

# TELEPHONE COMMUNICATION SYSTEMS

## VOLUME I EARLY SYSTEMS AND STATION EQUIPMENT

*Revised Edition*  
1970, Issue 2

CORPORATE EDUCATION CENTER  
WESTERN ELECTRIC CO., INC.  
HOPEWELL, NEW JERSEY

## CHAPTER 3

### LOCAL MANUAL SYSTEMS

#### 3.1 THE MANUAL SWITCHBOARD

##### A. History

On January 28, 1878, two years after Alexander Graham Bell was awarded a patent on his primitive telephone, the world's first commercial telephone exchange opened for business in New Haven, Connecticut. This enterprise was called the District Telephone Company of New Haven. It was a small beginning. There were only 21 subscribers, served by 8 lines with interconnecting service provided by the operation of two rotary switches. This was the first switchboard, a model of which is shown in Figure 3-1.

As more and more subscribers were added, switchboard designs had to be altered to enable the interconnecting of the steadily increasing number of subscriber lines. As local central office areas began to be established, each devoted to the interconnecting of a group of subscriber lines terminated on its switchboard, further alterations were required. It soon became necessary to enable a subscriber whose line terminated in one central office to be connected to a subscriber whose line terminated in another central office. With the ever increasing growth of subscribers, improvements in local central office switchboard designs were constantly made until they evolved into the manual switchboards described in this chapter.

##### B. Basic Switchboard Functions

A telephone switchboard is defined as the unit of central office equipment which requires an operator to perform the switching function necessary to provide the requested telephone service. In a manual office operators are required to switch all calls from one subscriber to another subscriber whose line is terminated in the same central office. Operators are also required to terminate calls received from another central office to any of its subscribers. Further, operators must also be able to connect any subscriber to a line terminated in another central office which will in turn connect him to one of the subscribers in that office or to another switchboard elsewhere.

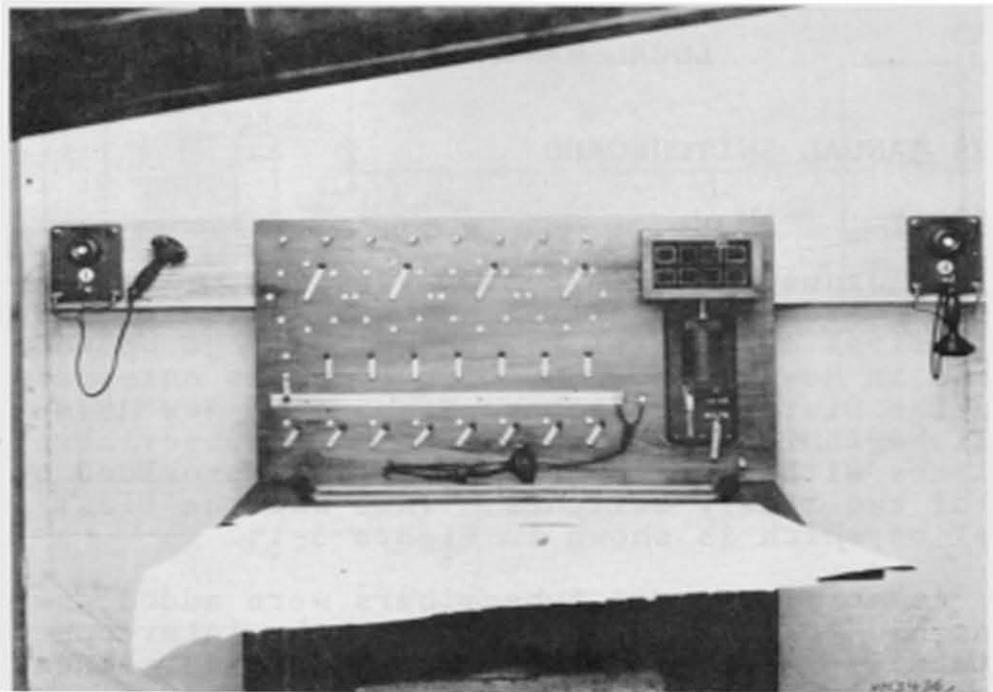


Figure 3-1 Model of First Switchboard

Thus a local telephone switchboard is designed to switch originating and terminating calls from and to subscribers in the local central office area. Originating calls are those made by subscribers which are answered by operators and completed to other subscribers in the same office or forwarded for completion in another office. Terminating calls are those incoming from other offices and completed by operators to subscribers in the local office.

The basic tool available to the switchboard operator and which she uses to establish any of the above connections is the cord circuit. Actually, each switchboard is equipped with a number of these cord circuits in order to enable the operator to establish the requested call connections while other previously established calls are still in the "talking" stage.

Each of these cord circuits is essentially a telephone line "bridge" with a plug at each end and a key in the middle for connection to the operator's telephone circuit. Since

each subscriber's telephone line is terminated in a jack mounted in the upright portion of the switchboard (facing the operator), the operator can establish a talking path between any two such subscribers by inserting the cord circuit plugs into the two subscriber line jacks and thus establish a connecting "bridge" between the two lines.

Before this can be accomplished however, the operator must be able to detect a subscriber's request for telephone service and then determine the nature of the call. If it is a call to another subscriber in the same central office, she locates the called subscriber's line jack, rings the subscriber and waits until she detects an answer. When the conversation between the two subscribers has terminated which she detects by means of the lit cord circuit lamps, she removes both plugs from the subscriber's jacks. The cord circuit is now available for the subsequent connection of any other two subscriber lines. Each switchboard contains certain basic equipment necessary for the completion of subscribers calls. This is described in paragraph 3.2.

Switchboards are usually referred to as local or toll, according to the type of traffic handled. The local switchboard is designed for operators to switch calls between subscribers in the same office, forward calls to another office or to complete incoming calls received from other offices. The toll switchboard is designed for switching calls between local offices and calls to and from other toll switchboards. In the more populated areas local and toll switchboards are generally separate units although they may be located in the same building. In smaller areas they may be separate lineups in the same operating room or even part of the same lineup. When part of the same lineup, the switchboard is sometimes arranged so that operators can switch both local and toll calls. This latter arrangement is called a combined local and toll board or a single channel switchboard. Toll Switchboards will be discussed in a later chapter.

### 3.2 SWITCHBOARD EQUIPMENT

Figure 3-2 shows the front equipment and keyshelf of a typical local manual switchboard. In the figure, the keys, lamps and plugs for 17 cord circuits are shown mounted on the keyshelf. The relays and equipment associated with these keys, lamps, and plugs are not shown in the figure, but are mounted on a relay rack behind the keyshelf. The figure shows

the lower portion of the front equipment which contains the subscriber line answering jacks and associated line lamps. Above these jacks and lamps are the outgoing (O.G.T.) multiple jacks and in the top portion, the subscriber multiple jacks are shown.

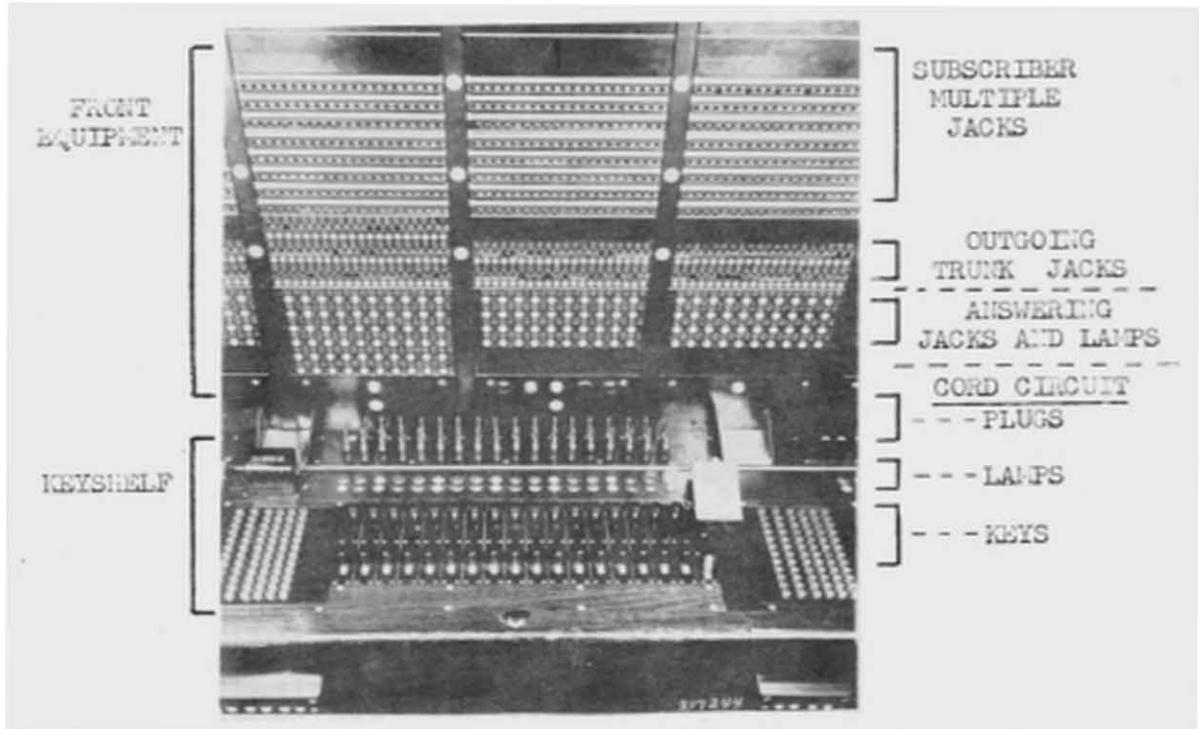


Figure 3-2 Front View of a Typical Manual Switchboard

A. Upper and Lower Units

The illustration shows only one switchboard position (for one operator). Usually three such positions are combined into one switchboard section. The front equipment for all three positions is known as the upper unit. This consists of the framework necessary for mounting the various jacks and lamps described above, the shelf and brackets for supporting the multiple cables, the answering jack cables and other miscellaneous switchboard cable. There is one lower unit for each position, and this consists of the key-shelf and framework for the cord circuits and other apparatus required by one operator.

### B. Subscriber Answering Jacks

The subscriber answering jacks are not assigned to the subscriber's lines in numerical sequence but are assigned so as to equalize the originating traffic (the request for telephone service) among the various operators. Each operator, therefore, is responsible for a proportionate share of the traffic load.

### C. Subscriber Multiple Jacks

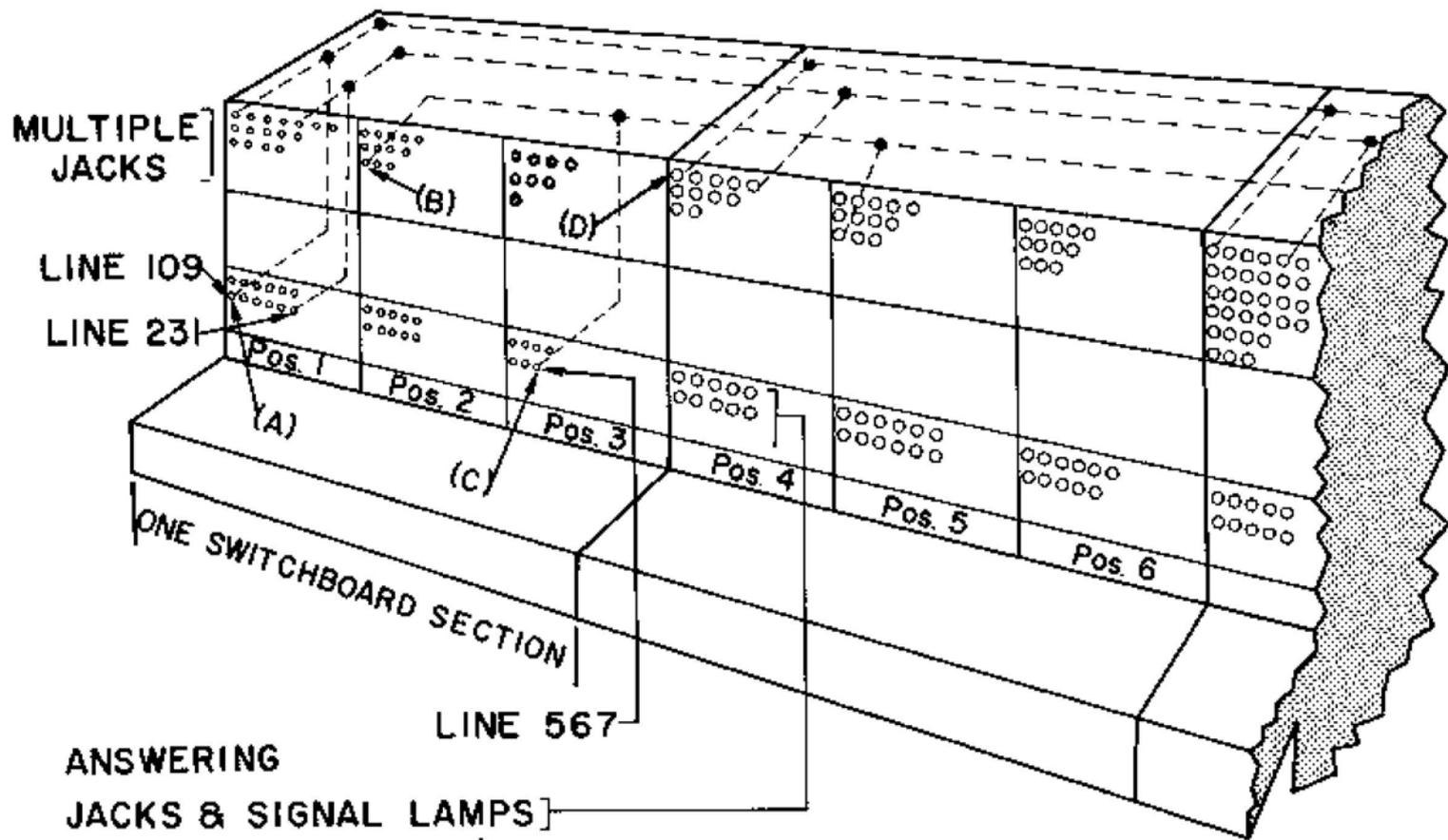
The subscribers multiple jacks are used by the operators to complete connections to subscriber lines whose answering jacks terminate in other positions. Except in very small offices, each line appears in parallel (multiple) at other jack locations at repeated intervals along the various switchboard sections. This enables each operator to connect the calling subscriber (whose answering jack appears in the answering jack portion of her position) to the called subscriber (whose jacks appear in the multiple jack portion within her reach). Normally each operator is able to reach all the multiple jacks in her position, and the positions on either side. Thus, the principle of the multiple jacks switchboard enables one operator to answer any one of about 150 lines and connect it to any one of about 10,000 lines. A multiple jack switchboard is shown diagrammatically in Figure 3-3.

### D. A Subscriber's Call

If a calling subscriber, whose number is 109 in Figure 3-3, calls a party whose number is 567, the calling subscriber's lamp in position 1, that is associated with the answering jack for line 109, indicates a request for service. The operator, upon seeing the lamp light up, then plugs one end of the cord circuit into the associated jack (A). After finding out that the subscriber desires number 567, the operator then inserts the other plug of the cord circuit into the multiple jack (B) for line number 567 located in position 2.

On the other hand, if subscriber 567 called subscriber 109, the operator at position 3 inserts the cord circuit plug into the jack marked (C) in Figure 3-3 and then inserts the other cord circuit plug into the multiple line jack marked (D) in position 4.

Each operator guards against plugging into a busy line. If she hears a "click" in her receiver when she starts to plug into a jack the fact that the line is in use somewhere else in the multiple is indicated.



3.6

Figure 3-3 An example of a Multiple Jack Arrangement

### 3.3 SWITCHBOARD CIRCUITS

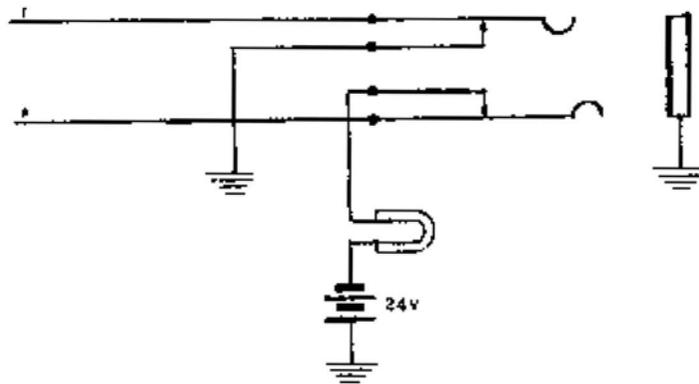
#### A. Subscriber Line Circuit

The evolution of the subscribers line circuit is illustrated in Figure 3-4. One of the circuits used in the early manual switchboards was the cut-off jack line circuit, Figure 3-4(a). When the subscriber removed his handset a circuit across the T and R leads was closed and the lamp lit. When the operator plugged into the jack with the answering cord, the plug physically opened the lamp circuit and at the same time connected the subscriber to the operator. The difficulty here was that different subscribers required different sizes of lamps depending upon the resistance of the subscribers loop due to varying lengths of line. Also, the jack cut-off springs were hard to adjust. An improvement was the line relay circuit, shown in Figure 3-4(b). The lamp was now replaced with a high resistance relay which operated regardless of the amount of loop resistance. The lamp circuit, controlled by the line relay, was office contained and in addition, all lamps were now of the same size. There was still one difficulty, which was, the jack itself. The jack was rather large and required the plug on the cord to physically break the circuit by the action of the plug in the jack. This was overcome by use of the line circuit with line and cut-off relays, shown in Figure 3-4(c).

Figure 3-4(c) shows that when the operator plugs into the jack of this circuit, the sleeve of the plug puts battery on the sleeve of the jack. This causes the cut-off relay to operate, releasing the line relay and extinguishing the lamp. There are fewer parts to this jack and it is smaller; since there is no required physical movement in the jack, the jacks can be located closer together, thus allowing more jacks to be placed in any switchboard position. There is another advantage to this circuit. When the operator plugs into this circuit she places battery on the sleeve of the jack. In a multiple switchboard this means that there is battery on the sleeve of every multiple of this jack. This allows other operators to test for a "busy" condition of a subscriber line. If a subscriber line is "busy," the operator will hear a click in her headset when she touches the tip of a cord circuit to the sleeve of the jack.

#### B. Cord Circuit

The cord circuit permits the operator to talk to subscribers, interconnect lines and trunks, ring the subscriber's telephone, supervise the connection and perform a number of other duties. It also provides talking battery for the subscribers.



-Figure 3-4(a) Cut-Off Jack Line Circuit

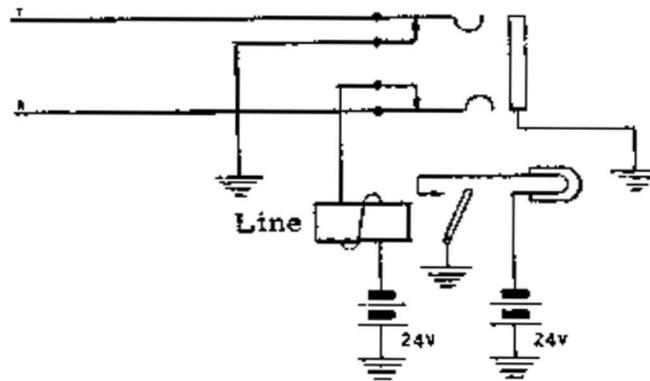


Figure 3-4(b) Line Relay Circuit

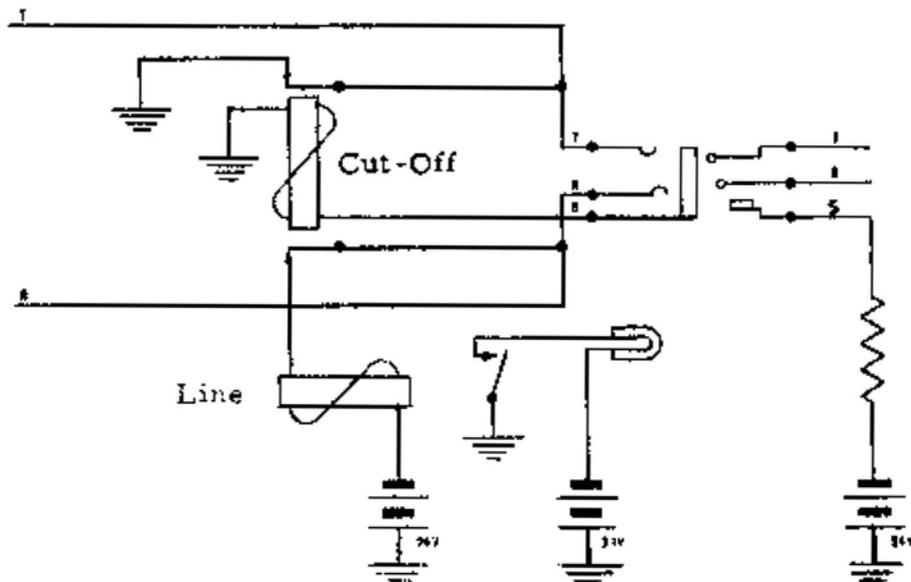


Figure 3-4(c) Line Circuit With Line and Cut-Off Relay

A cord and its associated circuits is illustrated in Figure 3-5. This figure shows a telephone connection between two stations terminating at the same central office. Here the telephone circuit at each station is normally open when the receiver is on the hook, with the exception of the ringer which is bridged across the circuit in series with a capacitor. It is a function of the capacitor to close the ringing circuit for alternating current and open in so far as the subscriber's signaling the operator is concerned and is closed through the ringer in so far as the operator's ringing the subscriber is concerned. Thus, the circuit is in such condition that the subscriber may call the operator or the operator may call the subscriber.

The subscriber calls the operator by merely closing the line, which is accomplished by removing the receiver from the hook. The operator answers the call by inserting plug  $P_1$ , into the answering jack associated with the lighted lamp and to which the line of the calling party is connected.

The operator learns the calling subscriber's wishes by connecting her telephone set to the cord circuit by means of the key  $K_1$ . She talks over the two heavy conductors of the cord circuit through the windings of the repeating coil, which by means of transformer action induces current into the other windings of the same coil. This current flows back over the calling subscriber's line and induces a current in the secondary of the induction coil, which in turn, flows through the telephone receiver.

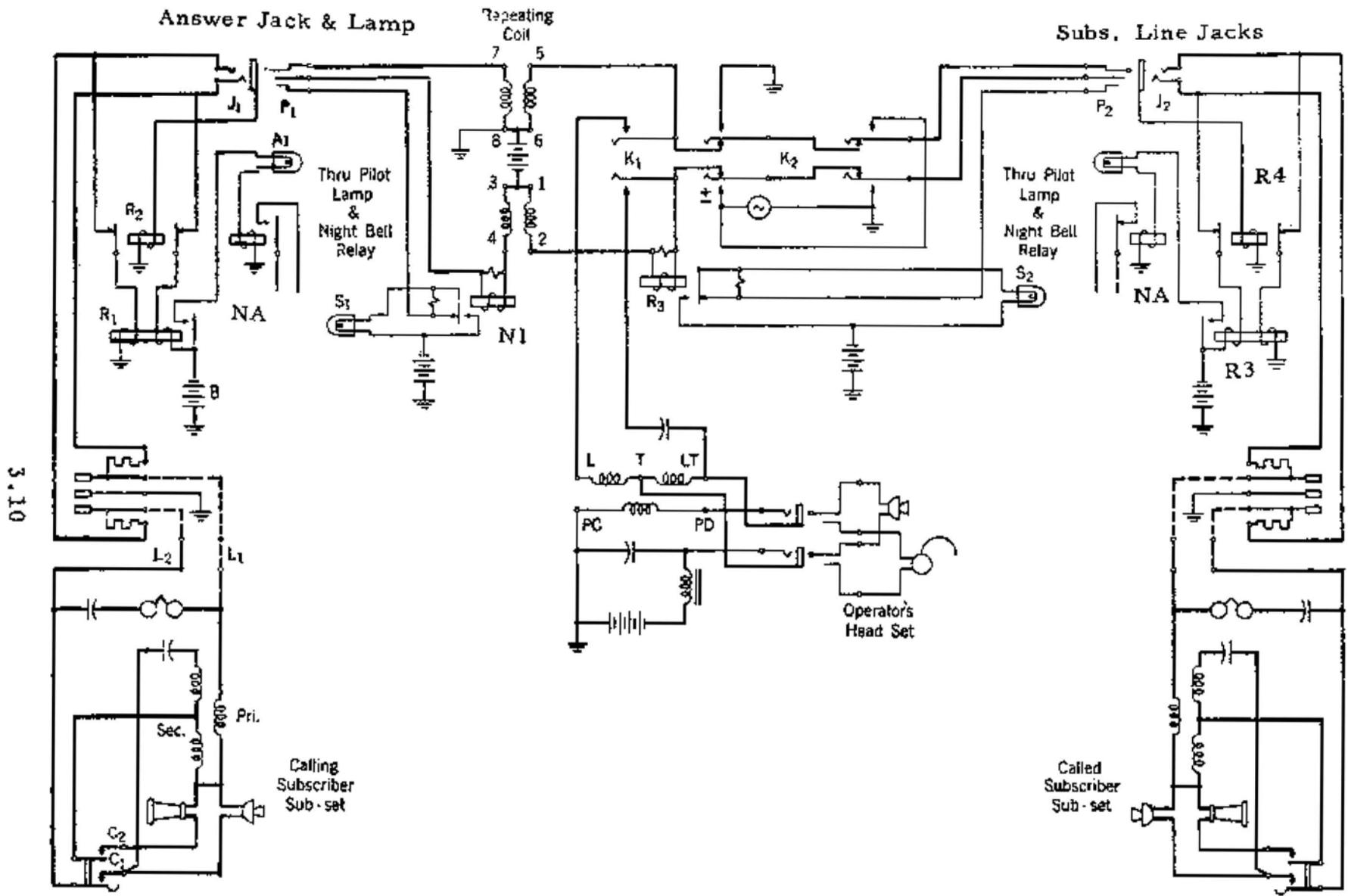


Figure 3-5 Telephone Connection Through Common Battery Exchange

Not only does the operator's voice current flow from the central office cord circuit to the subscriber's receiver, but there is direct current furnished by the central office battery through two of the four windings of the repeating coil of the cord circuit, over the line and through the subscriber's transmitter. This permits the subscriber to talk by virtue of the transmitter carbon resistance varying the strength of the current, which, by means of the repeating coil windings at the central office, induces an alternating voice current across to the opposite side of the cord circuit.

### C. Trunk Circuits

A "trunk" is a telephone line which connects one central office with another central office. In the case of a local manual system, when a subscriber calls a subscriber whose line terminates in another central office, the local switchboard operator connects him to a trunk line which routes his call to that office. The operator accomplishes this by inserting the cord circuit plug into one of the outgoing trunk jacks (O.G.T.) mentioned previously. The trunk jack is part of the trunk relay circuit. The number

and types of trunk relay circuits required depend upon the type of facilities, type of signalling, and nature of the distant office to which the particular trunk line is connected. In a similar manner, trunk circuits are also used to complete calls arriving from distant offices. These are called incoming trunks. Trunk circuits also enable operators stationed at different switchboards in the same office to communicate with each other. Some of these intra-office trunks are described later on in this chapter.

### 3.4 LOCAL SWITCHBOARDS

The use of switchboards containing multiple subscriber line jacks made it possible for one operator to service a great number of lines. However, as more and more telephones were installed, it became impossible to put enough multiple jacks within the reach of each operator. To solve this problem the local manual switchboard function was divided into two types of switchboard sections, the "A" subscribers section and the "B" trunk section. This brought about central offices with lineups of "A" type switchboards cabled to lineups of "B" type switchboards. These two different types of switchboards were usually located in different parts of the building.

#### A. "A" Switchboard

The subscriber or "A" switchboard is composed of three basic elements required to perform its switching functions. These are the subscriber line circuits, the trunk circuits over which connections are established, and the cord circuits which are used by operators to establish the desired connections. Although varying in appearance, characteristics and capacity, the different types of "A" switchboards all have these basic features.

#### B. "B" Switchboard

The incoming trunk or "B" switchboard requires only two basic elements to perform its switching function of completing incoming or terminating calls to subscribers. These elements are the subscriber line jack and the incoming trunk circuits.

The subscriber line jacks in the "B" board are a continuation of the multiple jacks in the subscriber line circuits of the "A" board.

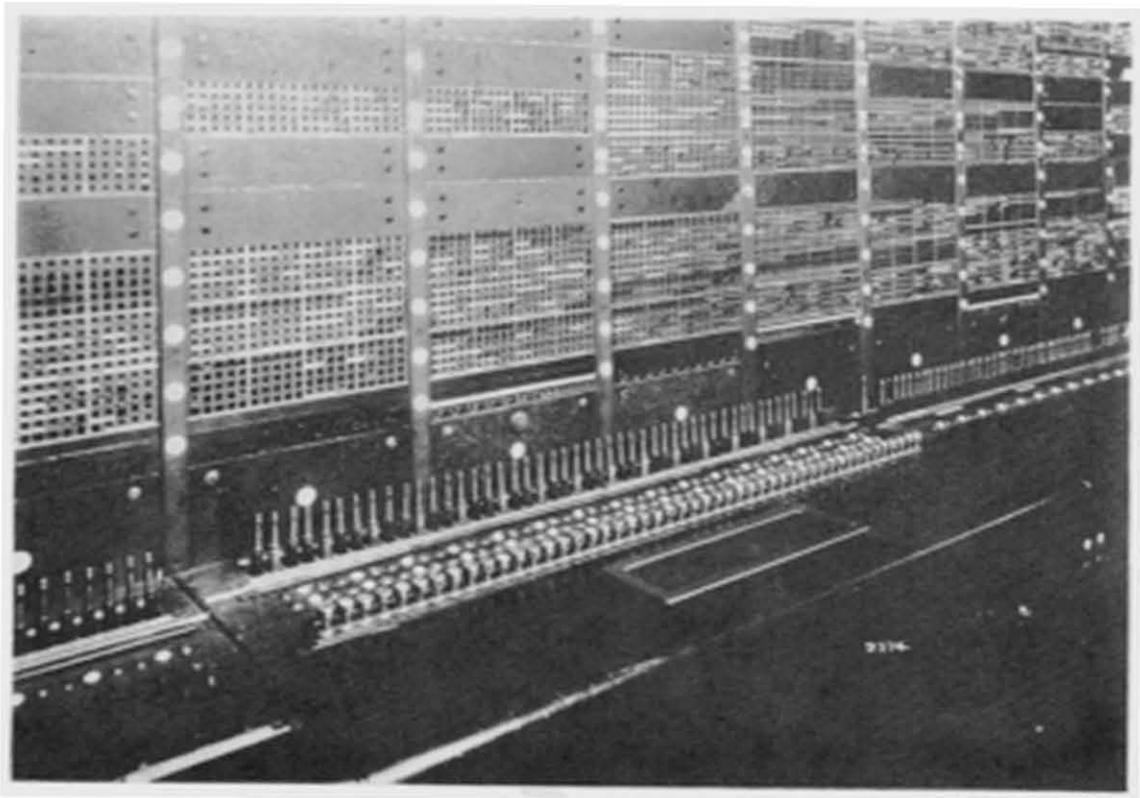


Figure 3-6 Front View of a "B" Switchboard

Incoming trunks at a "B" board handle calls specifically directed for completion to subscribers in the local office. This feature makes it practicable to terminate the trunks on single plug ended cords. Lamp signals are associated with each cord and operators complete calls directly to the subscriber multiple jacks. Since the average number of calls per trunk is comparatively high it has been found that from 30 to 48 trunks will generally furnish enough traffic for one operator. Accordingly, "B" position keyshelves are arranged for 30 to 48 incoming trunks.

Only the cords, keys and lamps of the trunk circuits are located in the switchboard. The trunk circuit relays and position control equipment are located on relay rack bays. Figure 3-6 shows a typical "B" board keyshelf and jack field.

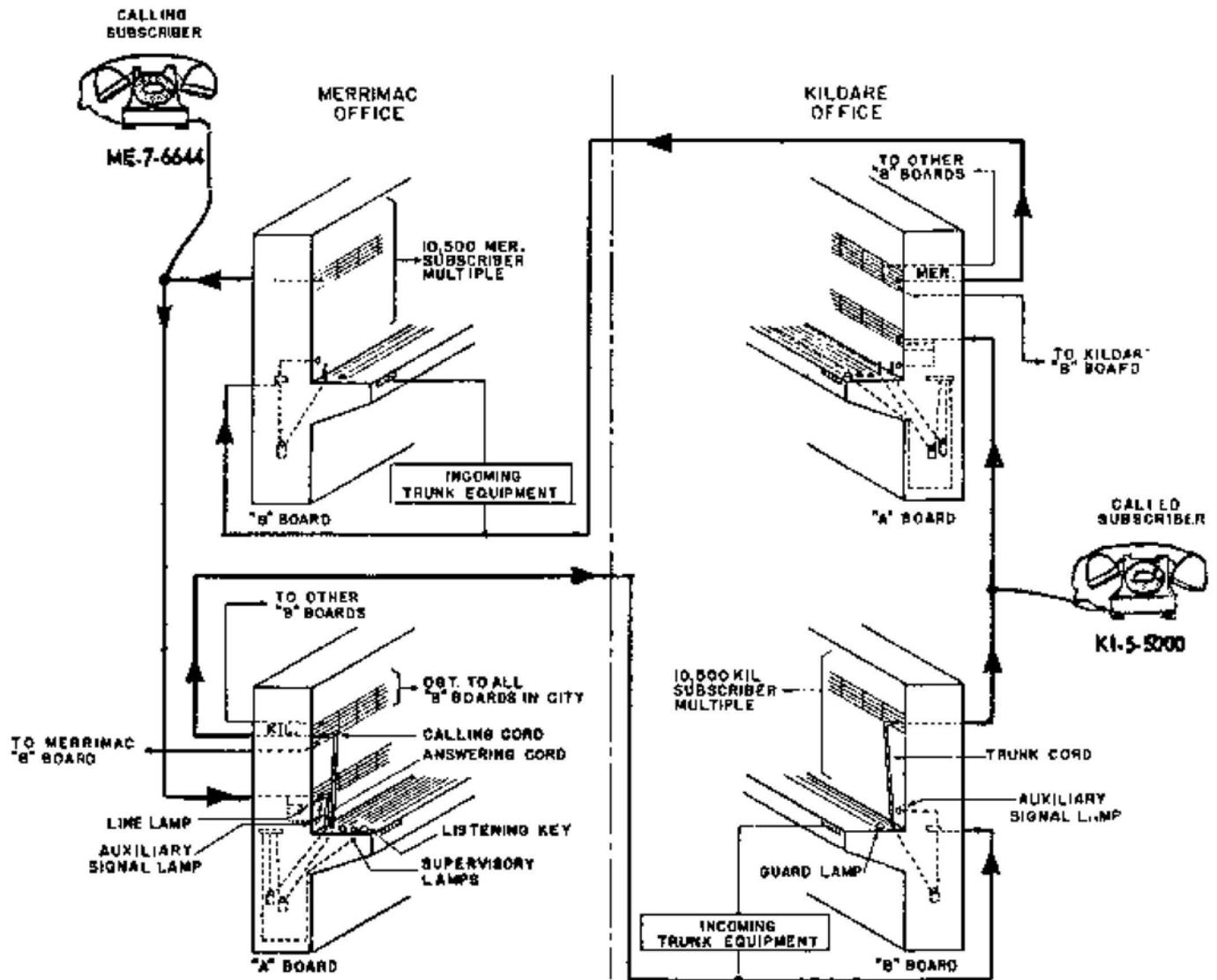


Figure 3-7 Completing Manual Call (Straightforward Trunking Method)

### 3.5 METHOD OF OPERATION

There are two general methods by which telephone calls may be completed in a central office containing "A" and "B" switchboards. One, the earlier method, uses "call circuit" trunks and the other or newer method, uses "straight-forward" trunks.

#### A. Call Circuit Trunk

When a call circuit trunk is used, the number called is passed by the "A" operator to the "B" operator over a separate circuit, known as a call circuit. The trunk to be used for the connection is assigned by the "B" operator. The "A" operator then plugs the calling cord into the outgoing trunk and the "B" operator plugs the cord on the other end of the assigned trunk into the desired subscribers multiple jack.

#### B. Straightforward Trunk

When a straightforward trunk is used, the number called is passed by the "A" operator to the "B" operator over the trunk to be used for the connection. In this case the trunk used is selected by the "A" operator. The call circuit is, therefore, not required.

It should be noted from the above comparison that the straightforward method entirely eliminates the call circuit. This has several advantages, among which are: elimination of interference between "A" operators, who use the same call circuit (each call circuit is multiplied to a large number of "A" positions); the clearing of the keyshelf of the large number of call circuit key buttons (in large central office districts the number of buttons required is above one hundred); and the service rendered to subscribers is somewhat improved.

Straightforward trunks are divided into three classes, known as:

1. Key listening
2. Automatic Listening
3. Jack listening

1. Key Listening Straightforward Trunks - This class of straightforward trunks is so called because each trunk has a key associated with it at the "B" board which must be operated before the "B" operator can be connected to it to receive the number of the line being called.

There are several types of key listening straightforward trunks, which differ mainly in the operation of their lamp signals; however, the CITS (Call Indicator Temporarily Straightforward) trunk will be the only one considered herein. The general description given below should furnish a basic understanding of key listening straightforward trunks.

A call is answered in the "A" switchboard in the usual way by an "A" operator plugging an answering cord into the calling subscriber's answering jack. After the "A" operator has received the subscriber's order, she leaves the listening key operated, and using the associated calling cord, tests in the usual way for an idle outgoing trunk to the office in which the called subscriber is located, by touching the tip of the cord to the sleeves of the outgoing trunk multiple jacks. Having selected an idle trunk and plugged the calling cord into it, the "A" operator waits on the connection for momentary tone signals signifying that the "B" operator's telephone set has been connected to the trunk. The "A" operator then tells the "B" operator the desired number. In the meantime, the calling party, while waiting for the connection to be established, can hear the number passed and can correct it if necessary. The "A" operator then restores the listening key and handles the call in the same manner as for call circuit trunks. When the called subscriber answers, the supervisory lamp of the cord connected to the trunk is extinguished.

In the "B" switchboard a key listening straightforward trunk terminates at the "B" switchboard in a cord and plug. Associated with this cord and plug are an assignment lamp, a disconnect lamp and key, all located in the keyshelf at the "B" switchboard. The relays associated with the trunk are located on a relay rack in the terminal room.

When a cord is plugged into a trunk at the "A" switchboard, the assignment lamp of this trunk is lighted at the "B" switchboard, thus indicating to the "B" operator that a call is waiting on that trunk. The "B" operator's telephone set is connected to the trunk when she operates the associated key. The operation of this key also sends momentary tone signals over the trunk to the "A" switchboard so that the "A" operator knows when the "B" operator is ready to receive the number called. In addition, the operation of the key changes the steady assignment lamp to a flashing signal. This indicates to the "B" operator the trunk to which she is connected.

After the "B" operator learns the number of the called subscriber, she tests the called line in the usual way by touching the tip of the plug to the sleeve of the called line multiple jack. If the line is idle, she inserts the plug in the multiple jack and the ringing starts automatically. If the line is busy, she inserts the plug in the busy back jack which returns a busy tone to the calling subscriber and flashes the supervisory lamp at the "A" switchboard.

Insertion of the plug into any working jack extinguishes the flashing assignment lamp and disconnects the "B" operator from the trunk. The operator is now ready to take up a call on another trunk.

Although both subscribers control supervisory signals (the lighting of the lamps) at the "A" switchboard, neither subscriber has any control over the disconnect signal associated with the trunk at the "B" switchboard. This signal is entirely controlled by the "A" operator.

The "A" operator disconnects from the trunk by removing the calling cord from the trunk jack. This causes the disconnect lamp to light. The "B" operator removes the trunk cord, extinguishing the disconnect lamp. Should the "B" operator fail to remove the cord before the trunk is selected for another call, the assignment lamp will relight together with the disconnect lamp, but ringing current will not be placed on the trunk. In such a case the operator must remove the cord, and extinguish the disconnect lamp. If this is not done, her telephone set will not be connected to the trunk when the key is depressed.

Several assignment lamps may be lighted simultaneously, each indicating a call waiting on the associated trunk; however, only one trunk can be connected to the operator's set at a time. In order to facilitate handling calls when traffic is heavy, the equipment may be arranged to permit the operator to overlap her calls, that is, operate a second key to disconnect her set from a trunk to which she is connected and cause her set to be connected to the second trunk while she is completing the connection for the first trunk. It is necessary for the operator to remember the number wanted on the first trunk until she completes that connection.

2. Automatic Listening Straightforward Trunks - This class of straightforward trunk is so called because the "B" operator is automatically connected to a trunk on which a call is waiting. This is the most generally used type of straightforward trunk.

The operation of the "A" switchboard is the same as described above for "Key Listening" operation. An automatic listening straightforward trunk terminates at the "B" switchboard in a cord and plug. Associated with the cord and plug is a trunk lamp which acts as both a guard and a disconnect signal and sometimes as an auxiliary signal lamp.

When a cord is plugged into a trunk at the "A" switchboard, the trunk lamp at the "B" switchboard lights steadily as a guard signal, indicating a call waiting on the trunk. The circuits are so arranged that the operator's set is automatically connected to the trunk.

When the trunk lamp lights, momentary tone signals are sent over the trunk to the "A" switchboard so that the "A" operator knows that the "B" operator is ready to receive the number called. This changes the steady guard lamp to a flashing signal to indicate to the "B" operator the trunk to which she is connected.

As an example of this type of call, assume that a subscriber in the Merrimack office, whose number is 6644, removes his handset to originate a call (Figure 3-7). This lights the subscriber line lamp and a panel auxiliary signal lamp on the Merrimack "A" switchboard. The Merrimack "A" operator operates the listening key of a cord circuit, inserts the plug of the answering cord into the associated answering jack, extinguishing the line and auxiliary signal lamps, and says, "Number Please." The calling subscriber at Merrimack - 7-6644, gives the number of the party being called, "Kildare - 5-5000". The Merrimack "A" operator says, "Thank you," and using the calling cord plug tests for an idle outgoing trunk (O.G.T.) to Kildare office. This test is made by touching the tip of the calling cord plug to the sleeve rim of the outgoing trunk (O.G.T.) jack. (When idle trunk indicating lamps are used the operator selects the idle trunk visually by means of the spot of light over the (O.G.T.) jack.) Having selected an idle trunk, the Merrimack "A" operator then inserts the plug of the calling cord into the O.G.T. jack, causing the calling cord supervisory lamp at the Merrimack "A" switchboard to light.

Current from the calling cord at the Merrimack "A" switchboard operates relays in the Kildare incoming trunk circuit which causes the associated guard and disconnect lamp and the auxiliary signal lamp to light at the Kildare "B" switchboard. If no other calls are waiting to be answered at the Kildare "B" switchboard, the control relays in the associated "B" switchboard position operate, causing the guard and disconnect lamp to flash and automatically connect the "B" operator's telephone circuit to the trunk, at the same time sending out two momentary "order" or "Zip" tones which are heard by the "B" operator, the Merrimack "A" operator, and the calling subscriber. The Merrimack "A" operator hearing the order tones knows that the Kildare "B" operator is connected and says "5000" and then releases the listening key. The Kildare "B" operator picks up the trunk cord plug associated with the flashing guard and disconnect lamp and tests line 5000 in the multiple by touching the tip of the trunk cord plug to the sleeve of the jack. If the line is found idle, she inserts the plug into the jack. This causes trunk relays to operate which extinguish the guard and disconnect lamp and auxiliary signal lamp, connect ringing current to the called line, and disconnect the operator's telephone set from the trunk.

The calling subscriber hears ringing induction, as an indication that the called party's bell is being rung. When the Kildare-5 subscriber "5000" answers, relays in the incoming trunk circuit operate disconnecting the ringing current and extinguishing the calling cord supervisory lamp at the Merrimack "A" switchboard. While the subscribers converse, battery is being furnished by the "A" and "B" board cord circuits. When they have finished and replaced their handsets the answering and calling cord supervisory lamps on the Merrimack "A" switchboard light up.

The Merrimack "A" operator then removes the answering and calling cord plugs from the jacks, again lighting the trunk guard and disconnect lamp at the Kildare "B" board. The Kildare "B" operator removes the associated trunk cord plug from the multiple jack extinguishing the guard and disconnect lamp and equipment is again normal.

There are some Special Features associated with these trunks. For instance, several guard lamps may be lighted at the same time, each indicating a call waiting on the associated trunk, but only one trunk can be connected to the operator's set at a time. Each trunk on which a call is waiting will be connected in rotation, the lowest number cord first, then the next higher, etc.

In order to facilitate handling calls, each position is provided with a button, called "master release key," mounted on the keyshelf. The operation of the release key permits the operator to overlap her calls, that is release her telephone set from a trunk to which it is connected and connect it to the next trunk on which a call is waiting while she is completing the connection on the first trunk. If an "A" operator plugs into a trunk but disconnects before the "B" operator is connected to the trunk, the guard signal will remain lighted and the "B" operator will be connected to the trunk in regular sequence as for a call. The "B" operator in such a case may release her set from the trunk by operating the release key.

Although both subscribers control supervisory signals at the "A" board, neither subscriber has any control over the disconnect signal associated with the trunk at the "B" board. This signal is entirely controlled by the "A" operator. When the "A" operator disconnects from the trunk by removing the calling cord from the trunk jack, it causes the lamp associated with the trunk to light as a disconnect signal. The "B" operator removes the cord, extinguishing the disconnect lamp.

Should the operator fail to remove the cord before the trunk is selected for another call, the trunk will be connected to the "B" operator's set in regular sequence and the lamp will flash as soon as the trunk is so connected, regardless of whether or not the trunk is still up in a multiple jack. Under this condition, however, the subscriber will not be rerung.

3. Jack Listening Straightford Trunks - This class of straightforward trunk is so called because the "B" operator connects her set to any trunk on which a call is waiting by plugging the trunk into a listening jack. After learning the number wanted, the "B" operator removes the cord from the listening jack and disposes of the call in the usual way.

### 3.6 LOCAL MANUAL SWITCHBOARDS TODAY

The conversion of local offices from manual to various electromechanical (Step-by-step, Crossbar #5, etc.) offices and eventually to electronic (No. 1 ESS, etc.) offices did not entirely eliminate the need for Local Manual Switchboards. Such a switchboard is still required to handle the originating and terminating traffic which the automatic equipment is unable to complete, or in certain areas where the installation of automatic equipment is as yet not economical.