CHAPTER 4

STEP-BY-STEP SYSTEMS

4.1 INTRODUCTION

The Step-by-Step System of automatically establishing telephone connections, is the oldest of the several types of machine switching systems which comprise the modern telephone plant. Its invention is generally credited to Almond B. Strowger in 1889; hence, it was originally known as the Strowger Dial System.

Step-by-Step Systems are quite flexible in that they may be used for local dial service in communities requiring about 100 lines, or for large central offices requiring 10,000 lines or more. Various types of PBX's also use a Step-by-Step System.

When intertoll dialing service was first introduced, the Step-by-Step configuration was readily adapted to it. However, recent Crossbar Systems, with their many advantages, have replaced some of the larger Step-by-Step intertoll systems. Most of the future intertoll systems will be of the crossbar and electronic variety except for certain situations such as small isolated toll centers, or toll centers with local Step-by-Step systems where Step-by-Step intertoll arrangements may be installed for economy reasons.

All Step-by-Step systems are somewhat alike; however, the circuit requirements vary with the size of the system. Also, some features which are desirable in larger offices are unnecessary in smaller, less complicated units. Because of this, various types of systems have been developed to provide adequate yet economical service. Figure 4-1 shows typical Step-by-Step office equipment.

The term "Step-by-Step" is not only descriptive of the intermittent motion of the principal switches used in the system but it is also descriptive of the manner in which a call progresses, one stage at a time, from the input terminal, through a tree-like structure of switches and trunks, to the output terminal. It is a progressive control system and distinct from a common control system which first determines the input and output terminals,

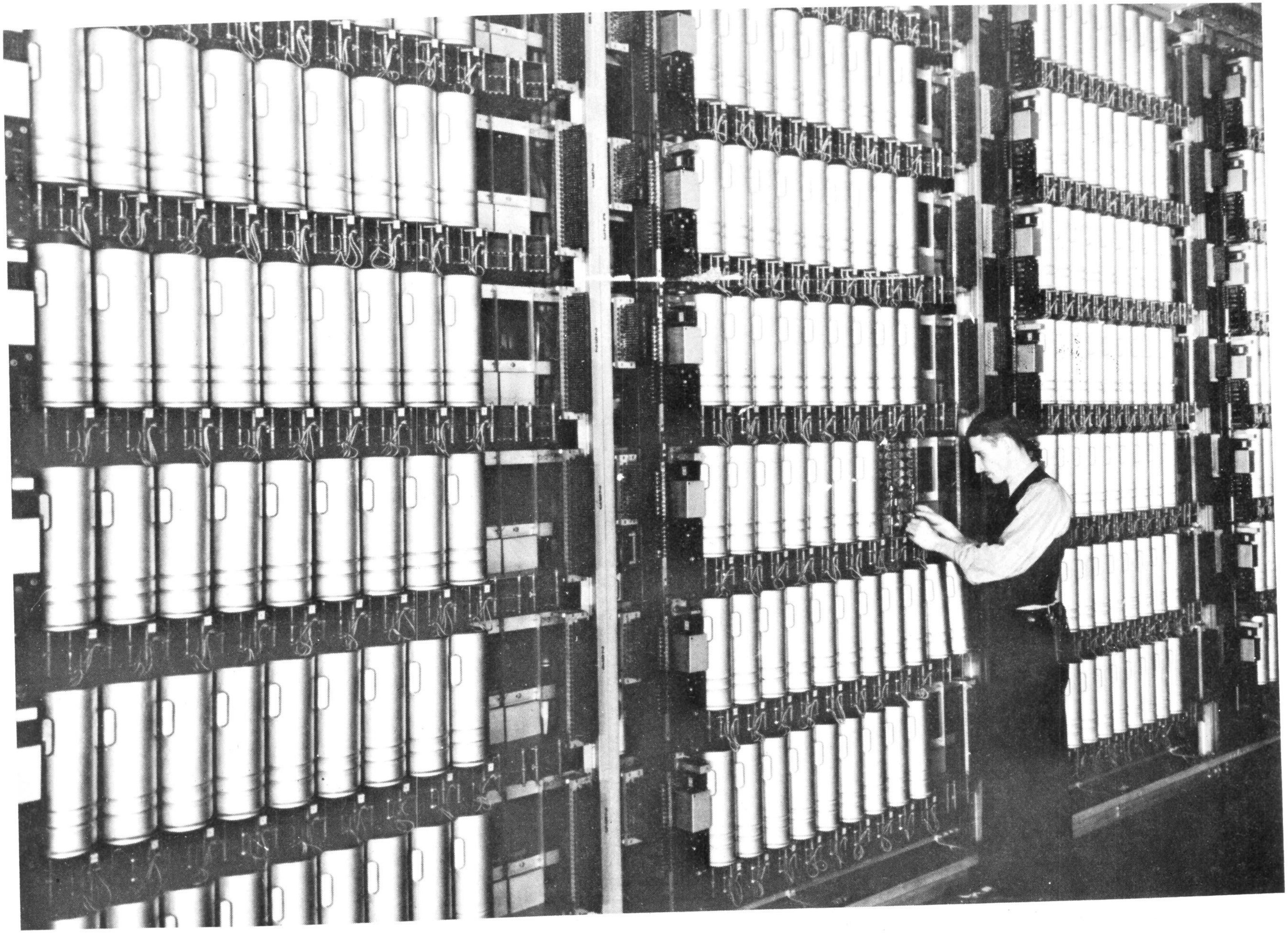

Figure 4-1 Typical Step-by-Step Dial Office Equipment

and then on the basis of this determination, causes a path to be established between them through a grid like network.

Progressive control systems are classified as direct progressive or register progressive control. Direct progressive control is defined as a system in which the switching network is under the immediate and direct control of the subscriber's calling device. A register progressive control system, on the other hand, interposes a circuit between the subscriber and the switching network that accepts and registers signals from the subscriber and which in turn controls the succeeding switches. Usually this circuit is called a register, although the registration function may be incorporated in other circuit units. The Step-by-Step system was originally a direct progressive control system. Recent developments, however, have provided various means of modifying it to a register progressive control system.

4.2 SWITCHES

In any switching network three fundamental aspects must be considered; these are the switch, the network and the control. While they are closely related and the nature of one influences the nature of the others, the Step-by-Step switch had a tremendous influence on the development of the system.

The Step-by-Step switch as shown in Figure 4-2, is the most important switching device in the system. Other switches, such as the "Plunger" type and simple rotary type, have been used for various minor concentrating jobs in early offices. The rotary type, which has shown itself to be a reliable switch, is still in use.

A. STEP-BY-STEP SELECTOR SWITCHES

Essentially the Step-by-Step switch is a two-stage rotary switch, and is shown schematically in Figure 4-3. The principle mechanical parts of this switch are shown in Figure 4-4.

The terminals are physically arrayed in banks, each bank consisting of 10 horizontal levels with 10 positions per level - a total of 100 positions as shown in Figures 4-5

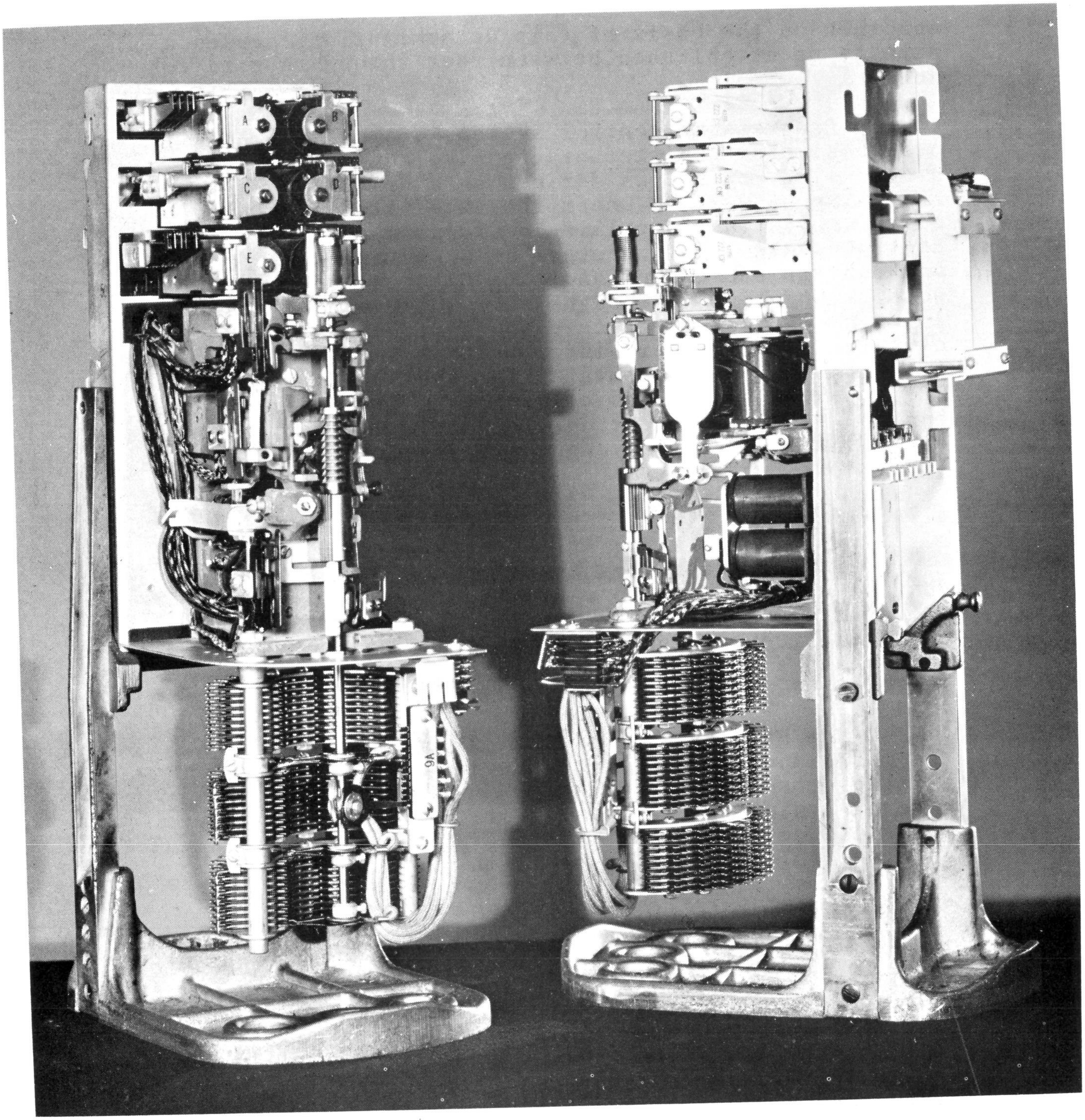

Figure 4-2 A Typical Step-by-Step Switch with Cover Removed

and 4-6. Some terminal banks have two terminals, insulated from each other, at each position, while others have only one terminal at each position. With each bank there is associated an assembly of two brushes, which are rigidly connected to a vertical shaft that is driven upward while the brushes are clear of the banks. Rotating the shaft horizontally brings the brushes into contact with the bank terminals of one horizontal level.

Two control magnets actuate the shaft and brushes during the establishment of a connection; a vertical magnet steps the shaft upward to the desired level and a rotary magnet steps the brushes along the terminals on that level. Both magnets are coupled to the shaft by means of pawl and ratchet assemblies. In both vertical and rotary stepping, the brushes move when a magnet is energized. The deenergization of the magnet permits the stepping mechanism to return to normal, preparatory to the next stepping action. As the shaft is rotated over the terminals, a helical spring located at the top of the shaft is wound up to provide a restoring torque.

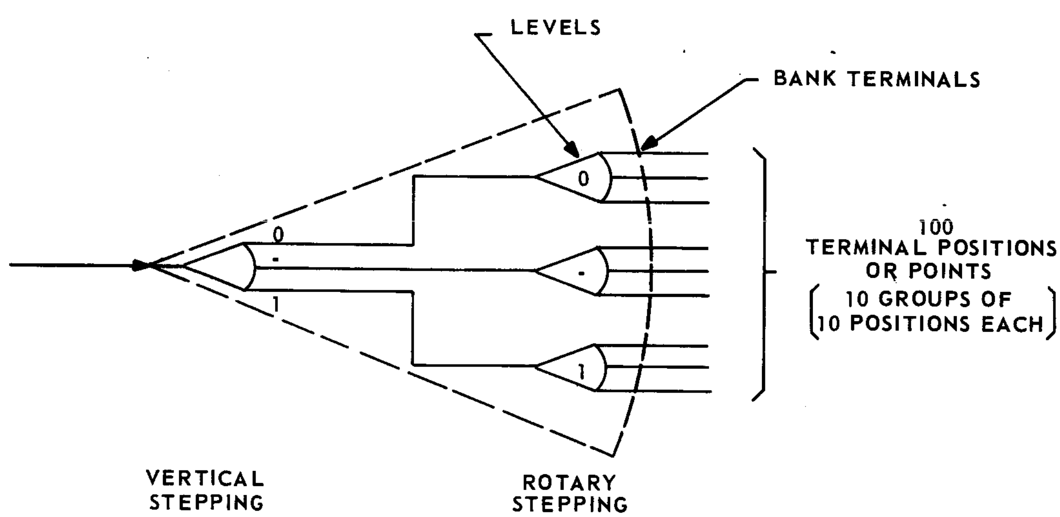

Figure 4-3 Equivalent Diagram of a Step-by-Step Switch

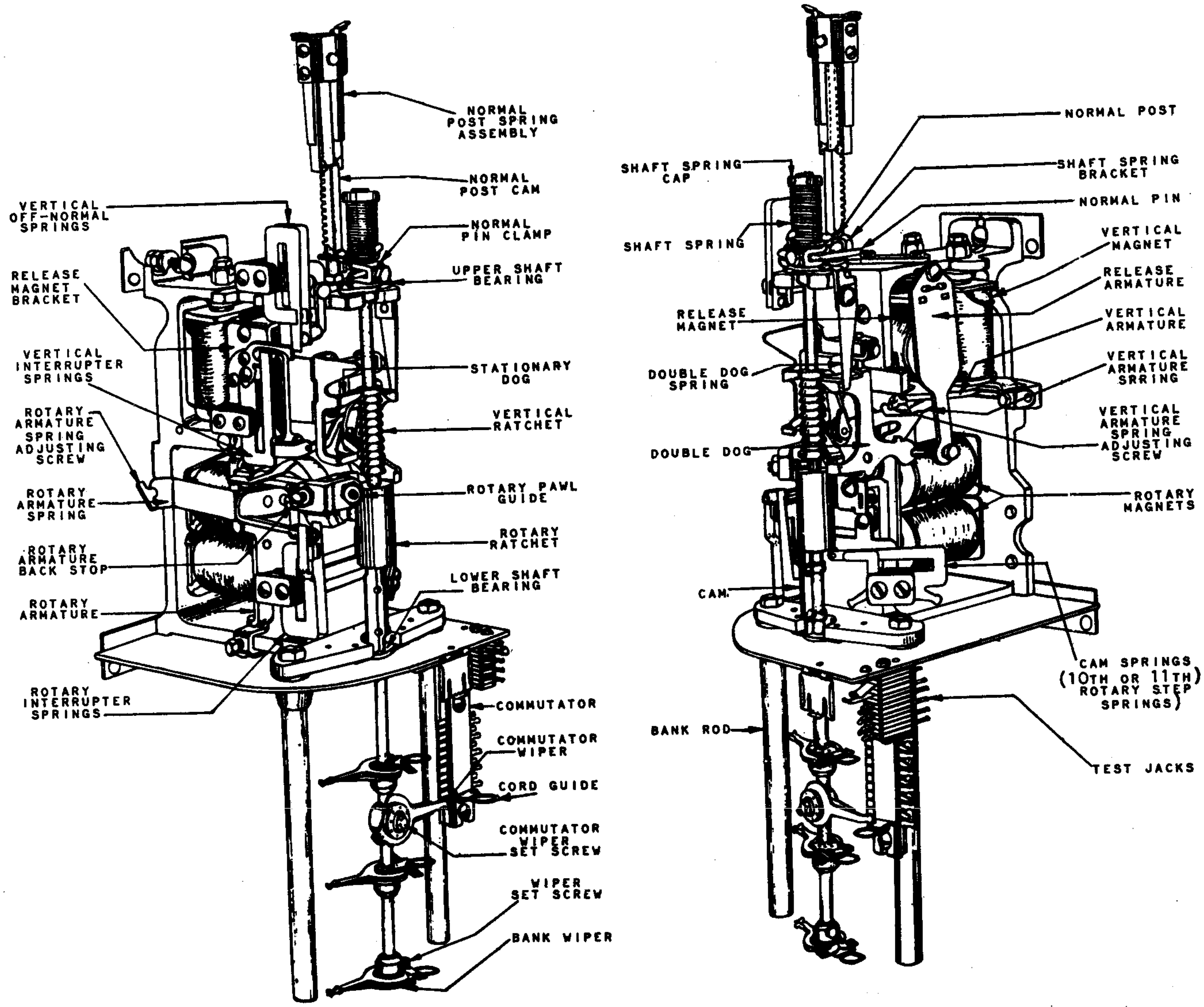

Figure 4-4 Line Finder Switch

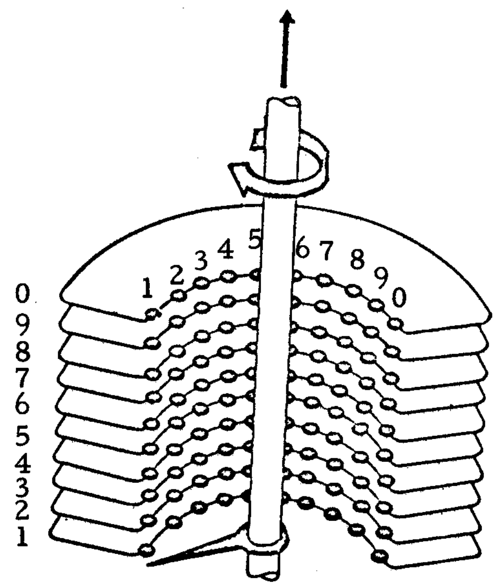

Figure 4-5 Representation of a 100-Point Bank Assembly

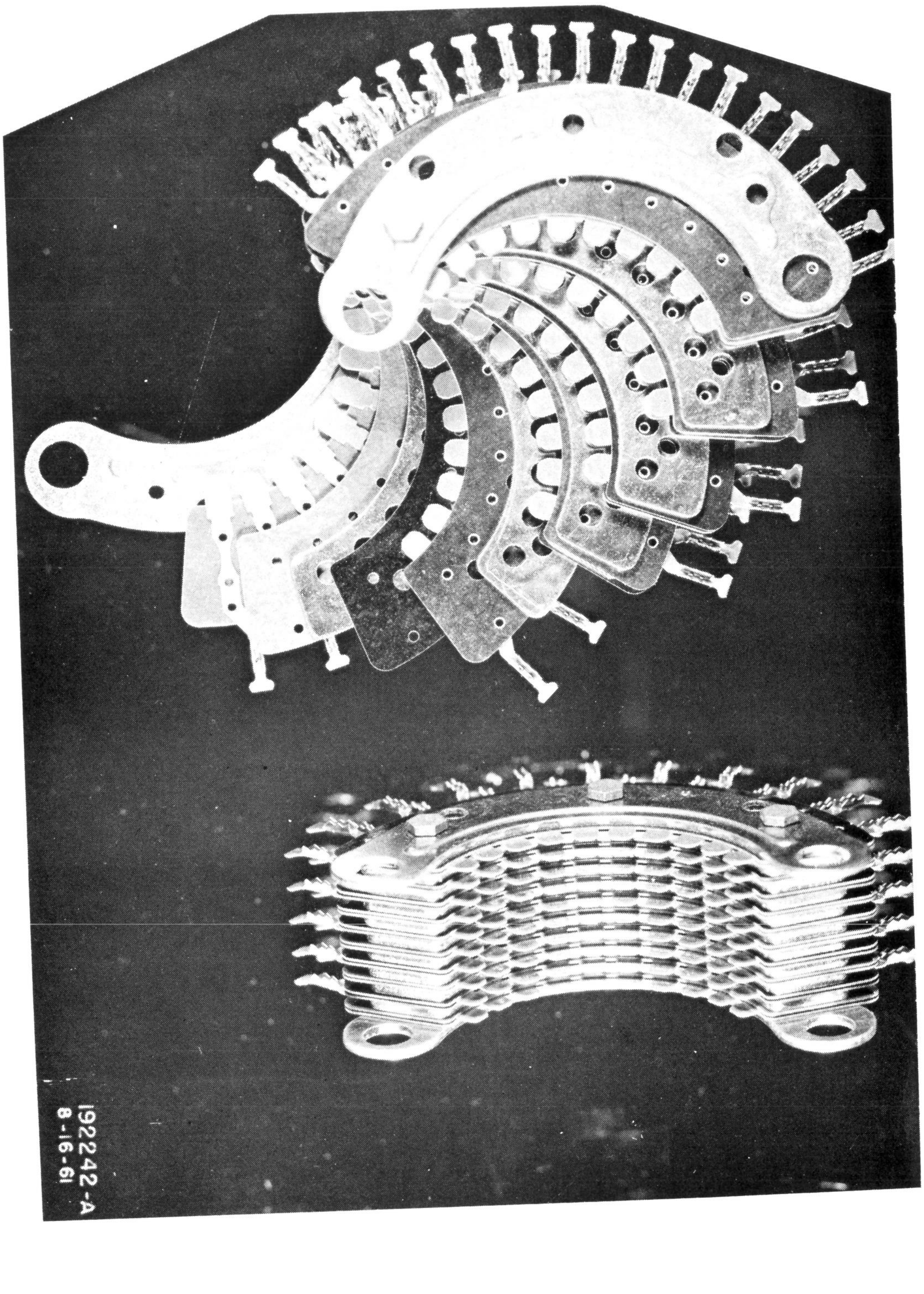

Figure 4-6 Typical 100-Point Bank

The shaft and brush assembly is restored to normal by energizing a release magnet which withdraws restraining fingers from the vertical and rotary ratchets. The helical spring is thus permitted to rotate the shaft back to its normal rotary position. Thereupon gravity drops the shaft to its normal vertical position.

Since a switch bank is limited to two terminals per position, a separate bank and brush assembly must be provided for each pair of conductors to be cut through the switch. Switches may be furnished with as many as four switch banks to cut through eight leads. The switch in Figure 4-2 is equipped with three banks.

Various contact arrangements controlled by the switch magnets and brush shafts are provided where needed to aid in controlling the switch. Interrupting contacts permit both vertical or rotary self-stepping, hunting feature. When the switch steps past the tenth and final rotary bank position, a set of contact springs are activated. The operation of these springs is referred to as making the "11th rotary step" which indicates a failure to find a desired terminal.

Since the basic step-by-step switch can be operated in one of two modes: select or hunt, it is theoretically possible, for a two-stage switch to operate in one of four modes; select-select, select-hunt, hunt-hunt and hunt-select. Actually step-by-step switches utilize only the first three modes, select-select, select-hunt and hunt-hunt.

B. ROTARY SWITCHES

Rotary-type selector switches consist, primarily, of arcs of terminals over which associated wipers pass. An electromagnet mounted on the switch assembly provides power to move the wipers from one terminal position to the next; each separate energization and deenergization cycle of the magnet causes the wipers to move one position. There are two basic types of rotary switches: forward-action or direct driven switches, which step from one terminal to the next terminal on the energization of the magnet; and back-acting or spring driven switches, that step on the deenergization of the magnet. The control magnet of either type of switch is known as the "step magnet."

When the step magnet of a forward-acting switch is energized, a pawl coupled to the magnet armature is forced against the teeth of a ratchet wheel on the shaft supporting the wipers, causing the shaft to rotate through a small angle, thus moving the wipers from one terminal to the next. A detent engaging the ratchet wheel insures that the wipers remain on the terminal just reached when the magnet is deenergized. In the case of a back-acting switch, energization of the step magnet pulls a pawl away from the ratchet wheel on the wiper shaft, against the force of a spring attached to the frame of the switch. When the magnet is deenergized, the pawl is pulled back by the spring, engaging a tooth on the ratchet wheel and advancing the wipers a single step.

Some rotary switches may be caused to step continuously in the same rotary direction over the same set of terminals, whereas others, after stepping their wipers over the associated arcs, must be returned to a normal position before the wipers can again be moved over the arc terminals. These two types of switches are designated <u>nonhoming</u> and <u>homing</u>, respectively. Switches of the homing type are normally equipped with a second magnet, a release magnet, which allows a spring to restore the wipers to the starting position.

Wipers may be either of two types: <u>bridging</u>, in which adjacent arc terminals are short-circuited by the wiper as it steps from one to the other; and <u>nonbridging</u>, in which the wiper leaves one terminal before it makes contact with the next.

Illustrated in Figure 4-7 is a back-acting rotary switch consisting of six arcs of 22 terminals each. The wipers are double-ended so that, when one wiper end has passed over the half-circle of 22 terminals, the other end is in position to start stepping over the same 22 terminals. Occasionally, single-ended wipers mounted in pairs staggered 180 degrees apart are utilized on a similar switch so that two adjacent arcs of 22 terminals may be employed as a continuous bank of 44 terminals. The switch may be driven by external circuit pulses at a rate of up to 25 or 30 steps per second; a rate of 50 or 60 steps per second may be realized if the switch runs under self-interrupted control by using the break contact of the stepping magnet.

A forward-acting ten-terminal two-arc switch is illustrated in Figure 4-8. In addition to the stepping magnet, this switch is furnished with a release magnet, shown in the lower left corner. In the normal position, the wipers stand in the position just preceding the first terminal. The switch may be driven at speeds up to 25 steps per second.

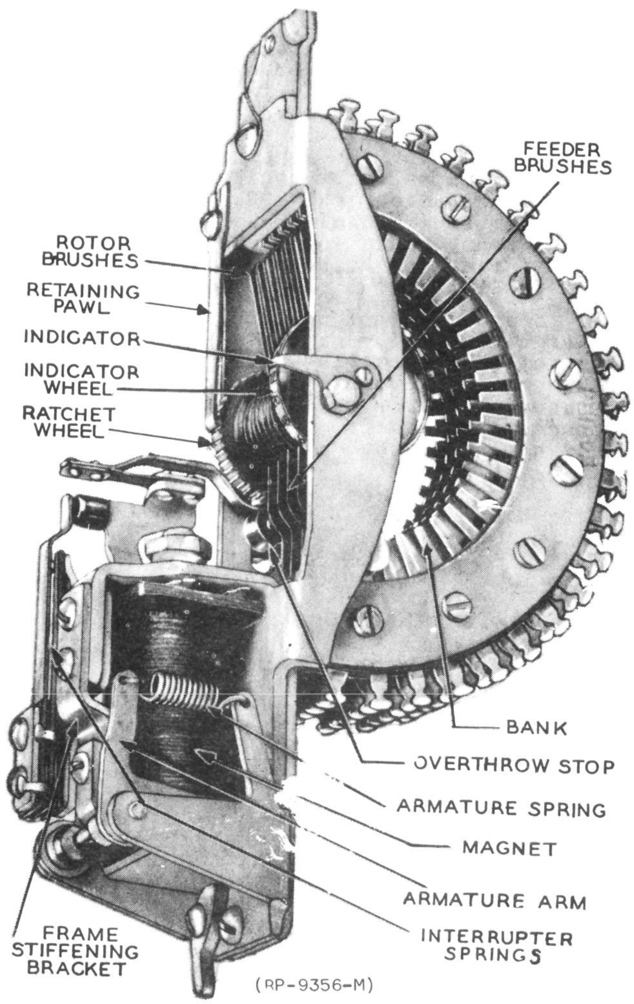

Figure 4-7 22-Point Rotary Selector

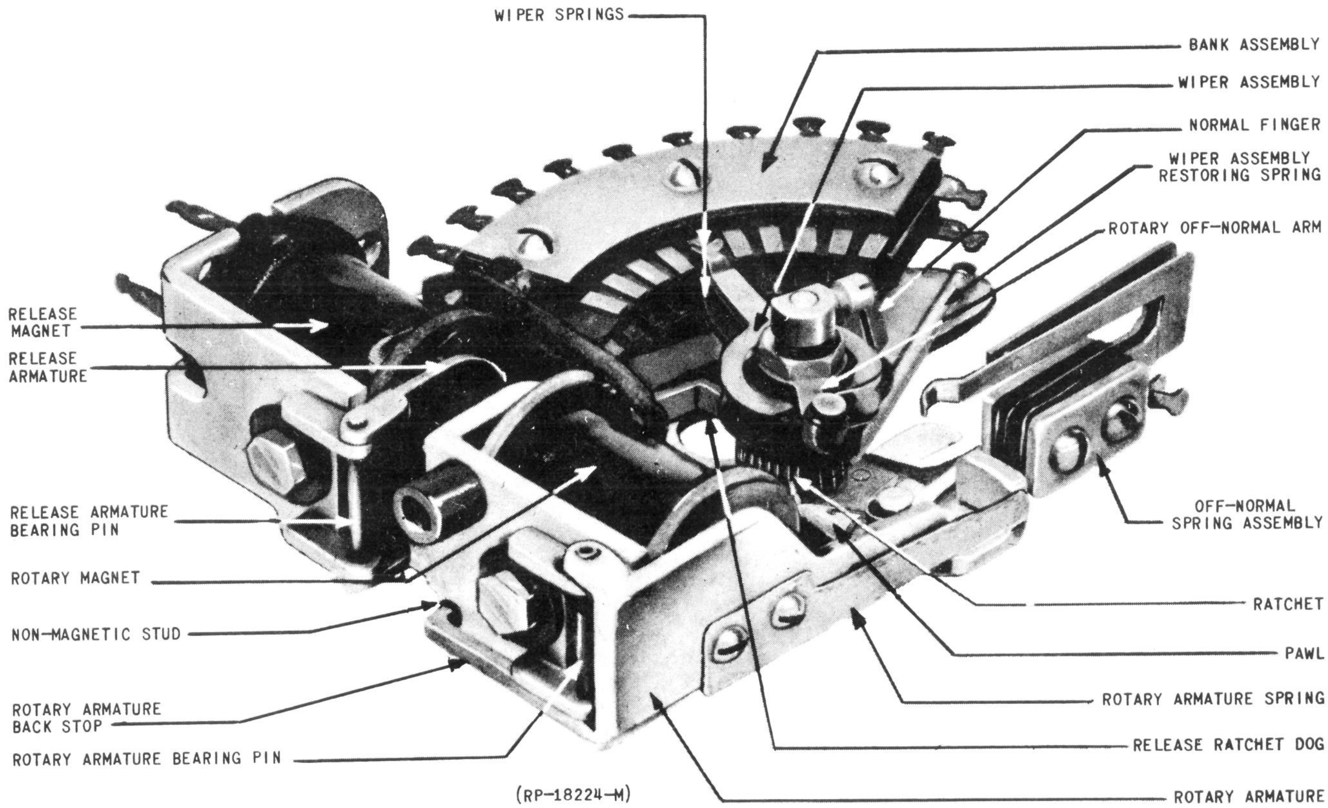

Figure 4-8 10-Point Rotary Selector

C. PLUNGER SWITCHES

Another switch which was widely used for concentration purposes is the plunger switch. This switch has been almost entirely superseded by the line finder switch, but they were widely used in early offices and are still in operation today.

The principal parts of a plunger switch is represented in Figure 4-9. It consists of a relay (not shown), a magnet, a plunger and a segment of a bank having ten sets of terminals arranged in an arc. The fixed contacts of the ten sets of terminals are multipled to a single input, while the flexible contacts each connect to a separate output.

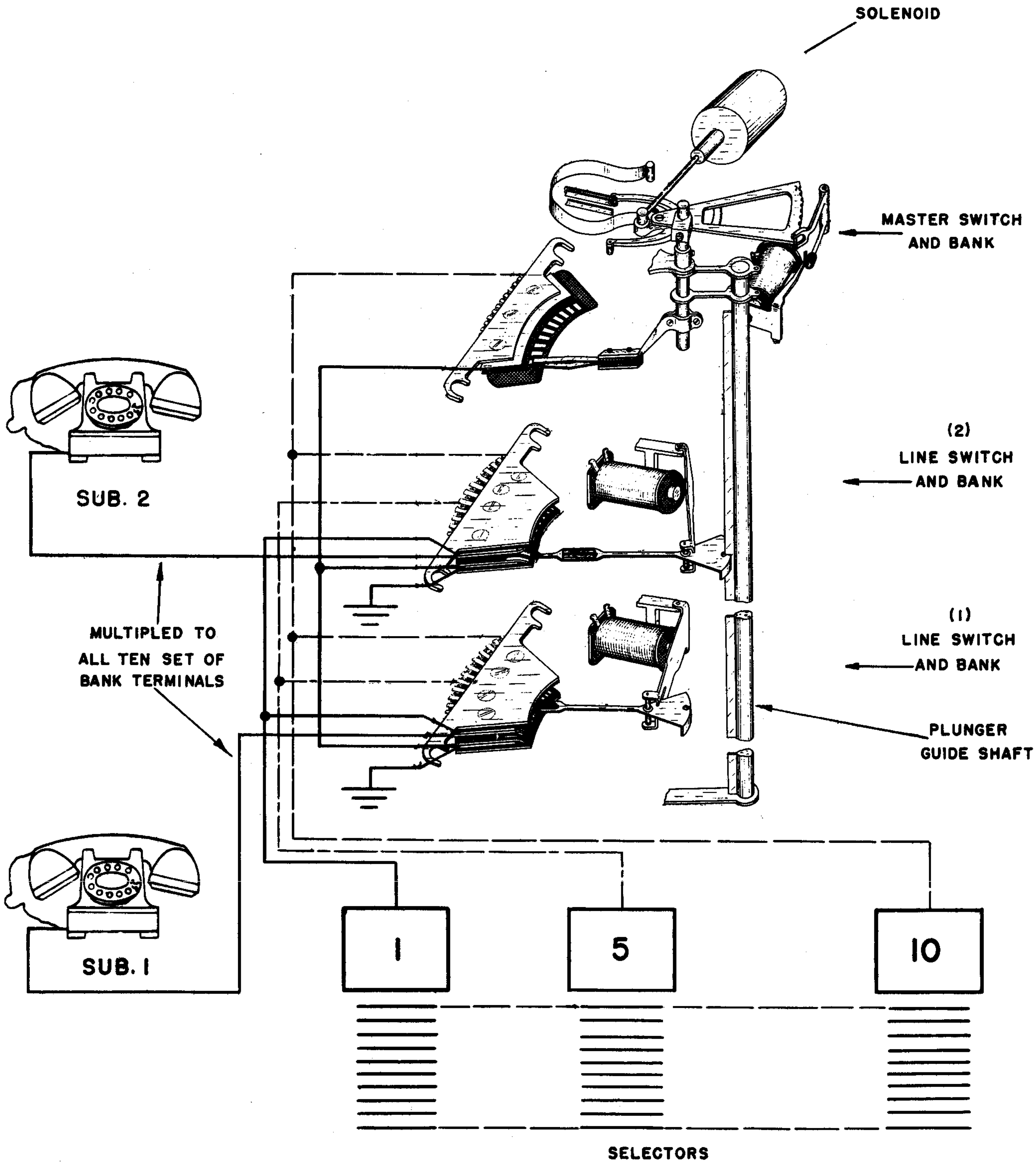

Figure 4-9 Plunger Switch

The "wing" of the plunger is slotted and engages a guide shaft which is capable of being oscillated through about 40 degrees. The motion of the shaft enables the plunger to be aligned with any one of the ten sets of terminals.

When an input demands attendance, the relay is energized which in turn energizes the magnet causing the switch to "plunge in" and extend the input to an output. While the switch actually is a crosspoint switch, it is convenient to consider it to be a 10-point rotary hunting, backward-facing switch. In this particular case the inputs are on the bank terminals and the output is via the wiper.

A number of plunger switches are associated with the same group of trunks by multipling the outputs, as shown in Figure 4-10, and by controlling the plungers with the same guide shaft as shown in Figure 4-9.

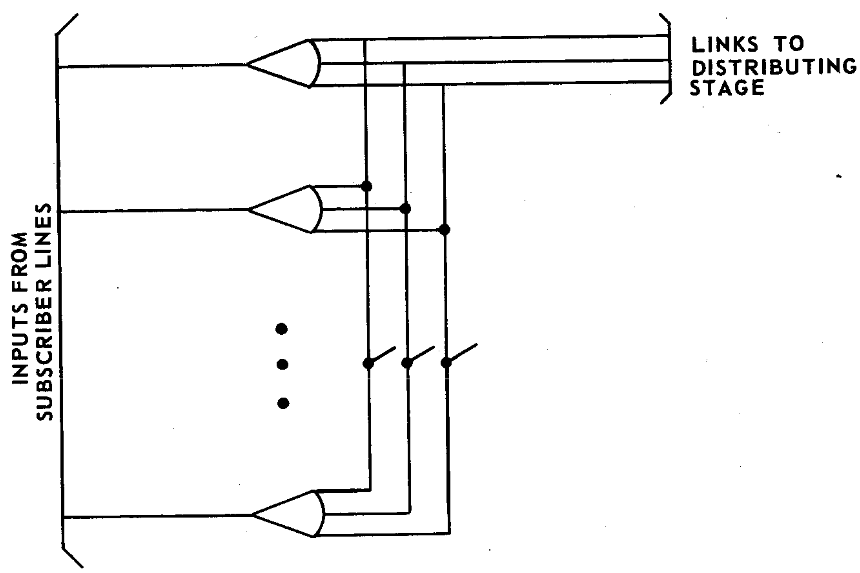

Figure 4-10 Concentration Stage Unit Using Multipled Output Line Switches

A master switch is provided for each guide shaft. Supervisory leads from each trunk terminate on a 10-point master switch bank and serve to "mark" busy trunks. The master switch rotates and controls the guide shaft so that it will only come to rest opposite an idle output. It also prevents switches from "plunging in" during the time it is hunting for an idle trunk.

When the line switch plunges in, it disengages itself from the shaft and the input is extended to the trunk, marking the corresponding terminal of the master switch bank to indicate that it is no longer idle. The master switch rotates the shaft and all engaged plungers from left to right until it reaches an idle trunk. When the shaft reaches the right hand position (Trunk No. 1) and finds it busy, a solenoid rotates the shaft, and plungers, back to the left hand position (Trunk No. 10) where the master switch continues its left to right search for an idle trunk. Hence a plunger switch is "<u>preselecting</u>" as opposed to a finder which is "<u>post selecting</u>."

When an input no longer requires attendance, the plunger is released. On some types of switches, known as self-aligning, the plunger is immediately aligned with, and engaged to, the shaft regardless of its position, while in other switches the plunger will "come out" but not engage the shaft until the shaft again swings in front of the trunk and "picks it up."

4.3 GENERAL SWITCHING PRINCIPLES

A. <u>GENERAL</u>

The primary objective of all switching systems is to permit any subscriber to establish a connection with any other subscriber within that system. Also, a switching system must provide the most economical means of switching various paths together.

The paths in the Step-by-Step system are one-way, since the connections are set-up or controlled through the switching elements in one direction. This characteristic suggests that a path may be divided into an originating and terminating stage.

The originating-terminating concept permits all connections from subscriber to subscriber to follow the same general pattern. The plan shown in Figure 4-11 embodies the concept of originating networks being linked to terminating networks by means of three kinds of trunks; outgoing, incoming and intraoffice.

Each call requires a trunk; consequently, the number of trunks which are required is a function of the number of simultaneous calls in an office, since the trunk or trunks used are held for the duration of the call. Obviously this is less than the total number of subscribers. Hence, one requirement placed upon the originating network is that it must concentrate a large number of inputs (subscribers' lines) into a comparatively small number of outputs (trunks) and, conversely, the terminating network must be able to expand the inputs (trunks) into a greater number of outputs (subscriber lines).

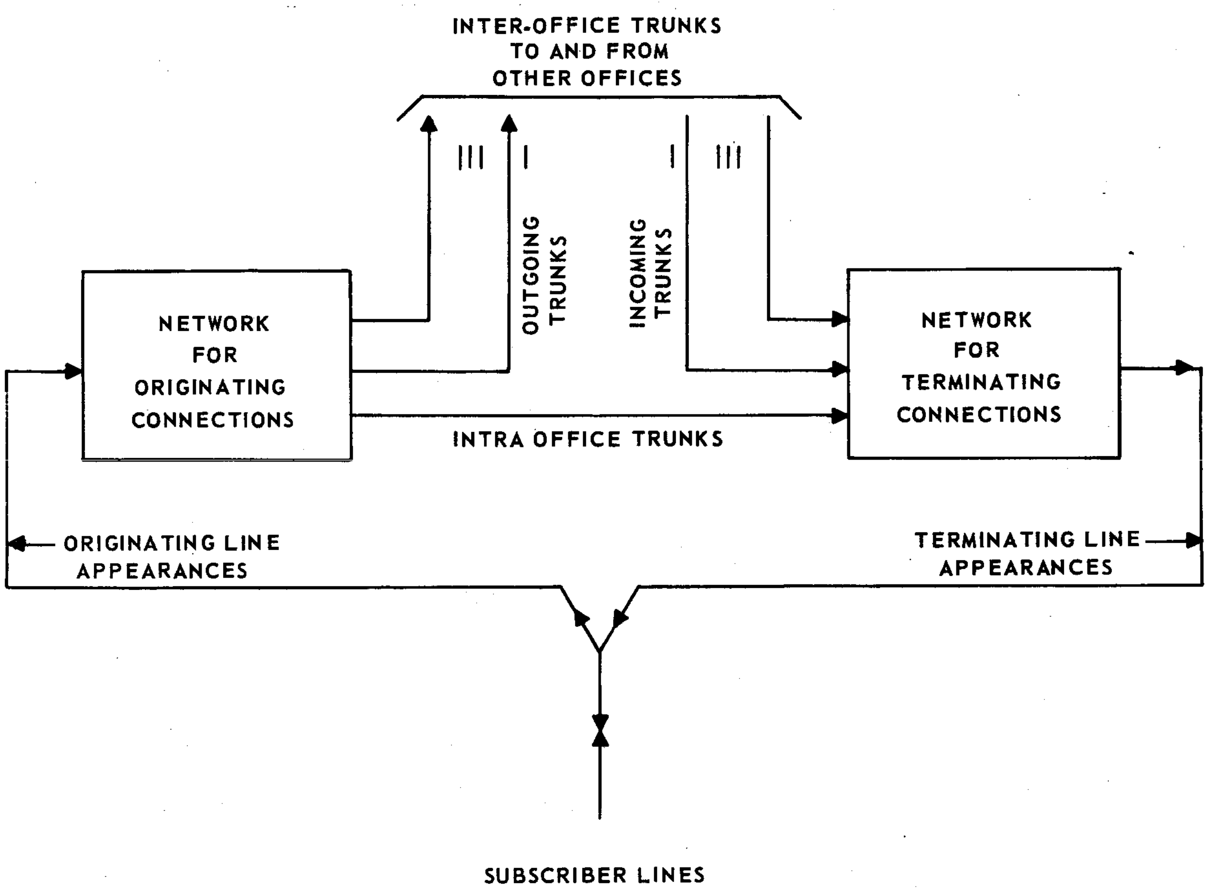

Figure 4-11 Originating and Terminating Connections

Figure 4-11 indicates that the originating network connects to a group of intraoffice trunks as well as several groups of trunks to each of the several "other" offices. A second requirement of the originating network, is that any subscriber's line must have access to every group of inter- or intraoffice trunks, but not necessarily to every trunk in each group in order to reach any other subscriber. However, in the terminating network all trunks in each group must have access to all subscribers.

The requirements placed upon the originating and terminating stages are symbolized in Figure 4-12. It can be seen that the originating network consists of a concentrating stage, where subscribers' lines compete with each other for a connection to the distributing stage. The distributing stage has the same number of inputs and outputs and provides a means of selecting a trunk to the desired terminating office. The terminating stage has a similar distributing stage and an expansion stage.

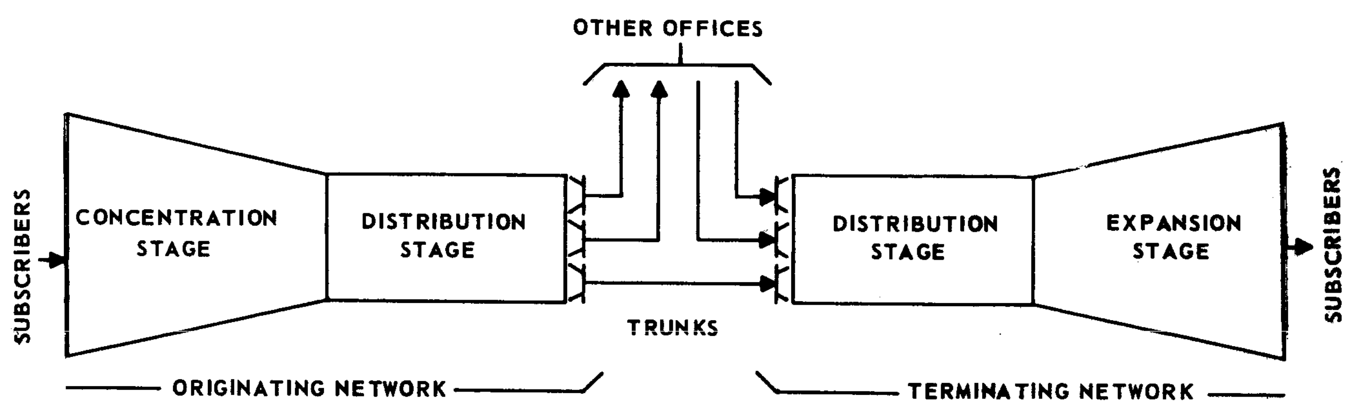

Figure 4-12 Basic Switching Network

The access of a switch is limited by the number of its points; consequently, a fundamental problem in designing a network is to provide access for a particular path that is equal to or greater than the access provided by the basic switch. This is particularly true in the step-by-step system which employs low access switches.

B. CONCENTRATION STAGE

The purpose of the concentrating stage is to provide a means of connecting a large number of subscriber lines to a smaller number of trunks to the distributing stage. Two switches are available for this purpose, the older arrangement utilizing line switches and the new arrangement utilizing line finders. In either case, the concentration stage must recognize when a call is being originated, provide a trunk to the distributing stage and guard (busy out) the calling subscriber's line so that the terminating network cannot connect to it.

(1) Line Finders

The line finder method shown in Figure 4-13 used either a 100- or 200-point line finder switch. When a subscriber originates a call, the switch hunts for the calling line and extends the connection to a permanently associated first selector.

A line finder switch is a concentrating device, or backward-facing switch, operating in the hunt-hunt mode. It is used to concentrate subscriber lines.

100- and 200-point line finders are available. When the switch is called upon to make a connection, it hunts for the terminal to which it must connect. However, in order to do this, control circuits must mark not only the terminal but also a segment of a commutator to indicate the level on which the terminal lies. The switch first steps vertically, examining the commutator to find the proper level, and when it is found, the switch then steps horizontally to find the marked terminal.

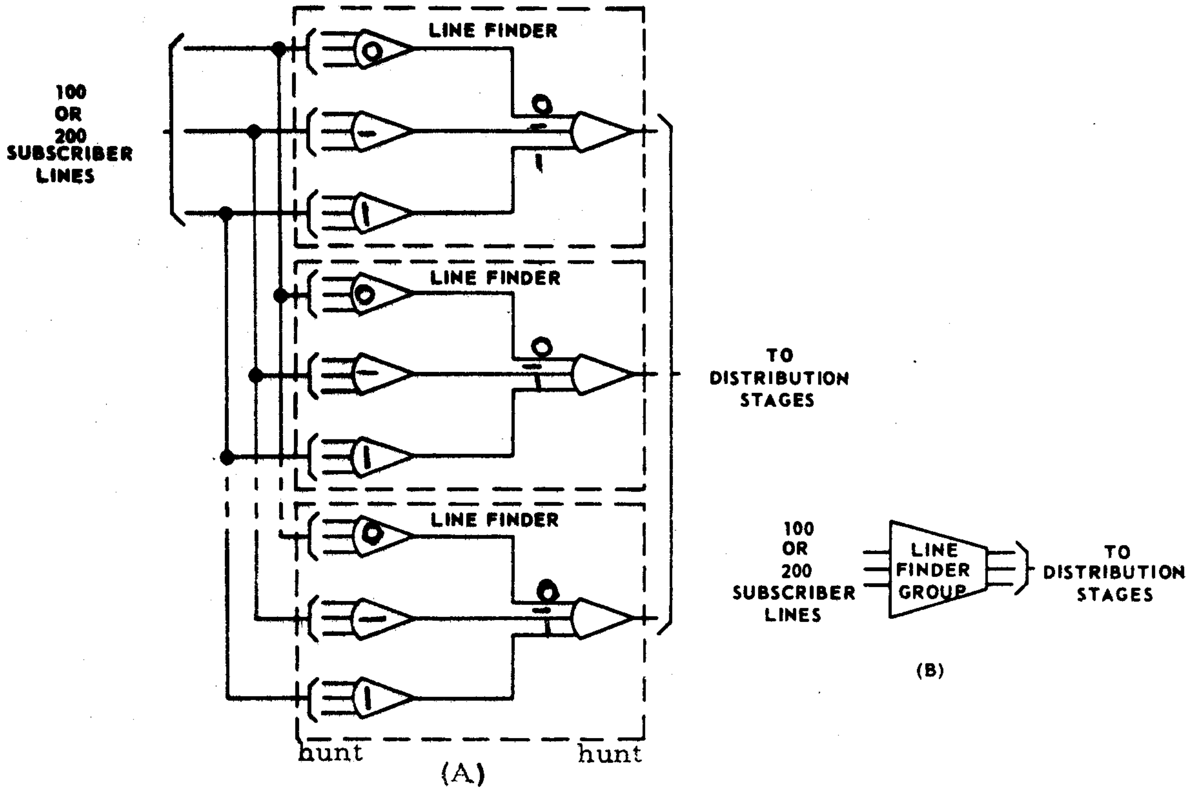

Figure 4-13 Concentration Stage Unit Using Multipled Line Finders

With the 200-point line finder, each of the switch positions is associated with two lines. As the switch conducts the horizontal hunt for the marked terminal, it simultaneously examines the terminal associated with both lines. When it finds the position, it then determines which of the two lines at that position is marked and then connects to it. To do this, the switch uses two sets of brushes or wipers, one set for the "upper" and the other for the "lower" set of terminals.

To discriminate between certain bank terminals, some switches are furnished with so-called "normal post" contacts. These contacts are actuated when the shaft reaches certain vertical levels, which thus enables the switch to discriminate between vertical levels. A cam mounted near the top of the shaft can be adjusted to operate these contacts at any desired level or levels.

Since the location of a subscriber's line in in a line group has no relation to the listed number, it may be relocated to other groups as desired.

(2) Line Switches

The line switch method utilizes a forward-facing hunting switch, as shown in Figure 4-10, for each line. A forward-facing switch is one in which there are a multiplicity of outputs for a singular input. The switch may be a plunger switch or a rotary switch but in either case the switch preselects an idle trunk and then establishes a connection to the trunk when attending a subscriber's line. The trunks are connected to first selectors in the distributing stage.

Since the line switch method requires one switch per line, it is at a cost disadvantage compared to the line finder method. As a result, plunger switches are no longer being installed except as additions to existing equipment.

(3) Rotary Switches

Rotary line switches, connected as shown in Figure 4-10, are used to a limited extent for groups of subscribers having a particular class of service, such as post-pay coin lines, which are so small that it would not be economical to use 100-point line finders.

C. DISTRIBUTION STAGE

The network for the originating and terminating distribution stages are essentially similar to each other. The basic distribution network consists of one or more stages of switches known as selectors. The number of selector stages depends upon the number of digits to be dialed and the type of selectors employed.

The selectors (see Figure 4-14) are forward-facing switches operating in the select-hunt mode. Each switch responds to D-C dial pulses at a nominal rate of 10 pps, the number of pulses in the pulse train represents the numerical value of the digit. The brushes are driven upward, one level, for each pulse that it receives. Hence, it will select that level of terminals which corresponds to the digit dialed.

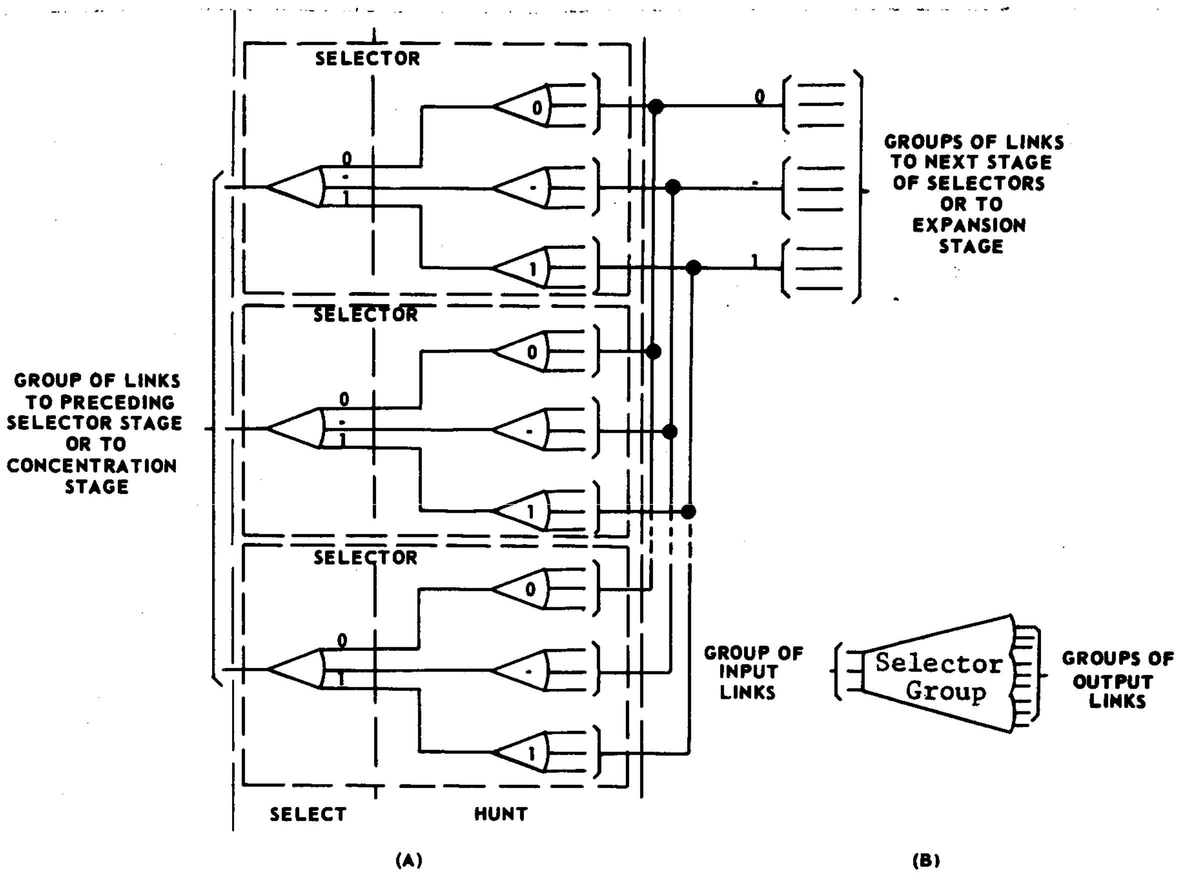

Figure 4-14 A Group of Step-by-Step Selectors in the Distribution Network

Upon selecting a level it will hunt horizontally for an idle terminal, during the interval between digits. After finding an idle terminal, it will cut the connection through to the next switching stage so that the next digit dialed will direct the succeeding switch. If an idle terminal is not found, the selector will step beyond the bank to the "eleventh rotary step" position where path-busy tone will be returned to the subscriber.

With the selector functioning in this manner, each digit dialed requires a selector stage.

The local selector stages are named to indicate the digit to which they correspond; hence, the first and fifth selector stages are controlled by the first and fifth digits, respectively, of the dialed number. Selectors to which incoming trunks connect are termed incoming selectors; i.e., incoming fourth selector.

In order to distribute traffic evenly over the distributing network, the trunks from the line finders are connected to the first selectors in a fixed pattern. The trunk distribution plan is indicated by Figure 4-15.

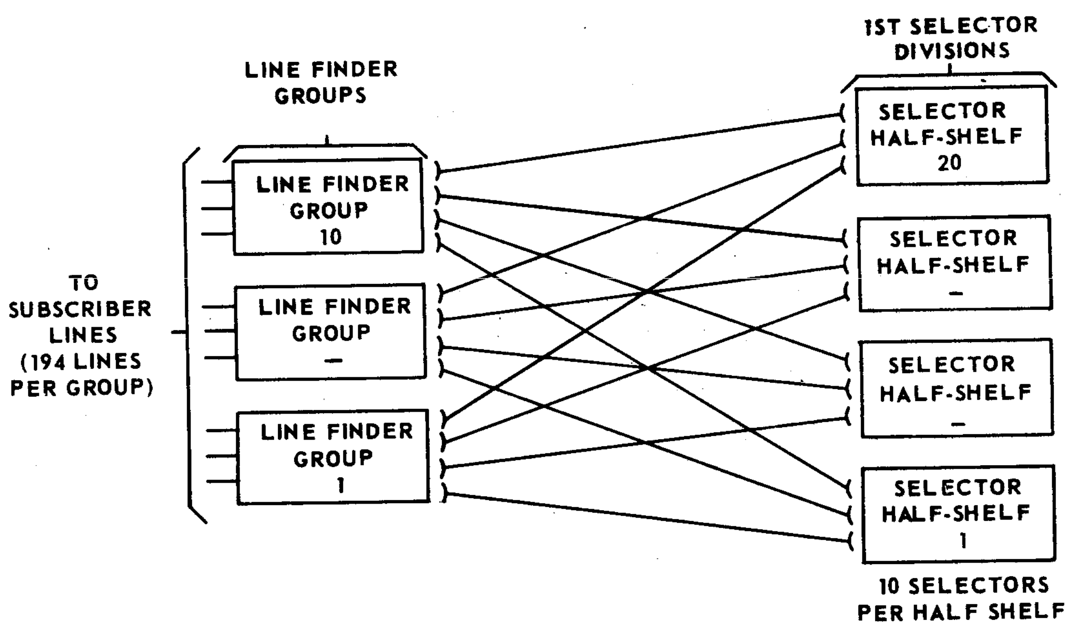

Figure 4-15 Plan for Distribution of Links From Line Finders to First Selector Switches

Selector switches are grouped in accordance with traffic and equipment considerations. The number of switches in a group is equal to the number of inputs which, of course, is dictated by the traffic to be handled. The outputs of a group are multipled and connected by trunks to a succeeding distribution stage or to the expansion stage.

D. EXPANSION STAGE

The purpose of the expansion stage is to connect a smaller number of trunks to a larger number of terminating subscribers. This is accomplished by having the last stage of a call completed through a group of switches known as connectors. The connector is a forward-facing switch operating in the select-select mode under direct control of dial pulses of the last two digits. The switch is shown schematically in Figure 4-16. In operation, the switch steps to the level corresponding to the next-to-the-last digit (tens digit) of the calling number and then steps horizontally to the terminal corresponding to the last digit (units digit). Before connecting to this terminal, it tests to see if the called line is busy. If it is, it returns lines busy tone; if not, it connects to the line, applying the proper ringing signal. When the called line answers, it removes ringing and indicates to the preceding trunks and switches, usually for charging purposes, that the call has been completed.

The subscribers connected to the 100 terminals to which the connector switch has access form a group known as a "connector hundreds group." A "connector hundreds group" is a group of 100 consecutive numbers differing only by their tens and units digits.

The number of switches in each group depends upon the expected amount of traffic and must be equal to the number of trunks from the distributing network. Since the location of each subscriber is exactly the same on the banks of each switch in the group, it is obvious that the banks of all switches in the group must be multipled straight through.

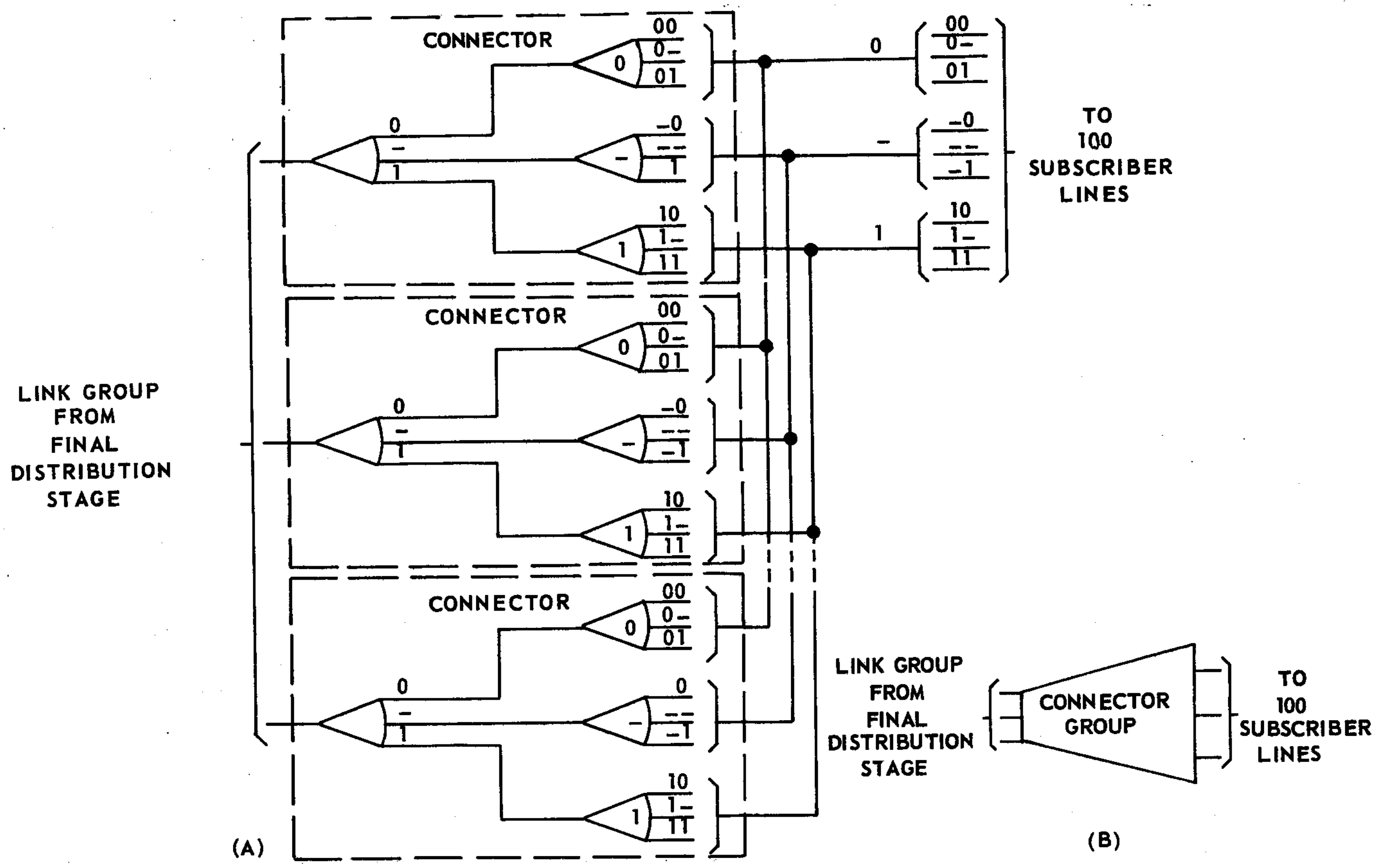

Figure 4-16 Group of Step-by-Step Connectors in Expansion Stage

There are several different types of connectors. They may be categorized as to the type of traffic which they handle: toll, local, or combined toll and local, or according to the types of lines to which they connect: two, four, eight or ten-party; terminals per station or terminals per line, or according to the type of ringing; full or semiselective, code ringing, etc.

Space limitations do not permit discussing the various categories of connector switches except for one important category known as "hunting." A connector operating in the pure select-select mode previously described is called a nonhunting connector. Sometimes a customer will subscribe to several lines but will have only one number listed in the directory. The group of lines is referred to as a PBX group and means are provided so that when the listed number is dialed, a connection is made to any idle line in that group. This is accomplished by a hunting connector.

When the directory number of a PBX group is dialed, a hunting connector selects the dialed terminal. If it is busy, the switch will hunt over successive terminals in the group in a left to right, bottom-up, order.

A rotary hunting connector is arranged to hunt over adjacent terminals on one level only, and may be used for PBX groups of 10 or less lines. Several groups may be located on one level. Level hunting connectors are arranged to hunt successively over terminals on adjacent levels and may be used for PBX groups of up to 100 lines. PBX grouping is accomplished by strapping together a "control" terminal associated with each line. If no idle line is found in the group, line busy tone is returned to the customer.

4.4 THE SWITCHING NETWORK

A. SWITCHING TRAINS

(1) 5-Digit Call

A generalized diagram of a 5-digit office is shown in Figure 4-17. The diagram shows the concentration, distribution, and expansion stages and also indicates the terminations within the network of incoming and outgoing trunks. Actually, the network shown represents three central offices within the same building. These offices have the single digit office codes 5, 6 and 8. Located nearby are two additional offices, 3 and 4.

When a subscriber lifts his receiver to place a call, a line finder having access to this subscriber's line, hunts and connects to the line. The associated first selector is seized and returns dial tone to the subscriber.

The first digit dialed by the subscriber determines which of the five offices the call is for. If the call is for one of the offices in the same building, the first digit drives the first selector to the level corresponding to that office. At the conclusion of the pulse train, the switch hunts over that level for an idle link to a second selector and cuts through the tip, ring and sleeve conductors. This same process is repeated in the second and third selector stages. In each case, the selector must find an idle trunk and cut through to it during the inter-digital time.

After the third selector has found and cut through to an idle trunk, the subscriber is connected to a connector switch. As he dials the fourth and fifth digits of the called number, the subscriber drives the connector to the desired line of the 100 lines it serves. The connection is established as soon as the subscriber finishes dialing. At this point, the connector tests the called line and, if it is idle, connects ringing current to it until the called line answers or the call is abandoned. If the line is busy, the connector returns busy tone to the calling subscriber. It is possible that during the establishment of a connection, a selector switch may have found all available links busy. In such a situation, the selector makes the 11th rotary step and returns an all-paths-busy signal to the subscriber.

If the dialing area contains a large number of lines, the office codes may of necessity be either 2 or 3 digit codes. Each additional digit dialed requires an additional stage of selectors in the switching train.

Each switch unit in the network provides supervisory control over all preceding switches in the train as a connection is being established.

This supervision is relinquished when the next switch in the sequence assumes control. Thus, during conversation, the connector maintains supervision of the entire connection. This connection is held until the calling subscriber hangs up.

(2) 7-Digit Call

(a) Using 7 Switching Stages

Figure 4-18 is a generalized diagram showing the originating portion of an office arranged for 7-digit switching. The diagram shows the concentration and distribution stages involved. The network shown represents 2 central offices within the same building and a portion of the other offices within the local dialing area.

A call progresses through the network in the same manner as a 5-digit call. The switching network contains two more stages of switches, 4th and 5th selectors and the customer must dial a total of 7 digits.

The additional digits are used in the originating network in selecting trunks to the local office or building. Reference to Figure 4-18 indicates that with some calls 3 digits of the office code are used in selecting outgoing trunks and in other calls only two digits of the office code are used, as in the case of codes 23- and 93-. All of the offices using 23 for the first two digits are located in one building. In this case the incoming third selector routes the call to the proper local office.

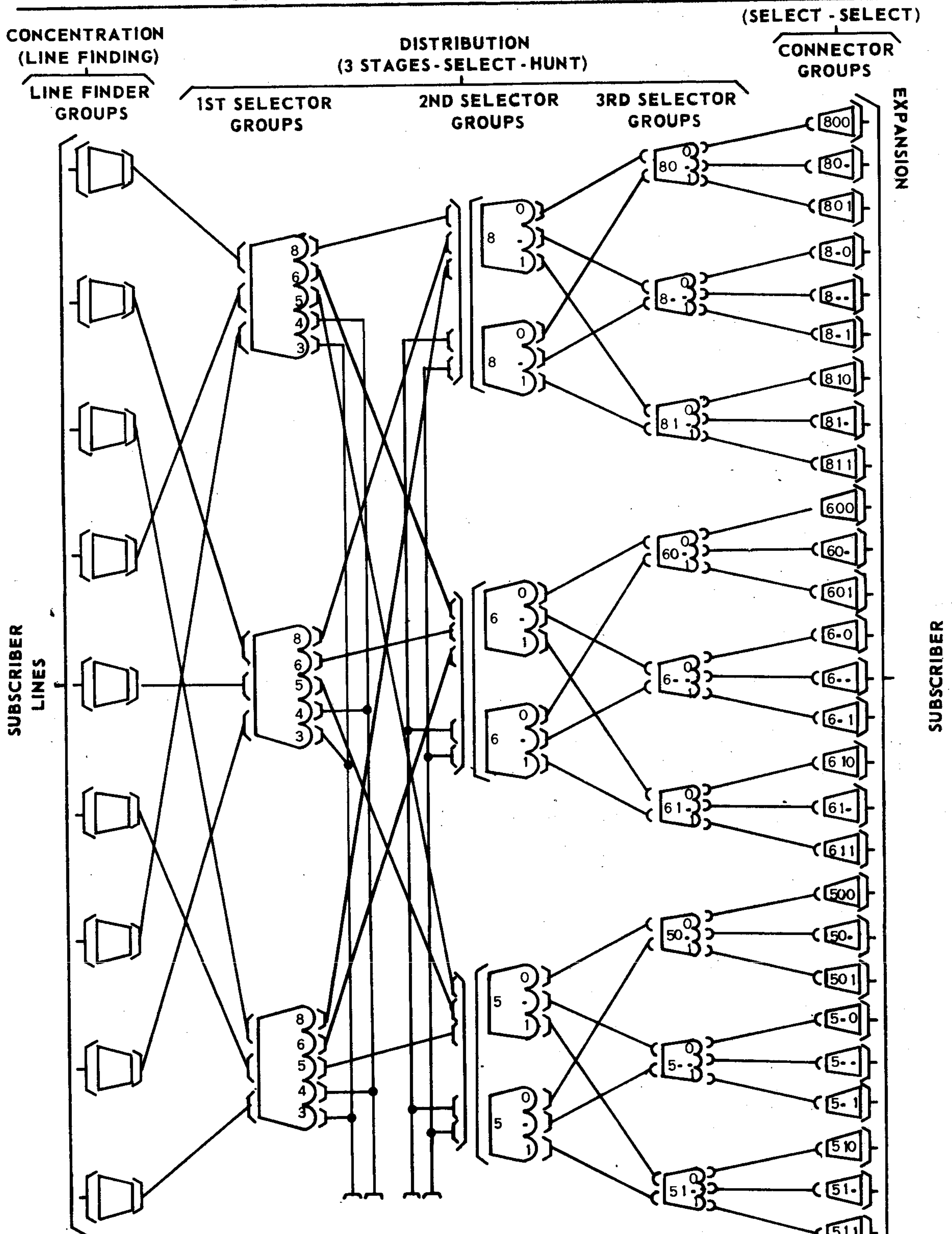

Figure 4-17 Fundamental Step-by-Step Switching Network for 5-digit Office

(b) Using Less Than 7 Switching Stages

The telephone companies have found it desirable to adopt a uniform numbering plan which provides a 7-digit number for all subscribers regardless of the size of the community; however, for smaller communities requiring only four, five or six digits, the 7-digit numbering plan imposes a heavy penality by requiring one, two or three selector stages that are not required from a switching standpoint. The use of selectors known as "digit-absorbing" selector avoids this wasteful practice.

As the name implies, a digit-absorbing selector absorbs digits that are not needed for economical switching but which are needed from the standpoint of uniform numbering. These switches are designed so that when a digit is received which drives the switch to a level marked for absorption, the switch drops back to normal. The levels are marked by bending cams associated with normal post springs.

Levels may be marked for "repeated" absorption and a switch will drop back to normal whenever it is driven to that level. On the other hand they may be marked for "once-only" absorption and the switch will return to normal the first time that digit is dialed but will hunt for an idle terminal on that level the second time it is dialed. Switches may also be marked to absorb on one level on the first digit and on a different level on the second digit.

Digit absorbing switches also provide a feature known as "blocking." When a level is marked for blocking, the switch, if it is driven to that level, will return paths-busy or no-such-number tone unless the switch has previously been driven to a level marked for absorption. This feature is used to restrict service and to prevent wrong numbers.

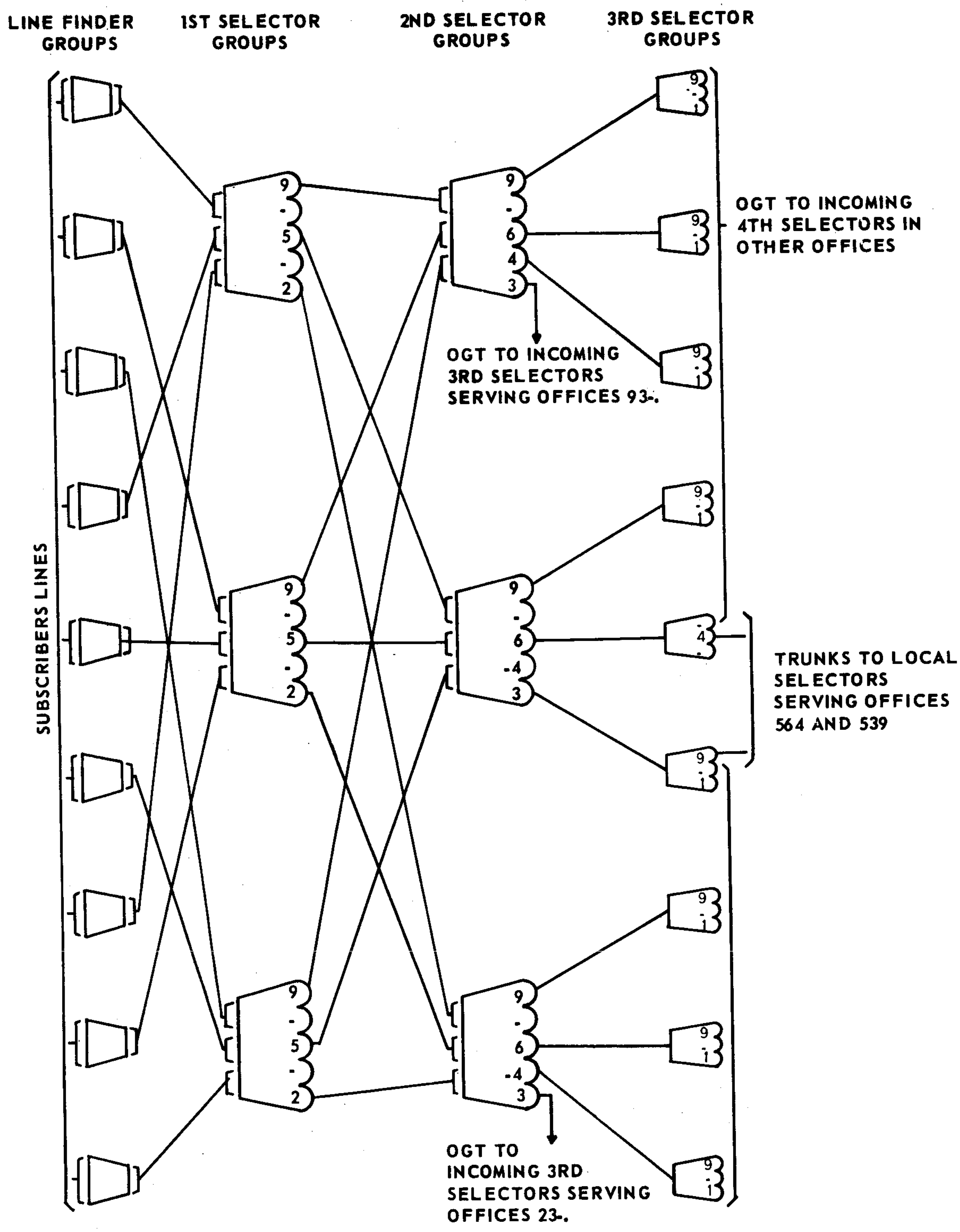

Figure 4-18 Fundamental Step-by-Step Originating Switching Network for 7-Digit Office

The following is an example of a possible arrangement of a two-digit, digit-absorbing selector. Levels 3 and 5 might be specified to absorb and level 6 to block on the first digit (see Figure 4-18); levels 4 and 5 to absorb and levels 0, 1, and 8 to block in the second digit; and to trunk hunt on all levels on the third digit. Assume present office codes with 5-digit effective trunking to be 354 and 545 and with 6-digit trunking to be 328. When code 354 is dialed, the first digit, 3, is absorbed, the second digit, 5, is absorbed, and the switch trunk hunts on the third digit, 4. Similarly, with code 545, the switch absorbs the first two digits and trunk hunts on the third. If code 328 is dialed, the switch absorbs the first digit, 3, and the trunk hunts on the second digit, 2. The third digit, 8, is handled by the succeeding switch (in another office). A nearby office which cannot be dialed from our sample office might have codes 677 and 587. If a customer tries to dial these codes, he will be blocked on the first or second digit, respectively.

(3) 11 X Service Codes

The 11 X codes are used for reporting trouble, requesting assistance, etc. These calls fall in a broad group known as service code calls, the "X" at the end of the code represents a digit between 2 and 0. This digit is preceded by two "1's" in order to distinguish the "X" digit from digits representing office codes.

Figure 4-19 is a line diagram showing how 11 X codes are handled. It can be seen that the first digit "1" received drives the first selector to level 1 where a trunk is seized to an idle service code selector. The service code selector is a digit absorbing selector arranged for repeated absorption of digit "1". Levels 2 to 0 of this selector can not be used unless digit "1" has been absorbed, unlocking the switch. Thus, on a code such as "117" the first selector trunk hunts on the first "1" received. The service code selector absorbs the second "1" of the code and unlocks the service code selector so it can trunk hunt on the digit "7".

If an accidental jiggling of the switch hook caused a false "1" to be sent ahead of the "11 X" code, the second and third "1's" would have been absorbed in the service code selector. On the other hand, a false "1" preceding an office code, will result in a blocked call.

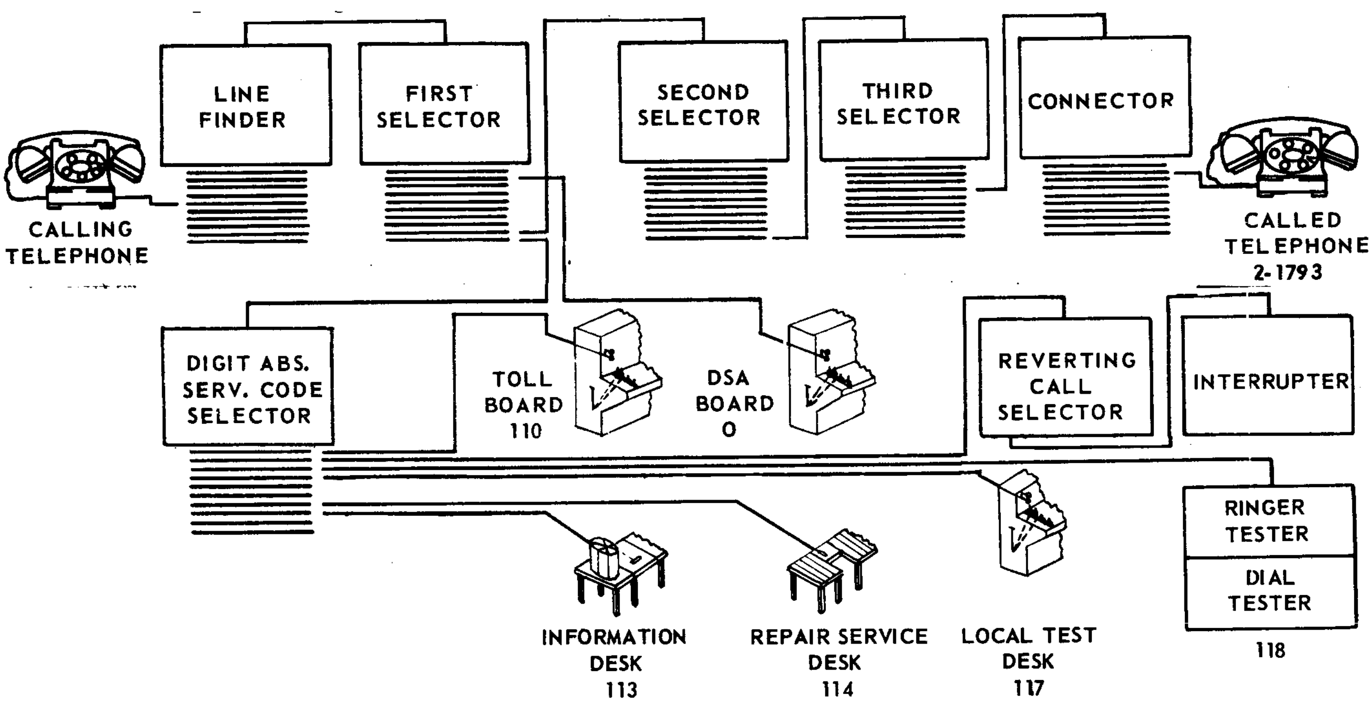

Figure 4-19 Switches, Switchboards, and Desks Used in a Step-by-Step Dial System

(4) One Digit Access

In placing calls into the direct distance dialing network it is necessary to present all 10 digits to the toll switching offices. In Step-by-Step offices this can be accomplished by having the customer dial a "11 X" code followed by the 10 digits required to route the call. With this technique the "11 X" code routes the call through the local office to outgoing trunks to toll.

A more desirable method is to precede the ten digits of the called number by the digit "1". A trunk is located between level 1 of the first selector and the service code selector as shown in Figure 4-20. This trunk has a connection to a trunk to toll as well as a connection to the service code selector. During the interdigital time between 1 and the first digit of the area code, a seizure signal is sent to the toll office, signaling it to prepare receiving equipment for the digits to follow. As the second digit is received it is sent to the toll office as well as to the service code selector.

If the call is a direct distance dial call, the second digit received is some digit other than "1". The trunk circuit recognizes this condition and releases the connection to the service code selector. On the other hand, if the call is a service code call, the second digit is "1"; the trunk recognizes this condition and releases the connection to the toll office.

A direct distance dial call is of the structure "1 X----"; while, a service code call is of the structure "11 X". The trunk permits the call to start routing into both networks; then upon determining if the second digit is a "1" or some other digit, it drops the connection to the undesired network.

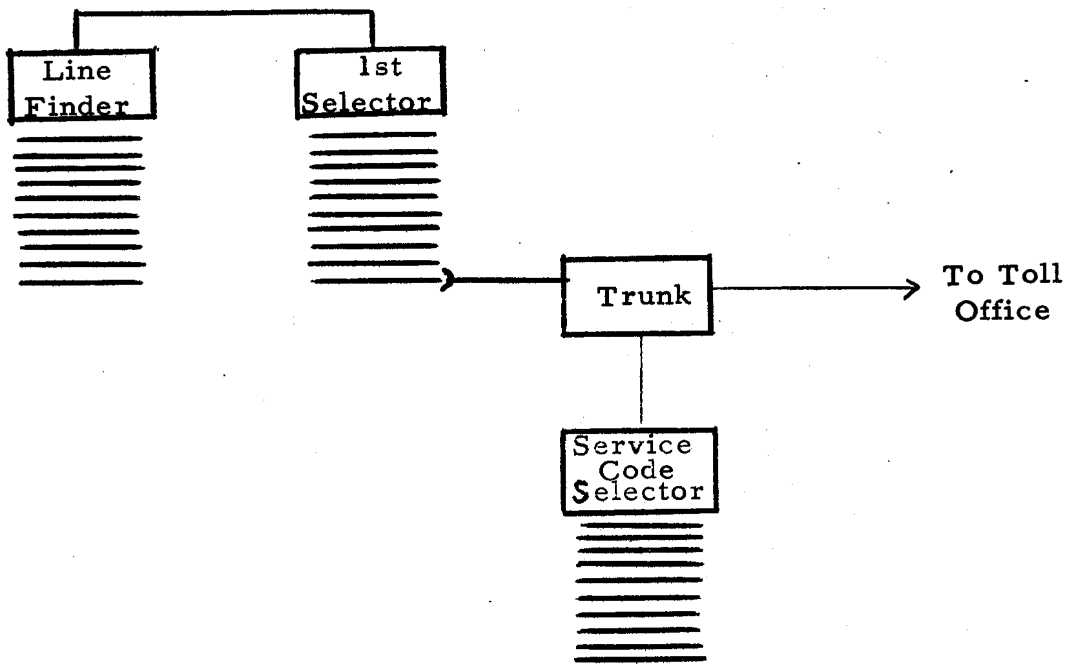

Figure 4-20 Routing For One Digit Access

(5) Toll

Step-by-Step toll switches are used to handle several categories of traffic; which, in general, can be classified as Toll Completing and Intertoll. Toll completing traffic can be defined as the traffic incoming to a local office from a toll operator or intertoll network. Intertoll traffic can be defined as traffic between toll offices.

The Toll Train (Toll Completing traffic) joins the local network at terminals of the connector switches through toll or combination toll and local connectors. The number of toll selector stages preceding these connectors is determined by the number of digits that must be dialed to reach the subscriber's line. Figure 4-21 is a block diagram of a Toll Train.

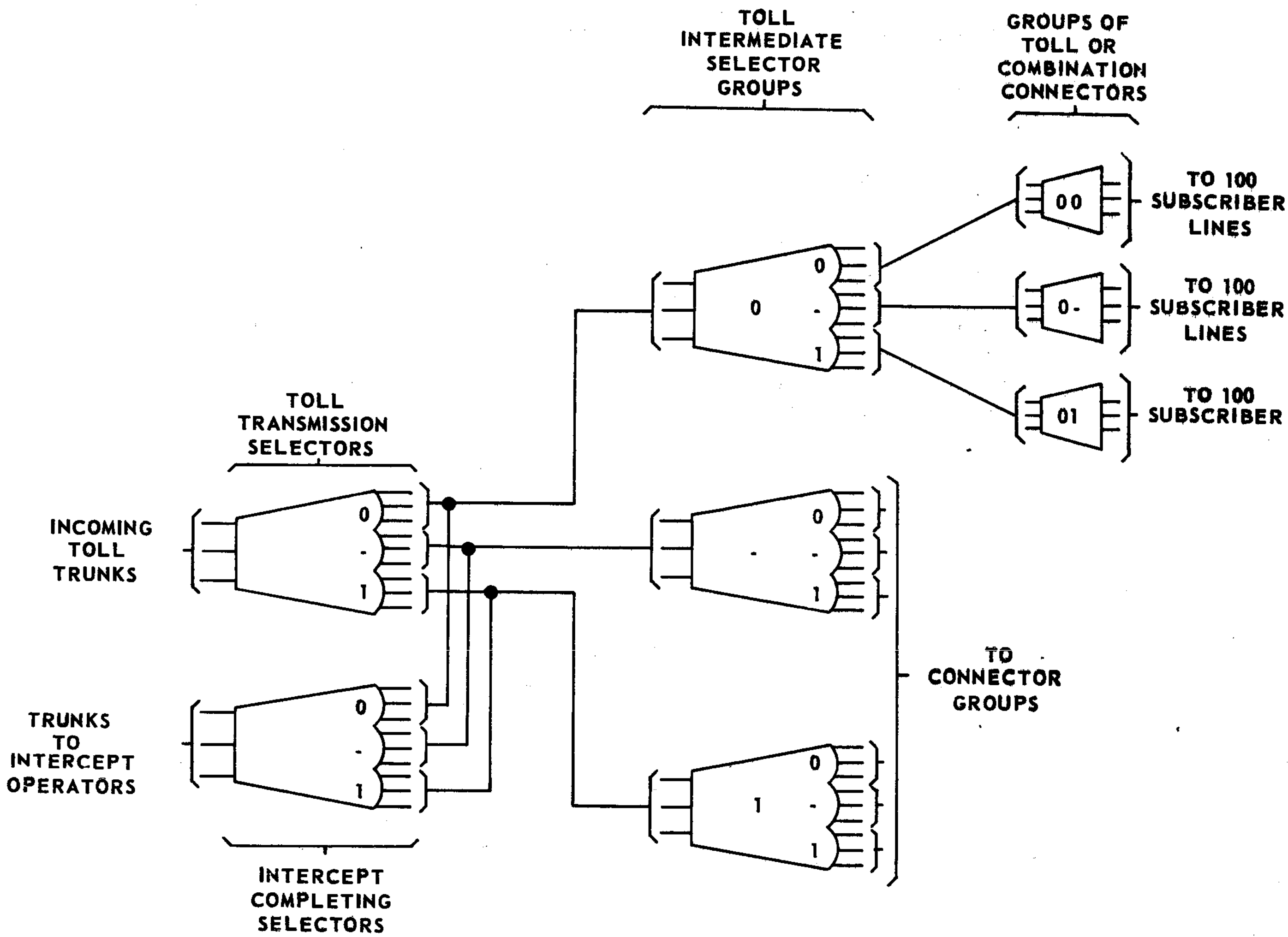

Figure 4-21 Typical Toll Train

The Intertoll Train is used to interconnect toll offices. Calls may be placed into the Intertoll network by operators or by "common control" offices. Likewise, calls can be terminated on toll switchboards or in common control offices. If calls are completed to Step-by-Step customers from the intertoll network, the last stages of the call is handled by Toll Trains. The number of stages of selectors required is determined by the number of outgoing trunk groups that the Intertoll offices have access to. One, two, or three stages may be required as shown in Figure 4-22.

The method of distributing trunks over the toll selector banks is identical to that used for the local selectors. The toll selectors are normally mounted on shelves designed for ten or twenty selectors; all switch banks on a shelf are permanently multipled. The basic selector subgroup, then, consists of ten or twenty switches. The bank levels of these subgroups are interconnected in a graded multiple, the exact arrangement depending upon the number of switch banks in a group and the number of trunks from each group to the succeeding stage.

B. SWITCHING FEATURES

(1) Slip Multiples

The lines are arranged on the switch banks of the line finders as indicated by the diagram of Figure 4-23. The lines which terminate on the tenth level of one line finder switch appear on the first level of the adjacent switch on one side, and on the ninth level of the adjacent switch, on the other side. In a group of twenty, 200-point line finders, for example, each group of twenty lines will terminate on the first level of two switches. The horizontal position of a particular line within the level remains the same on all switches. This method of multipling is known as a "slipped multiple."

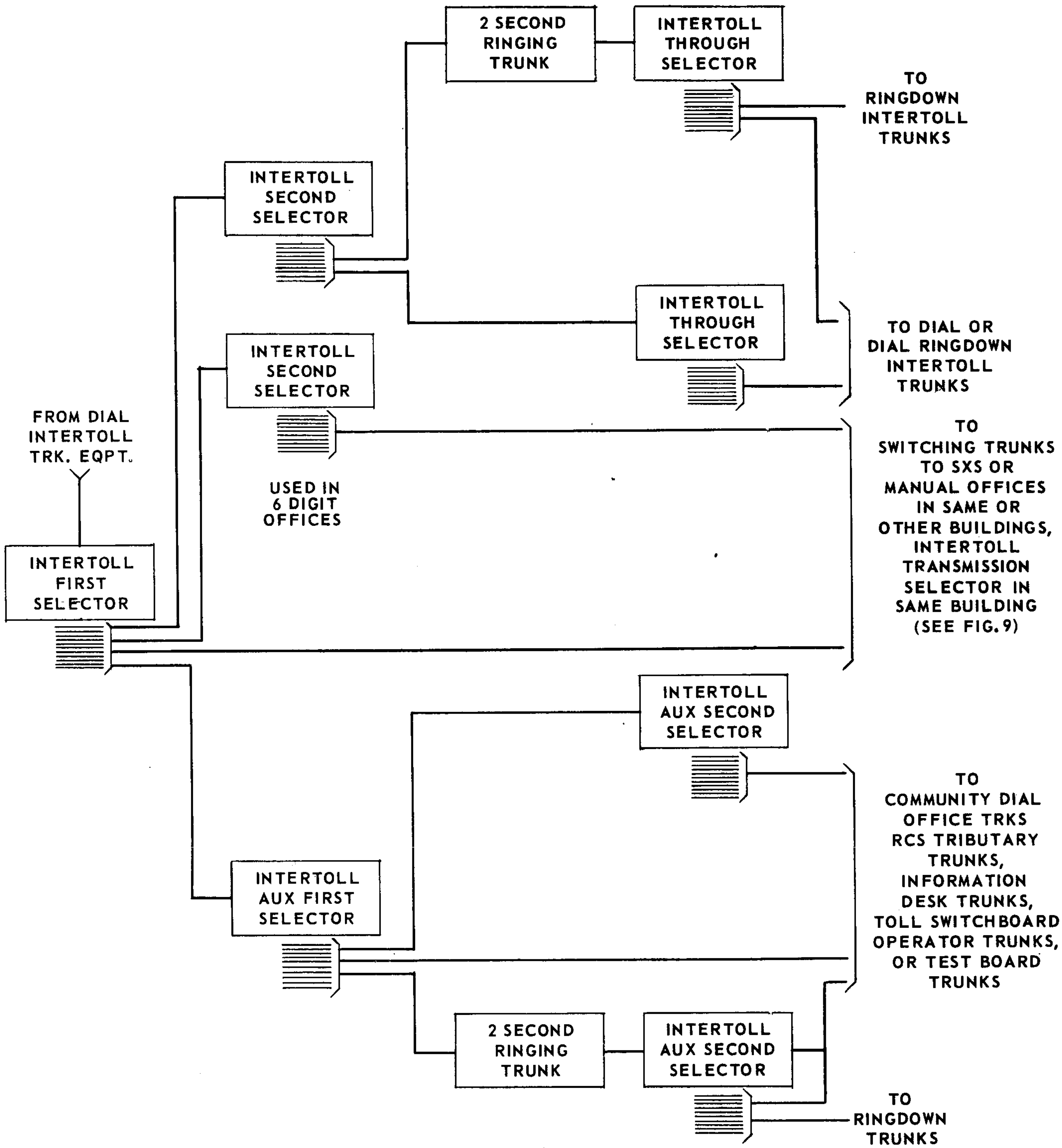

Figure 4-22 Typical Intertoll Train

The line finder group is controlled by an allotting circuit which allots to any call that finder, among those idle, that will find the requesting line on the lowest bank level. Thus, if all finders in the group are idle, a switch having the requesting line on its first level will be allotted to the call.

For charging purposes, subscriber lines served by a step-by-step office are divided into various classes of service such as: flat rate, individual message rate, two-party message rate, coin box, etc. Each class may be further subdivided into lines given extended dialing area service or restricted dialing area service. With certain exceptions, the lines served by a group of line finders must all be of the same class and have the same dialing area service.

(2) Graded Multiple

Selector banks are permanently multipled together in subgroups of ten banks. From an equipment standpoint, a group of selectors must be an integral multiple of ten selectors. From a traffic standpoint, however, fully equipping these subgroups with switches might not be warranted. Hence, while selector groups are fully equipped with banks, they are not necessarily fully equipped with switches.

A switching group has greatest efficiency when every input has access to every output. Figure 4-24 is an example of this arrangement, where every switch has access to every output and the maximum number of outputs depends on the access of the switch. For step-by-step switches, this limit is ten. When the number of inputs increases to the point where the output group is overloaded, the group can be split as shown in Figure 4-25. But smaller groups are less efficient than large ones and splitting the multiple would require increasing the total number of output trunks.

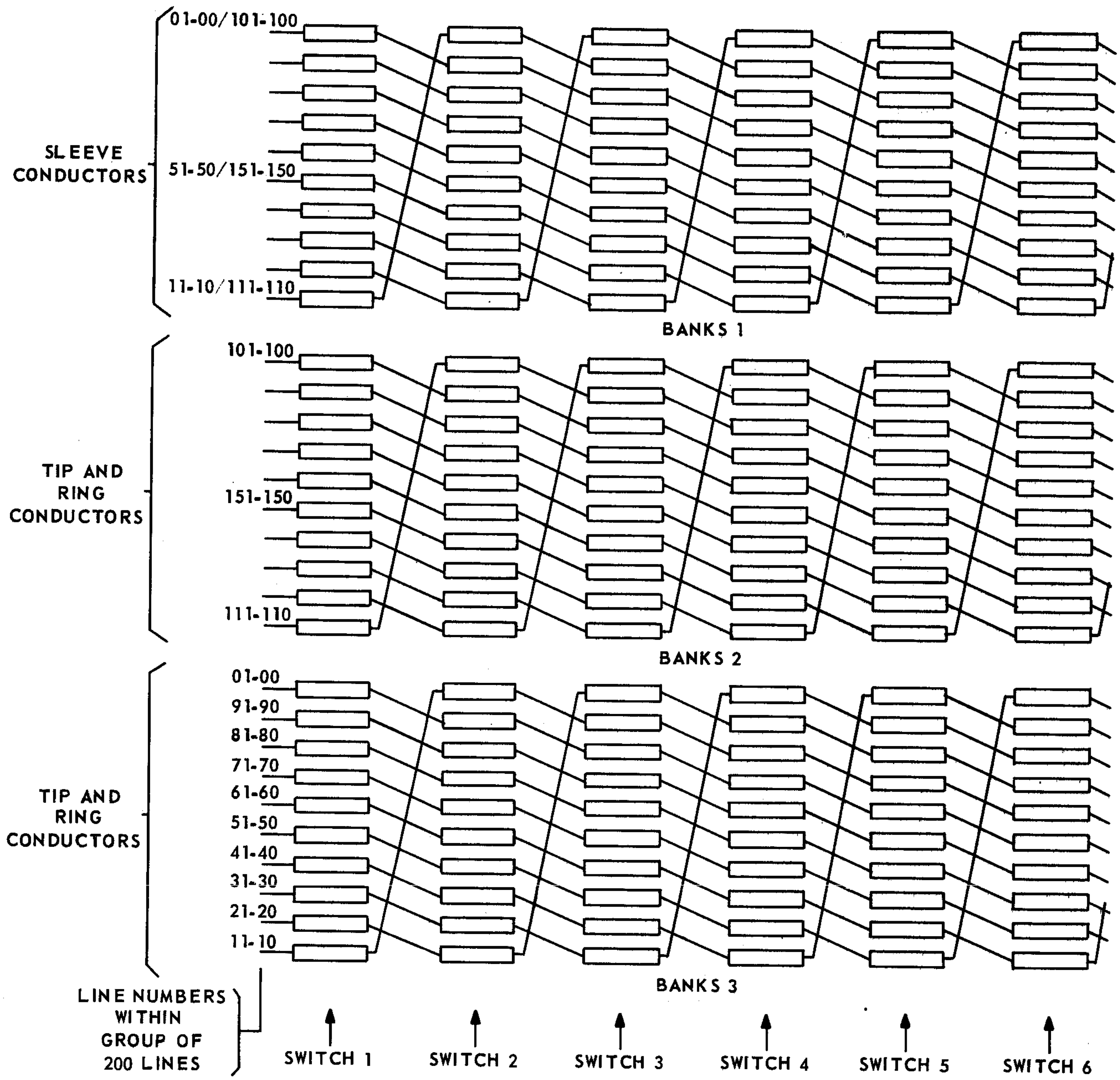

Figure 4-23 Slipped Multiple on Terminal Banks of Line Finder Switches

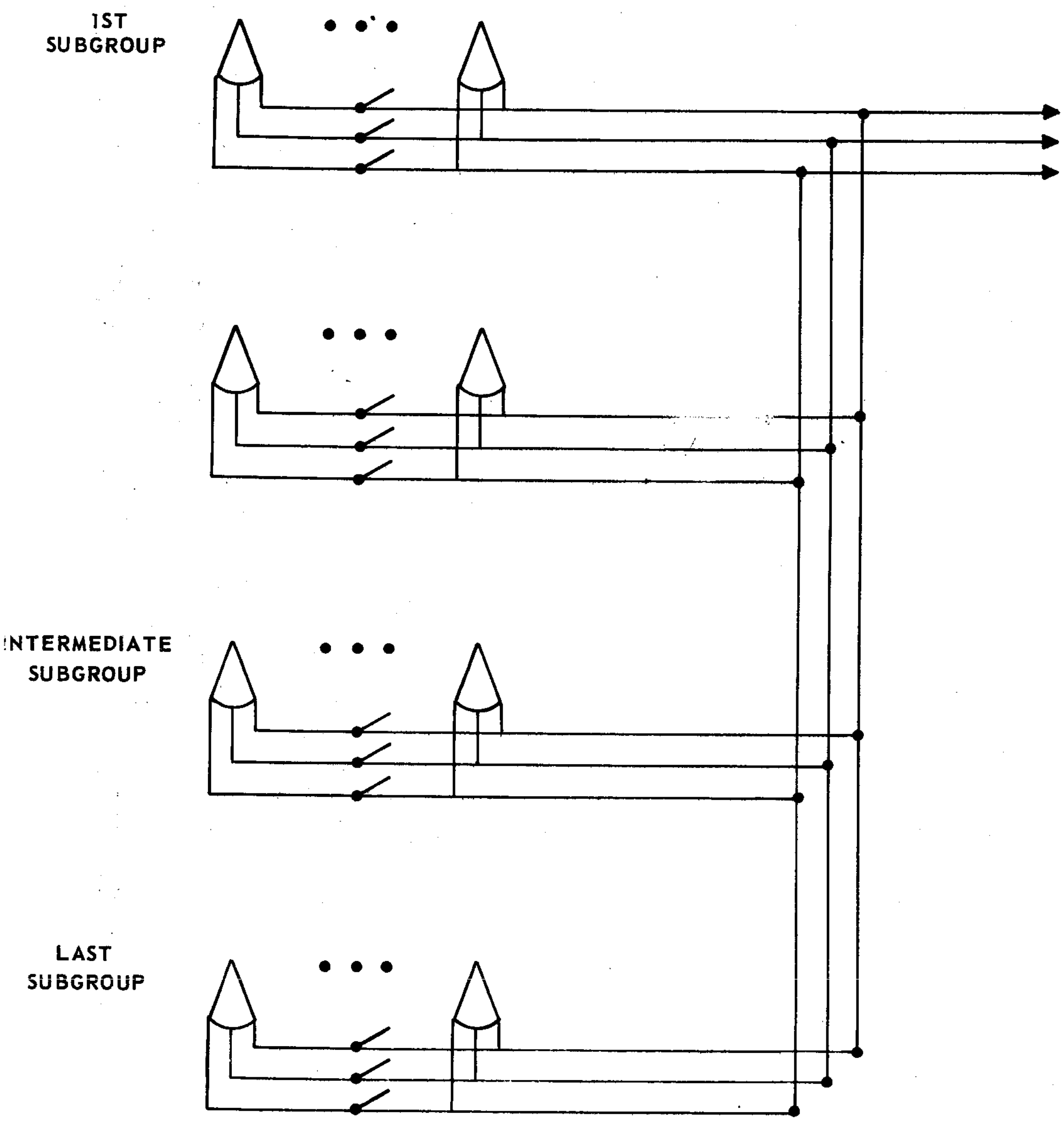

Figure 4-24 Common Multiple to All Subgroups

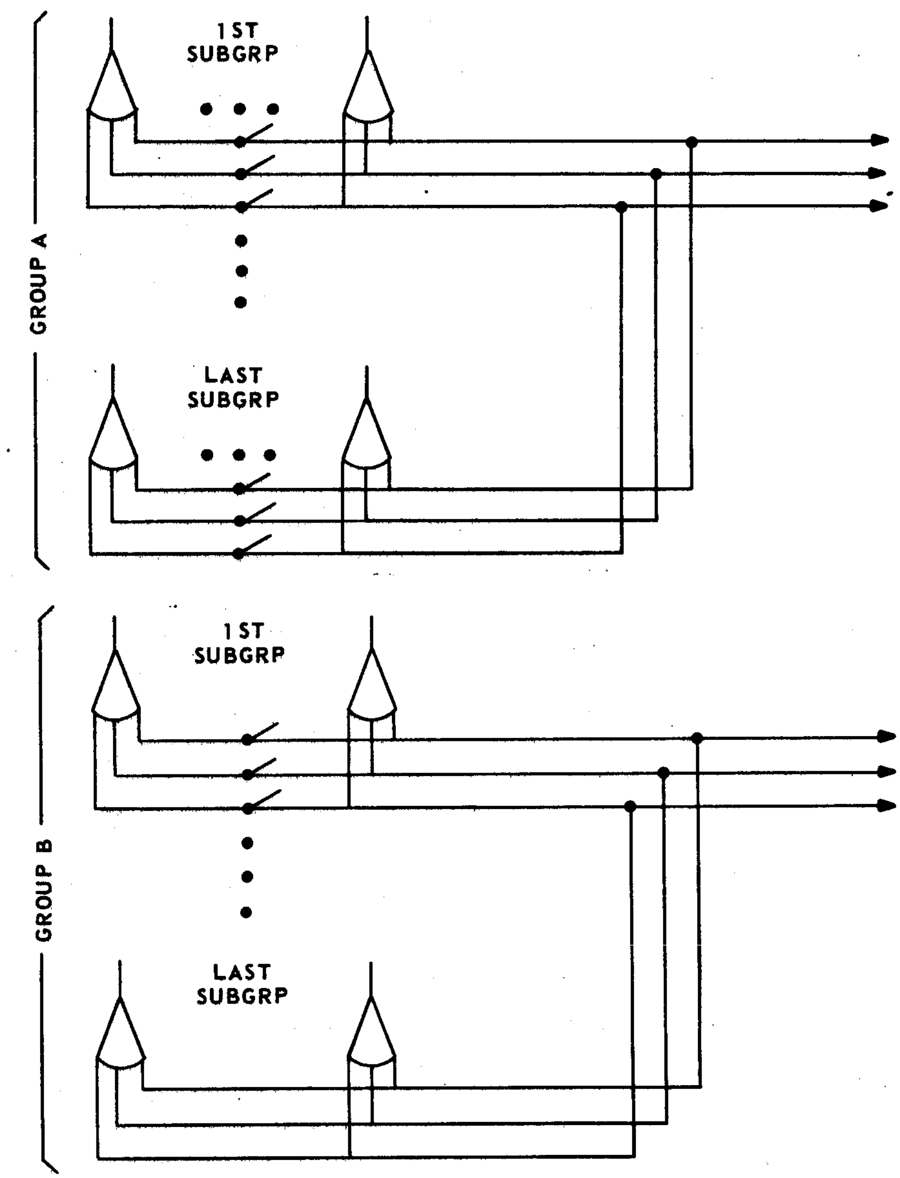

Figure 4-25 Multiple Subgrouped

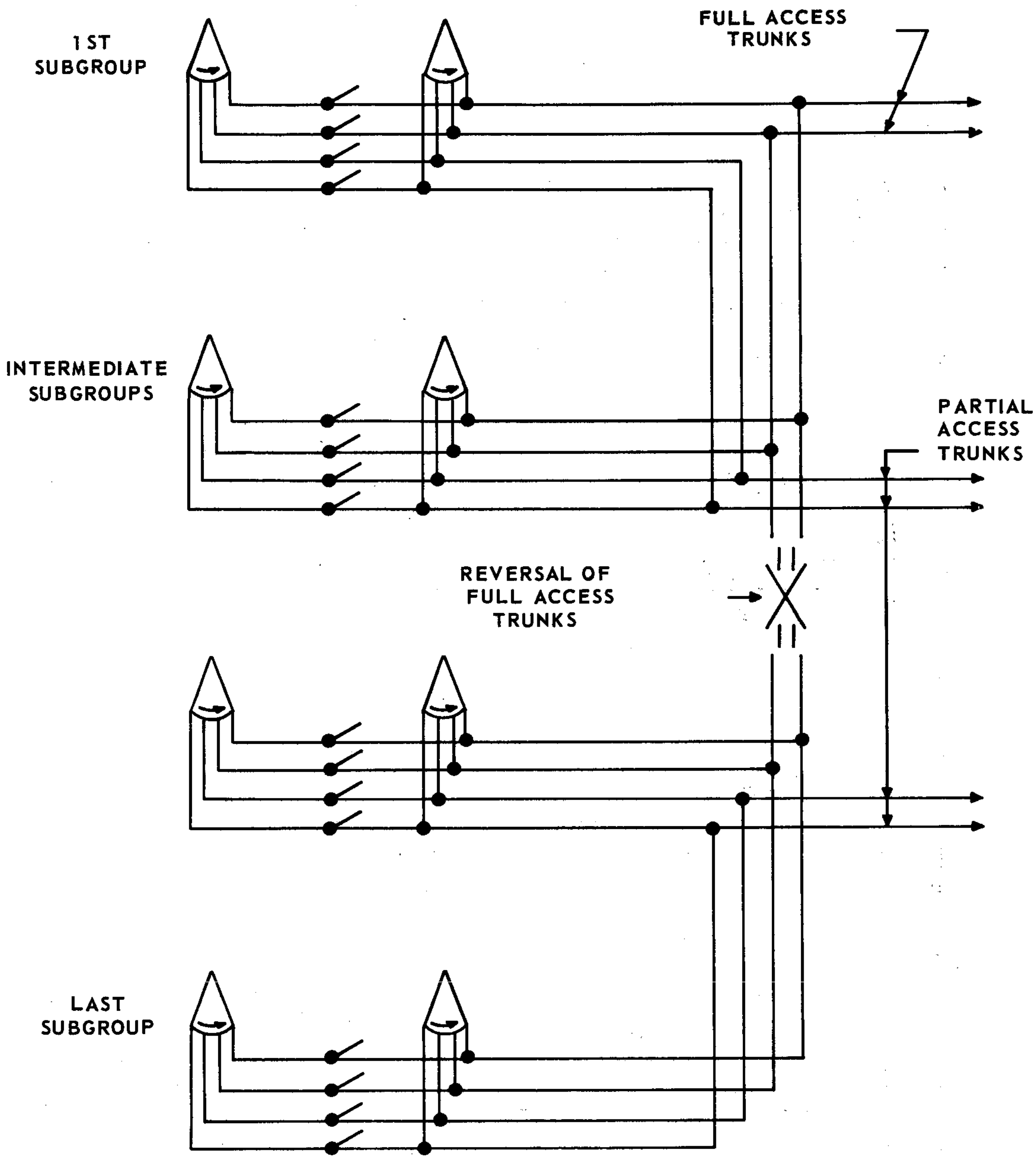

Figure 4-26 Graded Multiple

This situation is improved by employing graded multiples as shown in Figure 4-26. With this arrangement, there is full access to only a fraction of the trunks. The graded multiple may be thought of as a combined full access and split multiple. It is a compromise dictated by limited access switches, not as efficient as a full access multiple, but more efficient than a split multiple.

(3) Rotary Out Trunks

Traffic between local step-by-step offices leaves the originating office on outgoing trunks from the first, second or third selector stages. This traffic is distributed over the various groups and subgroups of the selector bank multiples.

Each of the above subgroups must be engineered for a given quality of service during its peak load condition. The total trunks required from all of the subgroups of trunks to a particular destination is greater than would be required if the traffic could be concentrated in one large group of trunks. The difference in the total number of trunks required by using one large group is of considerable importance from an overall cost standpoint since trunks between offices represent considerable plant investment compared to trunks within an office.

The use of Rotary Out Trunks is one method of reducing the number of interoffice trunks to the theoretical minimum. In essence, the rotary out trunks are a distribution stage between the selector terminals leaving one office and the incoming selectors of the terminating office. Approximately 40% of the outgoing trunks are connected directly to the terminating office. These trunks are in the individual subgroup portion of the graded multiple. The remaining 60% of the outgoing trunks are connected to the rotors of Rotary Selector Switches. The banks of the Rotary Selector Switches are connected to the previously mentioned individual trunks as well as to enough other outgoing trunks to meet traffic requirements. Figure 4-27 shows this arrangement between two offices; office 2 and 3.

With this technique the rotary selectors have access to individual trunks from a number of subgroups as well as what would normally be called common trunks. The banks of the rotary selectors are multipled; thus, we have a distribution stage that in effect groups a number of small groups into a larger group for greater efficiency.

The connection through the rotary selector must be established during the interdigital timing period but after the previous selector completed its rotary hunt. In order to avoid traffic blockage due to two rotary hunts during one interdigital timing interval, the rotary out trunk is always positioned on an idle outgoing trunk. Whenever a trunk that has been preselected by the rotary selector is seized by some other selector, another idle trunk is preselected. The rotary hunting action of the rotary selectors is stopped during an all-trunks-busy condition to prevent the selectors from continuous hunting action.

4.5 PROGRESSIVE CONTROL TECHNIQUES

A. GENERAL

(1) Direct Progressive Control

The system examined so far has various disadvantages inherent in direct progressive control systems.

First, since signals generated by the calling subscriber's device are received directly by the switching device, improvements involving major changes in control signaling cannot be made to one device without being made to the other. This limitation in signaling flexibility

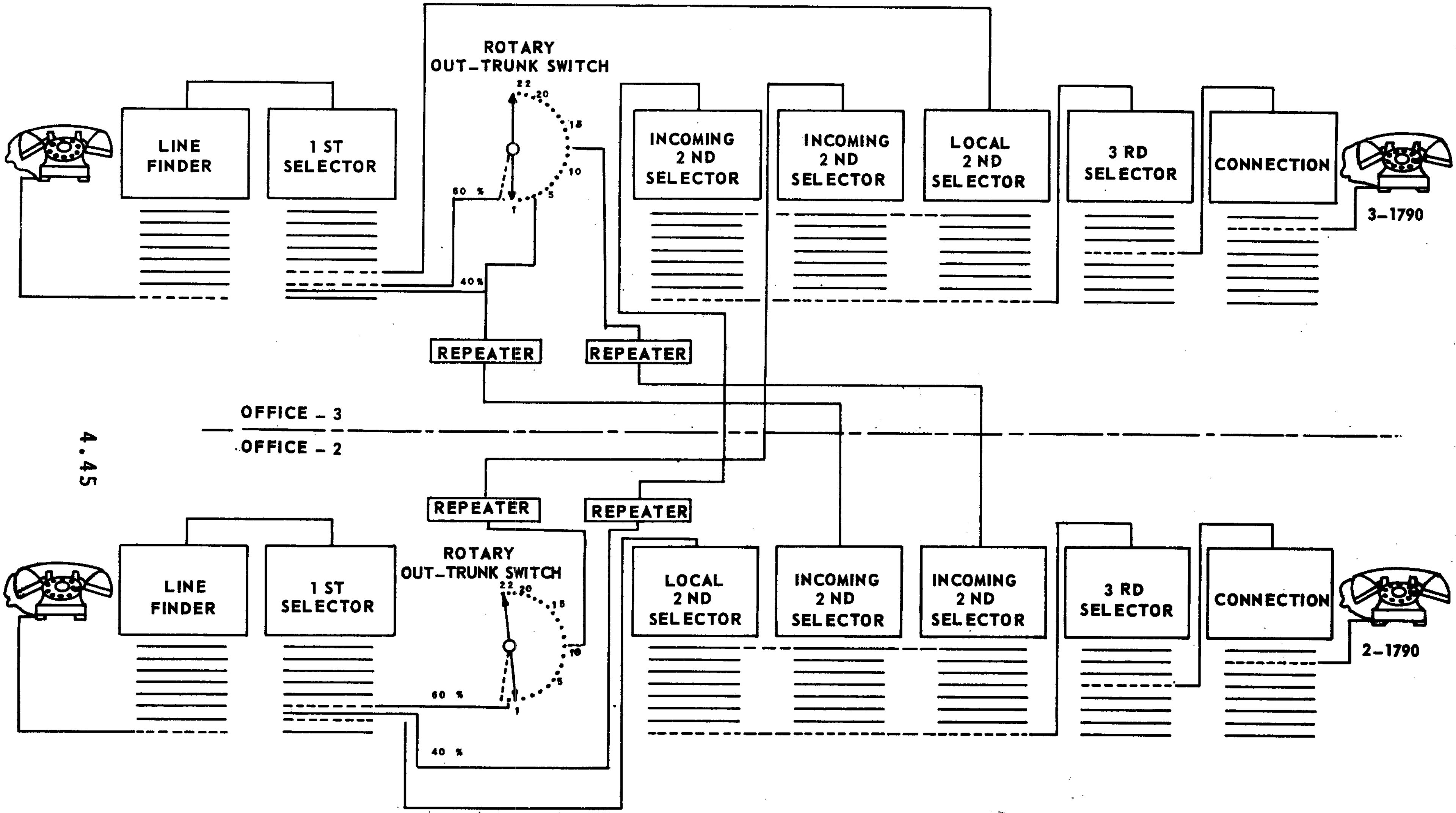

Figure 4-27 Trunking Using Rotary Out Trunks

has been brought sharply into focus by the introduction of touch-tone calling since the tone signals generated by the subscriber are not compatible with existing switches and it is not economically feasible to modify or replace the huge number of switches involved.

Second, the assignment of a numeric code to a subscriber specifically fixes the location of his line in the terminating stage. Similarly, assigning a numeric code to associated offices specifically fixes the location of the trunk groups to those offices in the distribution stage of the network. Extreme care is required to properly assign these codes to provide economical trunking and to insure against serious traffic imbalances or poor trunking arrangements. Also, subscribers are reluctant to have their numbers changed and it is not practical to reassign office codes to control the routing.

Third, since the switches are directly controlled by the subscriber, a signal must be generated by the subscriber for each "node" or switch in the tree-like structure of the switching network. When step-by-step intertoll facilities are used for long distance calls, from one to three switches are required at each intertoll office. When a call requires that several intertoll offices be connected in tandem, several digits must prefix the called subscriber's number in order to select the proper path through the intertoll network. Obviously this does not lend itself to the uniform dialing procedures required for direct distance dialing.

Fourth, the progressive buildup of a path through the network under the direct control of the subscriber, makes it impossible to try an alternate route if, as the path progresses, a blocked point in the network due to an all trunk busy or a trouble condition is encountered. Under this condition the call must be abandoned and another attempt made to complete the connection. This is a serious limitation.

(2) Register Progressive Control

In order to overcome certain of these limitation, various methods have been developed which provide, partial or full register progressive control for step-by-step systems. The step-by-step intertoll CAMA facilities is one such facility. Two other recent developments, common control and "noncompatible" touch-tone calling, also utilize register progressive control in local offices.

B. COMMON CONTROL

"Common Control" has been previously defined in terms of a switching system principle. It may also be defined, from a circuit viewpoint, as a control common to more than one switching device. When used in this context, common control circuits are used in progressive control systems.

Controlled outpulsing permits, translation, code conversion, alternate routing, multifrequency outpulsing and permanent signal routing. In addition, these facilities are compatible with the facilities needed to accept Touch-Tone signals. Hence, common control may be furnished to provide either Touch-Tone calling or controlled outpulsing or both. If only one of these features is originally provided, the other may be added at a later date by providing compatible features initially.

(1) Controlled Outpulsing

A block diagram of common control facilities is shown in Figure 4-28. When a customer lifts his receiver, a line finder begins to hunt for his line. At the same time the register trunk and link connects a register to the register trunk associated with the line finder. The register trunk splits the tip and ring between the line finder and first selector and extends the subscriber's loop to a relay in the register. A pulsing path is also extended from the register to the first selector. Dial tone is then supplied by the register to the subscriber who may be calling from either a dial or a Touch-Tone telephone. If the call is from a dial pulse subscriber, the register repeats the digits over the pulsing path to the first selector. If the call is from a Touch-Tone service subscriber, no dial pulses are given to the first selector at this time.

When three digits are stored (four, if a 0 or 1 prefix digit is received) the register bids for, and connects to, a translator and decoder through their respective connectors. The trunk class connector also connects to the decoder and passes the calling customer's class of service. Having determined the code dialed and the class of service, the decoder informs the register and outpulsing controller if controlled outpulsing is required, and, if so, how it is to be handled.

It should be remembered that before the decoder has determined whether or not controlled outpulsing is required, three or four digits will have already been repeated to the distributing stage, and a switch train will have been partially established. On those few calls which do require controlled outpulsing, the established switch train is dropped by the register. The decoder then provides the register and outpulsing controller with the following information:

1. The arbitrary digits which must be prefixed to the dialed number for routing or code conversion.
2. The number of digits to delete from the called number.
3. Which digits, if any, require MF pulsing.
4. The number of digits it must outpulse before releasing.
5. Whether an alternate route is available (so that the decoder can be recalled if on all trunks busy condition is found).

The translator and decoder now release and the required digits are outpulsed, after which the register trunk cuts through; the originating register and outpulsing controller then release.

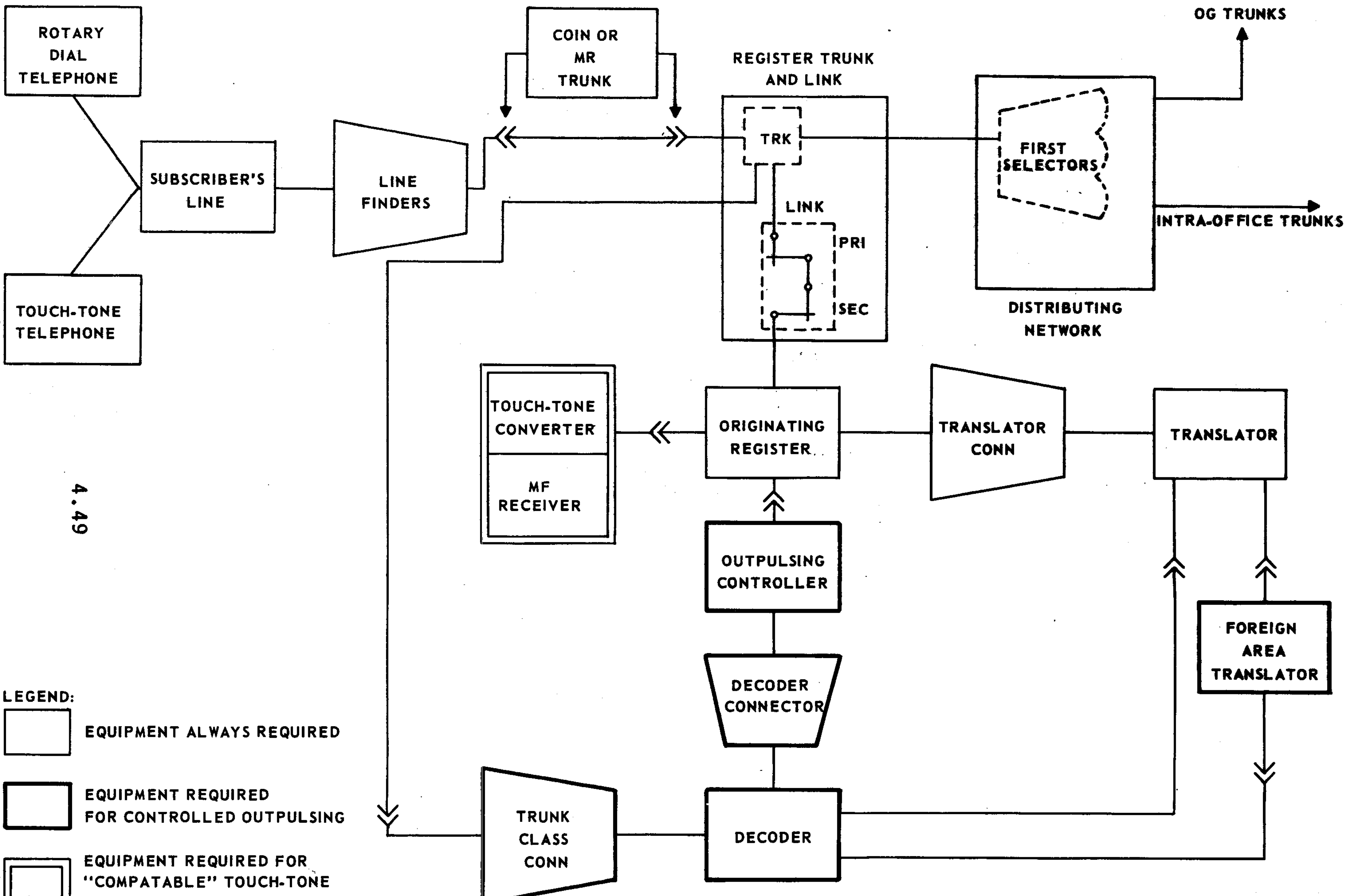

Figure 4-28 Common Control Facilities

However, if controlled outpulsing was not required, the action taken by the register, after the translator releases, would depend on the type of pulsing received.

When signals from a Touch-Tone phone are received, the digits are detected by the Touch-Tone converter and stored in the register. The register then generates and outpulses dial pulses to match the digits stored in its memory relays. At completion of outpulsing, the register and link release.

In dial pulsing, after the register repeats the pulses to the first selector, the register releases itself and the link during the inter-digital timing interval.

The register trunk then completes the pulsing path from the line finder to the first selector so the customers dial now controls the remaining switching stages in conventional manner.

(2) TOUCH-TONE Calling Without Controlled Outpulsing

Compatible Touch-Tone calling can be furnished initially and at some later date modified to add controlled outpulsing. In this case the equipment shown in the heavy solid line of Figure 4-28 is not required until the controlled outpulsing features are added.

Only those line groups having subscribers with Touch-Tone calling will require the register control equipment.

(a) Calls from Dial Pulse Subscribers

If dial pulses are received, the register repeats them to the first selector and then releases during the interdigital time between the first and second digit. The remainder of the digits are fed to the network on a direct progressive control basis.

(b) Calls from Touch-Tone Service Subscribers

If signals from a Touch-Tone phone are received, the converter and its associated receiver translate the tone signals into D-C signals and store the digits on memory relays in the register. After the first digit is stored, it begins to pulse the digits to the distributing stage at the standard rate of 10 pps.

When three digits are stored (four, if a 0 or 1 prefix digit is received) the register bids for and connects to a translator which tells it how many digits it must receive. When the required number of digits have been outpulsed, the register trunk cuts through and the originating register releases.

C. NONCOMPATIBLE TOUCH-TONE CALLING

In offices in which it would never be economically feasible to provide controlled outpulsing, a cheaper method of accepting signals from a Touch-Tone phone is available. This method is variously referred to as "noncommon control" or non-compatible" Touch-Tone calling. "Noncompatible" because this method cannot be modified to operate with controlled outpulsing. "Noncommon Control," strictly speaking, is a misnomer since this equipment does control several switching devices. However, the term control, when used in step-by-step, refers to the special case of controlled outpulsing.

This arrangement, shown in Figure 4-29, is similar to that described for "compatible Touch-Tone calling only" except that access is obtained through converter trunks and finder switches instead of a register trunk and link. In addition, the functions of the originating register and translator are built into the converter. This equipment is furnished only for those line groups having some subscribers with Touch-Tone service. When a subscriber lifts his receiver, a line finder seizes the line; the converter trunk recognizes that this is a new call and directs a trunk finder to connect to it. In smaller offices the trunk finder connects directly to a converter; but in offices with a large number of converters, increased efficiency is obtained by using converter finders which hunt for, and connect to, idle converters.

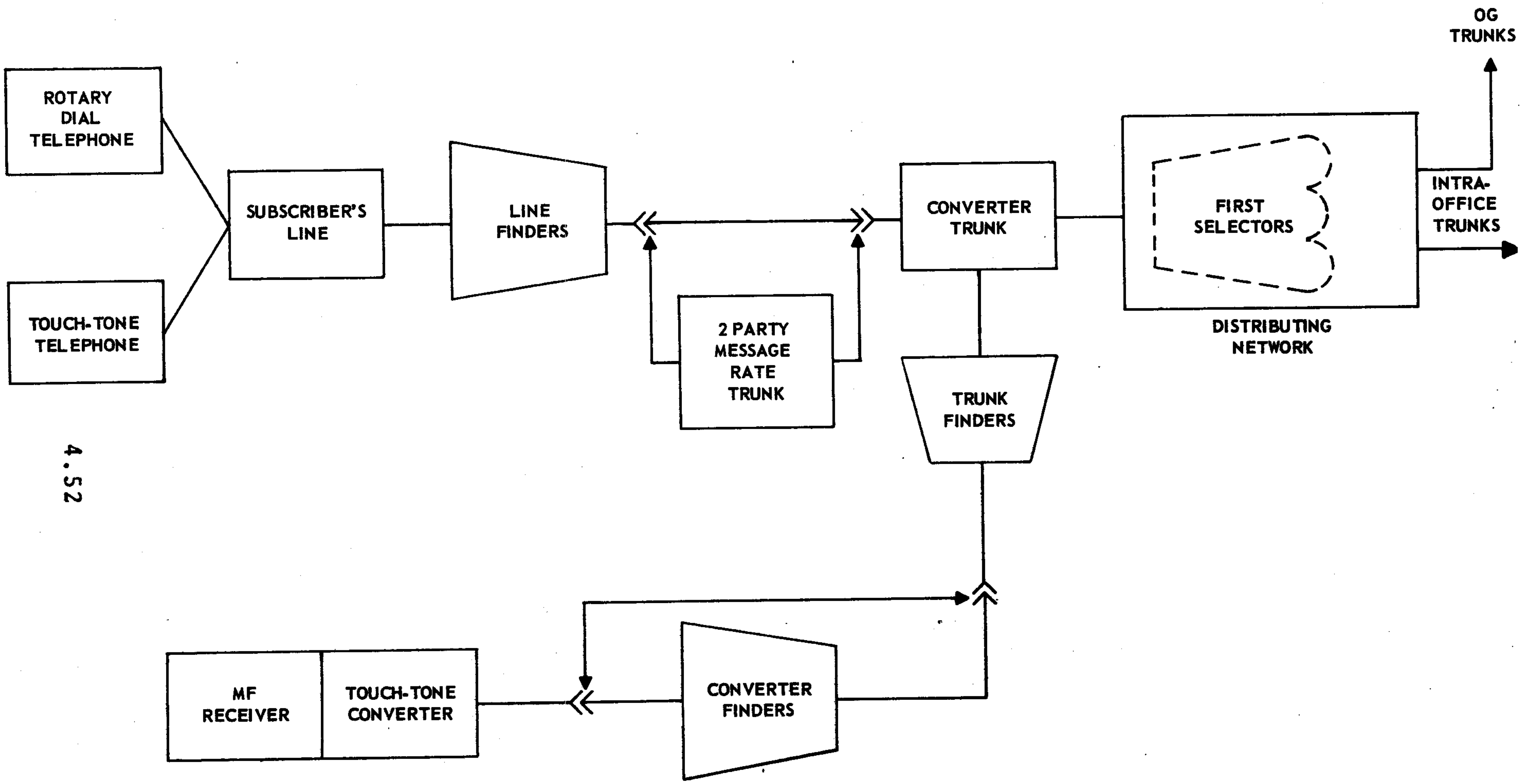

Figure 4-29 "Noncompatible" TOUCH-TONE Calling Facilities

The converter trunk splits the tip and ring leads between the line finder and first selector and establishes a connection through the trunk finder and converter finder, when provided, to a supervisory relay in the converter. The converter now furnishes dial tone to the customer.

If the call is from a dial telephone, the pulses of the first digit are repeated by the supervisory relay to the first selector, the converter releases during the interval between the first and second digit and the converter trunk connects tip and ring through to the first selector. The remainder of the digits are fed directly to the network on a direct progressive control basis.

When a customer having Touch-Tone calling originates a call, the converter and associated receiver translate the tone signals to D-C signals, stores them on memory relays and outpulses the digits to the distributing network. After the last digit is outpulsed, in a manner similar to that previously described for the originating register, they both release.

The modest amount of translation built into the converter enables it to minimize its holding time by recognizing the number of digits it must outpulse. However, the converter does not control the digits which are pulsed out, except in the case of permanent signals. Under this condition digits are pulsed which route the call to permanent signal holding trunks. Like the originating register the converter times out, returns recorder tone, and releases, if it has not completed a call in a specific allotted time.