STEP BY STEP
DIAL SYSTEM

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P R E F A C E

This pamphlet is issued for the benefit of the Western Electric Installer and describes in a general way the fundamental principles and characteristics of the step-by-step dial system.

The contents are taken from material which has been prepared by Bell Telephone Laboratories, Inc., for training purposes.

Although particular types of apparatus are discussed, it is not intended that this publication should be used for specific descriptions. The pamphlet will not be kept up to date with current changes in the equipment.

The contents of this pamphlet are of a purely descriptive nature and are not designed to prescribe methods or instructions for the installation of central office equipment.

STEP-BY-STEP DIAL SYSTEM

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SECTION 1

FUNDAMENTAL METHODS OF OPERATION

There are two methods of automatically completing telephone calls in general use in the Bell System today. Of these two, the step-by-step system was the first to be used. The term "step-by-step" is descriptive of the manner in which the call progresses, each digit dialed by the subscriber causing a separate mechanism to function to advance the call through the various "steps" necessary for completion.

The step-by-step system is quite flexible in that it may be used for communities requiring less than 100 lines or for central offices requiring 10,000 lines or more. In this respect, the step-by-step system is the more economical for rural towns or communities of average size and for larger metropolitan areas where the trunking problem is not too complex. The panel system, is more advantageous in large metropolitan areas where complicated interoffice trunking is necessary.

THE DIAL

The only difference between automatic and manual equipment apparent to the subscriber is the dial located at the instrument on his premises. It is for this reason that automatic systems are universally known as "dial" systems. The purpose of the dial is, of course, to enable a subscriber to control the automatic equipment so that a connection will be completed to the number he is calling. When the subscriber removes his receiver from the switchhook the circuit is completed through the switchhook contacts in series with a relay in the central office, as shown in Fig. 1. One of the functions of the subscriber's dial with the receiver off the switchhook is to open this circuit a specified number of times and by means of these open circuits or "pulses" to give the automatic equipment the proper information. The dial is provided with a series of finger holes, each of which is numbered. The subscriber places his finger in one of these holes and carries it to the back stop, after which the dial restores to normal under the influence of a governor which regulates its speed. As the dial restores to normal it opens the circuit a number of times equal to the number on the finger hole which was selected by the subscriber. Thus, dialing "2" opens the circuit twice; dialing "5" opens it five times. It should be noticed also that dialing "zero" opens the circuit ten times. The opening and closing of the circuit alternately operates and releases a relay which has been placed in series with the subscriber's line.

A pulse cycle consists of the time required for one open circuit and one closed circuit in the series of pulses sent out as the dial restores to normal. The open circuit is approximately 60% of the total pulsing time. This is to insure the positive release of the pulsing relay in the automatic equipment at the central office.

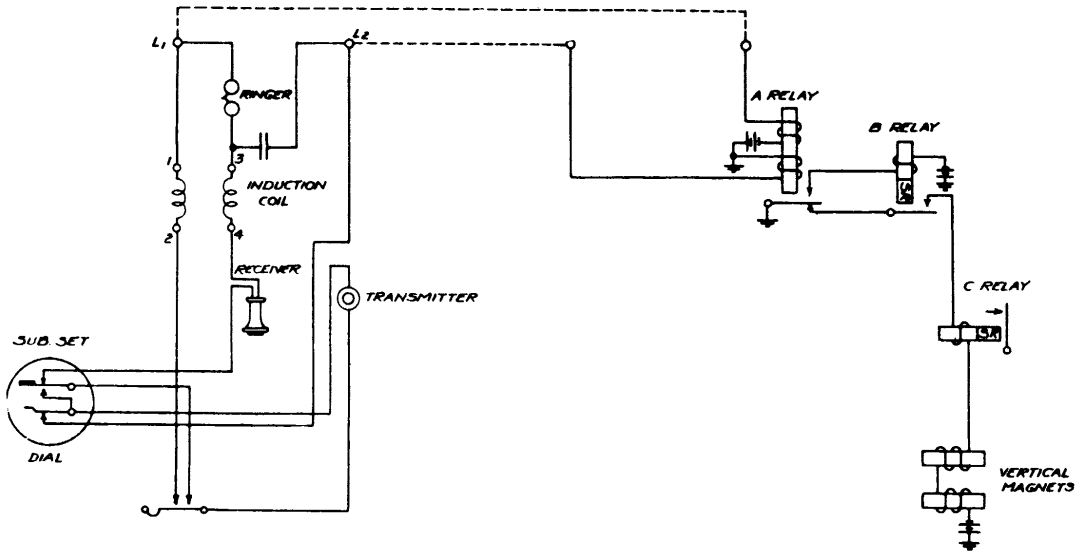


FIG. 1 SCHEMATIC OF PULSING CIRCUIT STEP-BY-STEP SYSTEM.

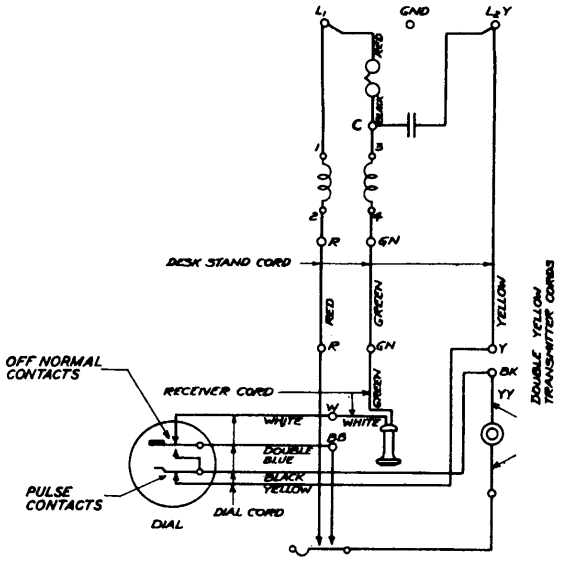


FIG. 2 DIAL SUBSCRIBER STATION CIRCUIT

Figure 2, gives a schematic of a subscriber's station circuit containing a dial. Here the dial is shown in its normal position. The receiver circuit is closed through the contacts shown as "off normal contacts". As soon as the subscriber moves the dial "off normal", the off normal contacts change position so that the receiver circuit is opened to prevent the annoyance of a series of sharp clicks in the subscriber's ear and a short circuit is placed around the transmitter to remove its variable resistance from the dialing circuit. The off normal contacts remain in this condition from the time the subscriber's dial first moves off normal until it has restored under the influence of a governor. The contacts labeled "pulse contacts", however, open and close only while the dial is restoring to normal at a constant speed determined by the governor.

SWITCHING MECHANISMS

The switching mechanism employed in the step-by-step system is illustrated in Figs. 3, 4, and 5 and is arranged to take ten vertical steps and ten horizontal steps, thus forming a switch having access to 100 sets of terminals. Variations of this fundamental mechanism are employed for the different functions required. One switch of this type, known as a "line finder", is used to find the calling subscriber's line, thus performing the same functions for the automatic equipment that the "A" board operator does in the manual system by inserting an answering cord in the answering jack of the calling subscriber's line. One or more of these mechanisms known as "selectors" are required to select a trunk to the distant office. Another selector determines in which 1000 lines the called line appears. Another selector picks the particular 100 lines in which the call is to be completed, and finally a similar mechanism known as a "connector is required to complete the call to the number which has been dialed. Such uses of the step-by-step switch will be described in greater detail in the sections that follow.

BANKS

The banks to which the switch has access, are shown in Fig. 6. The step-by-step system borrows the familiar terms "tip" and "ring" to refer to the conductors of the subscriber's line or to the conductors of a trunk and the term "sleeve" to refer to the supervisory lead required in the central office. The banks illustrated are so arranged that the switch has access to 100 tips and 100 rings in the lower bank and to 100 sleeves in the upper bank. The switch shaft has brushes mounted on its lower end which are so spaced as to have access to the banks. The lower brush mounted on the selector rod, therefore, makes contact with two terminals and the upper with one terminal. Variations of this are found at times where a second contact may be made in the upper bank giving a total of four instead of three, and in the case of the 200 point line finders where three banks are employed. The brushes mounted on the rod are wired through flexible cords to the relay equipment on the switch, access into the switch being by means of a flexible plug and jack arrangement at the back of the switch and access out of the switch being through the bank terminals.

SWITCHING ACTION

An intergal part of the switch shaft is a series of teeth, ten for moving the shaft upward and ten for rotating it. The vertical teeth are arranged along the shaft and are controlled by means of a "vertical pawl" and a vertical magnet. The rotary or horizontal teeth are arranged around the shaft and are controlled by a "rotary pawl" and a rotary magnet. The vertical arm of the "double dog", slides over the vertical teeth as the switch rises and prevents its falling back to normal. As soon as the switch begins to rotate the "stationary dog" engages one of the vertical teeth and prevents its restoring to normal while the rotary arm of the "double dog" slides over the rotary teeth and prevents its restoring in a horizontal direction until after the switch has been released upon conclusion of the call. The vertical and rotary stepping mechanism is illustrated in Figures 7 to 10.

The first series of pulses which come through from the subscriber's dial causes the pulsing relay in the switch to operate and release in synchronism with the pulses and in turn operate and release the vertical magnet. Under the influence of the vertical pawl the switch rises until the brushes are opposite the level determined by the number of pulses sent from the dial. If the switch is a"selector" it will now rotate automatically under the influence of the rotary magnet and pawl until an idle trunk on that level is reached. If it is a"connector" it will wait for the subscriber to dial another digit, in which case it will rotate under the influence of the dial pulses until it reaches the particular set of terminals determined by the last digit.

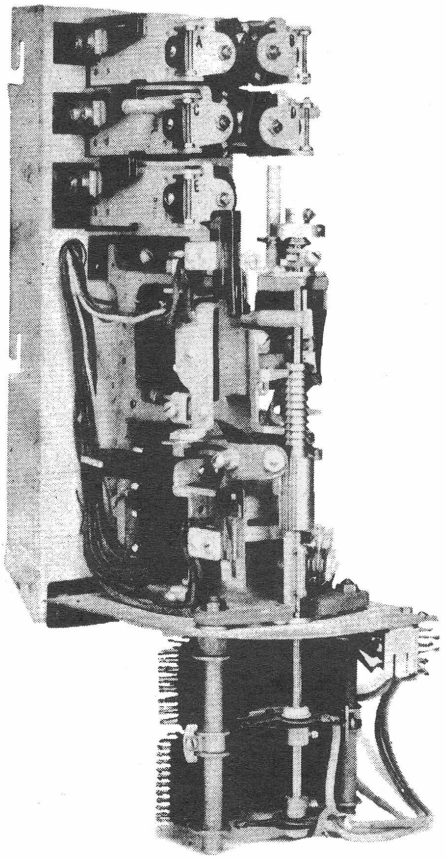


FIG. 3 STEP-BY-STEP SELECTOR SWITCH

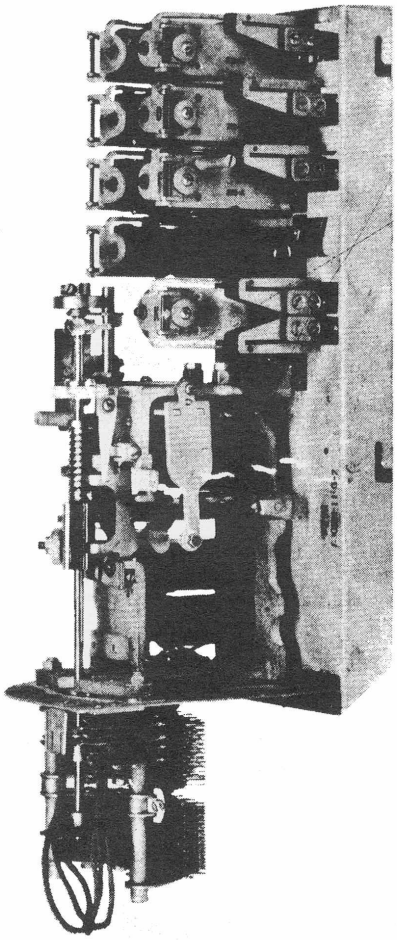


FIG. 4 STEP-BY-STEP CONNECTOR SWITCH

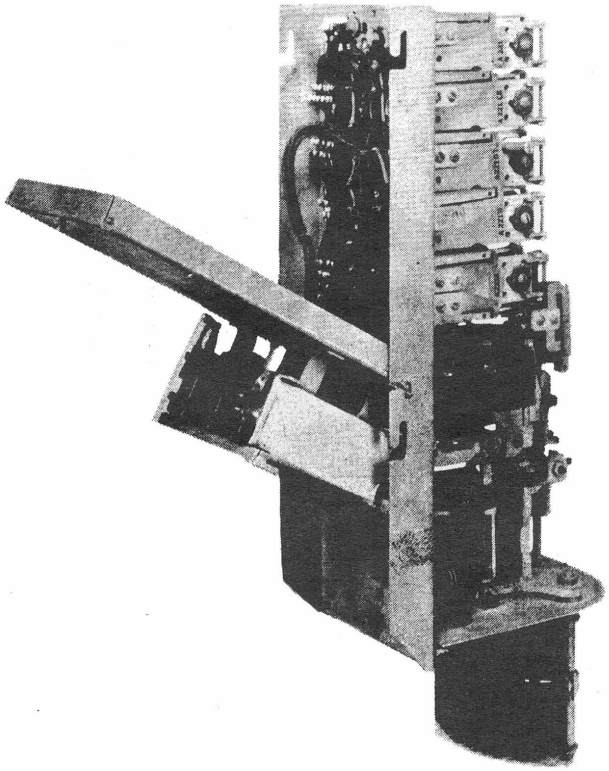


FIG. 5 STEP-BY-STEP CONNECTOR SWITCH REAR VIEW WITH COVER PLATE OPEN

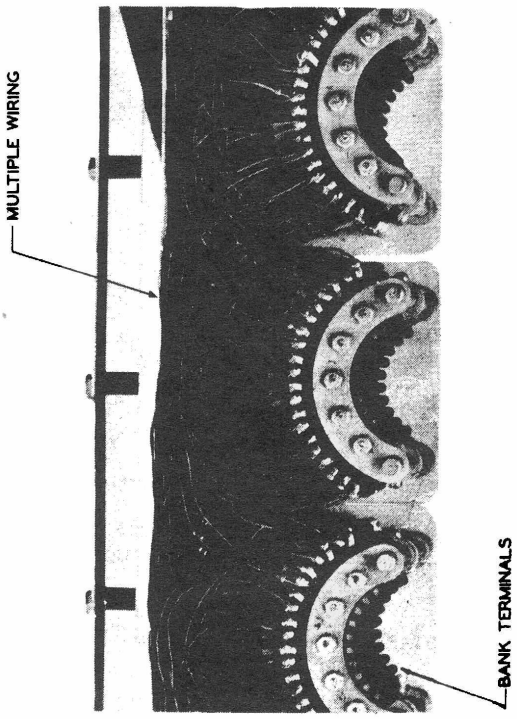


FIG. 6 STEP-BY-STEP MULTIPLE BANKS

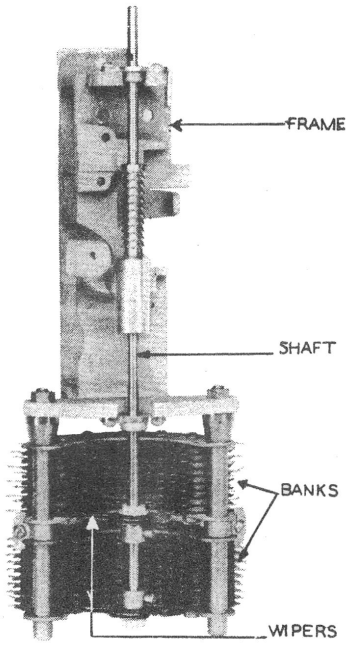


FIG. 7 FRAME, SHAFT AND BANK ASSEMBLY

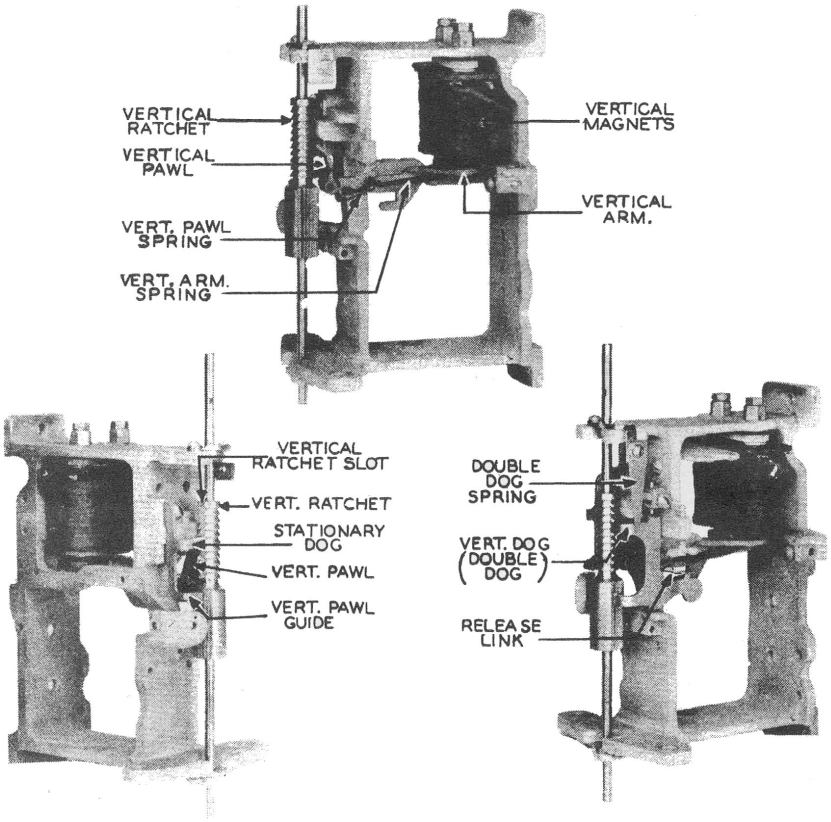


FIG. 8 VERTICAL STEPPING MECHANISM

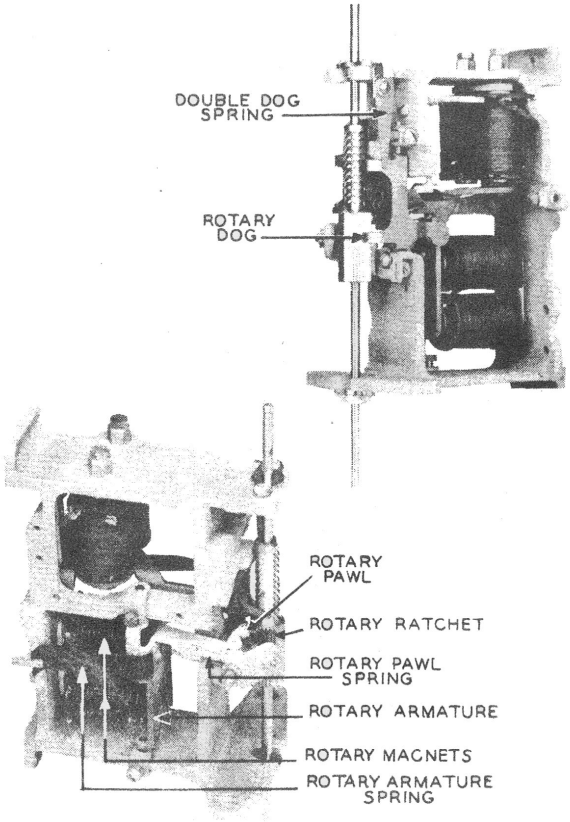


FIG. 9 ROTARY STEPPING MECHANISM

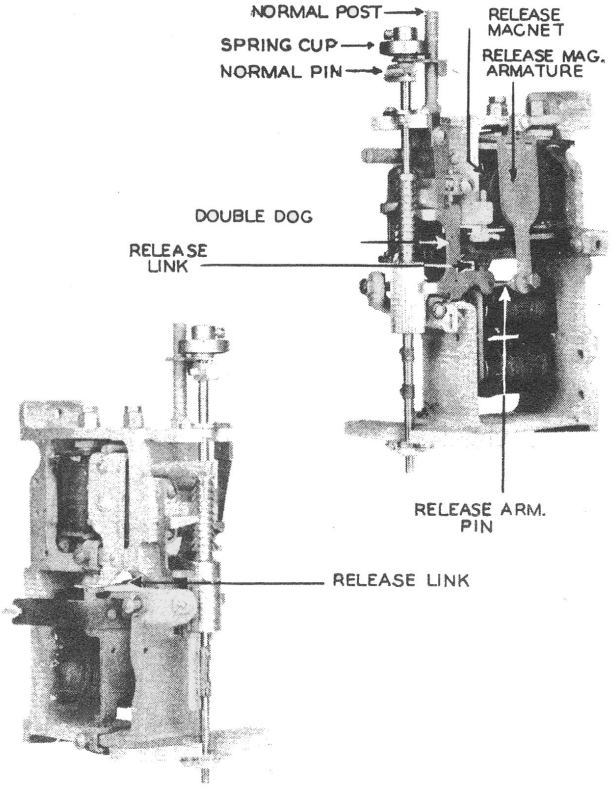


FIG. 10 RELEASE MECHANISM

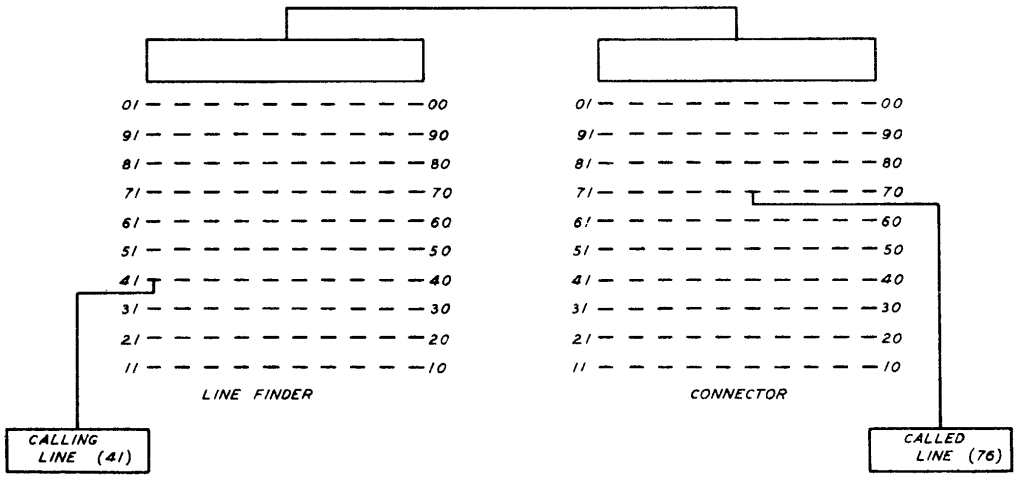


FIG. 11. 100 LINE STEP-BY-STEP DIAL SYSTEM

The switch is now held in its rotated position by the double dog and held in its vertical position by the fixed dog. Upon release of the switch a magnet is operated (known as the "release magnet") which removes the double dog from engaging the rotary teeth allowing the switch to restore horizontally under the action of a coiled spring in the spring cup. When the horizontal restoration is complete the fixed dog disengages the vertical teeth because of the vertical slot and the shaft restores to normal in a vertical direction by means of gravity.

THE FUNDAMENTAL STEP-BY-STEP SYSTEM

A simple 100 line step-by-step system is illustrated in Figure 11. Each subscriber's line terminates on the bank of a connector and is multipled to the banks of a line finder. The line finder acts as an answering cord in that it makes connection to the calling line and extends that line to a connector. The subscriber receives dial tone from the connector and dials the called number, the connector having access to all the 100 lines.

In order to handle more than one call at a time, the system illustrated might have ten line finders and ten connectors for a group of 100 lines. In this case each line finder is wired to a connector. The banks of all line finders are multipled together and the banks of all connectors are multipled. This means that ten paths are provided for the completion of calls. If the calling rate is very high more paths may be provided. In practice, sufficient line finders and connectors would be provided to handle the normal traffic but not quite enough switches to handle the extreme peak load condition which would probably occur only during a short period of the day. It would, of course, be possible for all paths to be busy and in that case a calling subscriber would not receive dial tone until after a line finder and its associated connector became idle.

As we shall see later the system illustrated in Fig. 11 is the basis for almost all step-by-step systems. By adding switches between the line finders and connectors so that each call is completed through a "train" of switches, the size of the office may be extended to 1000 or to 10,000 or more lines.

SECTION 2

LINE CIRCUITS AND LINE FINDERS

In the manual system, subscribers' lines are answered by an "A" board operator who is responsible for all of the subscriber lines appearing as answering jacks in her position. In order to establish contact with a calling subscriber who has removed the receiver from the switchhook, an answering cord is placed in the required answering jack as indicated by the lighted line lamp. In the step-by-step system the answering cord of the "A" board operator in the manual system is replaced by a step-by-step switch known as a line finder. The function of the line finder is to make contact with any calling line in a particular group and extend that line to a first selector (to a connector in the 100 line system previously described), the first selector giving the subscriber dial tone and receiving the first digit dialed by the subscriber.

In the manual system, the number of answering jacks appearing in each "A" board position is dependent upon the calling rate of the lines involved and the load which the "A" board operator is able to carry. In the step-by-step system, lines are in most cases arranged in groups of 200, the number of line finders having access to this group of lines varying with the calling rate.

200 POINT LINE FINDER

A line finder arranged to serve a 200 line group is illustrated in Fig. 13, and is known as a "200 point" line finder. Each line finder has access to 3 banks of 200 terminals each. The lowest bank contains the tips and rings of 100 lines numbered 11, 12, 13, 14,···19, 10 on the bottom level and 01 to 00 on the top level (see Fig. 12). It should be noticed that the tenth terminal on the top level is numbered "00" because the switch steps vertically ten times and horizontally ten times to reach it. The middle bank carries a second 100 lines the terminals of which are numbered 111 to 110 on the bottom level and 101 to 100 on the top level The top bank carries the sleeve terminals of the entire group of 200 lines, the sleeves 11 to 10 and 101 to 110 being arranged on the bottom level and 01 to 00 and 101 to 100 on the top level. The purpose of the sleeve bank is to permit the line relay of a calling line to put battery on its corresponding sleeve terminal to stop the line finder as it sweeps across the row of terminals. The line finder shaft carries three sets of brushes, one to make contact in each bank.

A vertical commutator consisting of 10 segments is arranged at the side of the line finder shaft so that as the shaft rises a commutator brush makes contact with the first segment when the line finder brushes are opposite the first level of the banks, the second segment when they are opposite the second level, etc. The line finder circuit is so arranged that, as soon as any line relay in the group of 200 lines is operated, one of the line finders serving the group will commence to step up and will continue stepping up until it meets a commutator segment that is grounded. There are 20 lines on each level and each "sub-group" of 20 lines has access to a common sub-group relay which may be operated by any line relay in the sub-group. The operation of this sub-group relay grounds the commutator segment corresponding to the level on which these 20 lines appear. This will cause the line finder to stop its vertical motion at the level on which the calling line appears.

After the line finder has stepped up to the proper level it will, of its own accord, begin to step over the terminals of that level, testing the sleeve terminals in the top bank, two at a time, as it goes along. As soon as it finds a sleeve terminal with battery on it from the operated line relay it will stop with its tip and ring brushes on the tip and ring of that line in order to extend that line to a first selector. Thus if line 12 is calling commutator segment 1 will be grounded and the line finder will step up to the first level and in on that level to the second terminal. After the line finder has stopped on a given set of terminals it connects the brushes in the bottom bank or in the middle bank to a first selector, in accordance with which of the two sleeves in the upper bank has the battery condition.

SLIP WIRING OF LINE FINDER BANKS AND COMMUTATORS

Obviously it takes a certain amount of time for a line finder to rise to the higher levels of its banks and cut into those levels until it finds the terminals of the calling line. The ideal condition would be to have the calling line on the first level of the line finder bank in every case, so that the line finder would have to step up only one level and then cut into that level to find the calling line. This would mean that the subscriber would receive dial tone from the first selector with a minimum amount of waiting. It is not possible to achieve this ideal condition for every call, but the hunting time for line finders is considerably decreased by "slipping"the line finder multiple as.shown on Fig. 12.

Suppose that a group of 200 lines is served by 20 line finders. In this case lines 11 to 10 appear on the first level of the lower bank of the first line finder of sub-group 1, and lines 111 to 110 on the bottom level of the middle bank of this line finder. However, these lines are wired to the top (or tenth) levels of the banks on the first line finder of sub-group 2 and to the ninth levels of the first line finder of sub-group 3, the eighth levels of the first line finder of sub-group 4, etc., and appear again on the first levels of the second line finder of sub-group 1. This means that the first and second line finders of sub-group 1, are "first choice" for the use of lines 11 to 10 and 111 to 110 since these two linesfinders have this group of 20 lines on their first

levels. Likewise the first and second line finders of sub-group 2 are first choice to lines 21 to 20 and 121 to 120, and the first and second line finders of sub-group 3 for lines 31 to 30 and 131 to 130. The wiring to the corresponding commutator segments is slipped in a corresponding manner.

ALLOTMENT OF LINE FINDERS

Fig. 12 illustrates the method of alloting line finders. The operation of the sub-group relay of a sub-group of 20 lines does two things. First, it places a ground on the commutator segment corresponding to the level in which the group of 20 lines appears on the line finder banks. Second, it grounds a start lead which operates a "start" relay in the line finder that is to be used for the call, causing it to step up and hunt for the grounded commutator segment.

Tracing the start lead from the sub-group relay in sub-group No. 1, we arrive at the back contacts of the (D) relay in the first line finders of the sub-group (which has the lines in sub-group No. 1 on its first level) and thence on to the winding of the "start" relay (A). If, however, this line finder is busy on a call the (D) relay will be operated and the start lead will be extended to the back contacts of the (D) relay of the second line finder of the sub-group. If this line finder is also busy the (D) relay will be operated and the start lead will be extended to the other line finders in sub-group No. 1. If all finders in the sub-group are busy the start lead is extended to the first line finder in sub-group No. 10 since the line finders of this group have lines 11 to 10 and 111 to 110 on their second levels. The process of allotment thereupon continues as necessary through the line finders in sub-group No. 10 sub-group No. 9, etc., the last choice line finders for the No. 1 sub-group of lines being the line finder in sub-group No. 2, since these line finders have sub-group No.1 lines on their top levels.

By means of this bank-to-bank slip on line finder multiples, each group of 20 lines is given equal preference in being chosen by line finders. If 20 line finders are provided to serve a group of 200 lines there are two first choice line finders per sub-group. If 30 line finders serve the group of 200 lines there are three first choice line finders per sub-group, three second choice, three third choice, etc. This insures that the waiting time for dial tone will be kept down to a minimum.

If it should so happen that all line finders are busy at the time a subscriber removes his receiver from the switchhook, of course he will not be connected to a first selector, will not receive dial tone and will not be able to make his call until some line finder becomes idle. This is comparable to the custom in manual offices of providing only that number of cord circuits in an "A" board position which is required to handle just a little less than the rush hour load.

The line and line finder equipment required to serve a group of 200 lines is mounted together in one equipment unit, as illustrated in Fig. 14, consisting of the required number of line finders with their banks, commutators and jack wiring, the line circuits with their associated wiring, the sub-group circuits required for each group of 20 lines and the relays required for the common group of 200 lines. This equipment unit is shop-wired and may be shipped from the factory ready to be mounted upon a line finder frame.

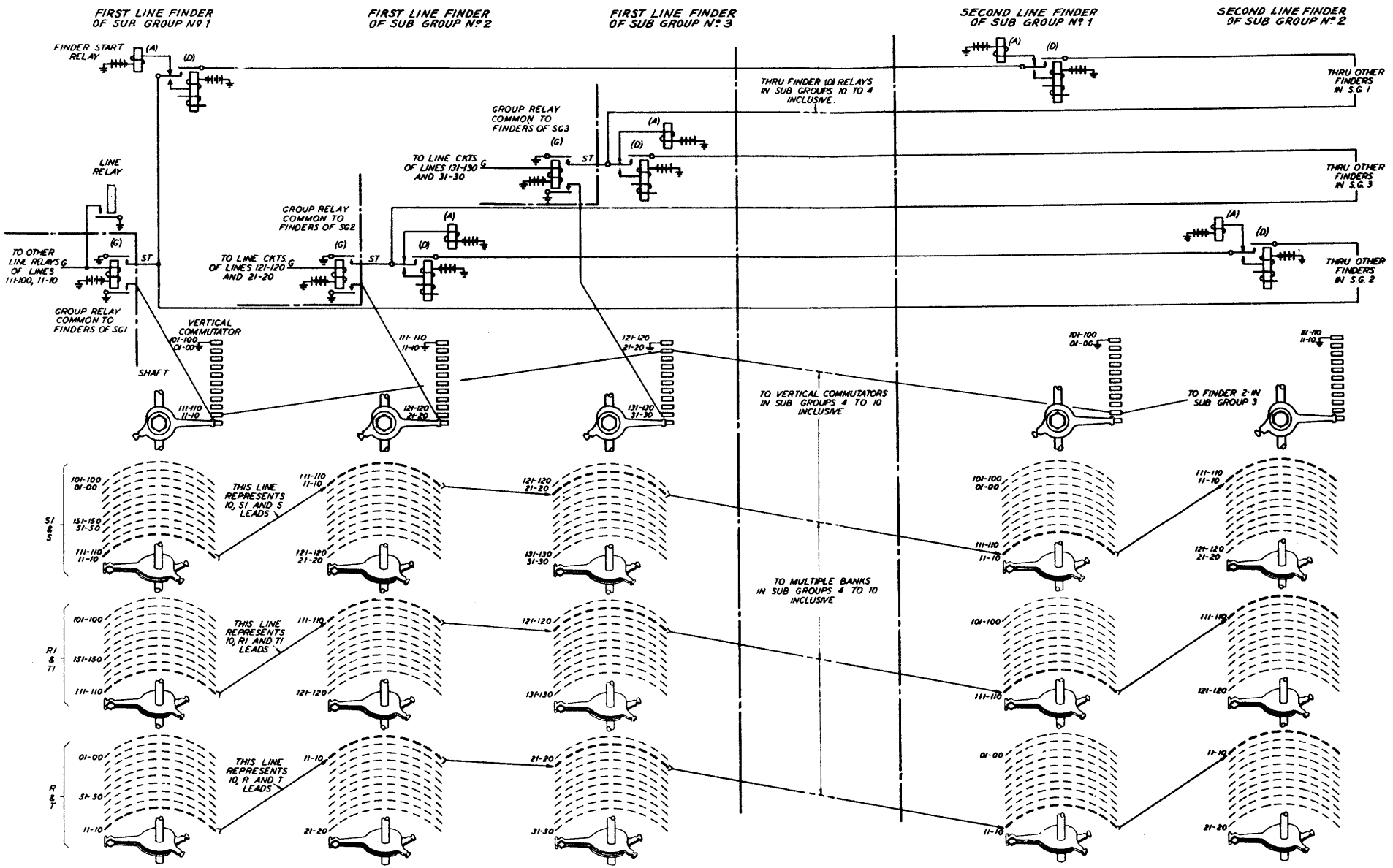


FIG. 12 ALLOTMENT OF LINE FINDERS AND MULTIPLE BANK AND COMMUNICATION MULTIPLE SLIP

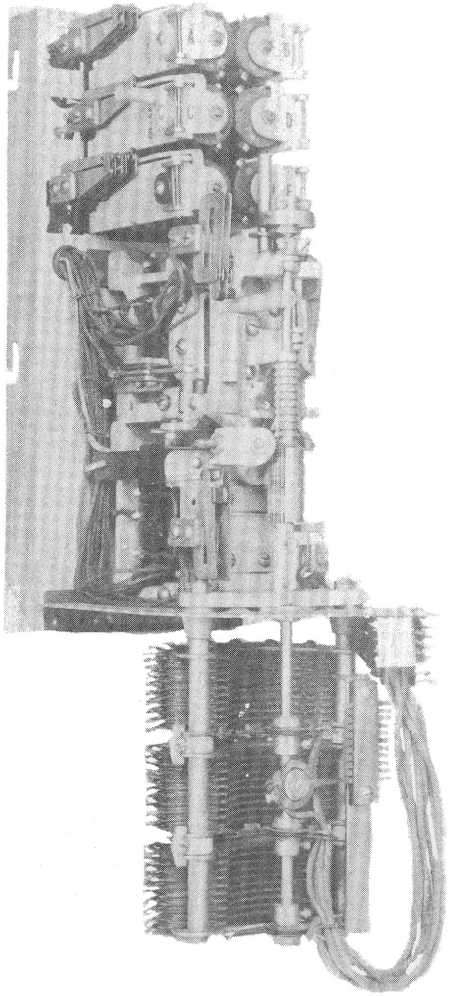


FIG. 13 STEP-BY-STEP LINE FINDER SWITCH

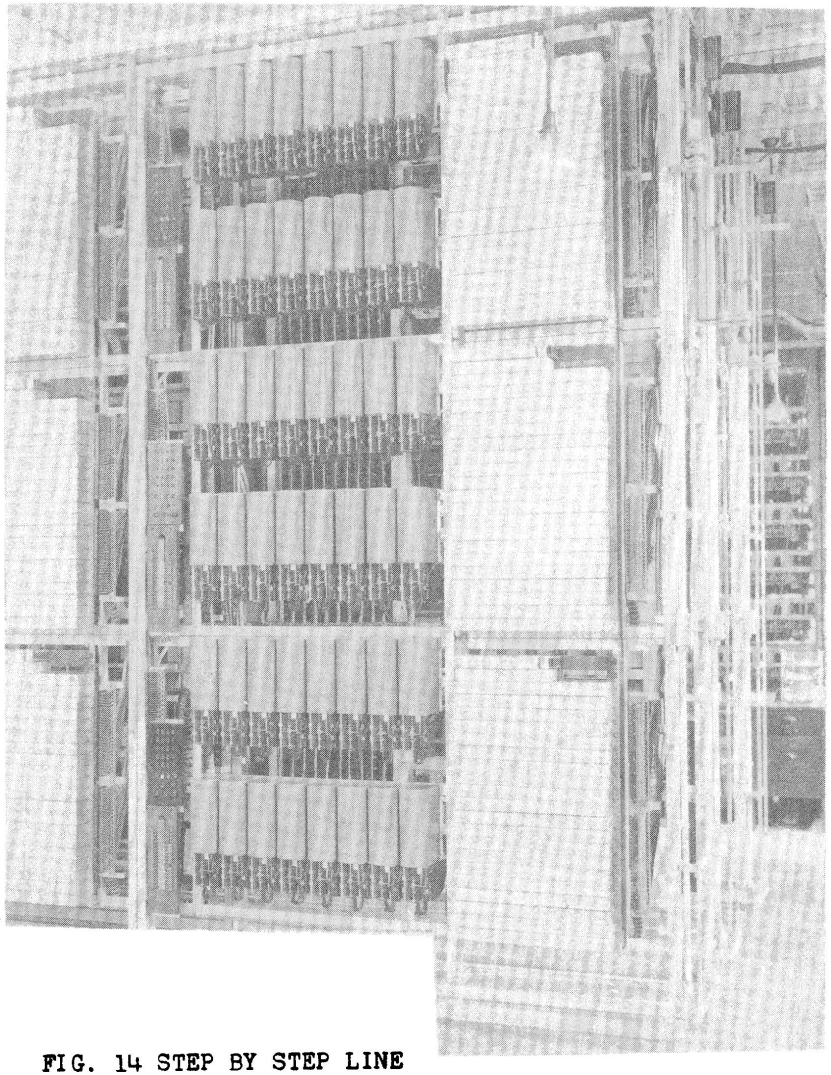


FIG. 14 STEP BY STEP LINE FINDER FRAME

SECTION 3
SELECTORS AND CONNECTORS

In Section 1 a step-by-step system employing only 100 point line finders and connectors was described and it was shown that this was a basic step-by-step system. Such a system, modified by the use of "selector connectors" capable of picking an idle trunk on one or more levels and lines on the remaining levels instead of the connectors described, is actually in use for small dial offices in rural communities. In this section the method of increasing the size of a step-by-step office beyond 100 lines will be described. This is done by inserting selectors in the "train" of switches required to complete a given call.

Figure 15 shows a method whereby the 100 line scheme previously described may be expanded to 200 lines by the use of selectors. The 100 point line finders of the previous system are now replaced by a group of 200 point line finders each line finder being capable of selecting any calling line in a group of 200. Each line finder is now wired to a "selector". The chief difference between a selector and a connector is that the selector will move up to the specified level under the influence of the customer's dial and will then proceed to find an idle trunk on that level <u>of its own accord</u>. The connector, steps up to the correct level under the influence of the customer's dial and finds the proper terminal in this level in accordance with a second set of pulses from the dial. In a 200 line system two groups of connectors would be required, each having access to 100 lines. Since it will be necessary for the customer to dial two digits in order to control whatever connector is used on the call, an additional digit must now be dialed to determine in which group of connectors the call will be completed. The digit will be dialed into the selector that has been introduced into the train. In order to cause the selector to choose the right group of connectors, the connectors having access to one group of 100 lines will be wired to one level of the selector, say the fourth, and the other group of connectors to another level of the selector, say the eighth. Thus, if the customer dials as his first digit a four, the selector will step up to its fourth level and will hunt along that level for an idle connector having access to the lines 400 to 499. If his first digit is an eight, the selector will step up to the eighth level and will choose an idle connector having access to the numbers 800 to 899. In addition, trunks may be provided on the tenth level of the selector to an assistance operator if required.

The presence of the one selector in the train of switches presents the possibility of increasing the size of this step-by-step office to 1000 lines, providing a separate group of connectors is wired to each level of the selector. The number of selectors required with their banks in multiple will be determined by the number of line finders required to handle the calling rate from each group of 200 lines. For a 1000 line office the calling lines will be divided as before into groups of 200 lines, each group of lines being served by its own line finders. The line finders of all groups will, however, be wired to selectors having their banks in multiple so that a subscriber in one group of lines, having gained access to a selector by means of line finder action, will have access to actually the same connectors as a calling subscriber in any other group,

In the event that any level of the selector is required for trunks to other than connectors, the total number of lines which it will be possible to serve will be reduced by 100 for each level required for trunks to other than connectors.

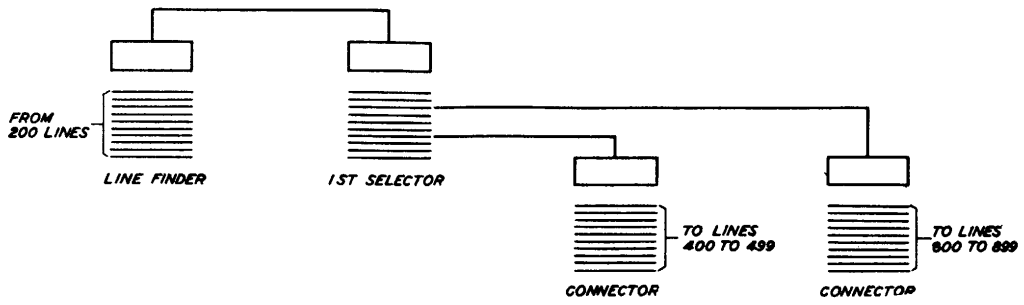


FIG. 15 - 200 LINE STEP-BY-STEP SYSTEM

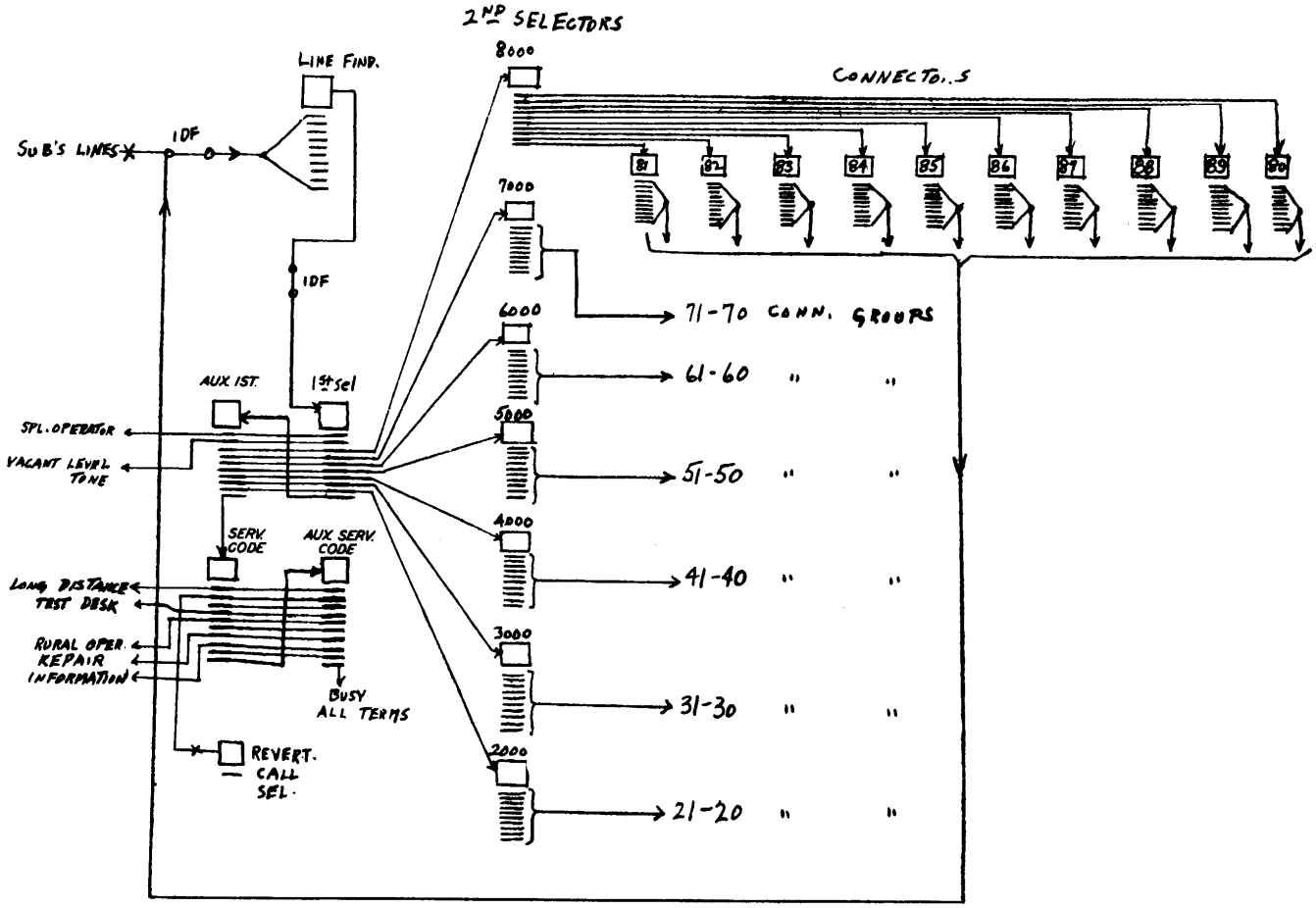


FIG. 16 STEP-BY-STEP 4 DIGIT OFFICE 7000 LINES EQUIPPED

The addition of a second selector in the train of switches required for the completion of each call permits the size of the office to grow beyond 1000 lines. Figure 16 illustrates the switches required to serve a four-digit office with 7000 terminals equipped. This system makes use of 200 point line finders as before, first selectors to choose the particular 1000 lines in which the call is to be completed, and second selectors to choose the particular 100 lines (or rather the particular group of connectors) in which the call is to be completed.

Referring to Figure 16 assume that the number to which a call is to be completed is 8195. The method of completing the call will be as follows:

When the customer removes his receiver from the switchhook, an idle line finder in the group serving the particular line will attach itself to the calling line and extend it to the first selector.

The customer receives dial tone from the first selector.

The customer dials 8 as his first digit, and the first selector steps up to tne eighth level.

The first selector hunts for an idle trunk to the 8000 group of second selectors, of which there are ten on its eighth level.

The customer dials a 1 as his second digit and the second selector steps up to its first level.

The second selector hunts for an idle connector in the 8100 group by testing the terminals on its first level.

The customer dials a 9 as his third digit and an idle connector steps up to its ninth level under the influence of the dial pulses.

The fourth and last digit dialed by the customer is a 5 which causes the connector to step to the fifth terminal on its ninth level which represents the terminal of the line 8195.

The called party's bell is rung by the connector until the called party answers.

The line finder, first selector, second selector and connector chosen for the call remain operated until the conclusion of the conversation.

When both parties hang up all switches restore to normal.

SPECIAL SERVICE SWITCHES

In the event that a customer requires special assistance with his call, he is instructed to dial "0". If this "0" is dialed as his first digit it will cause the first selector to step up to its tenth level and hunt an idle trunk on this level over which he will be able to reach a special service operator.

The first level of the first selector banks is reserved, however, for access to "auxiliary first" selectors. All levels of the auxiliary first selectors are multipled to the banks of the first selectors except the first level. The first level of the auxiliary first selector goes to "service code" switches. One purpose of the auxiliary first selectors is to nullify the effect of "preliminary impulses" from the customer's dial. If the subscriber accidentally opens the circuit once by touching his switchhook after the line finder has found his line this will have the same effect as dialing the digit "1" and the first selector will be stepped up to its first level connecting the customer's line through to an auxiliary first selector. If the customer now proceeds to dial the first digit of his number the auxiliary first selector will step up to the designated level and an idle trunk will be selected on that level just as though the digit had been dialed into the first selector in the proper manner. This is true regardless of whether the customer dials the first digit of a line number or whether he dials "0" in order to gain access to a special service operator.

The purpose of the service code switch is to enable the customer to gain access to long distance, repair service, information, etc., which are to be obtained by dialing one of several special service codes. Long distance, for instance, is obtained by dialing 110, the first digit being recorded by the first selector, the second digit by the auxiliary first selector and the last digit by the service code switch. If the subscriber inadvertently causes a preliminary impulse, the call will be completed to one of the service code switch whose banks are multipled with those of the regular service switches.

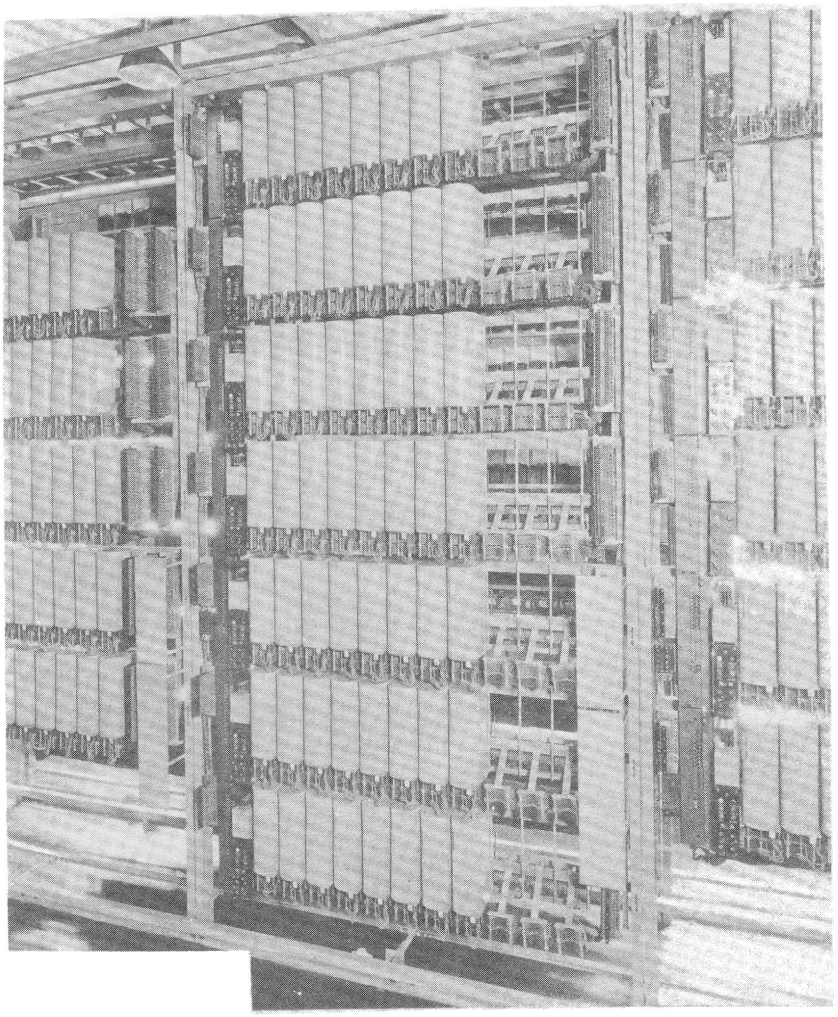


FIG. 17 TYPICAL CONNECTOR FRAME

CONNECTORS

Figures 4 and 5 illustrate a typical connector switch. There is little to distinguish this switch in appearance from other step-by-step switches. It has a larger number of relays associated with it than does a selector because it has more duties to perform on a given call. First of all, the connector is required to step both vertically and horizontally under the influence of the subscriber's dial in order to select a particular terminal representing the line being called. In addition, it must ring the called subscriber's bell, maintain supervision over the call in order to signal the other switches in the train when both subscribers have hung up and, on a local call, supply talking battery to both subscribers.

In the event that a connector finds the called line busy, there will be a ground on the sleeve terminal. This will set up a circuit condition which will cause a busy tone to be returned to the calling subscriber.

Figure 17 shows a typical connector frame. Each "shelf" of connectors on the frame is arranged to serve a separate group of 100 lines. The connector frame illustrated is equipped with eight connectors for each 100 lines. The first is wired as a test connector and is used by the maintenance forces for testing lines. The remaining seven connectors are used for completing calls by subscribers, and on the frame illustrated seven such calls can be completed simultaneously in each group of 100 lines. Under heavier traffic conditions more connectors would be provided. The maximum number of connectors per shelf is eleven including the test connector. Where more than ten are required for subscriber traffic to a group of 100 lines, two or more shelves may be multipled together, providing an additional 5 or 10 connectors per 100 lines.

Figure 18 illustrates how the various frames are cabled together. The subscriber's lines are wired to the banks of both line finders and connectors. The jacks of line finders are wired to the jacks of first selectors, the connections, however, going through the I.D.F. providing flexibility for the changing of the particular first selector wired to a given line finder. The banks of first selectors are wired to the jacks of second selectors, and the banks of second selectors are wired to the jacks of connectors.

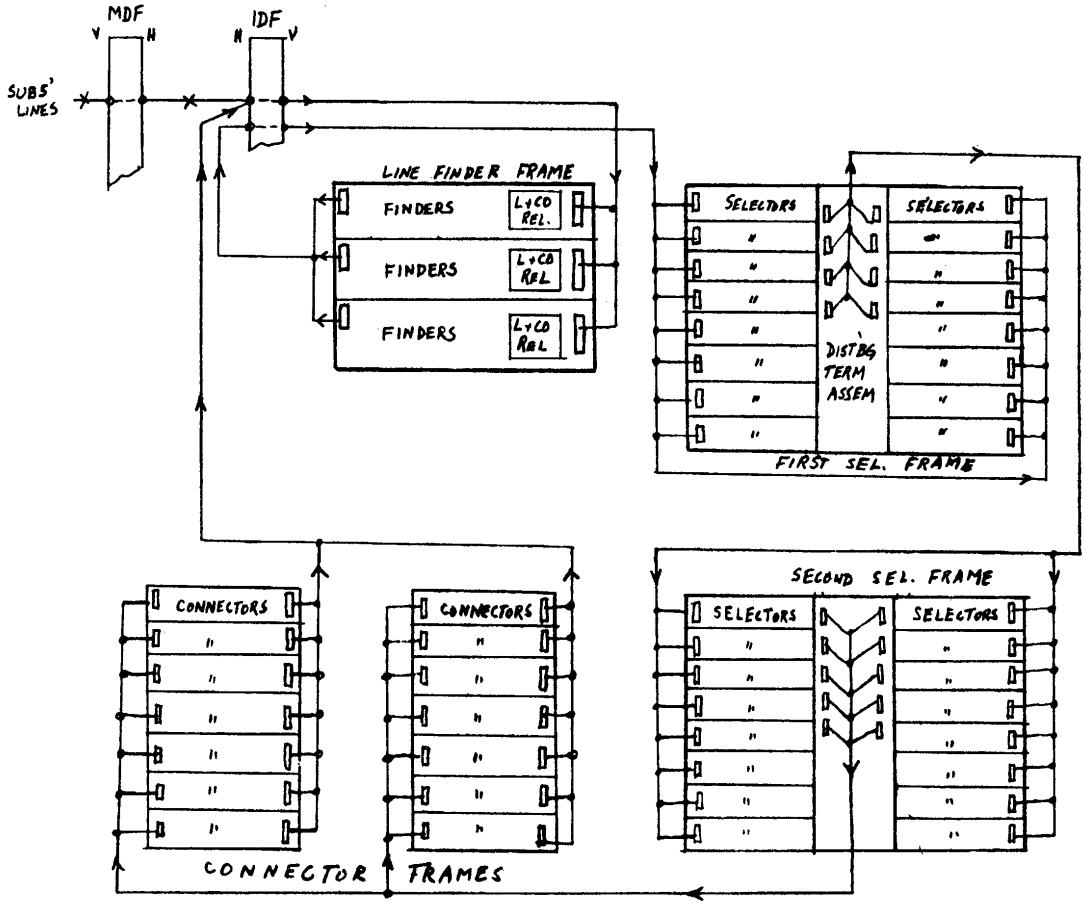


FIG. 18 CABLING SCHEMATIC OF REGULAR SWITCH TRAIN

SECTION 4
TRUNKING PROBLEMS IN STEP-BY-STEP OFFICES

The discussion in Section 3 in connection with the 4 digit office with 7000 terminals equipped assumed that no other offices were required in the area. In certain areas where more than one central office is required, the interoffice trunking problems may become quite complex. This section will outline methods of using selector levels to provide trunks to other offices in exchange areas with interoffice trunking problems of varying complexity.

5 DIGIT OPERATION

In exchange areas where there are few central offices, say 3 or 4, the trunks to other offices may be reached directly from the banks of the first selectors. In a case of this kind the first selector bank terminals will correspond directly to the out trunk multiple found on the "A" board in manual offices. The subscriber will be required to dial only one digit to determine in which office his call is to be completed. One level of all first selectors will be required for each office to which trunks are to be provided. This condition is illustrated by Figure 19 which shows trunks to other offices on levels 5 and 7 of the first selectors. Since it is customary to require the customer to dial 0 in order to obtain a special service operator, the tenth level of the first selectors will be required for trunks to an assistance operator. The first level will be wired to auxiliary first selectors in order to guard against preliminary impulses and to provide access to the service code switches.

Figure 19 indicates that, in a 5-digit system, trunks to local second selectors are also taken off one of the levels of the first selectors, the level being determined by the first letter of the local office code. The first digit dialed by the customer will therefore determine whether the call is to be completed in his own office through local second selectors or in some other office over interoffice trunks. If the call is to be completed in his own office the first selector will choose a trunk to a local second selector. The second digit dialed by the customer (which will cause a second selector to step up to the required level) will choose the proper third selector and thus determine in which 1000 numbers the call is to be completed. Trunks incoming from other step-by-step offices in the area will terminate on incoming second selectors whose banks are multipled with those of the local second selectors.

6 DIGIT OPERATION

Where the number of central offices in an exchange area is greater than the number of available levels on first selectors, two digits must be dialed by the customer to determine in which office his call will be completed. This condition is illustrated by Figure 20. In this case trunks to other offices will be taken off the banks of second selectors, trunks to all offices having the first digit in common being taken off the various levels of the same group of second selectors. In this case, third selectors are used to determine in which 1000 terminals a call through the local office is to be completed and incoming trunks from other offices will terminate on incoming third selectors with their banks in multiple with those of the local third selectors.

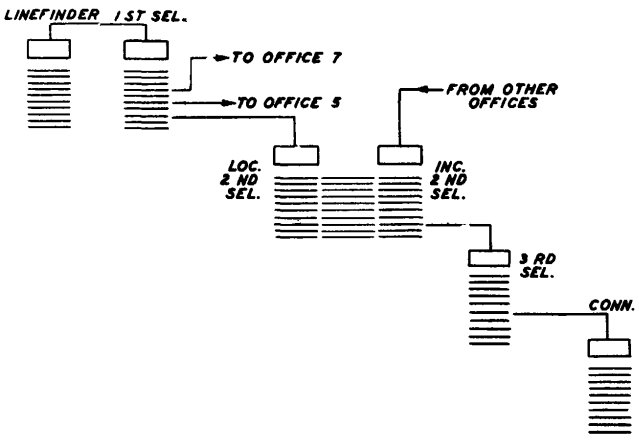


FIG. 19 "STEP-BY-STEP SYSTEM 5 DIGIT"

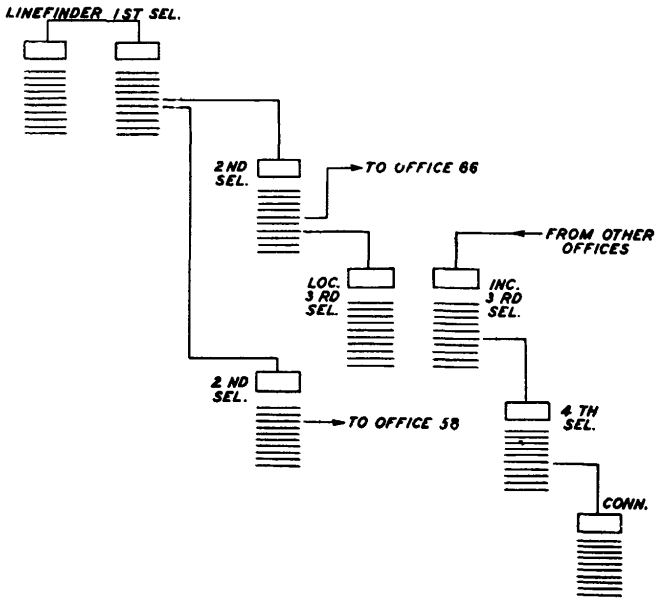


FIG. 20 "STEP-BY-STEP SYSTEM 6 DIGIT"

Trunks to O operator and to auxiliary first selectors will be taken off the tenth and first levels of the first selectors as before.

GRADED MULTIPLE

In previous discussions of selectors and selector levels it has been pointed out that while the selector is responsible for finding an idle trunk upon any given level, its choice of trunks on that level is limited to 10. This limitation in the size of a trunk group to which any given selector has access presents a different problem than does the outgoing trunk multiple in the manual "A" board. Any given "A" operator on an "A" board has access to all trunks to any other office regardless of the size of the trunk group. In step-by-step operation, however, where a trunk group to another office or to a succeeding group of switches in the local office consists of more than 10 trunks, other provisions must be made for efficient use of those trunks. This is done in part by what is known as "Graded Multiple" Without graded multiple, trunks in the step-by-step system would always have to be supplied in multiples of ten which might be uneconomical. With graded multiple, however, 40 selectors can be made to use, say, 13 trunks effectively.

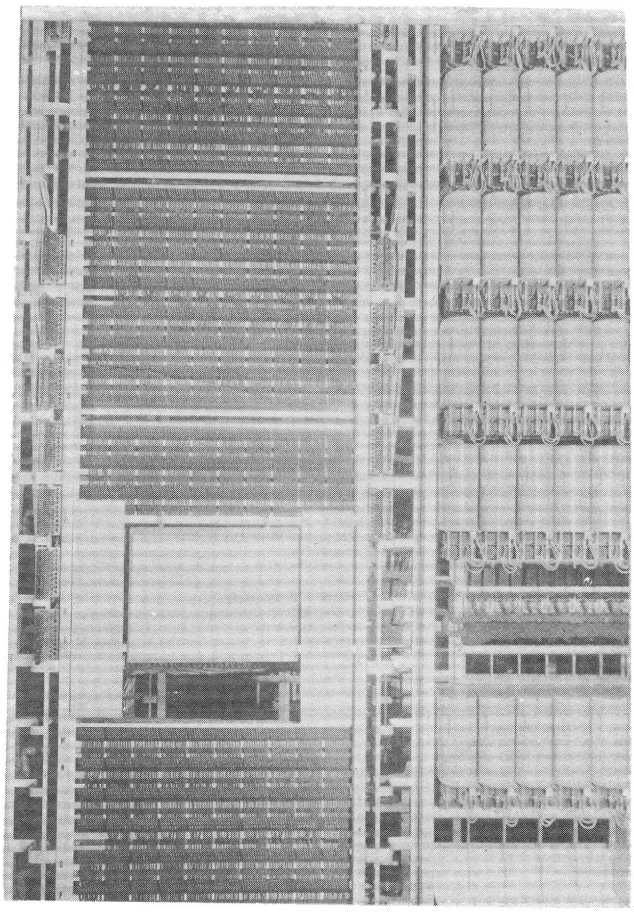


FIG. 21 "SELECTOR FRAME DISTRIBUTING TERMINAL ASSEMBLY"

In order to explain what graded multiple is, it is first necessary to understand how selectors are arranged with respect to each other and how their banks are wired. In step-by-step central offices each selector frame is arranged to mount 16 shelves of 20 selectors each, making a total of 320 selectors per frame. Each selector frame consists of two bays, each mounting 8 shelves of 20 selectors each. The 20 selectors on each shelf are arranged in two groups of 10 selectors each. Each selector in a group of 10 has its banks multipled directly to the banks of every other selector in the group. Each group of 10 selectors in addition has its banks wired to a long terminal strip which is mounted in the center of the frame between the two bays of selectors. (See Figure 21). Since there are 32 groups of 10 selectors each mounted on the frame, there are 32 of these terminal strips mounted one directly below the other down the center portion of a fully equipped frame. Each terminal strip therefore represents the 100 terminals of 10 selectors multipled together and these terminal strips are so arranged that each terminal, by means of an insulated vertical wire strap may be wired to the corresponding terminal of the terminal strip of any or all groups of 10 selectors on the frame. It is thus possible to multiple the banks of any one group of 10 selectors with those of any other group or groups as required. In addition to the bank terminal strips, the distributing terminal assembly bay includes two vertical rows of terminal strips on which switchboard cable to other frames is terminated. These outgoing circuits are associated with terminals on the bank terminal strips by means of jumper wires.

It does not always follow that the number of trunks to be considered in estimating traffic will be in multiples of 10. For example, cases may occur where 40 selectors are required to have access to a total of 13 trunks on a given level. In cases of this type graded multiple is used. In graded multiple certain trunks are termed first choice trunks and are not multipled together through all the groups of 10 selectors. If it is desirable to multiple the ten terminals of a given level of four different groups of 10 selectors each, on 13 trunks, one trunk will be connected to the first terminal of each group and these terminals will not be multipled together. The remaining 9 terminals of each of the four groups will be multipled together and connected to 9 trunks. Each group will then have one trunk which it alone uses and nine which it uses in common with three other groups. In graded multiple terms, the first trunks are termed "individual" trunks, while the remaining trunks are referred to an "common" since they are offered for the common use of all the selectors in all four groups.

In order to reduce the hunting period and also to reduce the wear on switches, a reversal is usually introduced in the strapping. For example, assume 40 selectors

having access to 10 trunks on a given level. Four groups of 10 selectors each are required and the first 2 groups will be multipled together straight and the last two groups will be multipled together straight with a complete reversal between the second and third groups for trunks 1 to 9. The tenth terminal is always multipled straight for all divisions in the group for last trunk busy registration.

REPEATERS

In order to establish connection between two step-by-step offices not in the same building it is necessary to furnish an auxiliary circuit known as an "outgoing repeater" in each trunk circuit, at the originating office. The purpose of this repeater is to connect the three wire circuit from the selector banks to the two trunk conductors which run between offices; to repeat the dial pulses to the switches in the distant office; to hold the switches in the originating office operated during the call; to furnish talking battery to the calling subscriber; and to enable the connector in the distant office to supervise the calling line. It is also necessary to furnish a repeater of the same general type in each trunk from step-by-step to manual offices.

The average outgoing repeater will not re-transmit the dial pulses with the same precision that a dial gives. Usually the switches in the distant office will operate satisfactorily on the repeated pulses. Where a trunk is very long however, the distortion of the pulses will be increased to a point where the distant switches will no longer function. In this case, a special repeater, called a "pulse correcting" repeater is added at the incoming end of the trunk. This repeater replaces the distorted incoming pulses by new pulses which will operate the switches satisfactorily.

OUTGOING TRUNK PRESELECTORS

Trunks to other offices must be carried in outside plant and where the distance is at all great it is highly desirable to keep the number of trunks between offices down to a minimum. As we have seen, the principle of graded multiple assists in accomplishing this purpose. Another device which considerably reduces the number of outgoing trunks provided from a group of selectors is known as the outgoing trunk preselector. The mechanism used for the preselector is known as a 206 type selector and differs radically from the regular step-by-step mechanism. This selector is a rotary switch with brushes which have access to 22 sets of terminals and are so arranged that as soon as one set of brushes leaves the last set of terminals, a second set of brushes reengages the first set of terminals. The brushes are mounted on a shaft or rotor which is driven by a ratchet and pawl mechanism actuated by a magnet. Any trunk terminating in the brushes of such a switch will therefore have access to 22 outgoing terminals or trunks. Figure 22 indicates how these preselectors are used.

Outgoing trunks are connected to the banks of these switches and trunks from the banks of step-by-step selectors to the brushes. The term "preselector" indicates that at any time when the preselector is not in use it will rotate to the terminals of an idle outgoing trunk and rest there so that if the trunk incoming to the switch is chosen by a selector, an idle trunk out of the preselector will be immediately available.

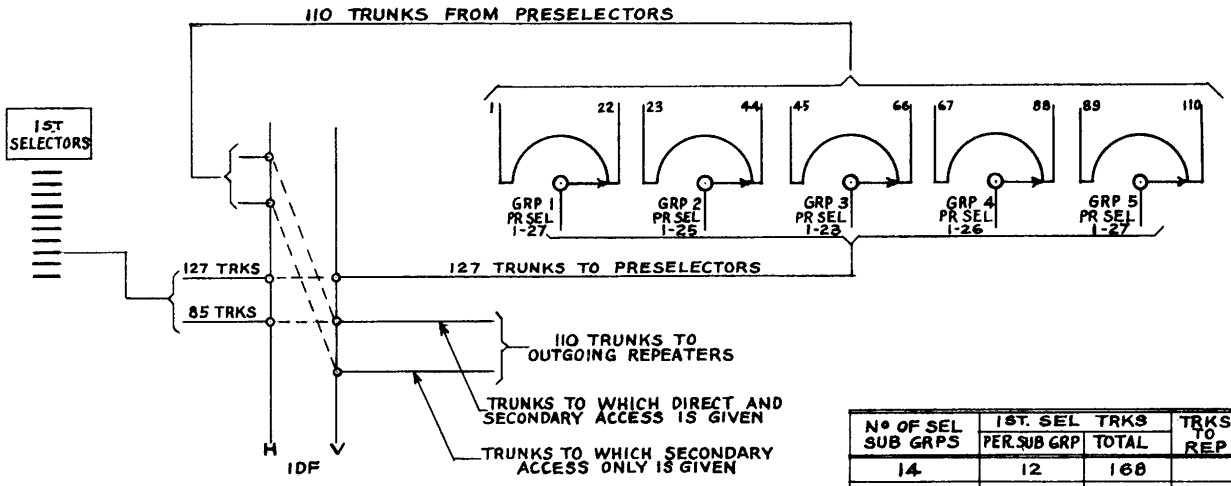
In order to illustrate the use of preselectors, assume that a group of trunks to a given office is outgoing from a certain level of several groups of first selectors. When outtrunk preselectors are used, forty per cent of these trunks outgoing from the first selector levels are connected directly to trunks outgoing to the distant office. These "direct access" trunks will be located on the lower numbered terminals of the selector levels so that if a first selector finds an idle trunk in the lower numbered terminals of the level it will usually be one of these direct access trunks. The direct access trunks will therefore carry all the traffic during the light load of the day.

The remaining 60% of the trunks from selector levels are cabled direct to the brushes of outgoing trunk preselectors. All trunks outgoing to the office in question, including the direct access trunks, will be wired to the outgoing terminals of the preselectors. During the peak load periods of the day when the direct access trunks will no longer carry the traffic the first selectors will choose trunks to the preselectors which will previously have chosen an idle trunk to the distant office. This use of preselectors results in a very considerable reduction of the number of outgoing trunks required.

PRIVATE BRANCH EXCHANGE TRUNKS

Business houses requiring private branch exchanges or small switchboards for handling their own private telephone business usually require a number of trunks from connector terminals. Usually the connector terminals representing the trunks to various business houses will be segregated into one or more groups of 100 connector terminals and the connectors serving these groups will be "rotary hunting" in that they will hunt over a group of trunks to a private branch exchange if the first happens to be busy. The trunks in each group must be arranged in sequence so that when the listed number is called, if the first trunk is busy the connector will automatically hunt over other trunks to the same P.B.X. on the same level. Since the calling rate to business house lines is usually higher than is normal for the rest of the office, special size groups of connectors will usually be required to serve 100 such lines.

If less than 10 trunks are required to a given P.B.X. several small groups of P.B.X. trunks may be placed on the same connector level. The listed number will be dialed in each case and the connector will step to the first trunk of a group under the influence of the dial and hunt over only those trunks on the level associated with the particular



NOTE -

Direct access trunks are cross-connected direct to repeaters. Secondary access trunks are cross-connected to outgoing trunk preselectors, the banks of which are cabled to the HIDF and cross-connected to repeaters.

No OF SEL SUB GRPS	1ST. SEL TRKS PER SUB GRP	1ST. SEL TRKS TOTAL	TRKS TO REP
14	12	168	
1	10	10	
2	12	24	
1	10	10	
		212	110

DIRECT TRKS TO REP - 85 (40% OF 212)
TRKS TO PRESELECTORS - 127 (60% OF 212)
PRESELECTOR GROUPS - 5

FIG. 22 APPLICATION OF OUTGOING TRUNK PRESELECTORS

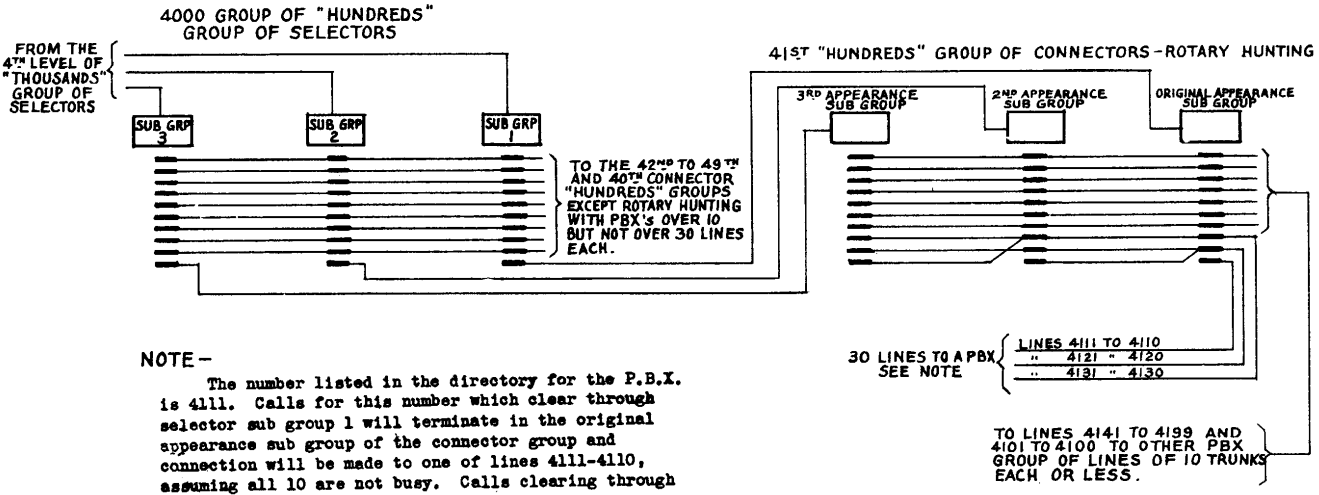
listed number. If all trunks are busy, a circuit condition on the last terminal of the group causes the connector to send back the busy signal in the usual manner. The only restriction is that the trunks in a given group must have consecutive telephone numbers.

In the event that the number of trunks to a given private branch exchange exceeds ten, various methods have been devised to give equal access to all trunks from connector levels. Figure 23 illustrates one arrangement whereby this is made possible.

Assuming for purposes of illustration that the P.B.X. 100 group is the forty-first hundred, the bottom row of terminals on the connector bank would normally be lines 4111 to 4110, the lines on the second level 4121 to 4120 and on the third level 4131 to 4130. Assume also that all 30 of these connector terminals are required to serve a group of trunks to a private branch exchange. The first group of connectors will have the first three levels arranged as we have just stated. The second group of connectors will have lines 4121 to 4120 on both the first and the second levels with lines 4131 to 4130 on the third level. The third group of connectors will have lines 4131 to 4130 on the first and third levels with lines 4121 to 4120 on the second level.

The number that will be dialed to obtain any one of these trunks will be 4111. If this call is to be completed through the first group of connectors, the particular connector will step up to the first level and will thereupon hunt over lines 4111 to 4110 for an idle trunk to the P.B.X. If a connector in the second group is used for the call, it will step up to the first level and hunt over lines 4121 to 4120 and if a connector in the third group is used, it will hunt over the lines 4131 to 4130. In this manner access is provided to each of the trunks in the group of the private branch exchange.

A connector equipped to serve a larger group of P.B.X. trunks is known as a level hunting connector. The trunks are connected to the various levels consecutively. The listed number is the first terminal on the first level. This type of connector will hunt completely over the first level, restore to normal if there is no idle trunk on that level and then by means of a commutator and a "recording switch", which is mounted on the connector, will step to the second level and hunt over that. This is continued over the various levels until an idle terminal is reached or until all trunks have been tested.



NOTE –

The number listed in the directory for the P.B.X. is 4111. Calls for this number which clear through selector sub group 1 will terminate in the original appearance sub group of the connector group and connection will be made to one of lines 4111-4110, assuming all 10 are not busy. Calls clearing through sub group 2 will terminate in the 2nd appearance sub group of connectors and will be connected to one of lines 4121-4120. Likewise, calls clearing through sub group 3 will terminate in lines 4131-4130.

FIG. 23 "MULTIPLE SLIP ARRANGEMENT FOR CONNECTOR GROUPS SERVING PBX GROUPS OVER 10 TERMINALS

SECTION 5

INTERCONNECTION OF STEP-BY-STEP WITH MANUAL SYSTEMS

Usually there are instances in which manual and dial offices exist together in the same area. Under these circumstances it is necessary to complete calls in a manual office which originate in a dial office and vice versa. Where the originating dial office is step-by-step, the calls are completed through a step-by-step "Call Indicator" "B" position in the manual office. On the other hand, where a call originates in a manual office and must be completed to a step-by-step subscriber, the usual practice is to equip the manual operator positions with dials and to provide dialing out trunks direct to the step-by-step office. A few step-by-step offices were equipped with "Call Distributing 'B' Switchboards" to complete calls of this type. However, this type of equipment is no longer installed in new offices.

Each step-by-step office has access to a "Dial System 'A' Board" for the handling of assistance calls, intercepting service, and the completion of "A" Board toll calls. This may be a local or centralized "A" Switchboard.

STEP-BY-STEP CALL INDICATOR

Step-by-step Call Indicator "B" positions are employed in manual offices that have enough trunks incoming from step-by-step offices to justify the provision of one or more complete "B" positions for the exclusive use of these trunks. Figure 24 shows a schematic diagram of the connection which is set up to handle such a call. The dial subscriber will dial the number in exactly the same manner as if the call were to be completed in a step-by-step office and there will be no indication, so far as he is concerned, of any difference in the handling of the two calls.

The digits of the office code will be used, in the usual manner, to select a trunk to the manual office. As soon as this operation has been completed, however, he will continue to dial, sending through the pulses which would, in a step-by-step office cause the switches to function to find the called number. However, this call is to be completed in a manual office at a manual "B" Board, and some provision must be made to receive the pulses from the dial and translate them into information readily intelligible to the Call Indicator "B" operator.

This is done by providing, in the manual office, what are known as "recorders" several of which are made available to each Call Indicator "B" Position. The number of recorders provided will depend upon the number of calls which are likely to be incoming at any time. The recorder will store up the dial pulses and hold the information if the "B" operator is busy handling other calls.

As soon as the "B" operator is ready to handle a call waiting on a certain trunk, she will either connect herself to it by depressing the display key associated with that trunk (Key Display Call Indicator) or will automatically be connected to it in the proper sequence (Automatic Display Call Indicator). The recorder will then use the stored information to cause the correct display on the call indicator screen. As soon as the number has been displayed, the operator will plug the associated trunk into the multiple jack of the called line, if the line is idle.

TANDEM OPERATION

Under certain traffic conditions it is sometimes advantageous to use tandem trunking rather than direct trunking in making interconnection between offices. Such tandem networks may include step-by-step as well as manual offices. Where the tandem point is a manual switchboard it will be necessary for the tandem operator to receive the call over a trunk from the originating office and pass it forward over another trunk to the completing office. If the intermediate point is a step-by-step office, however, the call will pass through a switch or train of switches in the tandem office (see Figure 25) in order to reach a trunk to the office required. In general, the equipment required in the tandem and terminal offices to complete the various types of interconnections will be obvious from what has been said before. However, there are several features of sufficient interest to warrant further discussion.

Thus, if a manual office is selected to act as a tandem point between several step-by-step offices, it is probable that enough step-by-step switches would be located in the manual office to reroute the step-by-step calls coming through. As a matter of actual fact it has been found advantageous in some cases to use step-by-step equipment in manual tandem offices to handle calls between manual offices. In this case, the operator at the originating "A" Board has a dial to enable her to control the tandem switches. After a trunk to the distant office has been selected by the tandem selectors, she passes the call in the usual way.

If both the originating office and the tandem office happen to be step-by-step and the completing office is manual, the trunks from the banks of the tandem switches will appear on a manual switchboard. This manual switchboard may be a call indicator position; on the other hand, it may be a straightforward trunking "B" position or it may be a small

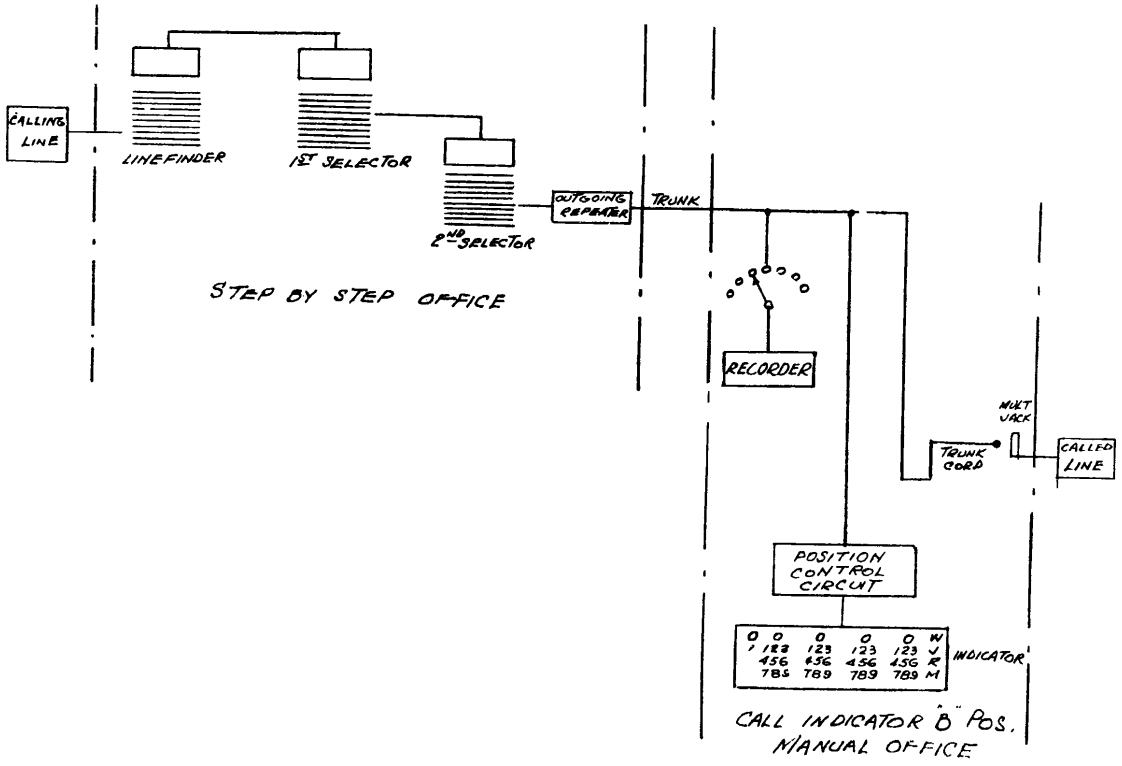


FIG. 24 "STEP-BY-STEP CALL INDICATOR"

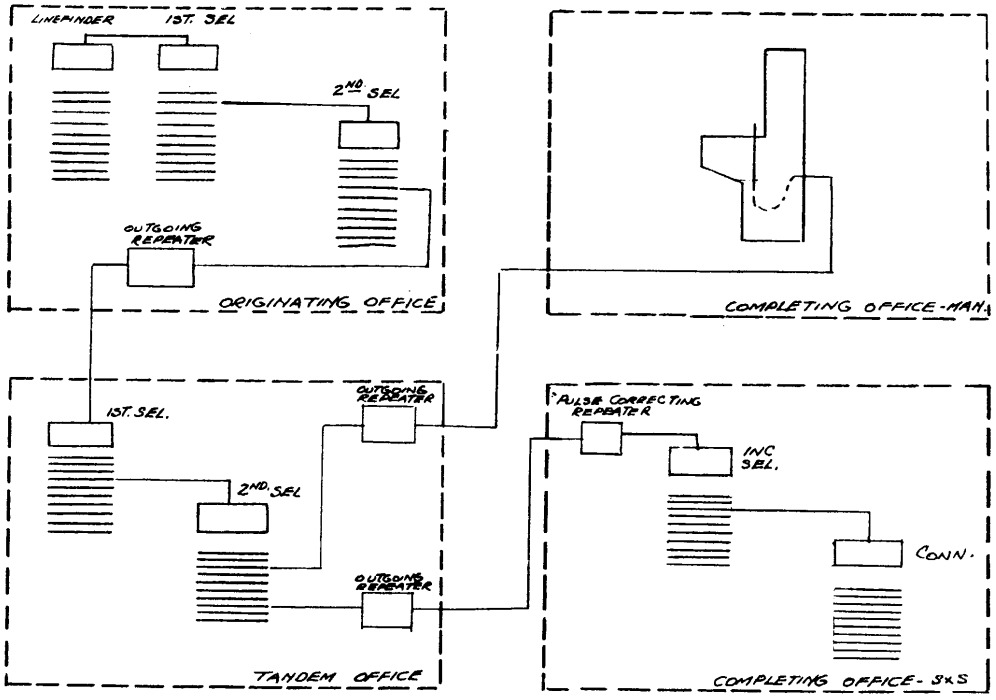


FIG. 25 "TANDEM OPERATION"

magneto (or common battery) switchboard with the trunks appearing as jacks in its face. In either of the two latter cases the step-by-step subscriber would be required to dial only those digits necessary to cause the various switches to operate to select the trunk. After the trunk had been seized, it would be necessary for him to tell the distant operator the number to which he wished to be connected.

Some manual offices may not have sufficient trunks incoming from step-by-step offices to really justify the provision of even one Call Indicator "B" Position. Where this problem arises, there are several possible alternatives, If there are a number of manual offices in the same area, each requiring a small number of trunks from step-by-step offices. a Call Indicator Tandem position may be justified. In this case the step-by-step subscriber will dial an office code which will cause the step-by-step switches to seize a trunk terminating on a cord in the key shelf of the Call Indicator Tandem position. The recorders associated with the tandem position will now be required to store up the pulses representing not only the number of the called line but also the office code of the manual office in which the call is to be completed. The number together with the office code will then be displayed on the tandem operator's screen. The trunks to manual offices will appear as jacks in the face of the board. She will select one of these trunks in accordance with the displayed office code and then pass the displayed number to the manual operator, either over the trunk or over a separate call wire.

Where the number of manual offices is insufficient to justify the provision of a Call Indicator Tandem position, it may be necessary to provide a Call Indicator "B" Position in the manual office, even though the number of trunks required will not use the position efficiently. This is particularly true if it is expected that the number of trunks from step-by-step offices will be increased in the future.

DIAL SYSTEM "A" BOARD

Assistance Calls

Assistance calls are those originated by dial subscribers who, for one reason or another, cannot use their dials in the normal way. This may be due to blindness, the extinguishing of lights or emergency. The subscriber, in this case, dials zero and reaches trunks to the "DSA" board through the top level of a first selector. As soon as the selector has reached an idle trunk, the lamp associated with that trunk lights on the "DSA" board and an audible ringing signal is sent back to the calling subscriber. The operator answers the call with an answering cord in the usual manner and completes the call with the corresponding calling cord in accordance with the subscriber's wishes.

Intercepted Calls

All unused connector terminals are wired to intercepting trunks usually terminating on the "DSA" board. If these numbers are called, the intercepting operator will advise the calling party as to number changes, disconnects, etc. Where "centralized" intercepting is employed the intercepting trunks will terminate on a centrally located intercepting position handling intercepted calls for a number of central offices instead of on the "DSA" board of the particular office.

"A" Board Toll Calls

An "A" board toll call is one to an outlying point, completed from the "A" Board, for which the "A" operator makes out a ticket charging the customer for the additional service over and above that to which he is entitled in making local calls. In step-by-step offices, a "DSA" operator performs this function and the step-by-step subscriber dials "zero" in order to obtain this service.

In most step-by-step central offices all vacant selector levels are wired to "vacant level tone" trunks. If a subscriber dials a number which directs a selector to a vacant level a tone is received similar to the "busy"tone. If through a directory error a number is listed which will direct a selector to a vacant level, this level is wired to a vacant level trunk terminating on the DSA board. The operator may ask the subscriber to dial again or may complete an "A" board toll call.

KEY PULSING "DSA" BOARD

At most "DSA" boards the operator will complete calls to local subscribers by dialing. The operator's selector will have access to the local train of switches and usually to trunks to other offices. By means of a dial key she can associate her dial with any cord circuit and thus complete assistance calls. This method of completing calls takes considerable operating time but any change to a faster method could not be justified since the number of positions and operators required would not be materially decreased.

Where a "DSA" board is large, however, a decrease in the operating time required on assistance calls may result in materially reducing the number of positions and operators necessary. If this is the case a faster but more expensive method of controlling the step-by-step switches may be justified. In such cases, the dialing method of completing assistance calls is replaced by a method known as "key pulsing" illustrated in Figure 26. The trunk from the "DSA" board terminates on an operator's selector. A key pulsing link associates an idle sender with the trunk which the operator has seized. A key set is provided on the "DSA" position, upon which the operator writes up the number. The sender registers the number and thereafter controls

the setting up of the switches, leaving the operator free to handle another call. The key pulsing sender and link are dismissed as soon as the called line has been reached. Since this type of call is completed through a cord circuit on the "DSA" board, the supervision rests with the operator and the switches will not be disconnected at the conclusion of the call until she takes down her cords.

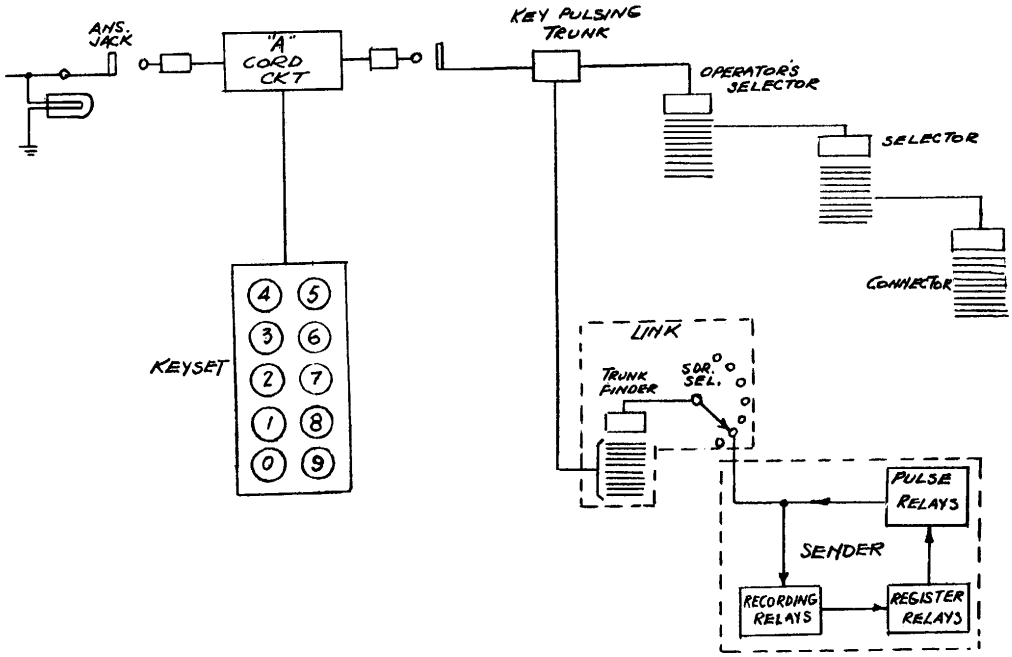


FIG. 26 "STEP-BY-STEP KEY PULSING 'A' SWITCHBOARD"