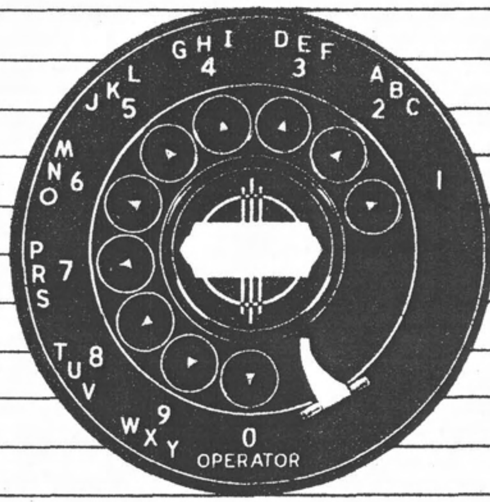
AUTOMATIC ELECTRIC TRAINING SERIES | Bulletin **802**

FUNDAMENTALS OF APPARATUS AND TRUNKING

STROWGER AUTOMATIC TELEPHONE SYSTEMS



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STROWGER AUTOMATIC TELEPHONE SYSTEMS

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May we send you others
pertaining to equipment in your exchange?

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FUNDAMENTALS OF APPARATUS AND TRUNKING

PART I. TRUNKING

1. INTRODUCTION

This bulletin deals primarily with the fundamentals of trunking. Facts concerning apparatus are included to give a better understanding of trunking.

2. TRUNKING

"Trunking" may be defined as the interconnection of equipment both within an office and between offices. A single trunk provides a path between switching equipment for one call. Therefore, the amount of traffic that can flow through an office, and the efficiency of the office to handle the traffic flow depends greatly upon the way the office is trunked. Strowger automatic switching equipment is, in general, mechanically and electrically standardized, while the way in which the equipment is connected or trunked is very flexible.

A trunk within an office will usually consist of either three conductors (+, -, C) or four conductors (+, -, C, EC). The plus (+) and minus (-) leads make up the transmission path, and the control (C) lead provides for control of the switches in the circuit. The extra control (EC) lead, when present, provides for extra control, restrictions, certain types of ringing, etc. It should be clearly understood that a subscriber's loop or an inter-office trunk, consists of only two conductors (+ and -), and that the control (C) and extra control (EC) leads never leave the office.

Trunks are connected to all Strowger switches either at the switch jacks (i.e., to the mechanism) or the banks. There are two types of banks associated with every Strowger switch, a line bank and a control bank. A line bank is made up of two hundred terminals or contacts, arranged in ten levels, with ten pairs on a level. Each pair of terminals represents the plus (+) and the minus (-) of a trunk or line. The contacts of the line bank are constructed so that the wipers will not be in contact with more than one pair at a time. These are known as non-bridging contacts.

A control bank is made up of one hundred terminals or contacts arranged in ten levels with ten terminals per level. Each of these terminals represents a control lead. The contacts of the control bank are constructed so the wipers will engage the succeeding set of terminals prior to leaving the present set, and are known as bridging contacts. Figure 1 shows a control bank (upper) and a line bank (lower) with the associated wipers. In cases where a switch has an extra control (EC) lead the control bank of the switch has two hundred terminals arranged in the same manner as a line bank.

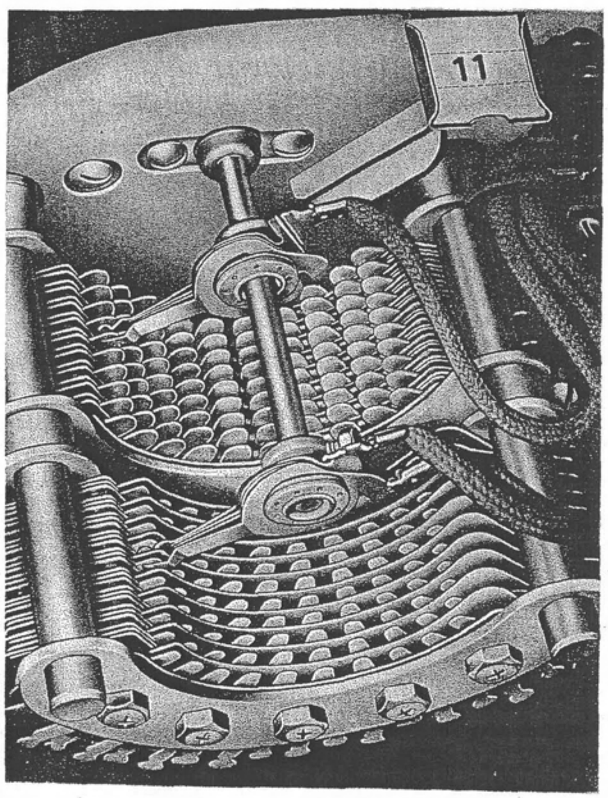

Figure 1. Control bank and line bank with associated wipers.

PART II. INTRA-OFFICE TRUNKING

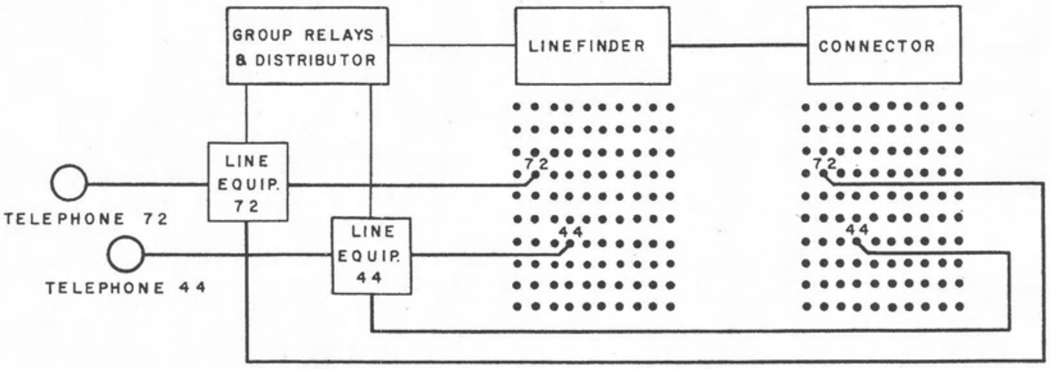

Figure 2. Schematic diagram of 100 line office.

To better understand intra-office trunking, we shall first discuss a small one hundred line office. Next we will expand to a one thousand line office and then to a ten thousand line office. In each case the equipment will be discussed as it is introduced into the offices.

3. 100 LINE OFFICE

No matter what the size of the office, in order that each subscriber may both originate and receive calls, his line must be terminated in two places within the office. To receive calls the subscriber's line must terminate on a set of connector terminals, and to originate calls, his line must terminate on a set of linefinder terminals.

Since the linefinder is a non-numerical switch and will not respond to the pulses of a subscriber's dial, it must be connected directly to a numerical switch that will respond to dial pulses. In the case of a one hundred line office, each linefinder is trunked back to back (switch jack to switch jack) with a connector. Through this type of an arrangement, commonly known as a linefinder-connector-link, only one call may take place at a time. Therefore, the number of calls that may take place simultaneously, depends directly on the number of linefinder-connector-links available. Figure 2 illustrates a one hundred line office, showing the termination points for two subscribers, the linefinder-connector-link and other apparatus involved, and the trunking between the apparatus. Only one linefinder-connector-link is shown for illustration, but let us say it represents ten such links.

3.1 Connector. The basic Strowger switch is the connector, and it functions to complete a call to the desired party in response to dial pulses. A call enters a connector through the connector mechanism, and is connected to one of one hundred lines, via the bank terminals, depending on the two digits dialed into the connector. The connector bank terminals are numbered as shown in figure 3. The number assigned to each position is the number that must be dialed to bring the wipers to that position. In other words, to reach position 53, the wipers must step up to the fifth level and rotate to the third position. Each position in figure 3 represents a set of terminals (+, -, C) or (+, -, C, EC) depending on the particular circuit involved. For our discussion we will consider each position as three terminals (+, -, C).

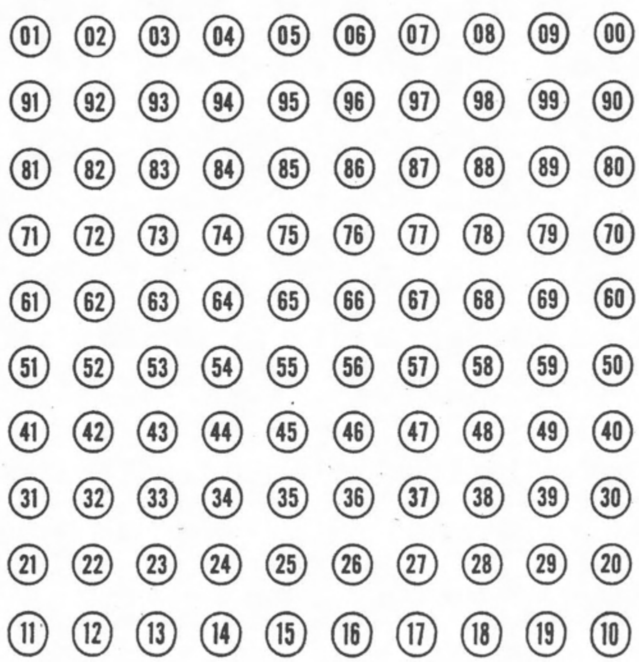

Figure 3. Bank-contact position numbering.

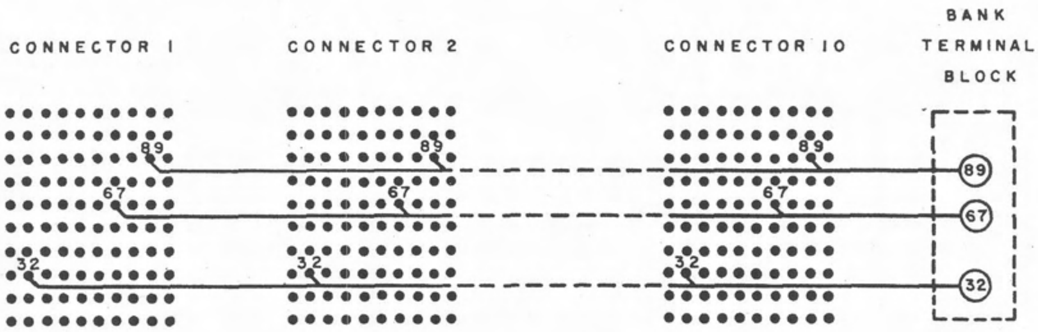

Figure 4. Connector bank multiple.

As was previously stated, we desire to have ten connectors serve the one hundred lines. These ten switches shall be arranged on a shelf having the corresponding positions in all the banks multipled together and then to a bank terminal block. The bank multiple is shown in figure 4. All of the connectors on the shelf have access to any of the one hundred lines. Of course if a connector's wipers are connected to a particular line, no other connector on the shelf may engage the same line. For example, if connector one on a shelf is engaged with line "35", none of the remaining connectors on the shelf may engage line "35".

3.2 Linefinder. There are two types of linefinders, the one hundred line and the two hundred line. The one hundred line linefinder has one hundred sets of terminals, through which calls may enter, while the two hundred line linefinder has two hundred sets of terminals, through which calls may enter. In each type there is only one point of exit, the switch jacks. In the one hundred line office with which we are concerned at the present, the one hundred line linefinders are used.

The group of linefinders that serve the same group of lines are mounted together on a shelf with their banks in multiple. Information on the bank numbering, multipling of banks and arrangement of linefinders is found in bulletin 801, §29, and in bulletin 821. The linefinder's main function is to find a line which is desiring service. Associated with the linefinders are the individual line equipments and the group relays and distributor.

3.3 Line equipment, group relays and distributor. Each line has its own line equipment. It most generally consists of two relays that control the traffic on the line. The line equipment's functions are to call for a linefinder when the handset of the telephone on the line is lifted, to provide markings so the linefinder can find the proper line, and to mark the connector terminals of it's line busy. A set of group relays and distributor are associated with each group of linefinders. The group relays and distributor assign an idle linefinder to search for the line and at the same time prevent the remaining linefinders from searching. After the calling line is found by the assigned linefinder, the group relays and distributor drop out of the connection, and prepare to assign another idle linefinder to find the next line desiring service.

3.4 Method of operation. So that we may better understand how all the equipment functions and the trunking that is necessary to complete a call, let us trace a call through a one hundred line office. In figure 2, when the subscriber on line 44 raises his handset to make a call, his line equipment signals the group relays that a line wants service. The group relays and distributor then assign an idle linefinder to find the line. The wipers of the assigned linefinder step vertical and rotary to connect line 44 through the linefinder to its associated connector. At this point the group relays and distributor drop out of the connection. When the subscriber dials the digits "7" and "2" the connector steps to the seventh level and rotates to the second contact. If line 72 is not busy, the connector switches through and telephone 72 is rung. It should be noted that in this one hundred line office, due to the small amount of apparatus involved, the trunking involved is also small.

4. 1000 LINE OFFICE

A one thousand line office is made up of ten connector groups or shelves and five two hundred line linefinder shelves. In order that all of the one thousand subscribers may call each other, a selector must be inserted between the linefinders and the connectors. This is illustrated in figure 5. As before each linefinder must be associated directly with a numerical switch, and in this case it is a selector. Therefore, instead of having a linefinder-connector-link as in the one hundred line office, there is a linefinder-selector-link. All of the selectors which are tied back to back with the linefinders are

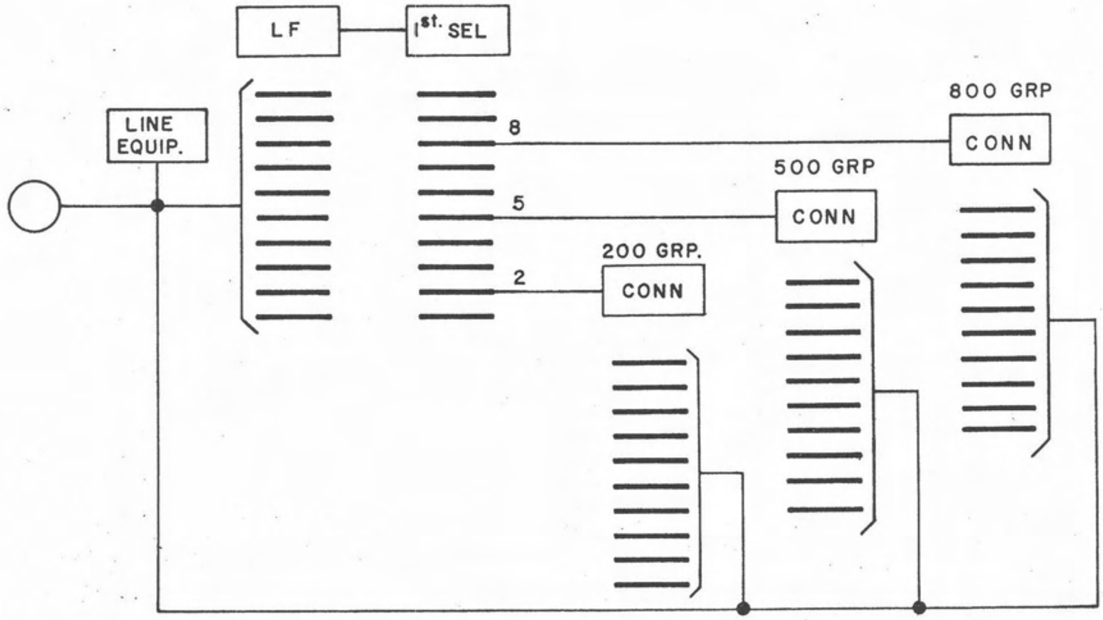

Figure 5. Schematic diagram of 1000 line office.

known as first selectors. Corresponding levels of all the first selectors are multipled together, and then trunked to the connector groups (only three of the possible ten are shown). The level from which each connector group is trunked determines the number of the connector group.

4.1 Selector. A selector operates vertically in response to dial pulses, but once it has reached a level it rotates automatically, hunting a trunk to an idle switch, in this case a connector. It searches from left to right and will switch through to the first idle connector that is found. If no idle connectors are found in the connector group the selector will return busy tone to the calling party. Figure 6 illustrates how trunks lead from a selector bank to the connectors.

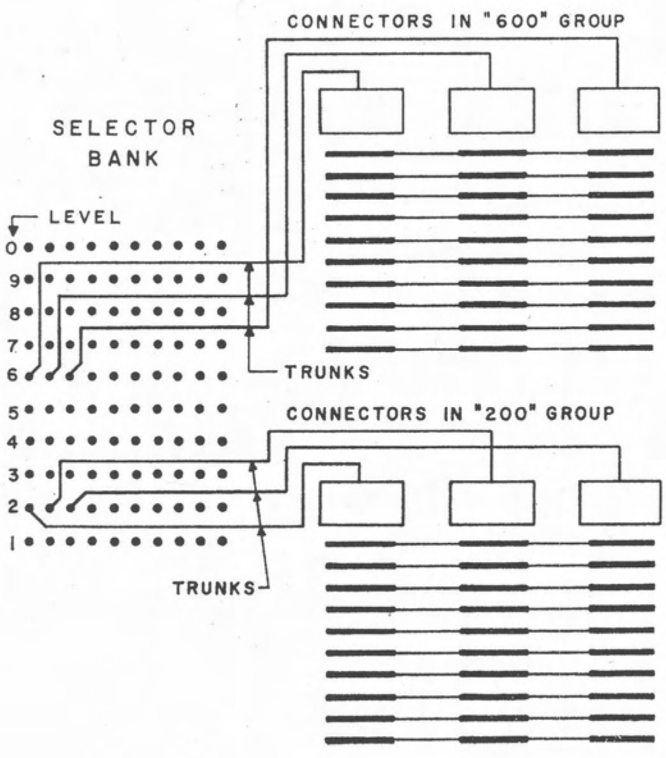

Figure 6. Trunks leading from a selector bank to connectors.

Selector banks, which are similar to those associated with the connector, are multipled in units of ten, and each such unit with its associated selectors is termed a "shelf". A straight bank multiple for one level is illustrated (only three selectors are shown) in figure 7. It should be noted that a terminal strip is associated with the bank multiple of each shelf. These terminal strips are mounted on a distributing terminal assembly (DTA) where it is convenient to multiple a large group of selectors on each level and trunk to succeeding switches.

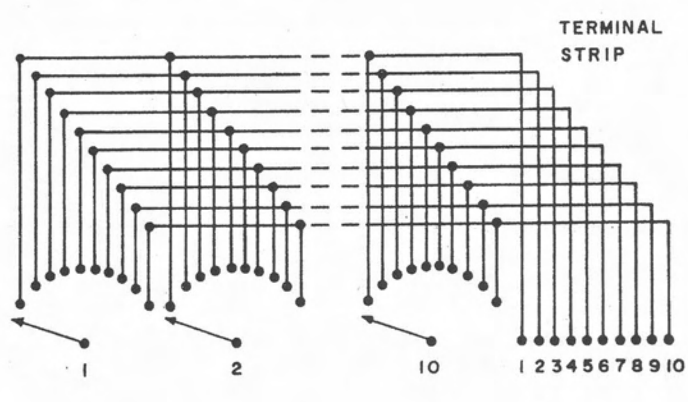

Figure 7. Straight selector bank multiple for one level. Trunks terminate on terminal strip.

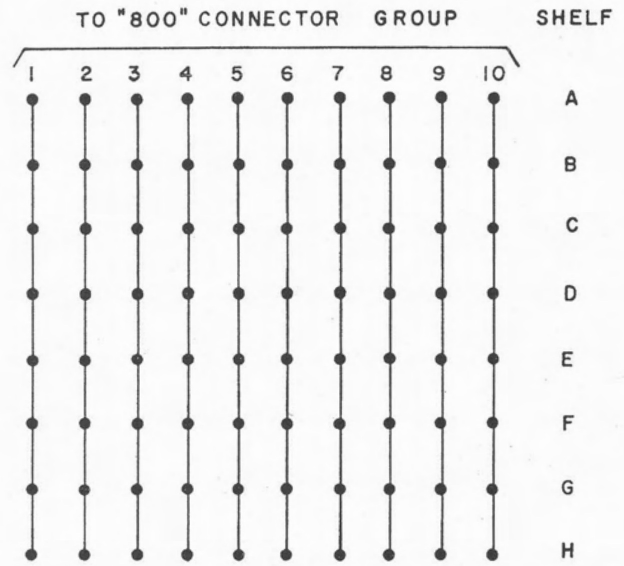

Figure 8. Straight multiple between the terminal strips of eight shelves on one level.

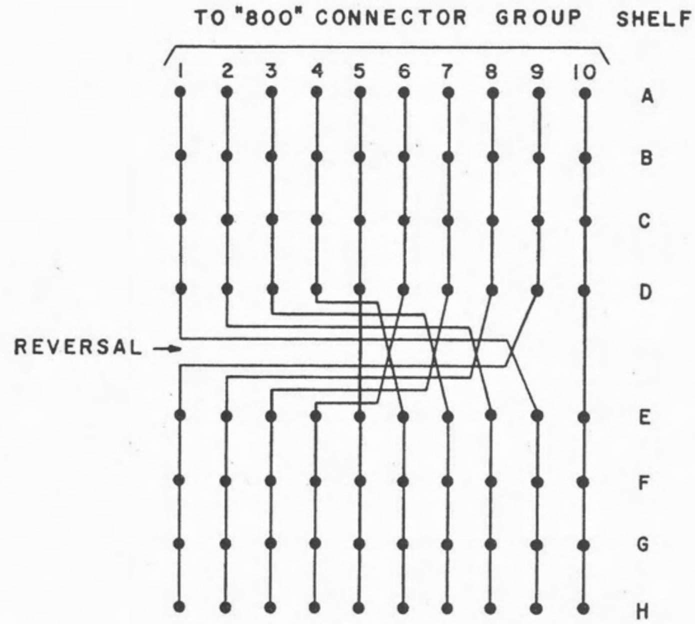

Figure 9. Multiple between the terminal strips of eight shelves with a reversal in first 9 trunks.

Let us use the 800 group as an example. There are ten connectors in the group and therefore there are ten trunks needed. These ten trunks can be made available to all the selectors by multipling all the terminal strips of the eighth level, as illustrated in figure 8. Since all of the selectors have access to the same trunks and in the same order, the first connector, which is associated with the first trunk, is used quite often in comparison to the connector associated with the tenth trunk.

4.1.1 Reversals. To help balance the connector usage within a shelf, a reversal may be inserted at the mid point of the selector group having access to this particular connector shelf. In figure 9 you will note that all the trunks with the exception of the last have been reversed. The tenth trunk is excluded from the reversal in order to meter how many times selectors must search over all ten contacts on the eighth level attempting to find an idle trunk. Because of the reversal the upper four shelves of the selectors search over the trunks in a 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, sequence, while the lower four shelves search over the contacts in a 9, 8, 7, 6, 5, 4, 3, 2, 1, 10, sequence.

4.1.2 Slips. Another method used to help equalize the load to succeeding switches in a small office is the slip. A slip may be found in the bank multiple of a selector shelf that terminates on a terminal block or a distributing terminal assembly (DTA). The slip changes the sequence in which the trunks to the succeeding switches appear to individual selectors within a shelf. Normally only the first five contacts in each bank are included in the slip, while the remaining five contacts are multipled straight. This type of slip is illustrated in figure 10, and is known as a "forward slip of one". In figure 10 only seven of the ten selector banks for one level are shown. Notice that trunk number one is the first choice of selector one; trunk two, the first choice of selector two; trunk three, the first choice of selector three; trunk four, the first choice of selector four; and trunk

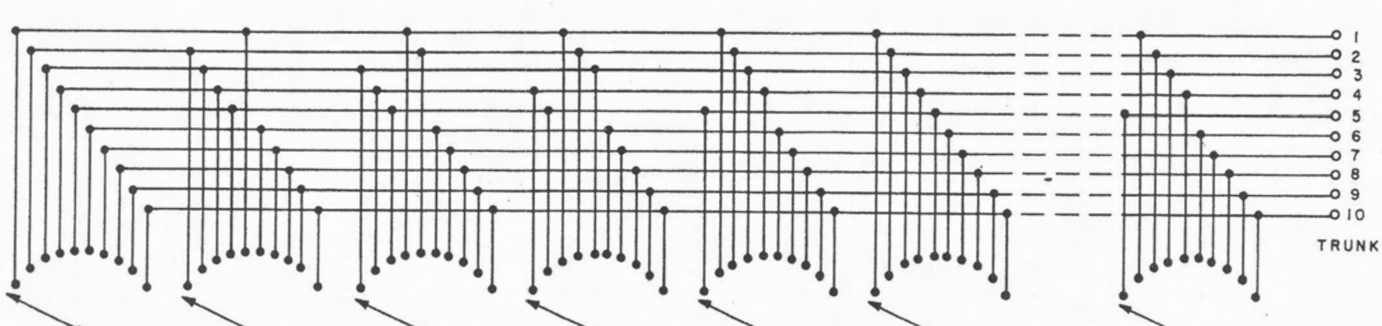

Figure 10. Selector bank multiple for one level having a "slip" of one in the first five contacts.

five, the first choice of selector five. Starting with selector six the same trunk sequence is repeated.

4.1.3 Grading. The method of making available to a particular level of a selector group more than ten trunks is termed grading. The traffic load to the succeeding switches determines the number of trunks necessary. Each selector shelf on one level, of course, still has access to only ten trunks, but a portion of the ten trunks may differ between shelves. As an example, the fifth selector level in figure 5 required fifteen trunks. The eight shelves could be graded as shown in figure 11 to provide fifteen trunks. With this arrangement, each shelf has access to only ten trunks, however shelves A, B, C, and D, each have access to trunks 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, in that order, while shelves E, F, G, and H, each have access to trunks 11, 12, 13, 14, 15, 9, 8, 7, 6, 10, in that order. Once again the last contacts of each shelf are multipled straight to provide for metering. The other four common trunks are reversed at the mid point of the selector group to further add to the equalization of usage of the succeeding switches.

4.2 Method of operation. In a one thousand line office a three digit directory number is required to reach a subscriber instead of a two digit number as used in a one hundred line office. The first digit selects the hundreds group and the remaining two, the proper line in the group. For example, let us say figure 5, represents five shelves of linefinders, each shelf having sixteen switches. These eighty linefinders are trunked to eighty first selectors

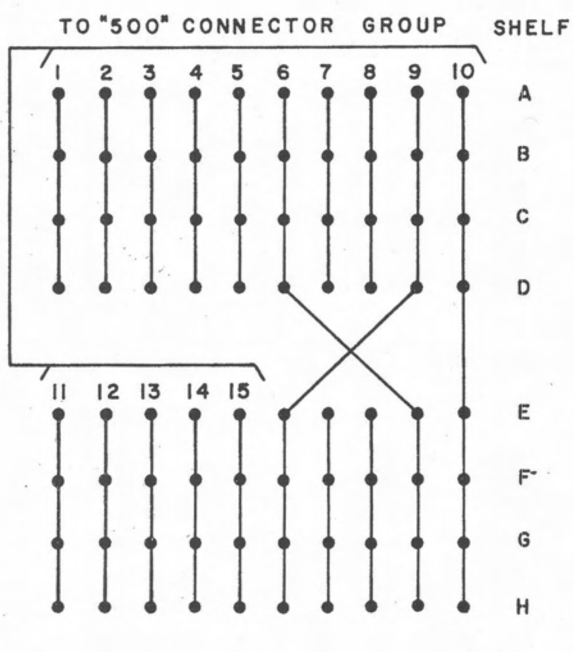

Figure 11. Grading arrangement giving eight shelves access to fifteen trunks from one level.

(8 shelves). The first selectors' banks are multipled straight on levels one to three and six to ten at the DTA, while levels five and six are graded on the DTA. Levels one to three and six to ten each lead to a connector group containing ten switches. Only two of these connector groups are illustrated. Levels four and five each lead to fifteen switch connector groups. Only one of these groups is illustrated. Even though there are one hundred and ten connectors serving the one thousand lines, only eighty calls may take place simultaneously, because there are only eighty linefinders and eighty first selectors. The number of calls that may take place at one time depends on the switch rank with the smallest number of switches.

5. 10,000 LINE OFFICE

In expanding a one thousand line office to a ten thousand line office there must be another rank of selectors introduced. Instead of accessing connector groups directly from levels of the first selectors, we must access a second rank of selectors. The levels of the second selectors then access the connector groups. Now in order to reach a party, four digits must be dialed instead of three. Figure 12 represents a ten thousand line office illustrating equipment and trunking to provide for three thousand of the possible ten thousand lines.

To serve the three thousand lines illustrated, it is necessary to have fifteen linefinder shelves. If there are twenty linefinders per shelf or a total of three hundred linefinders, the office then requires three hundred first selectors to be trunked back to back with the linefinders. Also assume there are one hundred selectors in each of the three second selector groups, and in each connector shelf, ten connectors. In actual practice the number of switches provided in each shelf or group in the office would depend on the traffic through the particular shelf or group.

6. SUBSCRIBER GROUPING

The major grouping of subscribers is the exchange. The exchange is further divided into various offices, and within each office the subscribers are grouped by directory number. Usually the geographic location of the subscriber determines his exchange and office within the exchange. While his location normally has nothing to do with the remainder of digits in his directory number.

At present, directory numbers in larger areas and those areas which desire to be a part of the direct distance dialing system, consist of

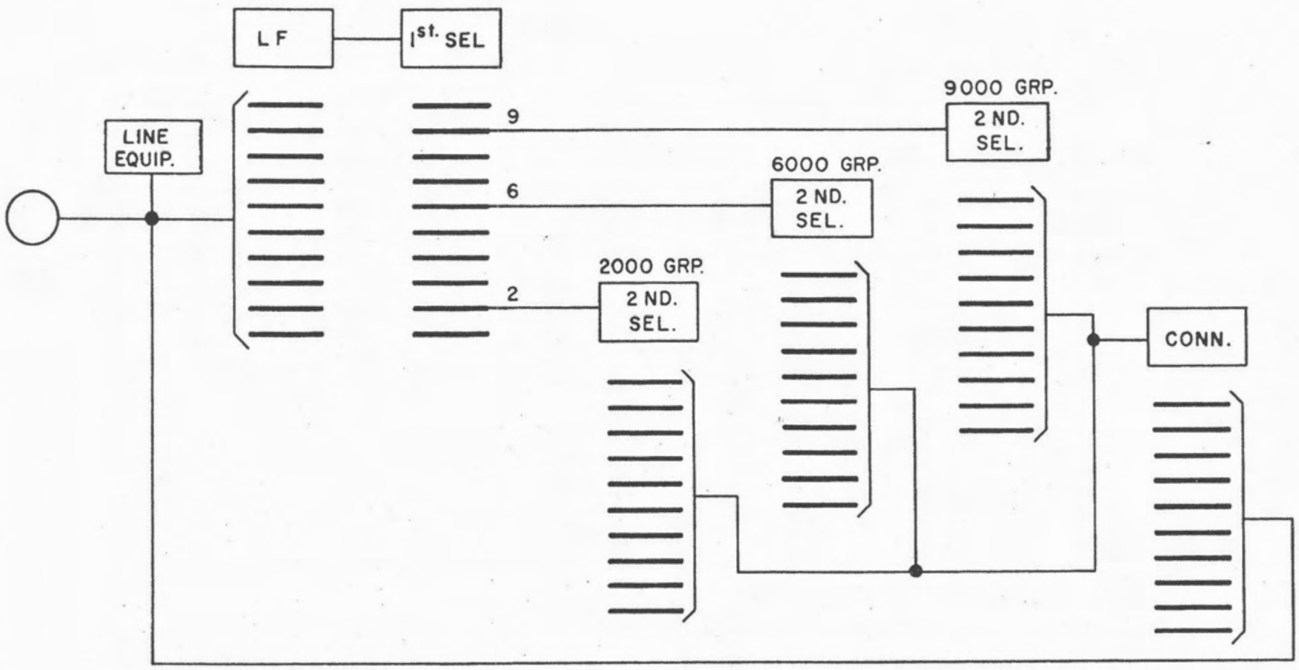

Figure 12. Schematic diagram of 10,000 line office.

seven digits, that is two letters and five numbers. The two letters of the directory number are the first two letters of the exchange name. Thus a telephone number might be written as Fillmore 5-7463, and dialed as FI 5-7463. Since the letters on the dial represent numbers, note figure 13, the resulting dial pulses when the number is dialed would be 3-4-5-7-4-6-3. Notice in figure 13 that no letters are associated with the numbers one or zero.

Theoretically 10,000,000 telephone lines may be represented by a seven digit numbering system. Starting with the called subscriber, the final two digits of the directory number locate his line within a hundreds group. The preceding digit selects the hundreds group desired, while the fourth digit of the directory number selects the proper thousands group. The third or "office" digit selects the proper ten thousand group. The desired one hundred thousand group is selected by the second digit and the desired one million group is

Figure 13. Telephone dial.

selected by the first digit. It should be noted that each rank is a multiple of ten, or within each rank there are ten choices.

Figure 14 represents the dial, the switch ranks, and switch levels involved in reaching a desired directory number. Essentially, the process of reaching a desired number is one of elimination. To better understand the

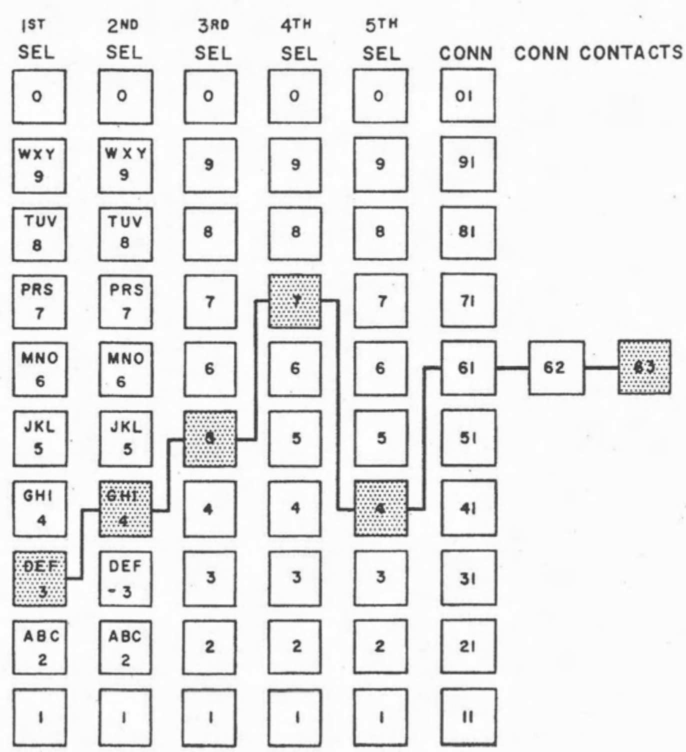

Figure 14. Theoretic 10,000 line system.

process let us take the number FI 5-7463 and trace it through the figure. When the "F" is dialed the first selector steps to the third level, thereby eliminating the nine other possible levels or a total of 9,000,000 lines. In dialing the "I" into the one million group (second selectors) the selector steps up to the fourth level and once again eliminates the remaining nine levels, or another 900,000 lines. Another 90,000 of the remaining 100,000 lines are eliminated when the third digit, a five, is dialed into the one hundred thousand group (third selectors) leaving 10,000 lines. Now by dialing the fourth digit, a seven, into the fourth selector we eliminate another 9,000 lines. The lines are reduced in number to one hundred when the fifth digit, a four, is dialed into the fifth selector. When the sixth digit, a six, is dialed into the connector ninety of the remaining one hundred lines are eliminated, leaving only the ten on level six. Nine of these are eliminated when the seventh and final digit, a three, is dialed, leaving only the desired line.

7. PARTY LINES

Thus far we have discussed only systems with one subscriber per line. In many cases a subscriber does not require a line to himself, for his traffic load is not great enough to warrant it. To serve several such subscribers living in approximately the same locality a party line is arranged, and it may serve from two to ten parties.

Party line service is divided into two classifications, terminal per station and terminal per line. On a terminal per station party line, each subscriber on the line is represented in the office by a set of connector terminals. If there are four parties on a line each connector group will serve one hundred subscribers, while only twenty-five lines are required. A terminal per station four party, party line is illustrated in figure 15. On a terminal per line party line, the line is represented in the office by one set of connector terminals, even though there are a number of parties on the line. This type of party line requires a special type of party line connector which is discussed in bulletin 813.

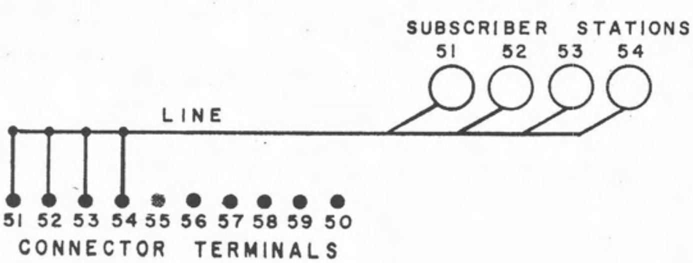

Figure 15. Terminal per station, four party, party line.

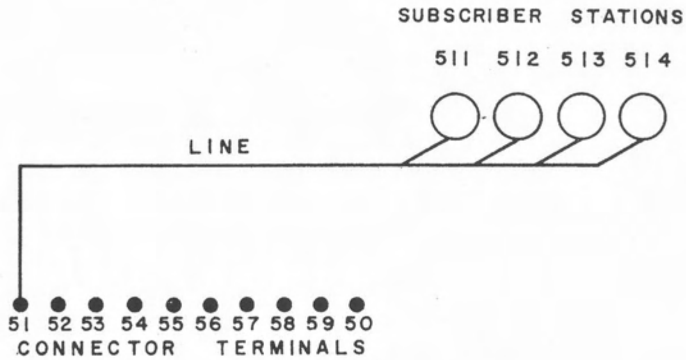

Figure 16. Terminal per line, four party, party line.

It is also necessary to dial three digits into this connector, two to find the correct set of terminals and one to ring the correct subscriber on the line. If there are four parties on a line as illustrated in figure 16, then such a connector group can serve four hundred subscribers on one hundred lines. To serve a given number of subscribers, terminal per station party lines require more shelves of switches, while the terminal per line party lines require more switches per shelf.

Whenever a subscriber on a party line dials the directory number of another party on the same line, he receives busy tone, because he is already occupying the line. In order that one party may signal and talk to another on the same line, special equipment, a reverting call switch, must be provided in the central office. Reverting call methods are discussed in detail in bulletin 814.

8. SWITCH TRAINS

Thus far we have discussed only the local switch train, but in each automatic office there are usually three separate switch trains. In addition to the local switch train, there is a toll switch train and a test switch train.

The toll switch train provides a separate path over which a toll call reaches the called subscriber. The switches involved have certain special features, which are not provided on local switches. The toll switch train is controlled by the toll operator and not by the subscribers, as is the local switch train. Bulletin 816 discusses in detail the toll switch train.

The test switch train is used by office maintenance men to test lines and equipment throughout the office. It is also used by toll operators to verify toll calls. Local subscribers never have access to the test switch train. Additional information on the test switch train can be found in bulletin 815.

PART III. INTER-OFFICE TRUNKING

When considering inter-office trunking, we must keep in mind that each office may be different. We are going to consider both trunking between automatic offices and automatic and manual offices. In both of the above cases the offices may be connected by either free service (sometimes termed extended area service) trunks or toll trunks. Figure 17 illustrates two offices, one automatic and the other manual, connected by one-way free service trunks. There is, you will notice, some equipment which we have not yet discussed. Namely the impulse repeater and the incoming selector.

9. IMPULSE REPEATER

The impulse repeater consists principally of relays, which repeat dial pulses originating in one office to the switching equipment of another office. The use of repeaters in inter-office trunking eliminates the need for the control (C) lead between offices, thereby limiting the inter-office trunk to two conductors. The impulse repeater does not improve transmission but it keeps the transmission level from dropping over long distances. The primary function of an impulse repeater is to improve pulsing over long distances. Between automatic offices, both one-way and two-way repeaters can be used. One-way repeaters allow calls to be made in only one direction over one trunk, while with two-way repeaters, calls can be made in either direction. Another type of repeater is used with one-way trunks between automatic and manual offices. It is commonly known as an automatic to manual (A-M) repeater. It provides for signaling the manual operator, supervision, and also allows a two conductor trunk to be used. It is not needed to repeat pulses. Bulletin 810 contains more information on impulse repeaters.

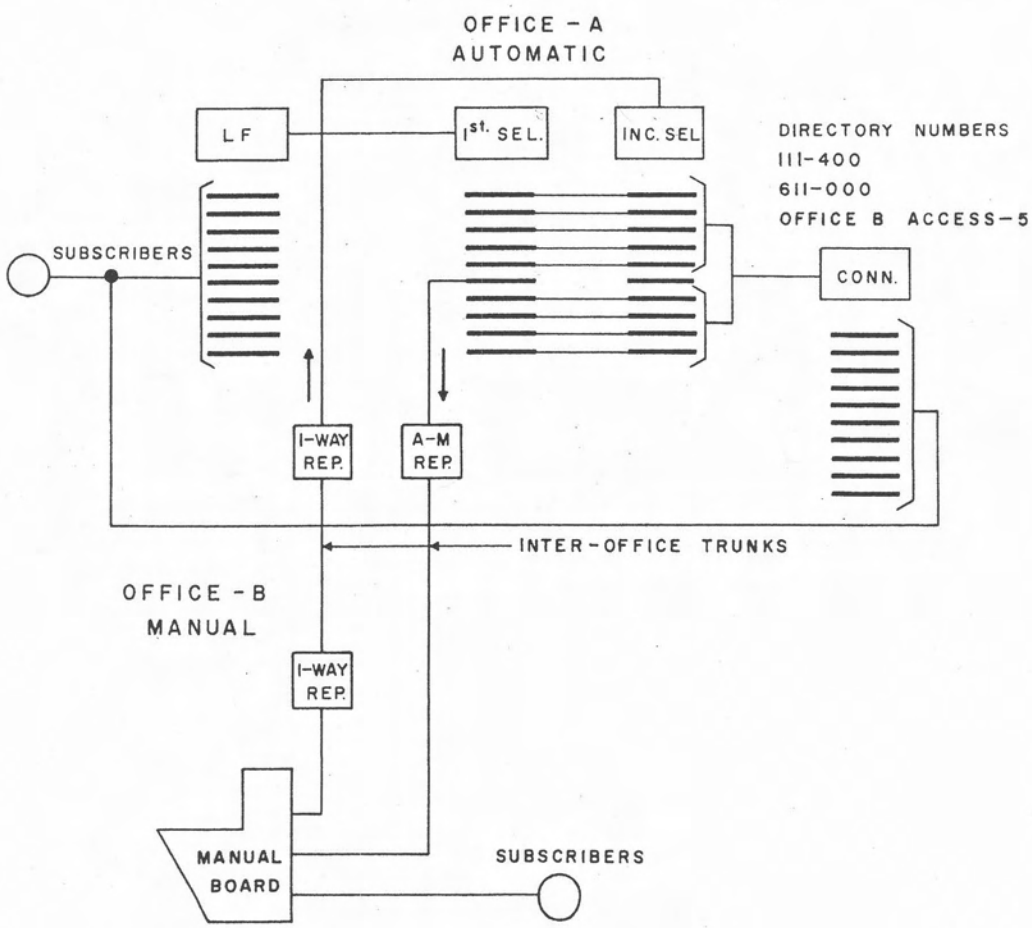

Figure 17. Automatic office and manual office connected by one-way trunks.

10. INCOMING SELECTOR

Incoming selectors are necessary in an automatic office where there are inter-office trunks involved. It is usually mechanically and electrically the same as a local selector; however, an incoming selector is not trunked back to back with a linefinder, but instead, is connected to an inter-office trunk. Each incoming one-way trunk or two-way trunk is connected to an incoming selector, so the number of incoming selectors depends on the number of incoming one-way and two-way trunks.

The incoming selectors' banks are usually multipled with the banks of the local first selectors on levels which lead to local subscribers. This multiple takes place on the DTA. Levels of local first selectors, which lead to other offices are usually not multipled to corresponding levels of the incoming selectors. This is illustrated in both figures 17 and 18.

11. AUTOMATIC TO MANUAL

Figure 17 illustrates an automatic and a manual office inter-connected with one-way trunks. You will notice that the trunk leading from office A to office B is accessed from the fifth level of the first selector, and goes through an A-M repeater and directly to the manual board. The one-way trunk leading from office B to office A goes directly from the manual board through the repeaters and into an incoming selector.

In order for a subscriber in office B to call a number in office A, he lifts his handset and gives the desired number to the operator, after she comes on the line. The operator then seizes a trunk to office A, and dials the desired number into the incoming selector and connector thus completing the call. A subscriber in office A, who desires to call a number in office B picks up his handset and after his line is found and connected through to a first selector, dials a "5". The selector finds an idle trunk on the fifth level and switches through to the manual board, via the A-M repeater. The operator then completes the call to the desired number with her cord circuit. The number of trunks between offices, of course depends on the amount of traffic.

12. AUTOMATIC TO AUTOMATIC

Three inter-connected automatic offices are illustrated in figure 18. They are inter-connected by two-way trunks, so that all subscribers may reach all other subscribers. Office A may access office B by dialing a "6", and access office C by dialing a "5". Office B may access office A by dialing a "4" and access office C by dialing a "5". Office C may access office A by dialing a "4" and access office B by dialing a "6". If there are seven trunks between offices A and B, seven trunks between offices A and C, and seven trunks between offices B and C, then there are fourteen two-way repeaters and fourteen incoming selectors needed in each office. The subscriber may after dialing the access digit of an office other than his own, dial the directory number of the desired party in the accessed office.

13. P-A-X AND P-A-B-X

The Private Automatic Exchange (P-A-X) is a compact intercommunications system for serving business organizations, institutions, ships, etc. It is made up of standard Strowger automatic equipment arranged and adapted to meet specified requirements.

P-A-X switchboards are made in a number of standard sizes and types ranging from a few telephones to any number desired. With the addition of certain equipment a P-A-X may be trunked to a central office, thus allowing calls to be made to and from the central office. Such a switchboard is called a Private Automatic Branch Exchange (P-A-B-X). It is common practice in P-A-B-X installations to have calls from a public exchange intercepted at an attendant cabinet. The attendant may then complete the call.

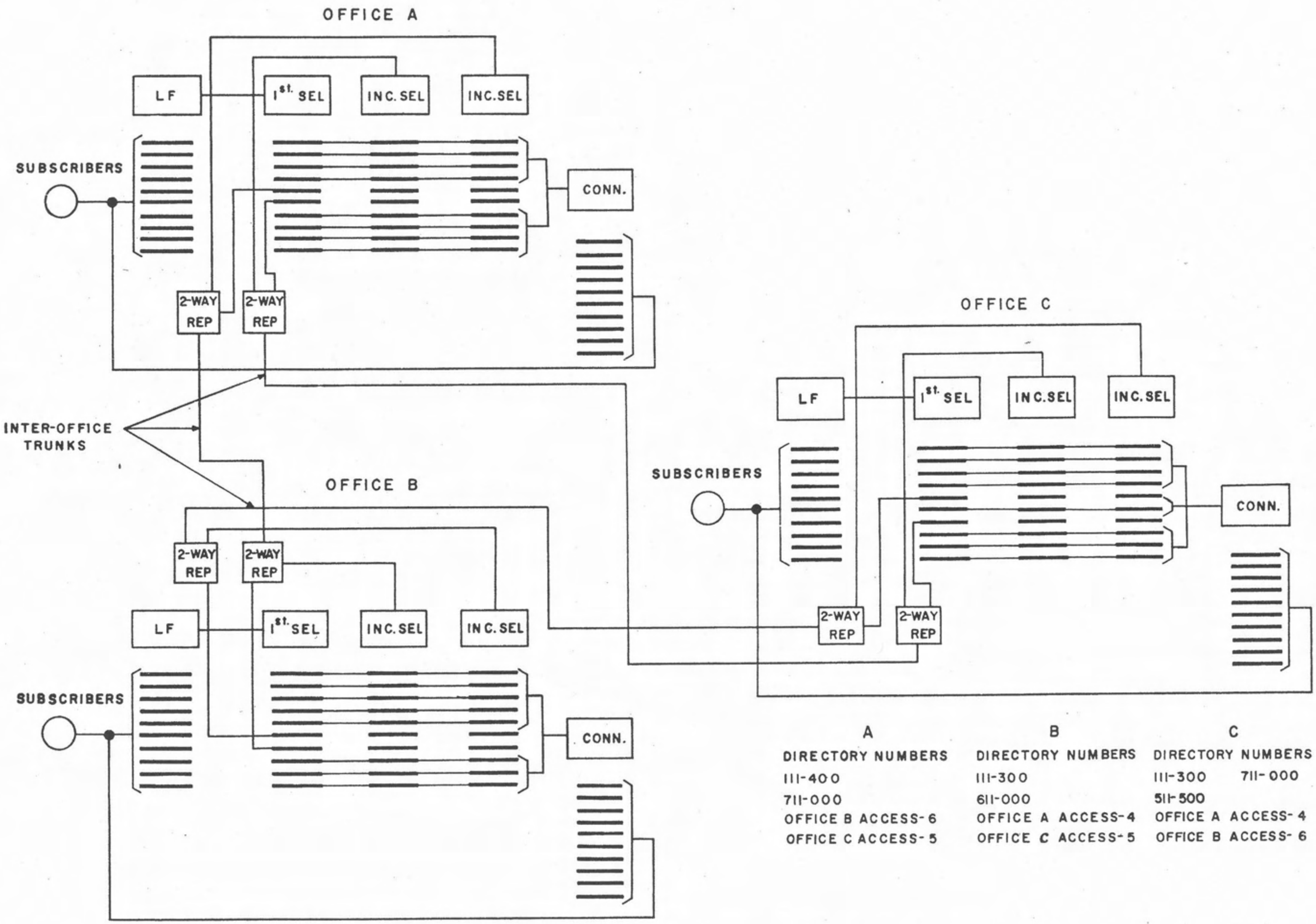

Figure 18. Three automatic offices inter-connected by two-way trunks.

Revised May 1958

Printed in U.S.A. by The Edward Keogh Printing Co. 2000 5-58

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