and "4536."

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," a fourth for "4400" and a fifth for "4500." The banks of these five 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," "4424" and "4500" also. Therefore, only one of the five 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 16.7 cycle ringing current to the ringing relay busbars of the "4100" group of connector switches, 25-cycle ringing current to the ringing busbars of the "4200" group of connector switches, 33.3-cycle ringing current to the busbars of the "4300" group, 50-cycle ringing current to the busbars of the "4400" group and 66.7-cycle current to the "4500" gruop. Consequently, when a subscriber calls "4424" he secures the same line that he would secure if he called "4124," but projects 50-cycle ringing current on to the line instead of 16.7-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 five-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 five numbers are used, only one lineswitch is necessary for each line; therefore, 100 party lines are served by one lineswitch unit, which carries on one side the customary set of 100 lineswitches with their master switches, and on its other side, the five groups of connector switches, to give five-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 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.

**Connectors with Frequency Selectors.**—The circuit of a connector equipped with a frequency selector (Fig. 81) is the same as that of the connector shown in Fig. 60, with the addition of the minor switch with five bank contacts. It is arranged so that the hundreds digit operates the frequency selector, after which the tens and units digits cause the lifting and rotating of the shaft as usual.

The minor switch (Fig. 82) was developed for general utility work and may have various numbers of bank contacts. It has its own release magnet. As used in this connector circuit, one wiper is normally on the first contact and acts as an off-normal switch. The other wiper stands off the bank and makes connection with the first contact when the magnet *FSM* makes one step.

The operation (Fig. 81) is as follows: When the connector is seized, the line relay and release relay pull up. The latter grounds the release trunk, closes the path from the back contact of the line relay to the off-normal springs *ONS*, and energizes the ring cut-off relay *RiCOR* through the 300-ohm resistance and the 200-ohm winding of the relay. Thus a circuit is prepared from the back contact of the line relay, through the front contact of the release relay, off-normal springs *ONS*, front contact of ring cut-off relay, back contact of wiper-closing relay *WCRy* to the frequency selector magnet *FSM* and negative battery.

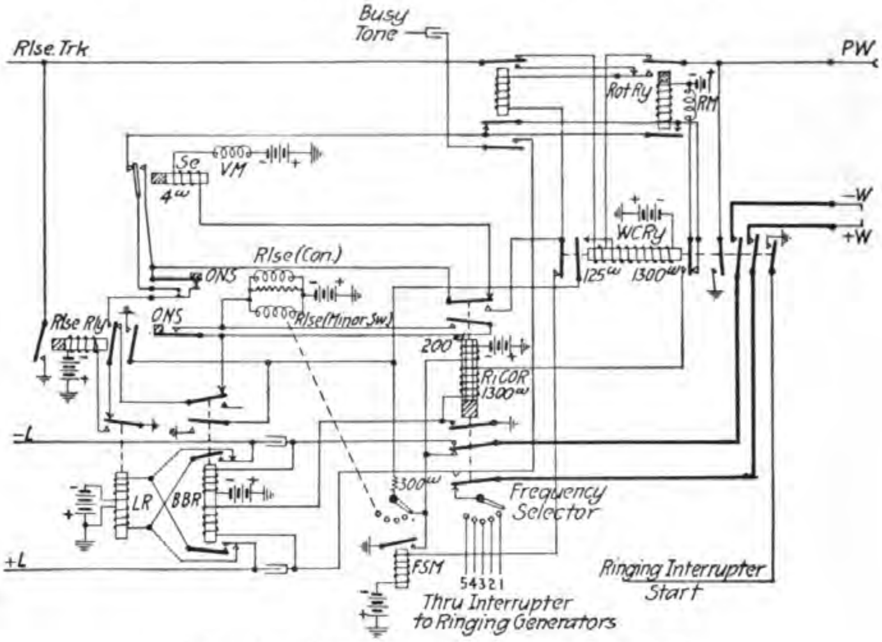



FIG. 81.—Connector with frequency selector.

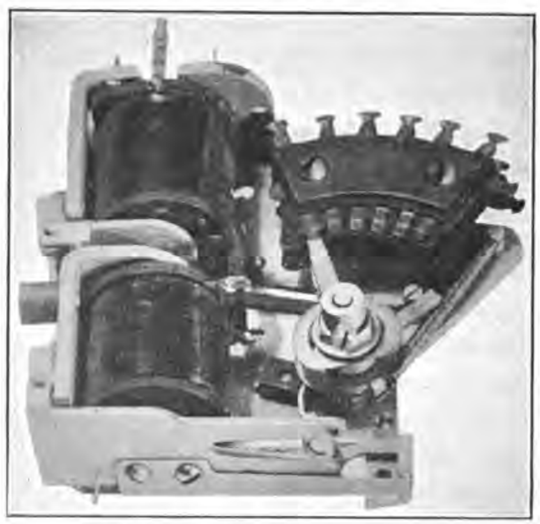


FIG. 82.—Minor switch.

When the subscriber pulls the hundreds digit, the pulsations formed by its back contact operate the frequency-selector magnet *FSM*, rotating the wipers of the minor switch. Pulsations formed by the contact of this magnet keep the ring cut-off relay energized. The latter depends solely upon the magnet, because the first step of the minor switch breaks the connection through the 300-ohm resistance.

At the end of the series of impulses, the ringing wiper of the frequency selector stops on the contact desired, and the ring cut-off relay falls back. This latter action switches the impulse circuit of the line relay onto the vertical magnet *VM* by way of the winding of the series relay *Se.* The action from here has been described in connection with Fig. 60, and need not be repeated.

The release of Fig. 81 is in general the same as that of the connector of Fig. 60, except for the addition of the minor switch. The release magnet of the latter is wired in parallel with the release magnet of the major switch. When the line relay and the back-bridge relay fall back, they and the release relay close the path for both release magnets named. This circuit is opened when the shaft has dropped to normal, thus returning the off-normal springs to normal.

If the subscriber hangs up after he has seized the connector, but before he has dialed any number on it, the release magnet circuit is completed through the springs of the ring cut-off relay instead of the off-normal springs. The reason for this is that in releasing, the first act of the line relay is to operate whatever magnet is at that time connected to its back contact. Initially it is the magnet of the frequency selector, *FSM*. This magnet, together with the ring cut-off relay will remain energized until the release relay falls back. Then the circuit of the release magnets wil close and will not open until the ring cut-off relay falls back, which will be after the usual delay of a slow-release relay. The time is ample for the frequency selector to return to normal. The momentary operation of the release magnet of the connector does no harm.

**Reverting Calls.**—This term is applied to a call of one subscriber on a 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 's, therefore, not considered good practice to put in the special lineswitches and connector switches required for handling them in this manner.

The customary method is to provide in the central office a number of "reverting-call switches" which are accessible to first selectors or second selectors. Each party line telephone is provided with an instruction card giving the numbers of the other stations on the same line with a special number opposite each. The subscriber is instructed to call the special number, hang up his receiver and wait while the desired station is being rung.

The reverting-call switch rings alternately the called station and the calling station. When the called party answers, the ringing stops. Then the calling subscriber takes down his receiver and the conversation proceeds.

The act of the called subscriber in answering releases the reverting-call switch and the selectors through which it was reached. But immediately a first selector is taken and it supplies talking battery current to the two telephones. When both of them hang up their receivers, the first selector and the lineswitch return to normal. Thus the reverting-call switch is used only long enough to ring the bells—it is not held during conversation.

The circuit of a reverting-call switch is given in Fig. 83. Its chief features are the usual vertical and rotary magnets and the release magnet,

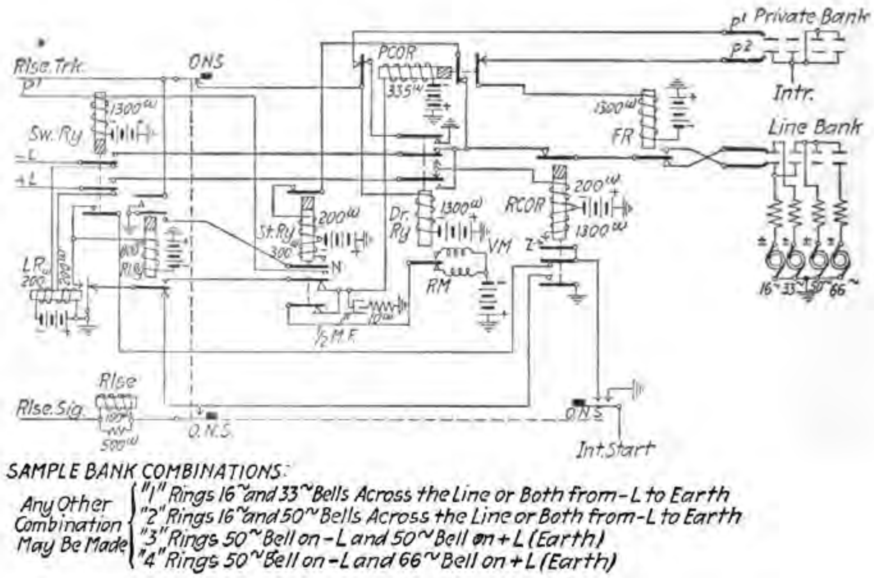



FIG. 83.—Reverting call switch circuit.

controlled by the line relay and the release relay; the relays for directing the ringing current to either side of the line and for cutting it off, and the wipers and banks arranged to supply the ringing current in all the desired frequencies and for controlling the directing relays.

When the calling subscriber has dialed the first part of the special number, he is connected to the incoming lines of the reverting-call switch. (See Fig. 83.) The line relay *LR* immediately pulls up, followed as usual by the release relay *RlRy*. The latter prepares part of the impulsing circuit, prepares a ground for the starting relay *StRy*, and grounds the release trunk. The latter, in addition to holding the connection through other switches, pulls up the directing relay *DrRy*. The directing relay switches the impulsing circuit to the vertical magnet, and prepares a ground to lock itself.

The first series of impulses sent to the switch operates the vertical magnet, lifting the wiper shaft to the desired level. During the series, the private cut-off relay *PCOR* is energized, being in parallel with the vertical magnet. The private cut-off relay closes the locking circuit of the directing relay, so that although the off-normal springs *ONS* open, the directing relay will be held energized to the end of the series.

When the first series of impulses end, the private cut-off relay falls back, permitting the directing relay to release. This switches the impulsing circuit of the line relay to be directed to the rotary magnet.

The second series of impulses causes the rotary magnet to rotate the wiper shaft to the desired set of contacts. At the same time the private cut-off relay pulls up and remains energized. It cuts off the two private wipers, *P*-1 and *P*-2, and also cuts off the circuit of the starting relay *StRy*.

When the second series of impulses ends, the private cut-off relay falls back, connecting three relays so that they may act if the conditions favor their action. The directing relay is connected to *P*-1, the frequency relay *FR* to *P*-2, and the starting relay to the line which is normally connected to the line wipers.

The connections on the private bank and on the line bank determine what frequencies shall be alternately rung, and how they shall be applied to the subscriber line. A few sample connections are shown to illustrate the plan. Many other connections are needed to ring all pairs of stations.

In general, *P*-1 and the directing relay cause the ringing current to be directed to one line wire or to the other, while *P*-2 and the frequency relay take care of the frequency or frequencies to be sent out.

If the units digit in the special call number is "1," *P*-1 will rest on an open contact, but *P*-2 will rest on a contact wires to the interrupter (ground). At the same time, the line wipers rest on contacts wired to the 16- and 33-cycle generators. Hence the negative line $-L$ is in a position to be connected to the ringing generators, and the positive line $+L$ can be connectedto the ring cut-off relay *RCOR* and negative battery.

As the interrupter acts, the frequency relay will pull up and fall back, sending out alternately the two frequencies mentioned. But the subscriber line must be connected.

The first bit of ringing current finds a path through the starting relay *StRy*, 200-ohm winding. It pulls up its locking contact *N* first, which enables it to cut off the initial circuit. This relay switches the impulsing circuit of the line relay from the magnets to the switching relay *SwRy*.

When the calling subscriber hangs up his receiver, the line relay falls back. The release relay will not fall back at once, because it is slow to release. The ground at the line relay causes current to flow through the front contact of the starting relay to the switching relay. The latter, pulling up, switches the lines from the line relay to the ringing generators which have been prepared. It also connects the release relay to a ground which was prepared by the off-normal springs (through the back contact of the ring cut-off relay).

Now the action of the ringing interrupter causes the frequency relay to switch from one frequency to the other, ringing the bell of the called station and that of the calling station.

When the called station answers, the switching of the talking apparatus of the telephone across the line permits the ring cut-off relay *RCOR* to energize (by direct current) and to lock itself by its 1300-ohm winding to the off-normal spring ground. This relay cuts off the ringing current, opens the circuit of the release relay, and energizes the release magnet. The reverting call switch at once restores itself to normal, at which point the off-normal springs cut the current from the release magnet.

The falling back of the release relay removes the ground from the release trunk so that the selectors can release. It also releases the starting relay *StRy* and the switching relay *SwRy*.

Since there is at least one telephone talking set across the line, the release of the switches is only momentary. At once the lineswitch will seize the same trunk or another trunk so that the line will draw battery current from a first selector during conversation.

If the units digit of the special call number had been "2," the frequency relay would have been used as before, but a different pair of frequencies would have been selected by the line wipers.

If the units digit is "3," the directing relay alone would be operated, and but one frequency selected. This frequency would be directed alternately to one line wire and then to the other. This would ring a bell from each side of the line to earth.

If the units digit is "4," both the frequency relay and the directing relay are operated at the same time This rings one frequency on one line and another frequency on the other line.

For a party line which has all bells bridged, the directing relay is not used—the bank contacts for the *P*-1 wiper are left open. The line bank is wired with the pairs of frequencies needed for all subscribers on a line to ring each other. The frequency relay alone is enough

For a party line which has bells bridged from each line to earth, both relays must be used at times, one *FR* to switch frequencies, and the other *DrRy* to direct the ringing current to the desired line wire.

**Group Connectors or Rotary Connectors.**—One subscriber may have more than one line. His lines may terminate on his premises in as many separate telephones; or on bells, with keys to permit any telephone to answer any line; or on a private branch exchange (manual) board; or in a private automatic exchange.

Usually only one call number is listed in the directory. If this line is busy, the others will serve as well, and must be tested, selected, and used.

The group connector is arranged to perform the above duties. It may operate with the customary two digits, being called a "2-digit group connector" or "rotary connector," to distinguish it from the ordinary "line connector" which connects only with single lines. It may operate with one digit, in which case it is called a "one-digit group connector." In this case the group of lines may occupy one level or more than one level.

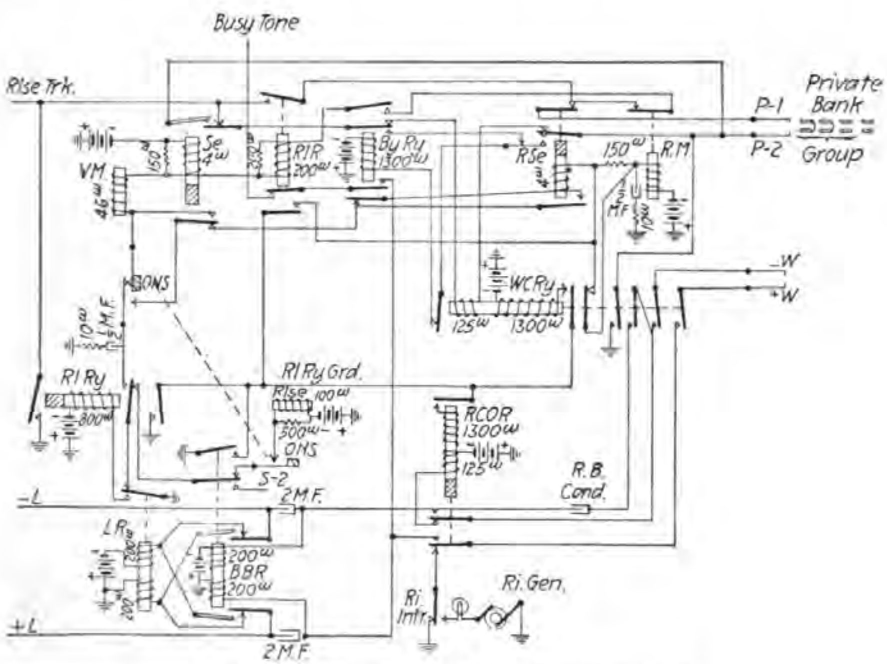



FIG. 84.—Circuit of 2-digit group connector.

**Two-Digit Group Connector.**—The circuit of a two-digit group connector is shown in Fig. 84. There are two private wipers, and the private bank has a pair of contacts for each point (like line bank). *P*-1 is the upper wiper and *P*-2 the lower wiper, each engaging the respective contact of the pair.

Each level may be divided up into a number of groups of lines, or may be used as separate lines. The grouping is done on the private bank. The two contacts of a pair are connected together for all the points except the last of the group. They are left open.

The lower contact of each pair, engaged by *P*-2, is the usual private contact and is connected to the *BCO* of the lineswitch of the called line. The private wiper *P*-2 is likewise the usual busy-test wiper of the connector described in Fig. 60.

The upper contact of each pair has to do only with hunting an idle line in the group. The private wiper *P*-1 is used in connection with the rotary magnet and the rotary-interrupter relay, very much as was described in connection with the selector of Fig. 63. Any line which is busy will have a ground on its lower private contact. (See Fig. 84.) It is the ground which operates the *BCO* of the called line and also insures privacy. This ground is transferred by the tie wire to the upper private contact, so that while the switch is hunting, the private wiper *P*-1 will find ground and cause the rotary magnet to drive on.

When an idle line is found, both contacts will have no ground.

If all lines in the group are busy, the switch will arrive at the last pair of contacts in the group. Here the wiper *P*-1 will find no ground, because the contact is open. The control now passes to the lower wiper, *P*-2, which tests the line as usual, and gives the busy tone on finding it engaged.

When the switch is seized, the line relay and the release relay *RlRy* pull up. The latter grounds the release trunk, prepares the impulsing circuit for the line relay, and grounds a very useful conductor known as the "release relay ground." The last-named wire enables the wiper-closing relay *WCRy* and the ring cut-off relay *RCOR* to lock themselves. Through it the rotary magnet gets current while hunting an idle line.

The hundreds digit of the call number operates the vertical magnet in the usual way. The series relay *Se* is placed next to negative battery so that it can later be used in the rotary test circuit. During the vertical action, it holds the vertical magnet circuit, even though the off-normal springs *ONS* have switched to the rotary magnet.

At the end of the hundreds digit, the series relay falls back and completes the switching of the impulsing circuit from the vertical magnet *VM* to the rotary magnet *RM*.

The units digit now causes the rotary magnet to move the wipers over the chosen level of bank contacts to a definite set of them. During this time the rotary series relay *RSe* remains energized, cuts off the private wiper *P*-1, switches the busy relay *ByRy* onto *P*2, and insures the rotary magnet circuit even though the busy relay pulls up while *P*-2 is passing over busy contacts.

When the units digit ceases its impulses, the rotary series relay falls back. This closes a gap in the *P*-1 circuit, switches *P*-2 onto the 125 pull-up winding of the wiper-closing relay, switches the busy-relay winding onto its own front contact, and opens the initial circuit of the rotary magnet.

Assume that the line is free. There will be no ground on either private wiper. Therefore there will be a path from ground on the release trunk through a back contact on the series relay, back contact of the busy relay, 125-ohm winding of the wiper-closing relay, back contact of rotary-series relay, *P*-2, *BCO* of called line to negative battery. The latter will pull up and clear the called line.

The wiper-closing relay will now energize, lock itself to the release relay ground, open the rotary magnet and the busy-relay circuits, ground the private *P*-2, and connect the line wipers to the ringing current supplies through the contacts of the ring cut-off relay.

Ringing current now flows from the generator through a resistance lamp, the 200-ohm winding of the ring cut-off relay, a back contact on the same relay, through the negative wiper $-W$ to the line, through the bell and condenser in the telephone back over the positive line to ground at the ring cut-off relay. A little current passes through the 0.04 *MF* condenser to the calling line to indicate that ringing is being done.

When the called station answers, the ring cut-off relay operates and locks itself to the release relay ground, and switches the lines from the generator to the calling subscriber lines and the back-bridge relay *BBR*. The latter supplies direct current to the called station, reverses the current flow to the calling subscriber line, and prepares a circuit for supervisory signal No. 2 (*S*-2).

This switch is arranged to release when the last party hangs up. The details need not be repeated here.

If a few lines are busy, the special features of the switch are revealed. Assume that the second series of impulses has just ceased and that the rotary series relay *RSe* is about to let go. At this time the busy relay *ByRy* will be energized, because there is a ground on *P*-2 and the rotary series relay is holding the busy relay onto that wiper. Since the busy relay is energized, the rotary-interrupter relay *RIR* circuit is prepared and the initial circuit of the rotary magnet is opened.

When the rotary-series relay falls back, it switches the busy relay onto the release trunk, where it locks itself. The rotary-series relay also closes the circuit of the rotary-interrupter relay to the wiper *P*-1.

We now have three circuits mutually interconnected. The series relay *Se* and the rotary-interrupter relay *RIR* are in one circuit to *P*-1 and are affected by the rotary magnet *RM* and the busy relay *ByRy*. The rotary magnet is in another circuit and is controlled by the rotary-interrupter relay. The busy relay is in still another circuit, locked through the series relay contacts.

As soon as the rotary series relay falls back, closing the *P*-1 circuit, the series relay and the rotary-interrupter relay pull up. The former transfers the busy-relay circuit from the release trunk to *P*-2, so that its continued energization depends upon busy lines. The latter pulls up the rotary magnet.

The rotary magnet rotates the wipers onto the next set of contacts. If they also are grounded, the busy relay will remain energized. Near the end of its stroke, the rotary magnet opens the *P*-1 circuit. The series relay holds on, but the rotary-interrupter relay falls back and opens the circuit of the rotary magnet. The latter falls back and closes the *P*-1 circuit so that the rotary-interrupter relay can test the line upon which the wipers are now resting.

In this way the rotary magnet and the rotary-interrupter relay play back and forth, driving the wipers over the group of line contacts.

As soon as an idle line is found, both *P*-1 and *P*-2 will fail to find ground. The busy relay will release. The rotary-interrupter relay will not be able to pull up. The rotation stops.

Now the series relay, failing to get pulsations, falls back and grounds the *P*-2 circuit through the 125-ohm winding of the wiper-closing relay. The latter now pulls up and seizes the called line as was described.

If all the lines in the group are busy, the rotation will continue until the wipers are resting on the last set of bank contacts. Here the *P*-1 wiper finds no ground but the *P*-2 wiper rests on ground. The rotary-interrupter relay will not pull up, so that the rotary magnet can not get a circuit and the rotation stops. But since *P*-2 is grounded, the busy relay will be energized. When the series relay falls back, it transfers the busy-relay locking circuit to the release trunk.

In this condition the wiper-closing relay can not operate and the busy tone is connected to the line.

When the calling subscriber hangs up under this condition, further rotation is prevented by the busy relay, which holds the rotary magnet circuit open.

**One-Digit Group Connector.**—If the number of subscriber lines in a group is greater than ten, more than one level must be set aside as one group. The one-digit group connector (Fig. 85) enables this to be done.

The bank has a vertical part which is attached to the regular bank at the right side. There is a vertical wiper *VW* attached to the wiper shaft in such a way that it will wipe over the contacts of the vertical bank, but when the shaft starts to rotate, the vertical wiper will swing away from the vertical bank.

This switch requires only one digit to operate it. This one group of impulses lifts the shaft to the desired level, after which the operation is taken out of the subscriber's hands. The switch tests the level at which the group of impulses delivered it. If the level has one or more lines free, the switch will rotate and find one. If all lines on that level are busy, the vertical wiper will discover it and cause the switch to lift the wipers to the next level where the test is repeated. In this way an idle level and an idle line are found. If all lines are busy, the wipers rotate off the bank at the top level of the group, close springs 11-*R*, and give the busy tone.

Attached to each private contact in a group of lines is a busy relay known as a horizontal-chain relay. Their contacts are connected in series, so that when all the lines of the level are busy, they cause the energization of the corresponding vertical-chain relay. The vertical-chain relay grounds the vertical-bank contact which corresponds to the level which is busy and on which the vertical wiper rests when the line wipers stand opposite that level.

The vertical wiper *VW* is connected to negative battery through the 500-ohm winding of the vertical relay *VRy*. This is the vertical testing circuit.

When the switch is seized, the line relay *LR* pulls up and energizes the release relay *RlRy*. The latter grounds the release trunk, prepares

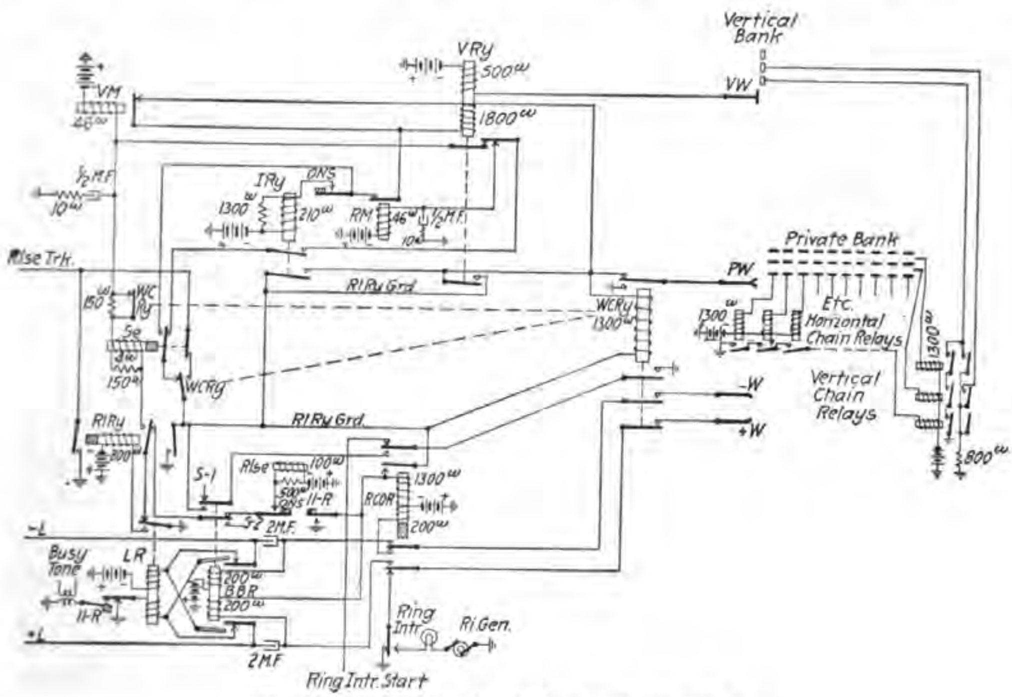



FIG. 85.—Circuit of 1-digit group connector.

the circuit for the vertical magnet, and grounds a wire known as the "release-relay ground" *RlRyGrd*.

While the subscriber is letting the dial rotate back on the digit, the line relay vibrates and sends impulses to the vertical magnet through the series relay *Se*. The former lifts the shaft, operating the off-normal springs *ONS* The series relay connects the interrupter relay *IRy* to earth as follows: through off-normal springs *ONS*, front contact of series relay, back contact of wiper-closing relay *WCRy*, to release relay ground *RlRyGrd*. The interrupter relay pulls up, short circuiting the 1300-ohm winding of the wiper-closing relay and preparing a circuit for the rotary magnet.

During the vertical motion, the vertical wiper *VW* has been wiping over the vertical bank. Whenever it found a ground, *VRy* pulled up, when it found no ground it fell back. Its condition at the time of stopping depends upon the condition of the level. Assume the latter to be busy, and the vertical contact grounded. The vertical relay therefore is energized. It assists the interrupter relay in short circuiting the 1300-ohm winding of the wiper-closing relay but diverts the circuit prepared for the rotary magnet to the vertical magnet.

At the end of the series of impulses on the line relay, the series relay falls back, switching the release relay ground to the circuit prepared by the interrupter relay and the vertical relay. This circuit runs as follows: release-relay ground, back contact of wiper-closing relay, back-contact series relay, front-contact interrupter relay, front-contact vertical relay, vertical magnet *VM*, to negative battery. The interrupter relay now is held energized through *ONS*, back-contact *RM*, back-contact *VM*, front-contact *IRy* to release-relay ground.

The vertical magnet now pulls up and lifts the shaft to the next level, which the vertical relay tests. Assume that a number of the levels are busy, so that we may get the action of the apparatus. If the level now tested is busy, the vertical relay will remain energized, so that the 1300-ohm winding of the wiper-closing relay will be short-circuited regardless of the interrupter relay.

Near the end of its stroke, the vertical magnet inserts 1800 ohms into the circuit of the interrupter relay. The latter falls back, opening the circuit of the vertical magnet. Then the vertical magnet falls back and closes the circuit of the interrupter relay. As long as the vertical wiper finds ground and the vertical relay therefore remains energized, this mutual vibration of vertical magnet and interrupter relay continues. The short pulsations through the 1800-ohm winding of the vertical relay keep it energized and prevent premature rotation.

When an idle level is found, the vertical relay's 500-ohm winding ceases to pull. Near the end of the vertical-magnet stroke which brings the wipers to this level, the vertical magnet takes the short circuit off the 1800-ohm winding of the vertical relay. The interrupter relay falls back and causes the vertical magnet to do the same.

The 1800-ohm winding of the vertical relay holds it energized a little longer than it would otherwise be. On the release of the vertical magnet the interrupter relay pulls up. The vertical relay now releases, switching the circuit from the vertical magnet to the rotary magnet *RM*. The latter at once rotates the wipers onto the first set of contacts in the level. The private wiper tests the private contact for ground.

Assume that the first few lines are busy. The private wiper then rests on ground, so that the wiper-closing relay cannot act. The mutual vibration above described is now repeated, between the rotary magnet and the interrupter relay.

When the private wiper arrives at a free (ungrounded) contact, the interrupter relay will be unable to pull up because of the 1300-ohm winding of the wiper-closing relay. But the latter *WCRy* will energize and perform the following acts: Switch the private wiper from test circuit to ground, to make busy the called line and to operate its bridge cut-off relay *BCO* to clear the line of attachments, switch the release-relay ground *RlRyGrd* from the magnets to the release trunk, ground the ringing interrupter-start wire, insert 150 ohms into vertical-magnet circuit, and close line wipers to ringing current through the springs of the ring cut-off relay *RCOR*.

Ringing now takes place by means of current from the ringing generator *RiGen* through the 200-ohm winding of the ring cut-off relay and battery. The ring cut-off relay is slow acting and will not respond to alternating current of the lowest frequency used. It acts only with battery current. The ringing interrupter *RiIntr* which was started by the wiper-closing relay now alternately cuts the generator into and out of circuit. When the generator is out of circuit, the positive wiper $+W$ is connected directly to earth.

When the called station answers, the direct current drawn from battery through the telephone set operates the ring cut-off relay, which locks its 1300-ohm winding to the release-relay ground. At this time the release trunk and the release-relay ground are connected together. The same action of the ring cut-off relay furnishes ground for the back-bridge relay *BBR*, so that the called station will get battery current for talking.

When the back-bridge relay operates, it reverses the current which is flowing to the calling station, takes control of the release magnet circuit, and completes a ground connection on the release-relay ground *RlRYGrd* through contacts on the ring cut-off relay and the wiper-closing relay. At this time the combined release trunk and *RlRyGrd* have three grounds on them, two on the release relay (separate contacts) and one through the *WCRy*, *RCOR*, and *BBR*.

The action during conversation and release is as was described for Fig. 60. The connector will not be released until both parties have hung up their receivers. If the calling station hangs up first, the ground on the release trunk will be removed long enough for the selectors and lineswitches to release, then it will be replaced. This is accomplished by the series relay *Se* which pulls up momentarily between the release of the line relay and that of the release relay. The 150 ohms which was inserted by the wiper-closing relay prevents the vertical magnet from acting, but permits the series relay to energize for that purpose. By the time that the series relay has pulled up and fallen back, the selectors and lineswitches have released and the release relay of the connector has let go, It is now the *BBR*, *RCOR*, and *WCRy* that mutually hold each other and place a ground on the release trunk so as to busy the switch.

If the first level of the group has one idle line, there will be no ground on the first contact of the vertical bank. Therefore the vertical relay will not act again, and the rotary motion begins as soon as the series relay falls back.

If all lines of all levels are busy, the switch will run up to the top level and rotate past the tenth set of contacts and off the bank (position 11-*R*) where it will give the busy tone to the calling subscriber. This is done by leaving the vertical-bank contact for the top level of the group unattached to anything.

The set of springs marked "11-*R*" operates when the wiper shaft rotates off the tenth set of contacts of any level. One part of the set grounds the 1300-ohm winding of the ring cut-off relay to cause it to pull up and lock, the other part switches busy tone into the positive winding of the line relay, by which device the calling subscriber hears the tone.

CHAPTER IV

## TRUNKING, ITS PHYSICAL ARRANGEMENTS AND VARIATIONS

Automatic apparatus may be mounted and installed in a variety of ways. A number of combinations have been used during the past

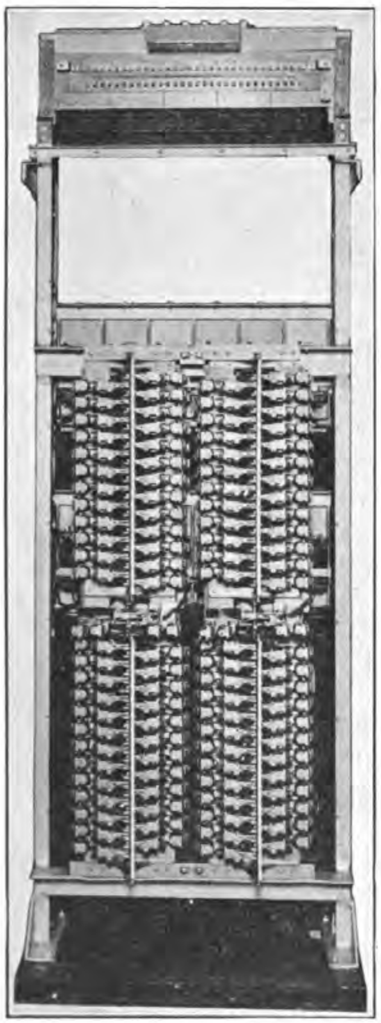


FIG. 86.—One-hundred-line switchboard, Keith lineswitches (front).

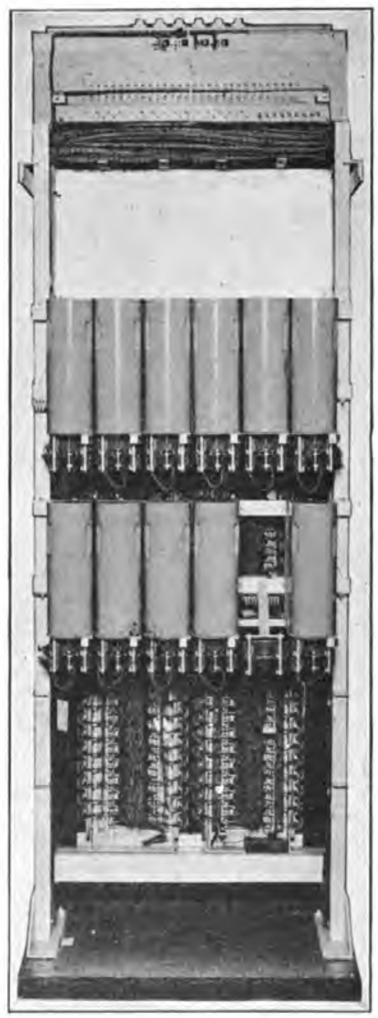


FIG. 87.—One-hundred-line switchboard, Keith lineswitches (back).

twenty-seven years and new arrangements are still being considered. Each has its own advantages, and an engineer can lay out a system with the assurance that the equipment can be moulded in such a way as fully to meet the needs of conditions. Flexibility is characteristic of automatic apparatus.

It is the purpose of this chapter to show the most approved ways of mounting automatic switches on frames for installation, to give an idea of how the switches are linked together in practice, and to illustrate the flexibilities in trunking arrangements.

**Lineswitches and Connectors.**—The prevailing practice is to mount lineswitches on one side of a frame, with the connectors on the other side. (See Fig. 86.) The Keith lineswitches here shown are in four

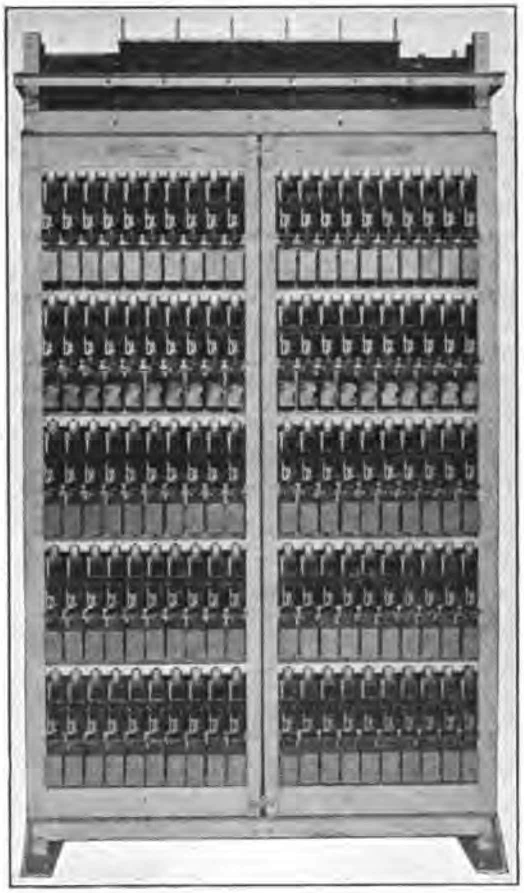


FIG. 88.—One-hundred-line switchboard, rotary lineswitches (front).

groups of 25 switches per group. The two at the left (50 lines) are mounted on one shelf, which is hinged at the left. It may be swung out to give access to the wiring on its back. The right shelf carrying fifty lineswitches is hinged at the right so as to swing out also.

As shown there is one master switch for each shelf of 50 lineswitches. Hence these 50 lines trunk into ten trunks. Such an association is called a "section." If the traffic is light, all of the hundred lineswitches may trunk into the same ten trunks, be governed by one master switch, and be termed one section. If the traffic is heavy, each shelf may be provided with two master switches, one for each 25 lineswitches. In this case 25 lines with their master switch constitute a section.

At the very top of the frame is a small powerboard, with bus bars for the battery, and fuses to protect the apparatus and wiring.

Just below the power panel is the terminal assembly. Here are a number of strips each containing 100 terminals, to which are connected the various pieces of apparatus. It is the meeting point for circuits, useful for interconnections and testings.

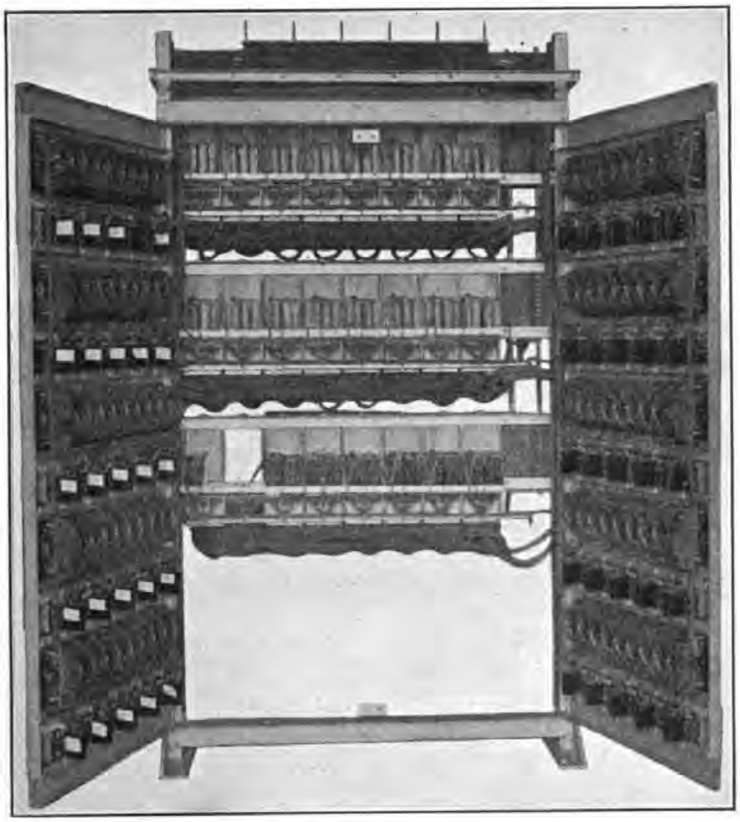


FIG. 89.—One-hundred-line switchboard, rotary lineswitches (front open).

On the back of the frame (Fig. 87) are the connectors which carry traffic into the 100-line group. Four shelves are provided, so that any number of connectors may be installed up to 24. Whenever a connector is removed, its bank is left behind, together with its bank rods. If the removal is to last for some time, or banks are installed without switches, the bank is held by a support which is bolted onto the connector shelf.

A 100-line switchboard with rotary lineswitches (Fig. 88) is also arranged with two shelves. Each shelf has 50 lineswitches arranged in five horizontal rows. The line relay and the cut-off relay of each switch is protected by a cover to keep out the dust. The second row is shown with the covers removed.

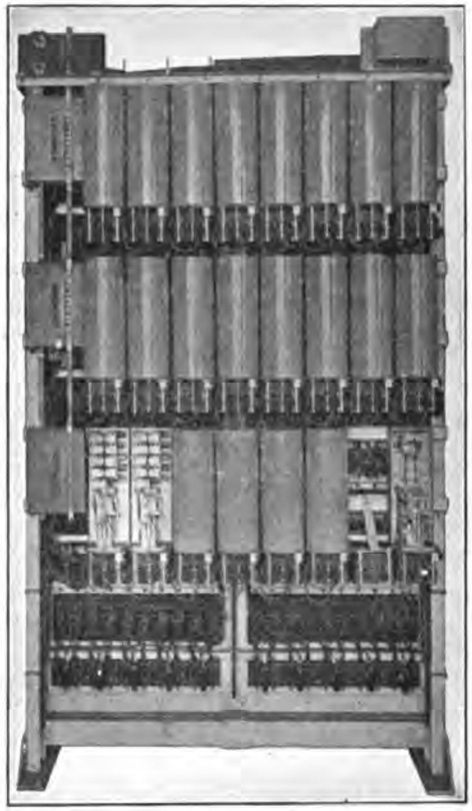


FIG. 90.—One-hundred-line switchboard, rotary lineswitches (back).

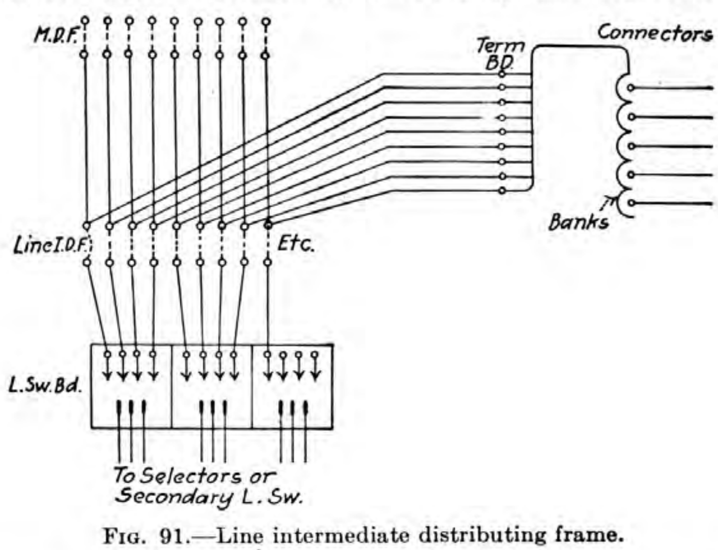



FIG. 91.—Line intermediate distributing frame.

The two shelves are hinged to swing outwardly. (Fig. 89.) This exposes the wiring and the condensers of the connectors. At the top is the terminal assembly.

The back of the frame (Fig. 90) supports the connectors on three shelves of eight switches each. Three of the connectors have their covers removed. The one at the extreme right of the bottom shelf is a test connector, used by a tester at the wire chief's desk. One connector is not installed, the bank being held by a support.

At the left are three little fuse panels, one for each shelf. There is one fuse per connector. At the top is another fuse panel with one fuse for each ten lineswitches.

FIG. 92.—Connector trunk shelf (front).

**Lineswitches and Connectors Separate.**—In recent years some installations have been made in which the lineswitches have been treated as separate from the connectors. Each line is connected permanently to the assigned place on the connector banks, corresponding to the call number. This is for outgoing calls and will not be changed as long as the call number remains constant. In addition the subscriber line is connected to a lineswitch This is for incoming calls to the central office and requires only that sufficient trunking facilities be provided. The grouping may be

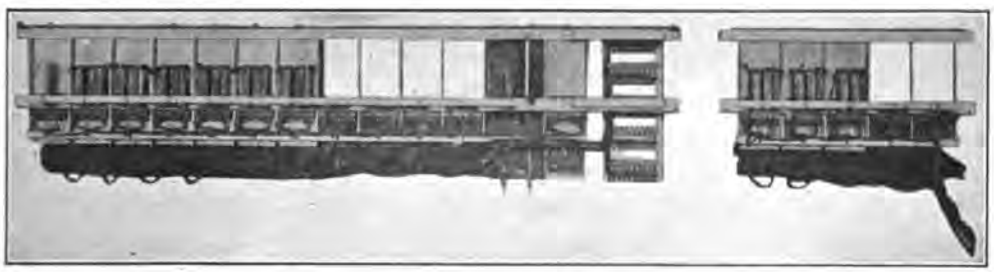


FIG. 93.—Connector trunk shelf (back).

larger than 100 lines. An intermediate distributing frame is provided between the lines and the lineswitches, so that any line may be connected to any lineswitch. This is very much like manual practice in a multiple switchboard.

The general arrangement is shown in Fig. 91. The subscriber lines arrive on the vertical side of the main distributing frame *MDF* at the protectors. From the horizontal side of the frame the lines are cabled to the horizontal side of the line intermediate distributing frame (line

*IDF*) where cables run to the terminal assembly on the connector frame and thence to the connector banks.

On the line *IDF* the lines are cross connected to the vertical side where cables lead to the lineswitch board frames. From the banks of the lineswitches the trunks run to first selectors or to secondary lineswitches.

The lineswitches are mounted on the usual frames, but occupy both sides of them. The connectors are mounted on shelves much like selector shelves. (Fig. 92.) There is, however, a short shelf carrying five switches, joined to the long one (ten switches) making fifteen switches in all. The bank terminal boards, fuses, and relays are between. The

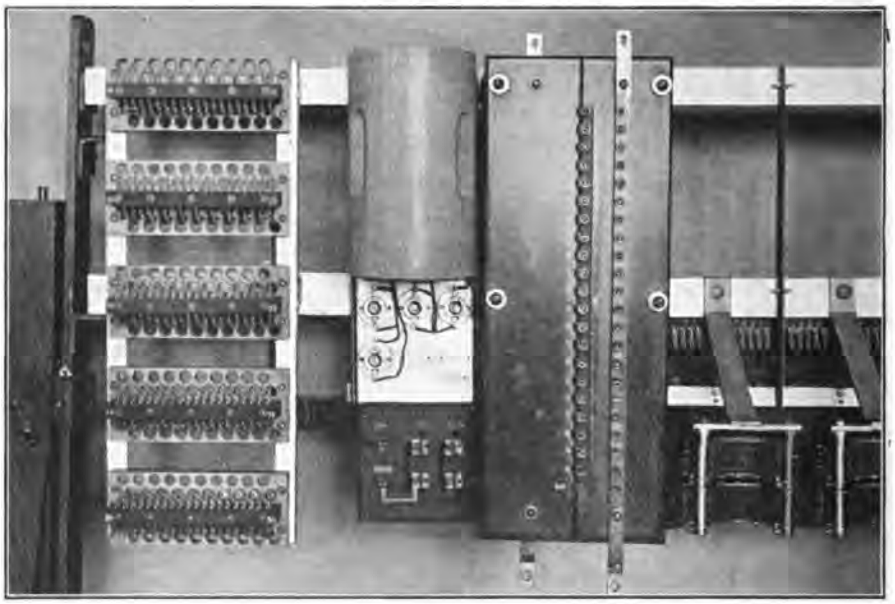


Fig. 94.—Connector trunk shelf, power panel and bank terminals.

back side (Fig. 93) carries the condensers. Five or six shelves are built into a frame. The battery bus bars are connected vertically. An enlarged view of the bank terminal boards, fuses and relays is shown in Fig. 94.

**Local Secondary Lineswitches.**—Local secondary lineswitches are mounted on frames like those used for the primary lineswitches, both sides of the frame being occupied by switches. (Fig. 95.)

Between the primary lineswitches and the secondaries is an intermediate distributing frame (primary *IDF*) on which are made the interconnections necessary to scatter the traffic, as described in Chapter 2.

Between the secondary lineswitches and the first selectors is another frame (secondary *IDF*) (Fig. 96) for the purpose of distributing the traffic among the sections. The general plan is shown by the figure.

The secondary lineswitches are divided into groups (Fig. 97) and the first selectors into bays. The secondary *IDF* accomplishes the distribution of traffic shown on the drawing. In a full sized installation, there are ten sections of secondary lineswitches in each group. Since each section has ten outgoing trunks, the group has 100 trunks. There are ten sections of first selectors (lettered *A* to *J*) in each bay. Since there are ten selectors in a section, the bay has 100 first selectors.

The distribution provides ten trunks from each secondary lineswitch group into each bay of selectors. Within a given group each section delivers all of its ten trunks to a given selector bay. Thus all the sections numbered "1" trunk to bay No. 1, all the sections numbered "2" trunk

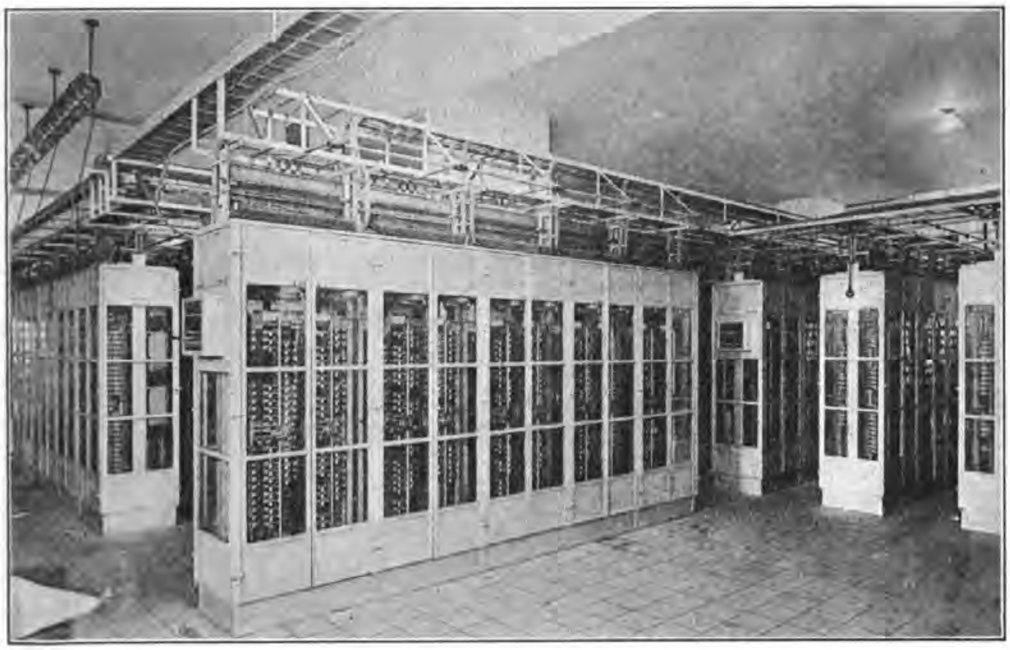


Fig. 95.—Secondary lineswitches installed.

to bay No. 2, etc. Within the section of lineswitches the ten trunks are distributed to all the selector sections in the given bay. Thus the first trunk goes to a selector in section A, the second trunk to a selector in section B, etc.

The above method secures an effective scattering of the traffic among all the trunks which leave the banks of 1000 first selectors, although each group of lineswitches is connected to only 100 first selectors.

**Selectors.**—Selectors are mounted on fixed shelves, each of which holds 20 switches. Fig. 98 shows a view of mounted selectors. Five or six shelves are mounted on one frame known as a "bay." Two bays make up a "selector board." Three such boards are shown in the illustration.

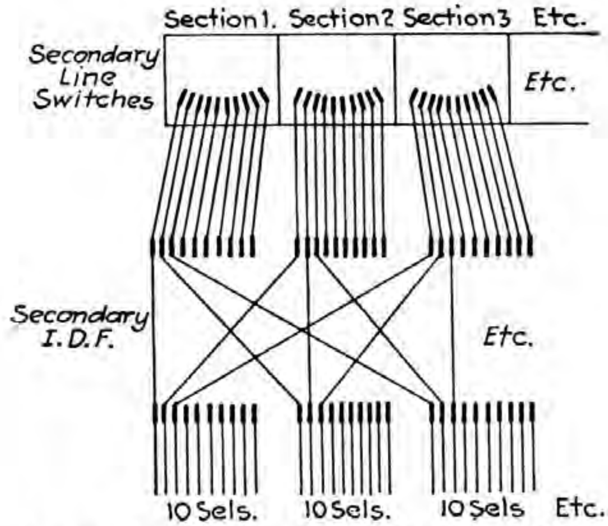
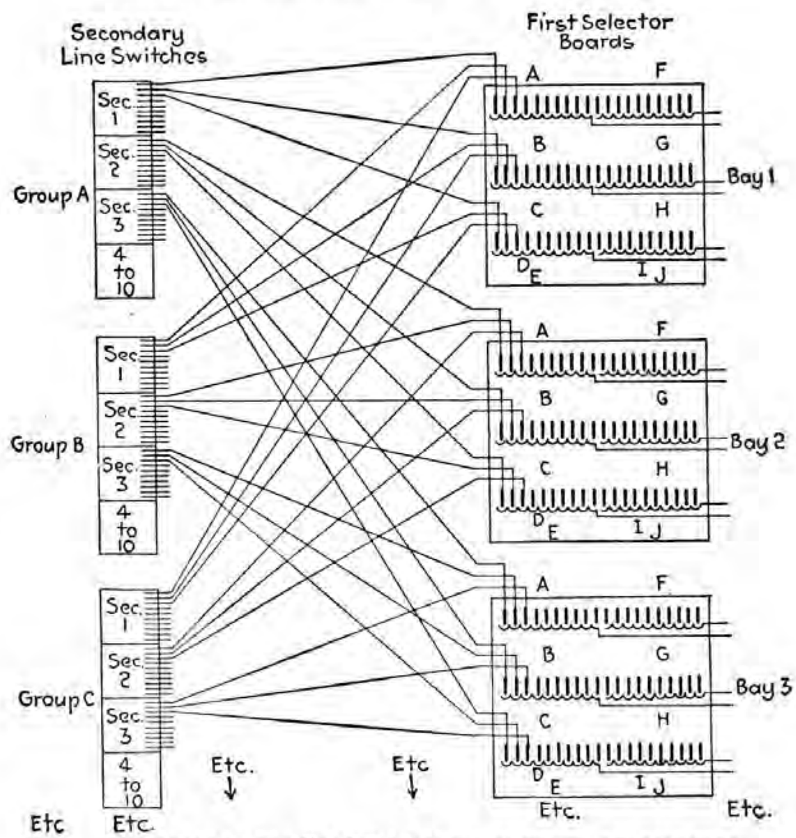



Fig. 96.—Secondary intermediate distributing frame.




*There are as many first Selector bays as groups of Secondary Lineswitches. Each Lineswitch Section spreads its trunks over the sections of only one Selector Board. All L.Sw. Sections 1 to Bay 1. All L.Sw. Sections 2 to Bay 2; etc. Each Selector Bay receives trunks from all L.Sw. groups. Each Selector Section receives trunks from particular L.Sw. Bank Contacts. A-from-1, B-from-2, Etc.*

Fig. 97.—Trunking secondary lineswitches to first selectors.

The end of the board nearest the reader contains the terminal assembly, covered by two doors. This is a very interesting and valuable part for by means of it all the trunking flexibilities are worked out, and a study of it will unlock the plan by which any office or exchange is linked together.

The other end of the selector board (Fig. 99) contains a doorway to give access to the interior of the board, and the fuses, lamps and relays used for supervisory purposes.

The plan of the board (Fig. 100) shows the relations more clearly. The names of the two bays (high and low) were derived from their

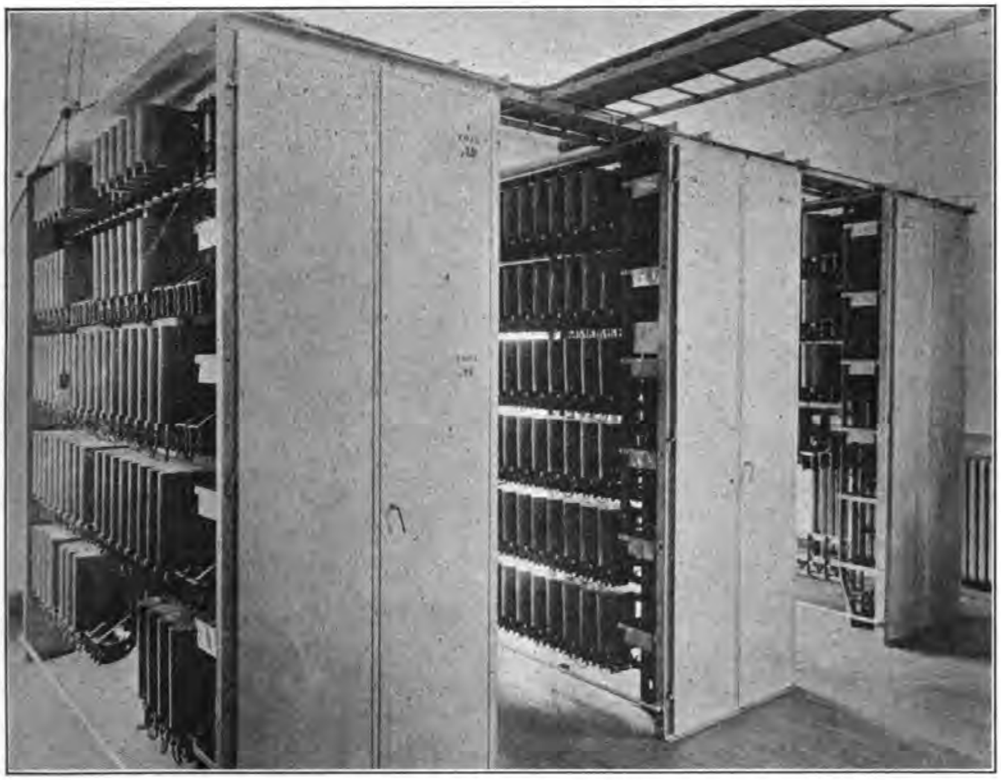


Fig. 98.—Selectors installed.

proximity to the ends of the terminal assembly. The strips in the latter are numbered from left to right. Hence, one bay adjoins the low numbered end of all strips, while the other is near the high numbered ends. It is now customary to number all the bays or frames in a straight row regardless of boards, and to identify them by those numbers.

A development of the selector board (Fig. 101) shows how the selector banks are wired to the strips of terminals. Usually the "*A* high" section and the "*A* low" section have their banks wired to the same terminal supports. Sometimes the *A* and the *F* sections on the high side have their banks together.

**Terminal Assembly for Selectors.**—The banks of the ten selectors of a section are multipled together and cabled to sets of terminal strips. (Fig. 102.) The 100 wires from the private banks are fanned out as shown above in the illustration. One strip holds all of them. The 100 pairs of wires from the line banks require two terminal strips of 100 points each. The pairs from the even numbered levels are wired to one strip and those from the odd numbered strips to the other strip, as shown in the lower part of the figure. The cause of this particular separation is purely historical. The old switches had two separate line banks.

In order for the proper connections to be made, these three strips are mounted on three separate supports, one above the other. The usual

Fig. 99.—Power end of selector board.

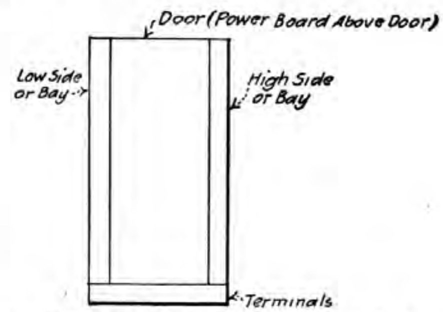



Fig. 100.—Plan of selector board.

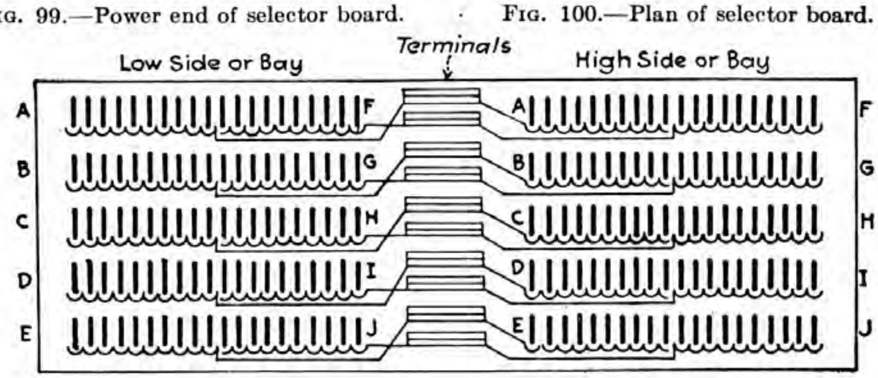



Fig. 101.—Development of selector board.

order from the top downward is private, even level lines, odd level lines. If the *A* high and *A* low sections are to be multipled together, there will be the two private strips on the first support, the two even level line strips on the second support, and the two odd level line strips on the third support.

The arrangement is illustrated in Fig. 103, using condensed symbols for the terminal strips. In this case, the *A* and *F* sections are multipled.

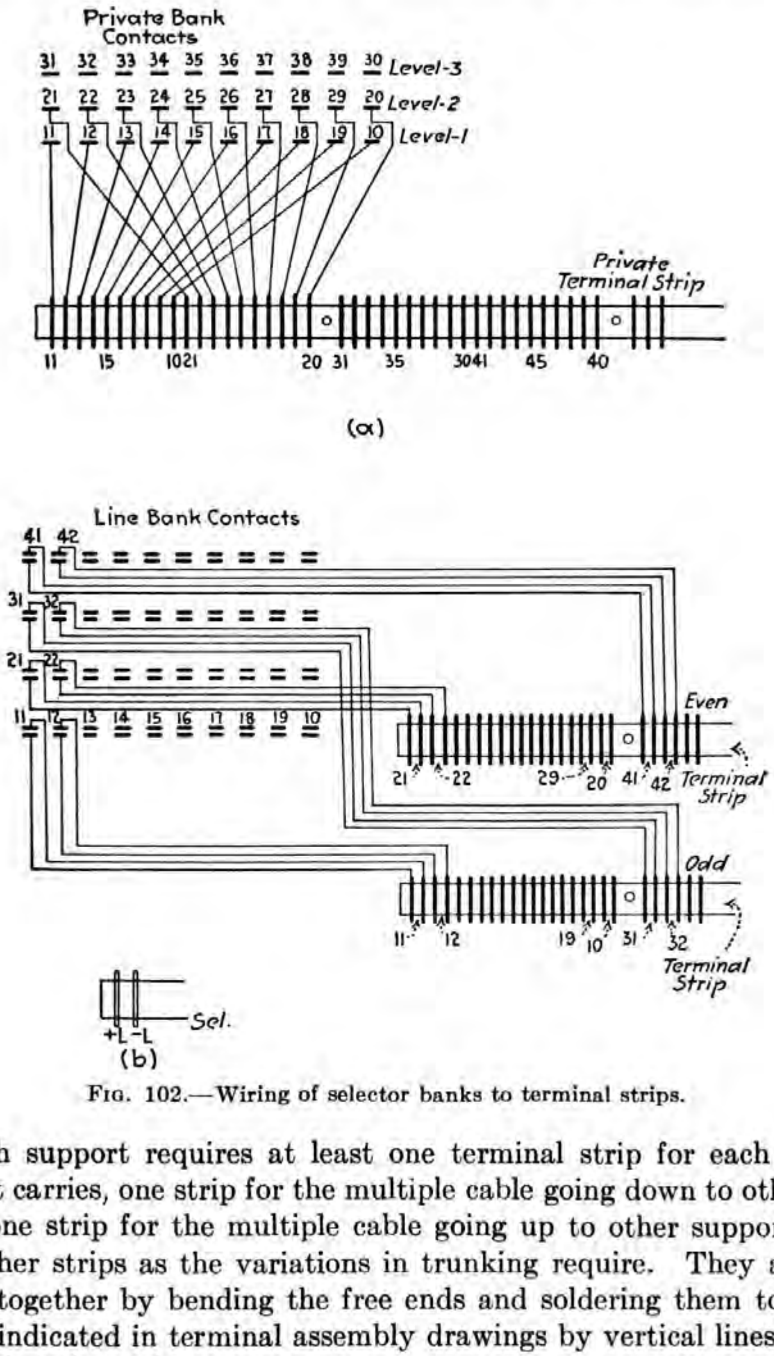



FIG. 102.—Wiring of selector banks to terminal strips.

Each support requires at least one terminal strip for each section which it carries, one strip for the multiple cable going down to other supports, one strip for the multiple cable going up to other supports, and such other strips as the variations in trunking require. They are connected together by bending the free ends and soldering them together. This is indicated in terminal assembly drawings by vertical lines joining the symbols for strips.

This illustration is based on a multi-office system. This office is No. 4. The first three levels are trunked out to offices 1, 2, and 3, respectively. The *A* and *F* sections of the high bay occupy supports 1, 2 and 3. Sections *A* and *F* low occupy supports 4, 5, and 6. Logically, sections *B* and *G* high will take supports 7, 8, and 9 and sections *B* and *G* low will take supports 10, 11 and 12.

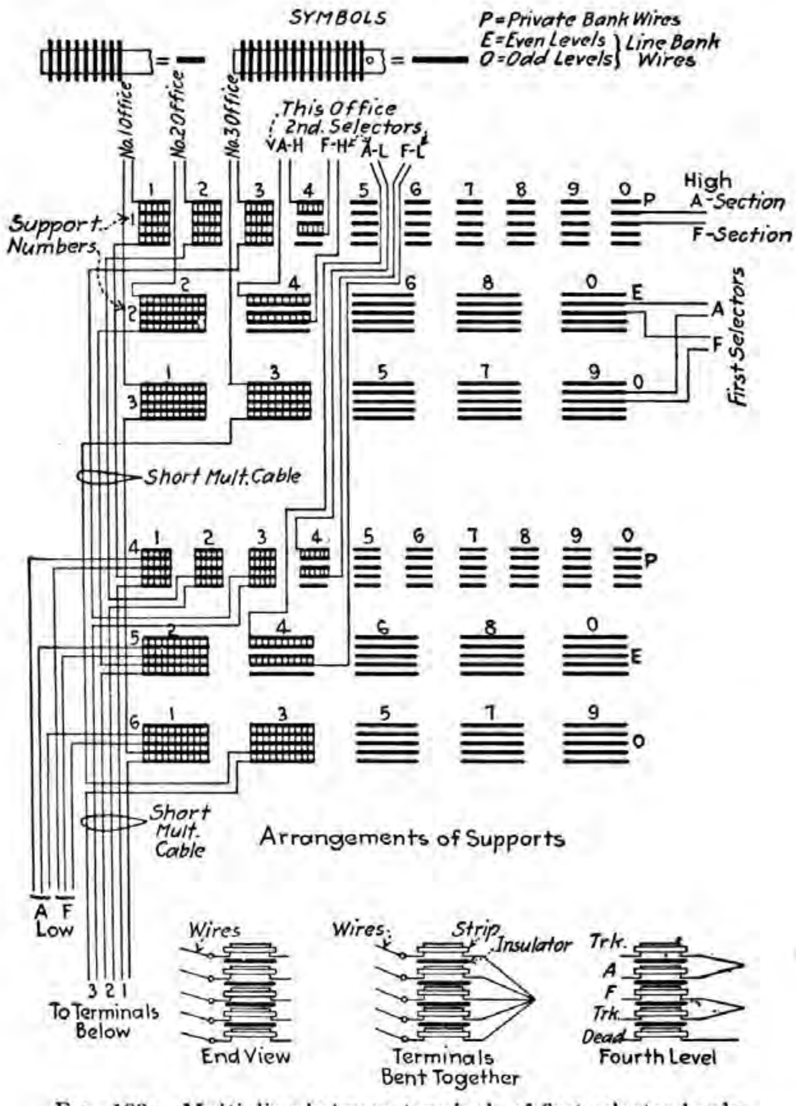



FIG. 103.—Multipling between terminals of first-selector banks.

The first three levels are multipled to all the sections which are shown here. This is because the outgoing traffic is light enough to warrant this grouping. The fourth level is local; it carries traffic between subscribers in this office. Accordingly, more trunks are provided by giving each section or group of sections its own group of ten trunks.

The above is accomplished by bending the free ends of the terminals. See support No. 1, strip for *A* high, level 4 These terminals are bent up and soldered to the terminals of trunks to a section of second selectors. The terminals for the *F* high selectors are bent down and soldered to trunks leading to another section of second selectors. This takes care of the private banks.

The line terminals on the second support are treated in the same way as the private terminals. In every case the privates and the lines are connected alike. Supports 4 and 5 reveal the same method for sections *A* and *F* low.

A wide variety of trunk connections can be effected by proper combinations of vertical connections in the terminal assembly.

**Trunk Symbols.**—The present symbol for selectors developed out of an older symbol which suggested the apparatus more nearly than does the present one. (Fig. 104.) Ten trunks arrive from the left and pass

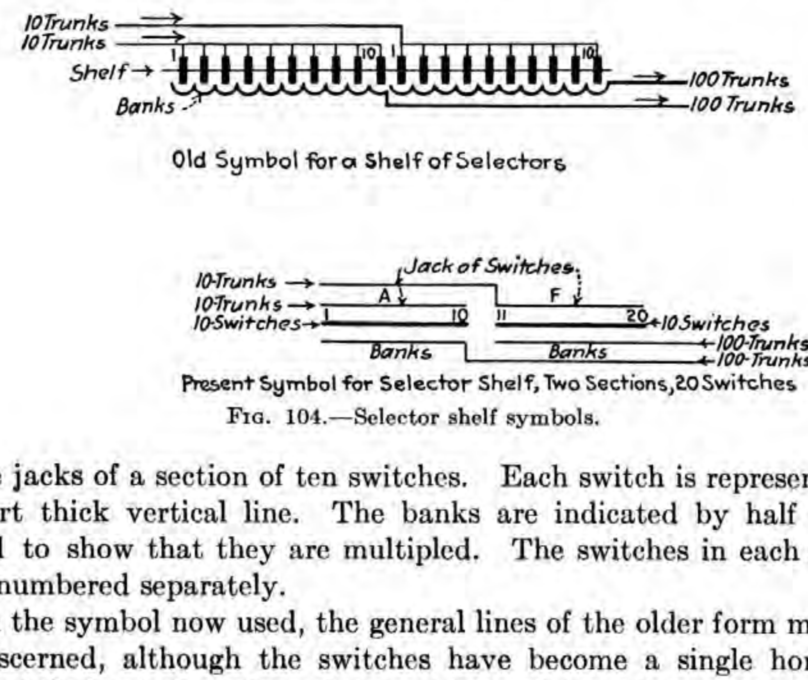



FIG. 104.—Selector shelf symbols.

to the jacks of a section of ten switches. Each switch is represented by a short thick vertical line. The banks are indicated by half circles, joined to show that they are multipled. The switches in each section were numbered separately.

In the symbol now used, the general lines of the older form may still be discerned, although the switches have become a single horizontal line and the banks have been flattened into a thinner line. It is now customary to number the switches of a frame consecutively from 1 to 100, beginning with the left hand switch on the top shelf and proceeding from left to right and from top to bottom.

The terminal assembly for bank cables which was shown in more or less detail in Figs. 102 and 103 is necessarily compressed into that shown in Fig. 105. The sample chosen carries the two *A* sections of one selector board, with short-multiple cable running down, long-multiple cable running to another board, and some of the trunk cables which lead directly to second selectors (second level to second thousand, third level to third thousand, ninth level to special selectors, and tenth level to long distance). There may be trunks running from other levels. If so, they are connected to the terminals on some other board, which is reached by the long multiple. This sample is supports 1, 2, and 3, the topmost supports, which accounts for the above mentioned trunk cables.

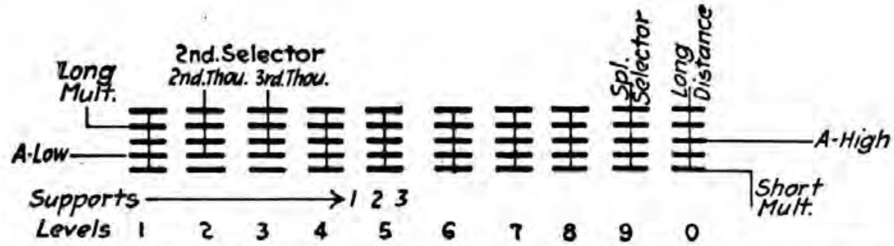



FIG. 105.—Terminal assembly, three supports, ten levels, symbolized by private alone.

Although the symbol of Fig. 105 seemingly provides for only one set of wires (the privates, for example) the same arrangement must be understood as applying to the line bank wires as well. A full expansion is shown in Fig. 106. All the levels, except two and three, are multipled together everywhere. Levels two and three are cut off from the short or up and down multiple. It means that on each of these two levels the

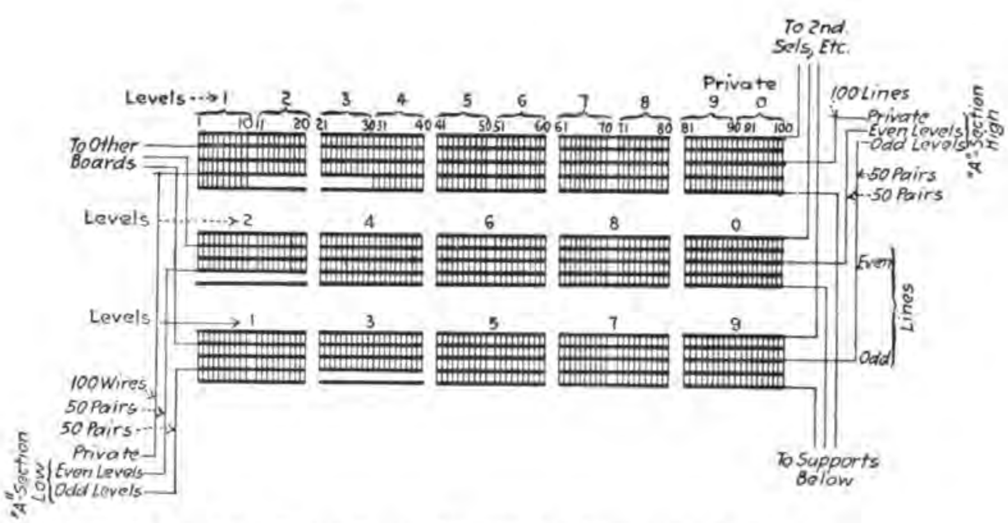



FIG. 106.—Expansion of Fig. 105 showing separate terminals.

two *A* sections have one group of ten trunks leading to second selectors.

Part of the ways in which terminals are soldered together have been reduced to definite symbols, which may be recognized wherever seen. Others occur not very often or are somewhat complicated so that their symbols are not clear or recourse is had to special notes and drawings.

Those which are most common are shown in Fig. 107, together with an example of one which is too complicated to receive a clear treatment without a detail sheet.

At *A* is a terminal assembly with some of the symbols as they appear on the drawing.

At *B* are three forms of the symbol for all ten trunks soldered through on all strips.

*C* shows two symbols for the attachment of a cable to the top strip, with all trunks connected.

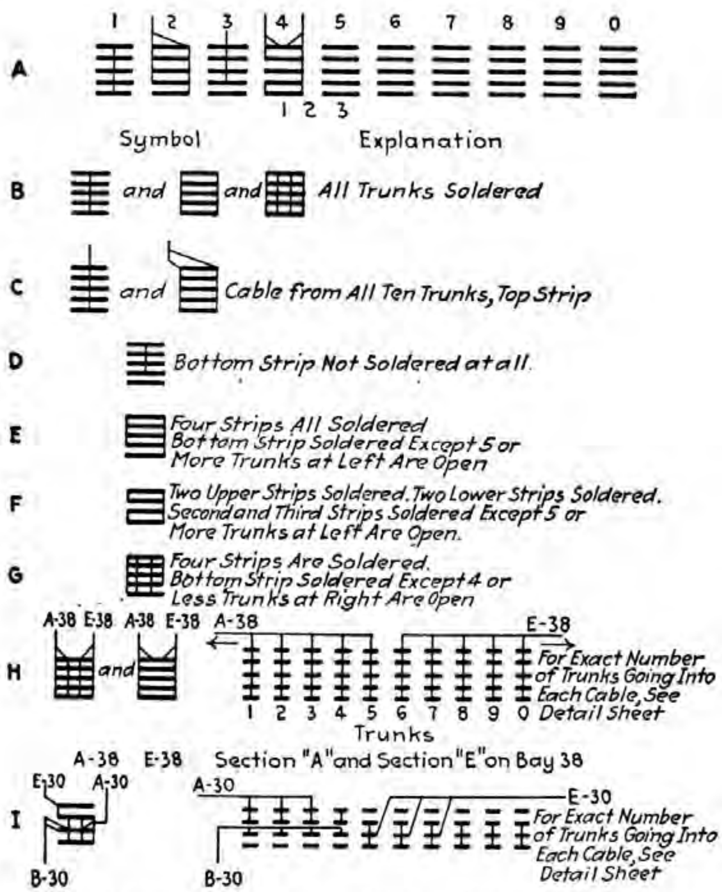



FIG. 107.—Symbols used for terminal assembly solderings.

*D* shows the bottom strip not soldered at all.

*E* shows all trunks soldered except on the bottom strip, where the number of trunks left open must be indicated by figures, a foot note, or a detail sheet.

*F* shows a few trunks left open on an intermediate soldering, in this case between the second and third strips.

*G* indicates in general the same as *E*, except that *G* is used if the number of trunks left open is about one-third the total or less.

*H* shows the leading out of cable from two parts of a level of ten trunks, five trunks going into one cable and five into another.

At *I* is shown a case of terminal soldering which is hard to reduce to a simple symbol. Part of the trunks are left open and there are three cables leading out from different places. The best that the symbol can do is to induce the installer to look up the detail sheet for the case.

The destination of a cable is indicated by a letter and a number. The number is that of the bay and the letter is that of the section of switches to whose jacks the trunks run.

**Trunking Devices.**—The term "trunking devices" covers those arrangements and combinations of trunks which give automatic telephony much of its flexibility. The trunking devices here discussed have been tried out in the furnace of experience. Part of them have been originated

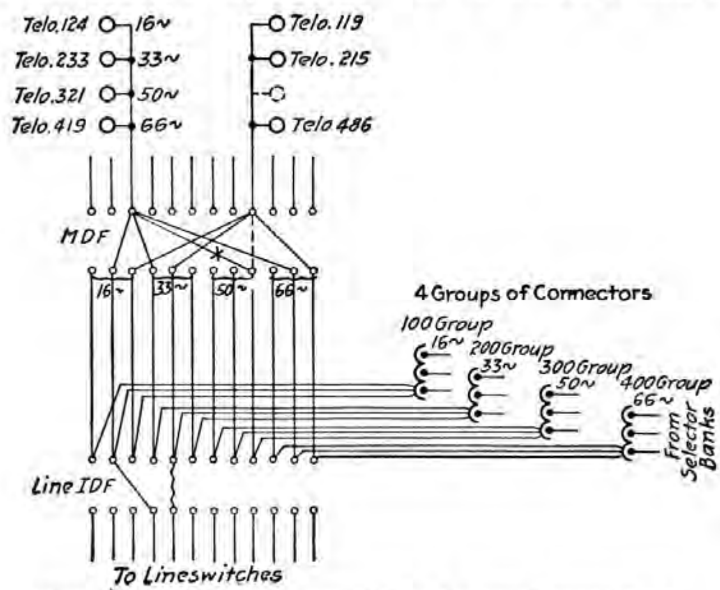



FIG. 108.—Party lines, line *IDF* and grouped connectors.

by the makers and part by the users of automatic exchanges. Usually, after describing a device, the way will be shown for carrying it into practice.

**Subscriber Lines and Line IDF.**—The use of the line *IDF* shown in Fig. 91 permits party lines to be handled very flexibly. Suppose that a four-party line is rung by four groups of connectors, each equipped to ring with a different frequency. (Fig. 108.) Let the 16-cycle connectors be in the group numbered "100," the 33-cycle connectors be in the group numbered "200," etc.

The party lines are connected to the line side of the *MDF* as usual. They are cross-connected to the switchboard side so as to reach the bank contacts of the groups necessary to get the frequency for ringing each bell on the line. For instance, telephone 124 is equipped with a 16-cycle bell. It is cross-connected to bank contact No. 24 in the 16-cycle group of connectors, numbered "100."

On the same party line is telephone 233. Hence the same line is cross-connected on the *MDF* to bank contact No. 33 in the 33-cycle group of connectors, numbered "200."

The rest of the jumpers are connected according to their needs as clearly shown. Lastly, a jumper on the line *IDF* connects one of the group of bank circuits of each party line to a lineswitch.

Suppose that subscriber 321 moves from his neighborhood to a region where he can easily be connected to another party line. Suppose that on a given line, like one shown in Fig. 108, the 50-cycle station is missing. Then subscriber 321 can have his telephone connected to this line without having his call number changed. The *MDF* jumper marked "*x*" will be removed from its old line terminal and connected as indicated by the dotted line. The dotted circle and line indicate the new location of the sub-station. In this way, although the station is on another line, it will be rung by the same group of connectors as rung it before the move. This flexibility extends even to cases in which all the digits of the call number are different.

**Divided Bank Wiring.**—Any 100-line board which handles more than 100 telephones is almost certain to require more than ten connectors. A board whose chief load is *P.B.X.* lines may have as many as 27 connectors.

There is also very often need for more than ten trunks to a *P.B.X.* This may be supplied by using the multi-level group connector. Or it may be met by dividing the bank wiring of the connectors, so that not all of them have access to the same group of trunks on a given level.

Suppose that level three is set aside for a certain *P.B.X.*, and that we have twenty connectors with the usual complete multiple. Then all of the connectors will hunt over the same ten trunks on that level.

If the need arises for more trunks to that *P.B.X.*, we can divide the multiple between the bank terminals of the tenth and the eleventh connectors. Connectors "1" to "10" still have the trunks on level 3 appearing at the same place and going to the *P.B.X.* Connectors "11" to "20" are provided with ten new trunks which run to the same *P.B.X.* Now, if a subscriber calling this *P.B.X.* gets a connector in the first group, lifting the wipers to level 3 will get him an idle trunk in one group of ten. But if he gets a connector in the other group, lifting the wipers to level 3 will get him an idle trunk in the other group of ten. Thus 20 trunks are available.

**Heavy Traffic from Keith Lineswitches.**—If ten trunks can not handle the traffic originated by 100 subscriber lines, the trunking can be increased by splitting the lines into two groups of 50 lines each. Each shelf of 50 lineswitches is then given a master switch and ten trunks, or seven or eight trunks if that many are sufficient.

Extreme cases have been known in which a reduction to sections of 25 has been used. But it is believed that the proper use of the line *IDF* to scatter the traffic will render this unnecessary.

In every case, the word "section" applies to a group of switches which are mounted adjacent to each other and trunk into the same group. In the case of lineswitches, the section comprises those which are governed by the same master switch.

| | BUSY HOUR CALLS | | | | | | | | | | | Total Daily Calls |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Connector Switches | | | | | | | | | | | |
| Day | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Total | |
| 20 | 59 | 45 | 34 | 27 | 13 | 5 | 4 | 4 | 0 | 0 | 191 | 1274 |
| 21 | 55 | 37 | 60 | 37 | 19 | 6 | 1 | 0 | 0 | 0 | 215 | 1229 |
| 22 | 66 | 68 | 63 | 40 | 23 | 15 | 5 | 0 | 0 | 0 | 280 | 1536 |
| 23 | 66 | 62 | 57 | 42 | 28 | 9 | 3 | 0 | 0 | 0 | 269 | 1453 |
| 24 | 57 | 48 | 48 | 32 | 15 | 3 | 0 | 0 | 0 | 0 | 203 | 1332 |
| 25 | 50 | 43 | 53 | 40 | 18 | 6 | 0 | 0 | 0 | 0 | 170 | 653 |

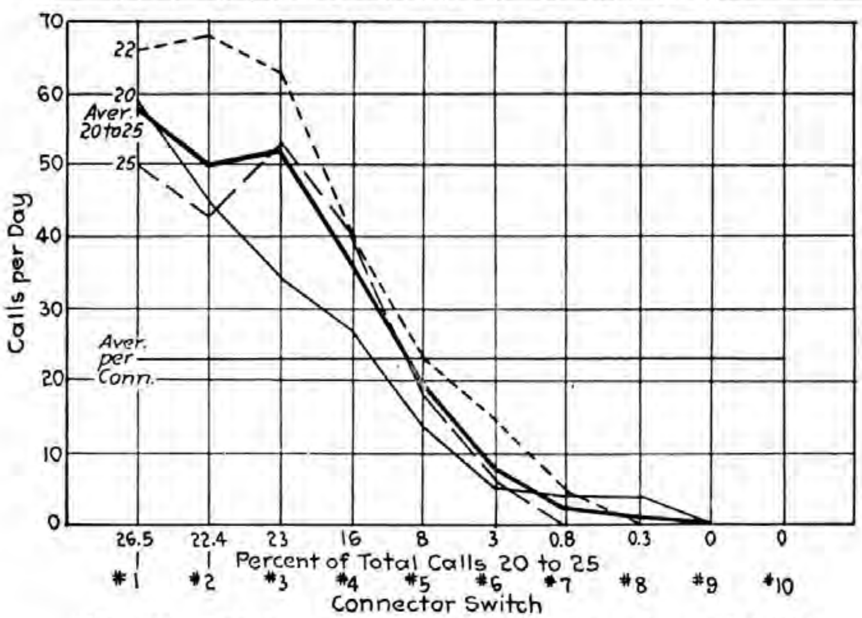



FIG. 109.—Telephone traffic, private automatic exchange *ELS*-133.

**Selectors and Trunk Slip.**—That method of bank multipling known as "bank slip" or "trunk 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 all the selectors which use the same ten trunks from a given level have their banks multipled point-for-point, all of them will have the same trunk as their first choice. This results in keeping the first few trunks exceedingly busy, and puts very little work on the last ones. This is shown by the traffic record of Fig. 109. The group of trunks and connectors whose traffic is shown was underloaded.

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. 110. 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. 111. 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. 112, 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. 112 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.

There are two places at which the trunk slip may be applied, in the bank wires (from bank to bank), or in the multiple cable which connects the different selector shelves together. The former is illustrated in Fig. 113. Let the four single selector levels, 1, 2, 3 and 4 at the top represent any given level in the ten selectors on shelf *A* in the first thousand (1000).

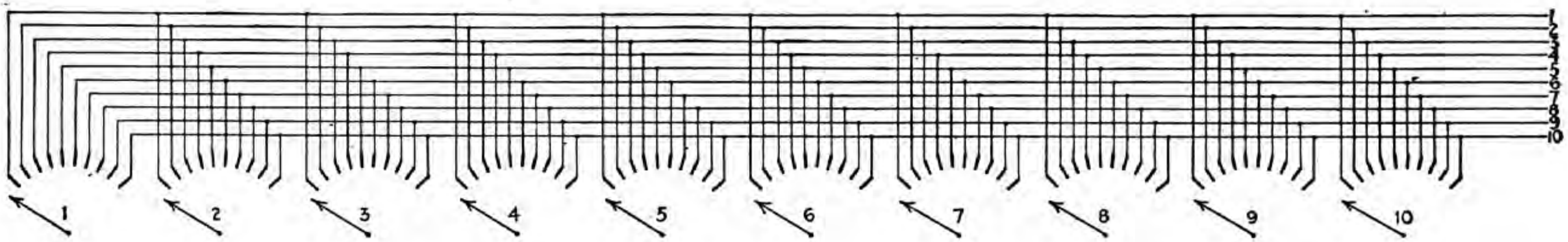



FIG. 110.

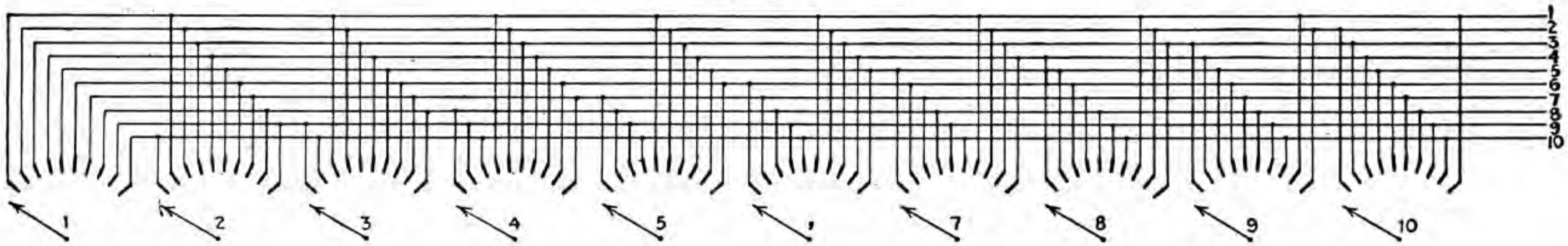



FIG. 111.

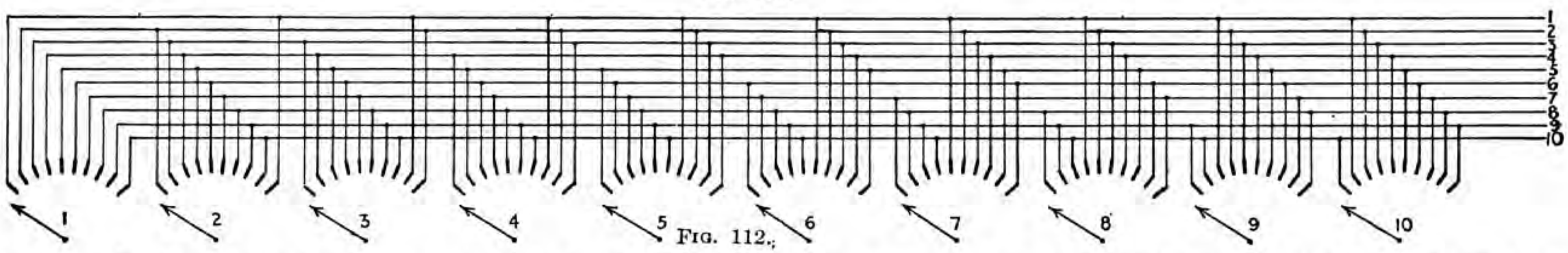



FIG. 112.

FIG. 110.—One level of selector banks, straight multiple. FIG. 111.—One level of selector banks, advancing bank slip. FIG. 112.—One level of selector banks, retrograde bank slip.

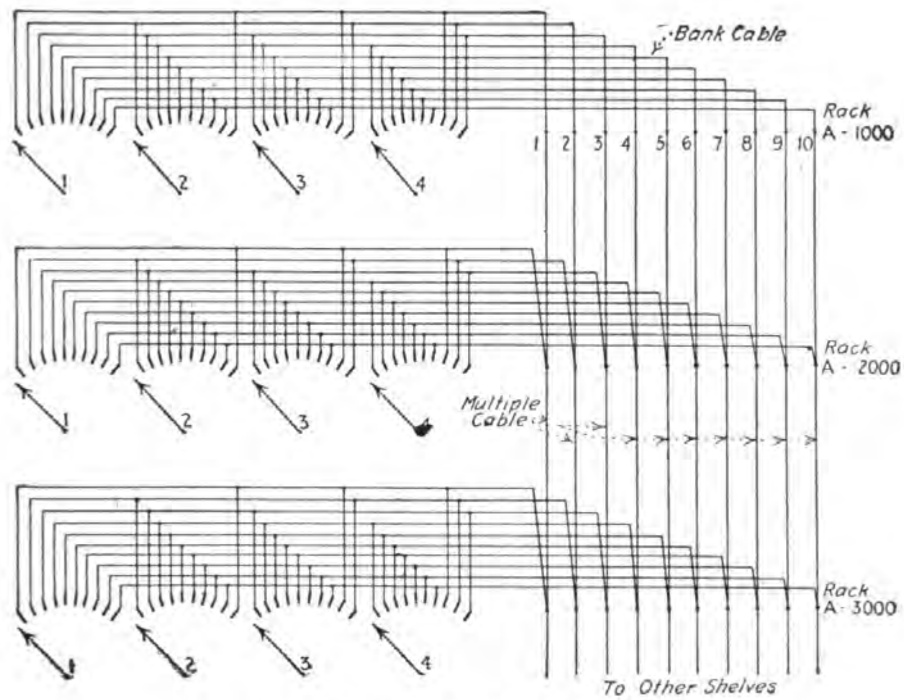



FIG. 113.—Trunk slip in bank wiring.

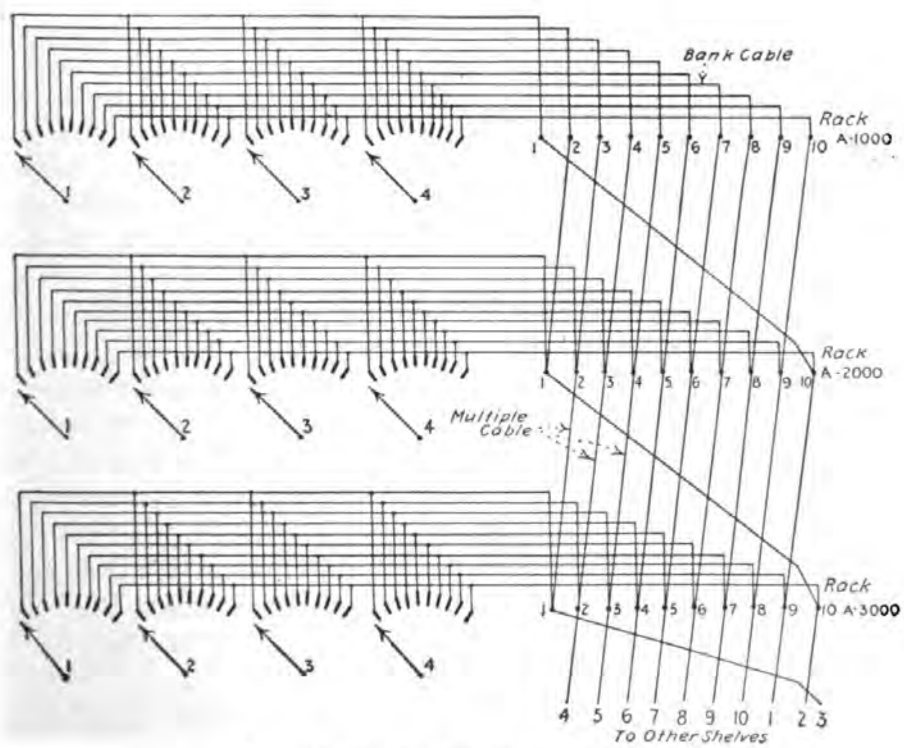



FIG. 114.—Trunk slip in multiple cable.

Below it are another four levels which similarly represent the ten switches of the "*A*" shelf of the second thousand (2000). The third thousand is also shown. At the right of each shelf is its connecting rack, to which the contacts are wired strictly in order, as they come from switch No. 1, contact No. 1 to terminal 1, contact 2 to terminal 2, etc. This is true of all the shelves.

Notice that the bank cable is slipped between the adjacent banks of the same shelf, while the multiple cable is run "straight," that is, from a terminal on one rack to the corresponding terminal on all the other racks. This causes switch No. 1 of all the shelves to have the same choice of trunks. Switches No. 2 of all the shelves also share their first choice with each other. In a complete layout of ten shelves thus multipled together, we would have ten switches whose first choice is trunk No. 1, ten whose first choice is trunk No. 2, etc.

The method of slipping the bank in the multiple cable is shown in Fig. 114. Each shelf is wired "straight" or "point for point" to the rack. But in connecting up the multiple cable, a backward slip is made, which accomplishes 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.

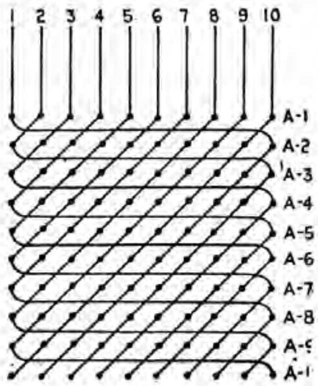



FIG. 115.—Symbol for trunk slip.

A very simple symbol for bank slip has been derived from Fig. 114. 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. 114 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. 115. 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 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.

Trunk slip is often applied by inserting in the terminal assembly a pair of "jumpered terminal strips." These two strips are wired together by jumpers which lie in the assembly. If a slip of one is desired, the wiring will be like that shown in Fig. 116. A slip of five (Fig. 117) is very common because of its usefulness.

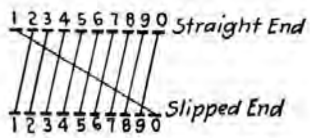



FIG. 116.—Wiring of jumpered terminal strips, slip 1.

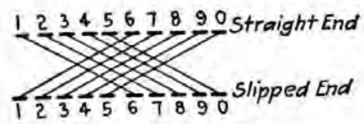



FIG. 117.—Wiring of jumpered terminal strips, slip 5.

The multiple cable between supports is either straight or slipped in the same way as jumpered terminals. Figure 118 shows the symbol and the meaning for straight cable, and Fig. 119 for a cable which is slipped one. This is frequently called the "short-multiple" cable, to distinguish it from the "long-multiple" cable which connects bays together.

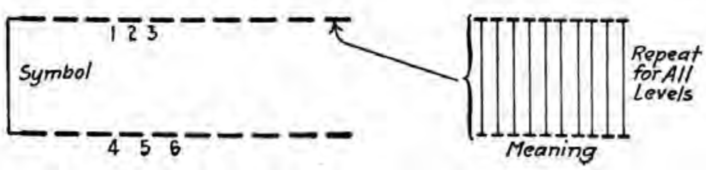



FIG. 118.—Multiple cable between supports.

A typical case of trunk slip is worked out in Fig. 120 showing how the terminals are actually handled to secure a given result. The slip which is desired is shown at the top of the figure. It is an orderly slip from section to section in alphabetical order. But the sections are grouped by twos on the supporting shelves. Sections $A$ and $F$ occupy the same shelf, $B$ and $G$ are together, etc.


FIG. 119.—Multiple cable between supports, slipped 1.

The terminal assembly to secure this slip is shown in the middle of the figure. The departing long-multiple cables are attached to the top strip of supports 1, 2, and 3. The next strip carries the bank cable rom section A. The next two are jumpered terminals with a slip of five. The free ends of these upper three strips are bent and soldered together as was shown in Fig. 103. This carries the banks of section $A$ straight out to the trunks.

The banks of section $F$ come in on the strip which is next to the bottom. The bottom strip carries the short-multiple cable. These lower three strips are soldered together.

Supports 4-5-6 have a similar arrangement beginning at the top. Sections $B$ and $G$ are brought together with a slip of five. But below

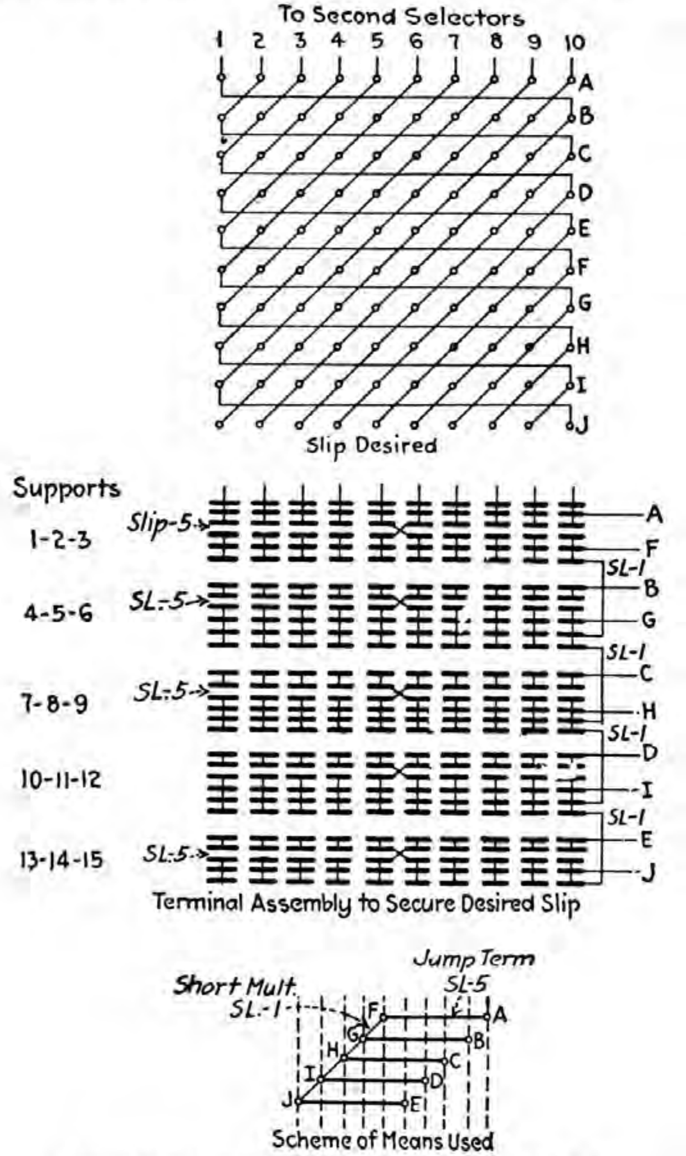



FIG. 120.—Typical case of trunk slip worked out.

these four strips lies the strip which carries the other end of the short-multiple cable mentioned above. The latter has a slip of one. Therefore, section $G$ is connected to $F$ with a slip of one, indicated in another way by the small sketch "scheme of means used" found at the bottom of the figure. Since $A$ is slipped five from $F$ and $B$ is slipped five from

*G*, and in the same direction, *A* and *B* have a slip of only one with regard to each other. This is brought out graphically in the small sketch and conforms to the slip desired and shown at the top of the illustration.

In the same way the reader can follow the slip secured for the remaining sections. By the use of jumpered terminals and slipped short-multiple cable, any desired scheme of trunk slip can be worked out.

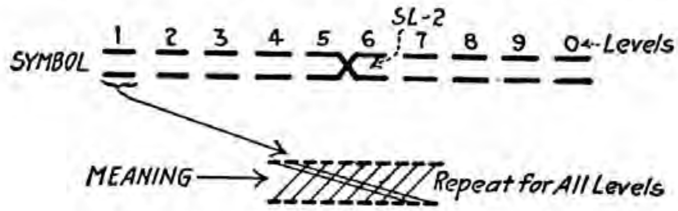



FIG. 121.—Jumpered terminals, slipped 2.

The standard form of jumpered terminals may sometimes be used to advantage upside down. Figure 121 shows such a form with a slip of two. Figure 122 shows the symbol and its meaning when used upside down. This secures advancing slip.

Another trunking device which is used is partial slip, that is, slipping part of a level, and wiring the rest of the level straight or point-for-point.

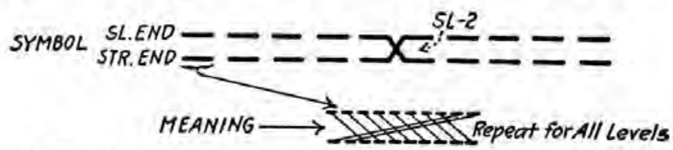



FIG. 122.—Jumpered terminals, slipped 2, upside down.

Figure 123 shows the symbol for this. The trunks which are to be slipped are indicated by a note, together with the amount of the slip (*SL*-1, *TRK* 1-5, *STRAIGHT* 6-10).

The conditions indicated by a symbol must be held to apply to all levels, unless especially noted to the contrary.

**Individual Trunks.**—The first automatic exchanges had individual trunks only, so that each switch or group of switches had but one trunk

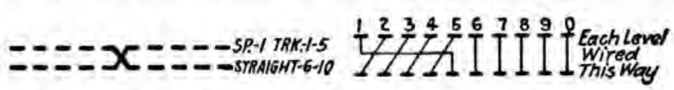



FIG. 123.—Symbol for partial slip.

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 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. 124. *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 multi-

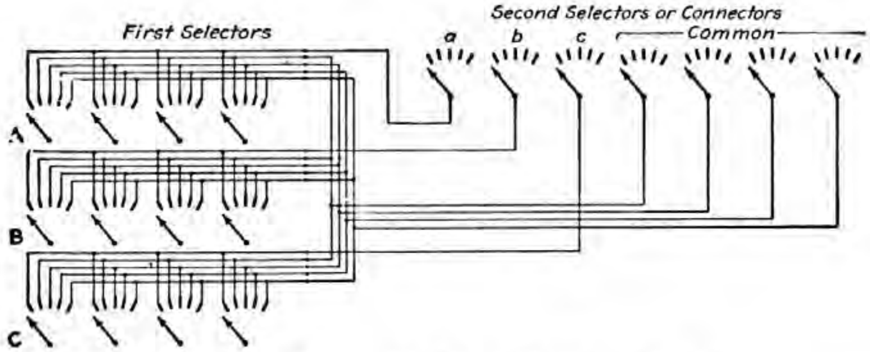



FIG. 124.—Individual trunks with common group.

pled 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. 125. It consists essentially of one or more individual trunks and a group of common trunks, the latter, however,

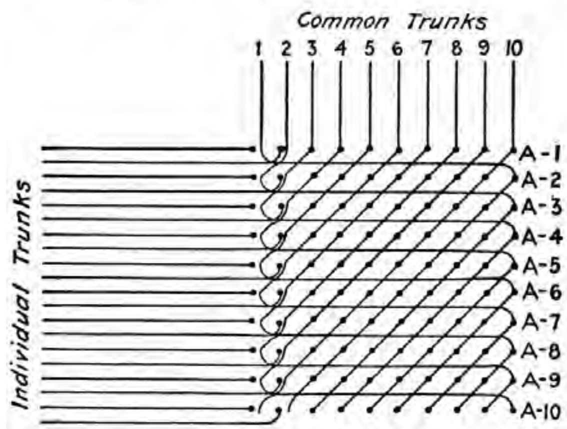



FIG. 125.—Individual trunks with slipped common trunks.

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. 125 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. 125. By this means the out-trunking from 100 switches (ten shelves of ten switches each) is increased from ten trunks to 30 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

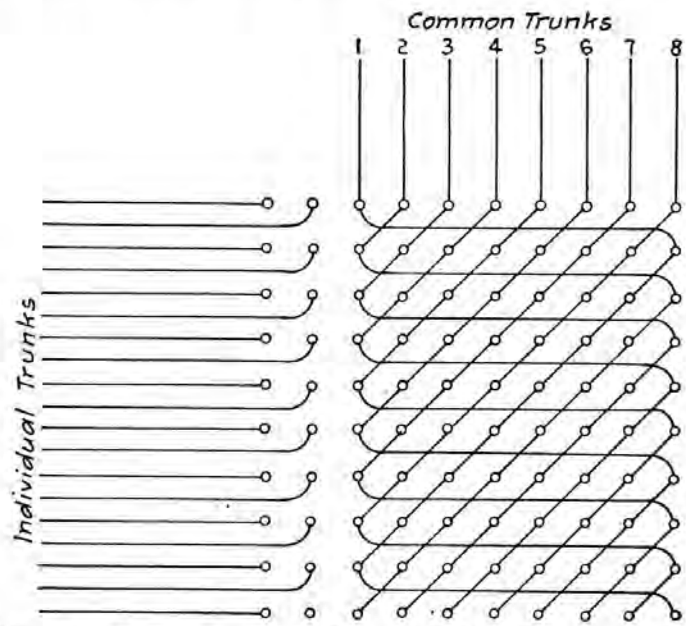



FIG. 126.—Common trunks added to individual trunks, *ELS*-15.

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.

If the exchange is laid out from the start with individual trunks and common trunks, they may be arranged as shown in Fig. 126. There are fewer common trunks than found in Fig. 125, but they have much less traffic to carry than if they were part of a general group.

**Preliminary Impulse.**—It sometimes occurs that a single impulse is sent in by the telephone before the impulses which represent the call number. The cause of this is not fully and definitely known, though people hold various ideas upon the subject.

While the receiver is being removed from the hook, it is possible for the subscriber to close the circuit and open it again momentarily before the final closure. If the hook is not properly shaped, the receiver may stick and be a little hard to remove, so that a downward pull may result after the hook lever has reached the top of its motion. Again, the receiver cord may interfere with easy removal of the receiver.

Calling devices now in use require that the subscriber shall pull the dial around to the finger stop and let it go, not interfering with its return motion in any way. If the user fumbles at the dial, a preliminary impulse may occur.

The second of these probable causes of preliminary impulse deserves only the attention necessary to educate the public to use the telephone

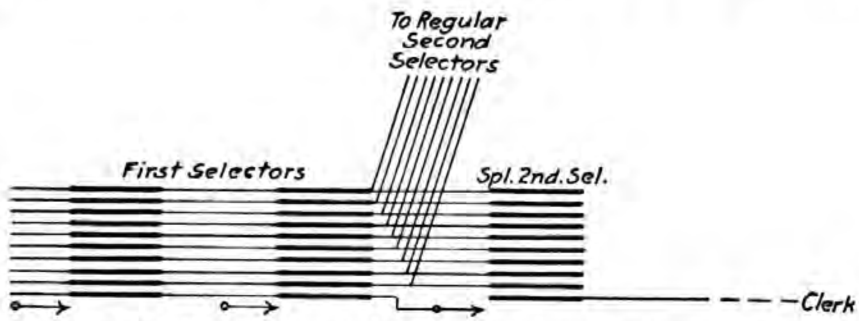



FIG. 127.—Special second selectors to care for preliminary impulse.

properly. Improper use of the dial is comparable to improper speaking of the call number to the operator of a manual exchange. It is necessary and reasonable to ask people to speak clearly and distinctly to the operator. It is just as necessary and reasonable to expect people to turn the dial continuously to the stop and to let it return to normal uninfluenced by the hand.

The former of these probable causes is partly within the province of the maker of the telephone instrument, or of the system to which it is connected. Attention may be directed toward preventing the preliminary impulse, or toward absorbing it if it occurs. The former calls for such a design of hook as will make it impossible or at least very improbable for the hook to descend enough to break the circuit after it has once reached the limit of its upward motion.

The preliminary impulse may be absorbed by installing a few special second selectors and multiplying their bank levels (except the first) with the banks of the first selectors. (Fig. 127.) If the subscriber dials any digit from 2 to 0 inclusive, the call will go directly to the regular second selectors. But if he prefaces the desired digit with an undesired "1," he will get one of the special second selectors. The next pull of the dial will trunk the call to the same level of the first selectors as would have been obtained if the preliminary impulse had not occurred.

This method of treating preliminary impulse apparently cuts down by 10 per cent the capacity of the exchange. But in practice much of this is recovered by assigning to the first level the special and miscellaneous services of the company. For instance, we may arrange 111 for trouble clerk, 112 for information, 100 for long distance, etc. Line trouble such as a swinging short circuit will usually be thus automatically routed to the trouble clerk.

Only as many special second selectors as are necessary for the traffic need be installed.

**Grouping Sections of Selectors.**—There is great freedom in the grouping of the banks of sections of selectors. The mounting of two sections on one shelf as described previously makes it natural to expect them to be associated. But the terminal assembly permits other groupings, for example:

1. *A* to *A*, *B* to *B*, etc.
2. *A* to *F*, *B* to *G*, etc.
3. *A* to *B*, *C* to *D*, etc.

By using this liberty, many trunking advantages may be obtained.

**Grouping Levels of Selectors.**—Each level of selector banks may be grouped in such a way as to secure greatest economy of trunks, with little regard to the grouping of the other levels. No two levels need be grouped alike.

The first level usually takes miscellaneous services, preliminary impulses, etc. Its traffic is relatively light. Hence, many sections of banks can have their first levels in common. It is not infrequent to find all the first-selector banks in an office multipled together on the first level.

The second level might happen to lead to a very busy office. If so, the two sections which share the same supports may have their own group of ten trunks. If this is not enough, each section may have its own group separate from all others.

There are two general methods of arranging the trunks from first-selector banks to second selectors: (*a*) treat the second selectors as if they were in one group, (*b*) treat them as if in separate groups. The former is more economical of trunks and second selectors, and requires approximately the arithmetical mean between the number required for a true single group and the number required for separate groups of ten trunks each.

In applying method A, the number of second selectors is first ascertained, enough to carry the total traffic from the first-selector banks under the conditions indicated above. Then scatter the trunks from the first-selector bank sections over these second selectors so as to divide the load as evenly as possible. The first and second choice of each first-selector section should fall on different second selectors from those of other sections, as far as possible.

In applying method B, multiple onto each section of (ten) second selectors as many sections of first selectors as will secure the proper traffic load. Provide as many such sections of second selectors as are necessary to care for all the first selectors. There will thus be a number of groups of trunks (ten each) which are independent of each other. Usually there will be a last group which is very lightly loaded.

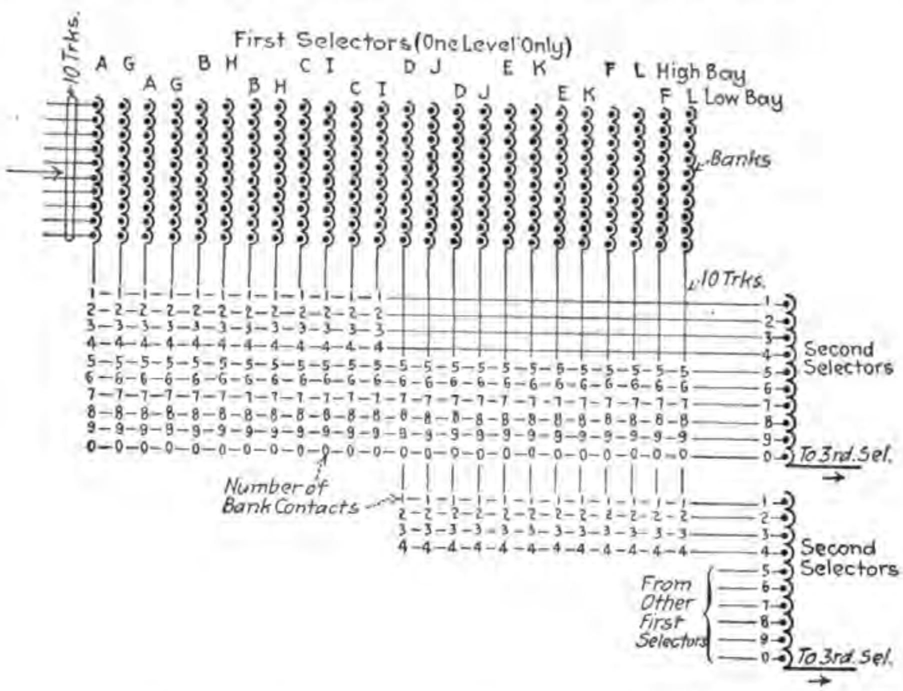



FIG. 128.—Selectors trunking into 14 switches (scheme).

Method A, the scattering of groups of trunks over other groups of trunks to save apparatus has been very greatly used in the past. A description of some of the arrangements will show what is available to the engineer.

All the selectors in a selector board of 240 switches may be trunked (on a given level) to one and a fraction sections of the next selector ahead. (Fig. 128.) Each of the first selectors is indicated by a point and semicircle, the latter is the bank.

Take section *A* high as an example. Its ten trunks are attached only to the ten second selectors shown at the right. The small numbers at the intersections of the lines indicate the number of the bank contact on the first selectors. Thus, contact 1 goes to second selector No. 1, contact

2 goes to second selector No. 2 etc. Half the first selectors are multipled alike.

The second half of first selectors (sections *DJ* to *FL*) have separate second selectors for their first four contacts, but share the last six with the other first selectors. Since most of the traffic takes the first few contacts of a level, this arrangement permits the last six second selectors to carry all that spills over.

Figure 129 shows how such a scheme is worked out in practise. It will be seen that it is possible, by properly resoldering the terminals on

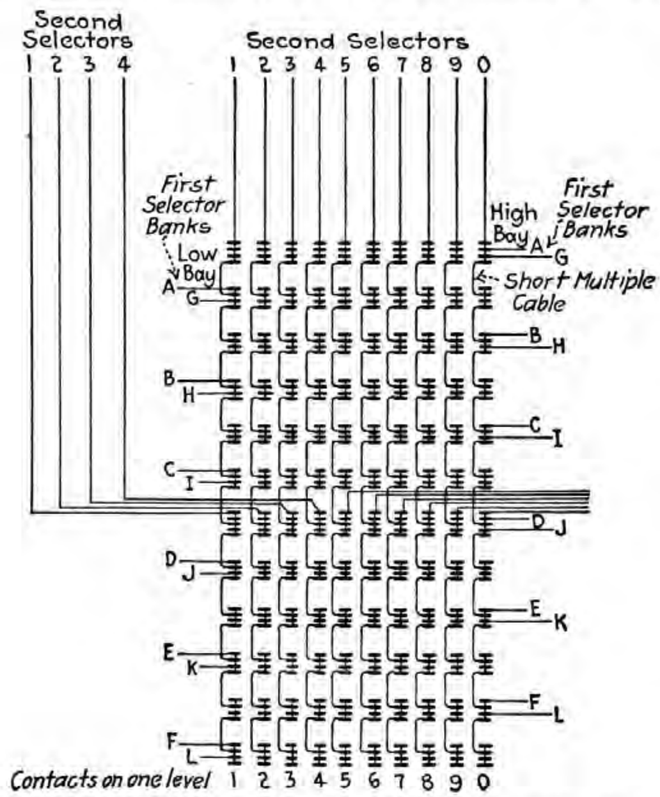



FIG. 129.—Selectors trunking into 14 switches (terminal connections).

the support for *D-J* high, to let the second half of the first selectors use the second section of second selectors alone, freeing the first section for the sole use of the first half of first selectors.

Another method where the traffic is light is to multiple together all the sections of a board (two bays) and treat them as one section, then to combine several such units so as to deliver their traffic into fewer sections than there are units. (See Fig. 130.) Here three boards, two bays each, are trunked into two sections of second selectors. Each has its own first five contacts individual. Bays 1–2 have 1 to 5 of the *A* section of second selectors. Bays 3–4 have 1 to 5 of the *B* section. Bays 5–6 have 6 to 0 of the *B* section. All are common on 6 to 0 of the *A* section.

In another case, all the *A* sections of selectors in a given number of frames are multipled together with trunk slip. (See Fig. 131.) We now dispense with the symbols for selectors and use letters and figures to

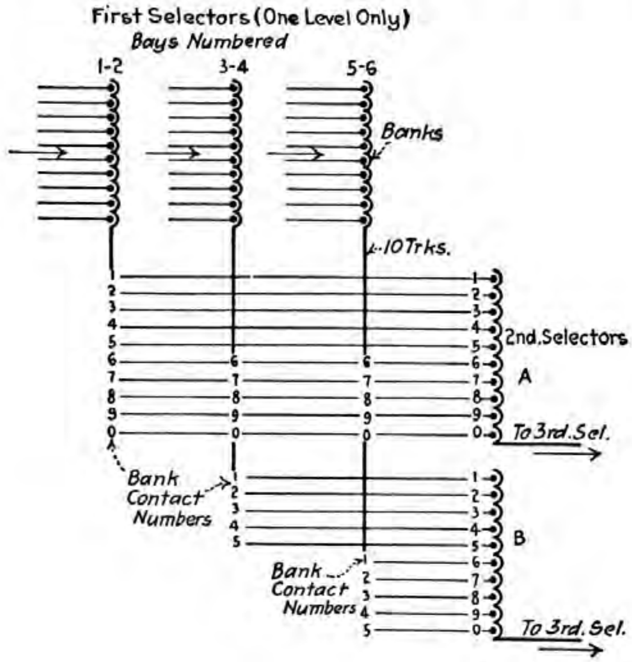



FIG. 130.—First selector trunking, 3 boards to 2 groups of trunks.

indicate sections. The *G* sections are likewise multipled, but on another group of ten trunks. A third group of selector banks, the *E* sections,

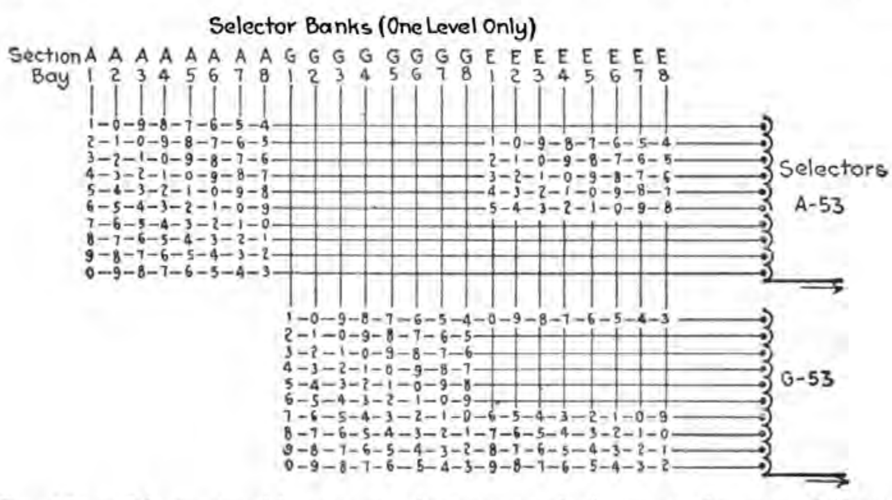



FIG. 131.—Selector trunking (one level) 3 groups of selectors to 2 groups of trunks.

are now divided, half of the trunks going to the *A*-53 section and half to the *G*-53 section. Because each kind of selector bank (*A*, *G*, and *E*) is slipped, the traffic is very effectually scattered over the 20 trunks.

Two groups of selectors may share 15 trunks. (See Fig. 132.) Bays 1-2 and 3-4 have individual trunks for the first five contacts, but common trunks for the last five. In this way four groups of selectors use three groups of trunks, ten trunks each.

Toll selectors are sometimes arranged as shown in Fig. 133. Each section of selectors has two individual trunks. The remaining eight contacts are common to two sections alone. Groups *A*-23, *G*-23 etc. contain individual trunks and common trunks, but group *D*-23 contains the individual trunks for sections *G*, *H*, *I*, *J*, and *K*. If the switches of a

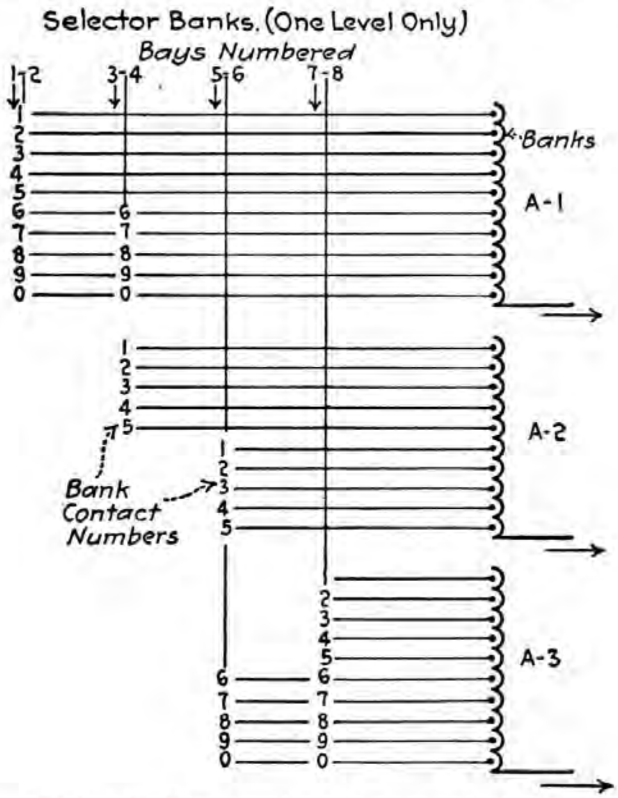



FIG. 132.—Selector trunking (one level) 2 groups of selectors to 15 trunks.

section have their adjacent banks slipped, then the traffic is all the better distributed, but the individual trunks will occupy different positions on different switches.

Selector banks are often grouped as if related in varying degrees. (See Fig. 134.) In this case each section has three individual trunks, three sections have five trunks in common, and six sections have the last two contacts common. This arrangement permits one group of ten trunks (*A*-37) to care for the first four contacts of three sections (*A* high, *G* high and *A* low). Also one group of ten trunks (*E*-37) cares for the last six contacts of six sections (*A* and *G* high, *A* and *G* low, and *B* and *H* high). In the same way the other six section sare handled by groups $C$-37, $D$-37 and $F$-37. To a certain extent this equalizes the load on the sections to which the traffic goes.

Another arrangement (Fig. 135) gives each section of selectors the first four contacts as individual, makes two sections common on the next two contacts, three sections common on the two following contacts, and 12 sections common on the last two contacts of the bank. Thus sections $A$ and $G$ high occupy all of the ten trunks of group $G$-29, using trunks 5

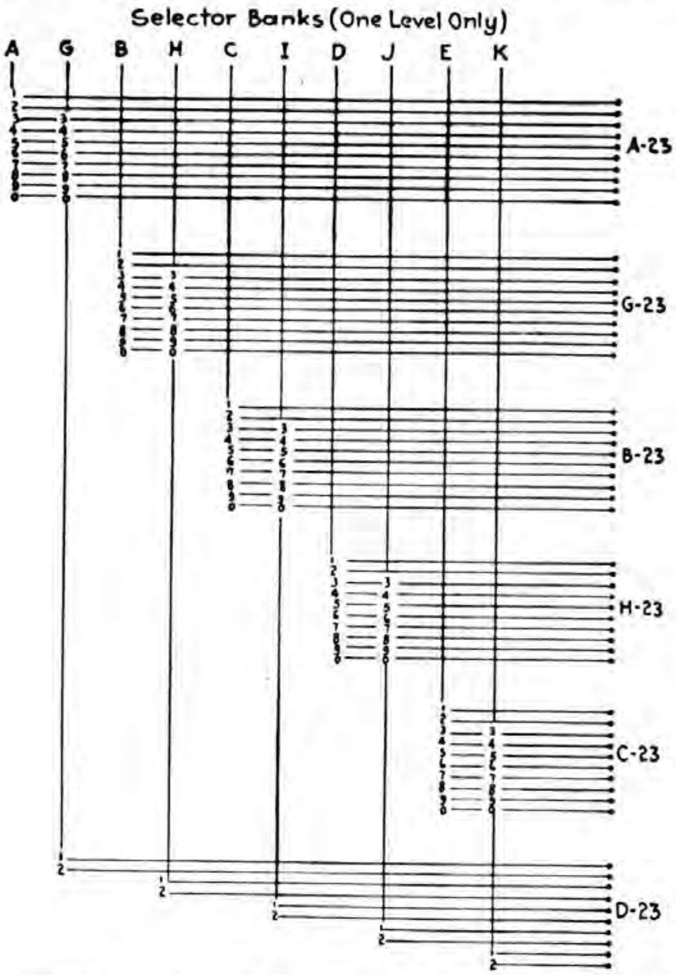



FIG. 133.—Selectors trunking (one level). Sections grouped by twos.

and 6 for the common two on contacts 5 and 6. Sections $A$ and $G$ high and $A$ low have contacts 7 and 8 common on trunks 1 and 2 of group $A$-35. All the sections use trunks 3 and 4 of group $A$-35 for their ninth and tenth contacts.

Those selectors which trunk to connectors work under slightly different conditions from other selectors, because the connectors are not limited to sections of ten. As many as 27 connectors have been mounted on one lineswitch-board, all their banks being common. Since there are many five digit exchanges, it has become common to speak of these selectors as "third selectors," although in smaller and in larger exchanges they are not thirds.

Fourteen connectors may receive traffic from selectors as shown in Fig. 136. Eight sections of selectors scatter their traffic over the whole number, except that connector No. 14 is not yet installed. Connectors 1 and 2 are for toll service, although they may be used for local calls as well. They are called "combined toll and local connectors." The toll third selectors reach only them. When seized by a toll selector, the combination connector gives the proper conditions for toll service.

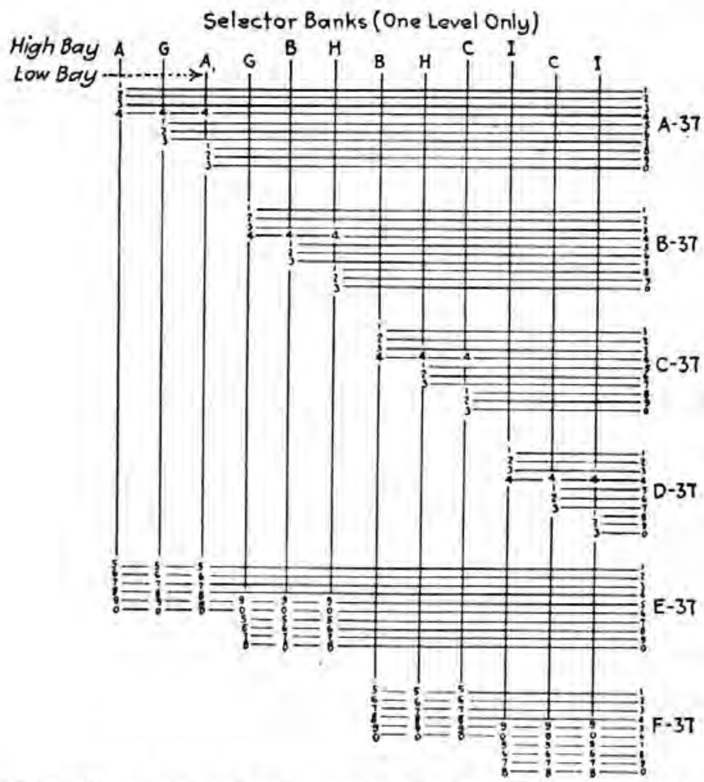



FIG 134.—Selector trunking (one level). Sections grouped by 3's and 6's.

But when seized by a local selector, it acts like other (regular) connectors.

The first eight contacts on the selector banks are slipped. The last two are straight. The tenth contact alone leads to the toll connectors, so that a toll connector will not be taken for local service until all the local connectors are busy.

Figure 137 shows how the terminals are arranged to secure this scattering. The letters at the right indicate the bank cable from the sections, *A* and *G* being on the same supports, *B* and *H* on another set, etc.

Ten of the connectors are brought onto the top terminal strip of the *A-G* support. This is all that would be necessary if there were only ten.

The extra connectors are cared for by having an extra pair of terminal strips above the *A-G* assembly, and by inserting an extra strip between the strips for the pair of sections. Thus there is an extra strip between *A* and *G*, between *B* and *H*, etc. There is also an extra strip above the *C-F* assembly.

The extra four connectors have their trunks wired to the top extra strip. From the companion strip (under it) run wires to the extra strips mentioned above. The number of each connector is added to the wires where they terminate so as to make it easier to follow the trunking.

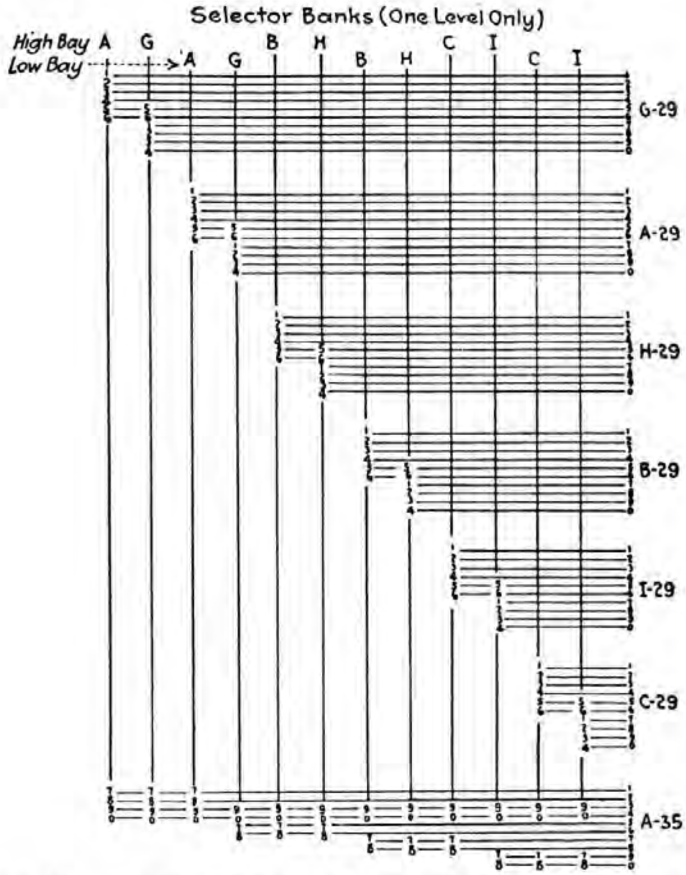



Fig. 135.—Selectors trunking (one level) sections grouped by 2's, 3's and 12's.

Connector 14 can be cut into service by soldering down its terminal at the ninth contact on the *C-F* support, and unsoldering the terminal of the short multiple on the *B-H* support above. This transfers the ninth contact of the four sections *C*, *F*, *D*, and *J* from connector 3 to connector 14, leaving only four sections (*A*, *G*, *B*, and *H*) on connector 3.

Individual trunks are provided for the first contact of each four sections of selectors. *A*, *G*, *B*, and *H* have connector 12, while the other four have connector 13. They are brought in on the strips inserted between the bank strips. In this way the individual trunks can be removed or added at will, for contact No. 1 has its place in the regular slipped eight trunks. If the individuals were done away with, it would (Fig. 136) throw each figure "1" up into the vacant space, which, because of the slip, is progressively higher as we go to the right.

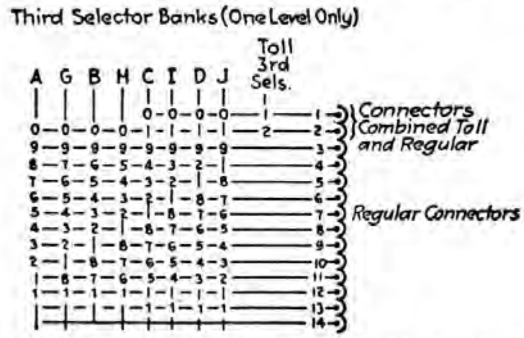



FIG. 136.—Selectors (3'd) trunking into 14 switches (scheme).

Seventeen connectors may be connected in two ways, of which one is shown in Fig. 138. Twelve sections of selectors are divided into two parts, six sections each for the first seven contacts. They unite without slip on the last three contacts.

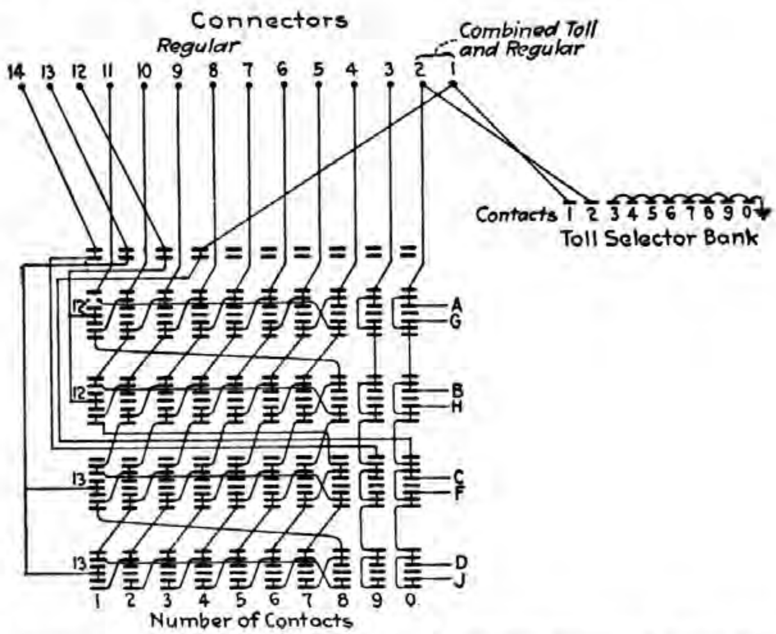



FIG. 137.—Selectors (3'd) trunking into 14 switches (terminal connections).

The first five contacts are slipped in the regular way, and there are no individual trunks. Contacts 6 and 7 are not slipped.

There are five toll and regular connectors, numbered 1 to 5. The toll selectors hunt over them in that same order. But the local selectors hunt in the opposite direction, so that what is first choice for one is last choice for the other.

The other way of connecting 17 connectors is shown in Fig. 139. It is alike except that there is more scattering on the toll and regular connectors and less on the regular connectors.

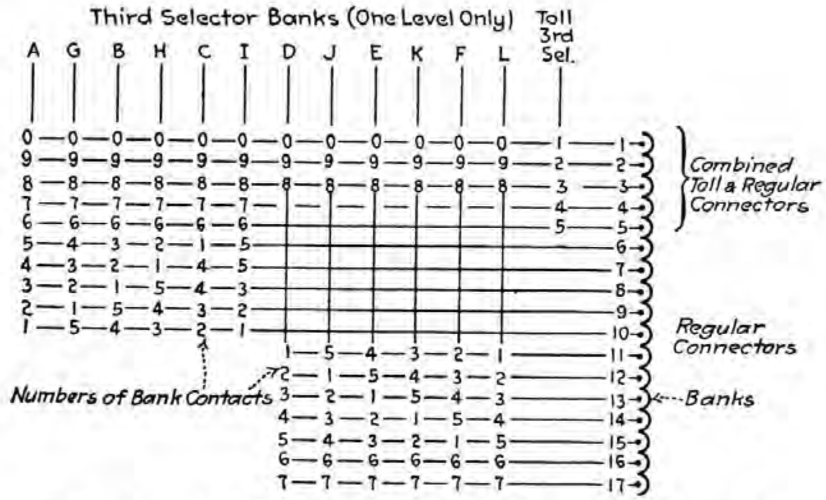



FIG. 138.—Selectors (3'd) trunking into 17 connectors (scheme 1).

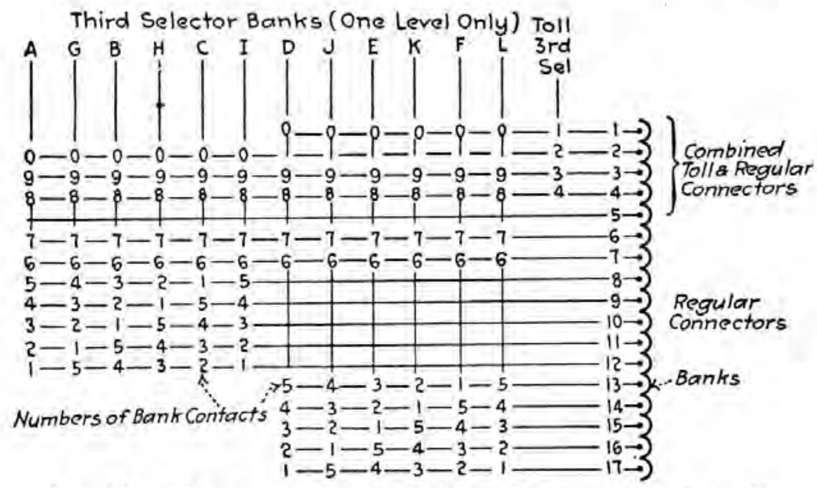



FIG. 139.—Selectors (3'd) trunking into 17 connectors (scheme 2).

Connector No. 5 is not installed, but may be added at any time. The arrangement of terminals is such that when this occurs, contact 8 of the second six sections (*D* to *L*) will be thrown from connector 4 to connector 5.

Twenty-seven connectors are arranged as shown in Fig. 140. The 12 sections of third selectors are divided into three parts as far as the first six contacts are concerned. The first five are slipped, the rest are not. Each group of four sections trunks to a different group of connectors for the first six contacts. This scatters the local traffic over 18 connectors.

Contacts 7 and 8 are common to all and are not slipped.

There are to be seven combined toll and local connectors, of which five are installed. On the ninth contact, the third selectors are divided into two parts, on the tenth contact, three parts. Thus there are only four sections of local selectors on the first three connectors, which are the first, second, and third choice of the toll selectors. As shown, the fourth and fifth choice of the toll selectors have six sections of local selectors each to share the trunk.

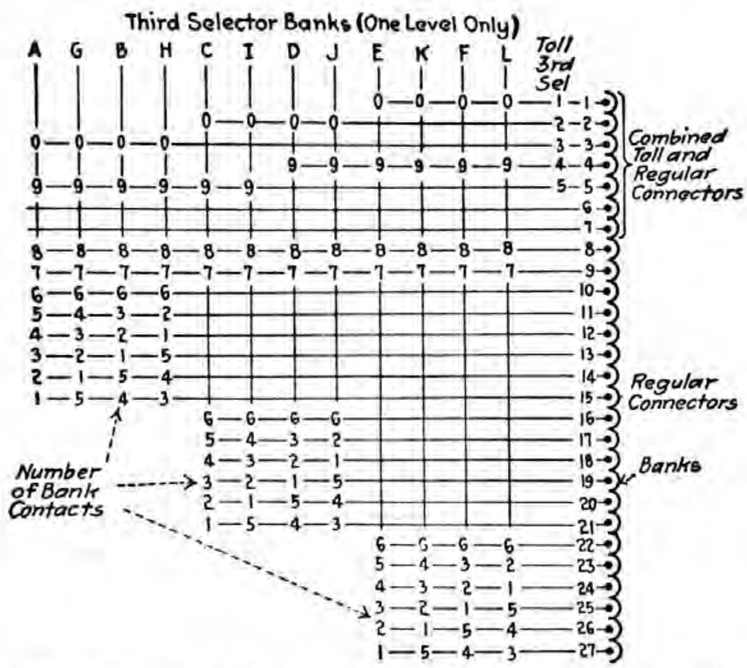



Fig. 140.—Selectors (3'd) trunking into 27 connectors (scheme).

When the sixth and seventh connectors are put in, they will be combination switches. By changing the soldering of the terminal strips, sections *A* to *I* will be cut over onto connector 7, and sections *D* to *L* will be changed to connector 6. This leaves connectors 4 and 5 individual to the toll selectors and permits increased traffic.

**Selector Section, Partly Equipped.**—If there is a section of selector switches which is very lightly loaded at the present time, not all of the switches need be installed at first. If seven or eight will carry the load, only that many are installed. If desired, the trunks leading to the vacant switch jacks can be made permanently busy by grounding the release trunk of each. When traffic calls for them, the additional switches need only to be hung on the shelf and the ground connections removed.

Since the complete set of ten trunks is slipped, the busied trunks may be the first choice of some of the switches which have access to this group. To enable such switches to find an idle trunk more quickly, it possible to tie the jack of each vacant switch position to some installed switch in the same section. (See Fig. 141.)

If possible, the switch to which the trunk is tied should not be the first choice of any of the other sections, or at least it should be one of the less used switches of the section. This device is only temporary and will be removed when the section is filled with switches.

**One Office on More than One Level.**—In a small multi-office exchange, it is sometimes advantageous to use several levels on the selector banks for one office. In this case the first selector is more than merely an office selector, it also selects a group in the desired office. This has been explained in the introduction to multi-office systems, page 18. It is a device which is useful chiefly in small exchanges, although occasionally it may find place for a small office of a large exchange.

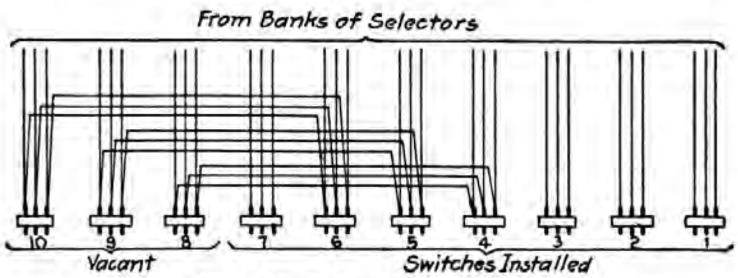



FIG. 141.—Selector section, partly equipped.

**Combined Levels and Trunks.**—Two levels on the banks of first selectors may be combined initially if the traffic at the start is light. (Fig. 142.) Suppose that it is expected that districts 3 and 4 will grow, although at present the traffic from the point under consideration to them is light enough to be carried by one group of trunks. In this case, district 3 would have its office numbers assigned from one part of the banks of second selectors, and district 4 from the other part. (See upper part of Fig. 142.)

If "31" is called, the first selector will lift its wipers to the third level, and trunk to a second selector in the switching office, and the wipers of the latter will be lifted to the first level which leads to office 31. If "44" is called, the first selector will take the fourth level, which is tied to the third level. This gives the subscriber the same group of trunks as before, but the second selector will lift its wipers to the fourth level, which leads to office 44.

As long as the two levels are thus combined, there can be no office 41 in district 4 nor any office 34 in district 3.

When either of the districts grows so that other offices must be opened which overlap on the numbers of the other, the levels are separated and new trunks run to new second selectors for one district (4). (See lower part of Fig. 142.) This step might be made necessary by an unexpected increase in the traffic, even if the number of offices did not increase to the overlapping point.

Not all offices and districts need to trunk into districts 3 and 4 as illustrated. Those which are differently situated might have separate trunks from the beginning, and some might even have direct trunks.

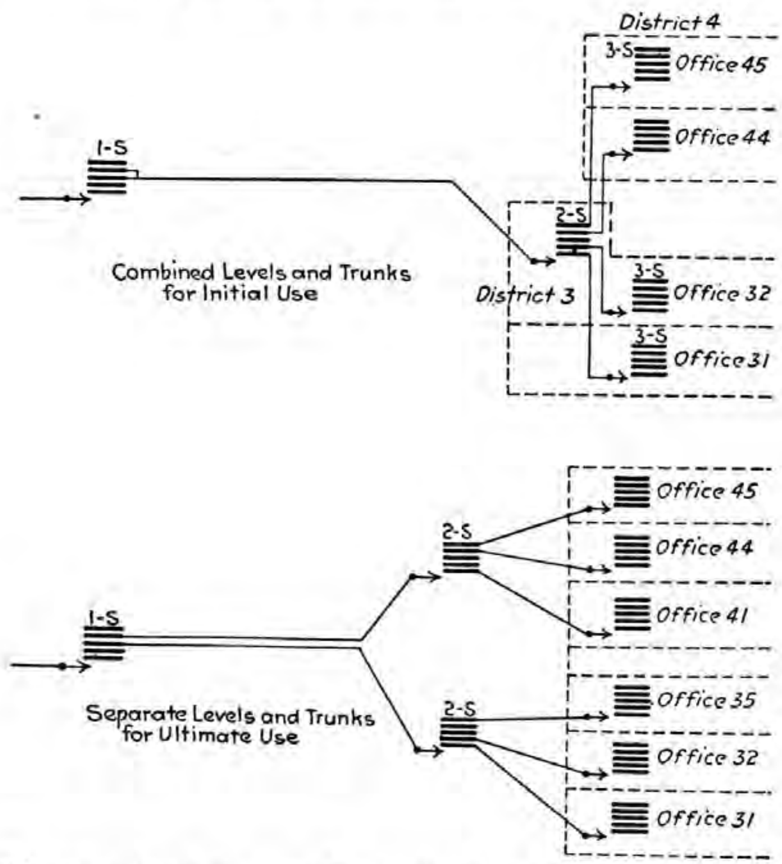



FIG. 142.—Trunking, inter-office, two levels combined for initial service.

Combination use of trunks is sometimes practised if traffic for special service (information, complaint, etc.) is light, and call numbers beginning with "1" are used for that service and recording toll.

The example chosen to illustrate this (Fig. 143) is an exchange which is divided into two parts, with one numbering scheme for the whole. The center for information, etc. for the upper half is office No. 3, while office No. 5 represents the conditions in any of the other offices in this part. The center for the same service for the lower part is office No. 2, and office No. 7 represents the rest of the offices in that part.

Special second and third selectors are installed in each office and reached from the first level of first selectors.

Toll is called by "100." This gives a direct trunk from any office to the toll recording operator.

Information is called by "1202." The special second selectors have their second levels multipled onto the regular trunks leading to the central office. In the upper part, if any office (No. 5) calls "12," the call goes to an incoming second selector in office No. 3. Calling "0" lifts the incoming second selector to the tenth level, leading to special third selectors, on whose banks are the information trunks, level 2.

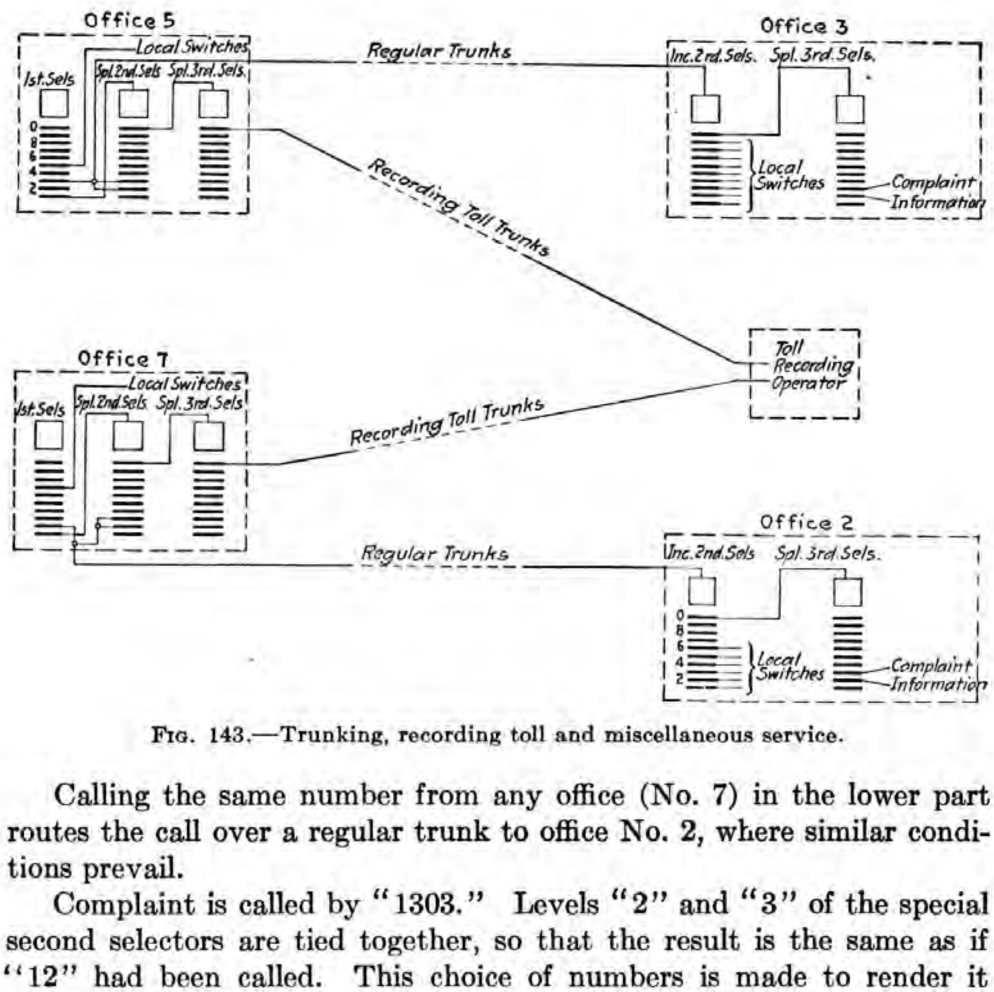



FIG. 143.—Trunking, recording toll and miscellaneous service.

Calling the same number from any office (No. 7) in the lower part routes the call over a regular trunk to office No. 2, where similar conditions prevail.

Complaint is called by "1303." Levels "2" and "3" of the special second selectors are tied together, so that the result is the same as if "12" had been called. This choice of numbers is made to render it easier for the public to remember them. The separation occurs on the banks of the special third selectors, because the complaint trunks are on the third level.

**Mixed System.**—The use of the terms "thousand-line exchange" "ten thousand-line exchange" etc., seems to indicate definite, fixed limits to the growth of a central office equipment. This is not true.

The expansion of a system does not depend upon its original design, and it may grow as rapidly or as gradually as may be desired.

A thousand-line exchange (Fig. 144) has originally not over ten groups of 100 lines each. To expand it beyond 1000 lines, insert second selectors between the first selectors and the connectors of one of the lower hundreds (second hundred, for example). Attach the connectors to the same level

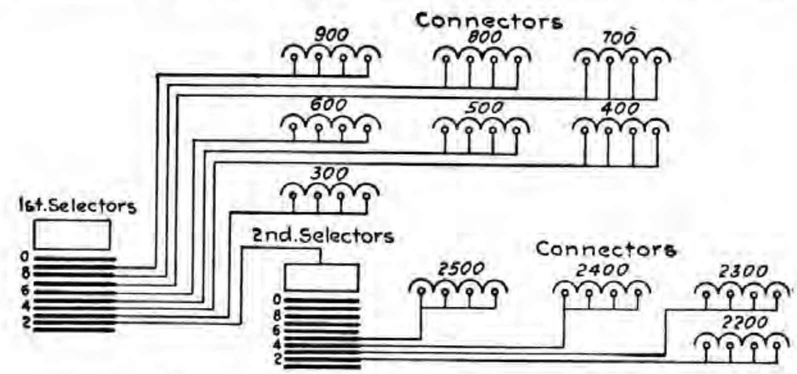



FIG. 144.—Thousand lines being expanded.

on the second selectors that they formerly occupied on the first selectors. The new numbers for these subscribers will be the old numbers with the first digit doubled. Thus, 245 will become 2245, etc. The remaining levels of the newly installed second selectors are now available for opening new hundreds, so that the capacity is now 1900 lines instead of 1000 lines.

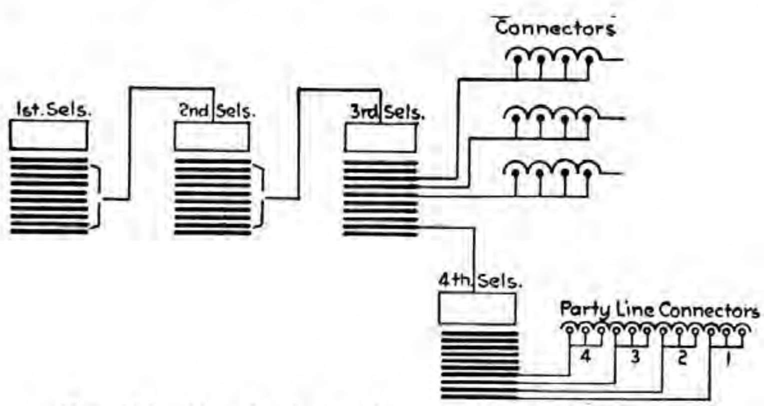



FIG. 145.—Fourth selectors for party lines in 5-digit system.

The next step in growth is to open a new thousand on some other level of first selectors, exactly as was done on the second level illustrated. In this way, level after level may be expanded until it is a 10,000-line system.

As the system grows, the number of first selectors must be increased to take care of the increased traffic caused by the greater number of telephones.

Even if an exchange is not being expanded, not all of the subscribers need have the same number of digits in their call numbers. Party lines are often rung selectively by separate groups of connectors, each equipped with the kind and arrangement of ringing current to which a class of bells will respond.

The selection of these groups of connectors uses up the hundreds digit of the call number. In a 5-digit system, this selection occurs on the third selectors. (Fig. 145.) This will use up one call number for each telephone, the same as individual lines.

To obviate this rapid use of numbers, fourth selectors are installed for the party lines alone. This gives the party line numbers one more digit than the individual lines, 6 digits in a 5-digit exchange.

**Midway Office Without Through Trunking.**—Sometimes between two separate exchanges there is a region which, because of local conditions, has free service to and from both exchanges although those ex-

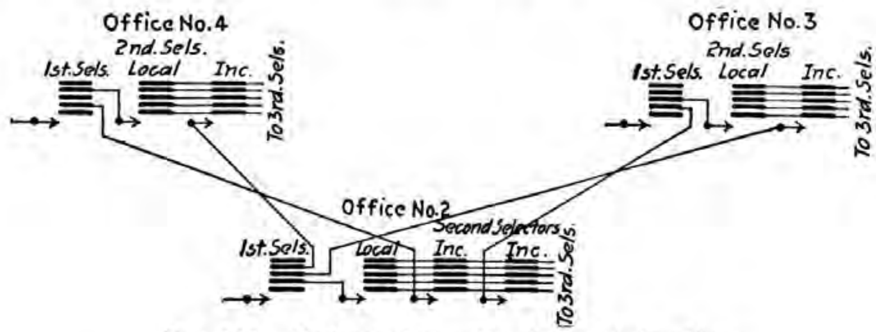



FIG. 146.—Midway office without through trunking.

changes are connected by toll service. It can be arranged so that although each exchange can call the midway office, it can not call through to the other office.

Assume the midway office be No. 2 (Fig. 146) and that the two exchanges are represented by office No. 4 and office No. 3.

Office No. 2 calls office No. 3 by dialing "3," which secures a trunk on the third level of the first selector, coming into the desired office on an incoming second selector. Likewise the other office is called by the midway office by dialing "4," which gets a trunk from the fourth level on the first selector, leading to an incoming second selector in office No. 4.

Office No. 3 calls the midway office by dialing "2," which leads to an incoming second selector in office No. 2. But there is no way by means of which office No. 3 can connect with the trunks which lead from office No. 2 to office No. 4, because they do not appear on the incoming second selector banks to which office No. 3 has access.

The same conditions apply to office No. 4 calling office No. 2, and trying to call through to office No. 3—the latter can not be done.

## CHAPTER V

## 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.

The last of these, the private automatic exchange, has become more than merely sub-station equipment, and is treated in the chapter following this chapter.

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 sub-station 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 3, 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.

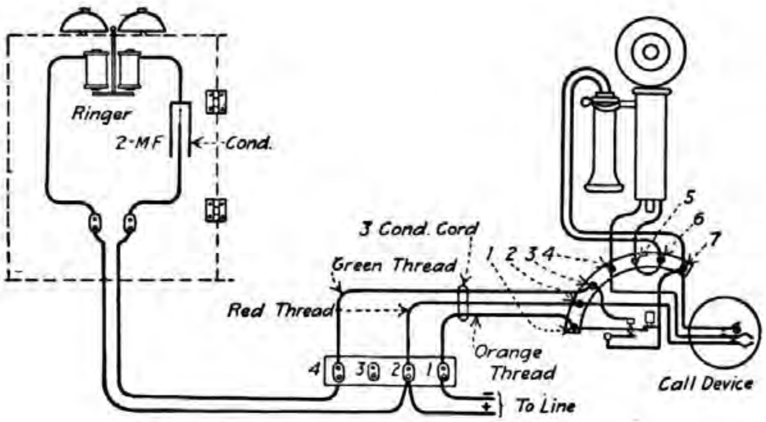



FIG. 147.—Desk telephone wiring diagram.

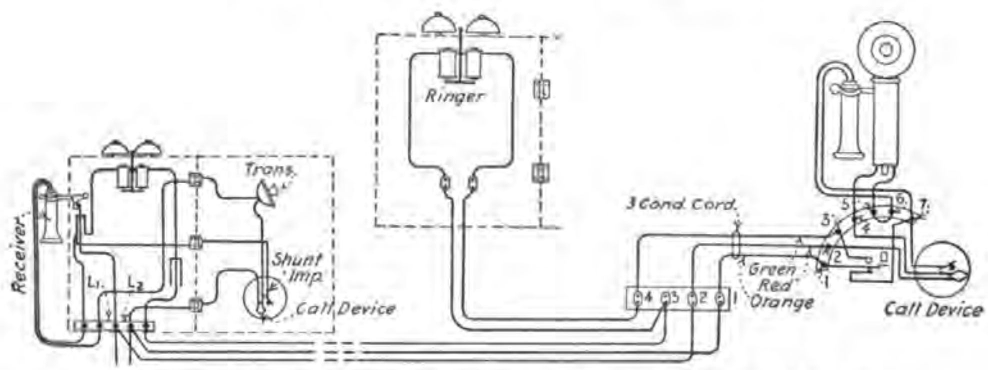



FIG. 148.—Wiring diagram for a wall telephone with an extension.

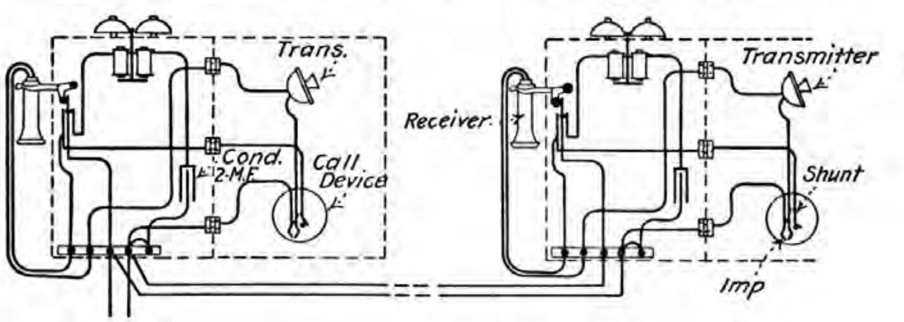



FIG. 149.—Wiring diagram of a wall telephone with an extension.

Figure 147 shows the circuit of a desk telephone of the direct-current receiver type just as the instrument is wired.

Figures 148 and 149 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.

Figure 150 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.

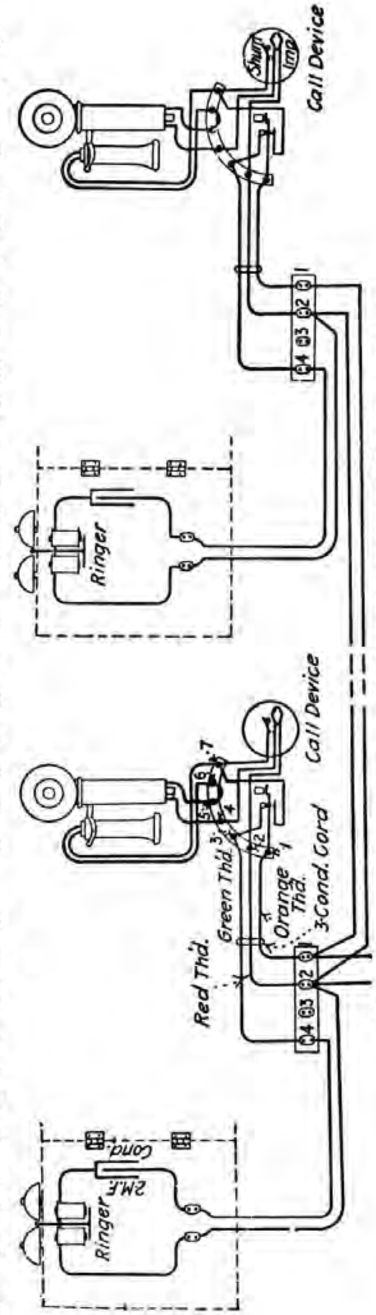



FIG. 150.—Wiring diagram of a desk telephone with an extension.

The calling device has been applied to several telephone circuits. Among them are the "booster" circuit of the Automatic Electric Company and the regular common battery circuit of the Western Electric Company. Other special circuits will be described in connection with the apparatus with which they are used.

The booster circuit (Fig. 151) employs an induction coil to increase the sending ability of the transmitter, while retaining the non-polarized receiver. One condenser, *CT*, is used for talking and has 2-m.f. capacitance. The other, *CR*, is used for the bell, and for party lines using harmonic signalling has 0.7-m.f. capacitance. There are three shunt springs, *S*, on the calling device, it being necessary to short circuit the transmitter and the receiver separately. Dialing occurs through the 3–4 winding of the induction coil without appreciably bad effect.

The same circuit applied to a wall telephone (Fig. 152) is simpler as only two shunt springs are needed.

The Western Electric Telephone with a calling device (Fig. 153) is the same for both wall and desk sets. The same condenser is used for talking and ringing. There are three shunt springs on the calling device. When the shunt operates, it opens the receiver circuit and short circuits the transmitter. Dialing is done through the 1–2 winding of the induction coil.

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

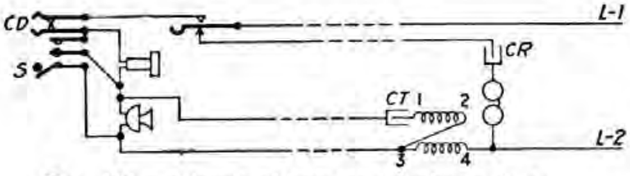



Fig. 151.—Circuit of booster telephone, desk.

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 15 stations, but larger sizes are so expensive to install and so expensive to enlarge or change that their use is generally not warranted.

When but one trunk is used for a little system it may terminate in a lineswitch and connector switch banks the same as any subscribers' line

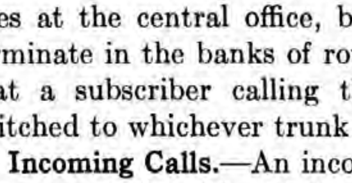



Fig. 152.—Circuit booster telephone, wall.

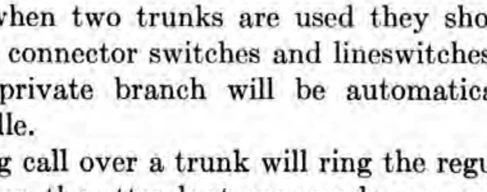



Fig. 153.—Circuit of Western Electric telephone with calling device.

does at the central office, but when two trunks are used they should terminate in the banks of rotary connector switches and lineswitches 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. 154.) 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.

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.

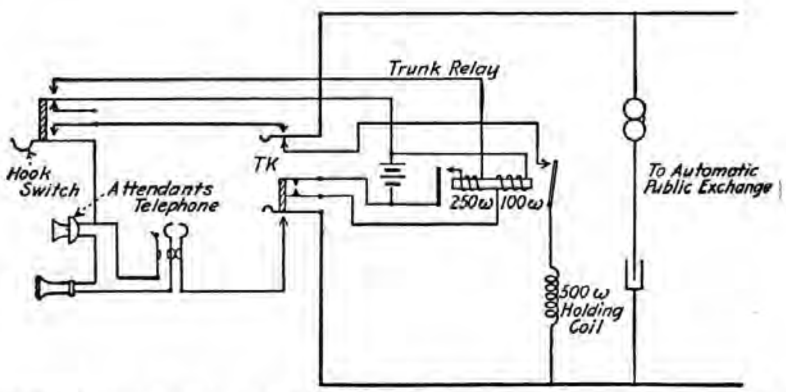



FIG. 154.—Trunk circuit to attendant's station of a push-key inter-communicating system.

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. 155) 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.

**Functions of the Keys.**—The circuit of this board is shown in Fig. 156. 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

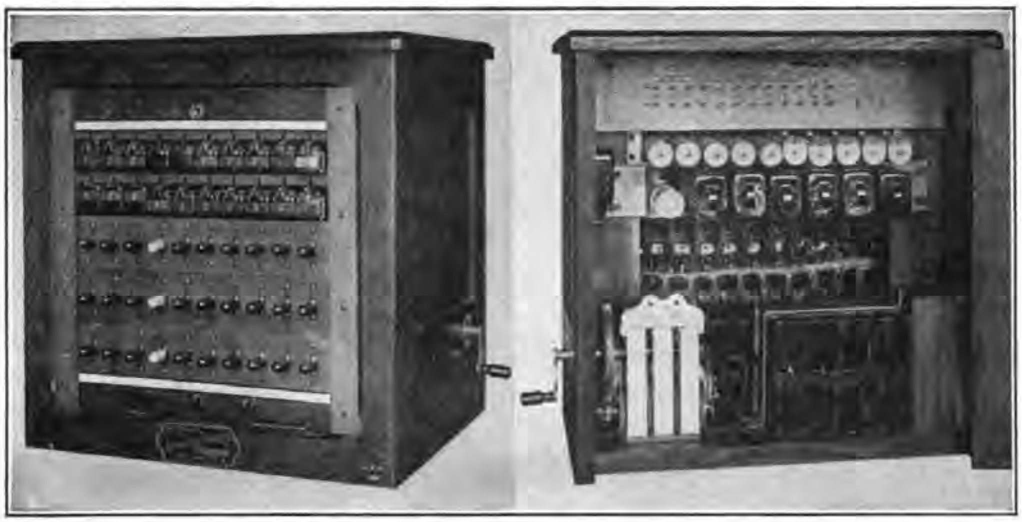


FIG. 155.—Cordless private branch switchboard.

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 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

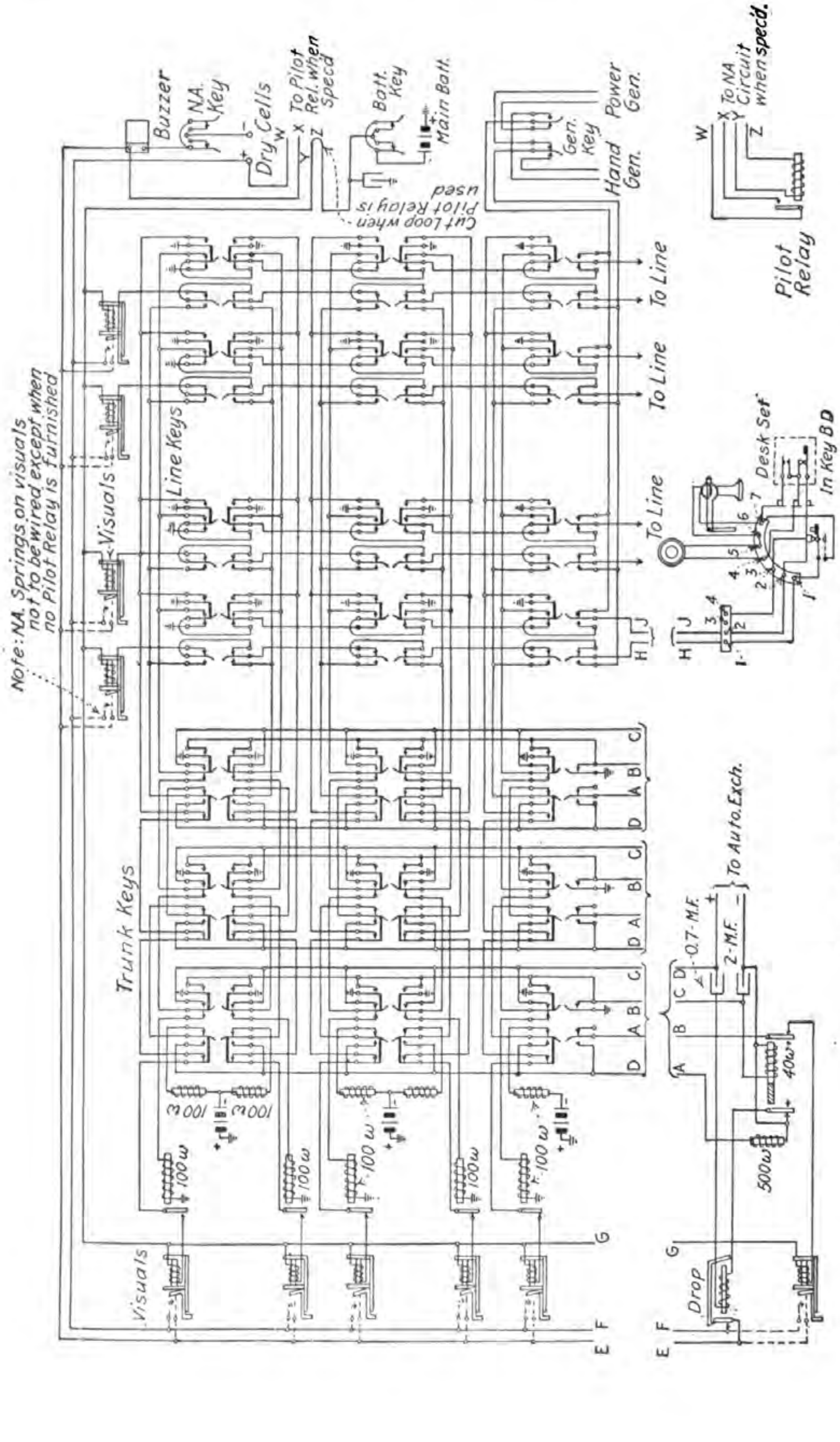



**FIG. 156.—Circuits of cordless private branch switchboard.**

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 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.

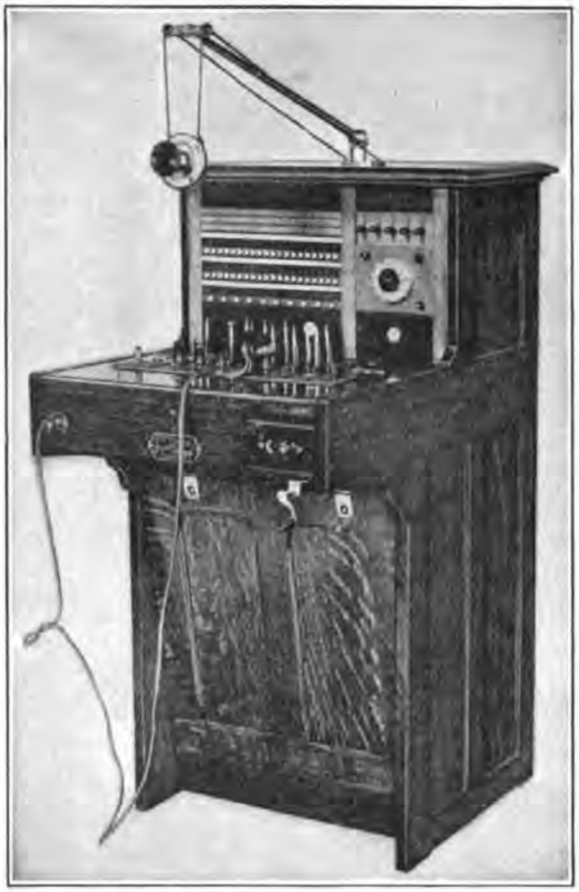


FIG. 157.—Private branch exchange switchboard.

**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 60 lines is given in Fig. 157. This type of board is commonly equipped with regular 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

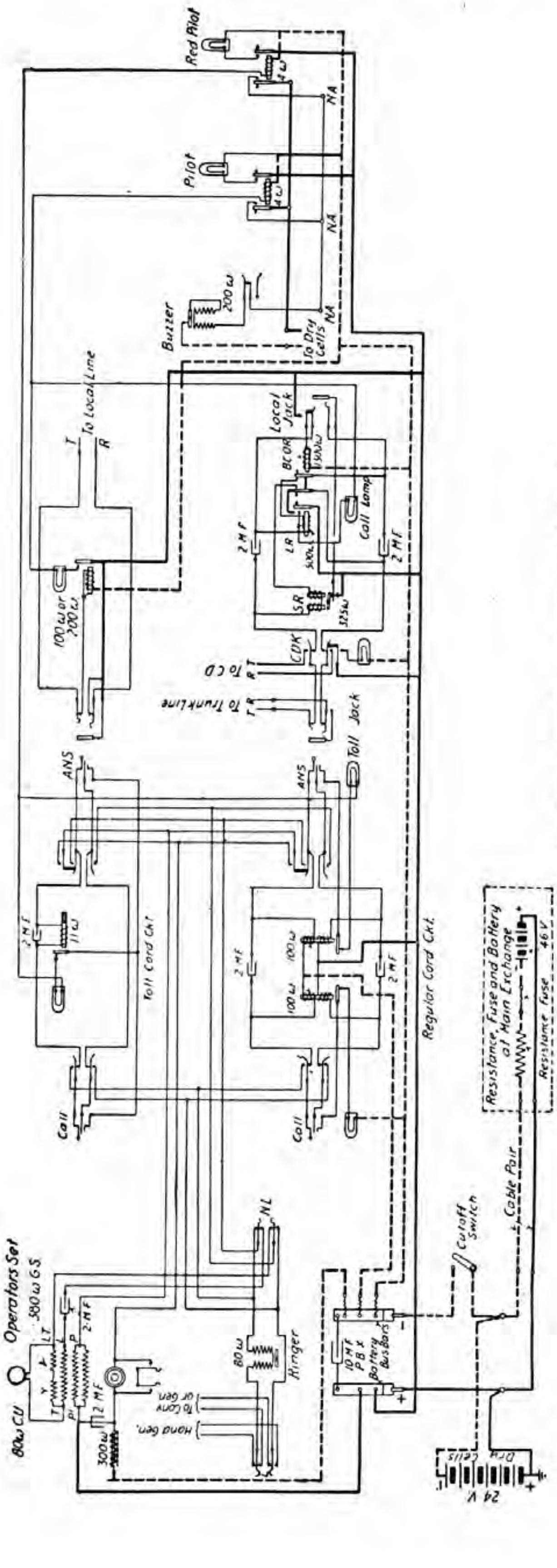



FIG. 158.—Circuits of private branch exchange switchboard.

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. 158. 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. This in 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 switchhook. 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 lineswitch 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.

# CHAPTER VI

## PRIVATE AUTOMATIC EXCHANGE

The private automatic exchange is radically different from a manual private branch exchange. The latter was developed out of the single instrument subscriber station. More stations were added as business demanded, more subscriber lines were put in, and finally a small switchboard was installed to switch incoming and outgoing calls. No matter how large the private branch exchange became it was and is still classed as "subscriber station apparatus." It is to that extent integral with the public telephone system. Local or interior traffic is incidental—it is imposed on the *P.B.X.* because it is there and will serve after a fashion. It was not devised for local traffic.

The private automatic exchange, on the contrary, was designed primarily for local traffic, within the business concern which it serves. Even for the tying together of a business by easy quick communication it is an efficiency device of high rank. But it has proven to be more than this.

**Requirements of Modern Business.**—Certain services have become necessary in the conduct of all modern business organizations. As a business grew from a one-man affair to a great organization of many departments the first and greatest need was a means of audible intercommunication. A still larger growth and it became desirable to provide a paging system by which any desired code might be sounded simultaneously throughout all departments. As the number of employes grew and the fire hazards increased it became necessary to provide a fire-alarm system. Owing to increased floor space and greatly enlarged stocks of valuable merchandise, it was found desirable to install a watchman's service.

To meet these requirements there have been provided in many instances a system of push-bottons and buzzers, a separate code-calling, or paging system, a distinct fire-alarm system and an unrelated watchman's service, all of this in addition to an antiquated form of telephone intercommunication. One manufacturing company had 28 detached systems in one building, and another had over 60 of them in the whole plant. Though handicapped by being unrelated to each other, these services have proven to be of great value.

Many establishments use all of the services which are applicable to modern business—some of the services are used by all establishments. Without the private automatic exchange it is the practice to use a distinct system to accomplish each of the desired ends. It is much better for them to be supplied by one system, in which all the services are properly correlated.

**Services Rendered by the Private Automatic Exchange.**

1. Telephone system, with many flexibilities.
2. Conference arrangement by telephone.
3. Code Call System.
4. Watchman's Service, or Watchman's System.
5. Fire-alarm System.
6. Emergency Service.
7. Credit System.
8. Secret Listening or Detective Service.
9. Dictating Service.
10. Miscellaneous Services.

Not all of these services need be used or even installed at first. The *P.A.X.* may be installed simply as a telephone system without any feature but intercommunication. As the business of the establishment grows, the features can be added as rapidly as desired.

### 1. TELEPHONE SYSTEM

**Local Traffic.**—Because it is automatic, the *P.A.X.* furnishes telephone service continuously, 24 hours per day. It is always available to coördinate the activities of the institution. This is as vital to one organization which exists for one central purpose, as to the general public with its diversified objects.

The *P.A.X.* greatly increases the amount of interior communication. Studies have been made of traffic before and after the installation of *P.A.X.*'s and it has been found in enough cases so that the statement may be made generally, that telephone use increases three to five times. One typical instance is found in the offices of the Louisville & Nashville Railroad, at Louisville, Kentucky, where the total jumped from 3000 calls per day to 10,000 calls per day over exactly the same number of telephones.

The cause of the increased calling is the greater ease of establishing connections and of disconnecting them.

In many cases the interior traffic which is thrust upon a manual *P.B.X.* seriously interferes with the normal flow of calls to and from the public exchange. One publishing company found that after their private automatic exchange was installed, their incoming calls from the public exchange increased 15,000 per year. Since no change in their organization or business had occurred to account for this, they believe that they were formerly losing this number of messages because their *P.B.X.* was clogged with interior traffic. In another case, that of a large stationery house, when the *P.A.X.* was installed, the operator expected to have an easy time with her job. But in fact, the incoming and outgoing calls passing through their *P.B.X.* increased from an average of 500 per day to 1500 per day.

**Secretary Service.**—The past education of important executives has been to discourage them from putting through their own telephone calls. This has been due partly to the attitude of operating companies and partly to the inherent nature of manual telephony. The *P.B.X.* operator, in many cases, became a sort of secretary to the manager.

So deep-rooted is this condition that it has become the standard practise when installing a private automatic exchange to equip the desks of important officials with manual telephones, and arranging it so that the secretary of each can do all the dialing. It has also been observed

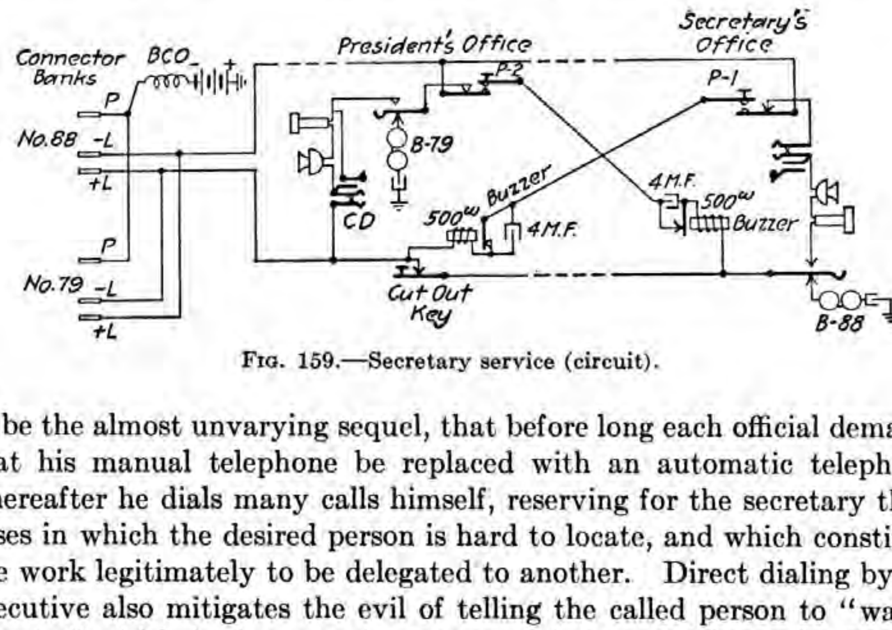



FIG. 159.—Secretary service (circuit).

to be the almost unvarying sequel, that before long each official demands that his manual telephone be replaced with an automatic telephone. Thereafter he dials many calls himself, reserving for the secretary those cases in which the desired person is hard to locate, and which constitute the work legitimately to be delegated to another. Direct dialing by the executive also mitigates the evil of telling the called person to "wait a minute," which is the annoying accompaniment of delegated calling.

Secretary service is provided in the *P.A.X.* as shown in Fig. 159. Assume that the president's number is "88." The line runs from the switchboard to the president's office, through a cut-out key, to the secretary's office, where the bell *B*-88 is located There are two buzzer wires between the two instruments, operated by the exchange battery without actuating the exchange apparatus.

When a call comes in, the bell *B*-88 rings. The secretary answers the call. If it is one which the president should answer, the secretary presses the button, *P*-1, which operates the president's buzzer. He answers and the secretary gets off the line. If the president desires to make sure of it. he presses the cut-out key, which cuts off the secretary's telephone.

When the president desires the secretary to make a call for him, he presses the button *P*-2, the secretary comes in on the line, and the instruction is given by telephone. The president hangs up his receiver and the secretary puts the call through, calling by buzzer when the call is ready.

An additional service is available in the form of a separate number which other officials may call and get the president directly. It is done by connecting the bank contacts of this separate number to the president's line, 88, transposing this connection, and installing an additional bell *B*-79 on the president's desk. Because of the transposition of the lines and the connection of each bell to ground the ringing will be selective. Calls on No. 79 will ring only the president's bell, and he will answer himself, because he knows that the call is coming from one of a

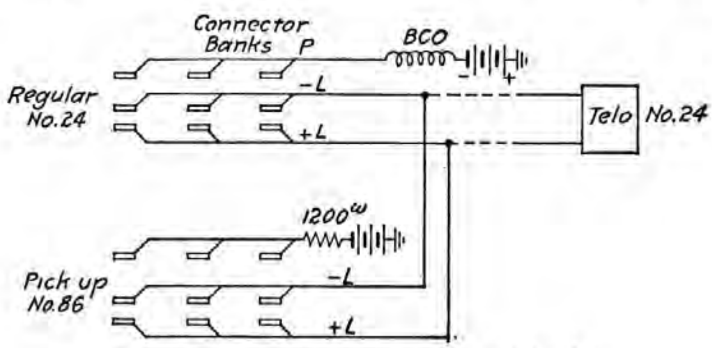



FIG. 160.—Double number pick-up (circuit).

restricted group of officials who alone know the number. Calls from all others will come in on No. 88, which ring the secretary's bell in the usual way.

**Double Number Pick-up.**—If an executive who has no secretary calls his office from any part of the plant and finds the line busy it is presumed that the call is for him. In a manual system he would flash the operator and ask her to transfer the call to the telephone he was using. The *P.A.X.* gives the same service as shown in Fig. 160. Line 24 is multipled throughout the various connector banks, and it is this number which appears in the directory. The line switch is now removed from line 86 (for instance), and the positive and negative side of this line are multipled with line 24.

The privates of the two lines are not multipled, a 1200-ohm coil is bridged from the private of line 86 to negative battery, should the executive chance to call his own office when the line is busy, he would immediately release and dial the "double number," (known only to himself) thereby extending the connection to his own line even though it is in use. Since the privates of the two lines are not multipled it is quite evident that the ground on the private of line 24 cannot cause the connector calling line 86 to give the busy tone. The connectors are of the type whose release is controlled by the calling person—the back-bridge relays can feed current to each other without preventing release.

This device is also useful in case the call to the executive's office has been answered by a private secretary. The latter can call the executive by the code-call system, and he can get in on the call to his office by means of the secret double number pick-up.

**Rotary Selection of Telephones.**—The *P.A.X.* connector incorporates the well-known group connector feature which is used a number of places to great advantage. One case especially is in a concern where they have an elaborate production system which necessitates the workmen going very frequently to pneumatic tubes and sending reports of their production to a dispatcher's office. It is very often necessary for the workman to reach the dispatcher by telephone in order to handle the system properly and efficiently. This is taken care of by a number of telephones seized by rotary selection from a common number. Telephone number one of the group always receives the first call, simultaneous calls being automatically passed on to the other telephones. This results in the saving of a great deal of time when two or more workmen want to get the dispatcher's office immediately.

**Loud Ringing Devices.**—In many institutions a great need is felt for loud ringing devices to operate regularly with the telephone. To give this service a 3-pole alternating current relay is wired in multiple with the regular bell, or if desired, in place of it. The contacts of this relay operate loud-ringing battery bells, lamps, 110-volt horns or bells, and in some cases air whistles. Many combinations have been used.

**Selective Two-party Line.**—The *P.A.X.* can furnish selective two-party line service by the simple scheme already shown in Fig. 159. This scheme furnishes no ring back between the two telephones, however, buzzers can be used. Although in a great many cases this divided party-line scheme is used between telephones in the same room, particularly where it is desirable that the incoming calls be distributed.

### 2. CONFERENCE ARRANGEMENT

To facilitate the close supervision required in a large organization the conference arrangement has been developed. This service enables several department heads or foreman to get in on the same line at the same time. This allows them all of the advantages of the conference table, without requiring them to leave their desks.

To give conference service some number, for instance 50, is designated as the conference number, the corresponding line switch will be removed and an impedance coil will be bridged across the line contacts. (See Fig. 161.) In addition the private multiple associated with line 50 is opened between each connector bank, and a 1200-ohm coil is bridged from each private contact to negative battery. We can now call the various departments and instruct them to dial the conference number. As each department calls the conference number his connector will come to rest with its wipers in engagement with line 50, following which the ring will be cut off by the impedance coil. The number that can get in on the conference is only limited by the number of connectors.

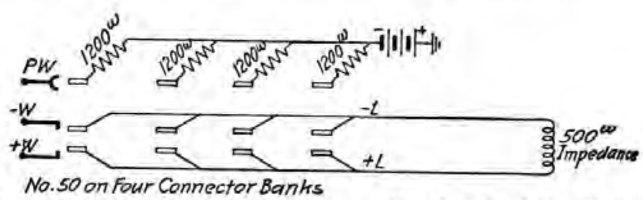



FIG. 161.—Conference connection. One-hundred-line *P.A.X.*

Two competing newspapers in Indianapolis, Indiana, use the conference feature of the *P.A.X.* to facilitate the handling of important news from the state capitol.

From each *P.A.X.* (Fig. 162) there are lines and special stations in the press rooms on the assembly and senate sides of the State House. The reporters who are detailed to state-house duty can call any department of their paper by dialing two digits, and they in turn can be called just as any other station on the newspaper's *P.A.X.*

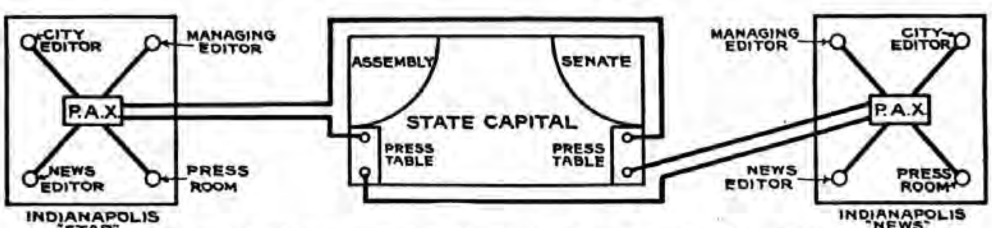



Diagram showing conference calling feature of Indianapolis newspapers' P. A. X.'s.

FIG. 162.—Conference calling feature of Indianapolis newspapers.

Whenever anything of exceptional importance occurs at the Capitol, especially during legislative sessions, the reporter of either paper can get his editor in three or four seconds and explain the circumstances. If the conditions warrant it, the city editor can summon a telephone conference at once. He calls the managing editor, the news editor, and the press-room foreman and asks them to come in on the conference line. Here all of them, including the reporter at the Capitol building, discuss the matter and decide within two or three minutes whether a special edition is advisable. This saves from 15 minutes to half an hour in determining what to do.

### 3. CODE CALL SYSTEM

It is of prime importance to make it possible to reach every man over the *P.A.X.* But in many establishments, those most frequently consulted over the telephone find it most necessary to be away from their desks most of the time. To meet this condition the code call has been developed. Failing to reach a man at his desk, the person calling simply disconnects, dials the code number, and immediately the man sought hears the summons; going to the nearest *P.A.X.* telephone, he dials the answering number and is connected direct with the man wanting him. The flexibility of the code call is so great that it can be applied to one or many buildings.

### 4. WATCHMAN'S SERVICE

The Watchman's Service furnished through the *P.A.X.* switches and telephones is a complete reporting and checking system, and in addition to the standard *P.A.X.* equipment requires only a recording clock and an annunciator. With it the chief or supervisor is in constant touch with all the watchmen wherever they may be. As the watchmen make their rounds, they report by momentarily lifting the receiver of certain designated telephones. Their reports are made visible (annunciator) as well as recorded (clock), so that the chief in effect follows them on their routes and can reach any or all of them at any time by either a direct call over the telephone or, in an emergency, by means of the code call, which reaches all of them at once. Every telephone is potentially a reporting station, consequently the daily routes can be changed to suit the conditions of the plant. For instance, the storage of valuable or dangerous material in some unusual place for one or two nights can be covered and reported on by rerouting the nearest man to include the telephone at the storage point.

When the watchman momentarily lifts the receivers of designated telephones while making their rounds, the corresponding annunciator drop falls, thus affording a check on the location of the watchman. At the same time the associated magnet in the clock operates to pierce a hole in the paper chart which is rotated by the clock. The position of this hole associates it with the magnet operating and also with the time of operation, thus affording a permanent record of the watchman's report. The annunciator cabinet consists of annunciators which stay operated until reset by a push-button which operates all annunciators in series, each annunciator having two coils, one to operate, wound to 250-ohms, and one to reset, which is of low resistance as it operates in series with all the others.

At the left of Fig. 163 will be found three relays representing the line relays of three-line switches. When a given line relay operates it closes a circuit through its associated pull-down winding in the usual manner, the operating winding of an annunciator and a clock magnet are in parallel with this pull-down winding, and will operate at the same time. The line relay will close the circuit for an instant only, therefore the operation of the perforator will not interfere with the rotation of the clock disk.

The supervisor's office or "gate house" is supplied with a regular telephone, number 22 for instance, and the special line number 11. This 11 telephone is not equipped with a calling device, the associated

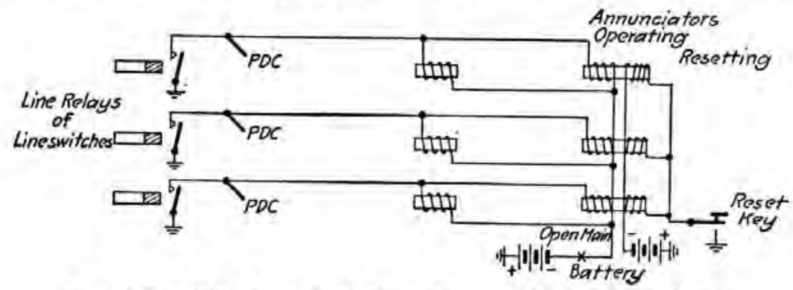



FIG. 163.—Watchman's clock and annunciator connections.

line switch is removed and the private multiple opened between each connector bank. Each private contact is now connected through a 1200-ohm coil to negative battery. From the foregoing it is evident that several persons (depending upon the number of connectors) can get in on line 11 at the same time. The use of this device in an emergency will be discussed later.

The telephone line 22 (as shown in Fig. 164) passes through a key by means of which the telephone instrument may be removed from line

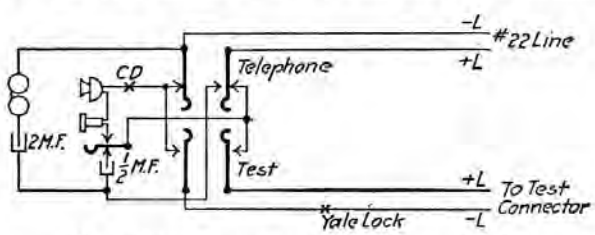



FIG. 164.—Supervisor's telephone circuit.

22 and connected to a test connector. This enables the supervisory watchman to cut in on any line in the plant, even though it is busy. The ringer remains across line 22 at all times, therefore an incoming call will be audiable even though the supervisor is using the test connector at the time. Because of the half *M.F.* condenser, the bell rings noticeably weaker in one case than in the other.

It is quite probable that there will be certain lines to which the supervisor should not have access. In such cases lines will not appear on the banks of the test connector. It is customary to indicate these restricted lines by a certain designation on the associated annunciator panel. A further restriction may be imposed by an executive operating the Yale cut-out lock, which opens up the circuit to the test connector.

It may be noted that the clock is not a watchman's service, it is simply a check on the supervisor. The clock and Yale cut-out lock are usually mounted in the office of some executive. A dictograph transmitter is usually placed in the annunciator cabinet so that the executive can pick it up from any telephone (the number being known only to himself) and thereby hear everything going on in the gate house.

Many times it is not desirable to have a watchman enter a private office to report, in which case the line may be extended to a push-button outside the door. With certain lines are also associated small open jacks by means of which the watchman can use small pocket telephones for reporting, etc. This is especially desirable in some plants for the use of plain clothes men.

The watchman's system in combination with the code-call equipment is very complete. The watchmen report by simply lifting the telephone receivers, pushing the buttons or inserting pocket telephones into jacks which throws up the annunciator in the gate house and also operates the clock. If the watchman desires to talk with the gate house (and he is required to do this at certain intervals) he simply strikes the receiver hook twice connects him with the 11 telephone. If the supervisor is answering a party, the second party who might try to get in at the same time will land in on his ear with a decided click. If he has answered some one and restored his receiver, and they have not hung up, the second call will ring his bell and will also sound in the receivers of all parties in connection with him. This makes a very complete and desirable operation.

If the supervisor should want to get all of his watchmen together, or those in a certain department, he can do so by means of the code call, the watchmen answering in on the 11 telephone. He can see them coming first by his annunciator, and can immediately decide whether or not he wants that particular man, as the annunciator gives him the location of the calling watchman. In small plants that do not have a supervising watchman the code call is invaluable for should there be only two watchmen in the whole plant they can immediately find each other.

### 5. FIRE ALARM SYSTEM

Regular telephones have proven to be in many cases the best fire-reporting system, because valuable information besides the mere location can be given to the fire fighters.

The code-call system gives as one of its functions a very excellent fire-reporting alarm. The ordinary fire box merely gives the location of the person who is reporting the fire. The fire itself may be at a very different place. By the code-call arrangement, full information can be exchanged between those who are interested.

The fire-alarm service consists of designating some number, usually 99, as the fire alarm. This number is arranged the same as the 11 telephone in the gate house, except that instead of having a telephone across it, it has a high-voltage relay which operates the general fire signal. This signal should have no connection whatever with the code-call signals.

When 99 is called the general fire alarm is sounded, which is a notice that all unimportant telephoning must cease at once so as to release the switches for certain officials whose duty it is to come in on 99 and listen

Fig. 165.—Fire and police box.

to the man reporting the fire to the supervisor. The supervisor came in on 99 by means of his test distributer the instant the alarm was sounded. The officials hear the report of the fire and in conference decide what steps are to be taken, and if it is to be kept a still alarm or the location given to every one in the plant. The supervisor then pulls the proper code on his code-call equipment (the general fire alarm having ceased because everyone who was in on the conference has hung up) and notifies everyone of the location of the fire. On cards placed throughout the departments are sketches of the plant, each subdivision bearing a number. If, after the general fire alarm has sounded, the code 53 is rung on the code call it indicates that the fire is on the third floor of building number 5.

During the course of the fire the 11 telephone is always open for everyone to reach the supervisor, the code call to reach individual officials and the 99 number to call all of the principals together for a conference. During the course of the fire the supervisor can pull other signals on the code call which will notify everyone of the progress of the fire in another direction. He can also use his code call to notify the proper persons for arranging to clear certain sections of the plant.

**Special Fire Alarm and Police Box.**—A special fire and police box has been developed in connection with *P.A.X.* systems. In Fig. 165 is shown two trip boxes, one marked "fire" and the other "police." Associated with this box is a musolophone with a horn and a dictagraph transmitter. On breaking the glass in the fire-trip box, it automatically sets up a connection with the 11 telephone, in the gate house. On turning the key on the police-trip box the door swings down and automatically sets up a connection with police headquarters. Each box also sends in a code which will record the number of the box. As soon as the mechanism in the trip box comes to the end of the stroke it cuts in the musolophone and dictagraph transmitter so that it is then possible for the man at headquarters to hold a conversation with the party at the box, the transmission being commercial within a radius of ten feet. A howl may be set up in the horn which can be used to call a person to the box.

### 6. EMERGENCY SERVICE

Industrial plants are subject to happenings other than fire which are classed as emergencies. It may be the breaking of a dam, the general failure of power lines—anything which calls for prompt, concerted action directed by those in authority who are best able to lead in actions which are out of the regular routine.

For this emergency alarm service, some number like 99 or 999 is arranged the same way as the "11" telephone in the gate house, except that instead of having a telephone across it, there is a high-voltage relay which operates the general signal. This signal should have no connection whatever with the code-call signals. In one plant it is a big steamboat whistle.

Red cards are posted throughout the plant stating that whenever the emergency signal is heard, all unimportant telephoning must cease at once, so as to relieve the switches for certain officials whose names are given on the card. These names are usually limited to eight or ten, although the only limit is the number of selectors or connectors which handle the traffic.

When any person becomes aware of a condition which justifies the use of the emergency alarm, he goes to any *P.A.X.* telephone and calls the general alarm number. When the signal sounds, the gate-house man or some other designated person, gets in on the alarm line and receives the report of the man who sent in the call. At the same time, all the officials mentioned on the red card who hear the signal call go to the nearest telephone and dial the alarm number, thereby getting in on the same line with the gate-house man and the person who reported the trouble. They at once have a conference as to the steps to be taken. It gives the men at the head of affairs the chance to know what is going on and to safeguard the business.

When those on the emergency line hang up their receivers and release the general signal stops.

### 7. CREDIT SYSTEM

The *P.A.X.* affords a very satisfactory means of asking for and transmitting information concerning credit in department stores and other mercantile establishments. When organizing a credit system as many clerks are provided as may be needed to handle the traffic. Each clerk is assigned the credits relating to certain positions of the alphabet. On each credit desk is provided a set of lamps and keys. Instructions similar to the following are given to all sales people:

For credits A to H dial 6.
For credit I to M dial 7.
For credit N to Z dial 8.

A Mr. Kenyon purchases a bill of goods and requests credit, the store clerk removes the receiver, dials 7, and is connected with the credit clerk who handles credits under the letter K. Ten trunks may be provided to each desk, connections may be held and the credit clerk may ring back when information is ready. Should Mr. Kenyon pass on to another department and again ask for credit, the store clerk will dial 7 and be connected with the credit clerk who handled the previous call.

Sometimes the head of the credit department wants to give all the credit clerks immediate and simultaneous instructions. In one case there were nineteen of these clerks, and time is an important matter. A spare number on the *P.A.X.* is run to a line which goes to the desks of all these clerks, each having a key by means of which they can get in on that line. Across the line is a relay which gives a signal to the clerks (green lamps or buzzers). The head of the credit department dials the number and the clerks switch over to the instruction line, leaving their bells on their regular lines for incoming calls.

### 8. SECRET LISTENING SERVICE

In treating of the watchmen's service, mention was made of a dictograph transmitter placed in the annunciator cabinet, so that the chief can by calling a secret number be connected to it and hear all that is going on there. This same idea may be carried out wherever desired. The transmitter is very sensitive and will pick up conversations in the average tone of voice within the ordinary room. The transmitter is located according to the conditions.

It is sometimes desirable for a head executive to know what is going on over the telephone lines. Such a case is met by providing him with a switch arranged to cut in on any line regardless of the busy test. The connection is arranged to come in quietly, so that those on the line being monitored are not aware of it.

If an executive receives a telephone call from a person and the conversation takes such a turn that he feels the need of a witness, he can by a secret signal (buzzer, etc.) have his private secretary come in on the line by the monitor switch and take down in shorthand the conversation which occurs. The same restricted monitoring can be had without the switch by using a tap taken off the telephone line.

### 9. DICTATION SERVICE

It is a frequent occurrence for a man who is out somewhere in the plant to call up his own office and dictate letters or memoranda over the telephone.

Another form of dictation service has been used in connection with the Edison phonograph. It has to do with incoming calls during the absence of the owner of the telephone.

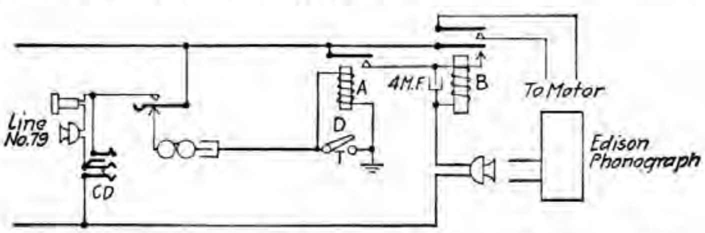



FIG. 166.—Phonograph to answer a telephone call (circuit).

*First*, there is a phonograph on which is recorded the record which it is desired that the calling person shall hear. It may be, say that the manager is out and will return after lunch, or it may direct that the caller dial another number and leave a meassage with some one else.

*Second*, there is another phonograph arranged to receive a message from the telephone which is calling.

In furnishing the dictating service Edison machines are used. These are standard machines and are not changed in any way. A standard telephone transmitter is mounted adjacent to the transcribing head of the machine, while a series receiver is mounted before the receiving head of the machine. In connection with the executive's telephone number 79, shown in Fig. 166, is a two-point switch marked *D-T*. The switch is normally in the *T* position, when the executive leaves his office he turns the switch to the *D* position. This removes the short circuit from relay *A*, and should a call come in, the first impulse of ringing current will operate this relay. Relay *A* closes the circuit of relay *B*, relay *B*, upon energizing locks its self up across the line and starts the Edison motor. The transmitter will now reproduce in the telephone circuit the words spoken into it by the transcribing head of the Edison machine.

The message on the record may be a standard form saying the executive is out, and requesting the calling party to call the dictating number, or it may be a special message left by the executive. The equipment for the dictating number 77 is shown in Fig. 167. When this number is called, relay *A* operates and closes the circuit of the Edison machine. The series receiver transfers the dictated words from the telephone circuit to the receiving head of the machine. A set of springs are mounted in place of the bell on the Edison machine so that when it comes to the end of a record a buzzer will operate which will indicate to

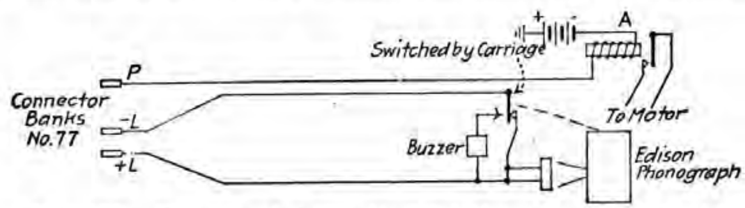



FIG. 167.—Phonograph to receive a telephone message (circuit).

those seated near the machine that a new record is needed, this buzzer produces a tone on the line which advises the person dictating of the fact that the record is completely filled.

## 10. MISCELLANEOUS SERVICES

An electrical house which sells lamps, fixtures, etc., has a private automatic exchange with a number of vacant call numbers. They also have about 30 demonstration lamps, chandeliers, etc., which they desire from time to time to light for the benefit of customers. They arranged it so that a relay on each of these vacant lines could be made to pull up and light one of the demonstration lamps. In this way, from any automatic telephone, the salesman could show off his wares.

This is an example of things which users of the *P.A.X.* have put upon it without in the least interfering with its intended major services. Others have used a spare number to operate an electric door opener. It is beyond the function of this book to enumerate more services—they can be thought out and applied whenever the need arises.

## CONNECTIONS TO PUBLIC TELEPHONE SYSTEM

There are many conditions under which it is desirable to have trunk connections between the private automatic exchange and the public system. It then becomes an automatic private branch exchange. Three considerations require attention, whether the public exchange is manual or automatic, the use of an attendant to supervise incoming and outgoing calls, and the handling of toll or long distance calls. We will first assume that the public exchange is automatic.

**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 III 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. 168. As already indicated, the lineswitch circuit is of the usual type with the exception of the resistance coil

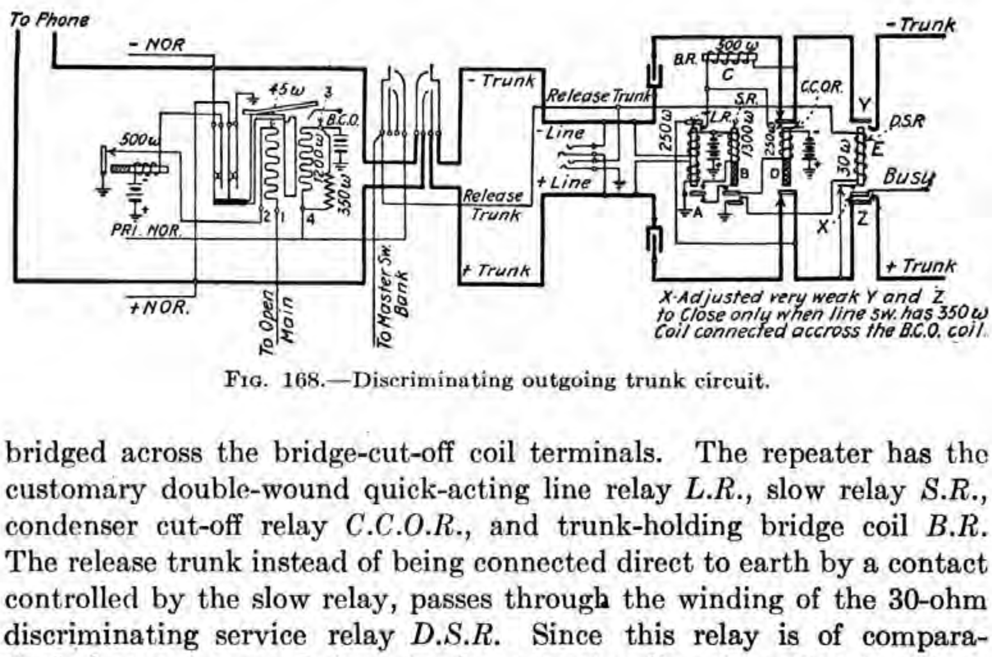



FIG. 168.—Discriminating outgoing trunk circuit.

bridged across the bridge-cut-off coil terminals. The repeater has the customary double-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 lineswitch 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 bus bar 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 ½ 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. 169. 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 lineswitch, 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 signaling 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 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 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 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.

**Night Calls.**—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

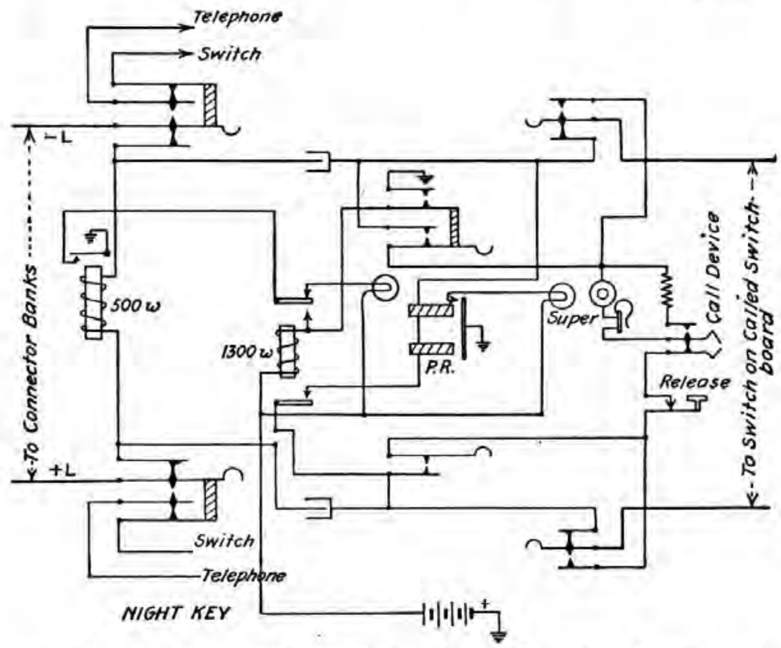



FIG. 169.—Circuit through an automatic *P.B.X.* attendant's cabinet (non-secret).

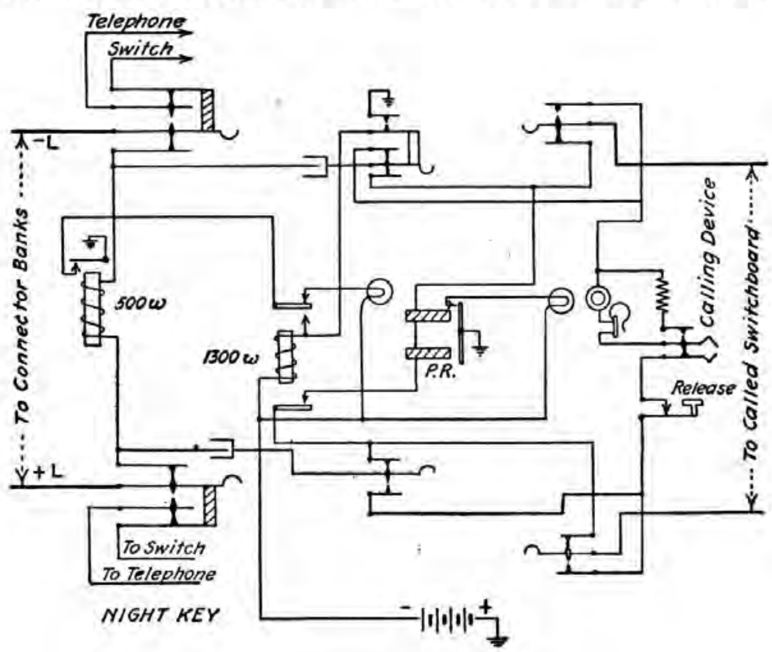



FIG. 170.—Circuit through an automatic *P.B.X.* attendant's cabinet (secret).

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. 169, is shown in Fig. 170. 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.

In many cases one telephone for night service is not enough. There may be no one near it all the time, although there may be a watchman who is making the rounds of the building all night. This watchman can be reached by running a line of call bells so as to get the sound to all places where he will be. The night key, shown in Figs. 169 and 170, is arranged to switch the incoming line to this night-call circuit. A vacant number on a connector bank is wired to this circuit. If during the night a call comes in, it is diverted from the attendant's telephone to the night-call circuit and rings all the bells. The watchman hearing the bells, goes to the nearest telephone, dials the answering number (this stops the bells) and answers the caller from outside.

**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. 171 so that the double 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 attendant they call the number which appears in the directory as that of the information clerk and thus secure connection to an incoming trunk terminating in a circuit like that shown in Fig. 169 or 170 in the attendant'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.

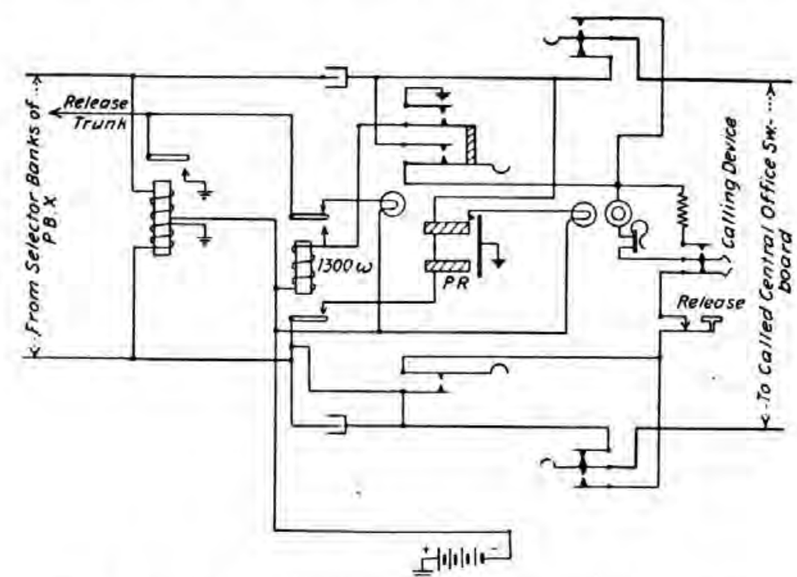



Fig. 171.—Outgoing trunk circuit through attendant's cabinet.

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 speciality 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 sub-offices rather than that used in regular automatic private branch exchanges and that using the sub-office type of apparatus facilitates central 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.

**Connections to Manual Public Exchange.**—When the public exchange is manual, the trunks to a private automatic exchange become somewhat more complicated because of the introduction of the operator at the public switchboard. It is, of course, possible to let these trunks be in reality subscriber lines as far as the *P.A.X.* is concerned, and to let the operators in the public exchange dial the numbers in the *P.A.X.* directly. But for operating reasons, and for the sake of a certain amount of control over incoming calls to the *P.A.X.* it is customary to have an attendant at the *P.A.X.*

Provision must be made for supervision of the call by the public exchange operator, for answering by the *P.A.X.* attendant, for dialing calls into the *P.A.X.* by the attendant, and usually for using the same trunks for calls *to* the public exchange as well.

The circuits shown in Fig. 172 are arranged for a three-digit *P.A.X.* which trunks to a Kellogg two-wire switchboard. A call from the manual board to the automatic board is intercepted by the attendant who extends it into the *P.A.X.* by means of a calling device. The manual operator controls the release and gets the usual supervision.

Calls from the *P.A.X.* to the public system are dialed through the selectors only, one level being set aside for it. The public exchange operator gets a line-lamp signal, plugs into the jack, and receives the number from the subscriber. The seizure of the trunk by the selector gives a busy signal to the attendant. The *P.A.X.* subscriber controls the release of the connection, and the manual operator gets a disconnect signal.

**Manual to Private Automatic Exchange.**—The public exchange operator plugs into the trunk jack. This reverses the polarity of battery on the trunk and operates the 12,000-ohm polar relay *P* which is normally across the trunk at the *P.A.X.* Relay *P* operates relay *C*, which grounds the private wire of the trunk coming from selector banks, and displays the visual busy signal.

The operator rings on the trunk as usual. This operates *A.C.* relay

*D*, which lights the line lamp on the attendant's cabinet and causes relay *H* to lock itself to ground at relay *C*.

The *P.A.X.* attendant answers by throwing the listening key on the trunk. This grounds the operating wire to the incoming selector so as to prepare it for dialing. Relay *E* operates and locks itself to ground at relay *C*, puts out the line lamp, releases relay *H*, and cuts off relay *D* across the line. At the same time polar relay *Q* (500-ohms) is connected across the trunk, to give supervision to the manual operator. Polar relay *P* may fall back, because relay *Q* will hold a ground on the same wire.

After the attendant has received the information and decided whom to dial, she throws her key over the dialing position (marked *C.D.*) This cuts off the trunk from manual and connects the attendant to the incoming selector with the calling device inserted in the operating wire. The connection is dialed up over an operating wire which is switched to the connector. The talking wires are clear from the battery feed in the trunk (relay *F*) to the called telephone. When the attendant gets the person or department desired, she restores her key to normal and conversation proceeds.

The lamp marked "*Supy*" on the trunk burns until the called subscriber answers, when it goes out. After that there is no local supervision, the public operator getting it by the bridging of polar relay *Q*.

As long as the plug is in the jack, polar relay *P* or *Q* will hold the connection. But when the operator pulls out the plug at the end of conversation, the reversal of battery on the trunk causes the polar relay to reverse, which lets relay *C* fall back, which takes ground off relay *E* and the operating wire to the incoming selector. Then the automatic switches release.

*P. A. X. to Manual.*—The subscriber dials one digit, which puts the wipers of the selector onto the out-trunk level. Current is at once drawn by the calling telephone through relay *B*, which operates relay *L*, causing it to ground the release trunk to hold the connection. Relay *L* pulls up relay *M*, which operates the busy visual signal, so that the attendant will know that this trunk is busy. Relay *B* also connects polar relay *Q* across the line and closes the talking circuit through the condensers.

The 500-ohm path through relay *Q* operates the line signal in the central office. The operator plugs into the jack as usual. This reverses the battery on the trunk and pulls up relay *Q*, but it does nothing at this time.

The number is passed to the operator, who completes the connection in the usual manual manner.

When the conversation is ended, the *P.A.X.* subscriber hangs up his receiver. Relay *B* falls back, cutting off relay *Q* and thus giving the disconnect signal to the operator. Relays $L$ and $M$ now fall back and release the selector and restore the busy visual signal.

There is only one mode of operation as far as the *P.A.X.* subscriber is concerned—if he hangs up his receiver, the connection releases. This is true if he makes an automatic call, and if he makes a manual call.

**Restricted Service to Public Exchange.**—If it is desired that not all of the stations in a *P.A.X.* shall be permitted to call out into the public system, it may be accomplished by causing the rotary magnet of the selector to depend (at a certain level) on a ground carried from the lineswitch of the calling telephone. Those telephones which are permitted to call out are equipped with this ground, the others are not.

Figure 173 shows a selector and a lineswitch arranged for this service. It is assumed that the lineswitch is that of a favored telephone and therefore has the ground marked "$M$."

The selector is equipped with a set of springs marked "$X$" which are set in relation to the wiper shaft so as to be operated when the wipers are at the out trunking level (level ten, for example). At this level the ground which otherwise would go through the off normal springs, front contact of relay $B$ and back contact of relay $C$ to the rotary magnet is cut off and a busy tone sent through the ground winding of the line relay $A$ to the calling subscriber.

Since this lineswitch has the ground $M$, the rotary magnet will use it and cut in on the level. The busy tone will be cut off when a trunk is found, so quickly that the subscriber is ordinarily not aware of it.

Telephones whose lineswitches have no ground $M$ can call all other levels, for the springs $X$ are not operated. But if they attempt to call level ten, the opening of the ground at springs $X$ prevents rotation, and the busy tone is left on until the calling subscriber hangs up.

**Night Calls.**—The night key (Fig. 172) is used to switch a trunk to one designated night telephone. This telephone may be one used for regular service during the day, and can not be said to differ from others. But when the night key is thrown, it will receive calls over this trunk, though it can make calls the same as during the day.

The night key cuts off the line lamp on the trunk in the *P.A.X.*, prepares the ring side of the line through the supervisory relay $J$, and connects relay $K$ to the private normal wire which runs to the *BCO* of the lineswitch which belongs to the night telephone.

When the operator plugs in to make a night call, the battery reversal on the trunk operates relay $P$, which pulls up relay $C$ to busy the selector bank, and pulls up relay $A$ which switches the night telephone from its lineswitch to the trunk. The operator then rings the station as usual.

When the night telephone answers, it operates relay $J$, which grounds relay $C$, because relay $P$ (12,000-ohms) will fall back. Supervision to the manual board is direct.

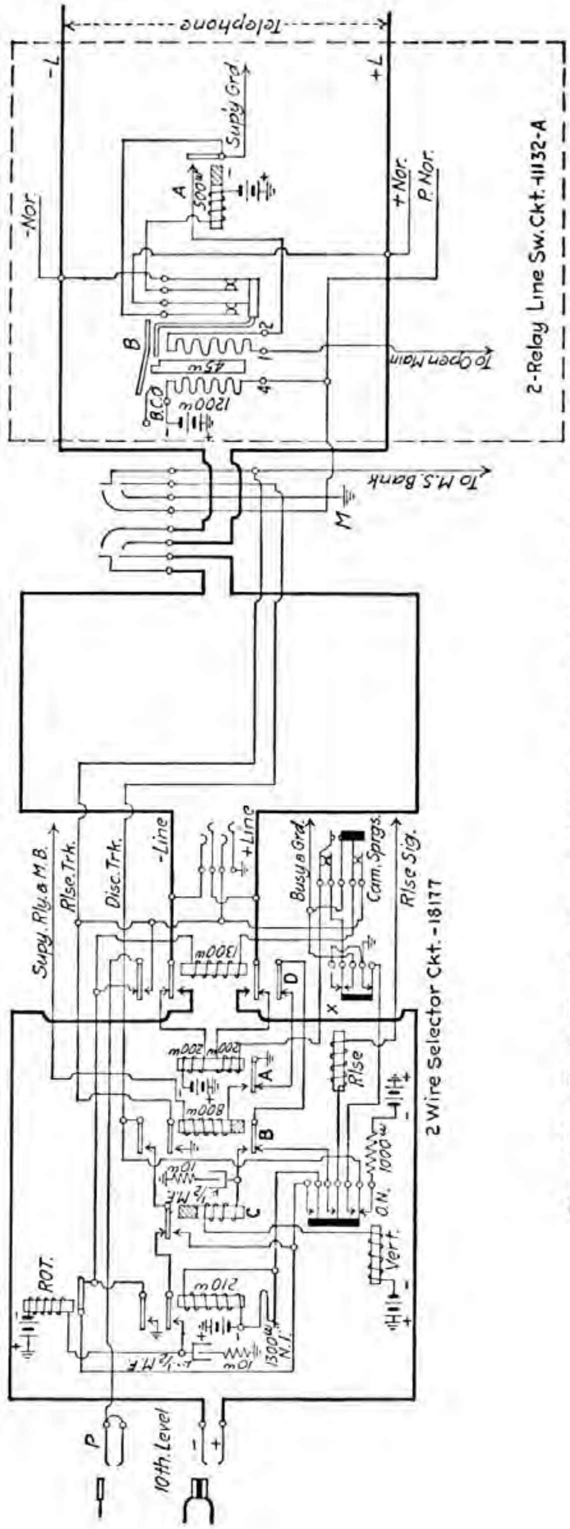



FIG. 173.—P. A. X. selector and lineswitch arranged for discriminating service.

$\frac{C^2}{E_T} = \frac{1}{M}$

If the night telephone initiates a call, the lineswitch grounds the private normal wire *PN* which operates relay *K*. The latter cuts off relay *A* to insure the circuit against being cut off.

If during the time that the night telephone is calling, the operator in the public exchange calls the *P.A.X.*, relay *P* will operate relay *C*, which in turn gives relay *N* a chance to operate periodically through the contacts of the interrupter *Intr.* This gives a busy tone to the operator, showing that the line is busy.

*Toll Connections to P.A.X.*—If the public exchange is manual, the toll connection is set up by the toll operator in much the same way as a local call is handled. The trunk conditions can be arranged so as to give ample transmission. If the public exchange is automatic, it is best to control the switches over a third wire, so as to leave the two line wires free for talking.

Figure 174 shows a complete typical set of circuits for toll and local calls, with the circuits in the main exchange outlined. If we trace a call from a toll operator to a *P.A.X.* subscriber it will show the operation of the circuits and open the way for further study by the reader.

When the toll operator plugs into the trunk jack, she seizes the first selector over the sleeve of the circuit, and dials the connection through. The toll third selector has a repeating coil, and in the case of a multi-office public exchange is located in the office to which the *P.A.X.* is tributary. The operating wire terminates in an operating delay *OpRy* in the third selector. The connection passes through a repeater, in which the impulses are repeated again by another operating relay, *OpRy*. This repeater is arranged for two-way service. Calls from the *P.A.X.* to the public exchange pass through to the lineswitch. When the repeater seizes the trunk in obedience to the toll operator's dialing, the repeater places ground on the private wire *P* of the lineswitch, operating the *BCO* and cutting off the line relay and ground of the lineswitch.

The repeater is seizing the runk to the *P.A.X.* grounds the operating trunk wire, which pulls up the operating and holding relays of the incoming selector in the *P.A.X.* They busy the trunk from the local selectors (marked "10th" level) and operate the visual busy signal on the attendant's cabinet.

The last three figures of the call number are then dialed by the toll operator, the impulsing being done over the operating trunk as before.

If the called line is not busy, the incoming connector will go to the third position and extend the talking wires through to the called telephone. From the repeating coil in the toll third selector to the telephone there is no bridge or break except the two condensers and feed relay *G* in the incoming selector.

When the incoming connector goes into the third position, battery from the busy common is placed back on the negative line for an instant, because relay $D$ is slow acting. This pulls up and locks relay $H$ on the incoming selector. Relay $F$ on the selector also pulls up and locks when the switch goes off normal by means of the ground on the ring through trunk.

When the toll operator rings out on this connection, ringing current is sent through the condensers of the incoming selector to the called telephone, ringing the bell.

When the called person answers, relay $G$ of the incoming selector pulls up and short circuits the condensers and at the same time the line relay $LR$ in the toll third selector pulls up and gives the toll operator supervision. Current supply to the *P.A.X.* telephone is double—the relay $G$ of incoming selector in parallel with the line relay $LR$ of the toll 3d selector.

The incoming selector in stepping off normal on this call grounds the supervisory trunk which lights the supervisory lamp on the attendant's cabinet. When the called party answers, this light goes out. It will follow the hook the same as the supervisory lamp on the toll board so that both the toll operator and the *P.A.X.* attendant have supervision. If it is desired not to have the attendant's lamp show until the called station has answered and hung up again, it may be secured by disconnecting the battery from the back contact of relay $A$ in the attendant's cabinet.

The toll operator releases the connection by pulling the plug out of the jack. The removal of ground from the operating trunk causes the operating relays in succession to fall back and to release the section of the connection for which they are responsible.

If the called line is busy on the call which we have been considering, the busy tone and negative battery will be placed back on the positive line at the busy relay $E$ of the incoming connector, which will result in giving the toll operator a busy tone and the supervisory lamp. If the toll operator leaves the connection up, when the line becomes idle the connector will move to the third position and extend the lines as explained before. The operator's supervisory lamp now burns, showing her that she may ring the called line.

If the called subscriber desires to signal the attendant to get the call switched or otherwise changed, he can operate the hook, which will flash the attendant's supervisory lamp. The attendant can answer by the listening key, release the incoming selector and connector, with the "release in" key, and dial up another local station by the "*C.D.* in" key and the calling device. In this case the *P.A.X.* station will be rung periodically automatically. But after this second party has answered and hung up again, he can only be rung by the toll operator at or.

When the attendant uses the "*C.D.* in" key for dialing, the impulses pass over the operating trunk with 200 ohms in series. She listens with

a condenser in series with her telephone set. When using the calling-device keys the incoming line is cut off so that she talks to the local station alone.

The "call through" key must be thrown in order that the calls from the outside may go through uninterrupted. This gives negative battery to relay *E* of the incoming selector so that it can rotate when it arrives at the desired level.

If it is desired to stop all calls coming in, the "call through" key is left at normal. Suppose that in this condition a call comes in from outside. As soon as the incoming selector shaft steps off normal, the ground that ordinarily operates the interrupter relay *E* now operates relay *C* in the attendant's cabinet and lights the answering lamp. Relay *E* in the selector does not operate and the shaft does not rotate at all. The call can go no farther. The operator can answer by using the listening key, and extend the call by the "*C.D* in" key and calling device. The 5000-ohm resistance coil in the attendant's circuit is to furnish a return path for the busy tone when the "*C.D.* in" key is thrown.

The toll operator can call the attendant by dialing a level on the incoming selector which is set aside for this purpose. The *P*-2 contacts of this level are all grounded so that the switch will rotate off the bank and open the switching relay, *D*. At this level a set of springs marked "10th level" operate and put relay *C* of the attendant's cabinet across the line with a condenser in series. When the toll operator rings, relay *C* operates and gives the signal. The attendant answers with the listening key, which puts out the lamp, and places a 500-ohm bridge across the trunk which is locked there until the call is extended or answered, or if the call is not answered, until the toll operator releases. This bridge is locked across the trunk so that when the attendant answers a toll call, supervision will be given to the toll operator as soon as the call is answered and held until the *P.A.X.* station has been dialed, answers, and then hangs up.

This same trunk handles calls from the public automatic exchange as well as toll calls. The local selectors come to the repeater in a different way, and the repeater automatically furnishes the ringing current, operates a quick-ring cut-off, reverses battery back to the switches behind it, and in general acts as the meeting point.

# CHAPTER VII

## 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.

The money spent for sub-station meters or coin boxes would produce a better effect if invested in additional switches at the central office. The cost of 5000 coin boxes will buy about 1400 additional selectors, which would double the number of selectors in the average 5000-line office. The cost of central office meters for 5000 lines will buy about 680 additional selectors. This is an increase of 50 per cent in selectors which will carry at least 50 per cent more traffic—perhaps 60 per cent.

It seems to the writers that to induce people to use the telephone freely is a public service of sufficient value and importance to cause the investment of money in traffic-carrying apparatus rather than in that which reduces traffic. It would therefore appear 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 gaging 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.

The automatic telephone system can furnish any kind of measured service which is desirable. There is no engineering obstacle. The use of flat rates or of measured service is entirely a matter of business policy.

Measured service at once divides itself into two classes, credit service and cash service. Credit service requires that the amount of service sold shall be recorded. Cash service imposes the more difficult task of collecting money for the service before the service is rendered. Thus the two requirements vitally affect the design of apparatus.

Individual lines may have the measuring apparatus in the central office or at the sub-station. Party lines require that this apparatus be located at the sub-station.

The following combinations of conditions have been met by devices for use in connection with automatic exchanges.

For credit service we have:

1. Meter at central office, records completed calls.
2. Meter at sub-station, operated by push-button to record completed calls.
3. Meter at sub-station, self-acting, to record completed calls.
4. Meter at sub-station, records time line is used (cumulative time meter).

For cash service we have :

5. Coin box, coin deposited when called station answers, collected at once.
6. Coin box, coin deposited before dialing, collected when the called station answers.
7. Coin box, automatic and manual, local calls free, toll calls cash (audible signal to operator).
8. Coin box, automatic and manual, coin deposited before dialing, collected or returned on release of connection, toll calls cash (audible signal to operator).

**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.

In Fig. 175 is shown a photograph of a lineswitch unit on which the meters are seen mounted in a group above the lineswitches. The mechanical design of the meters is the same as that of those which are widely used in manual practice.

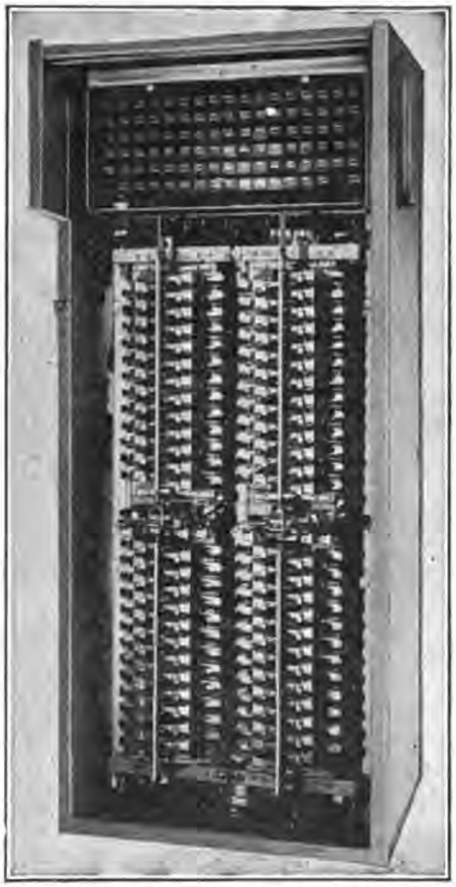


FIG. 175.—Lineswitch unit with meters at top.

A circuit showing a lineswitch with meter is illustrated in Fig. 176. The only difference between the lineswitch 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 lineswitch plunger enters its bank and extends the circuit to a selector 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 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 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 almost 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

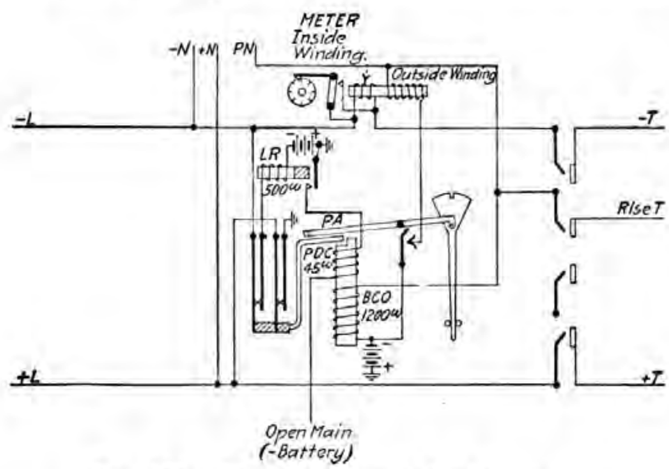



FIG. 176.—Circuit of lineswitch with meter.

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.

If it is desired to place the meters at a distance from the lineswitch boards, grouping them all at one place, a relay takes the place of the meter, but is placed in the trunk circuit. This relay merely closes a single wire circuit leading through the lineswitch bank to the meter itself, which now has only one winding. Thus it requires but one wire per meter from the lineswitch boards to the meter board.

**Push Button Meter at Sub-station.**—This type of meter is essentially a counting device, operated by a push button, with means for requiring the subscriber to register when the called station answers, and safeguards against registering more than once for such a call.

The meter (Fig. 177) has a train of counting wheels whose numerals appear at a rectangular window. A push-button at the lower right hand corner of the box is the subscriber's means of control.

Inside the meter there is the counting mechanism (5 numeral wheels) a group of electrical contact springs, and a polarized electromagnet whose winding is shunted by a condenser.

In normal operation, the subscriber dials the desired number in the usual way. When the called station answers, the connector switch reverses the current fed to the calling line. This energizes the polarized electromagnet in the meter and causes it to close the three contact

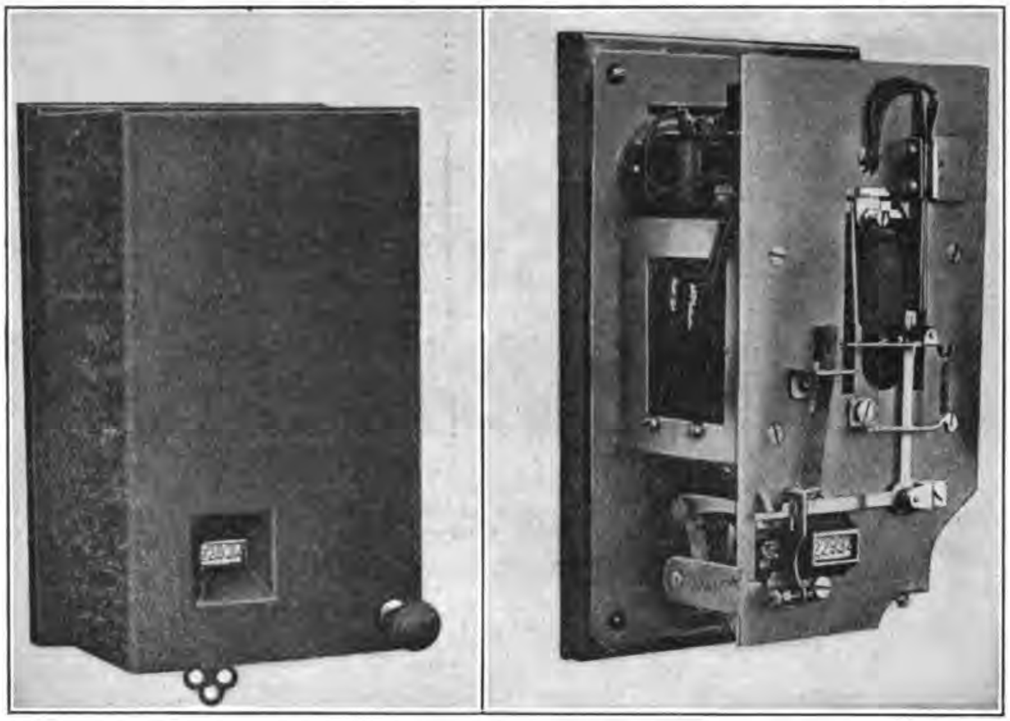


FIG. 177.—A subscriber's push-button meter.

springs. By them a dead short circuit is placed on the transmitter and a low resistance (30-ohms) shunted around the receiver.

The calling subscriber can hear the called party as he answers, but cannot speak to him. Pressing the button moves the counting wheel and frees the three springs. Conversation may now proceed.

If the push button be pressed when the telephone is not in use, no record is made, because normally the pawl which works the recorder is out of place and can not engage the wheel. It requires the movement of the polarized magnet to bring the pawl into line with the wheel, so that the pressing of the button can rotate the number wheel.

When a call has once been recorded, the pawl is again thrown out of line, so that further actuation of the button will have no effect.

All conversations are held through the electromagnet and the condenser. The magnet is wound to 16 ohms and the condenser has two microfarads capacitance.

Free calls do not require registry, because the battery current is not reversed, as was explained above.

This meter requires four wires between itself and the telephone set.

**Self-acting Meter at Sub-station.**—The self-acting meter (Fig. 178) appears like a cylinder with a window at which appear the numbers on the register wheels. It requires four wires to connect it to the telephone set.

The subscriber dials the number as usual. When the called station answers, the reversal of battery current actuates the meter so that the pawl is in a position to move the number wheel when release shall occur. The electromagnet is short circuited during conversation. When release

Fig. 178.

occurs, the apparatus restores itself to normal. In so doing, the pawl turns the number wheel so as to record the call.

In its normal condition the electromagnet is short circuited. When receiving a call, the coil is therefore not in the circuit. If, however, the dial should be turned while the receiver is off the hook, the electromagnet will come into the line in series with the talking apparatus.

On free calls, the electromagnet is in series with the line and conversation must be held through it. Its resistance is 40-ohms, and it is shunted by a half microfarad condenser. Since free calls are never set up over very long distances, the transmission is not much of a factor. On all calls where transmission counts, the coil is short-circuited and therefore does not affect speech.

The user might attempt to avoid registry by momentarily depressing the hook before the called station answers. He would expect by the momentary opening of the line to cause the meter operating magnet to restore the pawl to normal before it had caught the next tooth on the number wheel. This would be successful if it were not for a slow-acting element, which requires that the line be held open long enough to cause release of the switches. The dishonest person soon learns that he obtains nothing by this procedure.

**Cumulative Time Meter at Sub-station.**—The cumulative time meter is essentially a clock controlled by an electromagnet so as to run only while a completed call is held. In appearance it is a rectangular box, with a clock face appearing near the lower end. (Fig. 179.)

There are two varieties. The first counts time only, the second makes an arbitrary charge of one minute at the beginning of each call. The latter is to enable the operating company to collect part of its return in proportion to the number of completed calls, and the rest in proportion to the time of occupation of apparatus.

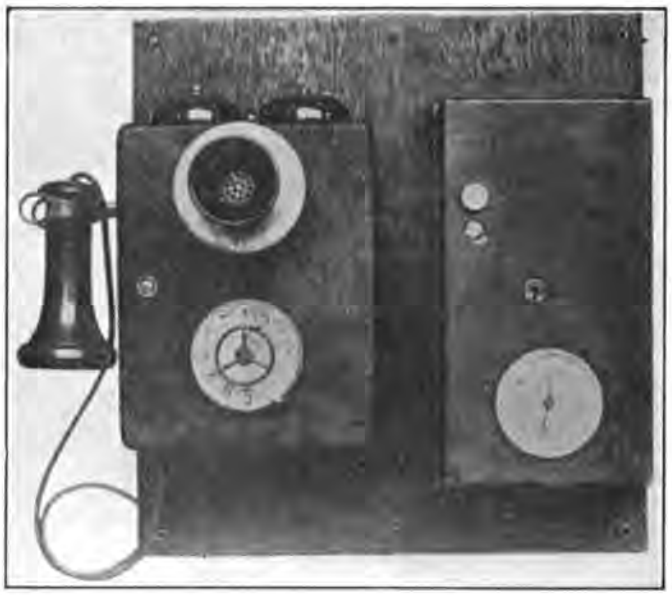


FIG. 179.

When the subscriber takes the receiver from the hook to make a call, it is necessary to turn a knob on the meter box. This takes the short circuit off the calling device. He now dials the call. When the called station answers, the reversal of current actuates a polarized magnet which starts the clock and short-circuits the relay.

If a fixed charge of one minute is made, the electromagnet advances the clock hands one minute at the time of starting.

The clock will run until the calling subscriber hangs up his receiver. Anything that the called party may do will not affect the clock, because the polarized electromagnet is shunted out.

When the calling subscriber hangs up his receiver, the mechanism restores itself to normal, stopping the clock.

Received calls do not disturb the meter and there is no added apparatus through which conversation must be held. Free calls do not affect the clock and conversation must be held through the electromagnet and its shunt.

**Coin Collectors for Subscribers Stations.**—Figure 180 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.

Figure 181 (right) is a diagram of the circuit of this collector in connection with the ordinary two-wire wall telephone. The essential feature

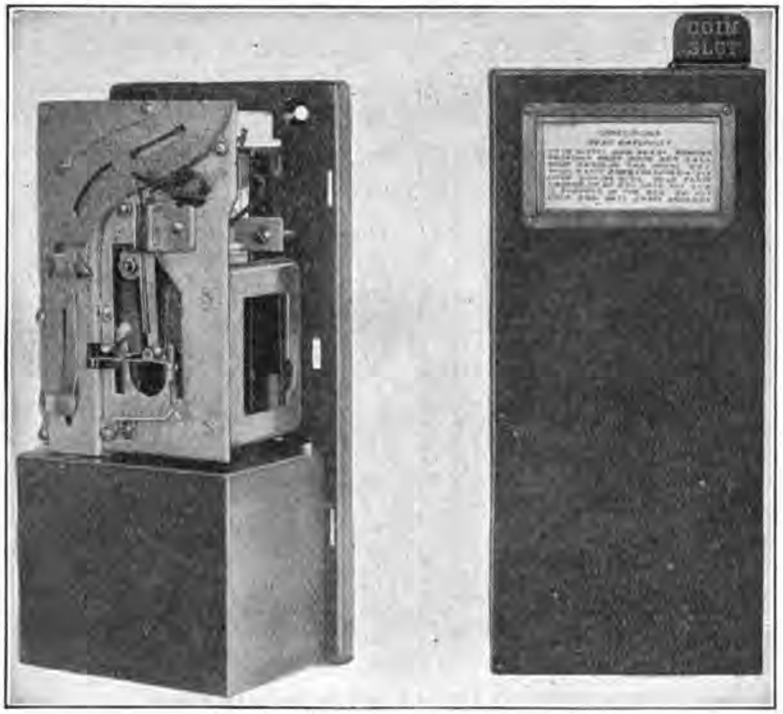



FIG. 180.—Interior and exterior views of automatic coin collector.

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 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

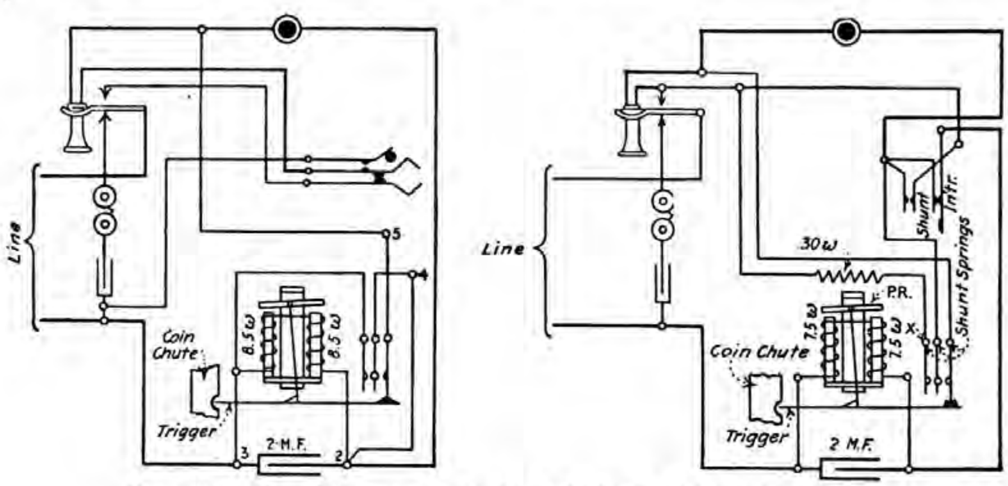



FIG. 181.—Two different circuits of a telephone with a coin collector.

response to the call the calling party is able to hear him but can not talk to him. The calling partly 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.

Figure 181 (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.

**Coin Box, Coin Deposited Before Dialing, Collected on Answer.**—It has been found that sometimes the calling party is a little slow in depositing the coin when the called station answers. This might result in the called subscriber hanging up and causing the calling party to call again. People ought to have the nickel ready and ought to drop it in the slot promptly.

To obviate this apparent difficulty, the coin box (Fig. 180) has been arranged to induce the user to deposit a nickel before dialing, so that it will be ready for instant collection. The coin is held there in plain view, where it can be removed by the subscriber if the called station fails to answer, or if the called line is one to which service is free.

The operation is as follows. The user first places a nickel in the coin slot where it rests. He then dials the number. When the called station answers, the coin box removes the support for the coin, whereupon it drops into the chute, trips the springs, and passes into the cash compartment.

If the coin is not collected, the user recovers it by hand.

Calls can be made without the preliminary deposit of a coin, in which case the payment must be made when the called station answers.

**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. The lines from these pay-station

FIG. 182.—Three-slot coin box telephone.

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 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.

**Coin Box, Automatic and Manual, Local Free, Toll Cash.**—This service requires no electrical connection between the telephone and the coin box. Any desired box is mounted so that its audible signals (bell or gong) will affect the transmitter. More than one type has been used in this way.

Local calls are dialed as if there were no coin box.

To call long distance, the user dials "O" or such other number as is indicated by the directory or information card. The operator may put the call through while the subscriber waits, or may ask for his number and call him when the line is ready. In either case, the operator requests that the coin be deposited, and verifies the correctness of payment by the audible signals.

**Coin Box, Automatic and Manual, Nickel First, Toll Cash.**—This coin telephone (Fig. 182) is built as one unit. Three slots are provided. The deposit of any coin gives a distinctive bell or gong signal and in addition prepares the line for dialing. No coin is necessary to receive a call.

To make a call, a coin is first deposited in the appropriate slot. The number is then dialed as usual. When the called subscriber answers, conversation takes place. When the calling subscriber hangs up to release, the machine drops the coin into the cash compartment.

If the call is unanswered, or is to a telephone for which calls are free, the release action of the subscriber causes the coin to be dropped into the return pocket where he can get it again.

Long distance calls pass through the hands of an operator, who calls for the deposit of the required fee in the usual manner.

# 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 aggrevated 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. 183.

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.

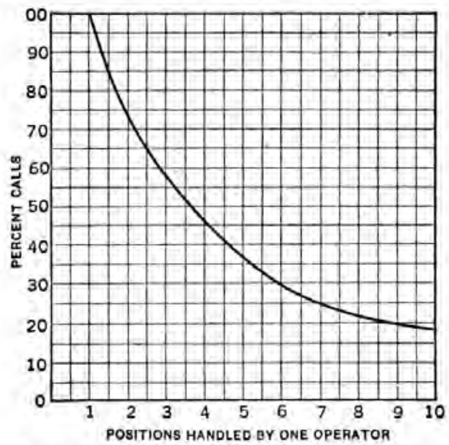



FIG. 183.—Curve showing relative efficiencies of a manual operator covering various numbers of positions.

*Second.*—The busy periods do not occur at exactly the same time on all positions. This causes a further loss in efficiency. Figure 184 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. 305.) These curves clearly indicate that a moderately steady flow of traffic can

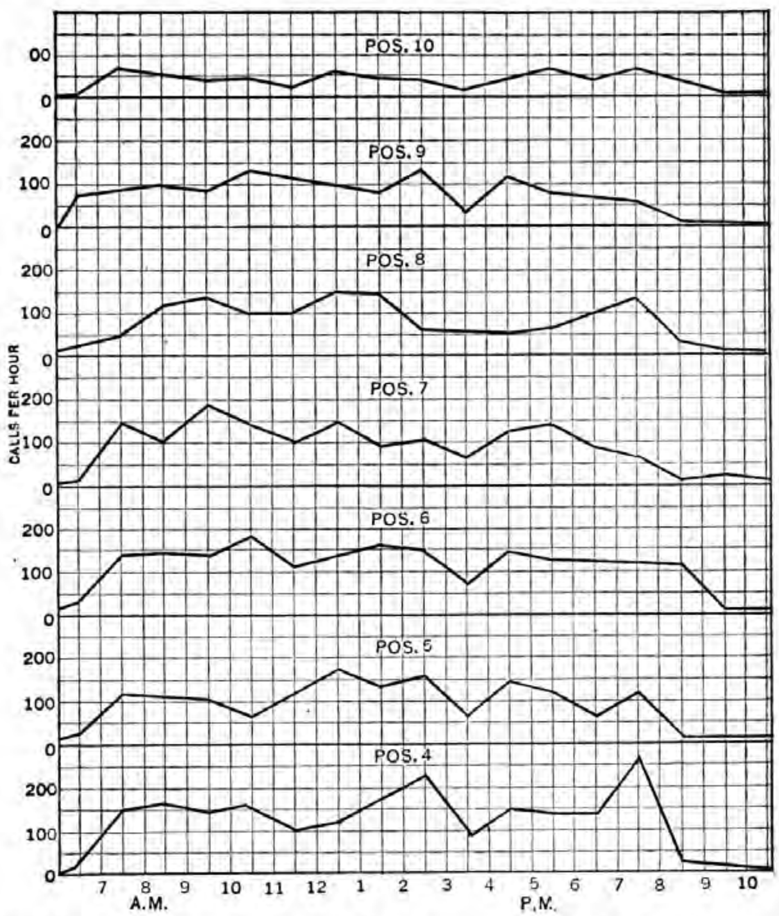



FIG. 184.—Simultaneous load curves of manual switchboard operators' positions.

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. P. V. Christensen, assistant chief engineer of the Copenhagen Telephone Company, Copenhagen, Denmark in 1904 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, while the system for securing better distribution of the work among "*B*" operators is called the "Automatic Order Wire System."

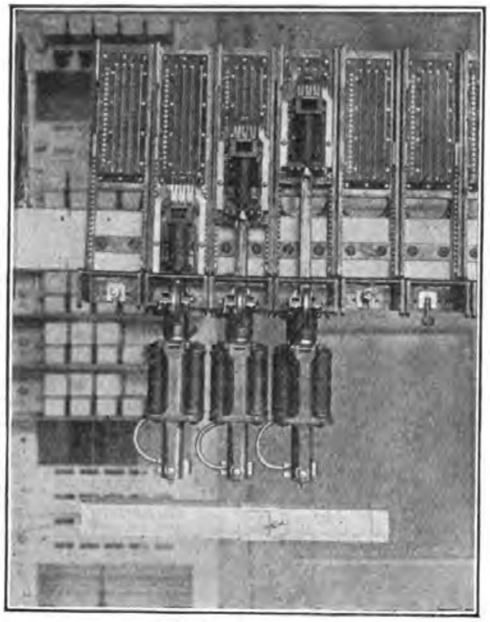


Fig. 185.—View from below of three Christensen pneumatic selectors.

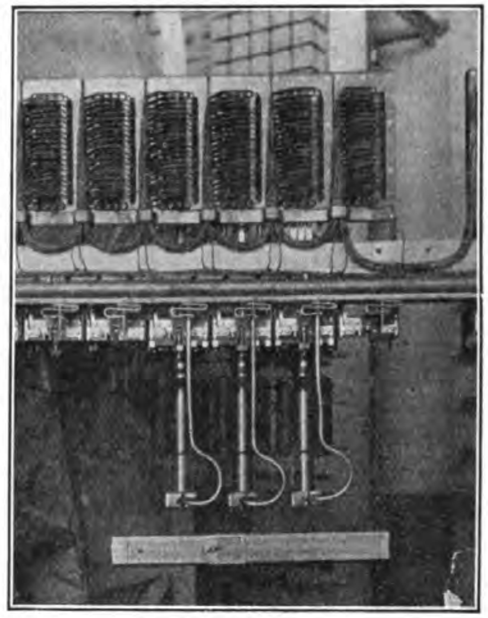


Fig. 186.—View from above of Christensen pneumatic selectors.

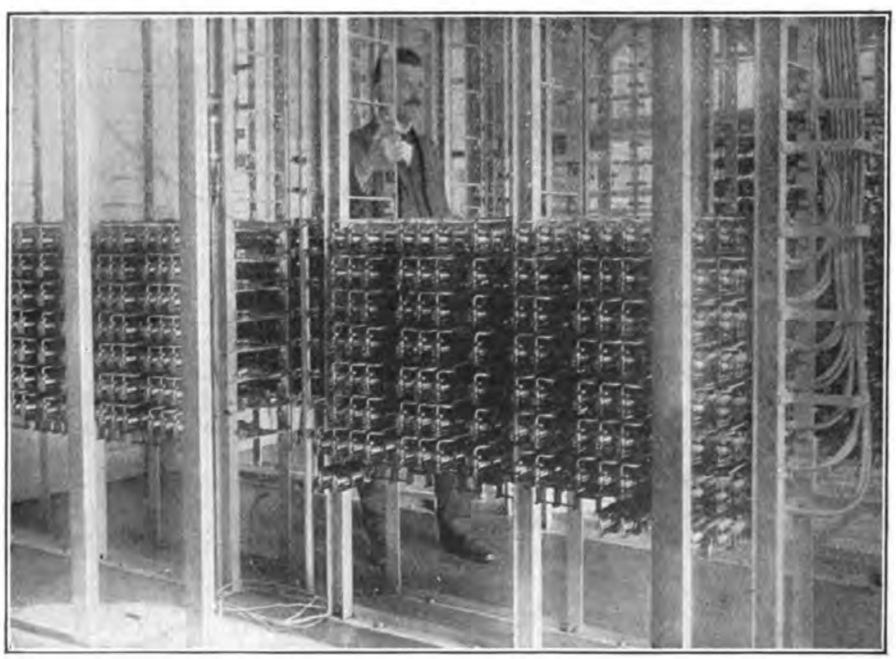


Fig. 187.—Racks with Christensen pneumatic selectors mounted upon them.

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

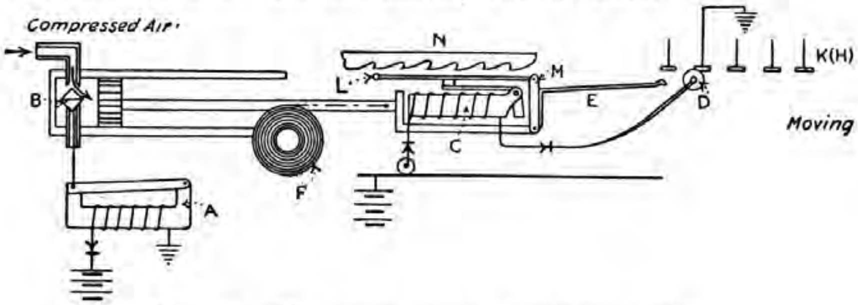



FIG. 188.—Christensen pneumatic selector moving.

Figure 185 is a view of the selectors from below, and Fig. 186 is a view from above. For comparing the dimensions an ordinary slide rule is shown.

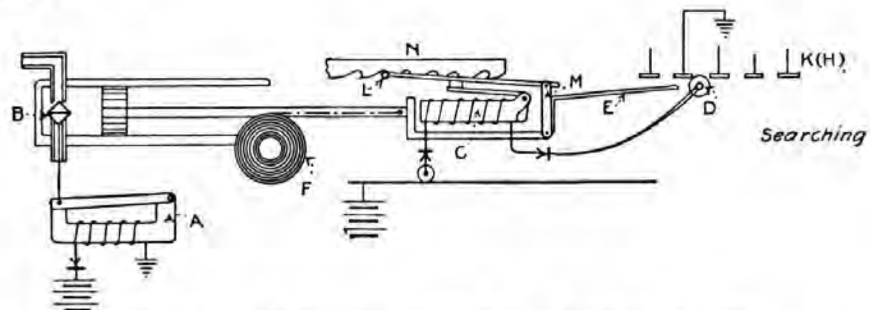



FIG. 189.—Christensen pneumatic selector "searching."

Figure 187 shows the iron framework with the selectors arranged in horizontal rows, each row having space for twenty.

Figures 188 to 190 are sketches showing the working method of the selector.

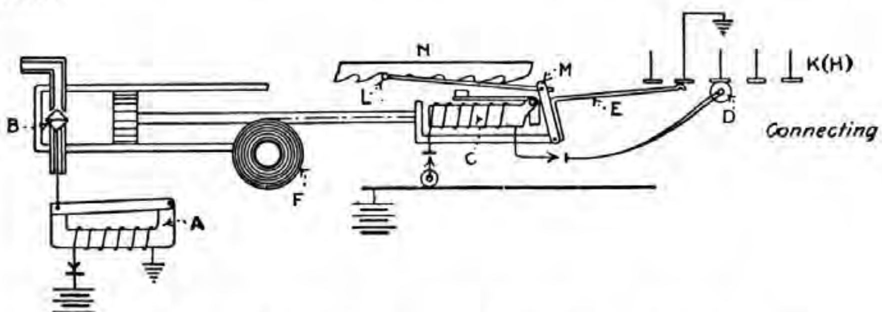



FIG. 190.—Christensen pneumatic selector "connecting."

Figure 191 is a diagram of the selector parts and circuits.

The motive power consists of compressed air at two atmospheres or 2 kg. per sq. cm. (29 lbs. per sq. in.) and is automatically maintained by a reserve at an excess pressure of 0.9 to 1.1 kg. per sq. cm. 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. 188). 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 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

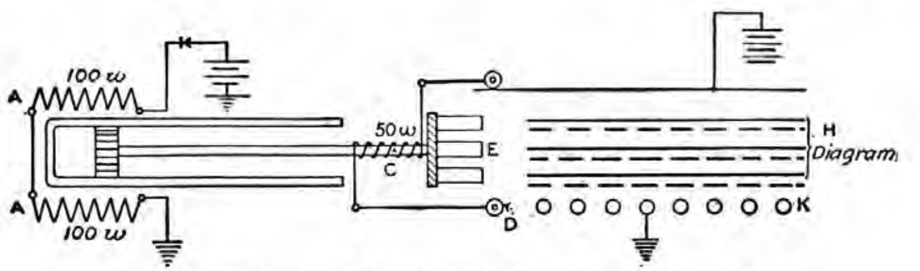



FIG. 191.—Diagram of circuit of Christensen pneumatic selector.

$N$ (Fig. 189). 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 of 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. 190) 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 one liter of air at atmospheric pressure per busy hour.

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

**The Automatic Order Wire System.**—This was made in 1907. Figure 192 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.

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

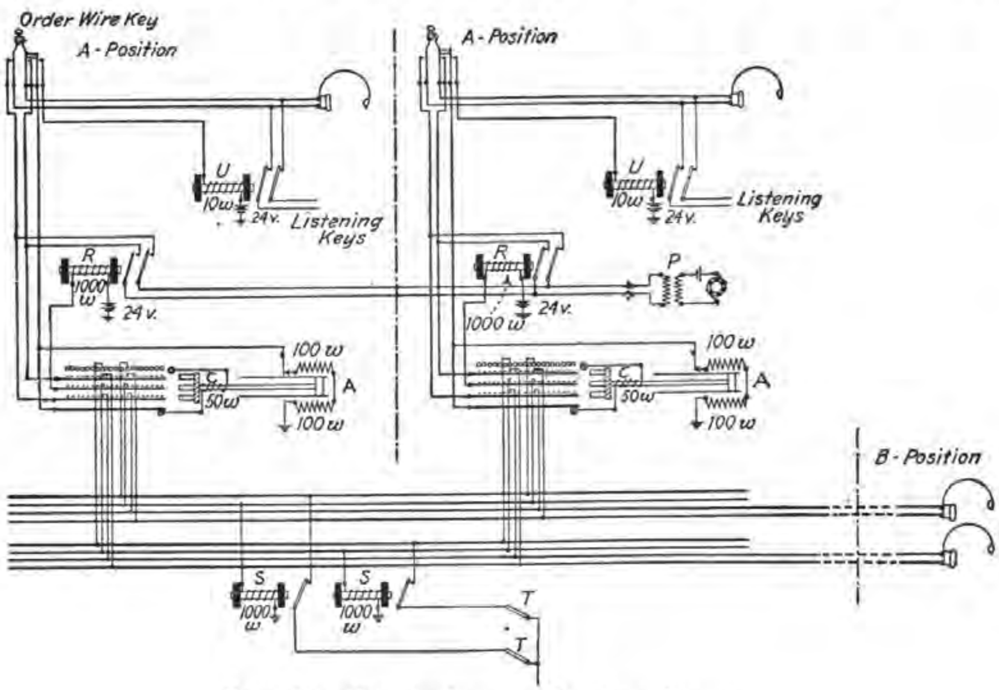



FIG. 192.—Circuit of automatic order wire system.

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 100-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," made in 1909, 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, was 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 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. 193.

If subscriber *A* should remove his receiver from the switch-hook 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 crcuit 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

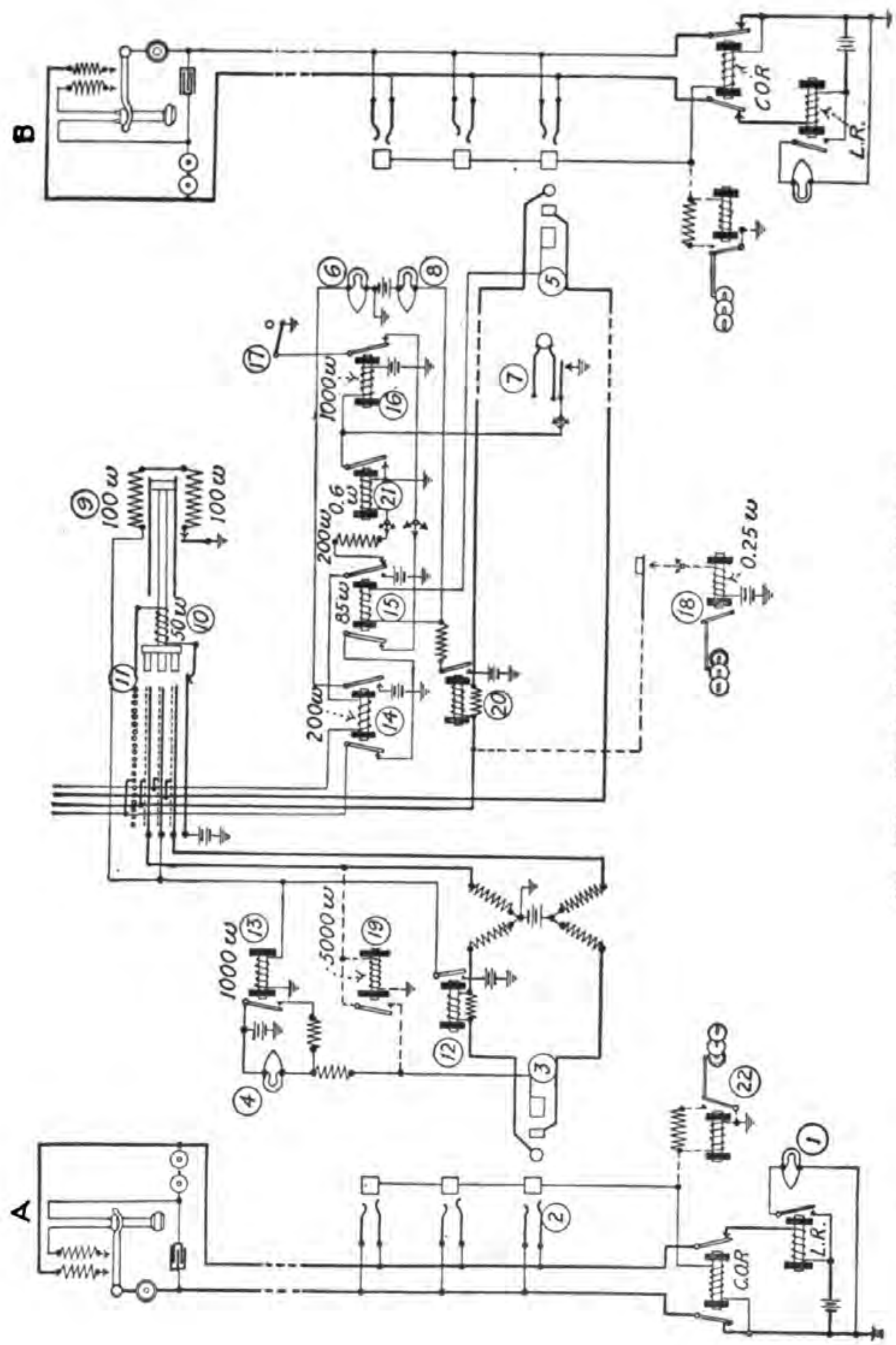



Fig. 193.—Circuit of operator's aid system.

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 as 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.

**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. Nevertheless later plans were all made for total traffic distribution by finder switches.

**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 lineswitches of the rotary type. The trunks from these lineswitches are divided among the "*A*" operators. The calls on these busy lines are distributed among the "*A*" operators. By arranging it so that a lineswitch 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 lineswitches of the Keith type. The trunks from the lineswitches terminate in cords and plugs in the "*A*" operator's positions. If not more than ten operators' positions are required, one of the ten trunks outgoing from each lineswitch 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 lineswitches in which the trunks from the primary line switchboards would terminate while the trunks from the secondary lineswitch groups would lead to the operators' positions.

From the description of these lineswitches, 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 lineswitch 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 may be expected to be secured by its use. Their deductions have been very closely approximated by the actual performance of several plants which have been in operation from four to six years. These theoretical efficiencies are presented here as a quotation from the first edition of this book.

"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 33⅓ 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.

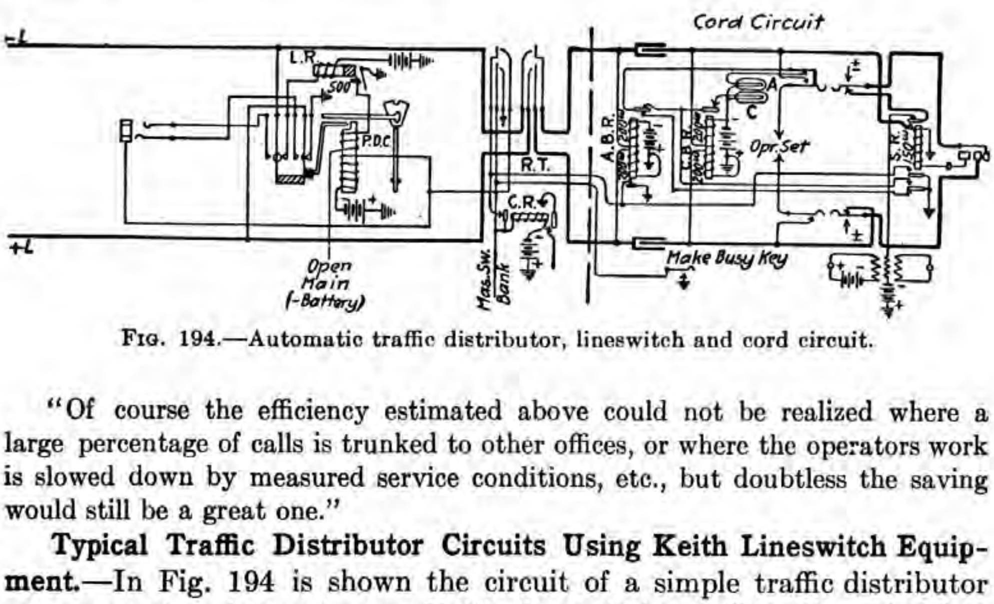



FIG. 194.—Automatic traffic distributor, lineswitch and cord circuit.

"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 Lineswitch Equipment.**—In Fig. 194 is shown the circuit of a simple traffic distributor arrangement using primary Keith lineswitches. The lineswitch 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 lineswitch 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 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 lineswitch bank contacts, and the bridge cut-off winding of the lineswitch to negative battery. The completion of this circuit causes the lineswitch 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 lineswitch. 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 lineswitch 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 lineswitch 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 lineswitch 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 lineswitch 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 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 with drawn from the bank it instantly lines up with the other idle plungers.

In a traffic distributor arrangement for a much larger office, secondary lineswitches 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 Lineswitches Used on Order Wires Between "A" and "B" O erators.**—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. 195.

The lineswitch 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 lineswitch 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 lineswitch 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

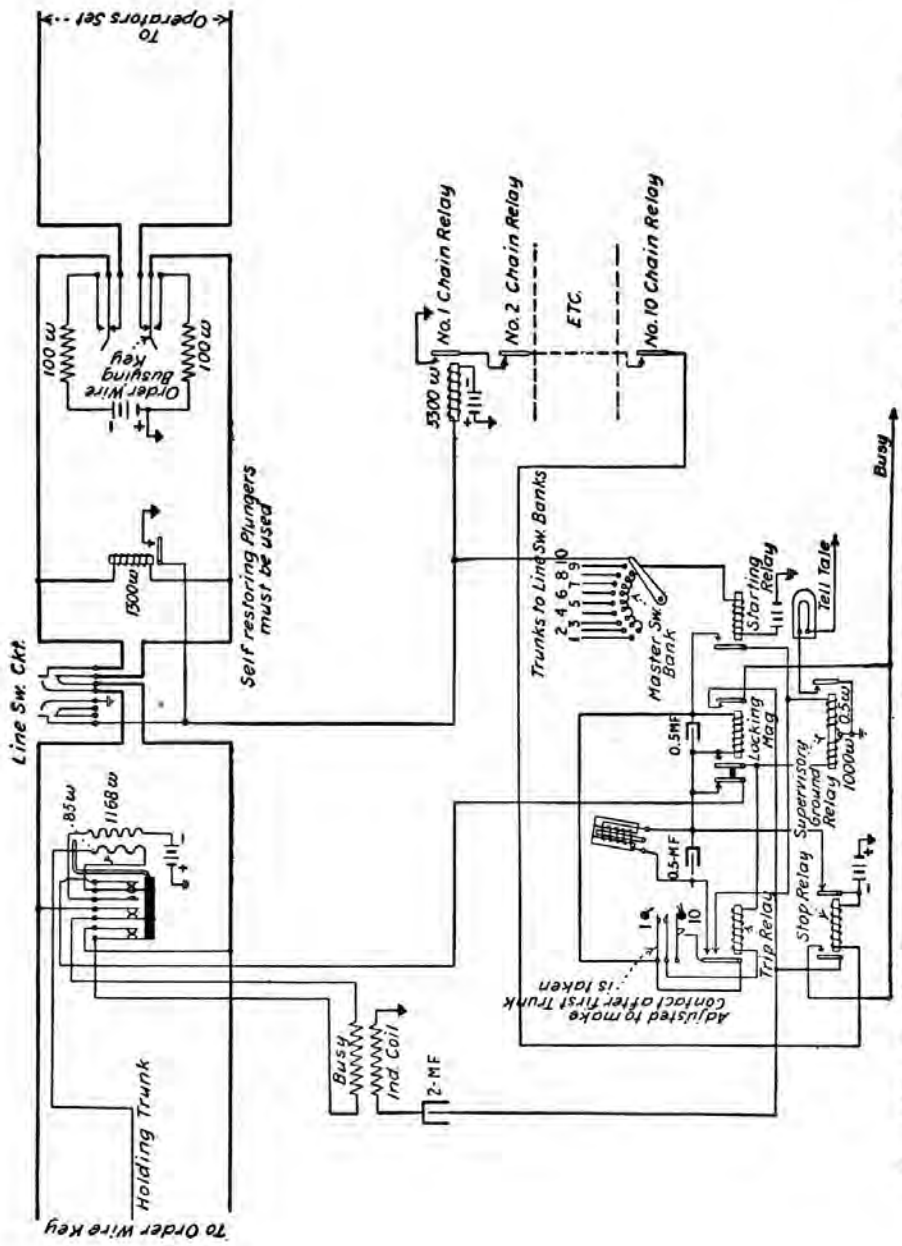


FIG. 195.—Circuit of traffic distributor equipment used on order wires from "*A*" to "*B*" operators.

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 lineswitch pull-down coils is cut off when the stop relay is energized, no lineswitch can be operated under these conditions, and the busy signal is transmitted through the back contacts of the lineswitch relay to any "*A*" operator depressing an order-wire key. The instant any chain relay is released, however, the lineswitch 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 rela-

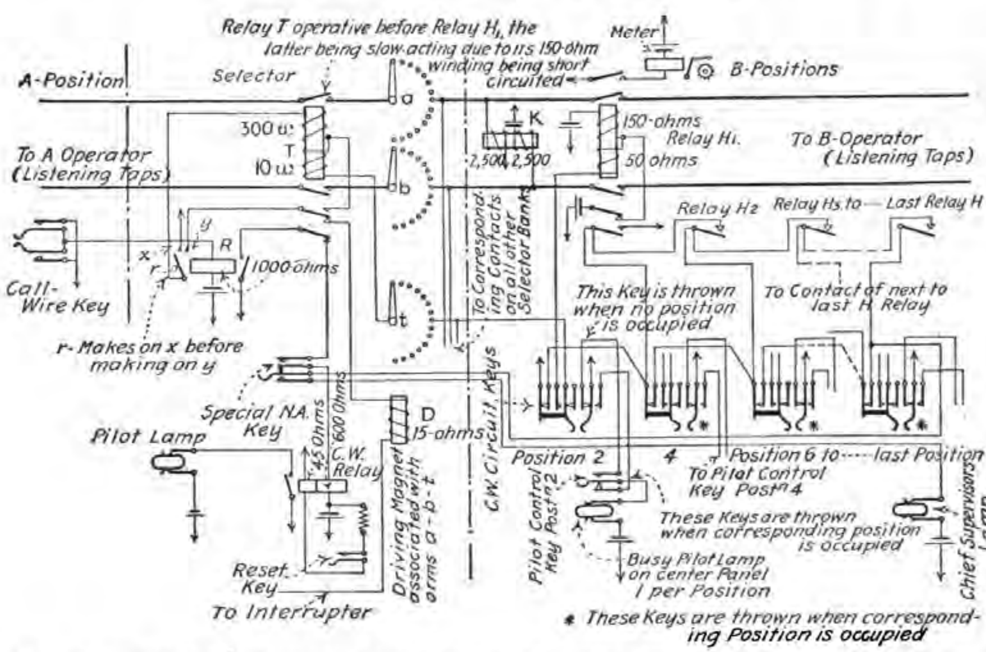



FIG. 196.—Circuit of Siemens-Halske call wire selector installed at the central exchange in London.

tive efficiencies of the operators. With this arrangement two or more "*A*" operators might secure connection to a given "*B*" operator simultaneously, 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 lineswitch 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 multiplied 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. The rotation continues until the wipers find an idle "*B*" operator, when the "*A*" operator is able to pass her call. Figure 196 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 multiplied 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 20 sets of contact springs (ten of which are at present spare). Each spring set supplies driving current to 20 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. 196.

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 SUB-OFFICES IN CONNECTION WITH MANUAL CENTRAL OFFICES

The purpose of an automatic sub-office 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 sub-office.

The same reasons which make sub-offices 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 sub-office than with a branch, manually operated switch board, 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 sub-office is used, the calls from the branch office locality to the main office are handled as speedly as if the lines were connected directly to the main office. Calls going in the opposite direction preferably pass through two operators, but the second operator is located at the main 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 sub-offices 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 sub-offices in some of the out-lying localities and reserving the line jacks and multiples of the main-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 sub-office.

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 sub-offices, by installing one or more of them to take care of the required growth; and these offices 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 sub-office arrangements, and such offices 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 main office from the banks of the lineswitches or from finder switches installed at the sub-office 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 sub-office 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 sub-office, so that the interconnections may be made with the least effort.

If a sub-office subscriber desires a connection to a main-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 lineswitch 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 lineswitch 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 switchhook up and down, thus flashing the operator's supervisory lamp. The talking current for the sub-office may be fed from the cord circuit at the main office or from the sub-office 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 sub-office are operated over the out going trunks frcm the central office to the sub-office. A calling device may be made available to each "*A*" operator, enabling her to complete connections from a central office subscriber to a sub-office 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 sub-offices is large. Generally, however, the latter method is preferable because of the comparatively small number of calls from central-office lines to sub-offices 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 sub-office. 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 sub-office. 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 sub-office 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 sub-office 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 main 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 sub-office battery through the relays of the connector switch.

**Interconnections Between Sub-office Lines.**—Where the trunks incoming to the main office from the sub-offices are scattered among the "*A*" operators, an interconnection is handled in the same manner as that described for an outgoing call from the main to the sub-office. Where the incoming trunks terminate in line jacks before the operator at the special position equipped for handling outgoing calls to the sub-office, 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 sub-office and from there on handles the call just as she would any outgoing trunk connection.

### PLAN NO. 2

The sub-office 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 Main Office.**—For this plan the trunks incoming to main from the sub-office 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 speeded up appreciably because it is not necessary to use an answering plug and cord.

**Outgoing Calls to Sub-offices.**—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 main-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 sub-office), 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 the main office. If the called party does not answer promptly, where ringing from the main 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 sub-office 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 main-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 sub-office battery.

**Interconnections Between Sub-office Lines.**—For use in such connections the "*B*" operator handling the trunks to the sub-office 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 main-office line.

**Sub-office Battery.**—A small storage battery of suitable voltage is generally used to furnish current for operating the sub-office switches. This battery may be charged by means of a simple automatic arrangement over idle trunks from the main office, so that it is not necessary for an attendant to go to the sub-office 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 sub-office and switched in and out of circuit by an attendant.

**Supervision.**—A sub-office apparatus is usually equipped with telltale signals so that it can be supervised quite easily from the main office. It is also supplied with testing switches, such as are generally installed in sub-offices 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 sub-office line without the assistance of any one, either at main or the sub-office. It is not necessary, and it is not customary, to keep an attendant on duty in one of these sub-offices; 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 sub-office, 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 Sub-office Using Lineswitches and Connectors of the Automatic Electric Company's Manufacture in Connection with Main 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. 197. 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 lineswitch 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 lineswitch unit master switch, when all of its outgoing trunks are busy. The object of this is to keep the master switch from seaching 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 lineswitch 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 subscriber 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 line. She receives the customary supervisory signals. The lineswitch 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 sub-office 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 sub-office. 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 sub-office, throws the calling-device key and calls the last two digits of the sub-office 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 lineswitch, 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 sub-office, and the "*B*" operator's cord circuits were already equipped with four-party line-ringing keys when the sub-office was installed, it was thought advisable to simplify the sub-office 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 Sub-office Subscribers.**—The method of interconnecting one sub-office subscriber with another, by using a trunk incoming from the sub-office for receiving the calling subscriber's order and another trunk outgoing to the sub-office 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 lineswitch does not release, however, for reasons already explained. The operator then presses the ringing key coresponding 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. 198. The lineswitch equipment is of the Automatic Electric Company's type and the central office equipment of the Stromberg-Carlson Manufacturing Company's make. The lineswitches 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 main office from the sub-office has coils through which talking current is supplied to a calling subscriber from the sub-office battery. When a lineswitch 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 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 lineswitch 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 main 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 sub-office number, she presses an order-wire key and repeats the order to the "*B*" operator in charge of the outgoing trunks to the sub-office. 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 supervisory relay, the jack springs, the tip conductor of the trunk and the 500-ohm relay $G$ of the connector 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 sideswitch 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 main office must be permanently connected to earth and two groups of connector switches must be employed at the sub-office, 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 main 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.

## CHAPTER X

## THE SYSTEM OF THE WESTERN ELECTRIC COMPANY

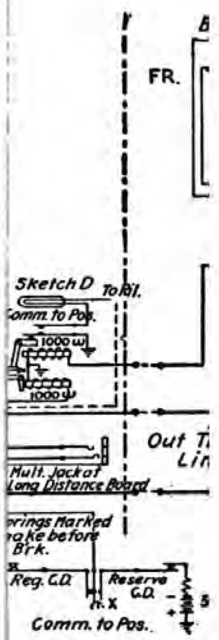
The Western Electric Company began work on an automatic system in 1899. It was developed to a commercial point in 1910, and for test a semi-automatic system of 450 lines was installed in the general offices of the Western Electric Company in New York City. This was maintained and operated by the New York Telephone Company as one of its offices in the metropolitan area.

Early in their development two switch structures appeared, the rotary and the panel. The former was characterized by having the bank of contacts arranged on the surface of half a cylinder, ten levels and 20 sets of contacts per level. There was a vertical shaft at the center which carried ten sets of wipers or brushes. All were connected in parallel but only the set which was released by a tripping device would engage the bank when the shaft was rotated. The panel-type switch had all the bank contacts arranged in a vertical row, and the wiper was driven up over the entire 100 sets.

About 1911 the work was separated. The panel switch was to be developed in America, the rotary type in Europe. For several years the factory at Antwerp, Belgium, manufactured and installed a few small exchanges in French and English cities. The work was stopped by the German advance in the war during August, 1914. Since the war ended, the work has been resumed.

American development concentrated on the panel switch and the system to work it. Special attention was given to its use in very large cities like New York, Chicago, etc. Much of the trying out of the apparatus was done in the offices of the Newark, New Jersey, exchange, and in the semi-automatic form. By this means the operation from the subscriber's standpoint was not changed, and the switches could be tried, modified, and developed as much as was desired.

An automatic system in a very large city requires large call numbers, often as high as seven digits on the decimal basis. In some cases there may be one more digit for party line stations. In the effort to reduce the mental labor of remembering the call number long enough to dial it, they devised the plan of spelling out the first two or three letters of the office name, which would be then printed in bold-faced type as in Fig. 199. The calling device has three letters in each number space in addition to the usual Arabic digit. (Fig. 200). All the letters of the alphabet are

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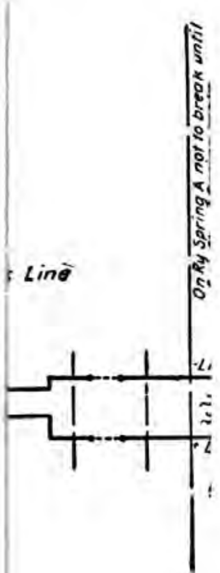


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used except "*Q*" and "*Z*." The last hole bears the digit "0" and the word "OPERATOR."

The plan proposed is that the subscriber shall dial the bold-faced letters of the office name, followed by the four digits of the number of the line in the office. In smaller cities it may be necessary to use only two letters in the office number. The subscriber will be cautioned not to use the tenth hole marked "0" while dialing the office name, but to use the sixth hole in which are the letters "*MNO*." Also not to mistake the letter "*I*" in the fourth hole for the digit "1" in the first hole.

**Argon Dress Co, 24 E 12..........STU yvsnt 2011**
**Argonaut Supply Corp, 50 Union sq..STU yvsnt 7476**
**Argonne Steamship Co, 17 Battery pl...REC tor 2493**
**Argos Ad-Art Co, 113S Bway.........FAR ragut 5986**
**Argosy The (A Pub). 280 Bway.......WOR th 8800**

FIG. 199.—Directory testing with office names.


FIG. 200.—Western Electric calling device.

FIG. 201.—Western Electric automatic telephone.

Capital letters must be used in the directory, to prevent confusion between the figure "1" and the letter "1"

The complete desk telephone is shown in Fig. 201. The post which carries the transmitter is set back of the center of the base, so as to give room for the calling device to lie down almost horizontal (15 degrees slope).

The general arrangement of apparatus is shown in Fig. 202.

All the subscriber lines terminate in the central office on the banks of finder switches (Line Finder Frame) and on the banks of the connector (Final Frame). The line finder has many vertical rods, each of which carries several wipers or brushes. The latter are to be lifted by suitable mechanism and made to touch the contacts of a calling line, connecting it to the first piece of numerical apparatus, the district selector (District Frame).

The distribution of traffic to the several offices is made by the district selector, or by it and the office selector (Office Frame). Both are mechanically alike.

The district frame has five large banks, each of which has 100 sets of contacts vertically and 60 sets horizontally (30 sets on each side of the bank). There are 60 vertical rods (30 on each side), each of which has five sets of wipers or brushes. The bottom set of brushes engages the bottom group of 100 contacts in a vertical row in the bottom bank. The next brush engages similarly the next banks, and the third brush the third bank, etc.

Each vertical rod, with its five brushes, represents one trunk from the line finder. By suitable means only one set out of the five is per-

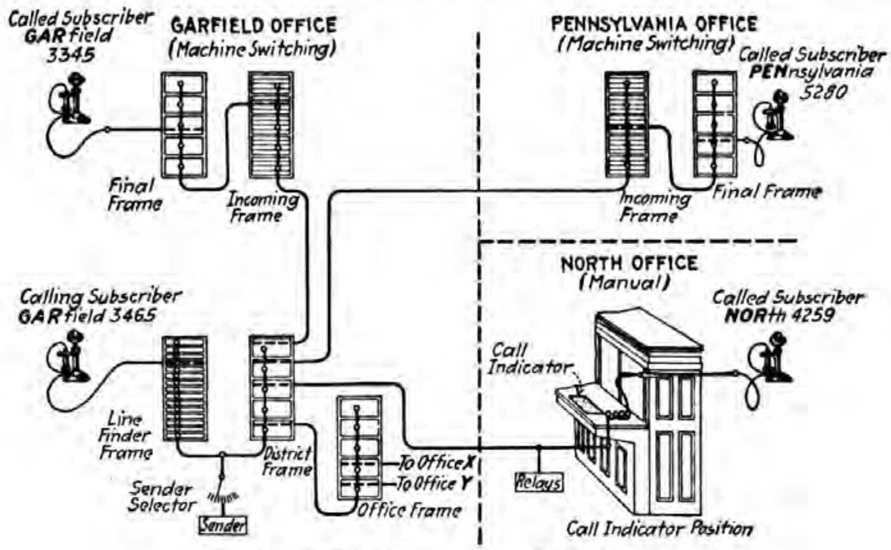



FIG. 202.—General plan of trunking.

mitted to touch the bank contacts at a time. At the bottom of the district frame is an elevator for each rod, which lifts the rod and its brushes so that the brush which has been rendered effective will wipe over the bank contacts in its own vertical row.

Because this system is primarily for very large cities, there will be a large number of offices. In general, there must be a group of trunks out of the office under consideration leading to each of the other offices. Since the district selector has only five banks and five sets of brushes, each bank cannot be set aside for one office alone, unless it be a nearby office and the trunk group is very large. Some, if not all, of the banks must be subdivided into smaller groups of trunks. Also, the office selector must be used to help the district selector to reach so many offices.

Some of the groups of trunks leaving the banks of the district frame run to brushes on the office frame, one trunk to a selector with its rod and five brushes. The office frame has five banks, and each of them must in turn have its 100 sets of contacts subdivided into smaller trunk groups. In this way it is possible to trunk to 100 offices, more or less.

It is evident that often two digits must be used to select a group of trunks in the district frame, one digit to select the set of brushes (one out of five) and another digit to cause the brush to move to a desired group of trunks in the bank of 100 over which the brush can act. The same is true of the office selector.

The first two or three digits of the call number must control the district selector and the office selector. These are represented by the first letters of the office name, but are translated into decimal digits by the calling device on the telephone. These two or three decimal digits must be translated into two or four digits of the kind which will properly control the selectors. This is done by the sender in the central office.

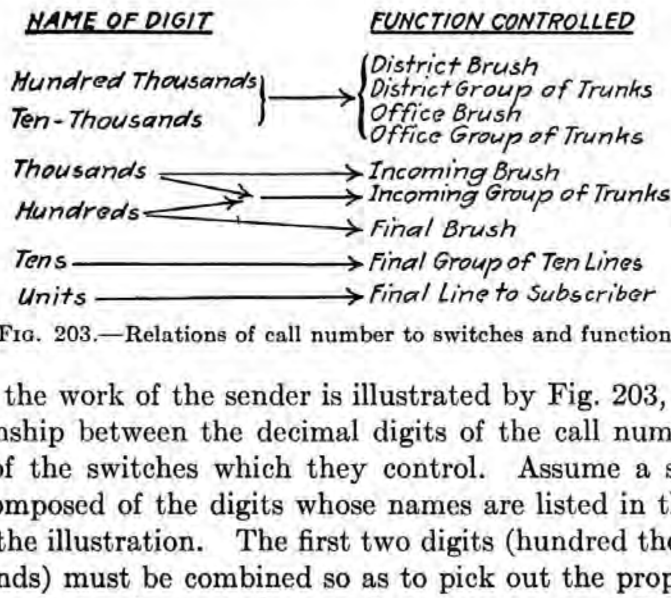



FIG. 203.—Relations of call number to switches and functions.

Part of the work of the sender is illustrated by Fig. 203, which gives the relationship between the decimal digits of the call number and the functions of the switches which they control. Assume a six-digit call number, composed of the digits whose names are listed in the left-hand column of the illustration. The first two digits (hundred thousands and ten thousands) must be combined so as to pick out the proper brush on the district-selector frame and cause it to move to a definite group of trunks. After the idle trunk has been found, the sender must (according to these same two digits) choose the right brush on the office-selector frame and move it to a certain group of trunks. It may be for some of the calls that the office frame may be omitted, and it is even possible for a very few to have only the choosing of the district brush.

The thousands digit fixes the brush which shall be taken on the incoming selector, but it wil be observed (Fig. 202) that each brush can reach two separate thousands, so that the relation is not decimal, although it is numerical.

The thousands and the hundreds digits (Fig. 203) must be combined to move the brush on the incoming frame to the right group of trunks, for each brush can reach each of the two 500-line frames in each of two thousands (Fig. 202). Both the hundreds and thousands digits are involved.

The hundreds digit fixes which brush on the final selector shall be taken (Fig. 203). This part is a simple choice along decimal lines (Fig. 202), for each brush can reach only 100 lines.

The tens and the units digits (Fig. 203) go through decimally, for bank on the final frame (Fig. 202) must be divided into ten groups of ten subscriber lines each.

Attached to each trunk from finder to selector is another switch called the "sender selector." It is the duty of this switch to hunt an idle sender and connect it to the trunk, so that the sender can receive the impulses from the calling device on the telephone, translate them, and repeat them to the district selectors and to the office selector if it is used, also to all the other switches used.

When a call arrives at the called office, it comes to a selector on an "incoming frame." Mechanically this is like the district frame, but the bank is subdivided differently.

It will be observed in the illustration that each of the five banks on the incoming frame is divided into four parts. Each of these parts contains trunks leading to a final frame, which corresponds to the connector of other systems. There they terminate in final selectors, one trunk to one rod with its five brushes. In this way one incoming frame can reach final frames leading into 10,000 subscriber lines.

The selecting of a brush on the incoming frame, the moving of this brush to the necessary group, and the selection of a brush on the final frame, are all non-decimal actions. They are cared for by the sender in the calling office. The moving of the brush on the final frame to a group of ten lines, and the last selection of the individual set of contacts, are decimal actions.

If there are manual offices in the exchange, the trunks will terminate in relays and plugs on the manual board. There is also a call indicator, on which the four digits of the call number will be indicated by lamps, so that the operator can read off the number and plug up the connection with certainty.

**The Handling of a Typical Call.**—Assume the call number to be PENnsylvania 5280. The subscriber will first remove the receiver from the hook and listen for the dial tone. In this interval the line finder has seized his line the sender selector has found an idle sender, and the sender is ready to receive the call. This is indicated by a "dial tone" sent to the calling telephone. The subscriber will insert his finger in the opening of the hole over the letter "*P*," rotate the dial until the finger comes into contact with the finger stop, remove the finger, and let the dial automatically return to normal. He will repeat this operation for the letters "*E*" and "*N*" and for the four digits 5, 2, 8, and 0.

The calling subscriber is assumed to be in the GARfield office. While the subscriber is dialing as above described, the calling device on his telephone is sending impulses to the "sender" which receives and registers them. If the subscriber, for any reason, should fail to dial the full number, the selection which is described later would not take place, but the call would be taken up by a maintenance employee and the subscriber told of his error, unless he had already hung up and dialed again.

The "sender" having received the call number, causes the proper brush on the district selector to be made operative, guides the elevating apparatus while it elevates the brush rod until the selected brush reaches the group of trunks leading to the PENnsylvania office, and causes it to hunt for an idle trunk in that group. This extends the connection from the sender to an incoming selector in the distant office.

The "sender" now controls the incoming selector in the PENnsylvania office very much as it did the district selector. It must select a brush and make it operative, it must cause that brush to be lifted to a certain group of contacts, and then guide it in the hunting of an idle trunk leading to a final selector or connector.

Lastly, the sender controls the final selector or connector by selecting a brush, lifting it to a certain group of ten lines, and then causing it to move to the particular line called, "5280."

If the call had been for another GARfield subscriber, the call would have been sent to an incoming selector in the same office, and thence to a final selector (connector).

When the final selector has completed the connection, the called line will be rung or a busy tone will be sent back to the calling subscriber if the called line is busy.

## APPARATUS DETAILS

**Line Finder.**—The line finder (Fig. 204) is a long vertical frame which contains the bank terminals for many subscriber lines. The general functions are as have been described in an earlier chapter of this book.

**Sender Selector.**—The sender selector is made up out of rotary switches like that shown in Fig. 205. The bank has 22 points; one is to lead current to the wipers, the rest are for bank connections. In form it is very similar to the rotary lineswitch described in connection with Fig. 48.

Many sender selectors are built up on one large frame (Fig. 206). At the right are relays and resistances used in connection with the sender selectors. To the left of the relays are the banks of rotary switches without wipers and magnets, as they are here in process of assembly. Still farther to the left are sequence switches, used with the selectors.

**District and Office Selectors.**—The district selector and the office selector are so nearly alike that one description will suffice for both (Fig. 207).

In the center are to be seen the five large banks, with 30 rods running vertically across them, each rod carrying five sets of brushes. At the bottom of the bank space are the elevators for lifting the rods, as well as for lowering them back to normal. Above the banks are commutators, one for each of the rods. On the other side of the banks are 30 more rods, making 60 selectors in all, which have access to the five banks.

At the right of the banks are the sequence switches, 30 of them, one for each brush rod. They are operated by friction clutches from a vertical shaft at their left.

To the right of the sequence switches are the relays and resistances covered by boxes to keep out the dust.

The bank itself (Fig. 208) is built up out of alternate strips of metal and insulating material. Above the assembled bank is a sample of each, the insulator being above the contact strip. The latter is punched out with 60 lugs, 30 on each side. Three strips form a set for

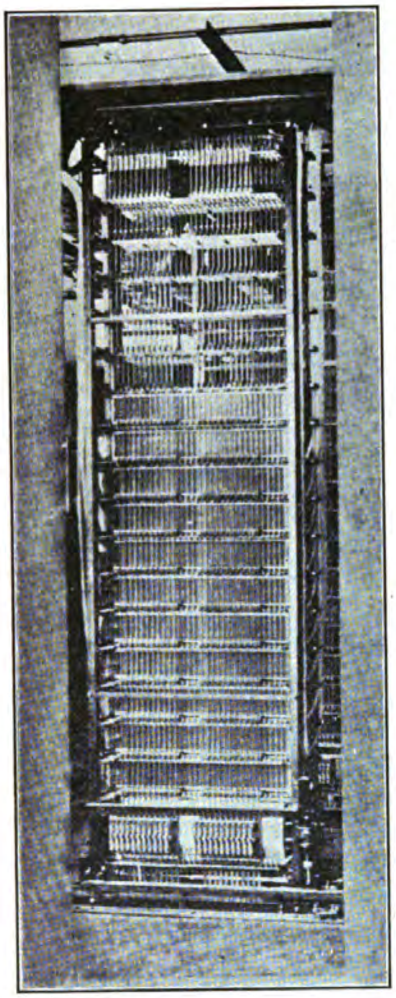


FIG. 204.—Line finder frame.

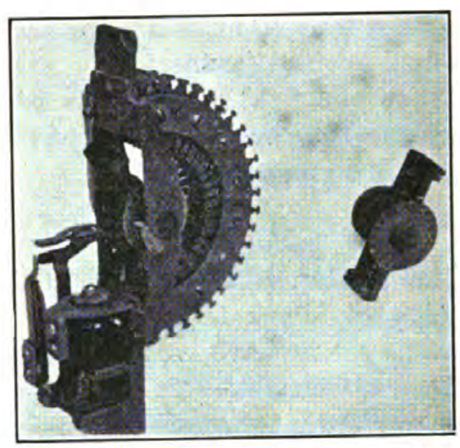


FIG. 205.—Rotary switch for sender selector.

one trunk line or subscriber line (tip, ring, and sleeve). One hundred sets of strips (300 strips) are built up into one bank. The arrangement is such that the lugs may be aligned vertically in rows, and groups of rows. At the extreme left may be seen three vertical rows of lugs or contacts. They are the row over which one set of brushes move. The next three vertical rows of contacts are for the next set of brushes. In this way 30 sets of brushes are accommodated on each side of the bank—60 sets in all. The total number of contacts on both sides is 18,000.

The nature of this structure is such that great accuracy of alignment must be obtained and maintained. The bank must be flat and the sides of the contact lugs ground to a straight line, because the brushes make contact with the edges of the contacts instead of their flat sides. The

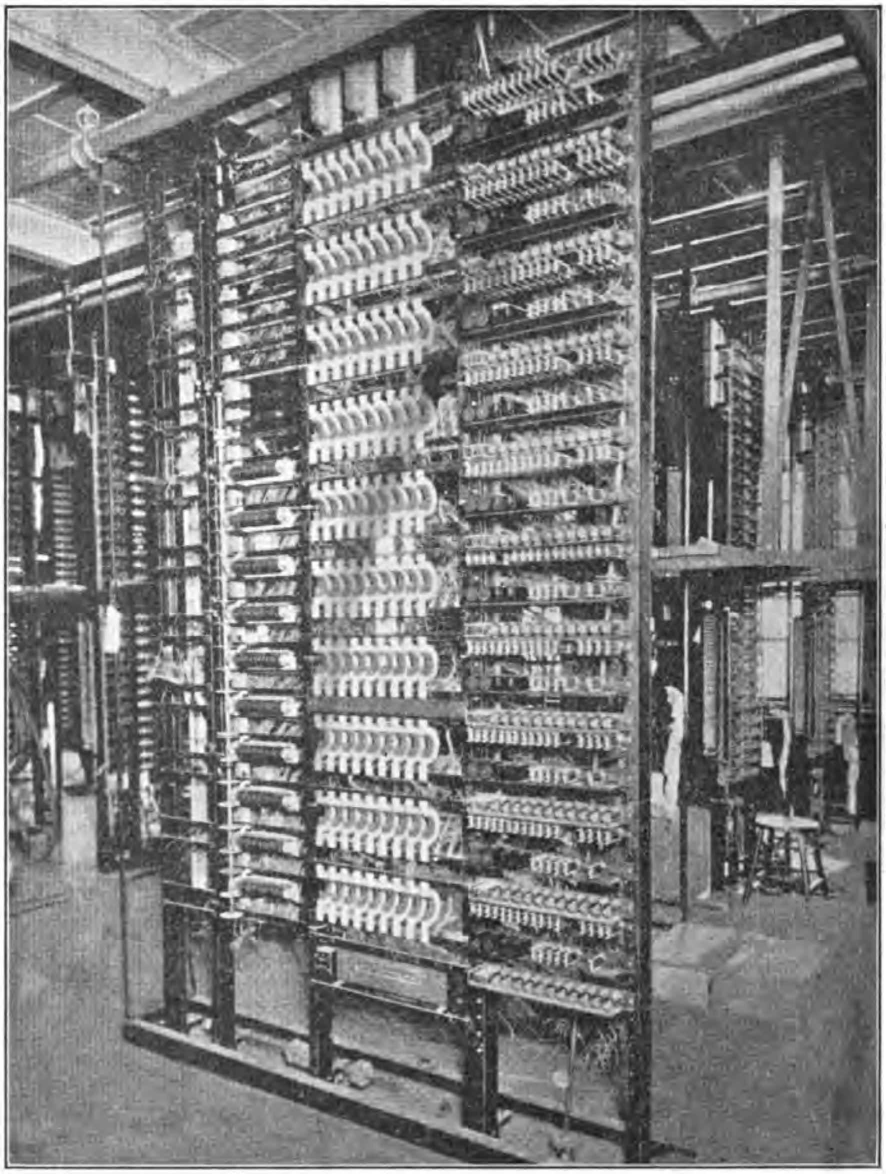


FIG. 206.—Sender equipment.

entire bank as a unit must also be carefully adjusted in position and maintained there, because the brushes are on long rods which are controlled from the bottom.

The set of brushes (Fig. 209) consists of four springs; 37 and 38 are the brushes for the "sleeve" or third wire; 36 and 39 are the line brushes.

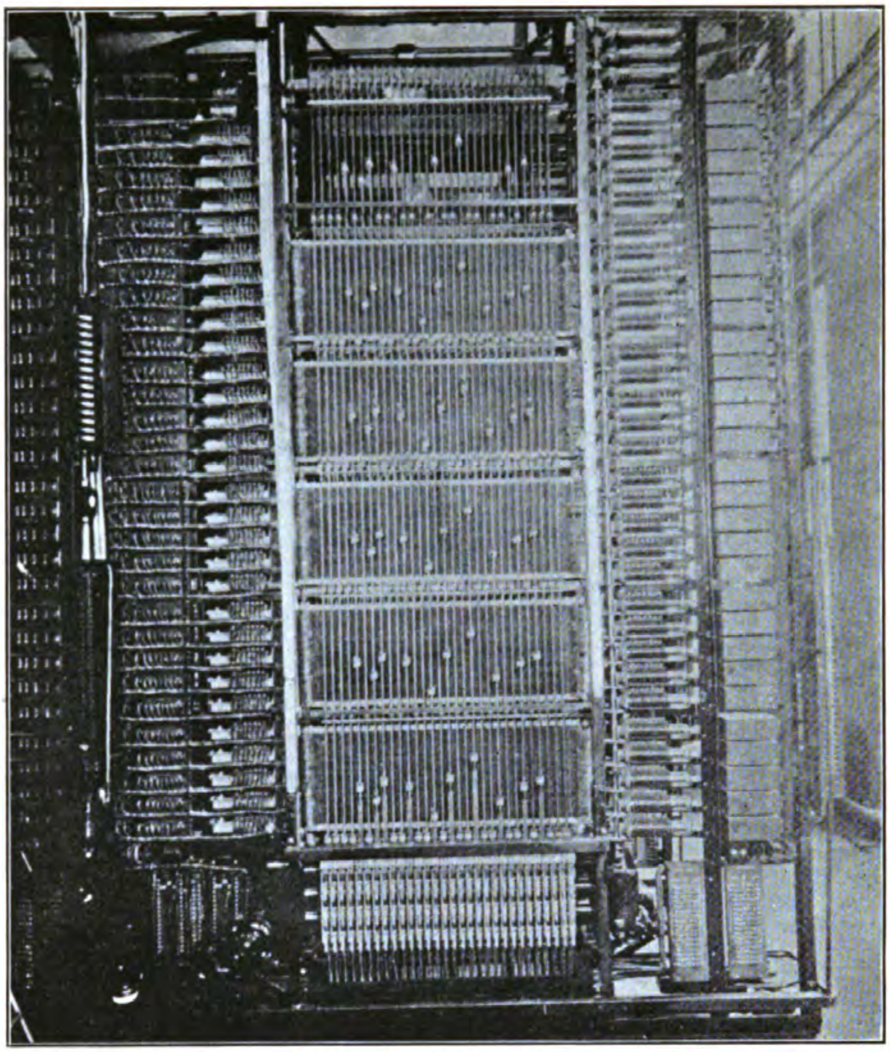


FIG. 207.—Selector frame.

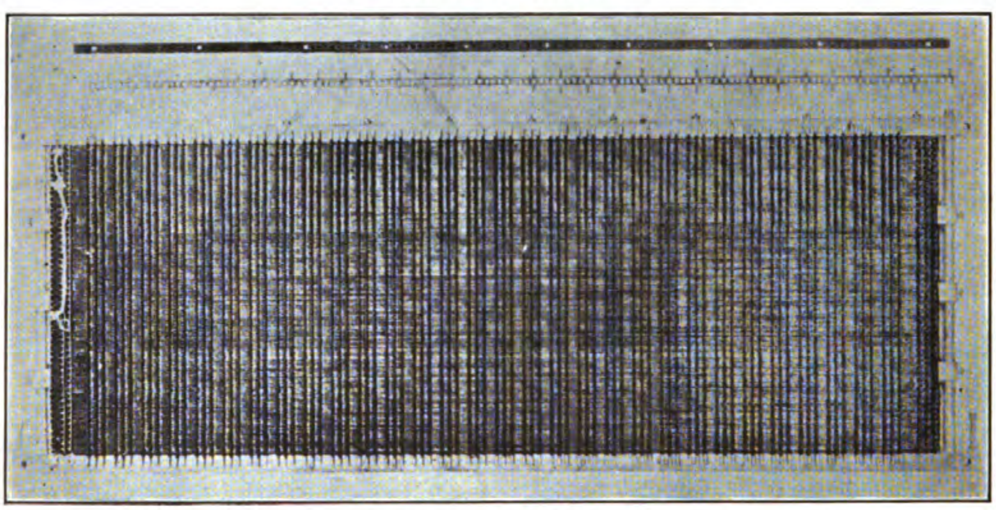


FIG. 208.—Multiple bank.

All are mounted on a carriage or frame which is clamped to the vertical brush rod at the left, inside of which are the wires which carry the circuits to the brushes.

Normally the brushes are kept apart by the piece 35 which has an insulator on each end; 34 is a lever used to trip the spreader down so as to permit the brushes to rub on the edges of the contacts; 33 is a finger

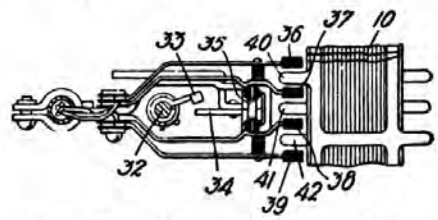



Fig. 209.—Selector brush and bank.

carried on rod 32 so arranged that if rod 32 is rotated, the finger 33 will be above the lever 34. If now the brush rod be lifted, the spreader will be tripped from between the brushes, and the latter brought against the edges of the contacts.

Figure 210 shows photographs of the group of brushes. The two lower ones show the brushes normal, the upper pair show them tripped.

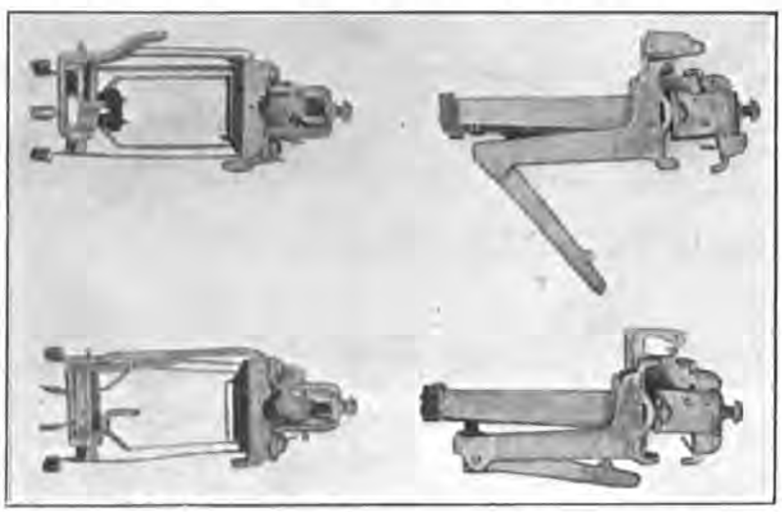


Fig. 210.—Selector brush, operated and non-operated.

The two at the right are side views, while the two at the left are views from below. In the upper right-hand view, the long lever which projects downwardly is the resetting lever which forces the brushes apart and off the contacts when the brush rod reaches the bottom of its motion on release.

The control of the brush rod is shown more clearly in Fig. 211. The bottom bank is shown quite clearly in the upper half of the photograph.

In front of it are a number of brush rods. The left rod is missing, but its brush trip rod is there. The third rod is shown partly elevated, revealing the perforated strap by means of which the elevating rolls lift and lower the rod. The connection between the flat strap and the round rod is somewhat flexible. The long, narrow slots in the strap are to hold the rod in its operated position—there is in the elevator a detent which engages the strap and whose point enters the slots.

The clutch mechanism is shown more clearly in Fig. 212. The brush rod is 11, at whose lower end is the flat strap 13. The up-drive roller 15

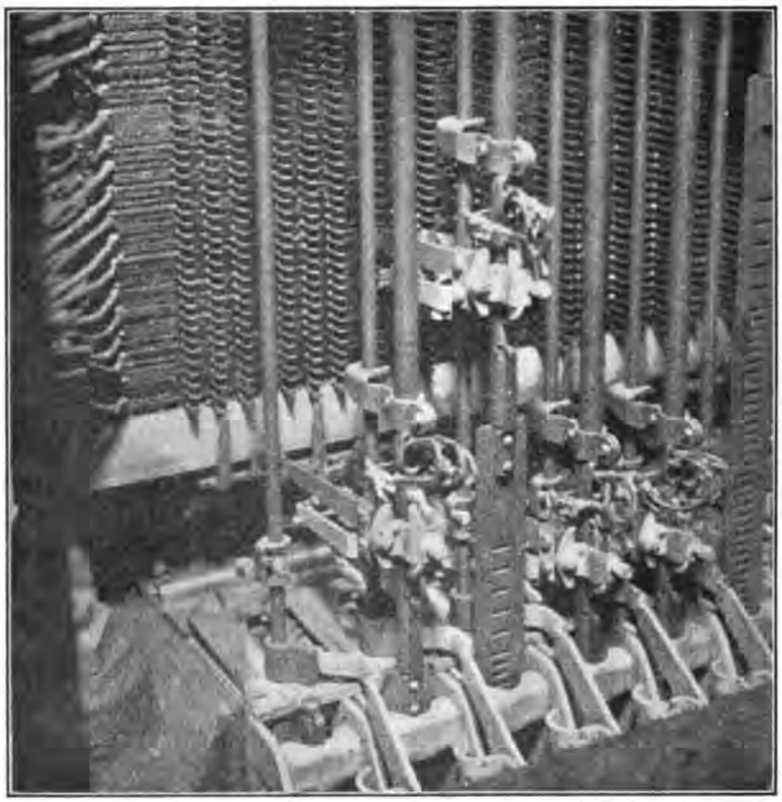


FIG. 211.—Selector frame, details of control mechanism.

clears the strap by very little space, and is running all the time. The magnet 19 pulls levers 24 and 18 so as to cause roller 16 to press the strap against the up-roll. The detent which holds the brush rod in the operated position is marked 25 and is opposite the down-drive roll, 29.

This same illustration also shows more easily the trip rod 32 and the magnet 31 which operates it.

The commutator (Fig. 213) is at the upper end of the brush rod, which is seen supporting the brush holder of the brushes which engage the commutator. The left part shows the back of the commutator, with the strips of metal which carry the current to the brushes on the front side (shown at the right). The front has three conducting strips, each of which is perforated by holes and slots of varying dimensions. These take part in placing the brushes where they belong during their upward motion.

Several sequence switches are shown mounted in Fig. 214. The constantly rotating drive shaft is at the left. On it is mounted one hori-

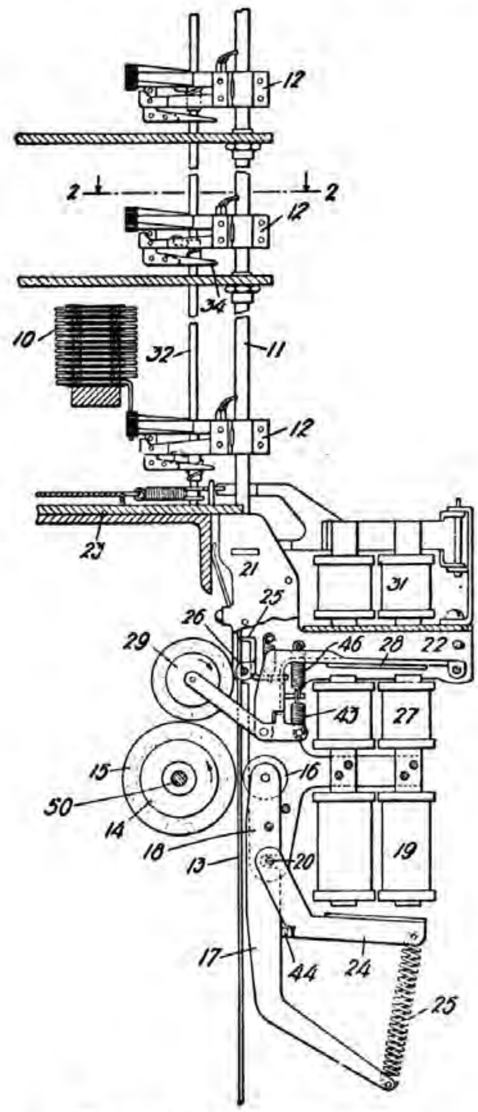



FIG. 212.—Clutch mechanism.

zontal disc for each sequence switch. On the shaft of the switch is a disc whose end is near the disc on the drive shaft. A stationary electromagnet is capable of magnetizing these two discs, drawing them into contact, and thereby causing a clutch action, rotating the sequence switch.

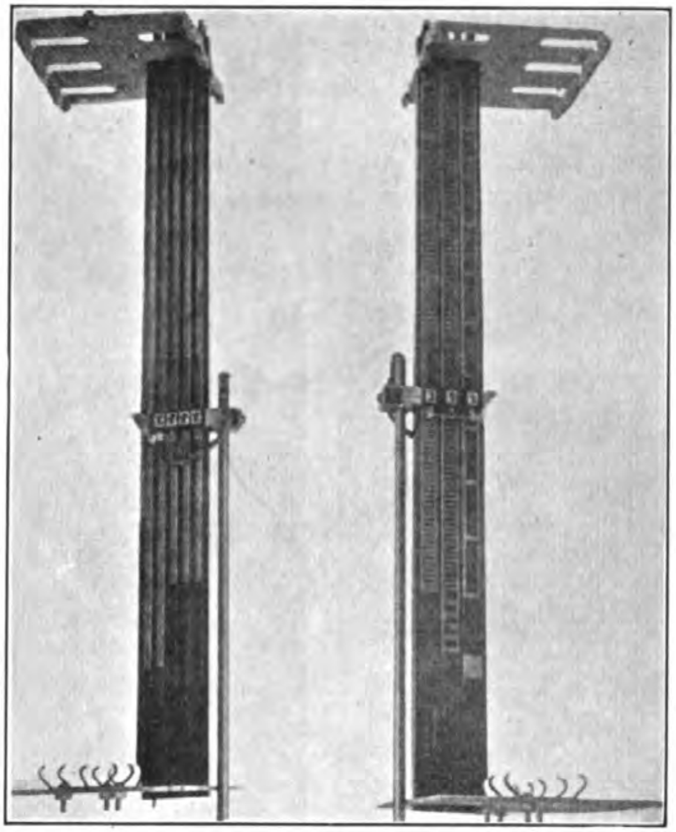


FIG. 213.—Commutator.

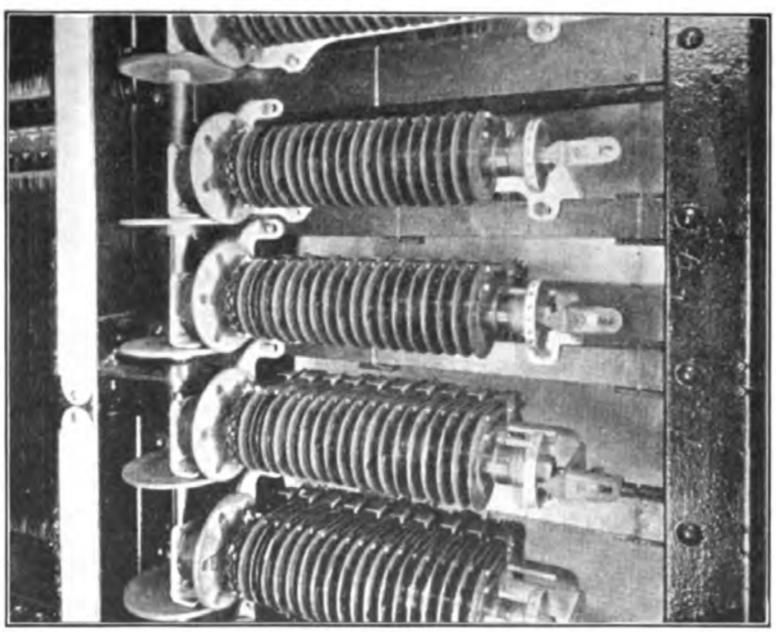


FIG. 214.—Sequence switches mounted.

A single sequence switch is shown in Fig. 215. It consists of a horizontal shaft with many insulating discs on it. Each disc is termed a

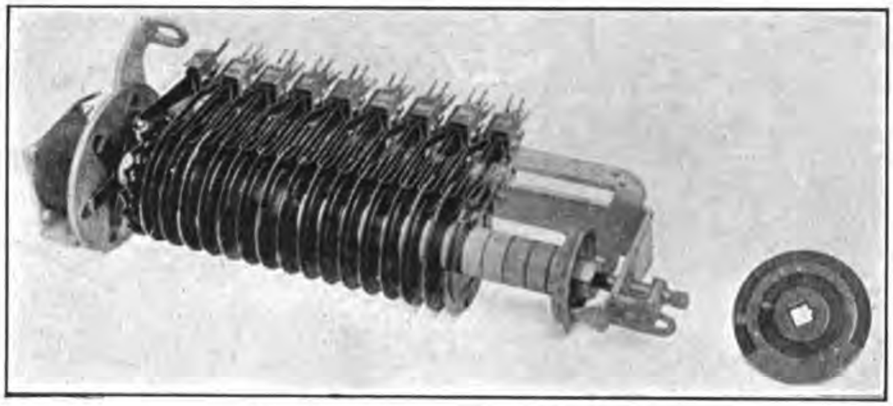


FIG. 215.—Sequence switch and cam.

"cam," of which a sample is shown at the right. Four stationary springs or brushes engage each cam, and the metal mounted on it. By it many complicated connections can be made and broken during the progress of

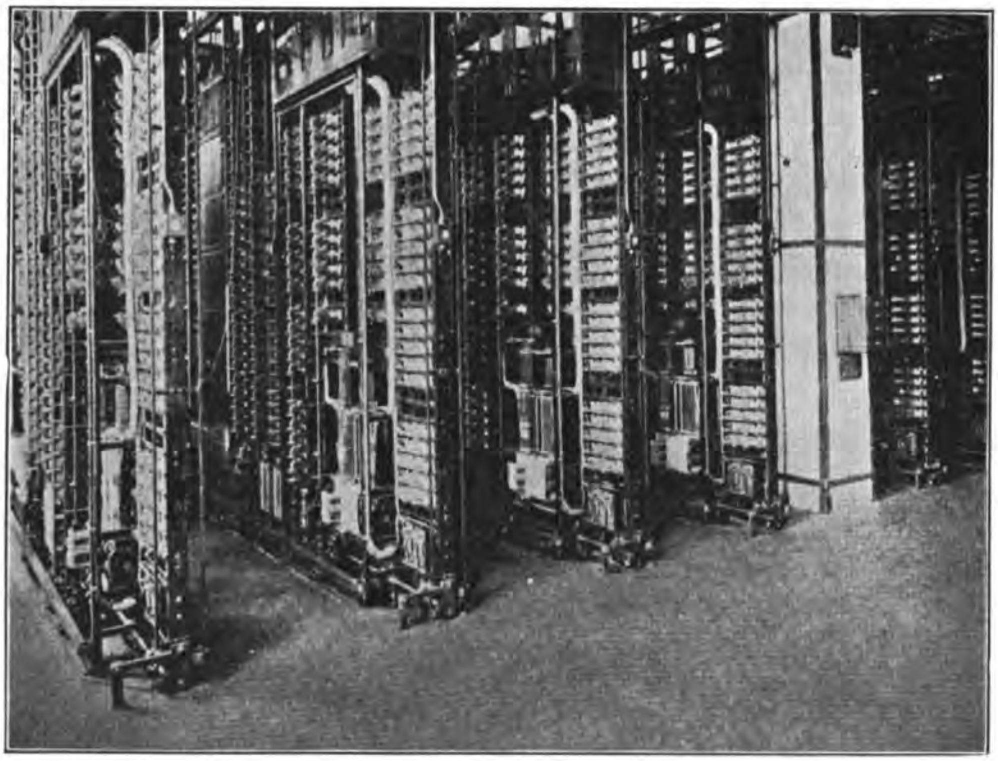


FIG. 216.—General view of panel type switch installation.

setting up a call. There is a position indicator at the right, showing that there are 18 positions, each of which is centered by the cam and roller *A* at the left.

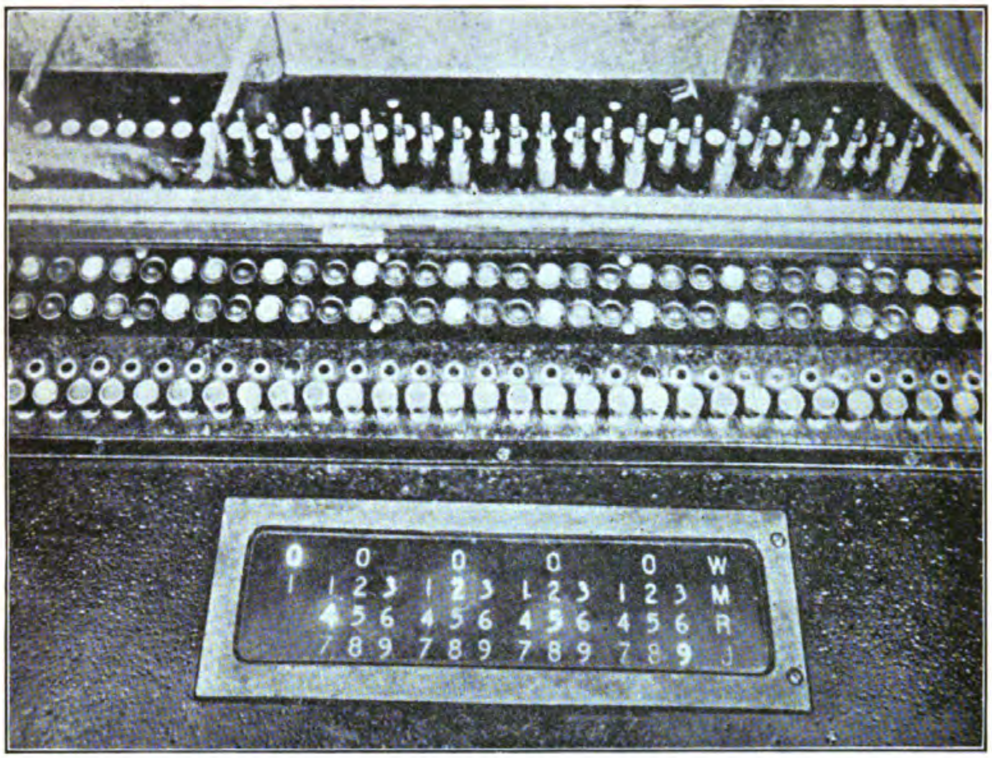



Fig. 217.

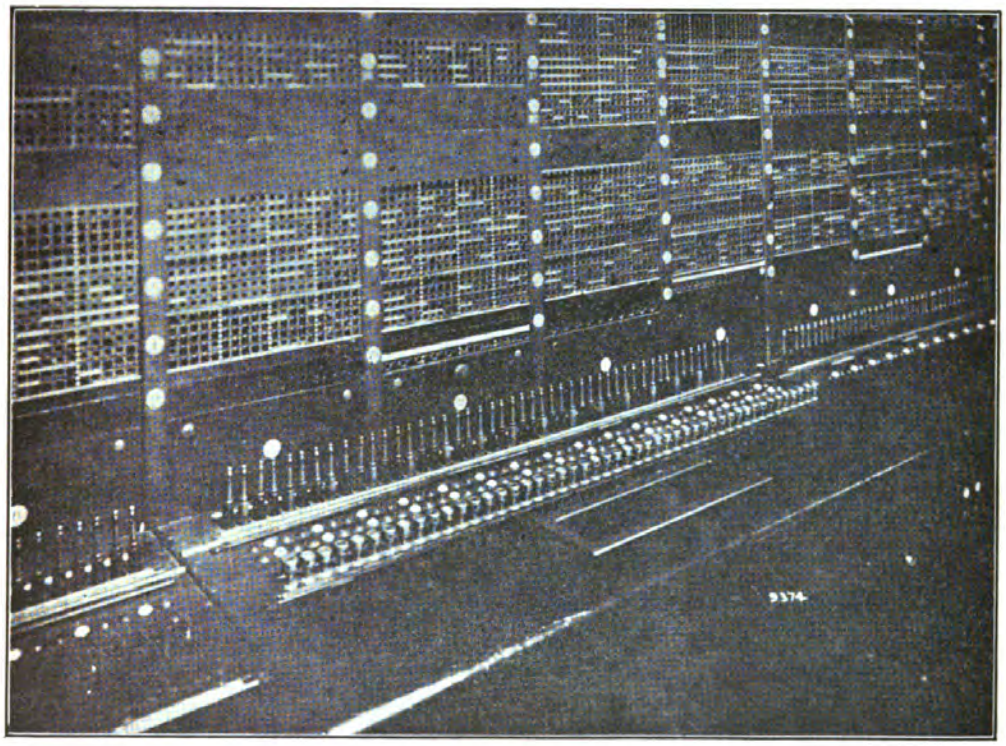


Fig. 218.

A general view of selector frames installed is shown in Fig. 216. The cabling is carried overhead on runways. No attempt is made to cover any part of the mechanism except the relays.

### CONNECTIONS TO MANUAL

**Automatic to Manual.**—Automatic subscribers dial complete numbers for all calls, regardless of their destination. All alike are recorded on a sender. If the called number is in a manual office (as NORth office in Fig. 4), it will be switched to a trunk which terminates in a plug on the

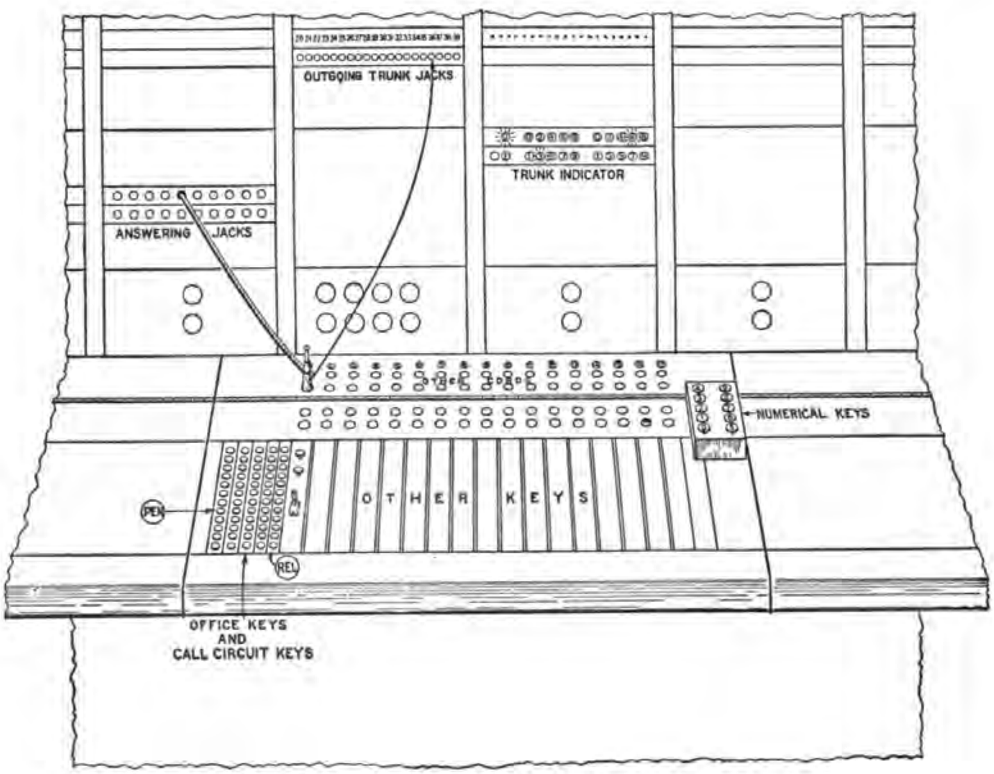



FIG. 219.—Manual position with push-button calling device.

"*B*" operator's position. Associated with that position is a "call indicator" on which the last four digits of the call number are displayed by lamps. (See Fig. 217.) The number here illustrated is "04259." The appearance of a manual position equipped with a call indicator is shown in Fig. 218. The dark rectangle lying between the edge of the shelf and the row of keys is the indicator.

**Manual to Automatic.**—If the traffic to automatic offices from the manual office under consideration is large, the latter will use push-button calling devices which will be operated by the "*A*" operators (Fig. 219), marked "Numerical keys." A call from a subscriber will be answered as usual with the answering plug of a pair. The "*A*" operator will press the office button which corresponds to the order-wire button used on calls to other manual offices. This will cause a trunk indicator to display the number of the trunk to be used, into which the operator will insert the calling plug of the pair used. She will then operate the keys of the calling device for the four digits of the call number in the called office. This will transmit the impulses for operating the switches in the distant office.

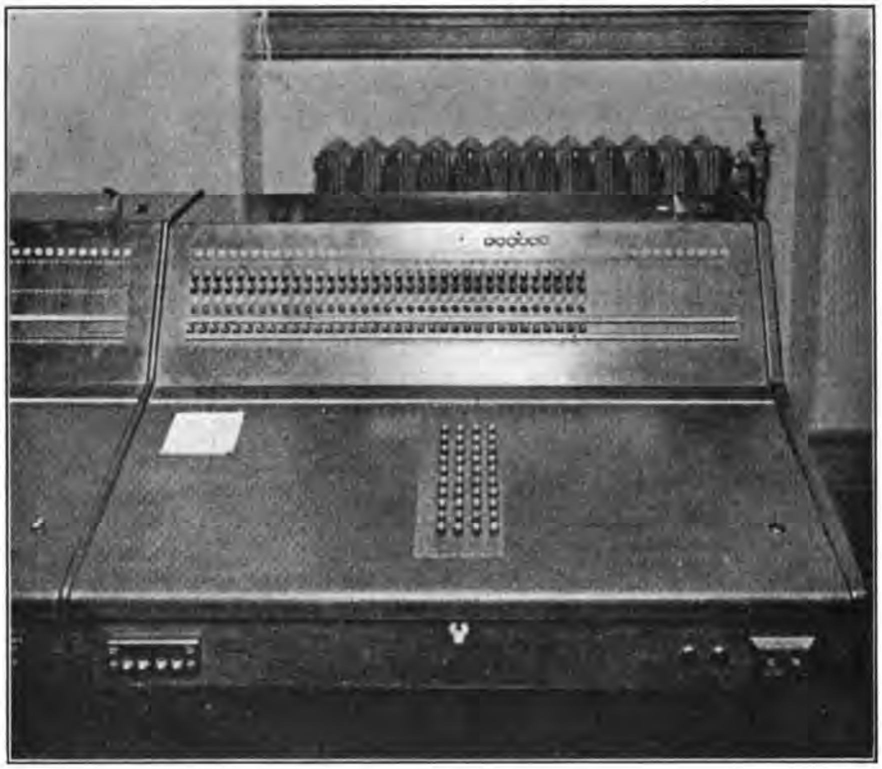


FIG. 220.—Cordless B board.

If the traffic to automatic is small, or the manual office under consideration is soon to be changed to automatic, the "*A*" operators will not do the calling, but it will be done by "*B*" operators located at a "cordless *B*" board in the automatic office (Fig. 220). The call is passed to the cordless "*B*" operator who sets up the four digits on a push button calling device which has four rows of push-buttons, like an adding machine.[1]

[1] NOTE.—This chapter is for the greater part drawn directly from the publications of the American Telephone & Telegraph Company, by whose courtesy the illustrations are reproduced. Reference was also had to certain United States patents.

# CHAPTER XI

## 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. 221. 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

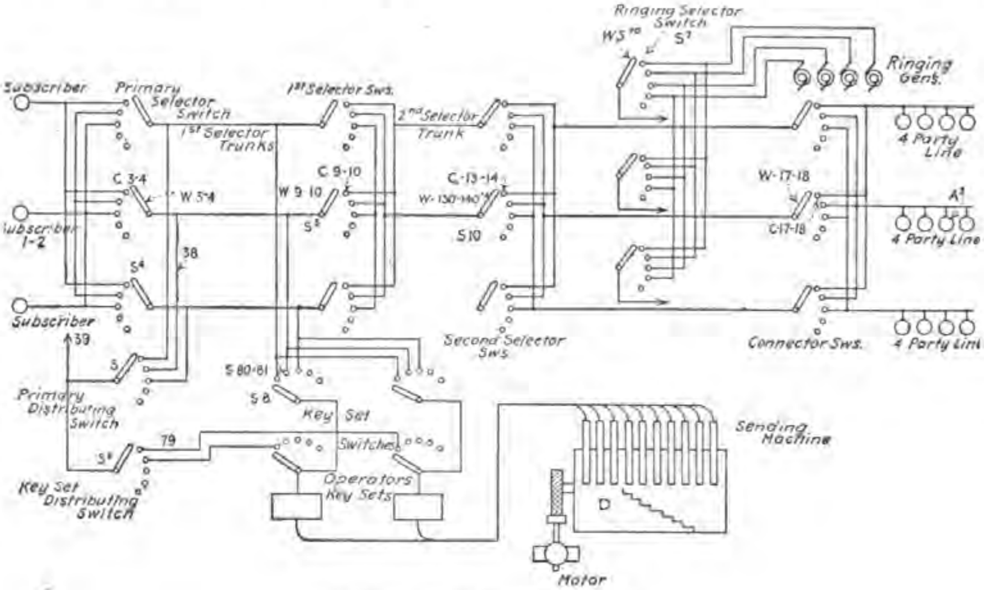



FIG. 221.—Trunking system.

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 (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,

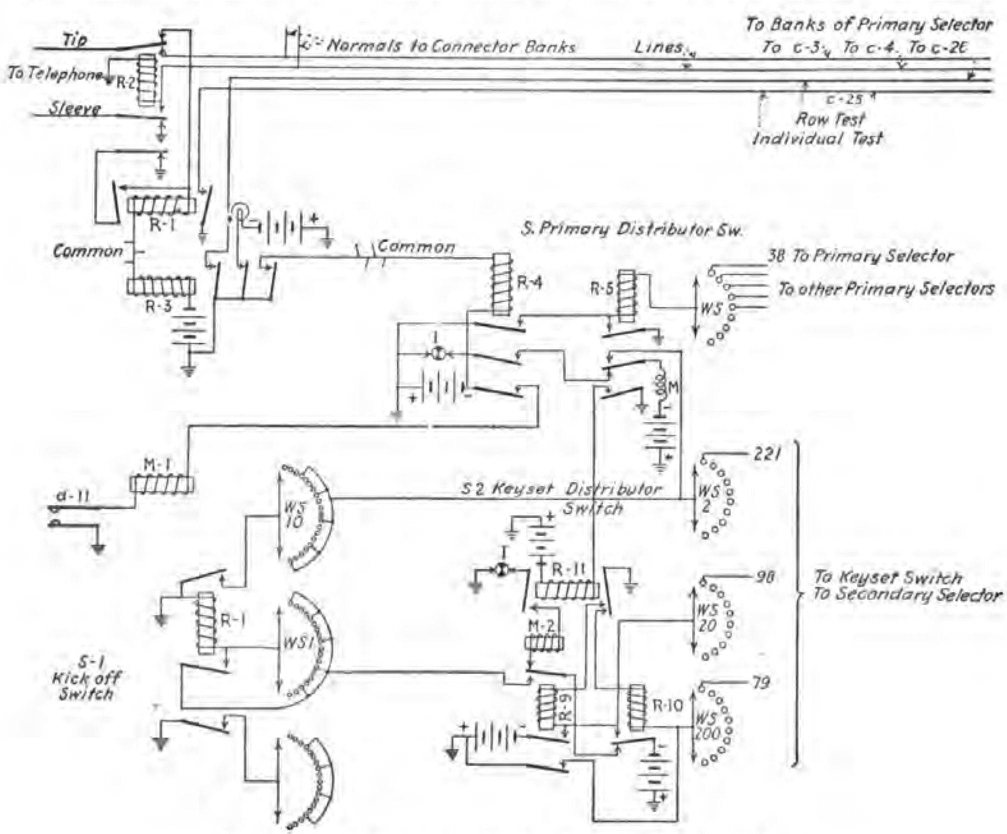



FIG. 222.—Subscriber's line and distributor circuits.

the third digit operates the ringing selector and the fourth and fifth digits operate the connector.

**Details of Circuits.**—The subscribers' lines (see Fig. 222) 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. 224) 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 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. 225) 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. 224, as well as other relays.

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. 229) 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 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.

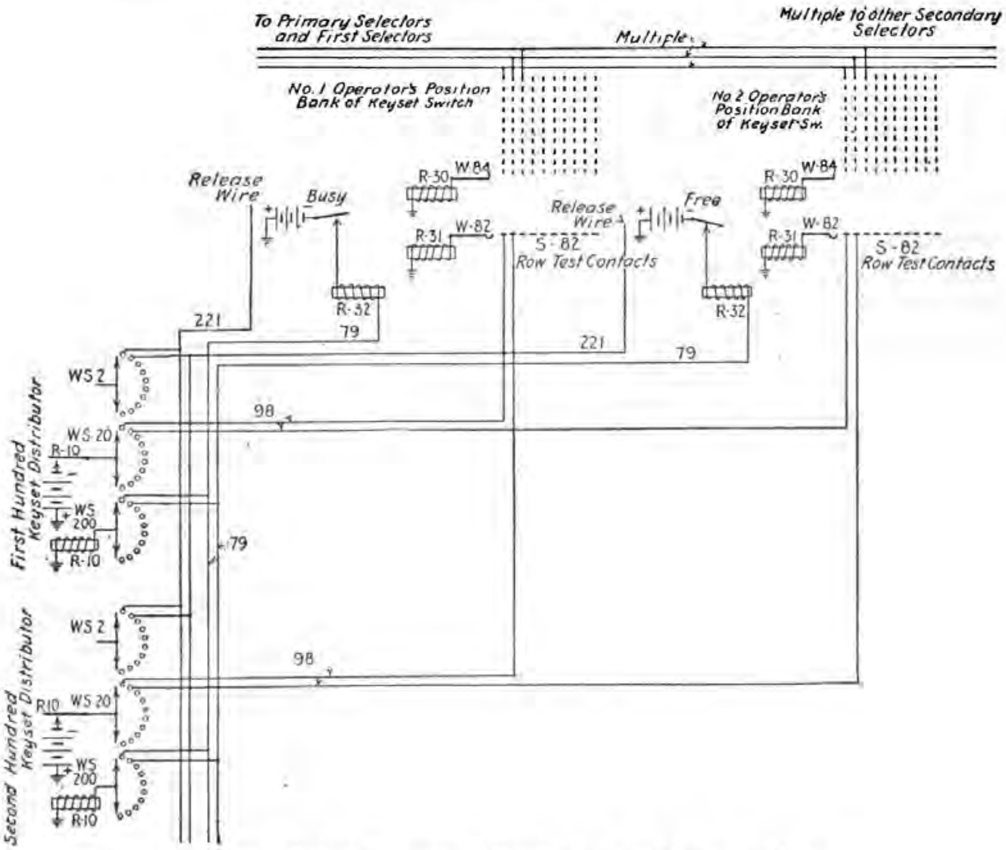



FIG. 223.—Relation between distributors and keyset switches.

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 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. 223. 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 mulipled together. Each operator can, therefore, be connected to any one of 100 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. 222) 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 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 enerigized 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. 224) 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. 225) 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.

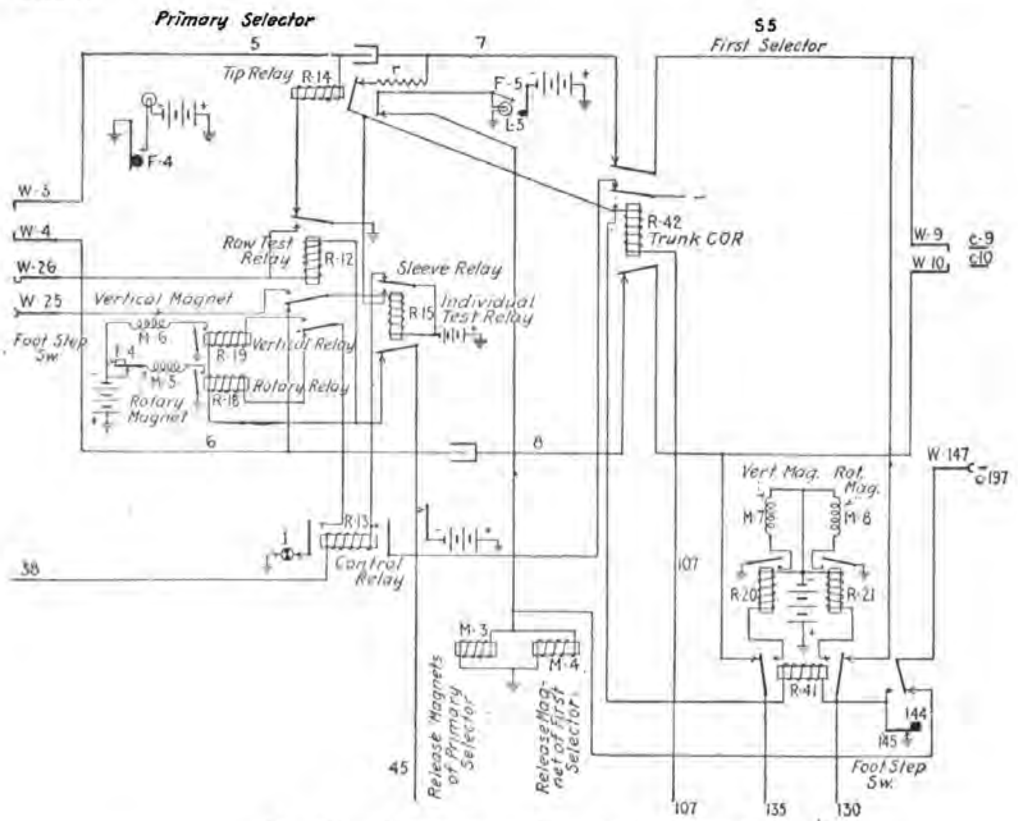



FIG. 224.—Primary and first selector circuits.

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. 226), placed a ground on the row test contact, $C$-26 (Fig. 222), 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. 224) 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 become de-energized, stopping the wipers of the primary selector on the calling line.

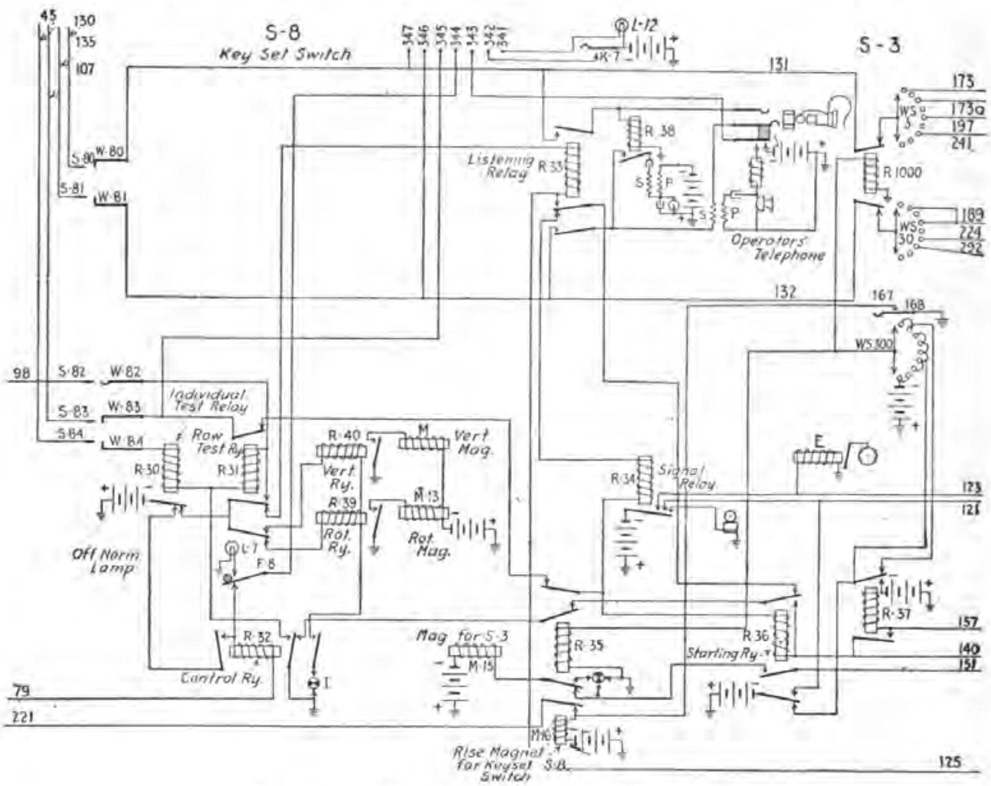



FIG. 225.—Operator's keyset switch circuit.

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. 222) 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. 225) 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. 232), terminal 343 key-set

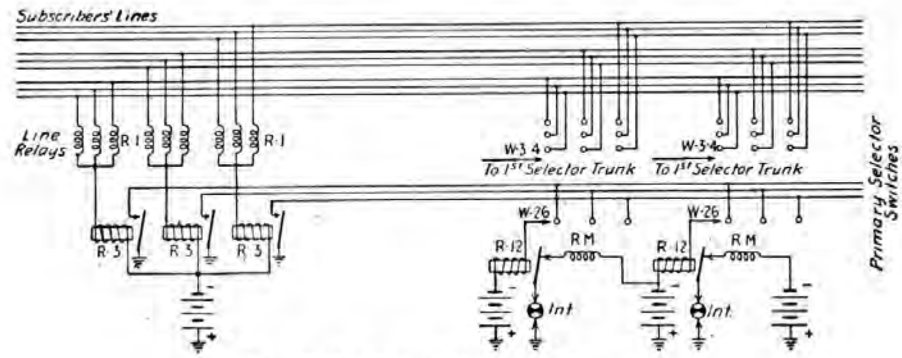



FIG. 226.—Identifying the calling line.

switch (Fig. 225) 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. 222) 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. 225). 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. 225) locks its own winding to negative battery through a back contact of relay *R*-30, 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. 224, 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. 224 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. 225) and wiper $W$-80 to wire 131. The other is from wiper $W$-10 of the first selector (Fig. 224); through a back contact of relay $R$-41; wire 135; bank contact $S$-81 of key-set switch (Fig. 225); 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: from negative battery, through front contact of sleeve relay $R$-15, primary selector (Fig. 224), winding of trunk cut-off relay $R$-42, wire 107, bank contact $S$-83 of key-set switch (Fig. 225), 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. 222). 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 contl relay $R$-13 of the priminary selector (Fig. 224) 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. 225) at the operator's position, lights a guard lamp $L$-2 (Fig. 227) which attracts the attention of the operator. It also rings a night alarm bell for night service, if desired, and operates a call register, $E$.

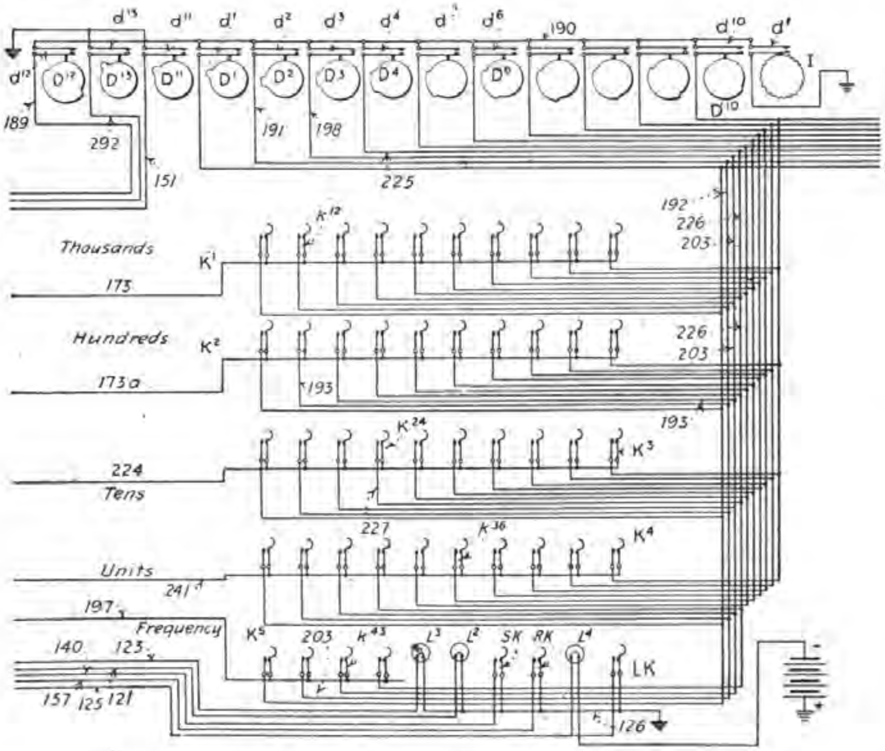



FIG. 227.—Sending machine and keyset circuit.

The operator now answers the call by pressing the listening key $L$-$K$ (Fig. 227). Current then flows from ground (Fig. 181) contact of key $L$-$K$ and wire 125 to (Fig. 225) 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 of the trunk cut-off relay $R$-42 (Fig. 224), 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. 227. 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. 225). The circuit over which this is done is as follows: ground, starting key *S-K* (Fig. 227), wire 140, winding of relay *R*-36 (Fig. 225), back contact of relay *R*-35, back contact of relay *R*-31, wiper *W*-83, contact *S*-83, wire 107 to (Fig. 224,) 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. 225) 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.

*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. 227), 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. 227), through wire 173, wiper *W*-*S*-3 (Fig. 225), 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. 224) 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.

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. 227) 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

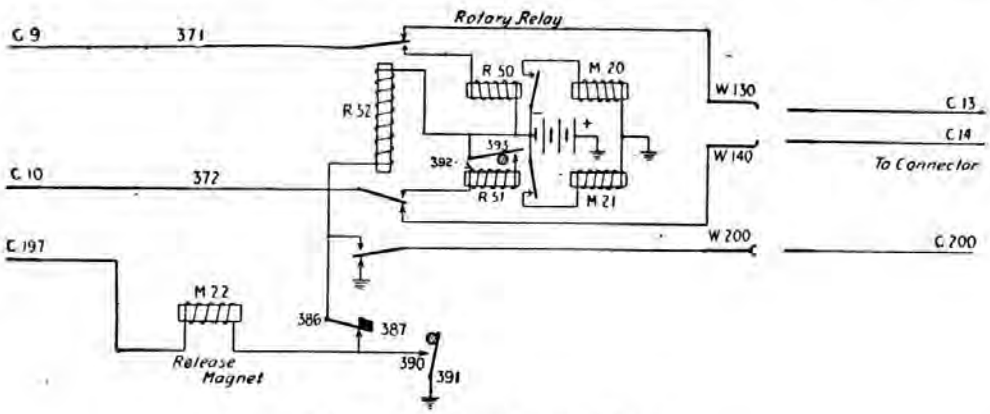



FIG. 228.—Second selector circuit.

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. 228), 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 relay 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. 225) 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

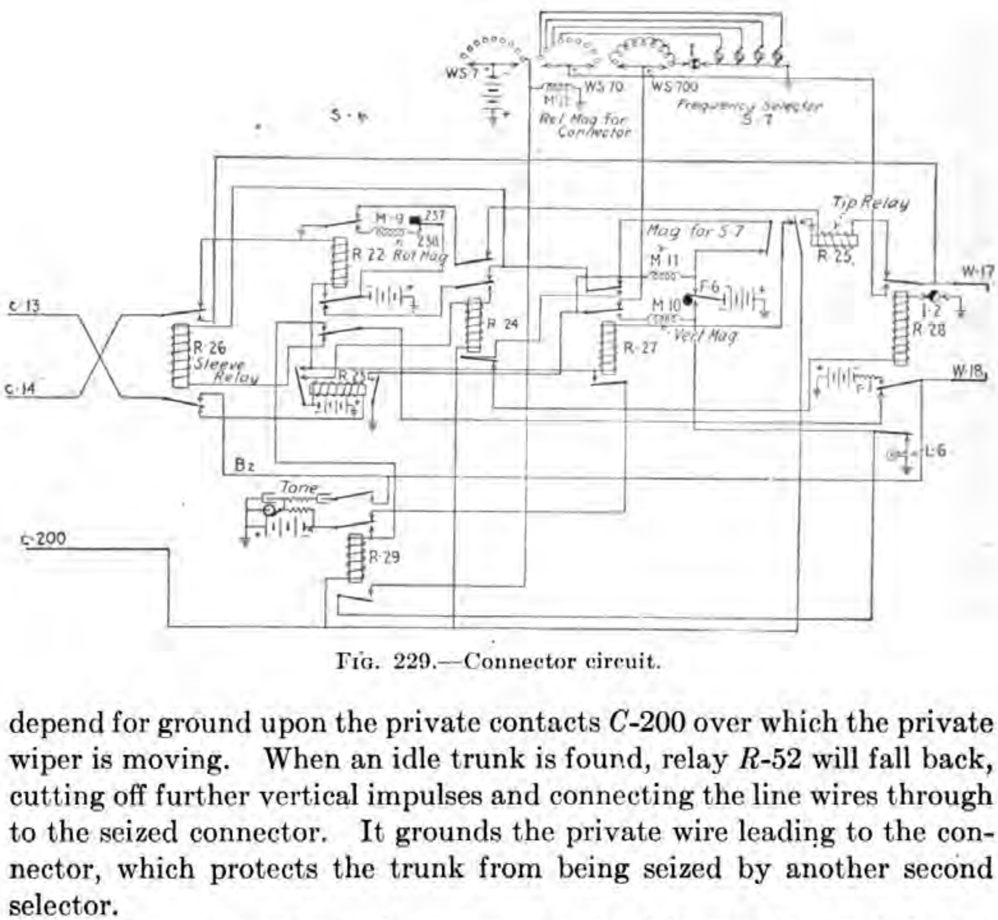



FIG. 229.—Connector circuit.

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. 225), is moved one step as before, so that its wipers rest upon contact 5. This connects the frequency impulses, wire 197 (Fig. 227), to the wire 131 of the secondary selector (Fig. 225). 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. 229), 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. 225) 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. 227), 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, theimpulses 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. 222). 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 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. 230.

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.

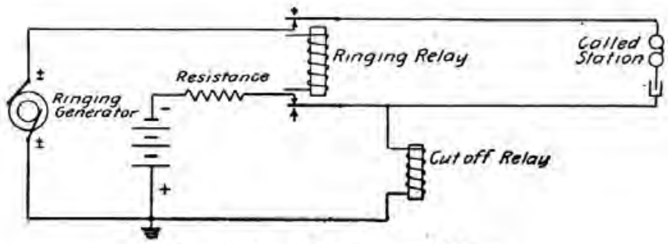



FIG. 230.—Ringing conditions.

During conversation the existing circuits are as shown in Fig. 231. 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.

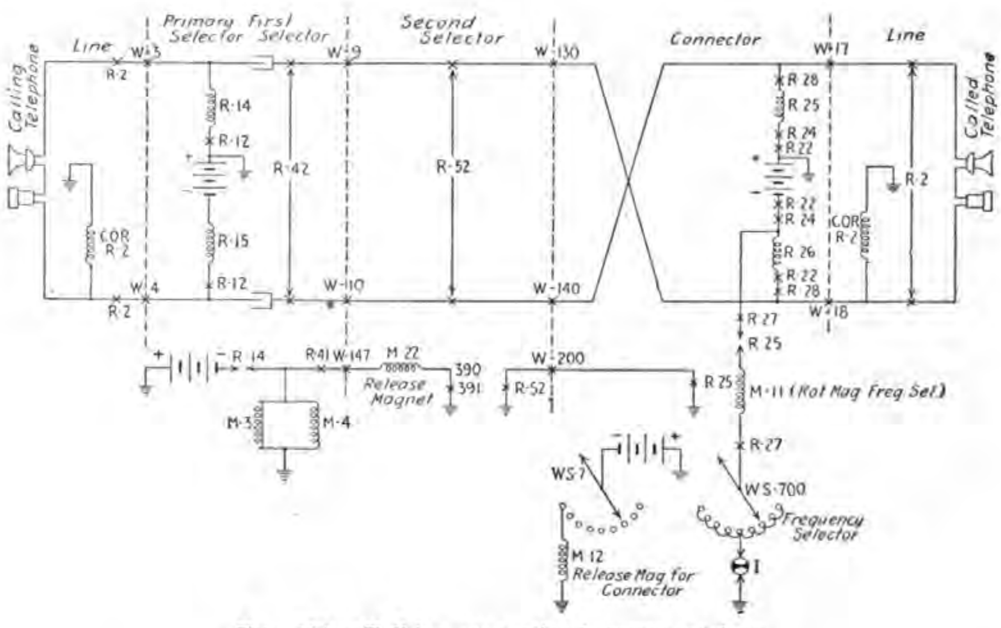



FIG. 231.—Talking connection between stations.

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 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. 229 as well as Fig. 231).

When the subscribers release, each controls only a part of the complete connection. The calling subscriber releases primary, first, and second

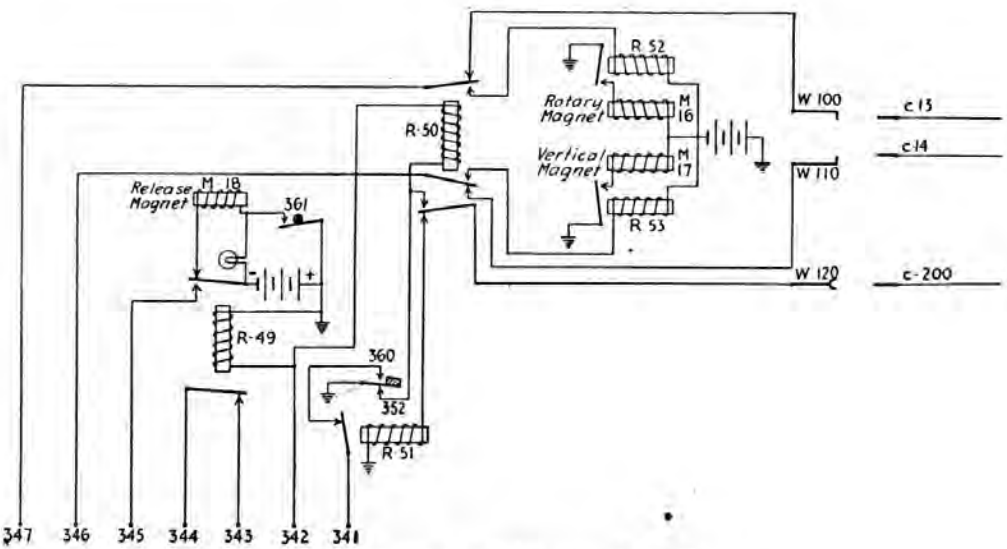



FIG. 232.—Selector for reverting calls.

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 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 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. 232) 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. 225 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.

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

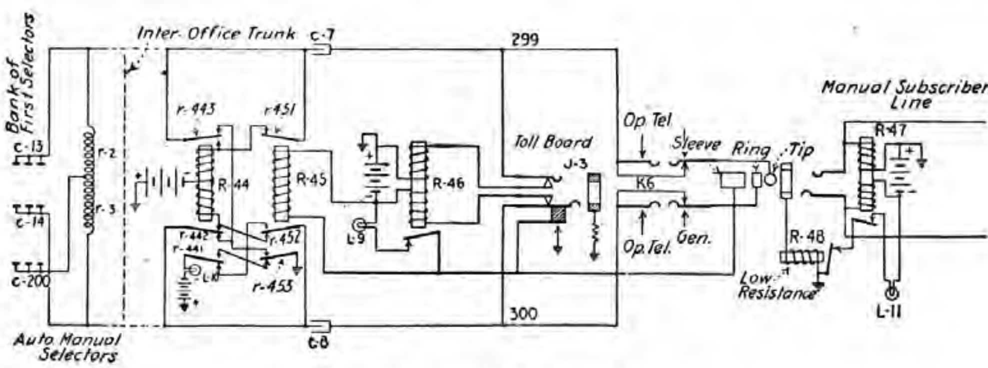



FIG. 233.—Trunk to manual office.

position. The current flow in this circuit is as follows: negative battery, front contact of relay *R*-49, wire 345 to Fig. 225, 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. 227), 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.

**Trunking from Automanual to Manual.**—A trunking circuit for handling calls from an automanual to a manual office is shown in Fig. 233. At the left are seen the banks of first selectors, it being assumed that the

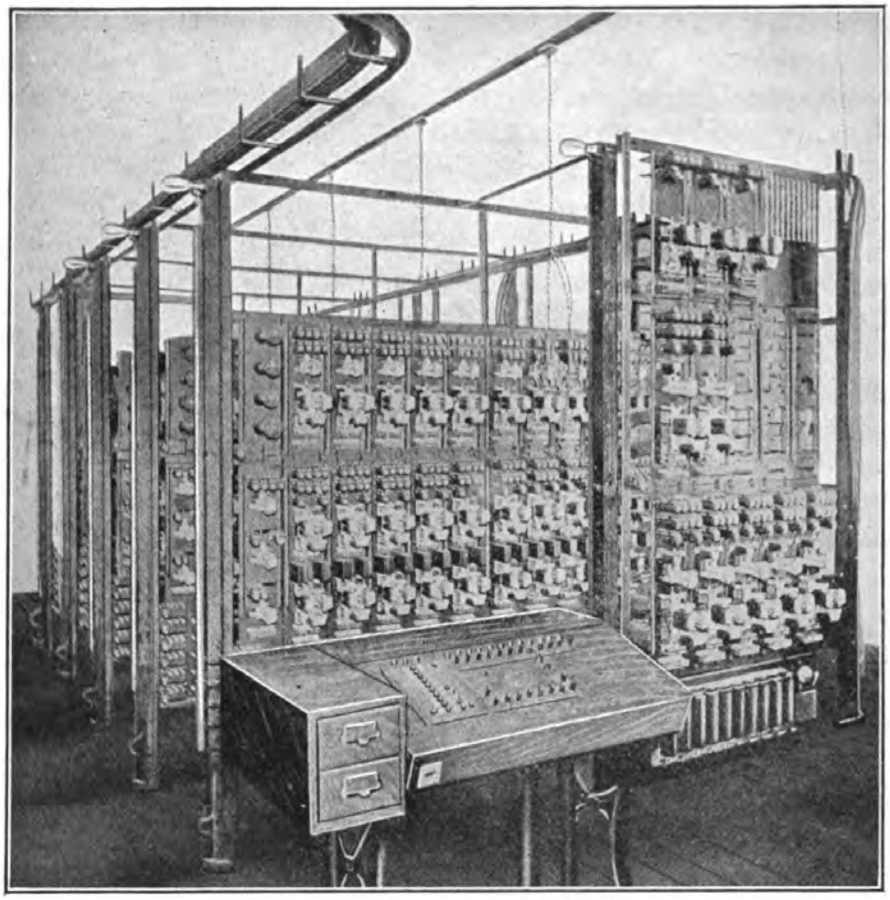


FIG. 234.—500-line installation.

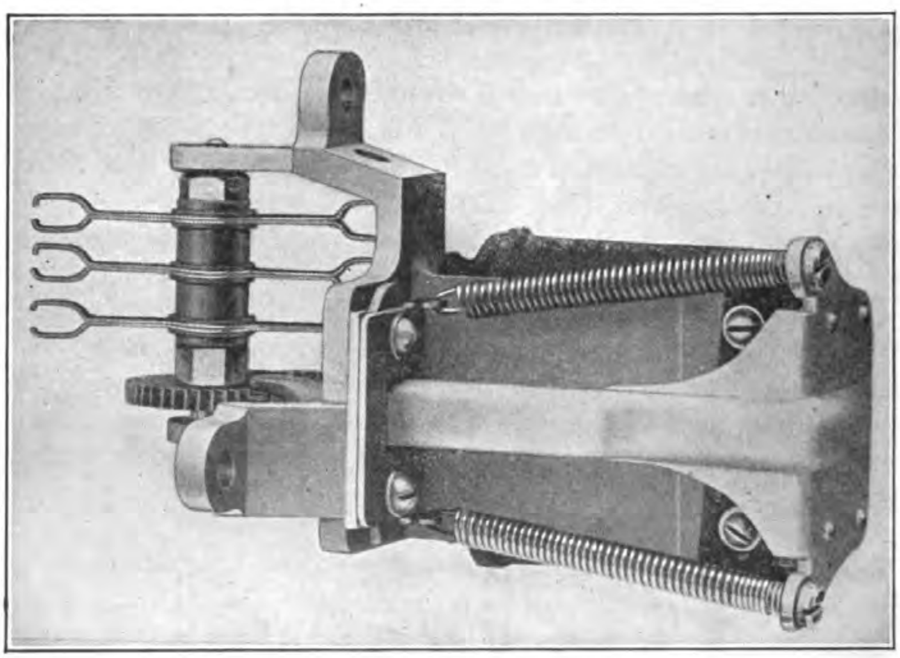


FIG. 235.—Wipers and magnet of rotary switch.

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.

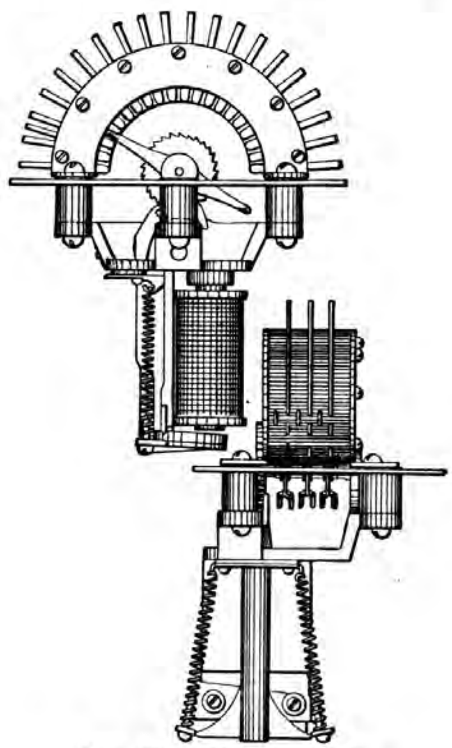


FIG. 236.—Rotary switch.

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 the 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

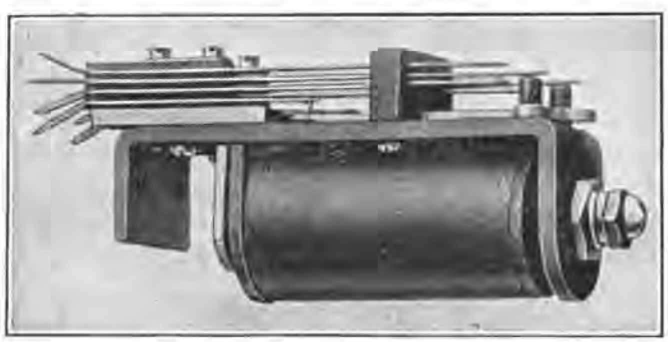


FIG. 237.—Relay.

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.

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.

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

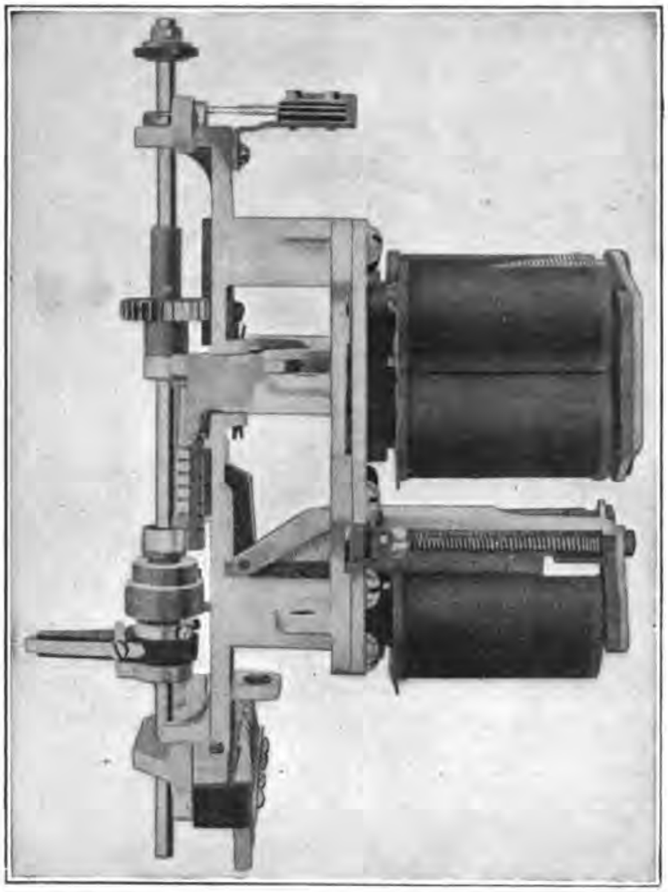


FIG. 238.—Wipers and magnets of switch unit.

"*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 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. 234. The operator's desk may be seen in the center foreground. It is equipped with

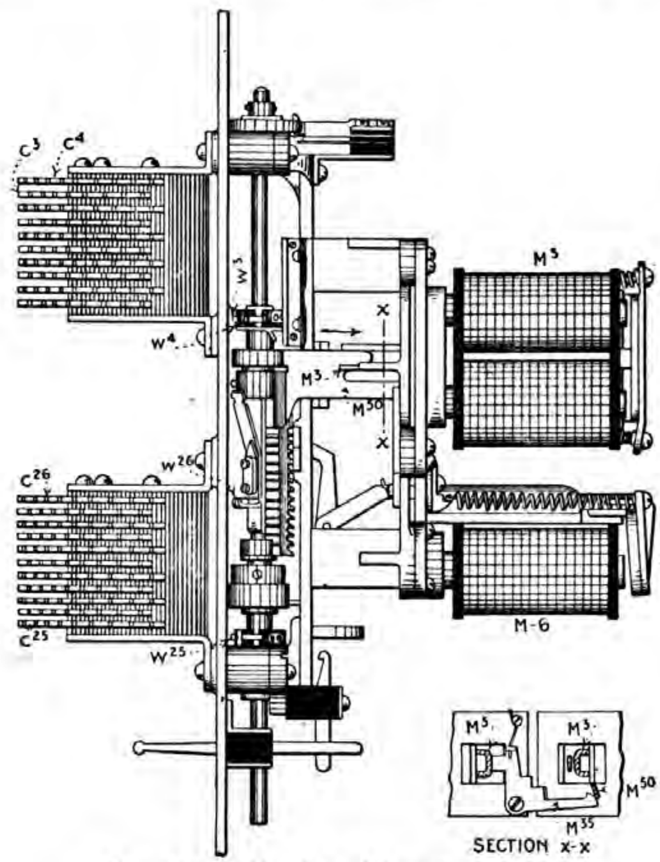



Fig. 239.—Side view of 2-motion switch.

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 Fig. 235 and 236. The magnet has a knife-edge pivoted armature, retained by coiled springs, adjusted by screws in the armature. The bank has 20 points.

The line relay (Fig. 237) has a heel piece which makes two bends, one end carrying the core and the other used for mounting. The armature is pivoted 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. 238) 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,

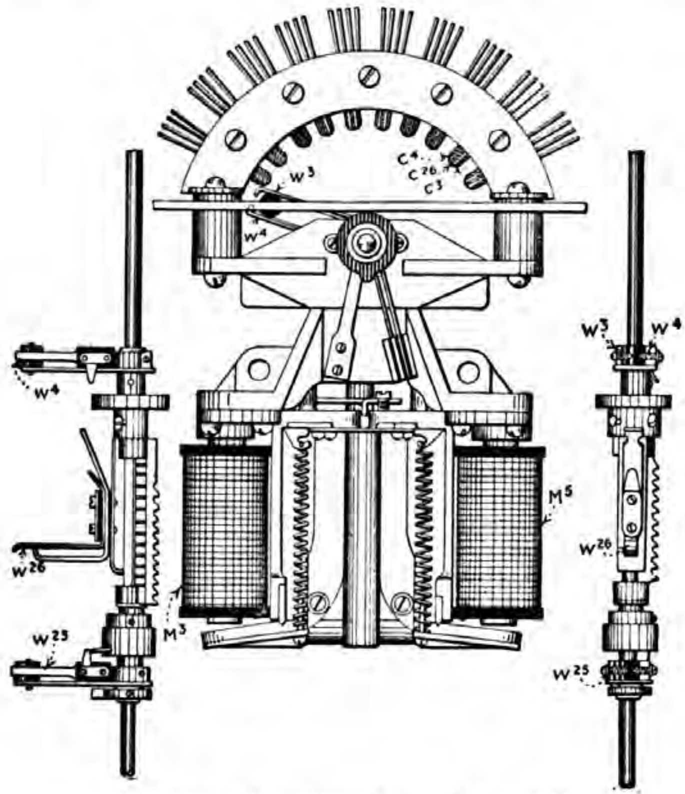


FIG. 240.—Plan-view of 2-motion switch.

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. 239 and 240. In these the banks are attached. The upper is the line bank, through which the telephone lines are connected. The lower bank carries the 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 XII

### LONG DISTANCE AND SUBURBAN 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 callings 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 usually the 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. Sometimes other numbers are used, such as 100, 110, etc., depending upon the numbering scheme. In any case the subscriber secures 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 distanct 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 used 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, toll selectors, and toll connector (one or more 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 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.

In working out method 2 it has become customary to use several combined toll and regular connectors in each hundred line board, arranging them so that they are the first choice of the toll selectors, but the last choice of the local selectors. This was referred to in the chapter on "Trunking, its Physical Arrangements and Variations."

The ringing is intermittent, but must be started by the toll operator. When the subscriber answers, the ringing stops automatically. If the subscriber hangs up his receiver, the usual supervision is given, and the toll operator may start the ringing again, if desired.

Intermittent ringing is used for toll calls because it has been found to be more effective than manual ringing. Where local ringing is periodic and toll calls are rung by hand, much delay results. The subscriber is inclined to think that the manual ring is merely some local call which is very shortly released. Consequently he pays no attention to it. But the periodic signal gets his attention and greatly shortens the time of response to toll calls as well as to local calls.

The toll connector tests the called line as does any connector. If the line is busy, it sends a busy tone to the operator and also extinguishes the supervisory lamp at the toll board. When the line becomes free, the connector seizes the called line, stops the busy tone, and lights the supervisory lamp at the toll board. When the operator sees that the line is free, she starts the ringing by pulling the ringing key.

The release of a toll-to-local connection is controlled by the toll operator. Merely pulling the plug out of the trunk jack causes the switches to be restored to normal.

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.**—It has become the practice to operate rural lines automatically much more generally than formerly. Great advantages have thereby been secured. Such operation will be discussed in the chapter on Rural Automatic Telephones.

Manually operated rural lines (in connection with automatic central offices) are generally run to the toll board, and where there are enough of them terminate on one or more rural line positions.

**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 name 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 position 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

[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.

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 lineswitch, secondary lineswitch, first selector and toll trunk repeater to a typical trunk circuit is shown in Fig. 241. The circuits of the primary lineswitch, secondary lineswitch 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 lineswitch 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 bus bar 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 lineswitch unit through condenser, release trunk, release trunk of secondary lineswitch, the release trunk of the first selector, the first selector private wiper, private bank contact, contact 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 lineswitch 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.

**Toll or Rural-line Circuit.**—A typical toll or rural-line circuit with its multiple connection and supervisory signals is shown in Fig. 242. 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.

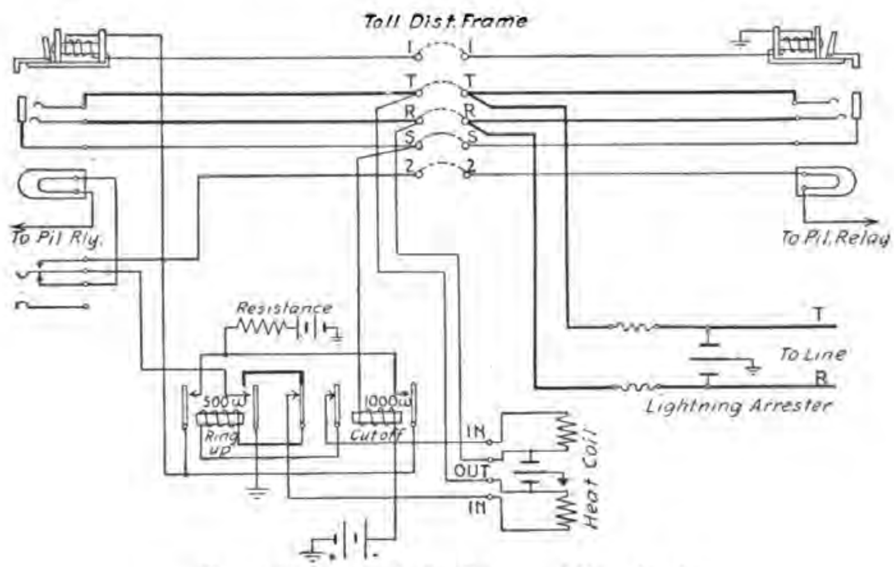
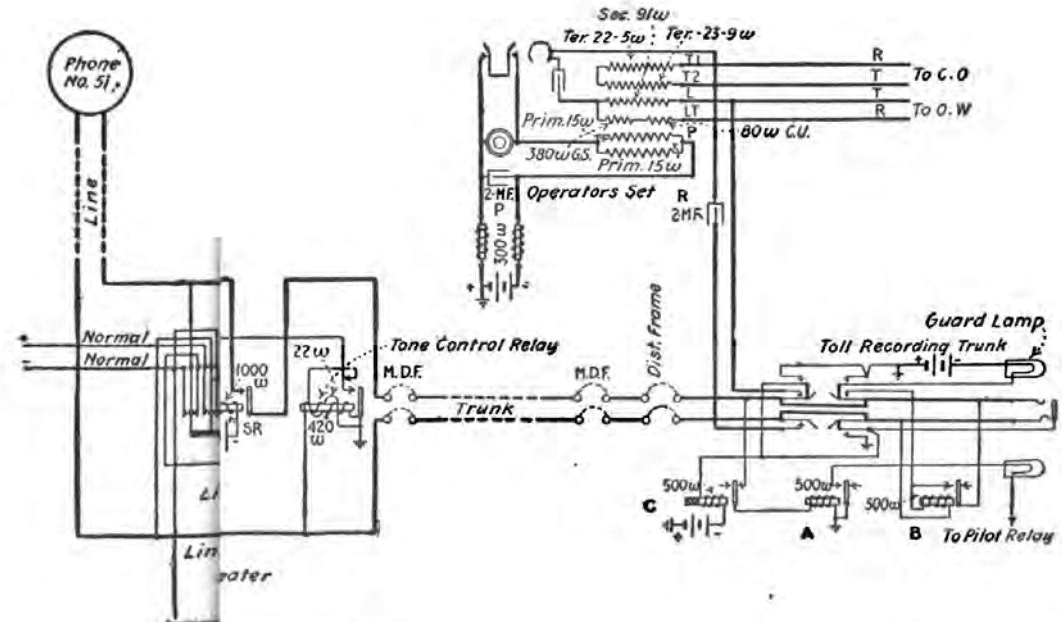



Fig. 242.—A typical toll or rural-line circuit.

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 multiplied 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




ting tone signals.

(Facing Page 284)

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. 243. 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

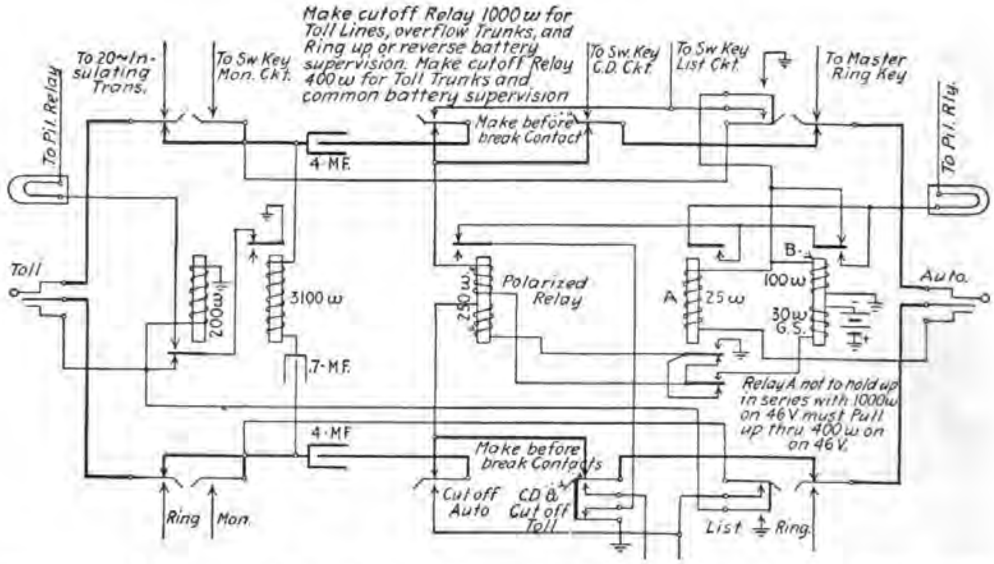



FIG. 243.—A typical cord circuit for connecting toll lines to local automatic switchboard lines.

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 bus bars. 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 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. 243) 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.

**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. 244. 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 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 selec-

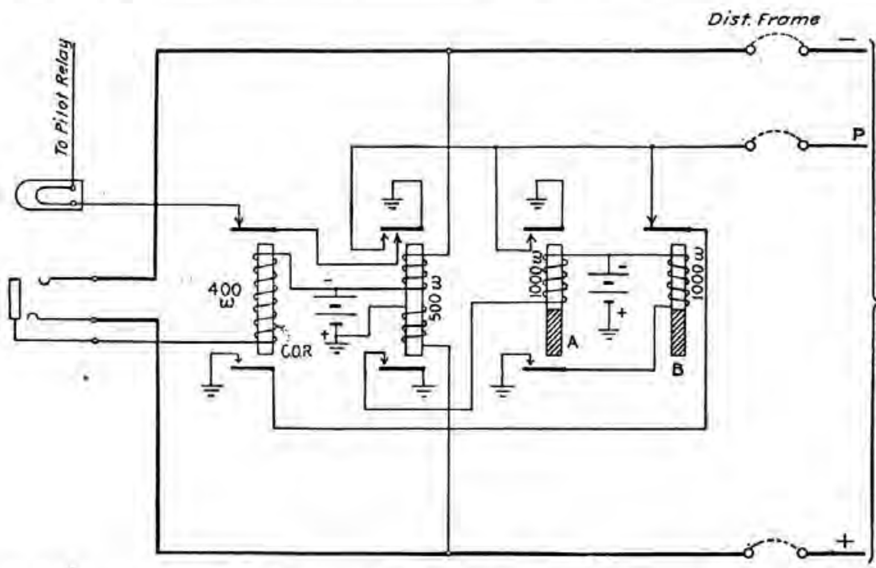



FIG. 244.—Circuit of trunk incoming to a rural-line switchboard from an automatic switchboard.

tor. 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. 243, 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. 242, 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.

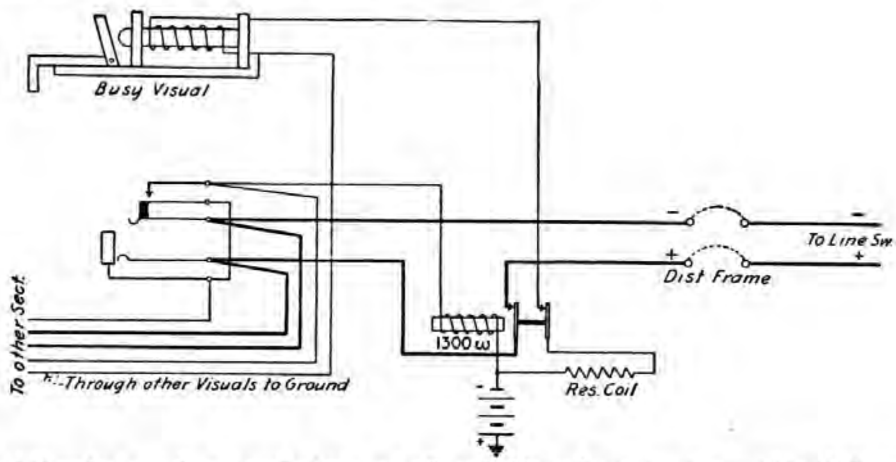



FIG. 245.—An overflow trunk from a toll switchboard to an automatic switchboard.

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.

**Overflow Trunks.**—One end of an overflow trunk is shown in Fig. 245. 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 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. 242) 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. 246), when a plug is inserted in the jack, current flows from negative battery through 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 Circuits.**—In modern automatic service it is customary to divide the connectors which serve a certain group of subscribers into two classes, regular connectors and combination toll and regular connectors. The regular connectors are seizeable only by subscribers in the ordinary course of their call. The combination connectors

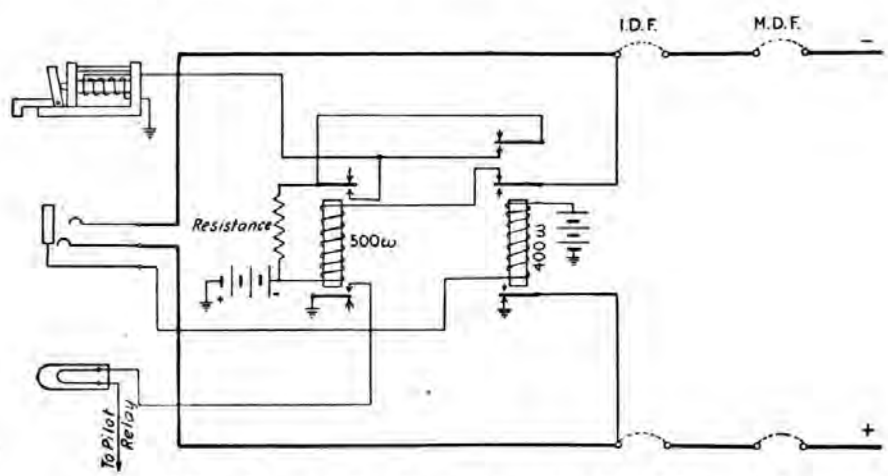



FIG. 246.—A pay-station line equipment at its toll-board end.

are also seizeable by subscribers, but the trunking arrangement is such that no combination connector of a group will be seized by a subscriber until after all of the regular connectors in the group are in use. When thus seized, the combination connectors give a service identical with that of a regular connector.

The trunks to the combination connectors, in addition to appearing in the bank of the regular third selectors, are also multipled to the banks of the toll third selectors. When a toll operator dials a certain number the toll third selector will route the call to one of the combination connectors serving the group of which that particular number forms a part. The combination connector will now function as a toll connector, the principal difference being that the starting of the automatic ringing will now be under the control of the toll operator. Should the toll operator call a busy line, the combination connector will advise her of the fact, and as soon as the line becomes idle, will indicate to her that she may now depress her ringing key.

A combination connector when giving either kind of service will, of course, busy itself both in the regular third selector banks and in the toll third selector banks.

In Fig. 247 is shown diagrammatically the various circuits used in extending a call from the toll board to an automatic subscriber. At *A* is represented any standard toll cord circuit with equipment added such that a dial may be cut in series with the sleeve of the calling plug. At *B* is represented an intermediate selector circuit. In this switch the impulsing relay is controlled over a third conductor. The talking circuit is cut straight through, and a fourth conductor forms the customary release trunk. At *C* is shown a final selector, or as commonly called "a toll third selector." Here the talking circuit is carried through a repeating coil and it is this switch which feeds talking battery to the called subscriber. The impulsing relay is here controlled over a fourth conductor, the usual release trunk forming the third conductor. At *D* is shown a

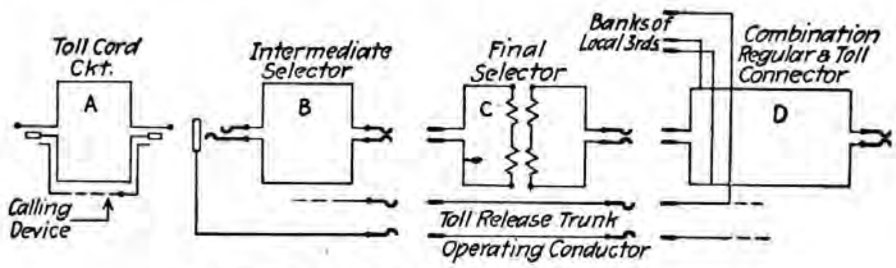



FIG. 247.—Toll to local circuits in skeleton.

combination toll and regular connector. The usual three-wire trunk is carried to the banks of the regular third selectors. The talking conductors are cut straight through for toll service. The third conductor is the usual release trunk for toll service and the impulsing relay is controlled over the fourth conductor.

**Toll-cord, Sleeve Dialing.**—This is shown in somewhat skeleton form in Fig. 248. There is enough to show the essentials of sleeve dialing and supervision over the loop of the line wires. Relay *B* is for ring-down supervision from a toll line when the latter is manually operated. Relay *A* is for supervision from the local automatic switchboard. The sleeve conductor is grounded. When it is desired to dial toward the automatic switchboard (local) the operator throws the calling-device key to "local" which operates the springs marked "*CD-L.*" This cuts off the toll end of the cord and switches the calling device *CD* into the sleeve of the local plug.

**Toll Selector, with Operating Trunk.**—The circuit of a toll selector which may serve as first, second, etc., is shown in Fig. 249. Here it is shown with a jack on the toll board. The insertion of the plug by the operator closes the sleeve circuit to the operating relay *OpRy* and operates the visual busy signal. The operating relay in the selector acts on the magnets and other relays exactly as was described in connection with regular selectors. When the selector cuts through to the next switch

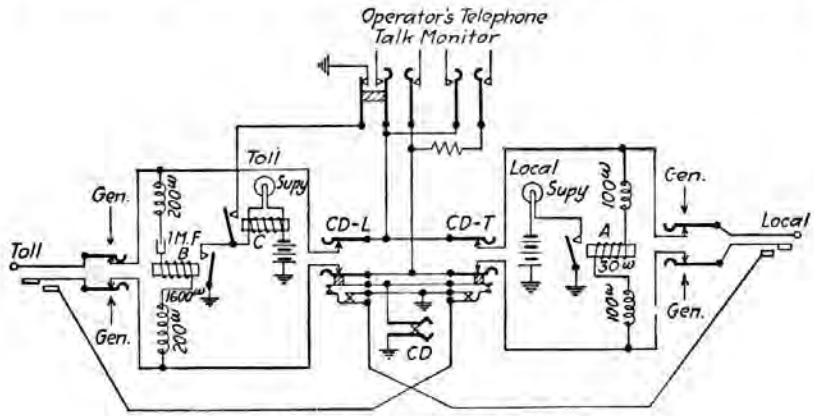



FIG. 248.—Toll to local cord circuit, sleeve dialing.

ahead, the operating wire is switched from the operating relay in this switch to that of the next switch. The release trunk is carried through separately.

**Toll Third Selector, with Repeating Coil.**—The toll third selector, as it is called, has a circuit like that shown in Fig. 250. Whether it is a

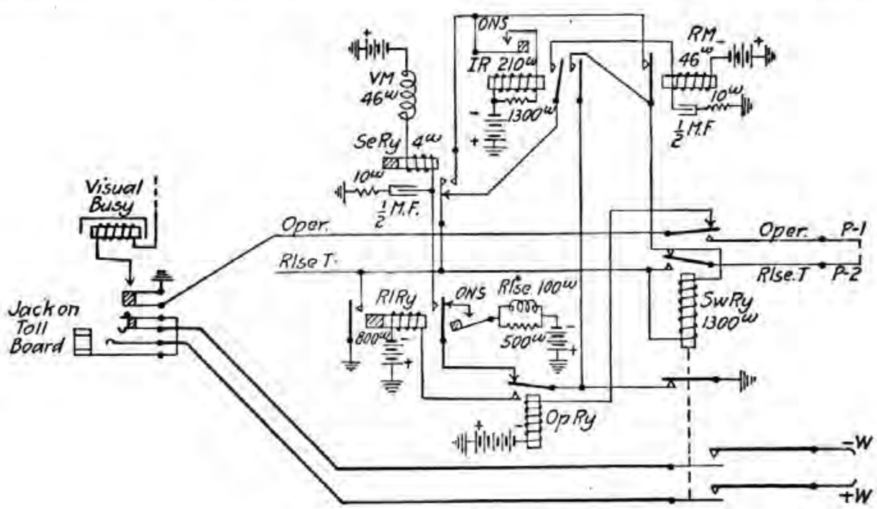



FIG. 249.—Toll selector.

real "third" selector or not depends upon the size of the exchange. In any case this is the switch which feeds battery to the called telephone.

This switch functions as an ordinary selector, except that the operating relay *OpRy* takes the place of the usual line relay and is controlled over the operating trunk, *P*-1. The talking circuit, indicated by the heavy lines, is entirely separate from the rest of the selector.

When a connection has been extended to this switch, the operating relay *OpRy* is energized and in turn pulls up the release relay *RlRy*. The release relay grounds the release trunk *P*-2 so as to hold the switches back of it in the operated position, opens the release circuit to the release magnet *Rlse*, and prepares the circuit to the vertical magnet *VM*.

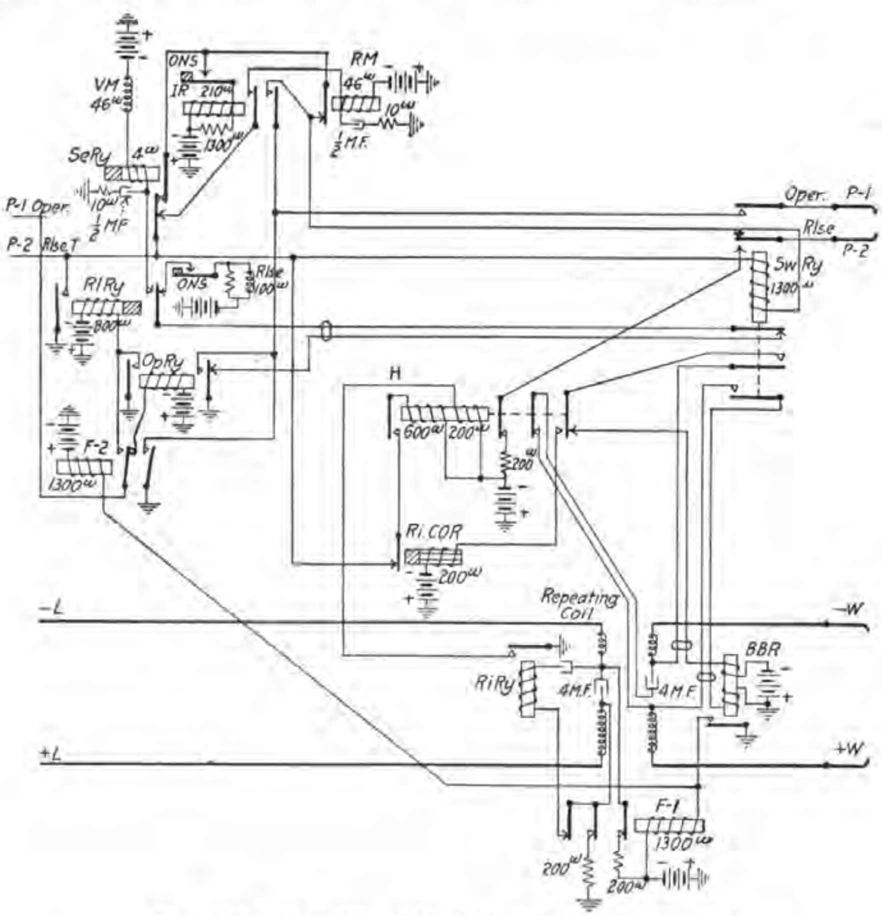



FIG. 250.—Toll third selector (transmission selector).

At each interruption of the calling device in the sleeve of the toll cord, the line relay drops back and operates the vertical magnet in series with the series relay *SeRy* through a back contact on the switching relay *SwRy*, and a front contact on the release relay.

The off-normal springs close on the first vertical step, preparing the release circuit and closing a circuit for the interrupter relay *IR* through the front contact of the series relay *SeRy* to release trunk ground. The interrupter relay pulls up and locks itself to the ground at the operating relay (front contact) which at the end of the group of impulses will be steady. The interrupter relay prepares a circuit for the rotary magnet.

When the impulses cease, the operating relay comes to rest energized. The series relay drops back and closes the circuit of the rotary magnet to release trunk ground. The rotary magnet pulls the wipers onto the first trunk in the level and near the end of its stroke opens the circuit of the interrupter relay so that the latter falls back.

As the interrupter relay falls back, it opens the circuit of the rotary magnet, causing it to fall back and close the interrupter-relay circuit. If there is a ground on the private wiper *P*-2, the switching relay *SwRy* will not be able to act and the interrupter relay will pull up again and cause the rotary magnet to move the wipers to the next trunk. When an idle trunk is found, no ground on the private contact, the switching relay will pull up, preventing by its resistance any further action of the interrupter relay.

The pulling up of the switching relay *SwRy* has several effects. It closes the circuit of the front contact of the operating relay *OpRy* through *P*-1 to the toll connector so as to pull up its operating relay. It switches the private wiper *P*-2 from the interrupter circuit to a 200-ohm resistance and negative battery by way of a back contact on relay *H*. It opens the impulsing circuit of the back contact of the operating relay, because the latter is now to act as repeater to the connector. It also closes the two terminals of the back-bridge relay *BBR* through the repeating coil to the talking wipers $+W$ and $-W$.

A brief examination of the repeating coil and its connections will show that there is a ringing relay which is responsive to ringing current from the toll board. There is also battery on the two-line wires through 200 ohms to each side, and this is removable by the pulling up of the back-bridge relay through relay *F*-1. Thus the called station may give supervision. As soon as the connection from the toll board gets this far, this battery operates the relay *A* bridged across the toll cord and lights the supervisory lamp.

**Combined Toll and Regular Connector.**—We pass now to the connector circuit which is shown in Fig. 251. It may on occasion be seized by a local selector, in which case the call arrives on the three wires shown in the lower left-hand corner. In that case it will function like the other connectors. But the call which we are considering will come in over the four wires marked "toll selector banks."

This circuit is that of a multi-level group connector such as is used for subscribers who have more than ten lines in one group. It will illustrate the action as well as the ordinary connector.

The seizure of this connector by the toll third selector pulls up the line relay *LR* by its negative winding alone, in series with relay *J*. The dead wire prevents noise.

The line relay pulls up the release relay *RlRy* which grounds the release trunk *P*-2 in addition to its other duties. The release trunk has relay *J* in it, which assures relay *K* of remaining energized. It also closes the positive line as relay *K* closes the negative line.

The vertical action is as usual in switches, the series relay preparing things for the next function. The interrupter relay *IR* prepares the rotary-magnet circuit for use at the first idle level.

At the end of the group of impulses, the vertical wiper *VW* takes charge of the vertical magnet and causes it to select an idle level. The vertical wiper passes over a vertical bank which is made busy by a ground through resistance if all the lines in a level are occupied. As long as the

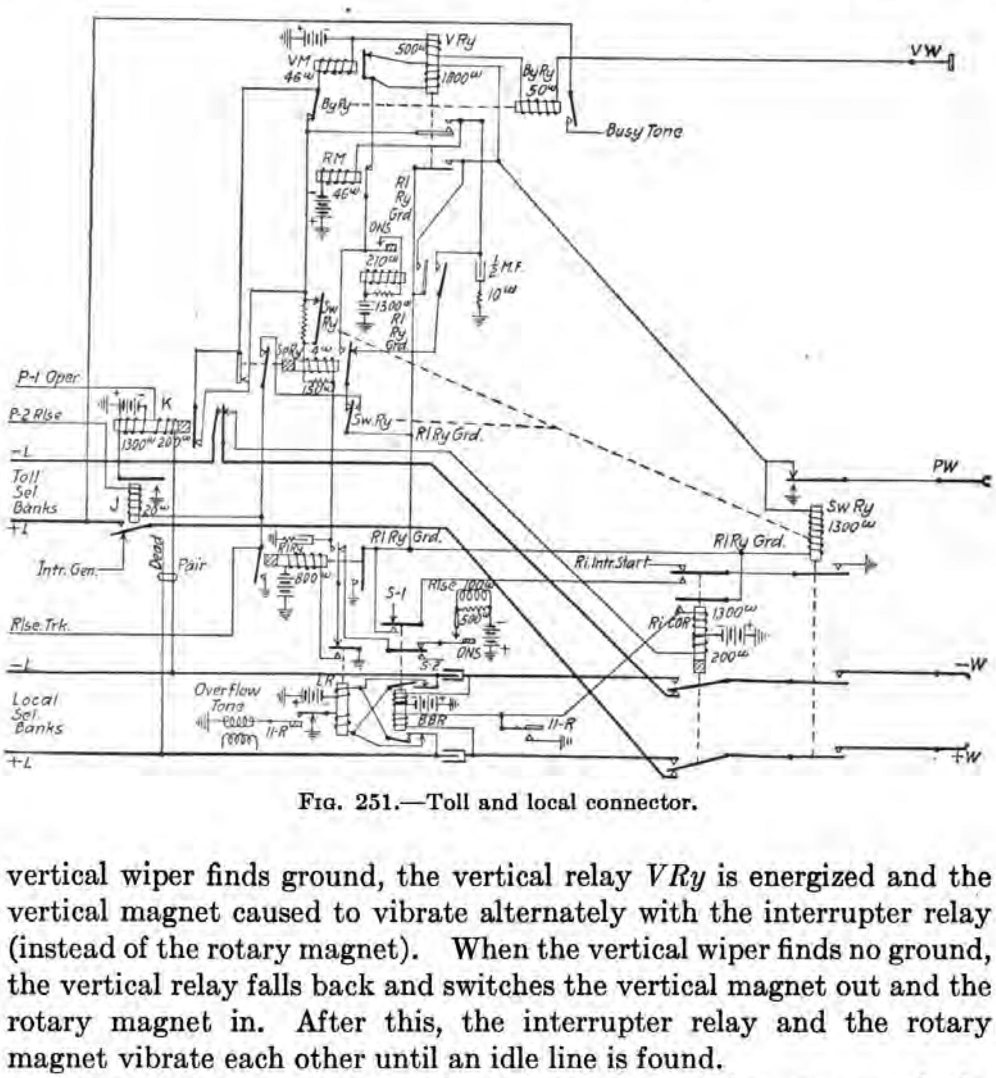



Fig. 251.—Toll and local connector.

vertical wiper finds ground, the vertical relay *VRy* is energized and the vertical magnet caused to vibrate alternately with the interrupter relay (instead of the rotary magnet). When the vertical wiper finds no ground, the vertical relay falls back and switches the vertical magnet out and the rotary magnet in. After this, the interrupter relay and the rotary magnet vibrate each other until an idle line is found.

When the private wiper *PW* has found the idle line, no ground, the switching relay *SwRy* pulls up and cuts the lines through to the line wipers, $+W$ and $-W$. It also grounds the private wiper and operates the ringing-interrupter start *RiIntrStart.* The latter controls the interruption of the ringing generator as has been described before. The switching relay also inserts 150 ohms in the vertical magnet circuit and switches release relay ground from the right-hand contacts of the series relay to a back contact on the same, which thus reaches the release trunk.

Now the toll operator rings on the trunk with alternating current. (Fig. 248.) This operates the ringing relay *RiRy* in the toll third selector (Fig. 250) which pulls up relay *H* of the same switch. Relay *H* locks itself through the back contact of the ring cut-off relay *RiCOR* to the release trunk. Relay *H* opens the wiper side of the repeating coil, switches the negative line from the back-bridge relay *BBR* to the winding of the ring cut-off relay and negative battery, and cuts off the battery connection of the release trunk which leads to the connector.

In the connector (Fig. 250) this last action causes relay *J* to fall back and connect the plus wiper $+W$ to the interrupted generator and ground. The ringing thus starts to operate just as was described in connection with regular connectors for local traffic. The ringing will continue until the called station answers or the toll operator pulls down the connection. It requires only a short ring to start it.

When the called station answers, the telephone set draws current through the ring cut-off relay *RiCOR* of the third selector (Fig. 250) which pulls up and releases the relay *H*. The latter falls back, restoring battery to the release trunk to the connector (Fig. 251) so that relay J pulls up and cuts off the generator.

The called station now draws battery current through the back-bridge relay *BBR* of the third selector. (Fig. 250.) This relay pulls up and energizes relays *F*-1 and *F*-2.

Relay *F*-1 disconnects the ringing relay *RiRy* so that the toll operator can not ring as long as the called station has the receiver off the hook, and cuts battery and ground off the trunk to the toll board. This permits the relay *A* (Fig. 248) to fall back and put out the local supervisory lamp.

After this, the called station signals the toll operator by the hook and the toll operator controls the switches.

To release the connection, the toll operator pulls out the plug from the jack. (See Figs. 248 and 249.) This releases the operating relay in the third selector (Fig. 250) which in turn lets the operating relay in the connector (Fig. 251) fall back. Each of these releases its part of the connection.

If the called line had been busy, the vertical wiper would have found no contact free from ground. The first level of the group would in this condition have dead ground on it, which will operate the marginal busy relay *ByRy*. The latter pulls up, cutting off the vertical magnet and placing a busy tone on the plus line, so that the toll operator will hear the tone and know the conditions.

If she leaves the connection up, and one of the lines in the group should become free, the busy relay *ByRy* will fall back and permit the vertical magnet to hunt for the idle level and the rotary magnet to rotate the wipers to the idle line in that level. This action of waiting is called "camping on busy."

**Combined Connector Used as Local Connector.**—If the connector of Fig. 251 is seized by a local selector, the connection comes in on the three wires at the lower left-hand corner. The line relay *LR* is pulled up, and it operates the release relay as usual. The latter grounds the release trunk from the local banks and the release trunk *P*-2 from the toll selectors, the latter through the 20-ohm relay *J*. Relay *J* will not operate at any time under this seizure, hence the lines to the toll selectors remain open. Relay *K* also remains inactive, so that the 200-ohm winding of the ring cut-off relay *RiCOR* is ready to be used.

The action of dialing and selecting an idle line out of the group is the same as was described. When it comes time to ring, it rings automatically, because the interrupted generator is connected through the back contact of relay *J* and the trip winding of the ring cut-off relay is connected through the back contact of relay *K*.

When seized by a local selector, the connector will not "camp on busy" for the contact of the busy relay *ByRy* is short-circuited by the back contact of relay *K*. The wipers will run up to the last level, then will rotate to the last line and off the bank, when the cam springs marked "11-*R*" operate, cutting the overflow tone into series with the line relay and pulling up the ring cut-off relay. The subscriber must release.

**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.

It has been found that the manual switching of toll lines, among themselves and to subscriber lines, entails considerable loss of time. This is chiefly due to the time required to gain the attention of operators who have other lines to serve besides the one in question. It lengthens the time required to set up a connection, it interferes with supervision, and delays the release of the circuits after both subscribers have hung up their receivers. This is so great a drag on the service that it has led to the establishment of many direct toll lines between important points, so as to do away with intermediate switching. This lowers the time efficiency of the long direct line, because it can not be used for any intermediate traffic.

For at least thirteen years (1920) toll lines have been switched by automatic means and experimenters have been at work producing apparatus which is adapted to this service. The first discovery made was that automatic switching increased the capacity of the toll line at least 50 to 100 per cent. This remarkable increase is due to the speed of connection, the accuracy and promptness of supervision, and the quick clearing of the line after both subscribers have hung up their receivers.

No matter how the switches are controlled, the line must permit manual operation at any time, must operate automatically in both directions if both ends are at automatic exchanges, when seized must give positive indication to all stations concerned, and must give supervision of both calling and called subscriber to the one operator who controls the connection.

Uniform operation is highly desirable. This point has received attention in developing automatic switching over toll lines. It is so arranged that if the operator plugs into the jack of an automatic toll line and rings, the call will go through manually, as formerly. But if, after plugging

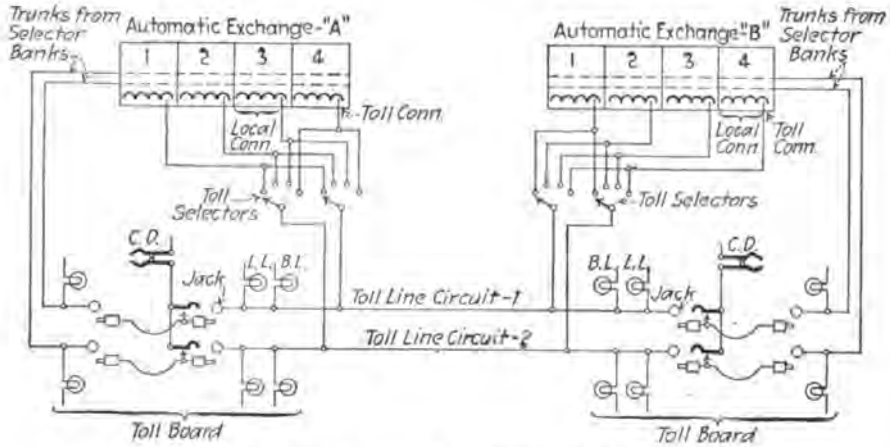



FIG. 252.—Automatic toll lines (scheme).

into the jack, the operator throws the calling device key, she can put the call through automatically. After dialing the number, the operator rings with the regular ringing key. This operation holds no matter whether she is switching toll lines only, or if she automatically completes the connection to the called subscriber.

**Inter-city Scheme.**—For the sake of simplicity, this is illustrated by two small exchanges, for the principles do not depend on the size. The toll lines (Fig. 252) terminate at each end in toll selectors, and in jacks and lamps on the toll board. The trunks from local selector banks also run to the toll board.

When a subscriber in *B* desires to call a subscriber in *A*, he dials the toll operator according to the number given in the directory. This gives him a trunk terminating in a lamp and jack as shown at the right in the illustration. The toll operator answers in the usual way. She has a calling device which may be associated with any pair of cords. When she plugs into the jack of the toll line, she makes it busy at both ends, showing the busy lamp at exchange $A$, so that the toll operator there will not try to use that line. The operator at $B$ then dials the call through the toll selectors to the subscriber desired.

The operator at $B$ controls the connection and gives it the usual supervision. When the subscribers are through, she pulls out the switchboard plug, which causes the switches to release.

The identity of the calling station may be verified by having the subscriber hang up his receiver. When the connection is ready, the operator calls the originating subscriber automatically and permits conversation.

**Toll Switching Office.**—If between two such exchanges there is a toll central office, the lines can be interconnected by automatic switches, so

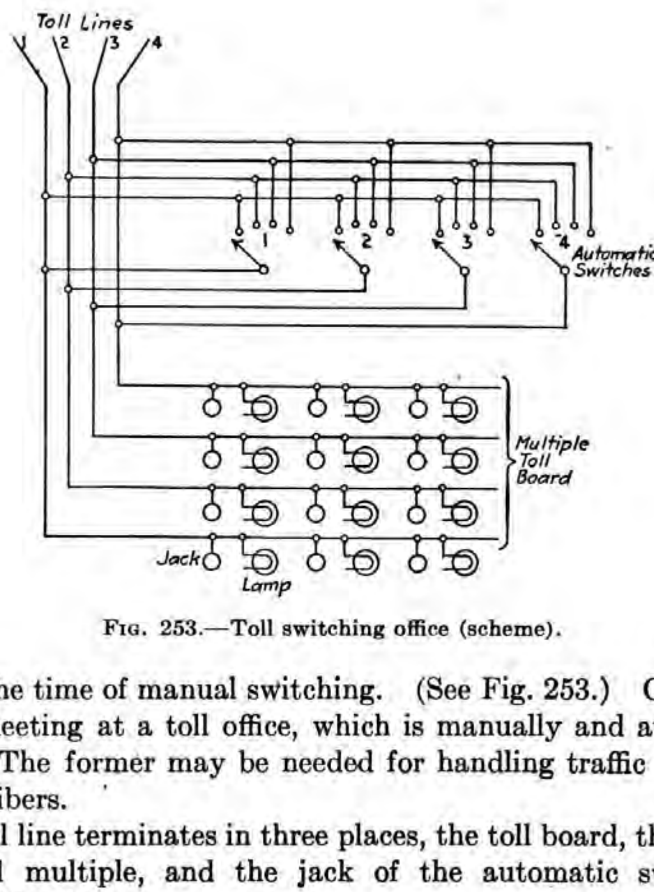



FIG. 253.—Toll switching office (scheme).

as to save the time of manual switching. (See Fig. 253.) Consider four toll lines meeting at a toll office, which is manually and automatically operated. The former may be needed for handling traffic to and from local subscribers.

Each toll line terminates in three places, the toll board, the automatic switchboard multiple, and the jack of the automatic switch which belongs to that line.

If a distant exchange seizes a toll line, it is automatically made busy on the banks of the toll selectors and the busy lamps belonging to it on the toll board are lighted. The distant exchange then dials the number of the toll line desired. When that line is seized, it is made busy on the selector banks and toll board.

**Toll-line Controlling Circuit.**—A toll-line controlling circuit which is very much used is shown in its simplest form in Fig. 254. There are two line relays, *LR*-1 and *LR*-2, both normally grounded. There is also a controlling relay at each end of the line, *CR*-1 and *CR*-2.

If the line is seized at the left end, the control relay *CR*-1 is energized and held so during occupancy. It switches the line relay from ground to battery and calling device (or the equivalent). This causes current to flow in the line and in both line relays. By suitable means, not shown, *LR*-1 at the sending end is not permitted to act on local automatic switches. *LR*-2 pulls up and closes the circuit of an automatic switch leading into the exchange. This seizes the line.

When the calling person (operator or subscriber) dials the call number *LR*-2 vibrates and repeats the number to the exchange apparatus at the right, and sets up the connection.

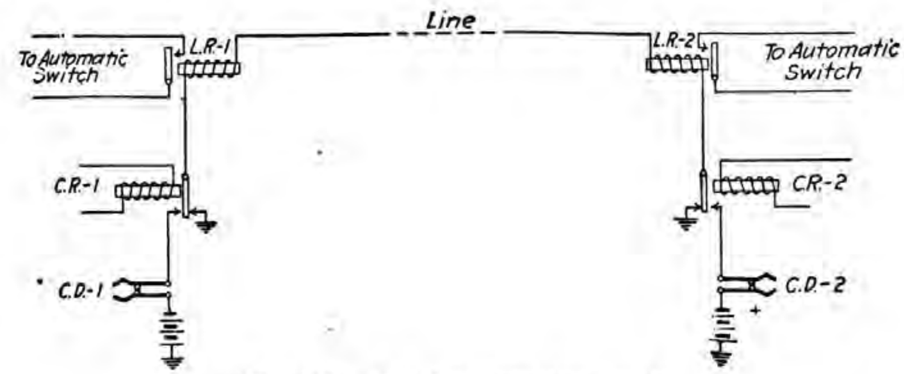



FIG. 254.—Toll line controlling circuit.

Release is accomplished by restoring relay *CR*-1 to normal. This switches the line back to ground, the current fails, *LR*-2 falls back, and releases the connection in the distant exchange as usual.

**Simplex Calling.**—Figure 255 shows the above described simple controlling circuit applied to a simplex circuit. The elements are so simple that further description is not necessary.

Figure 256 shows this circuit as it is used for one way calling 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.

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.

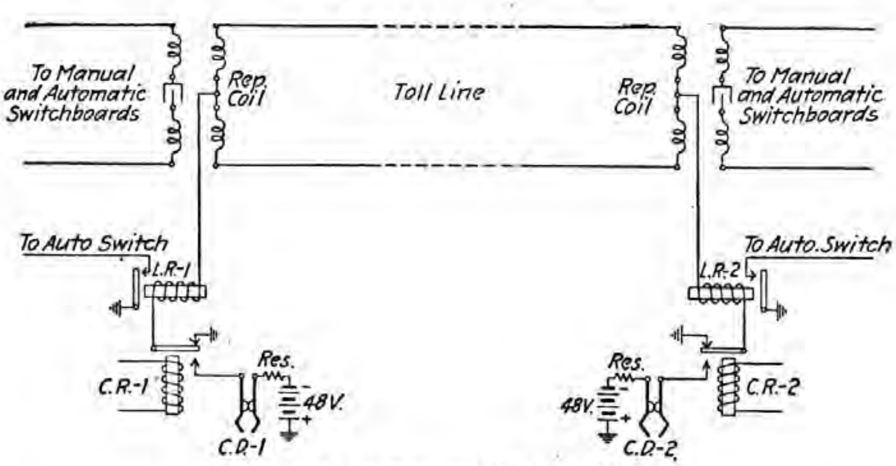



Fig. 255.—Simplex controlling circuit.

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

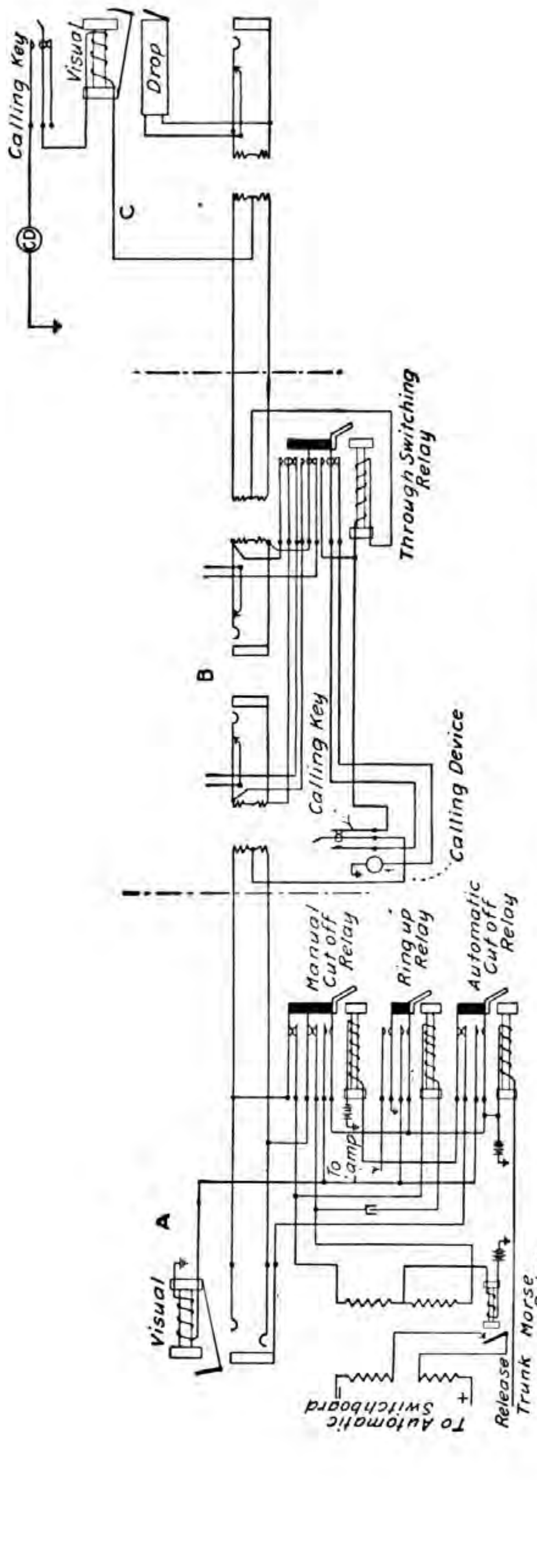



FIG. 256.—Simplex long distance automatic calling circuit.

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 manual 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.

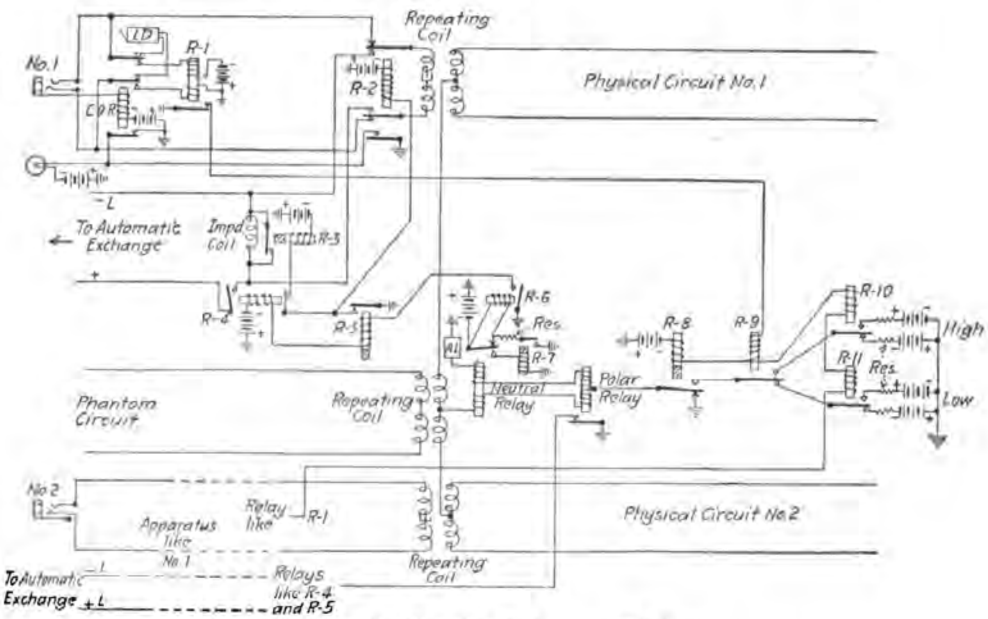



FIG. 257.—Quadruplex dialing on toll lines.

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 shut 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.

**Quadruplex Dialing.**—The principles of quadruplex telegraphy have been applied to automatic dialing over toll lines. (See Fig. 257.) A few simple changes were necessary to adapt it to this purpose, but they do not affect the fundamentals of quadruplex.

Two physical toll lines are shown, No. 1 and No. 2, and a phantom circuit superimposed on them. The quadruplex apparatus is attached to the center of the phantom, in simplex fashion. There is the usual neutral relay, with its "bug trap" relays *R*-6 and *R*-7, and the artificial line *AL*. Relay *R*-6 controls the automatic line by relays *R*-4 and *R*-5. The polar relay controls another automatic line by relays similar to them.

The various currents are controlled by a group of relays at the right. *R*-8 is common—it switches the line relays (neutral and polar) from ground to battery. *R*-9 switches from low voltage battery to high voltage. Relays *R*-10 and *R*-11 switch from negative to positive polarity.

If an operator plugs into the jack of line No. 1, the cut-off relay *COR* will cut off the line drop *LD* but the dialing relay *R*-1 will not pull up, because of a condenser in the bridge across the cord. The operator can ring with ordinary *A.C.* and throw the drop at the distant city.

If, after plugging into the jack, the operator cuts out the condenser in the cord bridge, relay *R*-1 will cause *R*-8 and *R*-9 to pull up, sending high voltage current onto the simplex circuit. The line relays at the sending end will not respond, but the neutral relay at the distant city will pull up. It will operate its slow relay *R*-7 which will energize *R*-6 in series with resistance. *R*-6 energizes *R*-4 and *R*-5 in series. The former closes the line to the automatic exchange, while the latter grounds a wire while pulls up relay *R*-2. The latter *R*-2 switches the toll line No. 1 to the automatic line and lights the busy lamp on the manual toll board.

When the operator at the calling end of the line dials, she controls her relay *R*-1, which makes *R*-9 vibrate, lowering and raising the current, to which the neutral relay in the distant city responds. The latter short-circuits *R*-6 every time that it falls back, but *R*-7 remains energized. *R*-4 follows the impulses and repeats them into the automatic line, setting up the connection. During this time *R*-3 short-circuits the impedance coil.

Release is accomplished by pulling the plug out of the jack. All the relays fall back, taking all current off the line, and releasing the automatic connection.

The polar side of the quadruplex controls the other automatic line in a very similar way. No bug trap is necessary. The calling operator controls relays *R*-8, *R*-10, and *R*-11 in series, the first switching the line relays as before and remaining energized during the holding time, the second and third reversing the polarity so as to operate the polar relay in the distant city.

The phantom circuit may be used manually, or one side of the quadruplex may be used for it instead of for one of the physical circuits.

**Composite Dialing.**—The principles of composite telegraphy have been applied to automatic dialing over toll lines. Figure 258 shows the essential principles. It is not necessary to give here a description of the laws upon which composite rests. The retardation coils and condensers are arranged in the way which telegraphy has found is best.

Each Morse leg has been brought out and treated exactly as shown in the simple controlling circuit of Fig. 254. There is a normally grounded

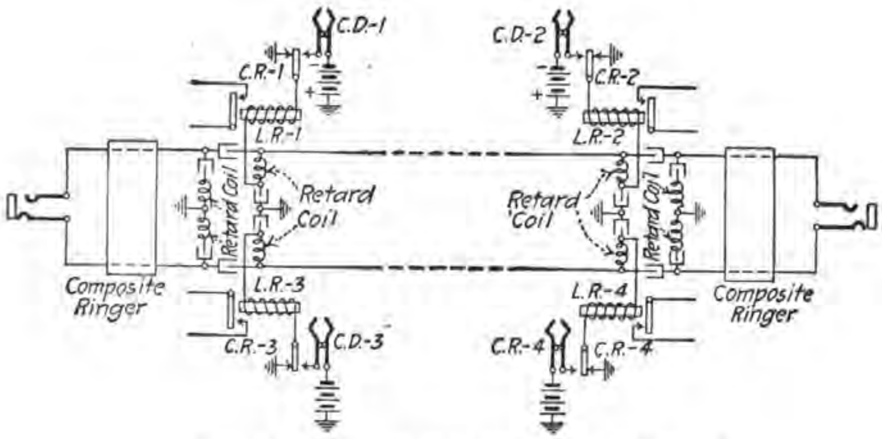



FIG. 258.—Toll line with composite dialing.

circuit from *LR*-1 over one line wire to *LR*-2, and another from *LR*-3 to *LR*-4. Each may be used separately without regard to the other.

Figure 259 shows the composite arranged to be called either manually or automatically. In the upper left-hand corner is the manual toll board

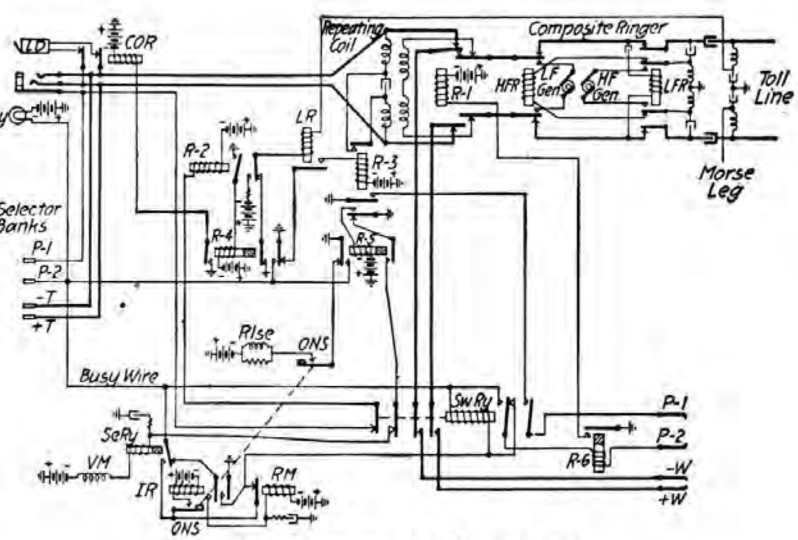



FIG. 259.—Composite dialing circuits.

apparatus. At the left center are the selector banks by means of which the toll line can be called automatically. This is used if this is a toll switching office as described under the head "Toll Switching Office." In the upper right-hand corner is the toll line with the composite ringing apparatus. The rest of the apparatus is a selector which has access to the automatic exchange or may form part of it.

The toll-cord circuit used with this apparatus is arranged for sleeve dialing—the calling device operates to interrupt the sleeve circuit. This leaves the line circuit free for talking and supervision.

If the operator plugs into the jack and rings, the distant city will be signalled by the line drop *LD* as usual, because the line drop can not be cut off except by the operator at that end of the line. But the mere act of plugging into the jack makes the line busy at the other end, by the lighting of the busy lamp.

The insertion of the plug into the jack sends current through the sleeve and operates the relay *R*-2. It pulls up relay *R*-4, which operates the cut-off relay *COR*, cuts ground off the Morse leg, and grounds the busy wire. The latter lights the busy lamp and grounds the private bank contact *P*-2 on the selectors, to prevent calling from that source. The relay *R*-2 also switches the Morse leg to battery (through a small resistance) so that current now flows through the line relay *LR* over the toll-line wire to the distant city where it passes through a similar line relay to ground. The line relay *LR* in the calling city can not do anything, because relay *R*-4 has taken away its ground.

The line relay *LR* in the distant city pulls up and operates *R*-3 which in turn pulls up *R*-5. *R*-3 short-circuits the condenser in the repeating coil, and prepares a ground for the circuit to private wiper *P*-1. Relay *R*-5 opens the release magnet circuit, grounds the busy wire, and prepares the impulsing circuit to the vertical magnet.

When the operator in the calling city dials over the sleeve, she causes *R*-2 to vibrate. *R*-4 remains energized. The impulsing of the line current causes the line relay *LR* in the distant city to vibrate, sending impulses to the vertical magnet of its selector. The off-normal springs *ONS* close, also the series relay *SeRy* causes the interrupter relay *IR* to lock up and prepare the rotary magnet for action.

When the group of impulses ceases, the line relay *LR* comes to rest energized. Soon the series relay *SeRy* falls back, upon which the rotary magnet rotates the wiper shaft and wipers onto the level selected. The rotary magnet *RM* and the interrupter relay cause each other to vibrate as long as there is a ground on the private wiper *P*-2. When an idle trunk is reached, the interrupter relay can not act, the switching relay *SwRy* is able to pull up and the rotation stops. The switching relay cuts off the sleeve circuit through *R*-2, also the vertical-magnet circuit, cuts the busy wire through to the selector ahead, connects the lines to the line wipers, and closes the circuit of private wiper *P*-1.

Further dialing is repeated by the line relay *LR* and relay *R*-3 by way of the fourth wire through *P*-1. At the same time relay *R*-6 operates relay *R*-1 to cut out the repeating coil and cut the talking lines through.

Release is accomplished by pulling the plug out of the jack, which restores *R*-2 at the sending end to normal, cuts off the line current, and de-energizes the line relay *LR* at the distant end. Relays *R*-3 and *R*-5

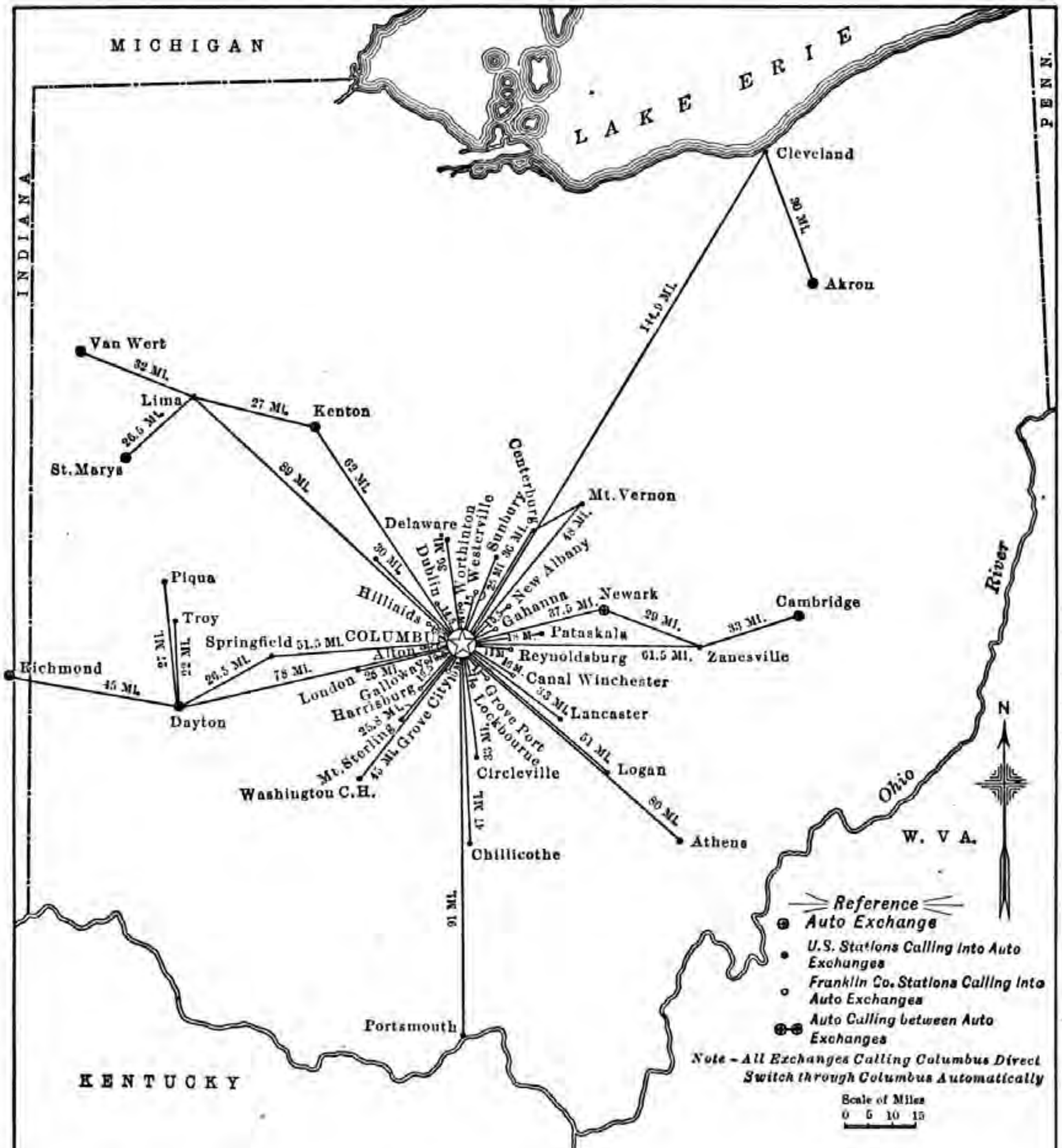



FIG. 260.—Map showing long distance automatic lines centering at Columbus, Ohio.

follow, closing the release magnet circuit which releases the selector as usual.

If the call comes to the toll line through a selector instead of through the manual jack, private contact *P*-2 acts as the regular release trunk and lights the busy lamp as soon as the selector seizes the trunk. Private contact $P$-1 is the carrier of the impulsing circuit, taking the place of the sleeve of the cord. As soon as $R$-2 pulls up, it causes $R$-4 to ground the busy wire and contact $P$-2. The rest of the action is as was described for manual calling.

**Automatic Long Distance Calling into Columbus, O.**—Figure 260 is a skeleton map of the state of Ohio, 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 Dayton, 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; and ARTHUR BESSEY SMITH, American Institute of Electrical Engineers, Dec. 12, 1919.

## CHAPTER XIII

### RURAL AUTOMATIC TELEPHONES

Telephone service on rural lines differs from that in cities and towns in that dwellings are much farther apart, there is usually no common center except the nearest town, and greater dependence is placed on the telephone. If we consider a larger area, there are several small towns which, with their surrounding country, may be considered as rural, and the arrangements for telephoning made to include all.

Manual service in small exchanges is necessarily poorer than in large exchanges, and the personality of the operator more easily felt. Even under the most favorable conditions of long training of operators and close supervision of them, large exchanges suffer from delays and inaccuracies. Small exchanges are even less well served.

Almost all communities require continuous service and are entitled to it. The value of night service is out of proportion to its volume. Such telephone calls as are made during the night are usually the result of necessity and deserve as prompt, accurate attention as can possibly be given.

It has been the experience of companies who operate automatic exchanges that before long the farmers begin to ask that they, too, be given automatic service, and in some cases demand it. This has resulted in a large growth of rural automatic telephones in the past years, so that today (1920) they form a considerable factor.

Viewed from a broad standpoint, these rural services may be classified as follows:

Individual line, the case of the prosperous farmer.

Party line, connected to an automatic exchange in town.

Isolated community automatic exchange.

String of small exchanges.

Radial or satellite system of small exchanges.

Network of small exchanges.

**Individual Rural Line.**—In general, the conditions are the same as for an individual line in town, except in those cases in which the line is so long that common battery can not be worked for talking. The range of common battery transmission has been extended by the bringing out of a sensitive transmitter for weak current. But beyond this, it is sometimes necessary to use local battery for talking. (See Fig. 261.)

**Rural Party Line.**—The method of signalling used is the factor which is most important in arranging the party line. Both selective ringing and code ringing are in use.

The placing of many telephones on one line, especially in rural regions, increases the chance that a subscriber will interfere with the dialing of another. If, while impulses are being sent by a telephone, another telephone comes across the line, it short-circuits the dialing instrument and causes the call to fail. This is obviated by providing each telephone with a hook stop, which permits the hook to rise part way, only far enough to connect the receiver across the line in series with a 2 m.f. condenser. It enables the subscriber to listen without interfering with whatever dialing may be going on. If the line proves to be free, the subscriber presses the hook release, the lever then rises to the full extent of its stroke, connecting the calling device. Besides preventing interference with dialing, this divice permits the rural subscriber to listen on the line—a habit which is firmly established and warmly defended by the subscribers.

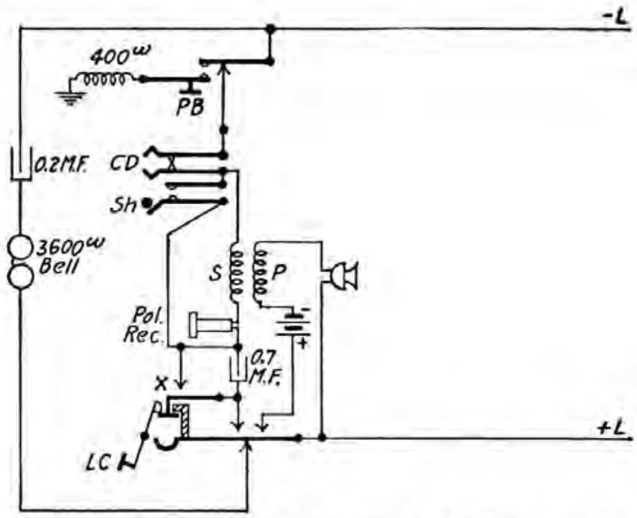



FIG. 261.—Local battery automatic telephone circuit.

Rural lines are often served by the regular lineswitch boards if there is nothing special to their operation. But if the number of such lines is considerable, or the conditions of their operation differ greatly from those of other lines, they will be handled by lineswitch units devoted to that service alone. The special apparatus required is localized to this part of the equipment.

It frequently occurs that rural lines produce so much traffic that it overloads the group of first selectors belonging to the lineswitch board. This is relieved either by subdividing the lineswitches into smaller groups, or by providing each rural line with its own first selector instead of a lineswitch. In this case the selector performs the functions of repeater as well as of selector. The relative cost of the two plans varies with conditions.

Because of the number of bells and condensers (sometimes ten) bridged across the line, and the lower insulation which is at times unavoidable, the control circuit and apparatus must have a greater factor of safety than is usual. To secure this repeater is interposed between the rural line and the regular exchange apparatus. This repeater has two line relays (Fig. 262), one in each battery lead. The impulsing is done with the relay which is connected to the positive grounded battery terminal. Also, during the time that impulses are coming in, the impedance of the negative line relay is greatly lowered. These two provisions greatly increase the reliability of selection.

The line requirements are as follows:

Maximum safe loop resistance. . . . . . . . . 1,000 ohms.
Minimum safe insulation resistance, wire to wire
or wire to earth . . . . . . . . . . 25,000 ohms.

If, however, there is a separate repeater or a selector-repeater for each line, so that its line relay can be adjusted for that line alone, the loop resistance can be greatly increased.

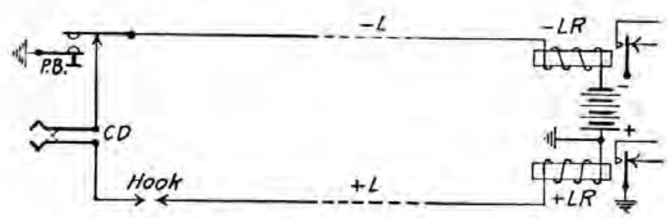



FIG. 262.—Rural line controlling circuit.

**Code Ringing.**—Code ringing is very largely employed in manual exchanges over large areas in the United States, is understood by the subscribers, and seems to be satisfactory.

Code ringing permits all the bells to be alike and to be bridged across the line. In order not to interfere with dialing, the bells are wound to 3600 ohms (approximately 5000 ohms impedance to ten cycles per second) and the condensers limited to about 0.2 m.f. Signals are made by combinations of long and short rings.

Under certain conditions push-button ringing seems to be desirable. By this plan, each telephone is equipped with a push-button which grounds the negative line wire and operates a ringing relay in the switch equipment. The code signals are sharper and more easily understood than when hand generators are used, but not as good as if made by a code-ringing machine in the central office. The grounding of the negative line and opening of the positive line causes the positive-line relay to fall back, while the negative-line relay remains energized and holds the switches. The positive relay controls the ringing indirectly.

Reverting calls are made by dialing the regular call number as usual.

The subscriber then presses the push-button for the code of signals, which are sent out on the line.

**Simplex Dialing.**—Simplex dialing on rural lines is accomplished by the plan outlined in Fig. 263. The line is equipped with local battery magneto ringing telephones. The center of each bell has a tap taken out and run through the switch-hook so that the calling device *CD* may be connnected to ground. The line runs through a repeating coil in the central office, the center of which is connected by a line relay to negative

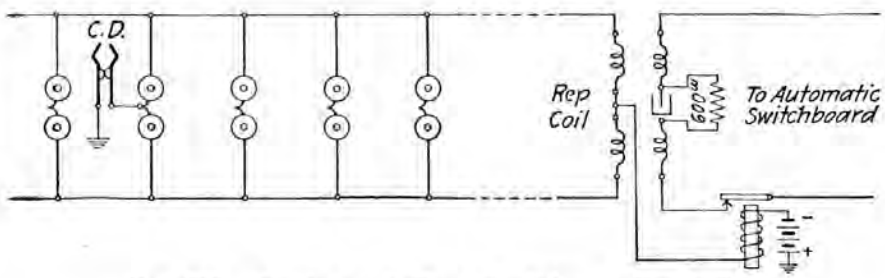



FIG. 263.—Simplex controlling circuit for rural party line.

battery. The line relay controls the loop-dialing circuit to the automatic switches.

When the receiver is taken from the hook, the line relay pulls up and closes the line to the automatic switchboard. The operation of the calling device is thus relayed to the switches, and the connection established in an obvious manner. Figure 264 shows the complete telephone circuit.

Reverting calls on this line are rung in the usual manner by hand generators. It is possible to add this equipment to existing magneto telephones of suitable type

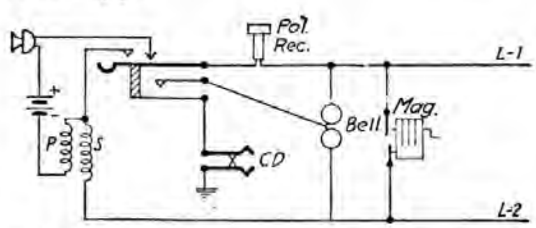



FIG. 264.—Rural telephone, magneto, simplex dialing.

**Code Ringing Machine.**—There is now in use a code-ringing machine which is part of the central office equipment which is capable of giving better signals than can be made by hand. As many as twenty codes are available, although good service from the traffic standpoint will not permit more than ten stations on one line, unless the conditions are unusual. In many instances the number should be much less than ten.

The subscriber dials the call number in the usual way and waits. The code machine begins to ring long and short rings according to the number selected, and stops when the called station answers or the calling subscriber hangs up his receiver.

Reverting calls are made by dialing a reverting call number, posted on the telephones of the line, and hanging up the receiver. All the bells on the line will ring according to the code. When the called station answers, the ringing stops. If the called party does not answer, the calling subscriber stops the ringing by taking down his receiver for a moment and replacing it.

**Selective Ringing.**—Selective ringing is in some cases better than code ringing and may even be requested by subscribers.

Ten bells can be rung selectively on one line by bridging five from each line to earth and using the five frequencies of the "multiple harmonic" or the "non-multiple harmonic." A telephone circuit arranged for this service is shown in Fig. 265. The bell is permanently bridged from the required side of the line to earth and is not cut off by the switchhook.

Reverting calls are handled in the same way as was described for city lines. By calling a special number connection is secured to a reverting

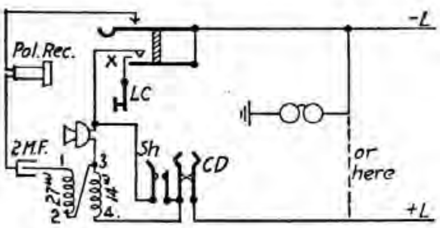



Fig. 265.—Rural telephone circuit 10-party line.

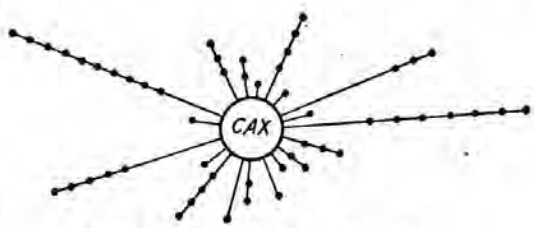



Fig. 266.—Isolated exchange.

call switch, which rings alternately the bell of the calling and of the called subscriber.

**Isolated Exchange.**—The isolated exchange is relatively rare. It has no connections to other exchanges. The switchboard is very simple, because there is no in and out traffic, which is the source of most of the complications. Figure 266 shows the relations, both town and rural party lines being served by the same small automatic board, which is termed "Community Automatic Exchange."

**String of Exchanges.**—A string of exchanges is found very often in new or sparsely settled country, or in more settled country where the topography causes this relation of interests. There may be but one toll line, following a line of railroad. In such a case (Fig. 267) a community automatic exchange is installed in each small town, with individual lines to town subscribers and party lines reaching out into the country.

The toll office and miscellaneous services (information, complaint, etc.) are located wherever they can receive the best attention. It often pays to have all the toll switching for several exchanges done by one of them, rendering it unnecessary to have any person switch toll lines at the other places.

For example, *A*, *B*, *C*, *D*, and *E* may be five exchanges on one line of railroad. At *C* may be located the toll board. An operator there can reach out over the toll line, dial up any desired connection, and control it. Any subscriber in a small town *A* can automatically call the toll operator at *C* and have her set up any desired connection, either to a subscriber in *C*. to one in *D* or *E*, or to one in *B*.

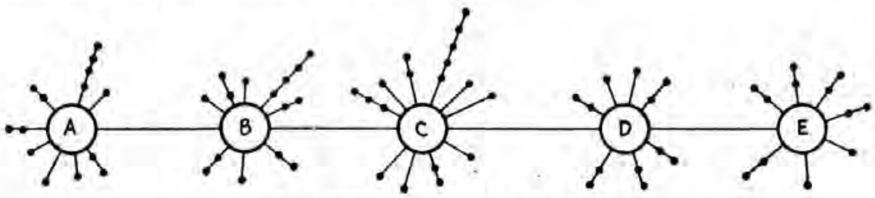



FIG. 267.—String of exchanges.

It is better if traffic is large enough to have two toll lines along the same route. One can be restricted to through service and can not be called by the subscribers, it is under the control of the operator at *C*. The other is the local line and can be called by any subscriber at the exchanges along the line.

One plan of operation gives each community automatic exchange a selector switch whose jacks are connected to the toll line (local). At exchange *A* level one is connected to the local switches. At exchange *B*

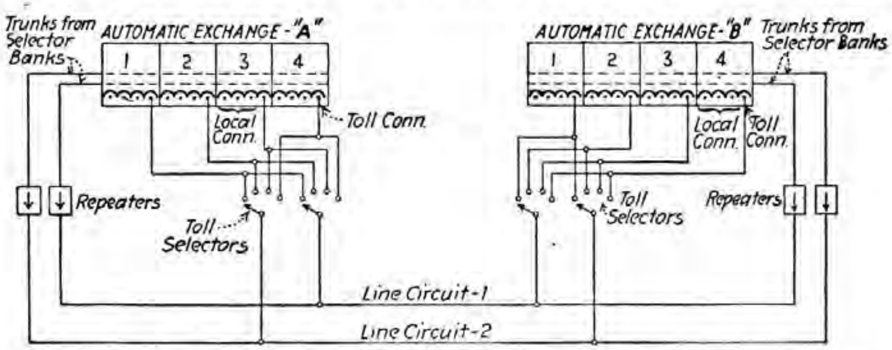



FIG. 268.—Two community automatic exchanges with free automatic trunks.

level 2 is connected to the local switches. At *C* it is level 3, at *D* level 4, and at *E* level 5, which is connected to the local switches.

All the selectors on the toll line are operated simultaneously by the toll operator in calling a small exchange. All lift their wipers together and stop at the same levels. By the different connections described above, they select and connect to the exchange desired and to no other.

Subscribers at any small exchange call the toll operator at *C* by loop dialing. The operator dials back over the line by simplex to get any exchange.

Consider the case of two adjacent exchanges which have free service from one to the other. (Fig. 268.) Let each exchange be represented by four 100-line boards, having selectors and connectors.

The lines, 1 and 2, which carry the inter-exchange traffic, are equipped at each end with a selector, and are in addition multipled to the banks of local selectors. A repeater is inserted between the selector banks and the lines for the purpose of holding the local switches from releasing, feeding common battery for talking, etc.

The banks of the toll selectors are connected to the jacks of toll connectors, one or more in each 100-line board. These toll connectors have their banks multipled to the banks of the local connectors, so that all subscriber lines can be reached.

When a subscriber in exchange *A* desires to call one in *B*, he dials a figure which causes his first selector to seize one of the lines, making it busy on the banks of all the other first selectors in both exchanges *A* and

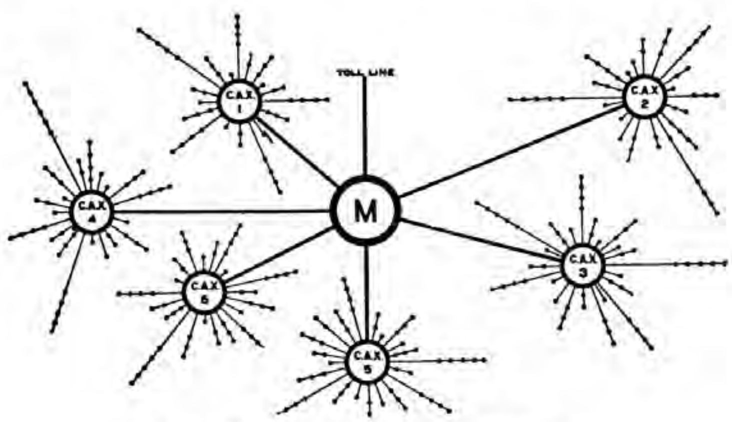



FIG. 269.—Radial system of exchanges.

*B*. He then dials the call number of the desired telephone, which operates the toll selector at *B* and the toll connector in the 100-line board chosen.

**Radial or Satellite Exchange System.**—The radial or satellite system of exchanges consists of a central exchange connected by radial trunks or toll lines to outlying smaller automatic exchanges. (Fig. 269.) The central exchange (manual or automatic) is the controller of the system. Although each community automatic exchange completes its own connections, it depends on the controlling exchange for all connections to the center or to other exchanges.

Many small exchanges are still operated manually, because it is necessary to keep someone there to make toll connections, and that same person can answer local calls in addition to the light toll business. Centralized toll switching removes this necessity and permits the small exchanges to be made automatic. The small exchange then runs much better and more cheaply than with manual attendance.

Service between the controlling exchange and a community automatic exchange may be free or a charge may be made. If the service is free, the two-way trunks from the community exchange will run directly to the local board in the controlling or "main" exchange. If the local board is manual, the trunk may terminate as a subscriber line for incoming traffic. One operator may handle all outgoing calls to the rural exchange, she alone being provided with a calling device. It is possible to give each "*A*" operator a calling device so that she may dial directly. If the local board is automatic, the two-way trunks may end on selectors for incoming traffic and selector banks for outgoing traffic.

If the service between exchanges requires a toll charge, the radial trunks will terminate as toll lines on the toll board at the controlling exchange and in a toll switch in the community automatic exchange. This rural exchange will operate a ring-down line signal on the toll board

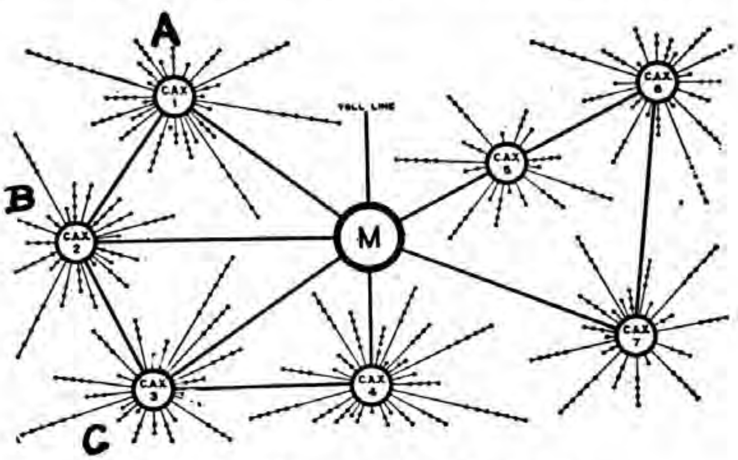



FIG. 270.—Network system of exchanges.

and the toll operator will record the call in the standard way, after which the subscriber will release. When the connection is ready the toll operator will call back through the toll switches and thus complete the line. If certain rural lines are permitted to have free service, a special tone is provided, so that the toll operator can discriminate in their favor. If the local conditions warrant it, separate trunks can be provided from the community automatic exchange running directly to the local board of the controlling exchange. In this case, the rural board will be arranged so that only certain lines can gain access to these free direct trunks.

**Network of Exchanges.**—The network system of exchanges and lines differs from the above in that there are direct trunks connecting the community automatic exchanges to each other and the controlling exchange part or all of its power as a checking agent. (Fig. 270.) Adjacent exchanges may call each other freely. These trunks are two-way, terminating at each end in a switch and the banks of switches.

Tandem trunking may be permitted or not, as desired. If permitted, a subscriber can dial a call from his own exchange *A* through one or more intermediate exchanges *B* to the desired exchange *C*. If the conditions of business require a toll service between exchanges so far apart, the incoming switches (in *B*) will not be equipped with outgoing trunk multiples. Thus, while local lines (in *B*) can call exchange *C*, a call from *A* into *B* can not get the out trunk to *C* and tandem trunking is impossible. The subscriber in *A* must call the controlling exchange, whose toll operator can make the record and complete the connection.

Further details in the application of automatic switching to the connecting links of a network may be shown by considering five small auto-

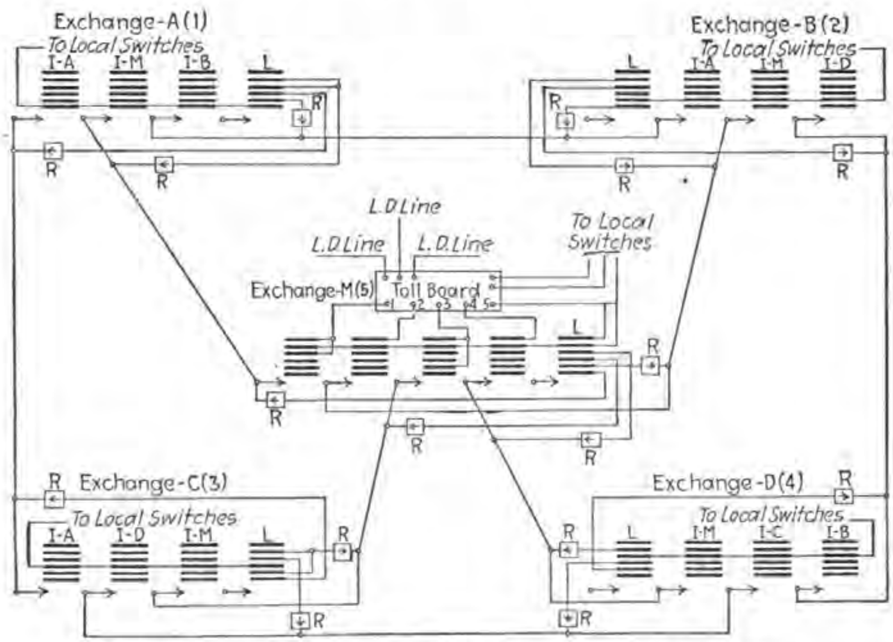



FIG. 271.—Typical network of community automatic exchanges.

matic exchanges, each limited to 1000 lines. The principles shown can be applied to exchanges of any size.

Four of these automatic exchanges (Fig. 271), *A*, *B*, *C*, and *D*, are supposed to be located approximately at the corners of a square or rectangle. Exchange *M* is near the center and is the controlling exchange. Assume further that free service is given between all adjacent exchanges, but that a charge is made for traffic between opposite corners (*A* to *D* and *B* to *C*). The exchanges are numbered from 1 to 5 as indicated.

The exchanges are connected by lines. To keep the illustration simple, let there be only one line between adjacent exchanges—eight lines in all. Any such link can easily be increased by adding lines and switches without changing the principles involved.

Each exchange has two kinds of first selectors, local and incoming. The local first selectors (illustrated by only one of them, *L*) handle all the traffic originated by the subscribers in that exchange. One bank level carries the traffic into the local switches to local subscribers. Since this is a small system, and to keep the numbering uniform, each exchange has a different level. In the *A* exchange it is the first level, in *B* it is the second level, etc. The other levels beside the local level lead to adjacent exchanges, each according to the number of the exchange. From the second level a trunk goes through a repeater *R* to the line leading to *B*, where it terminates on the jacks of an imcoming selector (*I-A* from *A*, *I-D* from *D*, etc.).

From the third level a trunk goes through repeater *R* to the line leading to exchange *C*, where it terminates on the jacks of an incoming selector (*I-A* from *A*, *I-M* from *M*, etc.).

The repeater inserted in the outgoing trunk holds the local switches in the originating exchanges.

The incoming selectors (*I-A*, *I-B*, etc.) have the correct level multipled to the banks of the local selectors *L* so that they have access through the local switches to the local subscribers.

These free lines are really two-way trunks. Each end of a line is attached to an incoming selector for incoming traffic and to the banks of all the local selectors *L* for outgoing traffic.

Suppose that a subscriber in exchange *A* calls for a subscriber in exchange *C*, whose local number is 3225. The subscriber in *A* will first dial the figure 3 which causes his first selector *L* to lift its wipers to the third level and seize the line to *C*, making it busy at both ends. Then he dials the figure 3 of the local number, which causes the wipers of the incoming selector *I-A* to rise to the third level and to seize an idle trunk to second selectors. The digit 2 chooses the hundred, and the digits 2 and 5 operate the connector to get the called line.

A subscriber in exchange *C* who calls the same number will dial the local 4-figure number only. He will not need to prefix the figure 3.

To handle pay traffic between *A* and *D* and between *B* and *C*, as well as between the network and the long-distance line to other parts of the country, a toll board is installed at exchange *M*. All incoming selectors in *M* have the fifth level multipled into the banks of the local selectors *L* because all the other exchanges are to call *M* free of charge. But the tenth or "0" level is run separately to the toll board. Any call for "Long Distance" made by a *C* subscriber will go directly to the toll board, because the directory lists the long-distance operator so as to secure that result. It may be listed "50" or "00" because the banks of the local selectors can be multipled that way in each exchange.

Trunks from incoming selectors at *M* are kept separate, so that the toll operator knows the origin of each call that comes to her.

If a subscriber in *A* desires to call someone in *D*, he is instructed by the directory to call "50," which leads his call to the toll board. The operator makes the charges and completes the call. The operator has lines (not shown here) leading into the local switches through which any exchange is available. If desired, toll selectors may be set aside for her use. If the identity of the calling station is in question, the operator directs the calling subscriber to hang up his receiver. Then she calls the number which he gave—this establishes the identity. The knowledge that this check may be made at any time deters fraud.

If the subscriber at *A* tries to avoid payment by calling through *B* or *C* to reach *D* he will fail. The incoming selector *I-A* in both these exchanges does not have any connection on its bank for the *D* exchange. It is impossible to call in that way out of that place. If he tries to dial from *A* through *M* to *D*, he will run against the same difficulty.

It is possible to multiple the banks of local selectors so that if a subscriber tries to avoid payment, his call will be diverted to the toll board. This is done by connecting the level which will be called to the level carrying the trunk to *M*. (See exchange *C*.)

Suppose another but very innocent case. A subscriber living in *D* has much business with a subscriber in *B*, whom he frequently calls free of charge by dialing "22" and the rest of the number. If that subscriber in *D* moves to live in *C* and by force of habit dials the same number (22) as before, he will find himself answered by the toll operator at *M*, who will make the charge and complete the call. Level "2" of local selectors in *C* is multipled to level 5 and the trunk to *M*. The incoming selector *I-C* in *M* has its second level multipled to the tenth, and thus to the toll board.

**Community Automatic Exchange.**—In the above descriptions of small rural exchanges, mention was made of the community automatic exchange. An account of its characteristics is now in place.

The term "community automatic exchange," abbreviated "*C.A.X.*," is now applied to a small unattended plant, whose toll switching and miscellaneous services are handled from a distance and whose apparatus is usually designed with the requirements of rural lines primarily in view. The community which it serves may be the farmers of a region, a small town or village, or the small suburb of a town. The traffic is chiefly local, though by no means confined to local.

The rotary lineswitch is standard for these exchanges. It is simple in structure, has individual control, moves very little in its work, and has access to a larger trunk group than the plunger lineswitch.

The selectors and connectors have the usual structure, and in general their circuits are the same as those used in large exchanges, modified to suit the operating conditions which are discussed below.

The equipment is made up in three general units, the switchboard, the storage battery, and the charging machine. The switchboard (Fig.

272) is made in two or three parts, which are installed side by side so as to form one unit. These parts are the power-board and main distributing frame, the local board, and the trunking board. The last is omitted if the exchange is isolated or if it has less than 100 lines and the connectors do the trunking. This is the case in the illustration. All but the trunk board have been fairly well standardized. Because of the many variable conditions found in different places, the trunk board with its selectors and repeaters is made up in accordance with the needs.

In Fig. 272 the *MDF* is at the extreme left, with the power board beside it. At the bottom of the power panel is the solenoid knife blade

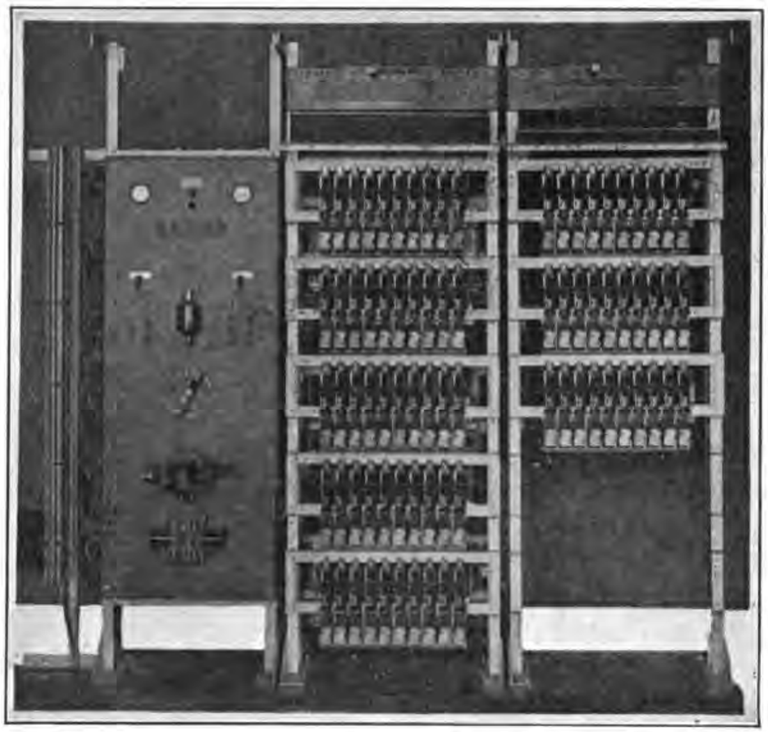


FIG. 272.—Community automatic exchange 100-line (front).

switch for starting the charging machine. Above it is the ringing machine which runs by battery current, next the counter-cell switch, and above it the self-closing reverse-current circuit breaker. At the right of the power board are the rotary lineswitches, ten per shelf, with a terminal assembly at the top of the frame with a battery panel carrying fuses, lamps, etc.

The back of the board (Fig. 273) shows the connectors on the line-switch frame and the cabling from the *MDF* to the terminal assembly. Near the center of the power board is the small motor which operates the counter-cell switch. Almost in the lower left-hand corner of the power board is the box containing the voltage governing relays.

The charging of the battery is done preferably by a motor-generator run by commercial power. The battery bus bars are equipped with a pair of voltage relays, which start the motor-generator whenever the pressure falls to 46 volts and which stop it when it reaches 52 volts. A self-closing reverse current circuit breaker stands between the generator and the battery. When the generator voltage is high enough to be safe, the circuit breaker closes the circuit and the charging begins. When the motor has been cut off by the high voltage, the generator voltage dies away until a slight reverse current operates the circuit breaker and opens the circuit.

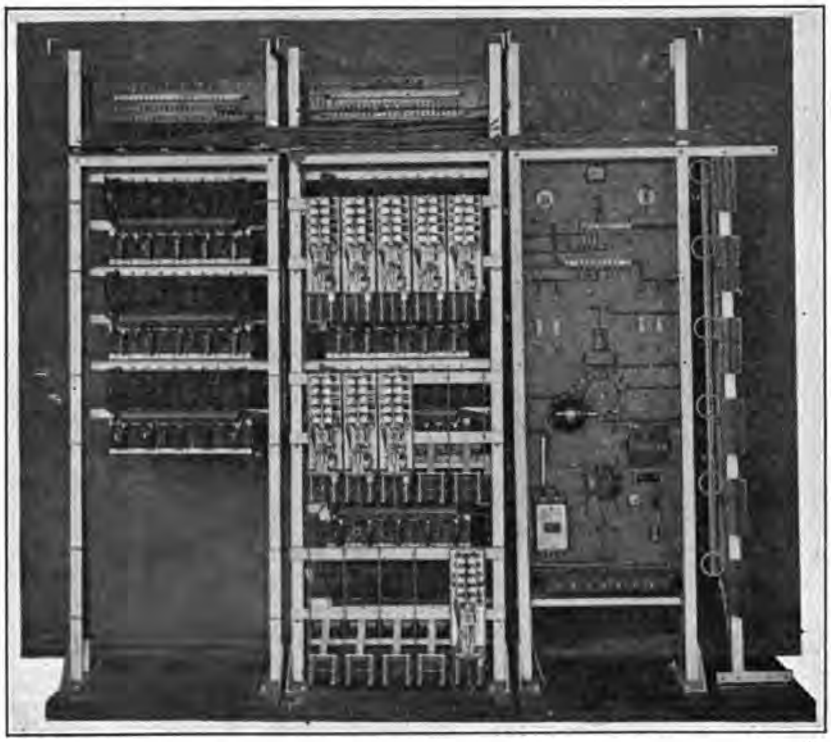


FIG. 273.—Community automatic exchange 100-line (back).

The power board circuits are shown in Fig. 274. The counter-cell switch consists of a heavy copper arm mounted on a shaft which rotates so that one end of the arm passes over a semicircular row of contacts. These are of heavy construction and carry wires leading to the counter cells. The arm is connected to the negative bus bar by its lower end which rests on a semicircular contact bar.

Inside the row of contacts for the counter cells is another row of smaller contacts. These control the automatic charging switch. When the upper end of the counter-cell switch arm rests on one of the heavy contacts, a small spring brush rests on the small contact in the inner row.

A small series motor on the back of the power board rotates the counter-cell switch by means of a worm gear. The motor has two opposing fields so that it may be driven in either direction.

At the point of time shown in the illustration, the battery is being discharged and it has reached the point where four counter cells are still in circuit. The two knife switches which control the charging are supposed to be closed. The voltage relays marked "high" and "low" in the rectangle in the lower left-hand corner are in the condition shown. The high relay is de-energized, but near the operating point. The low relay is energized, but almost ready to fall back.

If the bus bar pressure falls to 46 volts, the low relay falls back, pulling up relay $A$ which locks itself, pulls up the low relay again, and starts the switch motor to rotating the counter-cell switch to remove another cell. This brings back the bus bar voltage to a point above 46 volts. The wheel marked $D$ with its springs and relay $C$ form the centering device, to insure the accurate centering of the switch arm on the

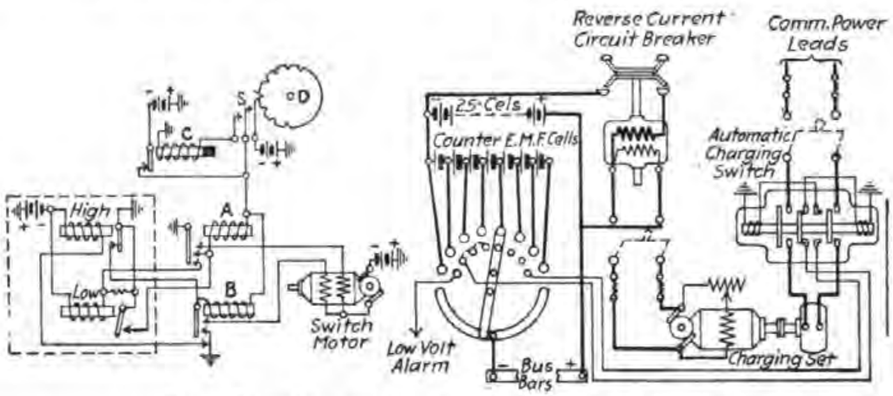



FIG. 274.—Automatic voltage regulation for *C.A.X.*

contacts. When the shaft rotates a little, springs $S$ close and energize relay $C$. When the switch reaches the next contact, the springs $S$ open again, cutting off battery from relays $C$ and $A$. The latter falls back at once; the former being slow-releasing, hangs on long enough to insure that $A$ has released before restoring the battery connection for $A$. Relay $A$ stops the switch motor.

If the three inside contacts on the counter-cell switch are wired together as shown, the cutting out of the cell just described closes the circuit which sends battery current through the right hand-coil of the automatic charging switch. This closes the commercial power leads to the motor generator and the charging begins. The charging switch at the same time opens the lead which operated it and prepares a circuit to the left-hand coil.

As the charging proceeds, the voltage of the battery rises. When the bus bar voltage reaches 52, the "high" relay pulls up and operates relay $B$. The latter locks itself, cuts off relay "high" and starts the switch motor to cut in another counter cell. The centering device operates as before to stop the switch and restore the relays to normal.

When the charging has proceeded to the point at which all the counter cells are cut into service, the arm of the switch closes the circuit to the left-hand coil of the automatic charging switch. The latter now opens the commercial power leads and stops the charging.

In regions where commercial power is not available continuously, the counter-cell switch is arranged to start the charging when there are still two or three cells in service. It is done by connecting to the starting wire the several inside contacts as indicated. In this way the charge is begun some time before the battery is fully discharged. If this happens at a time when the commercial power is off, there is reserve enough in the battery to carry the switchboard until the power comes on, when the motor generator will start up.

If for some reason charging does not begin when it should and all counter cells have been cut out, the lowest inside contact will close the circuit marked "low voltage alarm" which notifies the people in the controlling exchange that attention is needed.

If no commercial power is available, a gasoline unit is installed. It is started by hand as often as necessary. The regular maintainer need not do it, someone who lives near the exchange and is familiar with gasoline engines is employed to set it to going. The stopping is automatic. The preferred method is to put in the engine tank a measured amount of fuel, according to a chart furnished. The amount of fuel has been proportioned to the specific gravity of the battery. When the fuel runs out, the engine stops and the circuit breaker takes care of the cutting off of the leads to the battery.

Another method is sometimes used. The fuel tank is kept full, and the engine stopped by the voltage device, when all counter cells have been cut into circuit.

In case the charging must be more or less irregular, larger capacity storage battery is used.

Regardless of the kind of charging used, the battery is given its regular overcharge as specified by the manufacturer of the battery. This is necessary to insure the health of the plates and electrolyte.

The design of apparatus for a community automatic exchange is very largely determined by the following factors:

1. Transmission............... Local battery or common battery.
2. Line relay.................. Double-wound or ground relay.
3. Line equipment............. Lineswitch or selector (or connector).
4. Signalling.................. Selective or code.
5. Signal control............... Push-button or periodic.
6. Reverting calls.............. Push-button, periodic, or hand generator.
7. Battery charging means...... Motor generator or gasoline engine.
8. Battery charging method..... Float or hand start with automatic stop.

The tendency is to use common battery transmission as far as possible. The replacement of dry cells is a great and increasing expense. It is to be incurred only if the salvage of old equipment causes it to seem to be more profitable to retain the local battery, or if the lines are so long that it is necessary for good transmission. As far as automatic operation is concerned it makes no difference which is used. Most lines in rural operation are long enough to require a special weak current common battery transmitter. In all cases the polarized receiver is necessary, because the subscriber must be able to listen through a condenser to see if the line is in use.

The line relay which handles the impulses should be connected to the grounded terminal of the battery as described above. If the line conditions are as good as in larger exchanges, the usual double-wound line relay is fully adequate.

The usual practice is to carry all lines in the community automatic exchange to lineswitches. All selectors and connectors are usually equipped with the ground relay circuit, so as to render repeaters unnecessary.

In regions where the rural subscribers have been using local battery magneto telephones for years and are accustomed to code signals the code signal can be used with the *C.A.X.* The non-secret nature of the call is regarded by many subscribers as a positive advantage. In rural regions there is a community of interest and a mutual helpfulness which is difficult for the city dweller to realize. More congested rural regions seem to require greater secrecy, and the selective signal is favored and sometimes even requested.

Push-button ringing and periodic ringing by the central office apparatus are the same as described above.

Reverting calls are handled in accordance with the method of signalling used. If local battery magneto telephones with simplex dialing are employed, the subscribers ring each other just as they did on the manual switchboard. If the signalling is selective, the subscriber dials a special number and receives alternate signals as described above. If code signalling is used, it may be either periodic or push-button controlled. The latter requires reverting selectors available to the party lines.

## CHAPTER XIV

## CUT-OVERS AND INTERCONNECTING OF MANUAL AND AUTOMATIC OFFICES

**Cutover from a One-office Common Battery Manual Plant to an Automatic Plant.**—The arrangements required for giving service during the process of cutting subscribers from a single, common battery, manual central office to a single automatic central office are very simple. Since all automatic telephone instruments 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 board. Therefore, subscribers, stations using wall or desk telephones only are prepared for a cut-over by simply taking out the manual instruments and replacing them with the automatic instruments, one at a time. Until the cut-over 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 cut-over 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 tooth-picks, between the springs. (See Fig. 275.)

Pending the cut-over each subscribers' 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 employee operate the subscribers' 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 cut-over is reached.

It is customary to notify the subscribers through the daily papers and by special notices that the cut-over 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 cut-over 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 bridge cut-off relay springs, and in

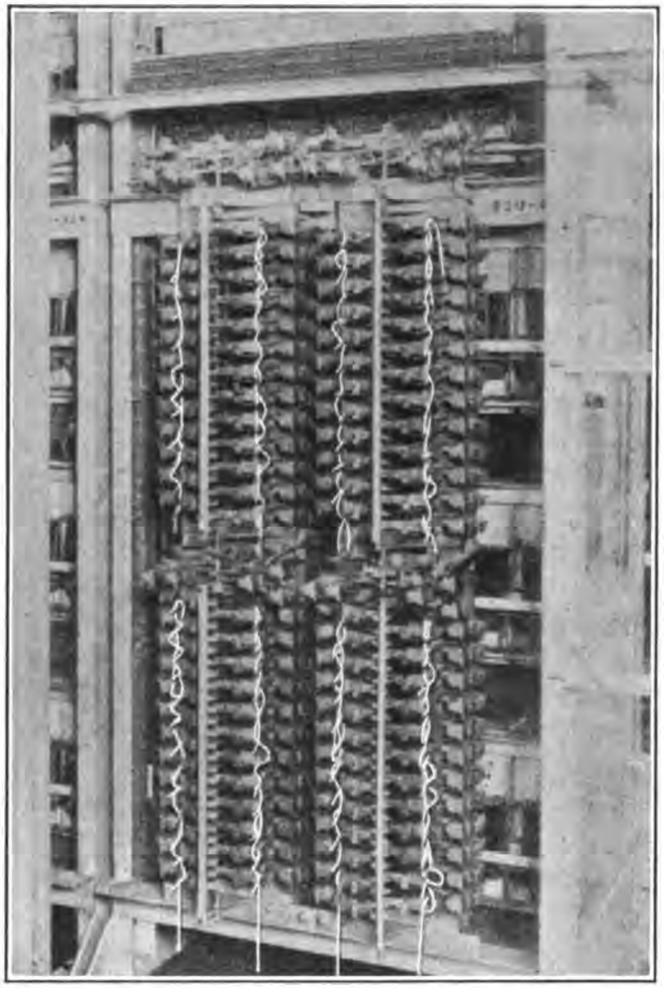


FIG. 275.—A lineswitch unit (100 lines) with toothpicks in the line and cut-off relays, tied together ready to be pulled out at the cut-over signal.

cutting the lines of inserting similar insulators in the manual central office. The circuit of the individual master switches are temporarily opened, the plungers being aligned opposite the first trunk. Should any permanents develop, when the cut is made, the associated lineswitches will plunge in on comparatively few first selectors, after which the master switch circuits are closed and normal traffic flows to the remaining selectors.

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 cut-over to automatic equipment is made.

A quick and satisfactory cut-over may be made under these conditions, however, just as when the change is made to one automatic central office only. If fact, the course of procedure is the same, with the exception that each subscriber' line must be multipled, prior to the cut-over, into the particular automatic office to which it is to be eventually connected permanently and these be temporarily kept open until the hour for cut-over arrives.

Furthermore, the trunks for automatic calling between offices must be prepared and thoroughly tested out prior to the cut-over along with the equipment installed in each office.

**Changing Subscribers' Station Apparatus.**—Subscribers' stations equipped with private branch exchange switchboards should be prepared for the cut-over 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 cut-over. After the cut-over 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 ringing relay of the connector switch which connected to a trunk would operate as soon as connection was established, and calls from desk, 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 cut-over 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 bus bars 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 bus bars. It must, of course, be remembered that as an automatic 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 cut-over, where conditions will permit, is to install trunk jacks with the associated supervisory relays, as shown in Fig. 158 in the chapter on subscribers' 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. As a result of many years' observation it may be stated that 90 per cent of the trouble following a cut-over to automatic will develop in the *P.B.X.*'s and Intercommunicating Systems. For this reason it is imperative that no pains be spared when testing out this equipment.

**Changing Service Desks and Toll Boards.**—The wire chief's desk complaint desks, and information clerks' desks are generally not remodeled when a cut-over is made from manual to automatic equipment, but as a rule new desks, especially designed for use with 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 cut-over 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 subscribers' 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 cut-over, because it is necessary to have the magneto for signalling, and the local battery of the instrument for furnishing talking current until after the cut-over takes place. Prior to the cut-over the automatic instrument should be bridged across the line and the ringer of the magneto instrument should be disconnected so that all 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 cut-over 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 mentioned 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 and 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 the office were the only one in the system; but arrangement 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 arrangements 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 over-load the "*A*" operator, 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, either before or just after the cut-over, 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 dial device, that by turning his dial from a certain finger hole (for example, finger hole 6) 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 and gives the number desired to the operator who responds, and who then completes the connection and rings the desired party just as in the regular manual practice.

**Plan 2.**—A plan which is more economical of operation, because it eliminates the "*B*" operator 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, 33⅓ 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; 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 the 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. 276 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 $X$ 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 III, only the operation 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 switchboard 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, make-springs relay $W$ and resistance coil $X$.

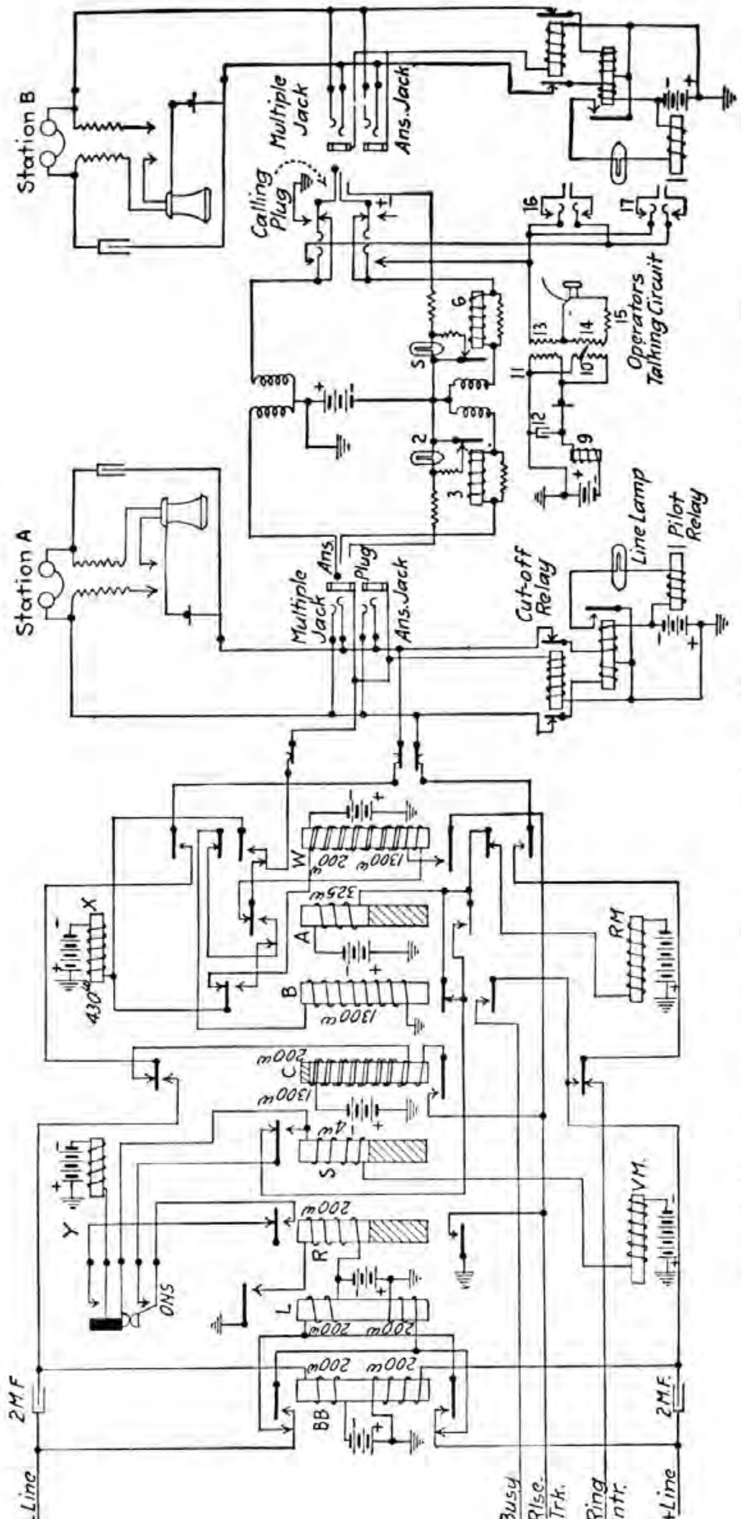



FIG. 276.—An automatic and a manual switchboard interconnected by multiple method.

On the other hand, whenever a connector switch finds a line made busy, in one of its jack, in the manual switchboard, a circuit may be traced from negative battery of the manual switchboard, through the lamp and contact of cord relay *B*, resistance coil 2, the sleeve of the plug, the sleeve of the jack, the private bank multiple, private wiper, break-springs relay *W*, make-springs relay *A* (relay *A* has not yet de-energized, following the rotary impulses), break-springs relay *W*, busy relay *B* to positive battery. The result is that the busy relay closes a circuit from the busy bus bar to the positive side of the calling subscriber's loop, at the same time closing a locking circuit for itself which may be traced from ground, relay *B*, break-springs relay *W*, break-springs relay *A* (which by this time has de-energized), make-springs relay *B*, resistance *X* to negative battery. Thus it will be seen that the calling subscriber will continue to receive the busy tone even though the called line should become idle. In addition to the foregoing the busy relay also opens the circuit to the rotary magnets, in order that there can be no further rotation of the switch should the subscriber again operate his calling device.

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.

When an automatic subscriber causes a connector switch to advance its wipers into engagement with a set of bank contacts associated with an idle manual line a circuit may be traced as follows: From ground through the cut-off relay of the manual switchboard, private multiple, private wipers, break-springs relay *W*, break-springs relay *A* (which has de-energized following the last of the rotary impulses), through the low-resistance winding of relay *W*, break-springs relay *B*, through resistance *X* to negative battery. Relay *W* will energize sufficiently over this circuit to close the locking springs *X*, following which a circuit may be traced from ground, make-springs relay *B*, make-springs relay *W*, through the high resistance of relay *W*, to negative battery. The current flowing in this circuit will cause relay *W* to become fully operated and accomplish the following results:

(*a*) Place negative battery through resistance *X* directly on the private multiple, in order to busy the line.

(*b*) Cut the ringing relay *C* through to the wipers.

(*c*) Open the circuit to the low winding of relay *W*.

(*d*) Open the circuit to the busy relay *B*.

(*e*) Open the rotary circuit to prevent further rotation should the calling subscriber again operate his dial.

The remainder of the connector operation is standard, and need not be repeated here.

**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 alongside 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. 276 just described, or according to any similar scheme. The old order wires from the "*A*" operator 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 arrangement that the "*B*" positions may be used in handling calls between the two manual switchboards up to the moment of the cut-over, and may be available for use as a switching section in multiple with the automatic switchboard immediately after the cut-over. 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*" operator's positions and terminate in lineswitches, 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 reassigning 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 provisions 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-distributor equipment, between the "*A*" operators and the "*B*" operators should be considered.

In some instances, where the traffic is very light, each "*A*" operator's position has been equipped with a calling device. When this is done the "*A*" operator by means of her calling device will, herself, complete connections to the subscribers in the various automatic offices.

The work of dialing calls over automatic trunks slightly increases the work of the "*A*" operator, about 0.078 of a unit call per additional digit. Take the operator's load as 240 unit calls and the following equating factors:

| | |
|---|---|
| Local call | 1.00 |
| Manual trunk call (order wire) | 1.50 |
| Automatic trunk call (4-digit) | 1.65 |
| Automatic trunk call (6-digit) | 1.81 |

Assume that the trunking to other offices is 60 per cent. Then an operator can handle 75 local calls and 110 manual-trunked calls. To handle this number of calls, if the trunk calls are dialed by four digits, would require 1.069 "*A*" operators, and if the calls have six digits it would require 1.14 "*A*" operators.

To dial four-digit calls requires about seven per cent more "*A*" operators, and for six-digit calls about 14 per cent more operators.

If there is much trunking, the "*A*" operator's busy-hour load is determined by the congestion on order wires which is beyond her control. But if the "*A*" operator can dial the calls, everything is within her own control.

The slight additional load is not the determining factor in deciding on a plan for trunking from manual to automatic.

**Changing a Manual System of More than Ten Offices to an Automatic System.**—If a manual system including more then ten offices, say 20 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 first level being reserved for special service trunks. 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, H, D, W, X and Y, respectively These letters are chosen because they are least likely to be confused one with another when spoken over 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 is 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 requires further cosideration.

*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 sub-offices only. One plan for trunking calls outgoing from "A" would be an enlargement of the scheme explained as Plan 1 in the discussion of method 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 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 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 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 in trunk mileage, it would entail a greater expense for operator's wages and will give slower service to 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, is to simplify the trunking plan and save trunking mileage. Over against the saving in trunk mileage, however, must be placed the increased cost of operators' 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 trunks run direct from the automatic district main office second-selector banks to each of the subsidiary manual offices, and there terminate in "*A*" operators' 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 call 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 jacks 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 then 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 layout for power plants to operate the automatic switches in the various 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 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 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 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 ininstalled 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 Cut-over Period.**—A third plan for changing over a multi-office metropolitan area embodies the use of semi-automatic or "Auto-manual" equipment during the cut-over period. While this increases the operating cost during the time of the cut-over, it simplifies the method of calling from the subscriber's 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 lineswitches 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, he 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 lineswitch group, the outgoing trunks from that group might be cut out of the operator's switchboard and connected straight through to secondary lineswitches, or first selector switches, if secondary lineswitches 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 9 on every dial might be labled "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 9 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 ninth 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 practiced. 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.

*Plan* 5. **The Use of Call Indicators.**—This scheme has all the operating advantages of Plan 2, page 330, but does not necessitate the large expenditure for second selectors, third selectors and connectors which are required in the manual offices as outlined in that plan.

Let us assume that we have eight offices in the network, each having an ultimate of 10,000 lines. The first four offices will be considered as being manually operated, while the last four will be full automatic. At each automatic office the second level of the first selectors leads to repeaters which are associated with trunks terminating on special equipment at No. 2 manual office. The third level leads to repeaters which are associated with trunks to the No. 3 manual office. The fourth level leads to repeaters which are associated with trunks to the No. 4 manual office. The fifth level leads to repeaters which are associated with trunks to the No. 5 manual office. The 6th, 7th, 8th and 9th levels lead to second selectors and repeaters as is common practice in an automatic network.

At the No. 2 manual office, for instance, the trunks incoming from the second level of the first selectors in the automatic offices are equipped with rotary lineswitches. When a trunk is seized at an automatic office the associated rotary lineswitch extends the connection to an idle "call-indicator register."

The "call indicators" will be installed on certain positions on the "*B*" boards of the various manual offices. Each of these call indicators is made up of 40 small lamps under a plate of numbers arranged as shown

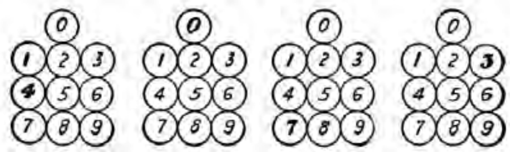


Fig. 277.—Call indicator lamp bank.

in Fig. 277. These numbers are on the reverse side of a piece of ground glass and are only visible when the associated lamp is lighted. The key-shelf equipment on a call-indicator position is shown in Fig. 278.

Should an automatic subscriber remove his receiver and dial the figure 2, his connection will be extended to a plug ending trunk on a *B* position and a rotary lineswitch at the No. 2 manual office. The rotary lineswitch will automatically connect the trunk with a vacant call-indicator register, of which there are eight for each call-indicator "*B*"

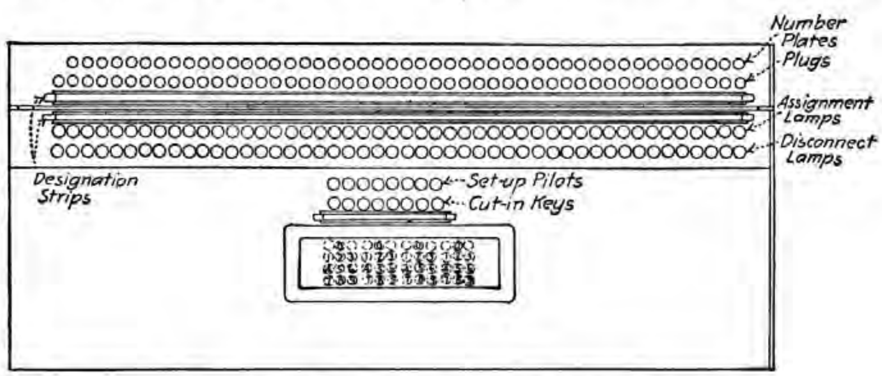



Fig. 278.—Diagram of keyshelf with call indicator.

position. As the subscriber dials the remaining digits of the number, 4-0-7-3 for example, the register records this number and as the last number is recorded, the "set-up pilot" of the register which is being used lights up, as also does the "assignment lamp" associated with the trunk on which the call is being made, and at the same time the numbers 4-0-7-3 will appear on the call indicator, as is indicated by the heavy type in Fig. 238. The operator now completes the connection by inserting the plug which is associated with the lighted assignment lamp, into the multiple jack 4073, following which the number displayed on the call indicator disappears, the set-up pilot and the assignment lamp going out at the same time. If, in the meantime, another call has come into the position the same cycle of operation is repeated.

In other words, the rotary lineswitch extends each trunk to a register which is not busy, and the remaining digits dialed by the subscriber are recorded on the register he obtains. The registered number is displayed on the call indicator, and is cleared as the calling plug is inserted in the jack of the line wanted.

The operator tests for busy in the usual way, and if the called line is busy the calling plug will be inserted into a "busy back" jack as is customary in manual-to-manual practice.

When employing this scheme no distinction is made in the directory between manual and automatic numbers, as from the automatic subscribers' viewpoint the operation of calling is the same in either case.

If at any time in the future it is desired to convert a manual office to automatic, it is only necessary to replace the call-register apparatus by incoming second selectors, third selectors and connectors.

**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 cut-over 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 cut-over 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 distributor 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 Sub-offices 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 lineswitch sub-office apparatus, such as described in the chapter on semi-auto sub-offices. 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 lineswitch sub-office 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 XV

## 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 25 cells with seven counter electromotive force cells. The latter are used to keep the pressure between 46 and 52 volts at the bus bars. 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 floor 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 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. Figure 279 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 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

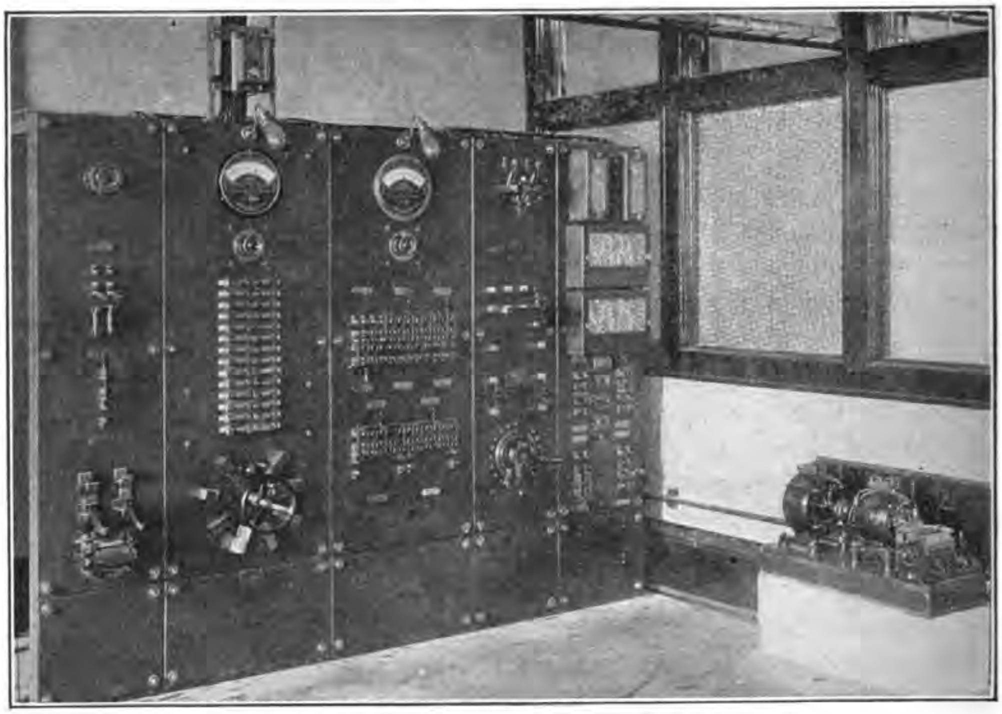


FIG. 279.—Typical power and battery switchboard.

disabled and the 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 Current.**—Harmonic converters (pole changer sets) and motor generators are used for ringing, one of the latter being shown at the right of Fig. 279. The motor generator is usually equipped with sets of springs (seen in the view referred to above) designed to furnish the make and break contacts for the generator control 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, dial tone and howler attachments. Sometimes the ringing machine used regularly is operated by the commercial power circuit, while the reserve machine is a dynamotor driven from the exchange storage battery. With this arrangement, a failure of the

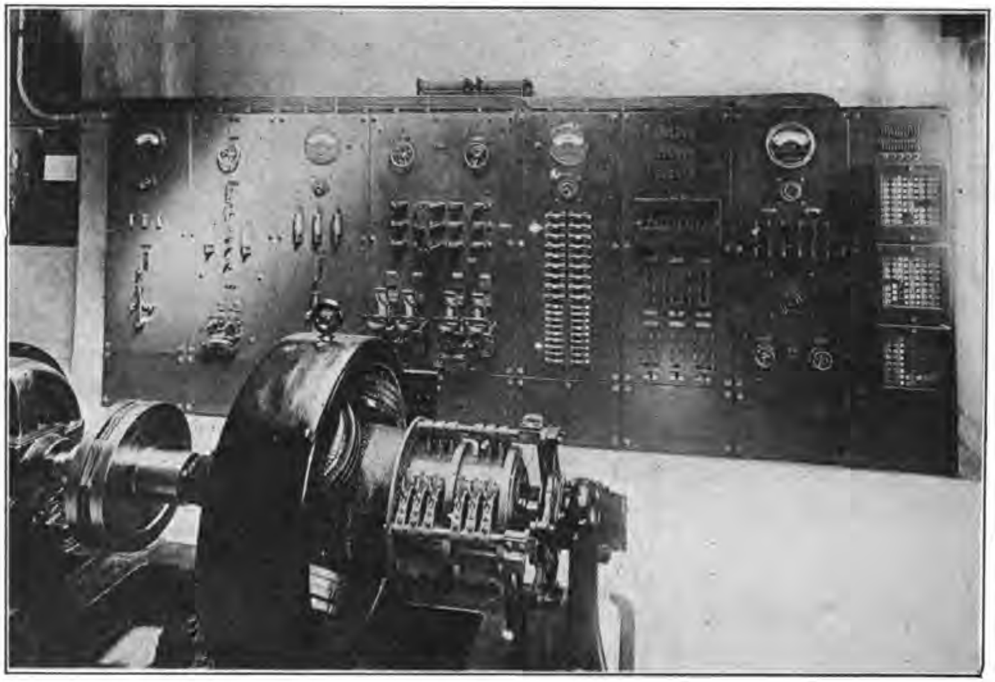


Fig. 280.—Power switchboard and charging machine.

commercial source of power supply for a few hours will not disable the telephone plant. The reserve ringing apparatus, in the plant in which the photograph reproduced in Fig. 279 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, and a device for furnishing the interrupted buzz, used as a busy signal.

When harmonic converters are used it is customary to provide solenoid ringing interrupters to feed interrupted ground to the generator control relays. Two of these interrupters are shown at the extreme upper right-hand side of the power board in Fig. 279.

This ringing interrupter (Fig. 281) 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.

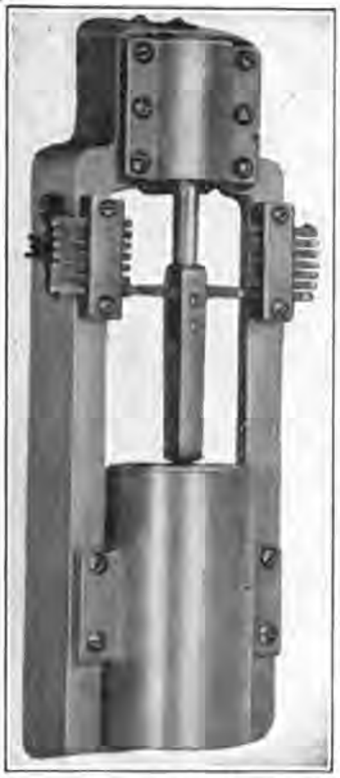


Fig. 281.—Solenoid ringing current interrupter.

**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. 279 and 280.)

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 of Fig. 279.

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 bus bars, 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 52.

**Typical Power-board Circuits.**—In Fig. 282 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 batttery 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 bus bars supplies current also to one of the two rotary ringing machines. The other pair of bus bars 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 voltmeter switch connections are made. Beneath the voltmeter are the ammeter circuits. One of the ammeter shunts is used for measuring the current of each charging machine, and the third is used for measuring the current flow from the battery to the automatic switchboard.

In Fig. 283 is shown the power switchboard wiring digram of a main office with three sub-offices. 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 trans-

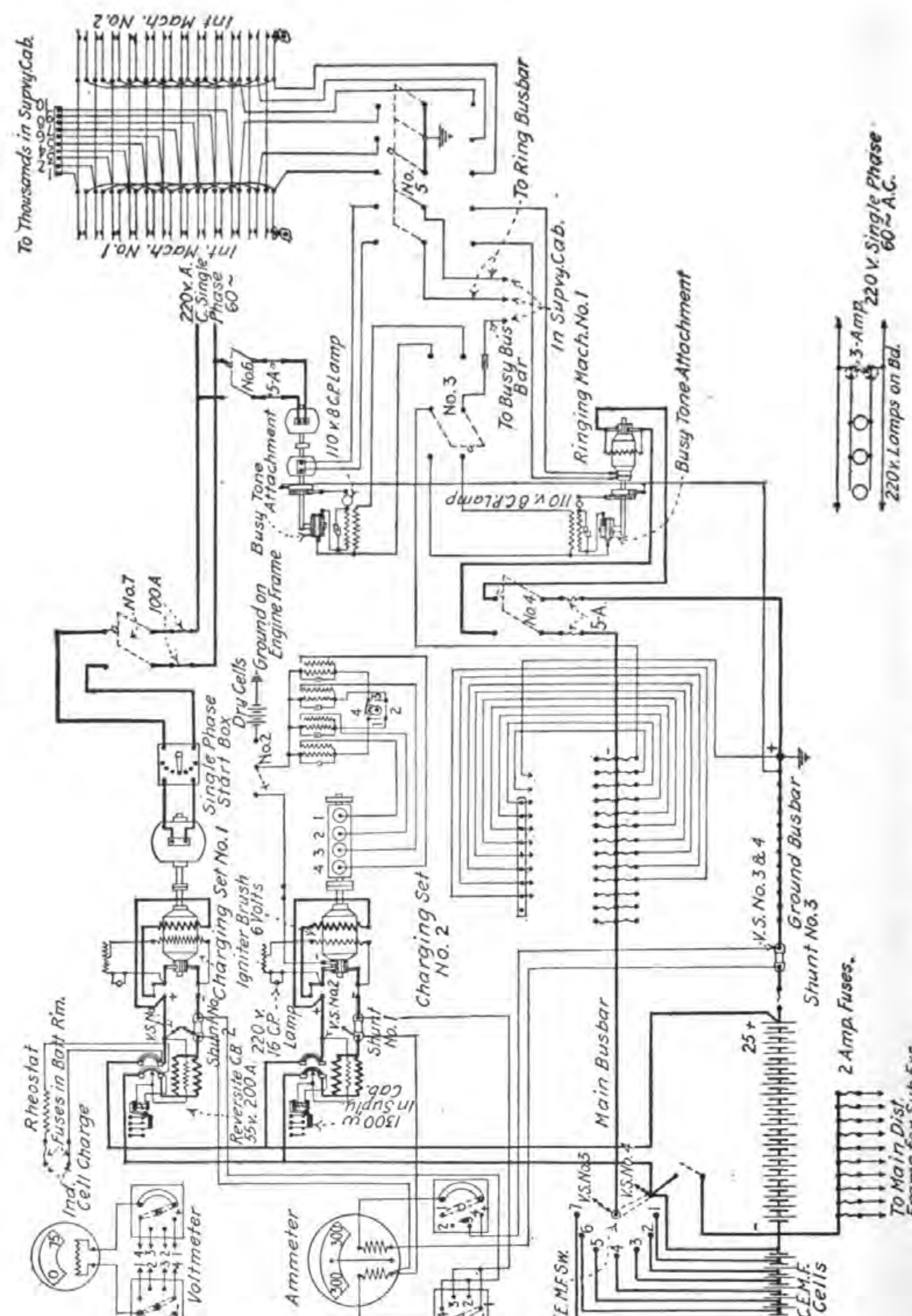



FIG. 282.—Typical power-plant circuit diagram.

former. 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.

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 sub-office.

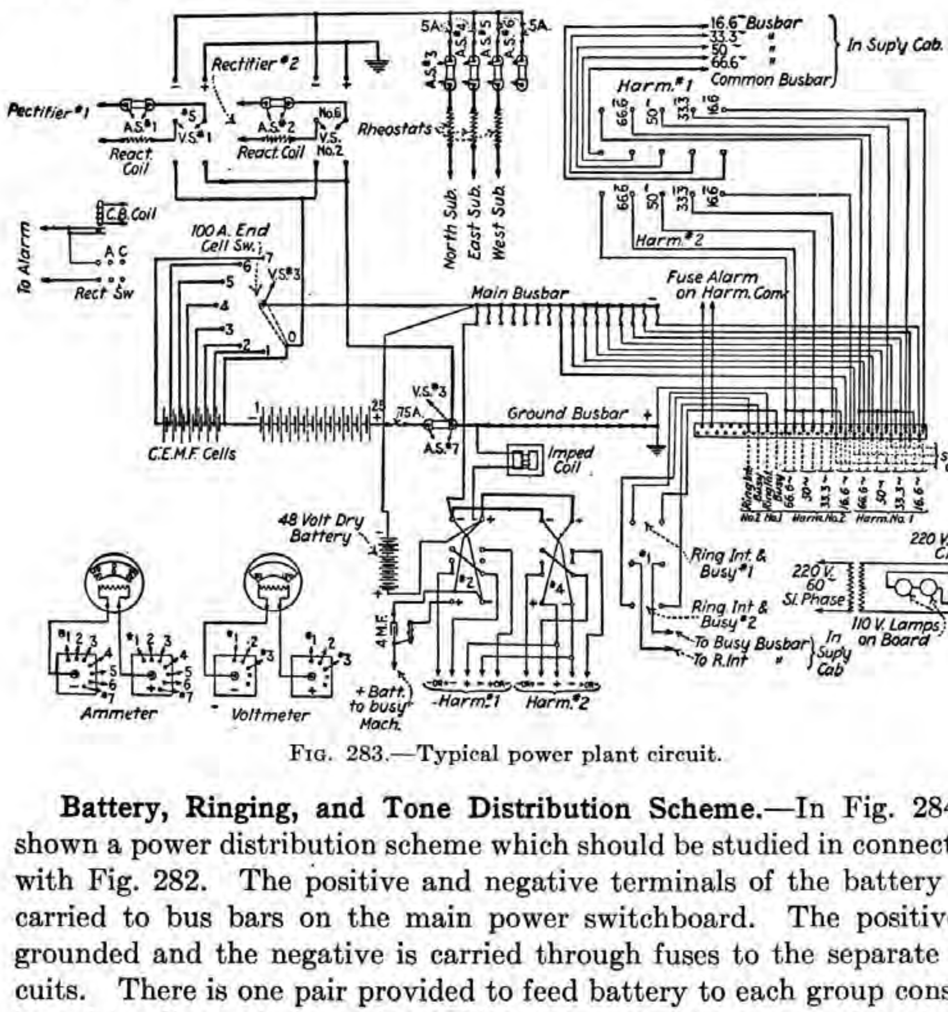



FIG. 283.—Typical power plant circuit.

**Battery, Ringing, and Tone Distribution Scheme.**—In Fig. 284 is shown a power distribution scheme which should be studied in connection with Fig. 282. The positive and negative terminals of the battery are carried to bus bars on the main power switchboard. The positive is grounded and the negative is carried through fuses to the separate circuits. There is one pair provided to feed battery to each group consisting of ten line switchboards. This pair runs to the nearest board of a group, and terminates upon the bus bars of a small auxiliary power-board at the top of the lineswitch upright. This pair of bus bars is strapped to a similar pair of bus bars on the next line switchboard of the group; the strapping is continued until all the boards in the group have been reached.

From each pair of bus bars the current is distributed to the various parts of the associated lineswitch board. Each connector switch receives its battery from the bus bar over an individual pair. This pair feeds

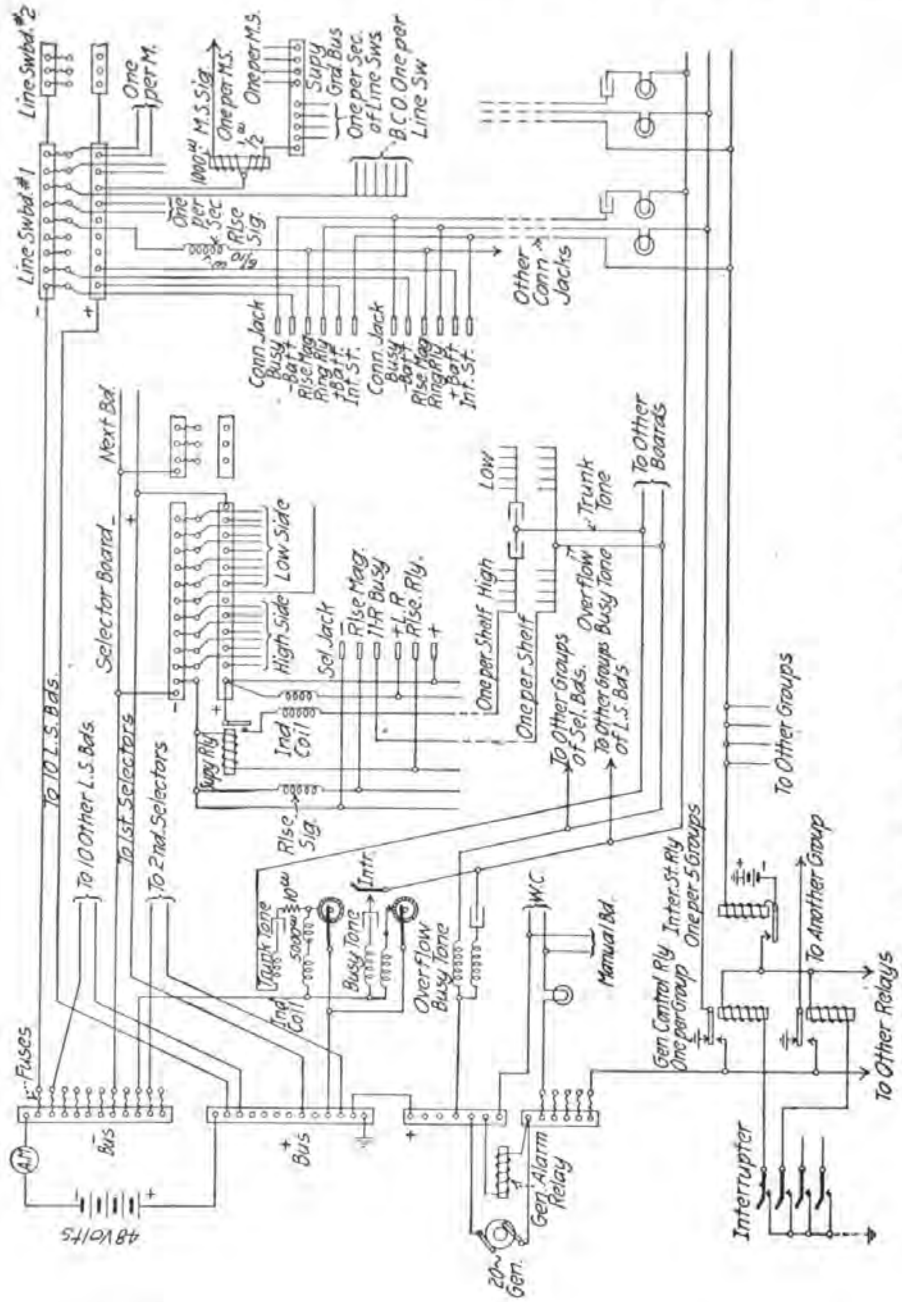


FIG. 284.—Battery, ringing current, and tone distribution.

everything in the switch, excepting the release magnet, which draws its current through a release signal relay which is common to all the connectors on this lineswitch board.

Each master switch has its own pair of wires supplying positive and negative battery. In addition, supervised positive battery comes through a one-half-ohm relay and the supervisory ground bus bar. One master switch signal wire is provided for each master switch; this operates on alarm if the master switch should stick between notches on the escapement sector.

One pair of positive and negative battery wires are provided for each section of 25 lineswitches. The *B.C.O.* coils receive their current through on fuse for the entire 100 lineswitches. There is one supervised ground wire for each section of lineswitches, which supplies positive battery to the line relay contact for operating the pull-down coil.

**Power to Selector Boards.**—There is one pair of battery feed wires for each kind of selector. Thus, there will usually be one pair for the first selectors (even though there may be several boards of first selectors), another pair for the second selectors, another pair for the third selectors, etc.

Taking the first selectors as an example, the battery pair runs along the tops of adjacent selector boards with a tap from each wire leading down to auxiliary bus bars placed on a small power board which is mounted just above the door leading into the selector board.

The distribution is divided into ten parts; the low side of the board and the high side of the board. There are five (sometimes six) shelves on each side or bay, each shelf carrying 20 selectors. There is one pair of wires carrying positive and negative battery to each shelf; the negative battery is fused, the positive is fed direct. After reaching the shelf the battery feed is multipled from switch to switch. There is a single fuse on the power panel which feeds the signal relays.

The line relay of a selector is supplied with two sources of positive battery. One conductor passes from the positive bus bar through one winding of an induction coil. When the switch is seized, the supervisory relay which is in series with the release relay causes a trunk tone to be sent through the primary winding of the same induction coil, so that the calling subscriber will hear the tone and be notified that he has secured a selector, and the circuit is ready for dialing. The other source of positive battery will be discussed later. The release magnet obtains its negative battery through the release-signal relay, which is for the purpose of indicating when the release magnet draws current longer than is safe.

The second and third selectors are wired in a similar manner, except that they are not provided with a trunk tone.

**Ringing Current Distribution.**—Ringing current for straight-line work is illustrated in this figure. If this is understood the slight variations found in party-line work can easily be mastered.

The alternating-current generator has one terminal attached to a separate positive bus bar connected to earth and the other terminal to a generator bus bar equipped with fuse distribution. Across the two bus bars is a generator-alarm relay which is normally energized. If the generator fails, the falling block of the relay sounds an alarm. Current for the wire chief's desk, etc., is supplied through a pair of wires equipped with a lamp resistance in the fused lead.

The ringing current for the automatic board comes through a fuse and is distributed to the front contacts of several generator-control relays. Each generator-control relay is operated by an interrupter, so as to supply ringing current at intervals, between which the ringing wire leading to the connectors is grounded. The purpose of this was described when discussing the connector switch.

There is one generator-control relay for each group of lineswitch boards. The size of the group may vary from five to ten boards. The ringing current is tapped off at each lineswitch board through a lamp resistance, after which it is multipled directly to the jacks of the connectors.

There is one interrupter-start relay for every five groups, this relay feeds negative battery to the generator-control relays.

The interrupter-start relay is controlled by a wire which is multipled to all five groups and distributed in each lineswitch board to the jacks of all the connectors. The interrupter which controls the generator-control relays is arranged so as to pull up one relay at a time. This spreads out the ringing so that the generator is supplying current to only one group at a time.

**Busy and Trunk Tone Distribution.**—As shown in the figure, the busy tone is generated by the feeding of battery current through a high-speed commutator to an induction coil. There is also an interrupter which breaks up the tone into suitable pulsations. There is one busy-tone wire leading from the power board to each group of lineswitch boards. The top taken off at each lineswitch board passes through a lamp resistance and a condenser, and is then multipled to the jacks of the connectors.

The overflow busy tone is taken from the regular busy-tone wire at the power board by means of an induction coil. This is done so as to secure connection to the positive bus bar. It is supplied by means of one wire for each group of selector boards. At each selector board the overflow busy-tone wire divides into two parts—one for the high side, the other for the low side. Each side again divides into one wire per shelf, which is multipled to the selector jacks. This is the second kind of ground furnished to the line relay and comes into use when all trunks on a given level are busy and the selector rotates of the bank. The second and third selectors are also provided with the overflow busy tone.

The trunk tone is generated in a very similar way to the generation of the busy tone. This is distributed to first selectors only. The trunk-tone wire is tapped off at each selector board and distributed through two condensers, one for each bay. There is one wire for each mechanical shelf of 20 switches. It runs to the primary of an induction coil so that when the supervisory relay is operated, it will put this tone on the regular positive battery feed for the line relays.

**Sub-office Power Equipment and Circuits.**—The battery of a sub-office not more than a mile from its main exchange may be floated on the main exchange battery of 25 cells through cable pairs. If the distance to the sub-office is too great, or the spare cable conductors not low enough in resistance, a 120-volt rectifier installed atthe central office, as indicated in Fig. 284, may be used. Where this plan is not pract-

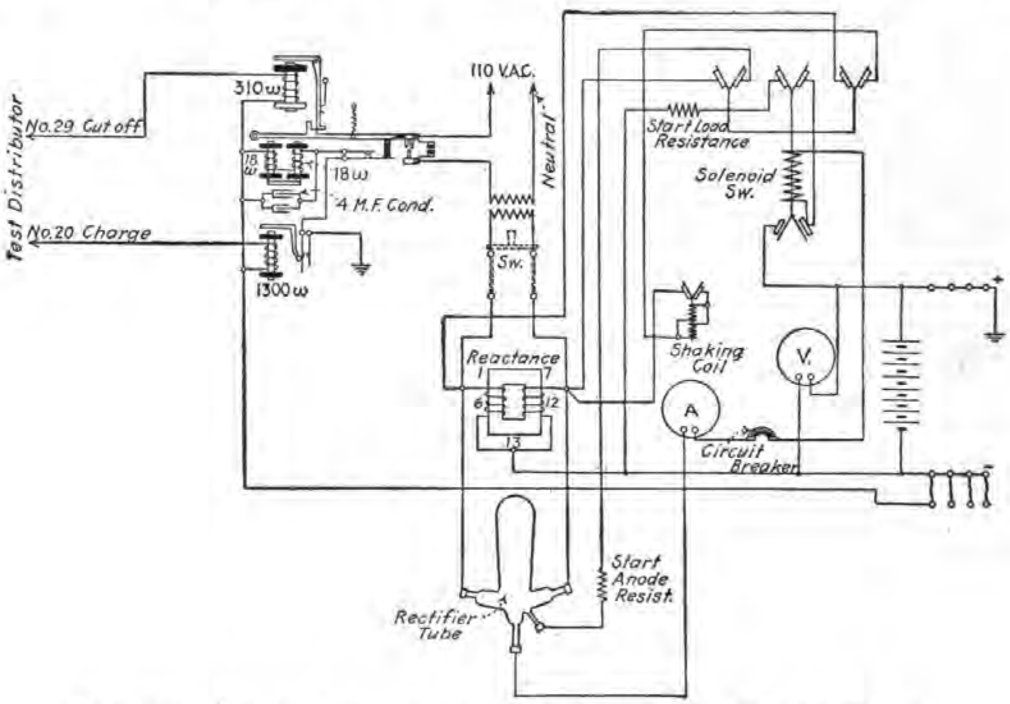



FIG. 285.—Circuits of a mercury arc rectifier charging outfit for a sub-office.

icable, it is common practice to charge the sub-office batteries by means of connections to the commercial source of power supply, tapped into the sub-office for the purpose. If 110-volt direct current is available, the sub-office 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 sub-office rectifier equipment is shown in Fig. 285. Relays are arranged to enable the wire chief at the central office automatically to switch the sub-office charging apparatus on or off, as desired, by calling certain numbers on his test-distributor switch, using a calling device on his desk. Circuits of these relays are indicated in Fig. 285. 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

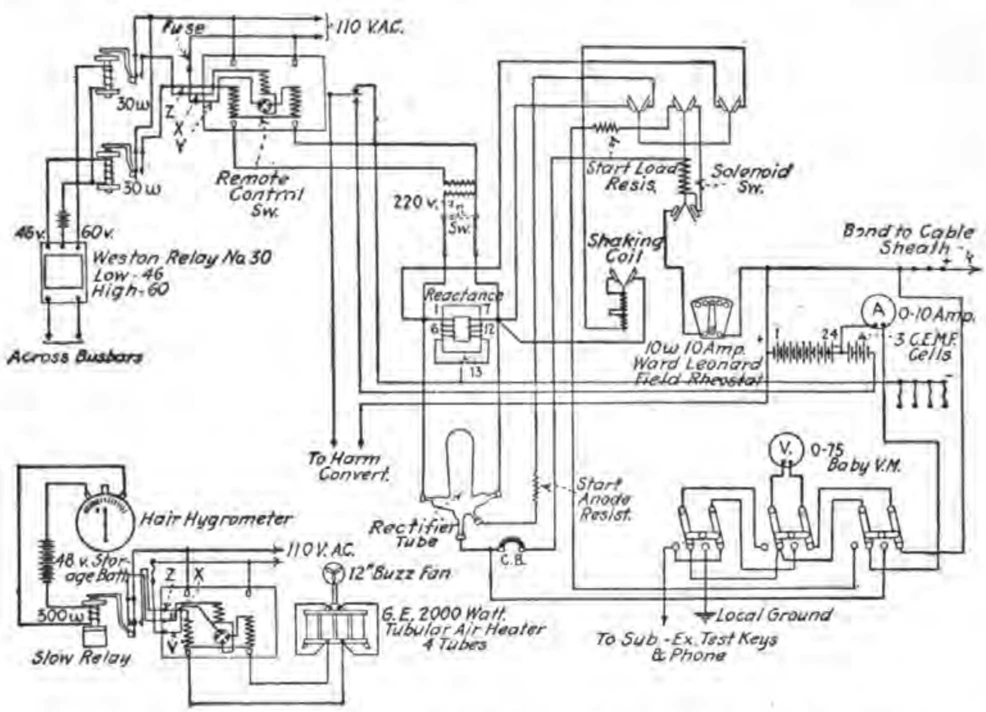



FIG. 286.—Circuit of sub-office power plant arranged for remote control of charging apparatus and automatic control of heating apparatus.

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 bus bars, shown at the right-hand end of the diagram. Each negative lead is fused as indicated.

Figure 286 shows the circuits of a sub-office power plant, arranged so that a mercury arc rectifier installed at the sub-office 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. 285. 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 sub-office 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.

**Fuse and Voltage Alarm Scheme.**—In Fig. 287 is shown a typical fuse and voltage alarm scheme. Every fuse gives an indication if it blows. Three means are employed: *A*, the alarm fuse with an alarm strip; *B*, the cartridge fuse with lamp in parallel; *C*, cartridge fuses with a relay connected across two of them. Practically all of the fuses control one fuse alarm bell, by means of a low resistance relay in series with a number of red tell-tale lamps on the ceiling.

The main central office battery on the power board is protected by enclosed fuses. These fuses have alarm relays across their terminals, two windings taking care of four fuses. Each relay locks mechanically and lights the red tell-tale lamp marked "Power Board."

The first selector boards are protected by alarm fuses which connect negative battery on to an alarm strip. This operates a 1300-ohm relay which in turn lights a fuse pilot lamp in series with a low resistance

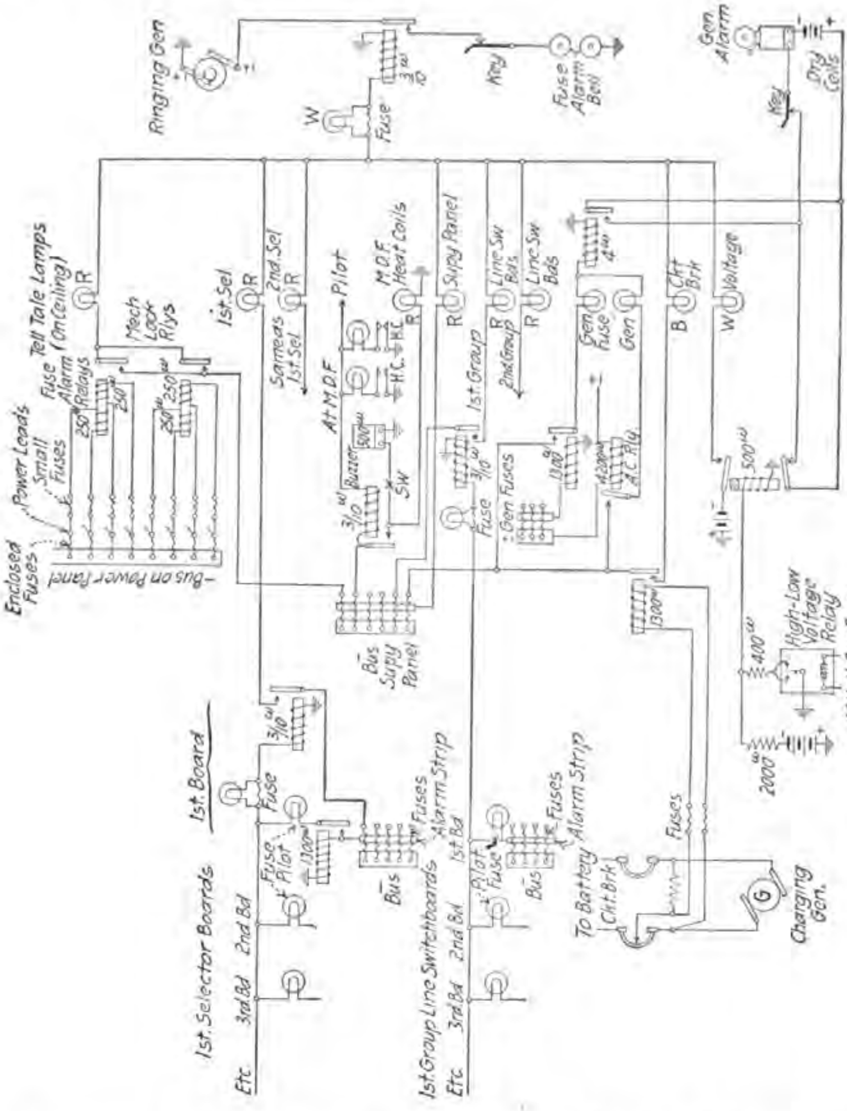



FIG. 287.—Fuse and voltage tell-tale and alarm scheme.

relay common to the first selector boards. This relay lights the tell-tale lamp on the ceiling.

The lineswitch boards are similarly protected, except that the fuse alarm strip is connected directly to the fuse pilot lamp.

The circuit breakers are provided with one 1300-ohm relay to indicate operation. It is in series with a resistance across the charging lead but short-circuited by the circuit breaker when closed.

The supervisory panel which contains supervisory apparatus is itself protected by fuses of the alarm type. The alarm strip connects directly to the tell-tale lamp.

The ringing-current generator fuses are of the alarm type. The alarm strip is carried to a 1300-ohm relay which puts negative battery on to the tell-tale lamp.

A failure of the ringing current is indicated by a tell-tale lamp controlled by a 4200-ohm *A.C.* relay which is held energized as long as the generator supplies current.

The ringing-generator fuses and voltage tell-tales have an alarm of their own, which consists of a bell operated by dry cells.

The main-battery voltage indicates by a white tell-tale if it is too high or too low. The high-low voltage relay on the bus bars controls a 5000-ohm slow relay, which in turn lights the tell-tale and sounds the generator alarm bell. The 500-ohm relay has a copper collar to make it slow to respond, so as not to indicate momentary extremes of voltage. The arrangement of resistances (2000 ohms and 400 ohms) is to protect the contacts of the voltage relay.

The *M.D.F.* heat coils light a tell-tale lamp by means of a common low-resistance relay, but do not sound the fuse alarm bell.

**Solenoid Ringing Interrupter.**—In Fig. 288 is shown the circuit of a solenoid ringing interrupter. When the "interrupter start" common, is grounded an interrupter-start relay (Fig. 284), will energize. The springs on the interrupter-start relay are multipled so that whenever a relay becomes operated it will close a circuit which may be traced from ground, make springs on the solenoid interupter, the two windings of the solenoid interrupter in series, make springs interrupter-start relay to negative battery. The solenoid will cause the plunger of the solenoid interrupter to rise. The mechanical arms and spring, shown midway of the plunger, are so proportioned that the springs will not be operated until the plunger has reached the highest point of its travel. When this point is reached the springs will disengage and open the circuit of the solenoid.

As the plunger with its rod drops by force of gravity, retarded in its movement by means of the dash pot, 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 generator-control relay will be energized.

When the plunger reaches its lowest point of travel the arms again operate and as a result ground is removed from the back of contacts. If the interrupter-start relay is still energized the solenoid interrupter will operate as before. The cycle of operation requires about three seconds time—one-half second for ringing and two and one-half seconds interval between rings.

**Release Signal and Tell-tale Alarm Scheme.**—The release magnets of all switches draw a heavy current momentarily; the same is true of lineswitches and master switches. To give an indication, should the current flow last too long, a system of release-signal supervision and ground-battery supervision is employed. It involves a dash-pot relay which is slow to act but relatively quick to release.

Referring to Fig. 289 it will be found that the selector boards have some common apparatus in the first board, the rest of the boards having

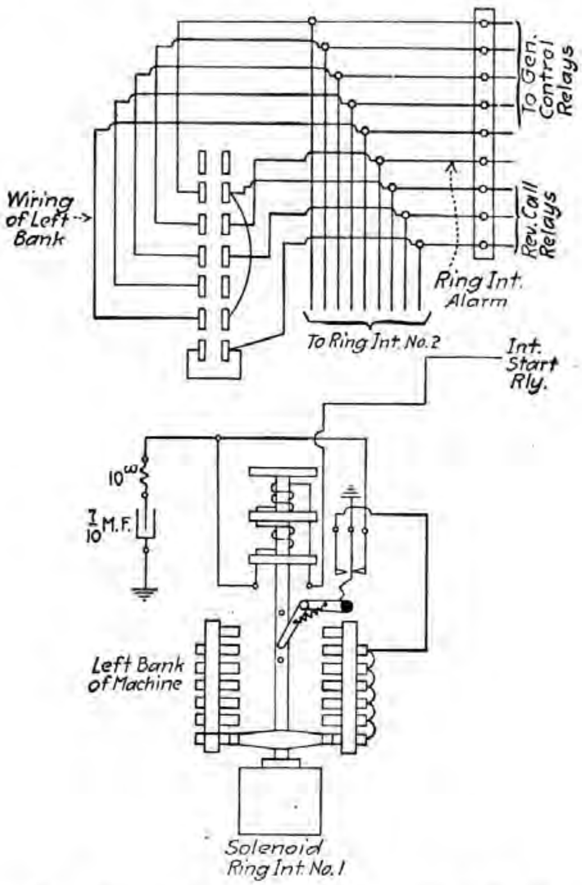



FIG. 288.—Solenoid ringing interrupter circuit.

only the pilot lamp and the shelf leads. Two leads are carried along to all the boards, the tell-tale wire and the wire for the time-limit apparatus on the first board only.

When a selector releases, its release magnet draws current through a 0.6-ohm relay on its shelf. This sends current through the shelf lamp which is in series with a 15-ohm relay common to the board, which in turn draws current through the 1300-ohm relay of the common time-limit apparatus; only this last relay energizes. It closes the circuit of the dash-pot relay. Ordinary release action is so brief that the dash-pot

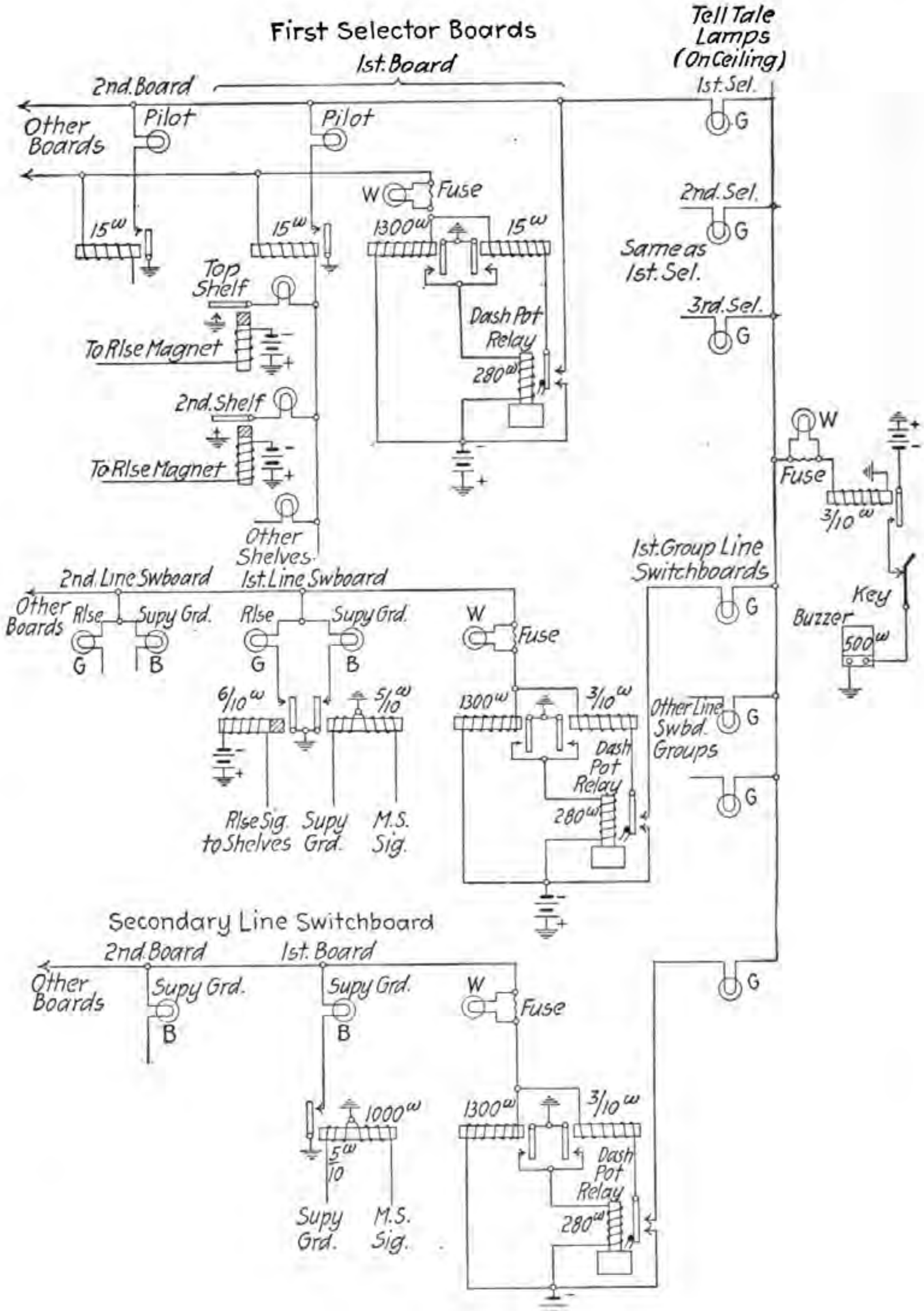



FIG. 289.—Release signal supervision, tell-tale and alarm scheme.

relay has not time to act. If for any cause the release magnet of a selector draws current longer than it should, the dash-pot relay has time to close its contacts. This lights the tell-tale lamp and shunts the 1300-ohm relay with a 15-ohm relay. This permits the 15-ohm relay on the board to pull up, lighting the pilot lamp. The tell-tale lamp current operates the 0.3-ohm alarm relay which causes the buzzer to sound. The second and third selectors are grouped in a similar way.

The lineswitch boards are also grouped for this purpose. The supervisory apparatus for a group is placed on the supervisory panel of the power board and a single wire run to the group of boards. There is one release pilot lamp on a board and no shelf pilot, for all the connectors are treated as if one shelf.

The lineswitches and master switches have the positive or ground battery wire "supervised." This means that it passes through a low-resistance relay. If the use of current is brief no signal is given; however, if the current flows too long the time-limit apparatus will light the tell-tale lamp, the pilot lamp and also sound the alarm buzzer.

Master switches have also a "master switch signal" which indicates if the switch sticks between positions. The lock lever will then put negative battery on to a wire leading to the 1000-ohm winding of the supervisory relay for the board. This produces the same results as if supervised ground were acting.

Secondary lineswitch boards have no connectors, hence they have no release signal. Otherwise their supervision is the same.

**Selector and Connector Supervisory Schemes.**—The action of selectors and connectors is supervised to reveal any abnormal action. Normally a selector should complete its selection and hunting within a few seconds. A connector should, at the end of the conversation, release promptly. Both subscribers having hung up their receivers within a few seconds of each other; such is the basis of supervision.

There is a white tell-tale lamp on the ceiling which indicates delayed action for all selectors. (See Fig. 290.) A 4-ohm relay acts as a common for all the group of selectors.

The release relay is one part of the selector whose condition is indicative of normal progress. Current flows in this coil from the seizure of the selector to the extension of the lines to the next switch ahead and the passing of the control from its selector. Hence, the negative current for the release relay is drawn through a 14-ohm relay which is common to the shelf. This relay, when energized, lights a pilot lamp for the shelf. The shelf pilot lamps draw current through a 30-ohm relay which lights the pilot lamp for the bay.

When a selector is seized the lamps light. When the switch has selected its level and hunted and seized the idle trunk, the lamps go out. Because of the time overlap of different switches, no time-limit apparatus can be used and no alarm signal is advisable. Even the tell-tale lamp is capable of being cut off.

The trunk tone is shown in connection with the first selectors; the other selectors do not have it.

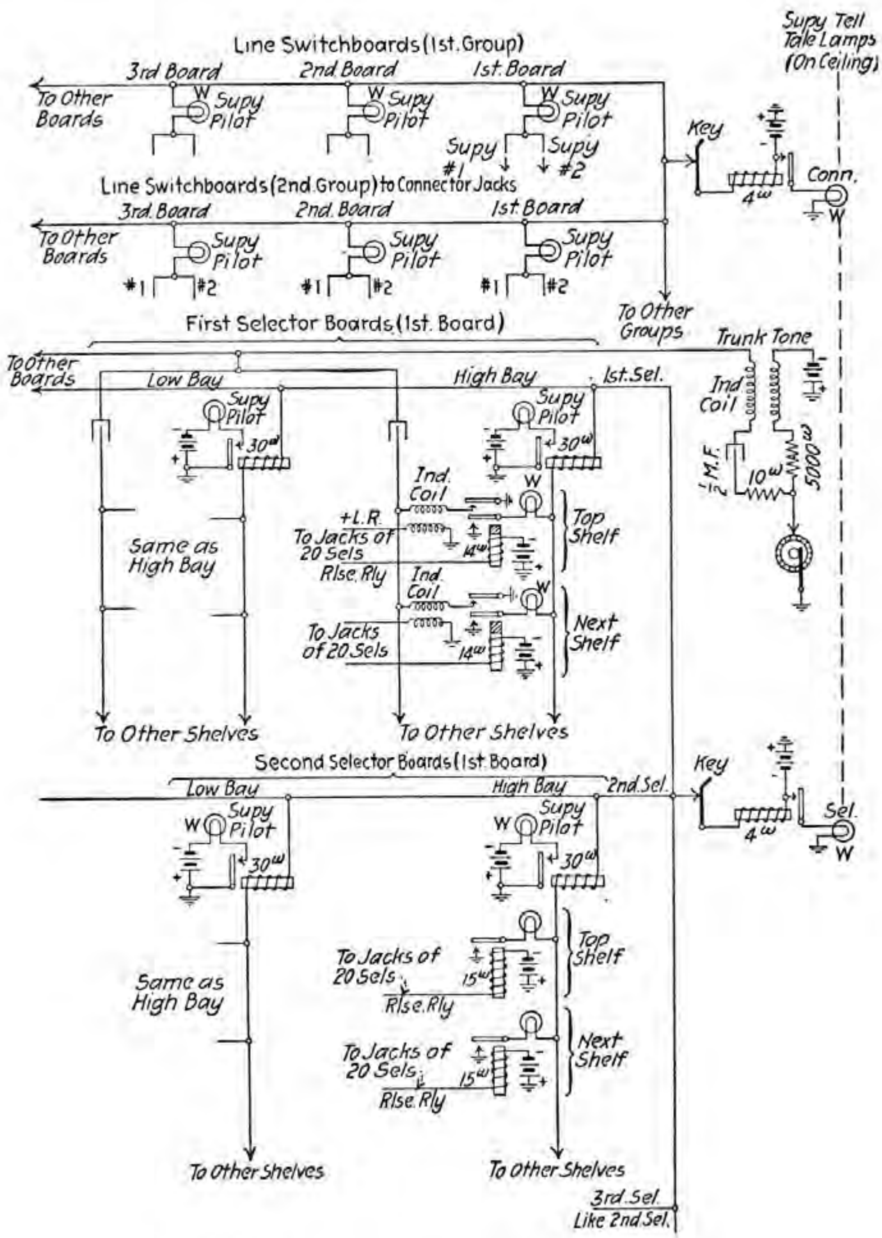



FIG. 290.—Selector and connector supervisory scheme.

The action of connectors on the lineswitch boards is supervised by the line relay and the back-bridge relay. As long as both subscribers are on the line, no supervisory lamp need show. If the calling subscriber alone hangs up, a pilot and a tell-tale lamp will show the condition. If only the called subscriber hangs up, the same lamps will light.

## TESTING EQUIPMENT

**Standard Impulse Length and Speed.**—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.

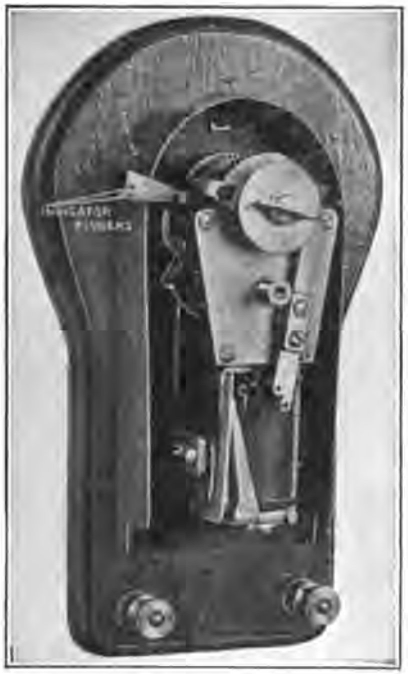


FIG. 291.—Calling device speed indicator.

**Calling Device Speed Indicator.**—This little piece of apparatus (see Fig. 291) 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 Adjustment and Testing.**—The adjustment of an automatic switch of the Strowger type may be divided into two parts, the relay adjustment and the adjustment of the motor magnets.

Each relay is adjusted to a definite armature stroke with a fixed residual air gap. The amount of contact of each spring with its mate is likewise fixed by the position of the armature when the contact takes place. These distances are measured with thickness gages placed between the armature and the pole of the relay.

The spring pressure of the contact springs of a relay is measured by the operating and non-operating currents. For instance, with the battery voltage as closely kept between 46 and 48 as possible, a certain relay must pull up through 3000 ohms but must not pull up through 3200 ohms. Such a pair of limits is set for each relay in a switch. In the case of quick-acting relays, it is assumed that in the factory they have passed a test for short-circuited turns. It is known that short-circuited turns make a relay slower to pull up and slower to fall back, the latter effect being more noticeable.

The motor magnets (vertical magnet, rotary magnet, and release magnet) are adjusted in a definite sequence to their proper relations to the wiper shaft. These relations are expressed in distances, most of them measured by thickness gages.

The final performance of a switch is tested by being operated under line conditions which are worse than any imposed by commercial use. The average calling device on a telephone delivers a 61 per cent impulse at about ten per second. (Circuit opened 0.61 of total impulse period.) The testing calling device or "varying machine" delivers impulses at 14 per second with the 61 per cent ratio under two-line conditions, zero loop with a 20,000-ohm leak, and 1200-ohm loop without leakage. The spring tension of the magnet (vertical or rotary) is adjusted until perfect operation is secured under these two extremes.

## 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.

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 apparant that this cam and

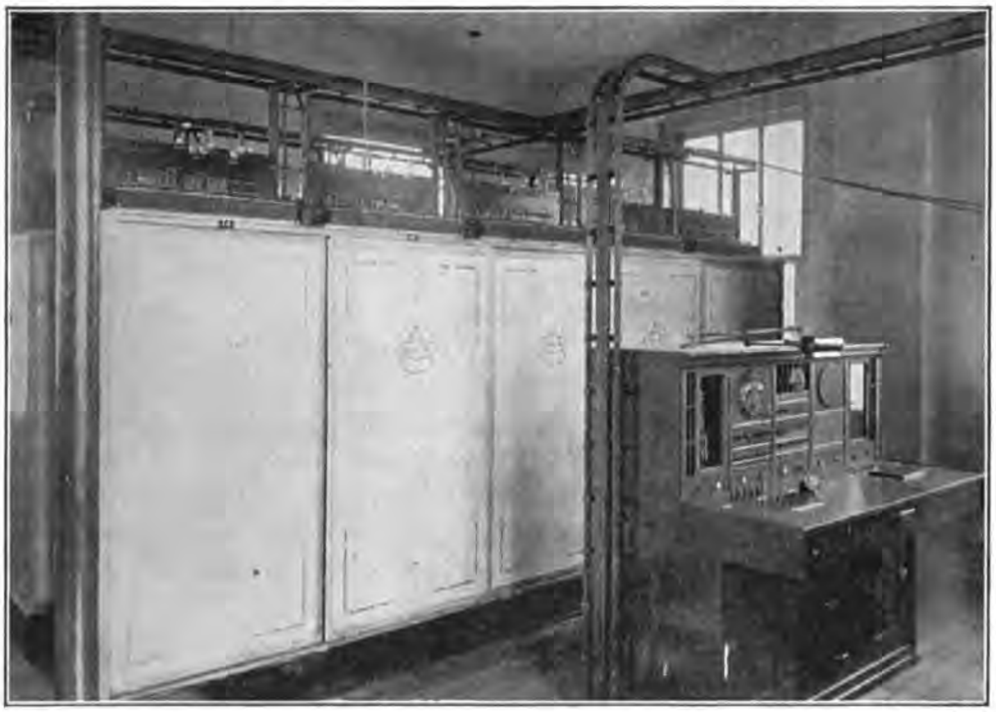


FIG. 292.—A view showing the wire chief's desk in an automatic central office.

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 13 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 20,000 ohms across the line, the other through 1200 ohms without leakage. A release button opens the line to release the switch.

*Wire Chief's Desks.*—A typical wire chief's desk (See Fig. 292) for an

Automatic Central Office contains one or more of each of the following circuits:

Operator's telephone circuit
Wire chief's test circuit
Trunks to test jacks on main frame
Toll-test plug circuit
Trunks to test distributers
In and Out trunk circuits
Hospital trunks
Howler circuit
Out order wire circuit
In order wire circuit
Master ringing circuit
Supervisory pilot circuit
Fuse alarm circuit
Lamp circuits for supervisory
Tell tale lamps in Main exchange

Sometimes one or more of the 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-distributer switch.

**Description of Circuits.**—In Fig. 293 is shown a typical wire chief's test circuit together with a test-distributer trunk.

The test circuit consists of a high-resistance voltmeter and sets of keys by means of which the test circuit may be connected to any one of a number of test-distributer trunks, or to the main distributing frame.

Besides a reversing and a ringing key there are keys for connecting the line to the voltmeter for the usual line tests *A*.

The dial-speed indicator key is used for connecting a line to the dial-speed indicator, for the purpose of receiving impulses from a telephone and line to determine whether the dial is operating at the proper speed or not. The wire chief may also supply current to the telephone on the line for talking purposes.

At the right of the figure the various key arrangements for the different meter tests, which may be made, are indicated.

**Trunks to Test Distributers and Test Connectors.**—These trunks enable the wire chief to test lines without assistance and without leaving his desk. The test distributers are useful in other ways, however, especially where district stations are used. A test-distributer 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-distributer trunk, test-distributer switch and test-connector switch circuits, shown in Figs. 293, 294 and 295, are typical of those in common use in two-wire plants using equipment of the Automatic Electric Company's manufacture.

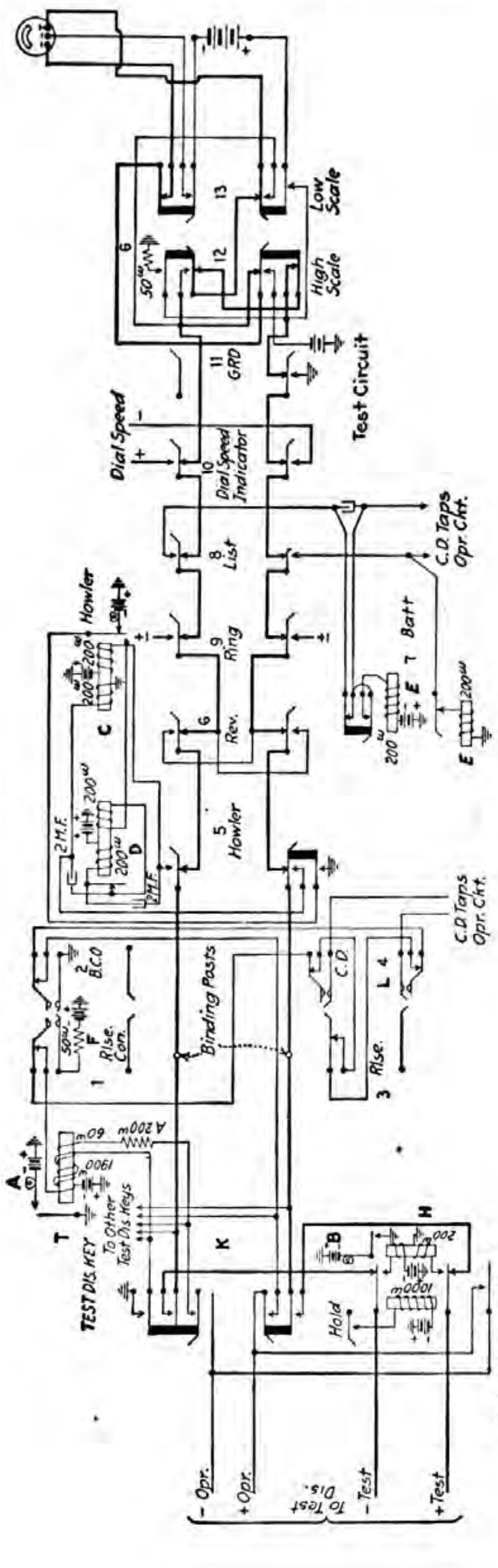



FIG. 293.—Wire chief's test circuit.

The wire chief prepares to use a certain test distributer by operating the associated "test-distributer key;" he then operates the test-distributer switch by making two turns of the calling-device dial associated with his test circuits, thus placing the test distributer in connection with the test connector mounted on the particular lineswitch unit in which the line which he wishes to test terminates.

The test-distributer 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 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 private wiper, while that marked *P*1 is for the special use of the wire chief in supervisory work.

We will now assume that the tester operates the test-distributer key *K* and the calling-device key *L*. When key *K* is operated this particular test-distributer trunk is cut on to the testing circuit, and at the same time a circuit is closed through the high winding of relay *T*. When key *L* is operated a circuit is closed from ground, relay *C* (Fig. 294) break-springs relay *F*, make springs key *K*, break springs *B.C.O.* key, make springs key *L*, calling device, make springs key *L*, break-springs release connector key, low-winding relay *T*, non-inductive resistance *A*, make springs key *K*, break-springs relay *F*, through relay *A* to negative battery.

Relay *T* will not operate at this time for the current flowing in the lower winding will oppose the current in the upper winding. Relay *D* and *A* will operate over the above-traced circuit and place the test distributer in readiness to receive the dial impulses.

When the tester dials the first figure, a six for example, the circuit of relays *A* an *D* will be opened six times. Each time the line relay *A* de-energizes a circuit may be traced from ground, break-springs relay *A*, make springs relay B, series relay C, vertical magnets, side-switch wiper in first position, to negative battery. The vertical magnets will energize over this circuit and will operate to raise the shaft and wipers to a position opposite the sixth level of bank contacts. The series relay will energize at the first vertical impulse and will close the circuit of the private magnet *P* and relay *G*; the energization of relay *G* has no effect at this time. After the cessation of the vertical impulses the relay *C* will de-energize and open the circuit of the private magnet; the private magnet upon de-energizing will allow the side-switch wiper to pass to second position.

When the tester calls the next figure, a seven for example, the relay *A* will momentarily de-energize seven times, and will send seven impulses of current over a circuit which may be traced from ground, break-springs relay *A*, make springs relay *B*, series relay *C*, break-springs relay *E*, rotary magnets, side-switch wiper in second position, to negative battery.

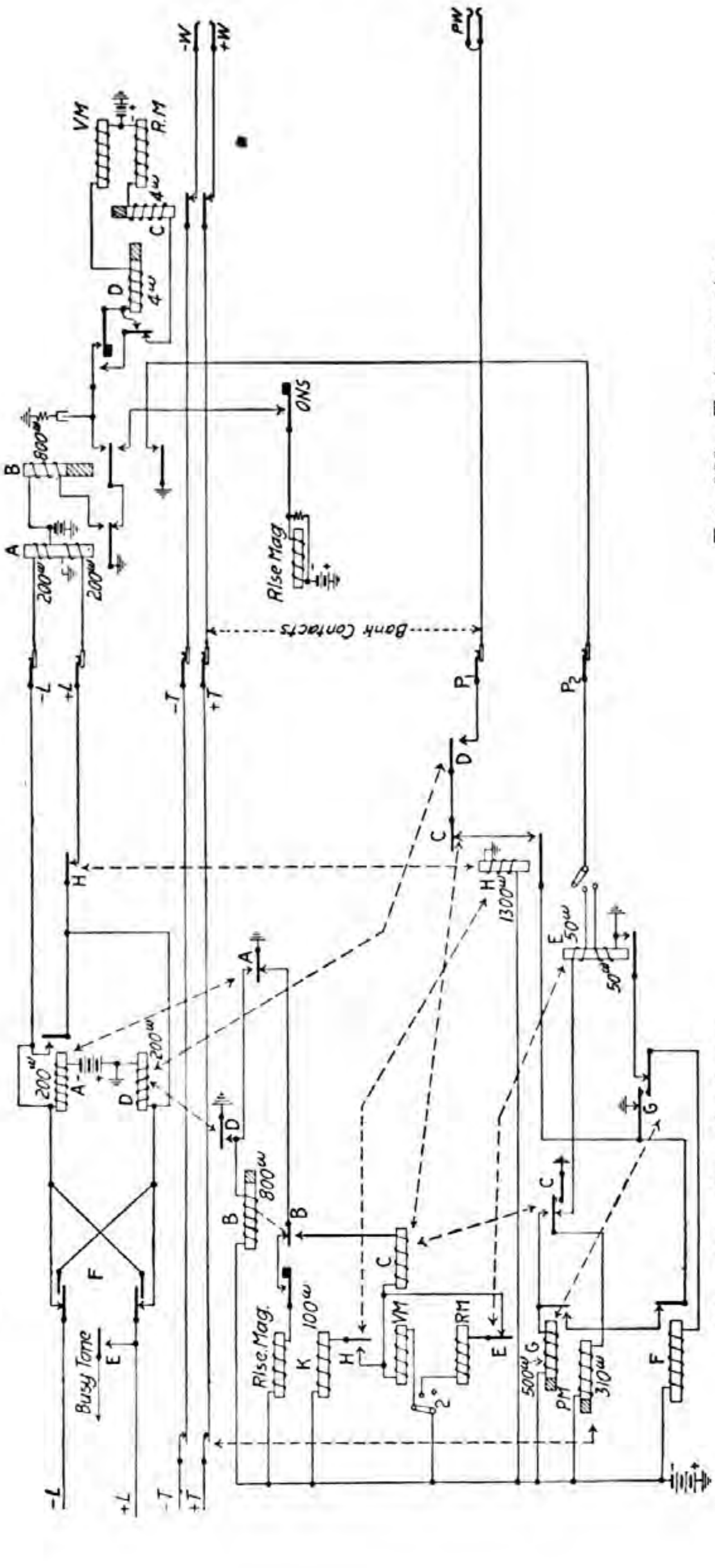



FIG. 295.—Test connector.

FIG. 294.—Test distributor.

The rotary magnets will energize over this circuit and will operate to rotate the shaft and wipers into engagement with the bank contacts associated with test connector number 67. The series relay will operate as before to close the circuit of the private magnet. After cessation of the rotary impulses the series relay will de-energize and open the circuit of the private magnet. If the test connector in board 67 is idle the private magnet *P* will now de-energize and allow the side switch to pass to third position.

When the side switch passes to third position a circuit may be traced from ground, relay *H*, side-switch wiper in third position, to negative battery. When relay *H* energizes, a circuit may be traced from ground, lower-winding relay *A* (Fig. 295), make springs relay *H*, make springs relay *A*, upper-winding relay *A*, to negative battery. Relay *A* will energize over this circuit and will hold the test connector in readiness to receive the impulses which will be sent it by the line relay of the test distributer. When the tester dials the next figure, an eight for example, the line relay of the test distributer will momentarily de-energize eight times, each time a circuit will be closed from ground, break-spring relay *A*, make springs relay *B*, series relay *C*, make springs relay *H*, resistance *K*, to negative battery. Each time relay *A* drops back the circuit of relay *A* (Fig. 295) is opened. Each time relay *A* (Fig. 295) de-energizes a circuit may be traced from ground, break-springs relay *A*, make springs relay *B*, off-normal springs (at normal), series relay *D*, vertical magnet, to negative battery. The vertical magnet will energize over this circuit and will operate to raise the shaft and wipers to a position opposite the eighth level of bank contacts. The series relay *D* will energize at the first vertical impulse, and will form a new circuit for the vertical magnet which which may be traced from ground, break-springs relay *A*, make springs relay *B*, off-normal springs (now operated), make springs relay *D*, relay *D*, vertical magnet, to negative battery. Following the cessation of the vertical impulses the relay *D* will de-energize and cannot again be energized because its circuit is now open at the break contact of the off-normal springs.

When the tester calls the next figure, a nine for example, the line relay of the test distributer will operate as before to repeat the impulses to the line relay of the test connector. Each time the line relay *A* (Fig. 295) de-energizes a circuit may be traced from ground, break-springs relay *A*, make springs relay *B*, off-normal springs, break-springs relay *D*, relay *C*, rotary magnet, to negative battery. The rotary magnet will energize over this circuit and operate to rotate the shaft and wipers into engagement with the bank contacts associated with telephone number 6789.

It will be seen that the test wipers of the test connector are held open during the rotary movement by the springs of relay *C*. During the rotary motion the private wiper of the test connector is held open at the springs of relay *C* (Fig. 294). Shortly after the last figure is called the relay *C* will de-energize, and a circuit may now be traced from ground break-springs relay *G*, make springs relay *H*, break-springs relay *C*, make springs relay *D*, private wiper of the test connector, *B.C.O.* winding of the called line switch, to negative battery. The *B.C.O.* winding will energize and operate to clear the called line of attachments. We now have a clear circuit from the called line, through the test connector and test distributer, to the test circuit on the wire chief's desk.

The tester may now restore the calling device key *L* to normal; its springs are adjusted to "make before break," and therefore the circuit will still be held up through relay *T*.

If the tester operates the *B.C.O.* key a shunt will be placed around relay *D*. (See Fig. 294a.) Relay *D* upon de-energizing, will open the circuit of the *B.C.O.* of the called lineswitch, thus causing the line relay of the called lineswitch to be bridged across the line. As a result the tester can now make an "in test."

If the tester desires to release only the test connector he operates the release-connector key, which by means of its make before break springs places coil *F* in the circuit in place of relay *A* (Fig. 294a). Relay *A*, upon de-energizing, opens the circuit of relay *A* (Fig. 295b). The test connector will now release following the de-energization of its line relay. The tester can now operate his dial to call any number to which this test connector has access. If the tester so desires he can advance the test connector across the level, one step at a time, by simply calling the figure one on his dial.

Let us assume that the test connector in the 67 board is busy; the test distributer will now pick up ground on the associated private-bank contract and as the series relay *C* de-energizes after the last rotary impulse a circuit may be traced from this ground, side-switch wiper in second position, upper-winding relay *E*, break-springs relay *C*, private magnet *P*, to negative battery. The private magnet will remain energized over this circuit, and will therefore hold the side-switch wipers in scond position. The relay *E* will energize over the above traced circuit and place the busy tone on the operating line to indicate to the tester that the called test connector is in a busy condition. The busy relay also opens the circuit to the rotary magnet so that a further rotation of the switch is impossible. Let us assume that the tester leaves the connection up and waits for the test connector to become idle. As soon as ground is removed from the private-bank contact the private magnet *P* and the busy relay *E* will de-energize. When the private magnet de-energizes the side switch passes to third position and relay *H* energizes and closes the operating circuit to the test connector. In order to allow the test connector to fully release before its operating circuit is again closed the private magnet *P* is made slow acting. The de-energization of relay *E* caused the busy tone to be removed from the line and the tester now proceeds to complete the connection.

If the called line is busy a circuit may be traced from ground at the associated private-bank contact, private wiper of the test connector, private wiper of the test distributor, make springs relay *D*, break-springs relay *C*, make springs relay *H*, make springs relay *G*, relay *F* to negative battery. The relay *F* will energize over this circuit and will cause the polarity of the calling line to be reversed; as a result relay *T* (Fig. 293) will now operate and light the lamp *A* as an indication to the tester that the called line is busy. The relay *G* will not de-energize following the release of the series relay *C* but will be locked up over a circuit that may be traced from ground at the busy private-bank contact, make springs relay *D*, break-springs relay *C*, make springs relay *H*, make springs relay *F*, make springs relay *G*, relay *G*, to negative battery. When the called line becomes idle the protecting ground is removed and as a result relay *F* and relay *G* will de-energize. When relay *F* de-energizes the polarity of the calling line will be returned to normal; relay *T* will now de-energize and extinguish the light *A* as an indication to the tester that the called line has become idle. When relay *G* de-energizes it places ground on the circuit leading to the *B.C.O.* of the called lineswitch. Relay *G*, being a slow-acting relay, will allow a certain interval to elapse between the removal of the protecting ground, and the second grounding of this circuit. This interval is required in order that the called lineswitch may have sufficient time to remove its plunger from the bank before its *B.C.O.* winding is again energized.

If the tester desires to leave this line up on test he operates the hold key and restores the test-distributer key *K*. The hold key causes a short to be placed across the operating line to hold up the connection, and at the same time relay *H* is bridged across the line under test. If the subscriber should remove his receiver he would draw battery through relay *H*, which would then energize and light lamp *B* as an indication to the tester that the subscriber had come in on the line.

After the test is completed the restoration of all keys will cause the circuit of line relay *A* (Fig. 294) to be opened. When relay *A* de-energizes it opens the circuit of release relay *B*, following which the test distributor releases in the usual manner. The de-energization of relay *A* also opens the circuit of line relay *A* (Fig. 295), following which the release of the test connector takes place.

**Information and Complaint 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, butat 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 desks. 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.

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. 296. 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 clerk 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. 296, 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 clerk 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 as long as the subscriber remains on the trunk these holding lamps will glow to prevent the call from being forgotten.

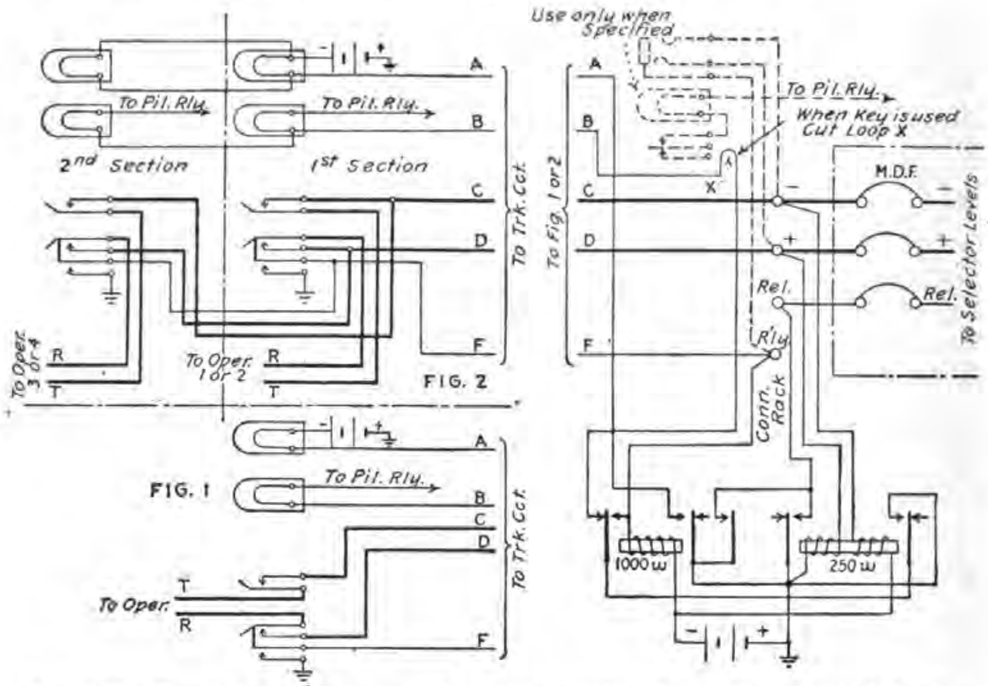



FIG. 296.—Trunk incoming to an information position from selector switch banks.

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. 296.

**Dead-number Trunks.**—These trunks are used to connect the connector bank contacts, coresponding 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

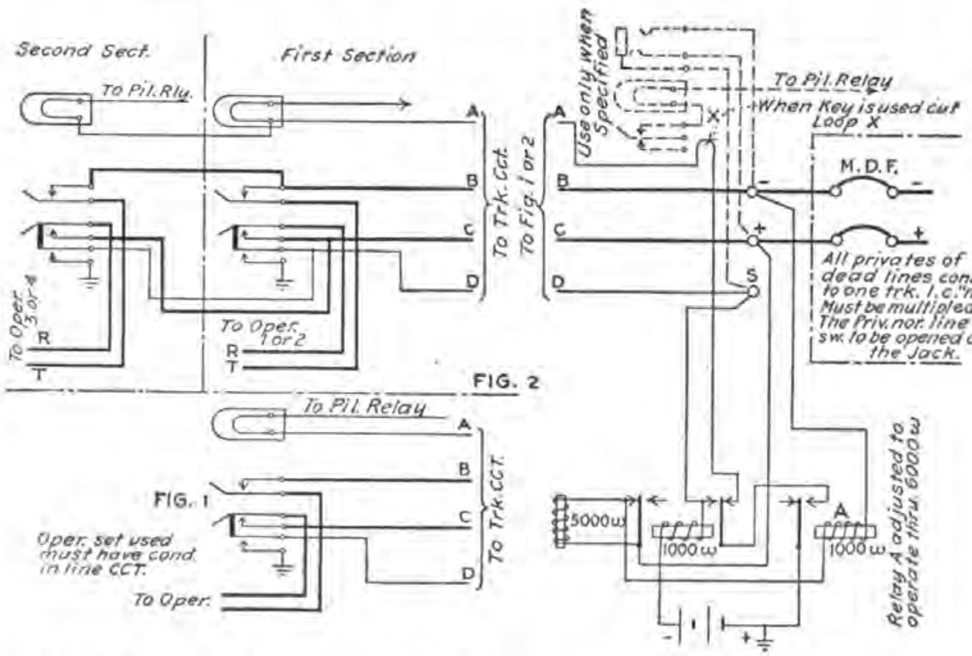



FIG. 297.—Trunk for connecting dead lines or numbers to an information position.

removed telephone 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. 297. 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 multiplying 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

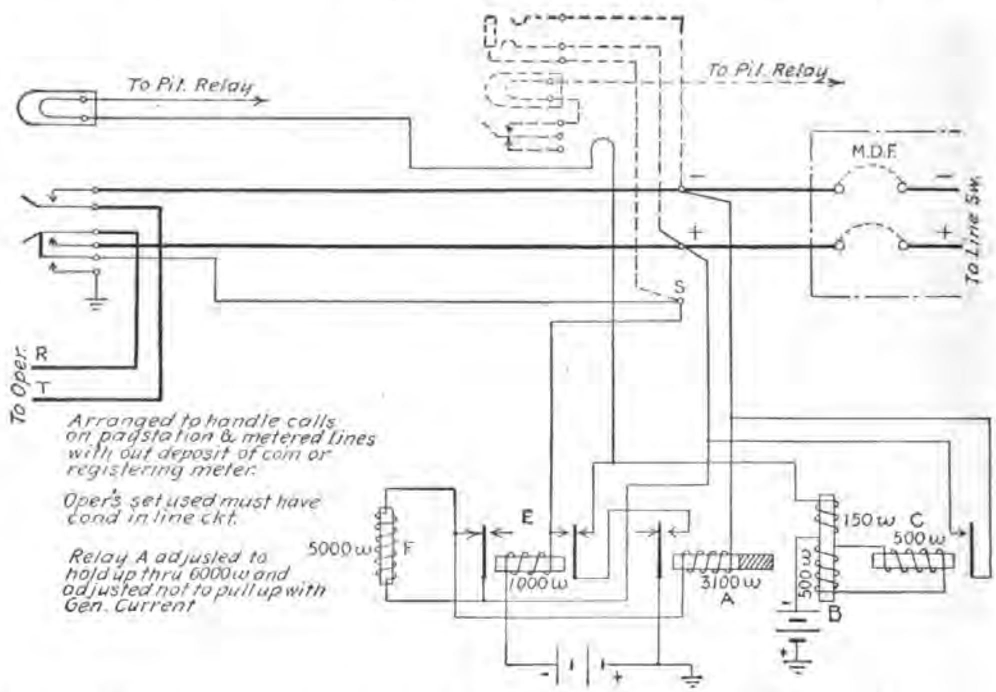



FIG. 298.—Dead number trunk circuit for use in an exchange having metered lines or sub-station coin collectors actuated by "reversing battery" connector switches.

paystation 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.

Another type of dead-number trunk circuit is that shown in Fig. 298, 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 clerk on a dead-number trunk without having the call registered.

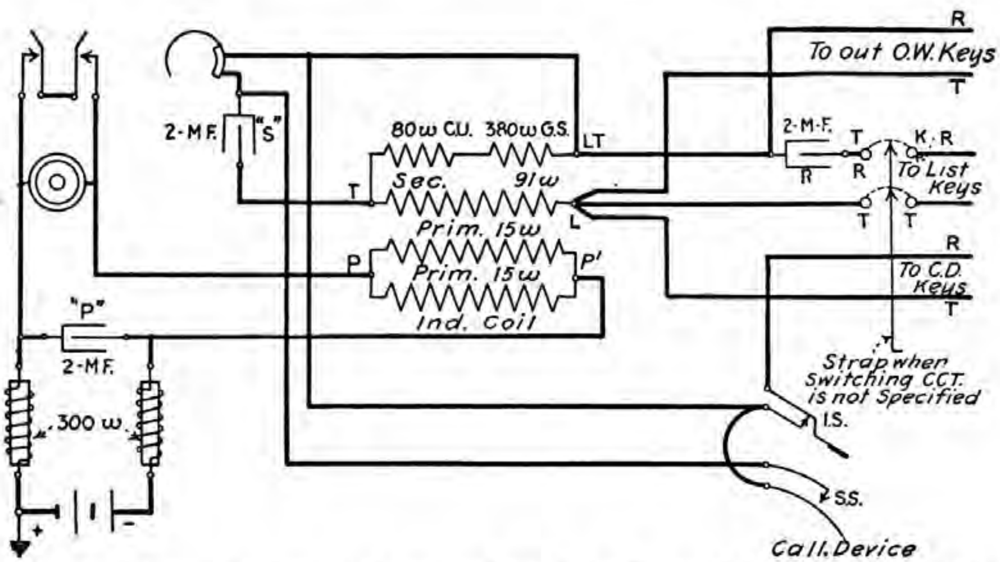



FIG. 299.—Operator's circuit, including calling device, for an information or complaint desk.

**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. 296 and described in the preceding paragraphs.

**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. 299. 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 lineswitch on the automatic switchboard for use by

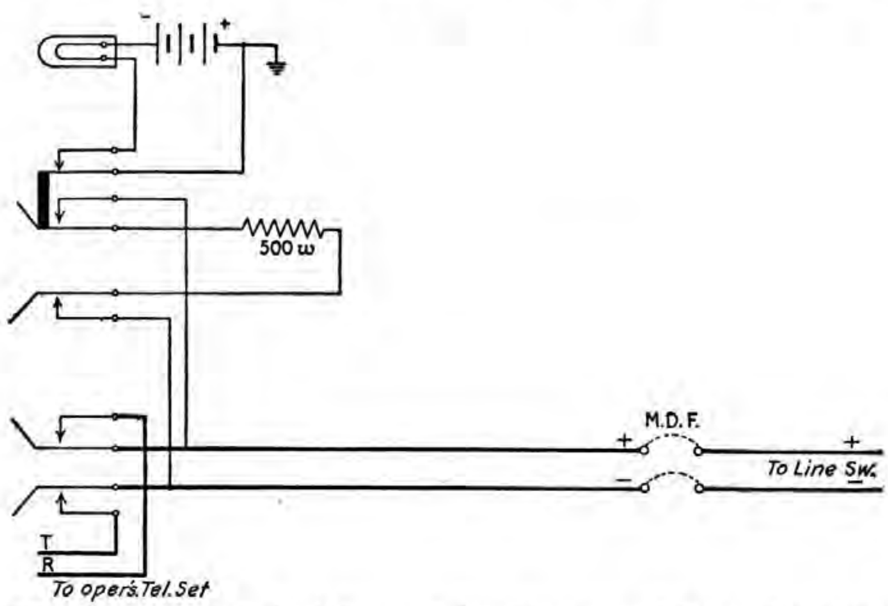



FIG. 300.—Outgoing trunk circuit from an information or complaint position to an automatic switchboard.

an information clerk in calling subscribers, by means of the calling device installed in her position, is shown in Fig. 300. To make a call the clerk 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 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 the line, the automatic switches used instantly release.

## CHAPTER XVI

## TRAFFIC

A knowledge of the amount of traffic in a telephone exchange and its distribution with respect to time and destination, is essential, to be able to provide central office equipment which is adequate for the subscriber's needs.

In the planning of an exchange it is important that the network be so designed as to accommodate the anticipated traffic demands on an economic basis, since in no other industry is there found such a heavy plant investment for the relatively short period of its useful service.

From the standpoint of the subscriber, telephone service does not measure up to its fullest efficiency unless facilities are available for completing his connection whenever desired. On the other hand, to provide the necessary equipment to take care of all emergencies and traffic demands not anticipated, would require an investment that would entail such high charges for service as to defeat its own purpose. For good commercial telephone service, therefore, we are chiefly interested in knowing how much switching equipment to provide so that not more than a certain number of calls, say an average of 1 to 100, or 1 to 1000 will be lost.

**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.

**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 $\frac{1}{8}$ (but varies from $\frac{1}{6}$ to $\frac{1}{12}$) of the day's total business. (See Fig. 301.)

**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 bus bar, in series with which is a $\frac{1}{2}$-ohm

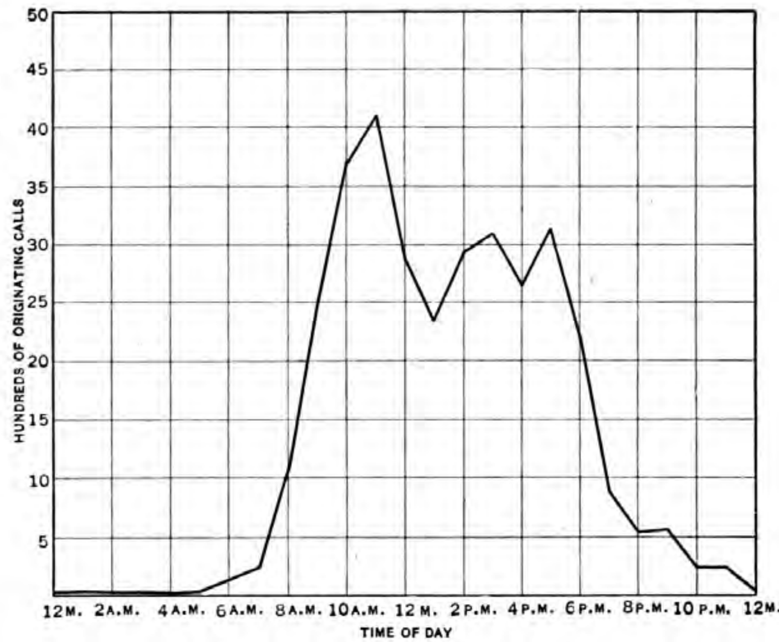



FIG. 301.—Typical load curve of a central office for a 24-hour period.

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.

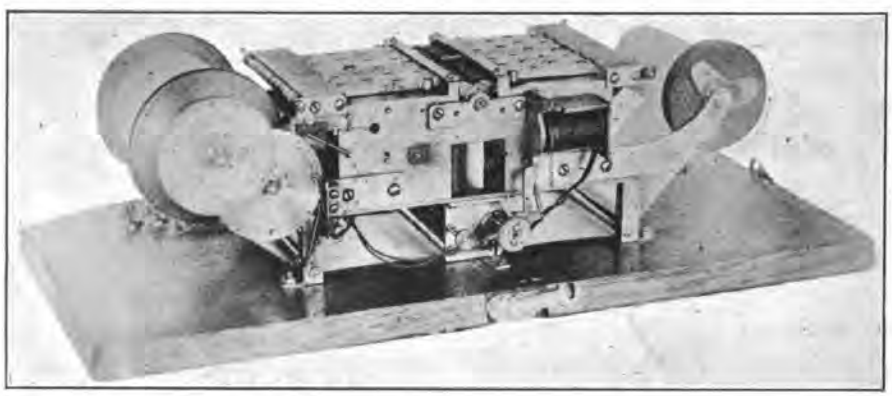


FIG. 302.—Traffic recording machine.

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.

In the proceedings of the American Institute of Electrical Engineers Mr. W. Lee Campbell describes the traffic-recording machine (Fig. 302) which he used to obtain much traffic data. Forty styluses in the center make records on a broad tape which passes from the roll at the right to the clock-driven roll at the left. Each stylus is connected by a relay to the release trunk of a group of trunks which is under study. As long as a trunk is occupied, the stylus for it draws a line on the paper tape. For details, the reader is referred to the paper cited.

**Average Traffic Requirements.**—Although the amount of apparatus placed on an automatic switchboard is the subject of much careful engineering, a general idea may be had of the customary numbers of switches placed at the disposal of hundred-line units.

With lineswitch boards equipped with Keith lineswitches, whose banks have ten points, from eight to 20 trunks are usually provided. The latter is secured by dividing the lineswitches into two groups of 50 each. In some extreme cases of party-line boards it has been necessary to give them 40 trunks, by dividing the lineswitches into four groups of 25 each, but naturally the efficiency of the trunks is low.

Rotary lineswitch boards have 25 trunks in a group. Individual line boards may be arranged from 200 to 500 lines per group of 25 trunks. Two-party line boards will run from 300 to 400 lines per group. Four-party line boards may have 200 to 300 lines per group of 25 trunks.

The arrangement of selectors other than firsts is calculated according to principles which will be explained in detail later in this chapter.

Connectors are furnished for lineswitch boards approximately according to the following table:

| | Average installed | Ultimate | |
|---|---|---|---|
| | | Keith | Rotary |
| Individual lines | 10 | 12 | 16 |
| Two-party lines | 10 to 12 | 18 | 16 |
| Four-party lines | 20 to 24 | 28 | 32 |

In each case, one of the connectors is a test connector, not available for public traffic.

## 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 slightly to smooth out the trunk load curve.

Automatic subscribers attain a similar storage, because if a user finds that he can not get through to his destination, he hangs up and dials again. Very often the second time he finds the trunk group with an opening.

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 50 lineswitches, 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:

| 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 |

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 a number equal to not more than 3½ per cent of subscribers lines would be required in the average office.

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 lineswitches, 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. 303 in which curves *A* show the ratio, in per cent, between the number of trunks in use and

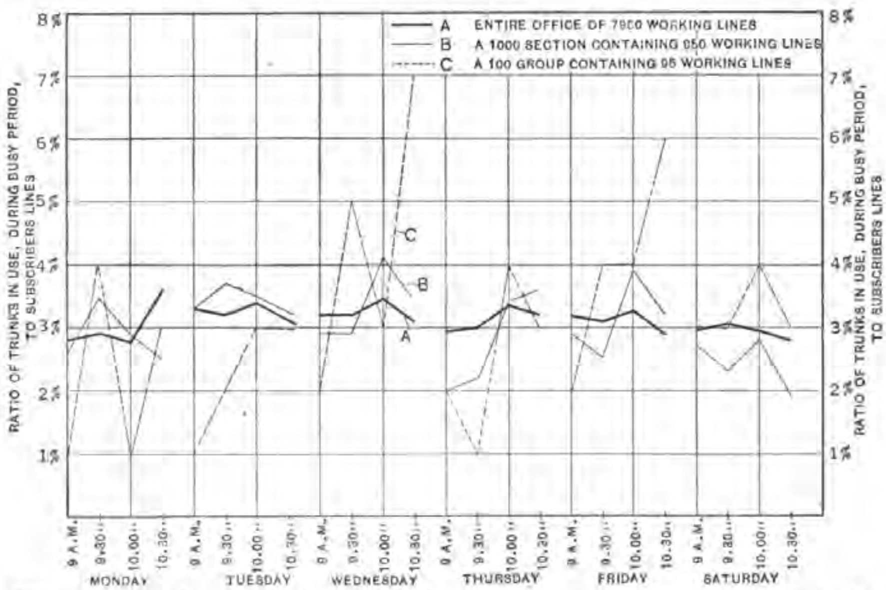



FIG. 303.—Curves showing ratios of trunks in use to subscriber lines during the busy hour of each day of a week.

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.

The curves *B* in this figure show the ratios at the same time for a 1000 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 384 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 or else the subscriber must hang up and dial again.

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 necesary.

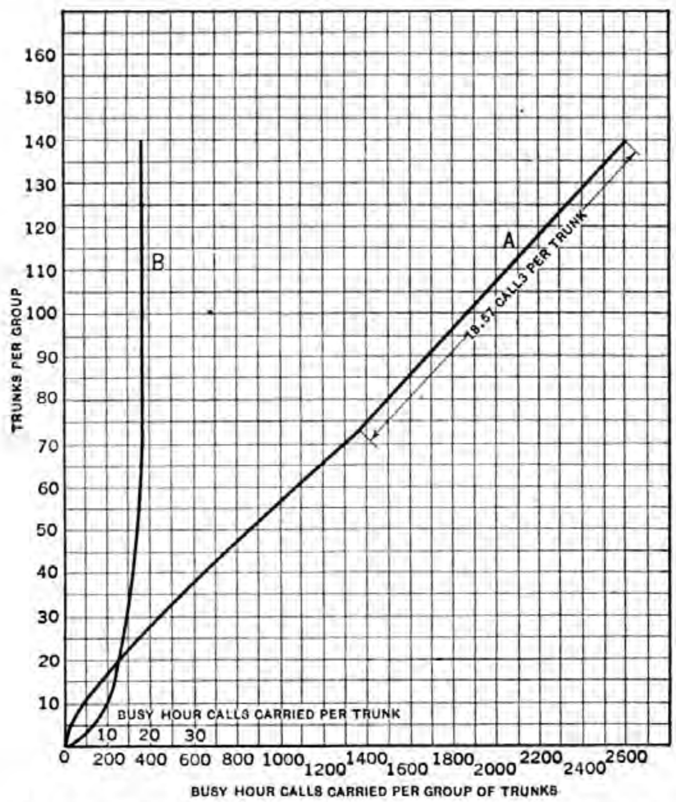



FIG. 304.—Curve *A* shows call-carrying capacities of trunk groups of various sizes, manual central offices; average trunk holding time of 120 seconds. Curve *B* shows call-carrying capacity of each trunk in groups of various sizes.

*Trunking Formulæ.*—Curve *A* Fig. 304 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 15 or 18 calls during the busy hour even between large, well-managed manual offices, while between smaller offices from 10 to 12 is all that can be expected.

Reference to Fig. 305 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

$$\text{Trunks} = CT + 3.7\,\sqrt[3]{TC}.$$

A review of various articles published in recent years brings out the following facts:

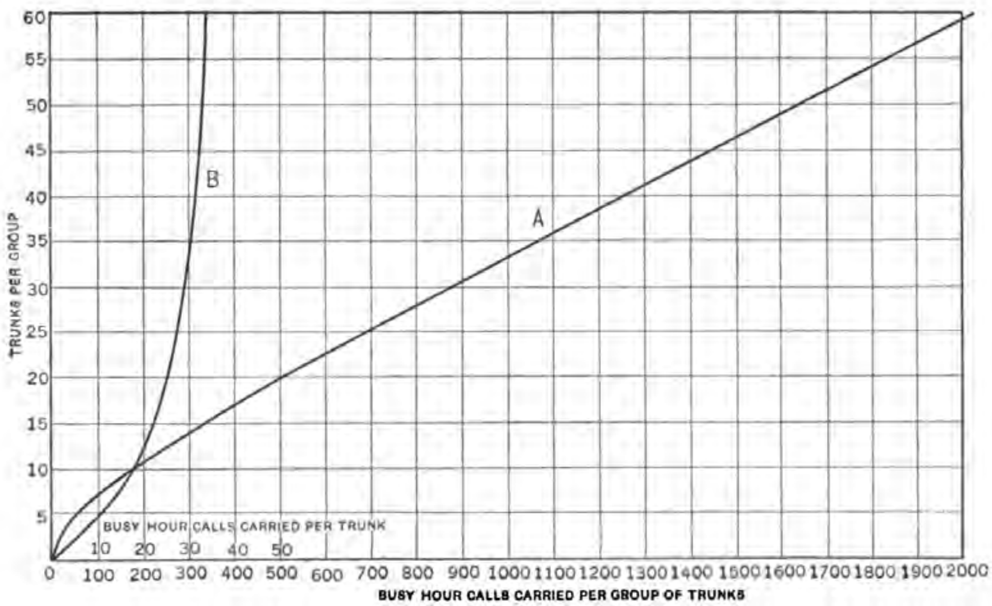



FIG. 305.—Curve *A* shows call-carrying capacities of trunk groups of various sizes between automatic central offices; average trunk holding time of 83 seconds. Curve *B* shows call-carrying capacity of each trunk in groups of various sizes.

First: That a fairly fixed relation exists between the number of busy-hour calls of a given duration, and the maximum number of simultaneous calls during the busy hour.

Second: That within the limits of holding times as ordinarily encountered in telephone practice, the preceding relation holds true regardless of the number of busy-hour calls and the average holding time, so long as the product of these two factors remains constant.

Third: That the average calling rate of a large group of subscribers usually differs somewhat from the average calling rate of a small part of that group.

While all of the methods described in the various articles are very interesting, since the ultimate results as shown in the chart (Fig. 306) do not differ materially, it will not be necessary here to go into details regarding the derivation of the curves, but use will be made of the results only.

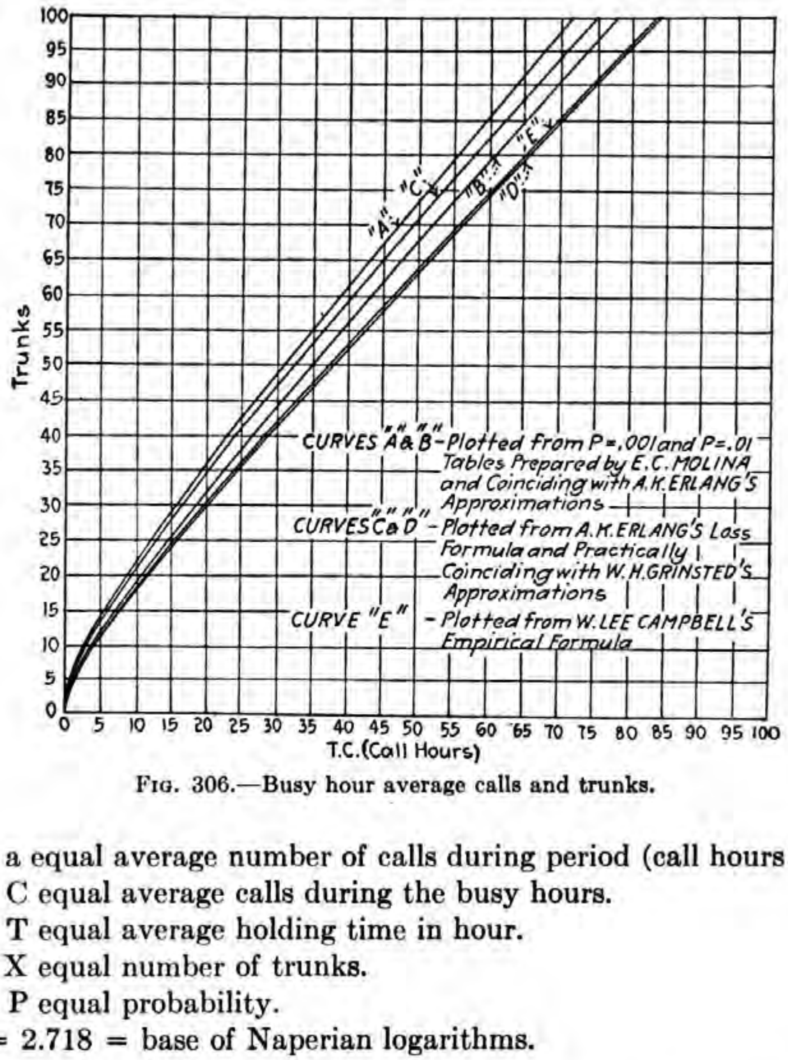



FIG. 306.—Busy hour average calls and trunks.

Let a equal average number of calls during period (call hours TC).
C equal average calls during the busy hours.
T equal average holding time in hour.
X equal number of trunks.
P equal probability.
C = 2.718 = base of Naperian logarithms.

Campbell's empirical formula $X = TC + 2.8 \sqrt[3]{TC}$, later changed to $X = TC + 3.7 \sqrt[3]{(TC)}$, was derived from observations of calls handled by groups of 40 or less trunks. If $X = 10$, the traffic indicated by this formula would be carried with a probability of loss of 1 call in 100. In the practical application of this formula to larger groups, certain percentages have been added that have not been taken into account by the various commentators. In curve E this formula is plotted without the percentage factor.

The probability that in a certain interval there will be various numbers of simultaneous calls may be represented as follows:

$$0 \text{ calls} = P_0 = \frac{1}{(1 + a + \frac{a^2}{2!} + \frac{a^3}{3!} + \dots\dots\dots\dots \infty)} = e^{-a}$$

$$1 \text{ call} = P_1 = \frac{a}{(1 + a + \frac{a^2}{2!} + \frac{a^3}{3!} + \dots\dots\dots\dots \infty)} = ae^{-a}$$

$$2 \text{ calls} = P_2 = \frac{\frac{a^2}{2!}}{(1 + a + \frac{a^2}{2!} + \frac{a^3}{3!} + \dots\dots\dots\dots \infty)} = \frac{a^2e^{-a}}{2!}$$

$$X \text{ calls} = P_x = \frac{\frac{a^x}{X!}}{(1 + a + \frac{a^2}{2!} + \frac{a^3}{3!} + \dots\dots\dots\dots \infty)} = \frac{a^xe^{-a}}{X!}$$

$$X \text{ or more calls} = P_{x+} = e^{-a}\left\{\frac{a^x}{X!} + \frac{a^{x+1}}{(X+1)!} + \frac{a^{x+2}}{(X+2)!}\right\}$$

$$\text{More than } X \text{ calls} = P_{(x+1)+} = e^{-a}\left\{\frac{a^{x+1}}{(+1)!} + \frac{a^{x+2}}{(X+2)!}\right\}$$

The probability that in certain intervals there will be X calls in progress in a group limited to X outlets, is expressed by

$$P_{LX} = \frac{\frac{a^x}{X!}}{\left\{1 + a + \frac{a^2}{2!} + \frac{a^3}{3!} + \dots\dots\dots \frac{a^x}{X!}\right\}}$$

This latter expression more nearly represents a theoretical measure of the lost calls, while the expression for Px above is a very accurate approximation and lends itself to ready calculation. This is shown as curves C and D in Fig. 306.

The results for the expression Px + are in more general use, and while perhaps not theoretically representing a measure of the lost calls, in providing slightly more equipment for a given amount of traffic, the error is on the safe side. This is shown in curves A and B (Fig. 306), and tabulated in Table A.

For our purpose the values of curves A and B shown on the chart and in Table A will be used. These values have been taken from the table appearing in an article by Mr. Molina, of the American Telephone and Telegraph Company, published in the **American Mathematical Monthly** of June 1913.

TABLE A

| TRUNKS | P = .001 TC | P = .01 TC |
|---|---|---|
| 1 | 0.0010 | 0.010 |
| 2 | 0.0454 | 0.149 |
| 3 | 0.191 | 0.436 |
| 4 | 0.429 | 0.823 |
| 5 | 0.739 | 1.28 |
| 6 | 1.11 | 1.79 |
| 7 | 1.52 | 2.33 |
| 8 | 1.97 | 2.91 |
| 9 | 2.45 | 3.51 |
| 10 | 2.96 | 4.13 |
| 12 | 4.04 | 5.43 |
| 14 | 5.20 | 6.78 |
| 16 | 6.41 | 8.18 |
| 18 | 7.66 | 9.62 |
| 20 | 8.96 | 11.1 |
| 30 | 15.9 | 18.7 |
| 40 | 23.3 | 26.8 |
| 60 | 38.9 | 43.5 |
| 80 | 55.2 | 60.7 |
| 100 | 71.9 | 78.2 |
| 140 | 106.3 | 114.0 |
| 180 | 141.4 | 150.3 |
| 200 | 159.0 | 169.0 |
| 300 | 249.0 | 261.0 |
| 400 | 341.0 | 355.0 |
| 500 | 434.0 | 450.0 |
| 600 | 527.0 | 545.0 |
| 700 | 621.0 | 640.0 |
| 800 | 715.0 | 736.0 |
| 900 | 810.0 | 832.0 |
| 1000 | 905.0 | 928.0 |

**Arrangement of Multiple.**—If a trunk searching element is limited to 10 outlets, the amount of traffic handled is independent of the order of selection, assuming the selection to be instantaneous, as is practically the case. That is, if 10 outlets are available say, to 100 selectors, it is immaterial whether the outlets are tested in regular rotation beginning with the first one each time, or whether they are arranged so that the first 10 selectors will begin by testing the first outlet, the second 10 by first testing the second outlet and finishing with the first, the third by first testing the third outlet and finishing with the second, etc. The first arrangement, however, would not be used because of the excessive wear on the switch connected to the first trunk and the excessive amount of rotation on each of the hundred first selectors, since if the traffic indicated an average of 4.13 simultaneous calls, it would mean that half the calls would be extended to the first four trunks, and for the remaining half the switches would rotate over at least four contacts, to find one of the six remaining trunks.

Table B shows the amount of traffic handled per trunk in a group of ten when the trunks are selected in regular rotation beginning from the first. These figures were derived from the 1 in 100 column of Table A by subtracting adjacent values.

Table B

| Order of Selection | Traffic per Trunk | Summation of Traffic |
|---|---|---|
| 1 | 0.62 | 0.62 |
| 2 | 0.60 | 1.22 |
| 3 | 0.58 | 1.80 |
| 4 | 0.54 | 2.34 |
| 5 | 0.51 | 2.85 |
| 6 | 0.457 | 3.307 |
| 7 | 0.387 | 3.694 |
| 8 | 0.287 | 3.981 |
| 9 | 0.139 | 4.120 |
| 10 | 0.01 | 4.13 |

From the foregoing table we can determine the probable traffic-carrying capacity of a group of trunks with various methods of bank multiplying. Consider case 1, Fig. 307, where the first five trunks in each group would handle 2.85 TC and the common group would handle 1.28 TC or a total of 6.98 TC. This is capacity greater than that of either a group of 10 and a group of 5, or 1.5 groups of 10, but not as great as that of a group of 15. Advantage is not taken of this increased capacity in the direct computation, which in this case would be 1.5 groups of 10, but the arrangement is used to provide an additional margin of about 12½ per cent to care for unforeseen variations.

In case 2, having three individual groups of 5, and a common group of 5, the 20 trunks would carry 9.83 TC or about 20 per cent more than two groups of ten. In case 3, the 30 trunks would handle 14.725 TC or about 19 per cent more than three groups of 10. In case 4, in a similar manner it may be computed that the 20 trunks would handle 9.83 TC or about 20 per cent more traffic than two groups of 10.

## CALCULATION OF AUTOMATIC EQUIPMENT

The following description shows how the traffic data are used to compute the quantities and distribution of the various elements of switching equipment in a Strowger automatic exchange.

**Primary Lineswitches.**—Since there is a lineswitch associated with each subscriber's line, the number of working primary lineswitches is determined from the number of working lines.

When a subscriber's intermediate distributing frame is interposed between the lineswitches and the connector banks, so that any lineswitch can be cross connected to any terminal number, it is necessary, due to circuit requirements, to group the primary lineswitches in classes for the following services: Flat Rate, Message Rate, and Pay Station Rate. On the other hand, if an intermediate frame is not used and the lineswitches are permanently connected to the terminal numbers, then the flat rate group must be further subdivided into individual lines, party line and *P.B.X.* groups, and the message rate group must also be subdivided into individual line and *P.B.X.* groups.

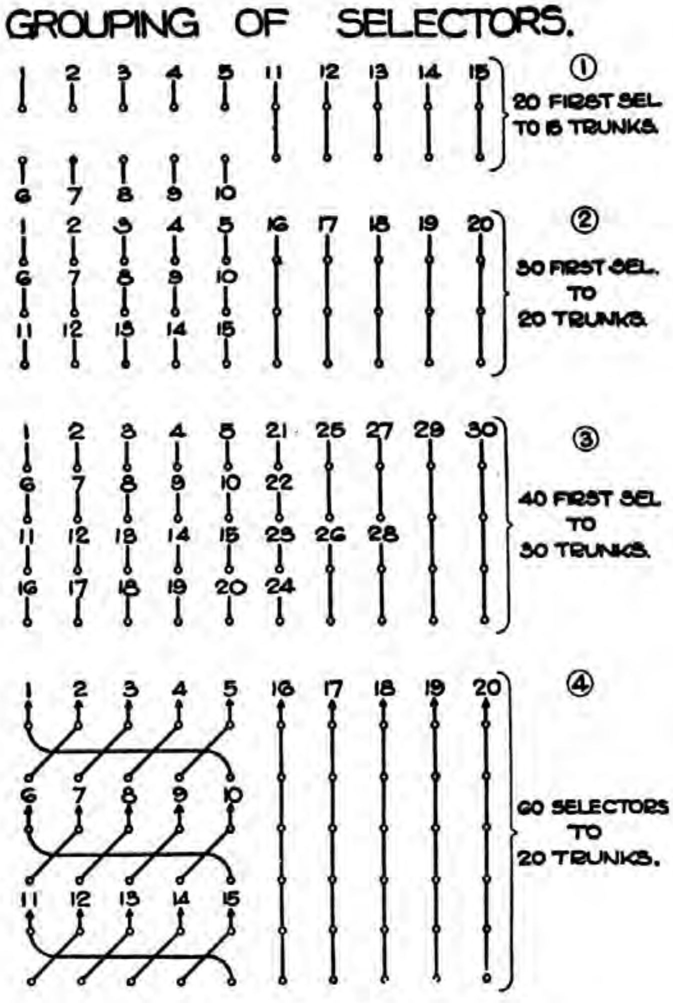



Fig. 307.

In either case in grouping the lineswitches for the various classes of service, precautions must be taken so that the pay station lines and message rate lines do not have access to the same first selector switches; otherwise, under certain conditions, there would be premature registration of meters on message rate lines, due to the circuit requirements of pre-payment pay station service.

The number of primary lineswitches provided for the initial period for each class of service is usually 5 per cent greater than the number of working lines and the number of terminals (connector numbers) is usually 10 per cent greater than the number of working lines.

**Grouping of Primary Lineswitches.**—It is recognized that the average calling rate per line for a certain class of service is based on the originating traffic on a thousand or more lines, the calling rate for any small groups, such as 25, 50, 75 or 100 lines, will vary from this average rate. However, if the average calling rate is based on a smaller number of lines, there will be little or no variation when considering small groups. Table C shows the percentage variation that can be allowed for the various small groups at different calling rates:

TABLE C.—AVERAGE CALLING RATE PER LINE

| SIZE GROUP | LESS THAN 0.8 | 0.8 TO 1.3 | 1.3 TO 2. | MORE THAN 2. |
|---|---|---|---|---|
| 25 | 70 | 60 | 50 | 40 |
| 50 | 50 | 44 | 37 | 30 |
| 75 | 40 | 35 | 30 | 25 |
| 100 | 35 | 30 | 25 | 20 |

Assuming that the number of lineswitches is 5 per cent greater than the number of working lines, Table D indicates the proper grouping of plunger type lineswitches per master switch, for various calling rates and with a holding time of 120 seconds.

TABLE D

| Primary lineswitches per group | 100 | | 75 | | 50 | | 25 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Calling rate per working line | 0.85 | 1.0 | 1.1 | 1.28 | 1.61 | 1.89 | 2.1 | 2.63 | 3.16 | 3.72 |
| Calling rate per equipped line | 0.81 | 0.957 | 1.04 | 1.22 | 1.53 | 1.8 | 2.0 | 2.5 | 3.0 | 3.54 |
| Trunks per group.......... | 0.9 | 10.0 | 9.0 | 10.0 | 9.0 | 10.0 | 7.0 | 8.0 | 9.0 | 10.0 |

Ordinarily the average traffic would not be so great as to necessitate groups of less than fifty lines per master switch, except in unusual cases, such as where *P.B.X.* trunks or other flat rate lines are grouped together. In this case the lines of heavy traffic can be isolated and grouped 25 per master switch, thus reducing the average calling rate of the remaining lines.

If local secondary lineswitches are not used, the number of first selectors would correspond to the number of equipped outlets from the primary lineswitches as explained in the previous paragraphs.

**First Selectors (with Secondary Lineswitches).**—When each of the 10 trunks from each primary sub-group loads to a secondary lineswitch, which in turn has 10 outlets of first selectors, then each primary lineswitch will have access to 100 first selectors, and these 100 first selectors function as one group. As explained in the following section, a group of 100 outlets reached through secondaries is not fully as efficient as if reached direct. The 100 first selectors may, however, be considered as having the effectiveness of a group of 85. If we consider that first selectors are sometimes held busy by line "shorts" or "grounds" or by subscribers unwittingly leaving their receivers down, it becomes necessary to allow for some margin, and this margin is obtained by using the 1 in 1000 probability.

From Table A it can be determined that a group of 85 trunks will handle 59.4 TC (call hours) with a probability of loss of 1 in 1000. Therefore, 100 first selectors reached through secondaries can be considered to carry safely 59.4 TC and under certain conditions it has been considered that satisfactory service could be given on the basis of 100 first selectors carrying 75 TC. On the basis of 100 first selectors carrying 59.4 TC the efficiency of the switches would be 59.4 per cent and the average occupancy per switch would be 0.594.

**Local Secondary Lineswitches.**—Experience has shown that good service can be given on the assumption that not more than 85 switches are ever in use simultaneously.

In order to minimize the difficulty of unavailable trunks from primary switches it is necessary to distribute the traffic evenly among the secondary sub-groups, and the following three methods are practiced to contribute toward this end:

*First*: A special scheme of cross connection between primaries and secondaries so that whenever there is a tendency for the primaries to build up before a certain sub-group, the next call attempted will break up the combination.

*Second*: The "step-off" relay on each secondary sub-group is so arranged that when this secondary sub-group has a predetermined number of calls in progress on successive trunks, all of the primary switches which had pre-selected trunks to this secondary section are stepped off to another sub-group.

*Third*: When a secondary sub-group has all trunks busy, all of the primary master switches associated with that entire secondary group, are caused to operate momentarily. This aligns all of the disengaged primary lineswitches on the shaft, and re-groups the primary preselections.

If, from each primary sub-group, only 8 outlets are equipped, even though 10 secondary sub-groups are used to carry the traffic to 100 first selectors, there would not be a theoretic group of 100 but rather one and one-fourth times a theoretic group of 80. However, there is so little difference between the two that a theoretic group of 100 can be considered as correct.

To compute the number of secondary lineswitches to a group of 10 sub-groups, we must first determine the number of primary sub-groups required to load the group. Consider that 100 first selectors reached through secondaries will handle 59.4 TC. The number of primary sub-groups to be placed in one group may be computed by dividing this by the average traffic offered per primary sub-group represented by nTC (n being the number of working lines in the primary sub-group, C being the number of calls per line, and T being the holding time in hours). If the result is a mixed number, then only as many primary sub-groups should be grouped together as are represented by the whole number, unless it is known that there are margins in the original data, which would permit using the next larger whole number. After this has been determined the average occupancy of the first selectors should be determined on the basis of actual traffic handled, which will usually be somewhere near 59.4 TC.

**Rotary Secondary Lineswitches.**—If rotary type secondaries are used, each group is made up of 10 sub-groups having 25 outlets, providing a theoretic group of 250 outlets or an effective group of $0.85 \times 250$ or 212.5. If a theoretic group of 250 is too large, by using less than 25 outlets, various smaller theoretic groups, such as 240, 220, or 200 may be obtained.

The number of primary sub-groups required to furnish traffic for a secondary group is determined much as in the case of plunger type secondaries. A theoretic group of 250 trunks or an effective group of 212.5 will handle 174 TC (call hours), hence from 50 to 60 primary sub-groups will be required to keep a group of rotary secondaries busy. Present practice in mounting the secondary lineswitches prohibits the placing of more than 50 primary sub-groups to a group.

**Second Selectors.**—From the traffic data we can obtain the percentage distribution of the originating calls, and thus determine the calls that are to be handled by second selectors.

A group of 10 trunks will handle 4.13 TC with a probability of loss of 1 in 100. Dividing the total number of call hours to be handled by 4.13 will give the number of groups of 10 of second selectors.

When the first selectors are reached through secondary lineswitches the resulting increase in efficiency is felt beyond the first selectors. In other words, 10 second selectors should carry more traffic than 4.13 TC.

Suppose in an office that had just sufficient traffic for 200 first selectors ($TC = 2 \times 59.4$), that 70 per cent of the total traffic (83.16 TC) was local. Dividing this by 4.13 would indicate a need for slightly more than 200 second selectors. Obviously such a number of selectors is too high since it would be more than the number of first selectors. Accordingly some allowance can be made for the greater efficiency of second selectors when a relatively large percentage of the traffic is local.

It is also necessary to determine the method of multiplying the first selector banks, because sometimes the number of second selectors must be adapted to the method of multiplying.

*First Method.*—The preferred method is to determine the number of second selectors working in groups of ten, and then arrange the first selectors so that each group will have a number of second selector trunks individual, and the remainder common to two or more groups. For instance, 15 trunks from 20 first selectors may be so arranged that there will be five trunks individual to each group of 10 selectors and 5 trunks common to the entire 20. If the arrangement is such that the individual trunks are tested first, the entire group will handle 6.98 TC with a probability of loss of 1 in 100.

*Second Method.*—The other method is to determine the occupancy of the first selectors for the particular level under consideration, and group together a sufficient number of first selectors on the basis of this occupancy, to offer 4.13 TC to the second selectors. If the resultant number of first selectors is not a multiple of five, the number of first selectors is cut down and sufficient trunks are equipped to handle the traffic from such reduced group of first selectors.

**Trunks to Other Offices.**—If the trunks are taken directly from selector levels, the number of trunks is determined in practically the same manner as the number of second selectors just described. Since the trunks operate through cable pairs to other offices, it is advisable to provide some margin to allow for trunks that may be unavailable because of cable conductors being in trouble. This margin is usually provided by using 1 in 1000 probability instead of 1 in 100, or in other cases, by using the 1 in 100 table and adding a certain percentage to the resultant number of trunks.

If outgoing secondary lineswitches are used, the number of trunks in the group is determined from the 1 in 1000 probability table, on the basis of the theoretic group being only 85 per cent available as explained for first selectors. Either plunger type or rotary type lineswitches may be used for outgoing secondaries.

The number of trunks thus determined gives also the number of impulse repeaters required at the originating office, and the number of incoming second selectors in the distant office.

**Outgoing Secondary Lineswitches.**—After the number of outgoing trunks has been determined, as just outlined, then the number of secondary sub-groups can be determined on the basis of a certain number of trunks per sub-group. If the number of sub-groups is less than 10, each ten trunk group must be divided as evenly as possible among all secondary sub-groups so that there will be more than one outlet for each trunk group, leading to each secondary sub-group. This results in somewhat lowered efficiency, since if a certain secondary sub-group is momentarily or permanently busy, two or more outlets would be busy to the first selectors. In such cases the 10 trunks are considered at only 85 per cent of their theoretic efficiency, and will handle $0.85 \times 4.13$ or 3.51 TC.

The number of outgoing secondary lineswitches can be determined on the basis of 10 outlets handling 4.13 TC or 3.51 TC as the case may be, and then grouping the first selectors so that each group has a certain number of trunks individual to the group, and the remaining trunks common to two or more groups; or, as in the case of determining the number of second selectors, the occupancy of the first selectors, for the particular level under consideration is determined and the first selectors arranged in groups so as to offer 4.13 TC or 3.51 TC per group. If the resultant number of first selectors is not a multiple of five, the number of first selectors is cut down and a sufficient number of outlets are equipped to care for the traffic offered by the reduced number of first selectors.

**Third Selectors.**—The third selectors in a five-digit system are used for distributing the calls to the various hundred groups in each thousand. Third selectors working in groups of ten can handle 4.13 TC. Accordingly, the number of groups of ten required for each thousand may be computed by dividing the total amount of traffic to be handled by each level, by 4.13 TC. The second-selector banks should then be so multipled as to keep these groups of ten uniformly busy.

In case the scheme of multiplying which is used, is such that the local traffic is kept separate from the incoming traffic, because of the fact that the incoming switches may be reached through outgoing secondaries at the originating office, they will handle traffic at a different rate. Therefore, the occupancy per second selector for each level will have to be determined for both incoming and local switches, and the proper number of switches combined to supply ten trunks. The resultant grouping of second selectors should be in multiples of ten.

**Connectors.**—The number of connectors is computed by first determining the average calls terminating in each hundred and applying a percentage for variation as shown in Table C. Then if the traffic is less than 10 trunks will carry we determine from the equivalent TC value the number of connectors from the second column of Table A. If the number of calls is greater than 10 trunks will carry, then by dividing the number of calls by the number that 10 trunks will carry, the necessary number of groups of 10 may be found. The third selector multiple may then be arranged so there will be individual and common trunks. If this is not done, the number of connectors must be determined on the basis of full groups of 10 and a remaining partial group.

To take care of toll calls from toll-selector banks, combination toll and regular connectors can be provided. These should be arranged so that they are the last choice for regular calls, so as to secure maximum availability for toll calls.

**Rotary Connectors.**—The method of determining the number of these connectors is the same as for regular connectors. Due to the fact that the calling rate to *P.B.X.* rotary groups is much heavier than to regular groups, and that the calling rate given is usually the result of observation of this particular class of calls, it is not necessary to add much, if any, percentage for variation.

Combination rotary connectors are, as a rule, rather complicated and there is therefore, little economy in providing them. Accordingly, separate toll rotary connectors are provided and their number is computed in a similar manner as for local connectors.

**Summary.**—In the first method the number of trunks is determined on the basis of independent groups of ten, but the resultant number of switches is so arranged by means of overlapping multiples or common groups of trunks as to afford team work between groups. This extra-call handling capacity is used as a margin to care for possible peak and emergency traffic. This is essential if, as in this case, the busy hour originating traffic is the basis of distribution, since the peak traffic in any given direction may not coincide with the peak for the originating traffic.

In the second method, each group of trunks is independent of all other groups and is accessible only from a fixed field. There is no team work, and each group must be arranged to take care of its own peak.

A sample calculation was worked out for a four-office exchange computing the amount of equipment for one of the offices. Without going into details, for which we have not space, the equipment required is shown in the following summary, which compares the first and second methods of computing the number of selectors.

SUMMARY

| | First method | | Second method | |
|---|---|---|---|---|
| | Number | Remarks | Number | Remarks |
| Primary lineswitches | 6300 | | 6300 | |
| Secondary lineswitches | 1260 | | 1260 | |
| First selectors | 600 | | 600 | |
| Local second selectors | 360 | 30% margin | 360 | |
| Outgoing sec. L. S. to B | 300 | 30% margin | 200 | |
| Repeaters to B | 130 | 10% margin | 130 | 10% margin |
| Outgoing sec. L. S. to C | 300 | 16% margin | 300 | |
| Repeaters to C | 200 | 10% margin | 200 | 10% margin |
| Repeaters to D | 45 | 10% margin | 48 | |
| Incoming 2d sel. B | 145 | | 145 | |
| Incoming 2d sel. C | 185 | | 185 | |
| Incoming 2d sel. D | 50 | | 50 | |
| Third selectors | 850 | | 879 | |
| Non-rotary connectors | 640 | 15% margin | 640 | 8% margin |
| Combinations connectors | 256 | 15% margin | 256 | 8% margin |
| Rotary connectors | 180 | 9% margin | 222 | |
| Toll-rotary connectors | 30 | | 30 | |

**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. 308. 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, because of the comparative ease with which a connection may be reestablished.

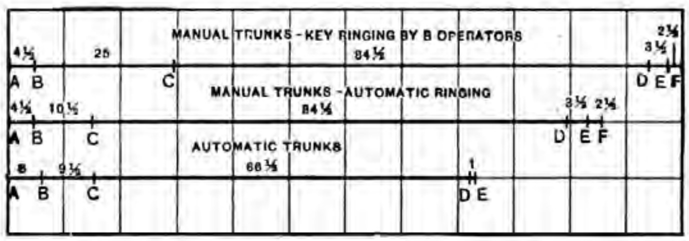



FIG. 308.—Graphical analysis of trunk holding times: $A$, is instant at which a trunk is assigned by a "$B$" operator or taken by an automatic selector switch; $B$, connection completed and ringing started; $C$, subscriber answers; $D$, Conversation completed—disconnect signals given to "$A$" operator; $E$, "$A$" operator or automatic selector disconnects from the trunk; $F$, "$B$" operator releases the trunk.

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 subscribers 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 does not wait on a "don't answer" call until an operator tells him that the wanted party does not 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. 305 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.

Formerly it was the practice to follow unvaryingly the second method, because it was known that most operating companies at that time did not wish to incur the expense of line intermediate distributing frames, which the first plan requires. It was even sometimes the practice to install a special unit to which very busy lines were transferred from an overloaded unit, without changing the subscriber's number.

Recent years have seen an increasing use of the line intermediate distributing frame, for the flexibility which it affords is appreciated.

Whether the trunks outgoing from any lineswitch unit lead to secondary lineswitches 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 lineswitch 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 lineswitch 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 sub-classes should then be distributed among the lineswitch 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 lineswitch 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 following bibliography:

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## CHAPTER XVII

## 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 15 years, the ultimate requirements are usually referred to as the requirements 15 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 15-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 15 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 15 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 15-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 15-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 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

[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.

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., party 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.

The second remedy offers more hope and is capable of much development by judicious engineering. The unattended sub-office has a large field of usefulness in the growing part of a city, where it is not certain just how thickly settled it will untimately become. If the region fails to develop beyond a certain point, then let the sub-office remain. If the real estate venture proves successful and the region becomes thickly settled, the sub-office may be converted to a main office without loss of 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. gage 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.

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 ex

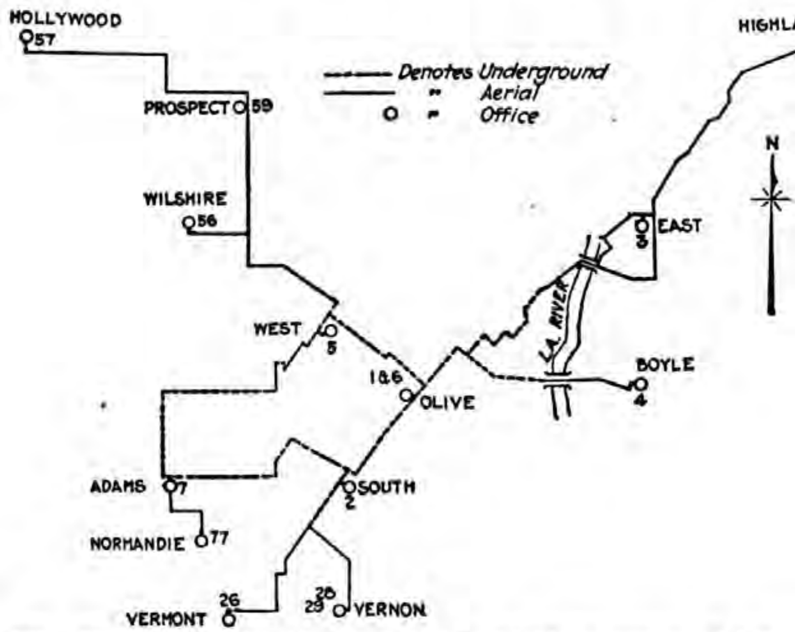


FIG. 309.—Skeleton diagram of the automatic telephone system of Los Angeles, Cal.

penses, 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. Sub-offices.

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.

A sub-office is dependent upon a branch or a main office for its selectors —it is made up chiefly of lineswitches and connectors.

**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. 309. 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 Sub-office........ | 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 Sub-office........ | 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 Sub-office...... | Numbered from 77,100 to 77,999. |

South office has one branch, Vernon and a sub-office Vermont; West office has two branches, Prospect Park and Hollywood and a sub-office, Wilshire; East office has a branch, Highland Park, and Adams has a sub-office, 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 as 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" part 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" part. 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.

**Sub-offices.**—A sub-office installed by placing one or more lineswitch 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 sub-office and are there connected to the lineswitches. The first selectors to which these lineswitches are trunked remain at the nearest large central office, consequently when a sub-office 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 sub-offices telephones are mounted in their usual places on the backs of the lineswitch units, and are connected by trunks to the banks of second, or third selectors, also located at the nearest central office, unless the sub-office is a comparatively large one (500 lines or over) in which event the third selectors may be installed at the sub-office instead of at the central office. Thus all calls from and to the sub-office 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 sub-office, a total of 23 trunk pairs is sufficient between a sub-office of 100 lines and the central office. This leaves a net saving of 77 pairs of wires per 100 lines. In sub-office 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 14) that the wire chief can test every line entering each sub-office without leaving his desk at central. Sub-office 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 sub-offices is that at Columbus, Ohio, which, as indicated in Fig. 310 employs one large main central office and nine sub-offices varying in size from 50 to 625 working lines.

To illustrate how connections between sub-office 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 office in the southern part of the city. When the Blake subscriber turns his dial from finger hole 1 his lineswitch 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. 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

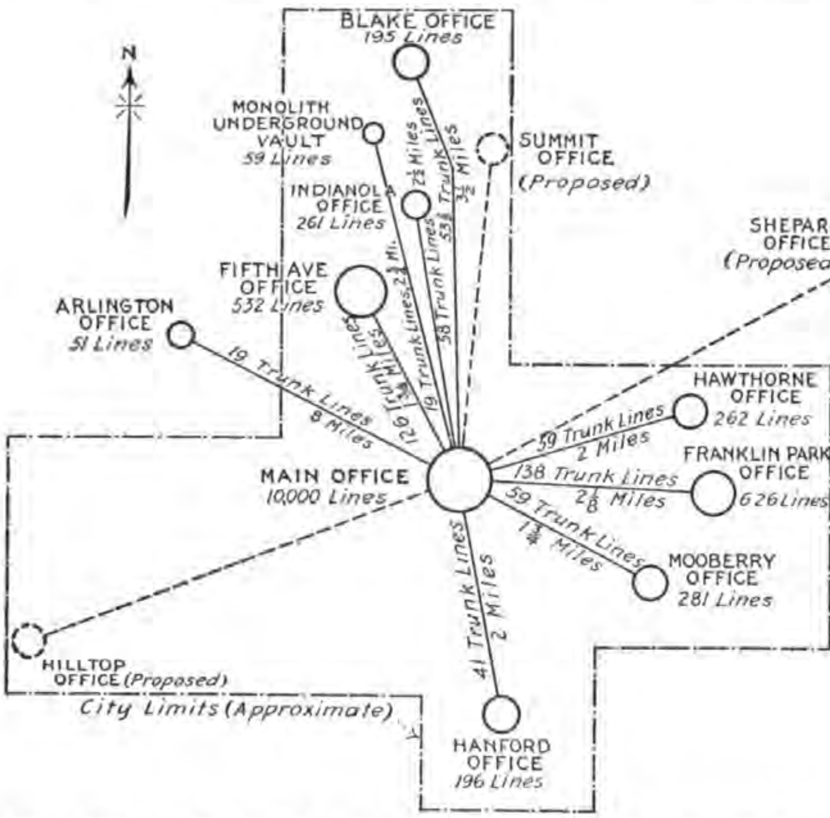


FIG. 310.—Skeleton diagram of automatic telephone system of one main central office surrounded by sub-offices in Columbus, O.

on the "500" board at the Hanford station. This connector switch responds to the last two motions of the dial and completes the connection

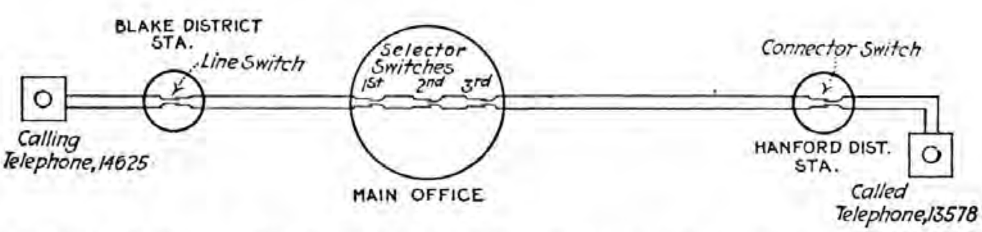


FIG. 311.—Diagram illustrating steps in setting up a connection from a subscriber connected to Blake to one connected to Hanford sub-office.

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. 311.

**Trunks for Reverting Sub-office Calls.**—Since, as stated, a sub-office line is instantly connected to a trunk to main office as 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 office that the connection will pass through the main office and will then be extended back to the sub-office, in which the call originated, when the connector switch trunk is occupied. Therefore, as indicated in Fig. 312, such a connection occupies two trunks between the sub-office and its main office.

Where conditions warrant the use of somewhat more complicated and expensive sub-office apparatus, equipment may be installed at a sub-office which will avoid the necessity of using any trunk between a sub-office and its main office during a local conversation. When

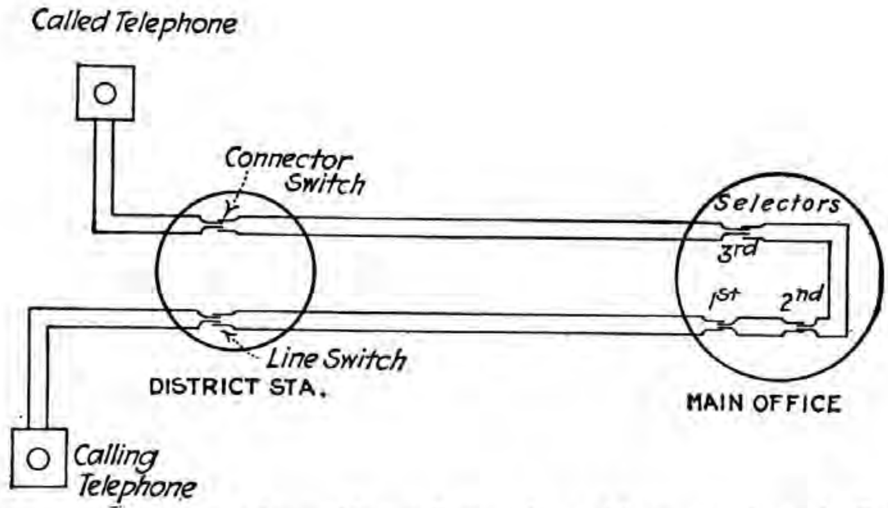


FIG. 312.—Showing switches and inter-office trunks used for a reverting sub-office.

this apparatus is used the trunk from the sub-office 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 sub-office, whereupon the entire connection is automatically released and a local connection made to an idle third selector or connector in the sub-office.

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 sub-office 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 Sub-offices.**—To the talking trunks for each sub-office 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 be grouped with any of the other trunks. They are used for furnishing ringing and busy-signal currents, to the sub-office from its main office and for supplying the main office attendants with supervisory signals, which enable them to supervise the sub-office from main. The wire chief at main also uses some of these utility wires for operating a "test distributor" at each sub-office which enables him to connect to a test connector on any lineswitch board and thus test all sub-office 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 sub-offices 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 Sub-offices 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 sub-office 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 office and where the expense of a constant local attendant would be unwarranted. A sub-office uses the simplest known automatic apparatus and all calls to or from it can be supervised at its main office.

A sub-office 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 sub-office 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 sub-offices 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 15-year period, and especially if more than 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.

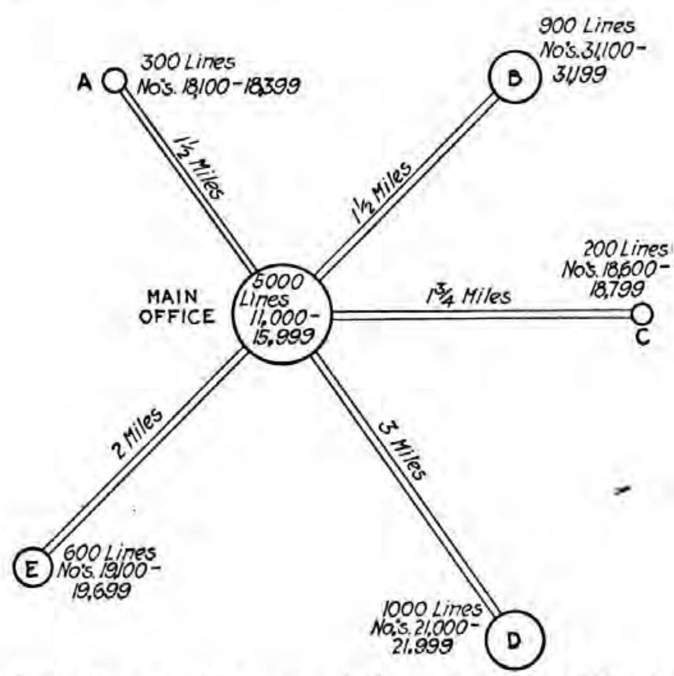


FIG. 313.—Skeleton diagram of a system of three main offices, "Main" B, and D, and three district stations A, C, and E.

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. 313, 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. 313, 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 sub-offices 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 15-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 sub-office, will be given primary consideration.

The location of this central office will be affected by the number of sub-offices installed, unless the same number of subscribers should perchance be put into sub-offices 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 sub-offices 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 sub-offices, and, consequently, trunk their calls into the main office.

**Sub-office Locations.**—Installing lineswitches for serving a given group of subscribers in a sub-office 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 sub-office 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 sub-office 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 sub-office 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 sub-office to the main office requires, in addition to the usual first selector, cross connecting frame terminals at each end, and a repeater at the sub-office. When secondary lineswitches are used between the lineswitches and first selectors at the central office the number of first selectors is increased by the use of sub-offices. For example, when secondary lineswitches 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 sub-offices 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 sub-offices of from 100 to 500 lines, the battery charging will be done from the main office and in sub-offices of 500 lines and up, the charging and ringing equipment will be located at the sub-office.

In sub-offices of 500 lines or over, and especially when situated at a considerable distance from the main office, it is generally advisable to use secondary lineswitches on the trunks in order to reduce the cost of cable pairs, but that should be a matter of special study for each sub-office.

**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 sub-offices, because it is customary in sub-offices 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 sub-offices 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 c. per cubic foot, (1914 prices) for purposes of comparison; while experience would indicate that in sub-offices the cost per cubic foot of space may be taken at not to exceed 10 c., 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 sub-office system is practically the same as in a one-office system, nad the cost of the space in sub-offices is cheaper than in the main office, it follows that the total cost of all office buildings may be reduced by the use of sub-offices.

It will generally be found that the land on which a sub-office 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 sub-office on the rear of it, and then sells the rest for residence purposes that the cost of the land occupied by the sub-office 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 sub-office, a comparatively small figure by purchasing, or renting a residence, installing the sub-office 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 sub-offices. The necessary data must be secured by a study of local conditions. Generally if the use of sub-offices is decided upon before an unecessarily 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 1½ per cent per annum, and interest at the rate of 6 to 8 per cent per annum. Depreciation and obsolescence on automatic equipment should be calculated on a life of not less than 15 years and it would not be unreasonable to consider the life 20 years. The amount which must be set aside annually at 6 per cent compound interest to equal 100 per cent in 15 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 20 years. At 8 per cent the annual charge is 3.05 per cent. 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 ½ 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. Or 14 per cent at the higher rates.

When estimating the annual charges on sub-office 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 sub-office.

**Central Office Operating and Maintenance Labor.**—The average operating and maintenance labor cost in branch offices or sub-offices 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 sub-office 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 sub-offices can test all lines from his desk at central without the aid of an assistant at the sub-office. 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 gage cable is commonly taken at $2.55. In the case of a snaller 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 gage 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 gage circuits should be taken at about $2.40 per annum, and on No. 19 gage cable at $3.60 per annum.

If more accurate figures than these are desired, the cost of the conduit manholes and underground cables, 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.................. | 11½ per cent |
| Annual charge on pole lines.......................... | 21½ per cent |
| Annual charge on aerial cable and suspension.......... | 14½ 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

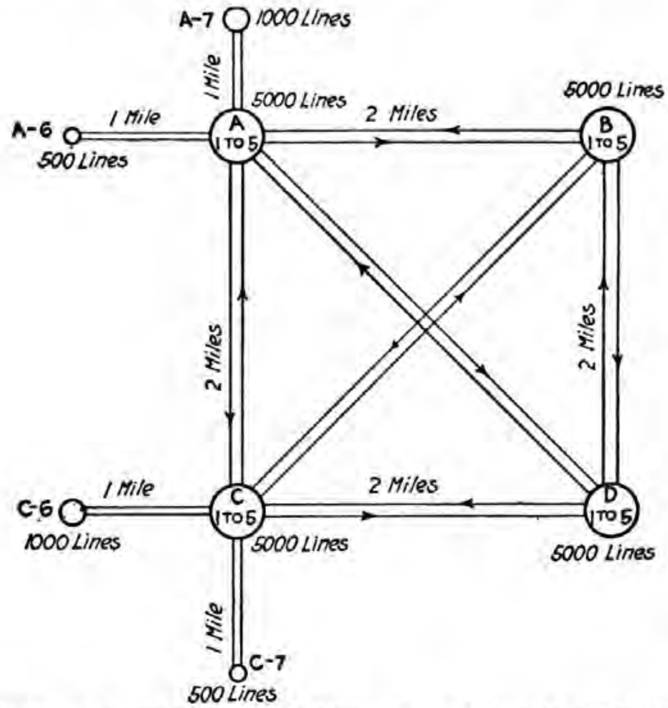


FIG. 314.—Diagram representing hypothetical system of 4 main offices A, B, C, and D and 4 subsidiary offices, A-6, A-7, C-6, and C-7.

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 sub-offices 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 sub-offices are used. For illustration, refer to Fig. 314 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 $C$

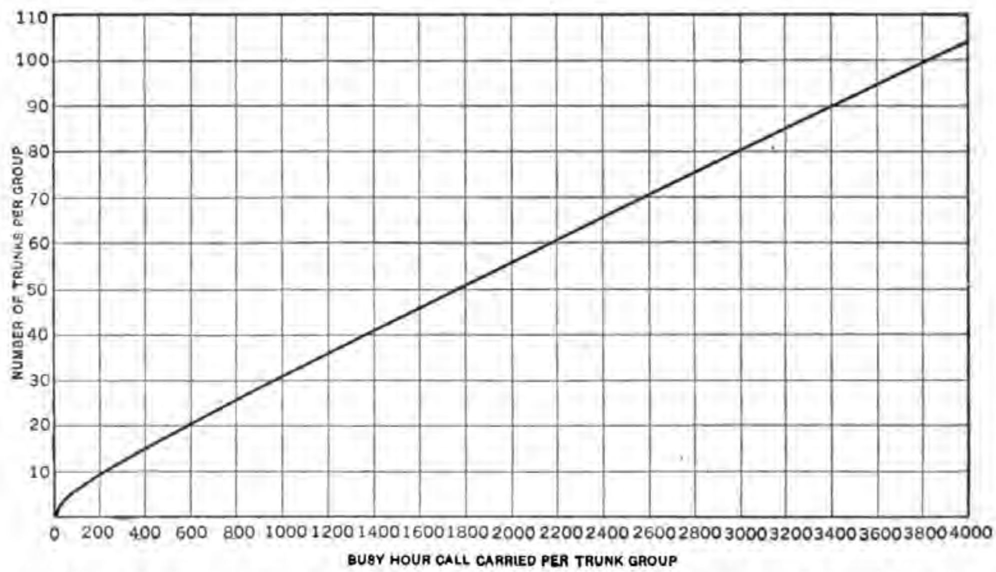


FIG. 315.—Curve showing carrying capacities of trunk groups of hypothetical system in Fig. 314.

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. 315. Calculations with these hypotheses give the results for the calls and trunks from and to $C$-6 shown in the following tables.

The trunks are figured for a system without secondary lineswitches 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.

BRANCH OFFICE ARRANGEMENT

| (Outgoing from *C*-6) | | | | (Incoming to *C*-6) | | | |
|---|---|---|---|---|---|---|---|
| To office | Busy hour call | 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 |

Now consider *C*-6 as a sub-office containing lineswitches, 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 lineswitches it will have ten groups of outgoing trunks, one group for each lineswitch 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*, aso the additional trunks from *C* to other offices.

SUB-OFFICE 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 lineswitches on the trunks from the sub-office *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 lineswitches 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 sub-office arrangement by using secondary lineswitches 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 sub-office 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 selector banks direct to the toll board, but would not be taken into account in arranging for the trunking facilities of a sub-office, 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 sub-office. Of course a separate engineering study should generally be made of each case to determine whether a branch office or a sub-office 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 sub-office is very clearly indicated.

By employing sub-offices only the trunking system is kept as simple as possible, regardless of the number of offices used.

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