Switchboards and Signaling Facilities of the Teletypewriter Exchange System *

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The development of a nationwide teletypewriter exchange system in the United States required the design of switchboards and signaling facilities adapted to this special service. The two types of switchboard now in use are described in this paper, and the operation of the circuits by means of which connections between the various subscribers are established and supervised by the operators is explained.

A NATIONWIDE teletypewriter service giving direct connection between subscribers for the exchange of written messages by means of the teletypewriter in a manner similar to the service offered by the telephone system for the exchange of spoken messages was offered to the public as a new aid to business by the Bell System on November 21, 1931. This service, known as the teletypewriter exchange (*TWX*) service, introduced a switching technique which, although familiar in the telephone art, involved many new technical problems when applied to the telegraph art.

Records show that during the nineteenth century some telegraph exchanges were established at which connections could be made on a message basis for to and fro telegraph communications between subscribers. These earlier exchanges had a commercial appeal although the various forms of subscriber instruments then used were slow and required considerable skill for operation. Later, when the telephone was introduced, these exchanges gradually disappeared because the public naturally preferred the more convenient instrument. With the introduction of the modern teletypewriter the telegraph exchange idea was again revived because the teletypewriter, being very similar to an ordinary typewriter and permitting an accurate written record of a to and fro communication, has, from a subscriber standpoint, overcome the objectional features of the early telegraph instruments.

The private line telegraph and teletypewriter service furnished by the Bell System has formed a very important background for the new teletypewriter exchange service. The older service, which provides relatively permanent networks interconnecting various stations in a predetermined manner for a predetermined time, has been available to the public since about 1890. During the earlier period it was used

* Published in *Electrical Engineering*, September, 1936. Presented at A.I.E.E. Southwest District meeting, Dallas, Texas, October 26–28, 1936.

chiefly by the press and brokers and was operated on a Morse telegraph basis, generally using composite or simplex line facilities. Later, with the introduction of the modern teletypewriter, the carrier telegraph, and other improvements, together with the growth of American business and the demand for rapid and accurate written communications, this private line business expanded rapidly and service was furnished not only to the press and brokers but also to other financial institutions, manufacturers, government bureaus, police departments, and a wide variety of retailers and distributors of goods. This business has become nationwide. Many of these private line systems are provided with switching facilities for use by the customer in each system, although the supervisory arrangements are rather elementary.

In addition to the private line telegraph service and the arrangements which had been developed and applied to that service, the many developments in the telephone field formed an important contribution to the teletypewriter exchange service. It is obvious that in providing *TWX* service, which is a point-to-point service with connections set up and taken down on the subscriber's order, use can be made of many traffic and service practices used in the telephone service. Furthermore, certain telephone apparatus such as switching relays, cords, plugs, etc., can be employed to advantage.

With this background, when it was decided to furnish a nationwide teletypewriter exchange service to the public, Bell System engineers had the problem of determining what general plan of design to adopt. There were two alternatives: (1) to provide a service using the telephone plant and existing telephone switchboards, or (2) to provide separate switchboards for use with the telegraph plant. The important advantages of the first plan are:

(*a*) The switchboards and signaling arrangements designed for and in use in the telephone plant could be employed.

(*b*) The same operating groups handling the telephone service would handle this service. Inasmuch as telephone service is on a 24-hour basis throughout the country, the *TWX* service could be furnished on the same basis with a relatively low operating cost.

The disadvantages of the first plan are:

(*a*) Because the teletypewriter operates on a d-c. basis it would be necessary to provide an oscillator and associated apparatus at the station to generate an audio-frequency alternating current for modulation by the signals sent by the teletypewriter, and a rectifier to convert the a-c. pulses received from the distant station to d-c. pulses for operation of the receiving mechanism of the station teletypewriter. Furthermore, it would be necessary to furnish a telephone instrument at the station to permit the subscriber to communicate with the operator unless a teletypewriter or other type of recording instrument were provided at each operating position.

(*b*) Relatively expensive telephone lines known as inter-toll trunks would be required between central offices. If the cheaper telegraph channels were used as inter-toll trunks it would be necessary to provide frequency converters at each terminal to translate the frequency band required on the subscriber loop to a band suitable for application to the telegraph inter-toll trunks. If the telegraph channels were used between switchboards it would also be necessary to provide the operators with teletypewriters or other means of communication because the telegraph channels do not permit oral communication.

(*c*) A number of miscellaneous engineering and plant problems other than those listed in (*a*) and (*b*) would be introduced if standard telephone facilities were used to interconnect the stations in the teletypewriter exchange network.

After due consideration of all these factors it was decided to utilize the telegraph plant and to design and provide the necessary teletypewriter switchboards and inter-office signaling arrangements. By following this plan it has been possible to establish service on a nationwide basis using switchboards at the larger switching centers and employing modified telegraph private wire testboards at the smaller centers.

This paper describes the signaling and switching arrangements used in the present system, and particularly the two principal types of switchboards that are in use. The discussion is limited to the most important signaling and switching arrangements, as the transmission features are described in another paper.[1] A description is included of the principal factors entering into the design of the more important circuits used in these switchboards: the subscriber lines, inter-toll trunks, and cords. The subscriber line treatment is divided into three broad classes: local subscribers having either attended-only or unattended service; distant subscribers served over telegraph toll line facilities; and distant subscribers served over telephone facilities. Particular attention is given to the fundamental problem of providing supervisory signals over the telegraph lines used as inter-toll trunks in the inter-office connections.

Teletypewriter Switchboards

To reach subscribers in all parts of the country there has been established a network of teletypewriter switching points interconnected by telegraph lines. At each of the larger switching points a teletypewriter switchboard is provided, the principal switchboards being the No. 1 Teletypewriter Switchboard having a capacity of 3,600 subscriber lines, and the No. 3*A* Teletypewriter Switchboard having a capacity of 1,200 subscriber lines. The former, a general view of which is shown in Fig. 1, is used in large cities such as New York and Chicago, while the latter, a general view of which is shown in Fig. 6, is used in smaller cities such as Pittsburgh and Kansas City.

[1] "A Transmission System for Teletypewriter Exchange Service," R. E. Pierce and E. W. Bemis, this issue of the *Bell System Technical Journal*, and *Electrical Engineering*, v. 55, September 1936, pp. 961–70.

Fundamentally, a manual switchboard consists of two parts: the terminations for subscribers lines and inter-toll trunks, and the switching facilities used by the operators in interconnecting the lines and trunks. The line and trunk terminations are in the form of multiple jacks and lamps located in the jack field and are accessible to all operators. The switching facilities, or cords, together with the means for communication to subscribers or other operators, are individual to each operator and are, in general, located at the keyshelf. Although the design of the switching equipment and the multiple are to some

Fig. 1—No. 1 Teletypewriter Switchboard at New York, N. Y.

extent dependent upon each other, the principal factors influencing the design are, for the purpose of discussion, considered independently.

No. 1 Teletypewriter Switchboard Position Equipment

The No. 1 Teletypewriter Switchboard position consists essentially of a teletypewriter for the operator's use in sending and receiving the instructions for establishing the connections, together with a number of cords for making the various interconnections between the line terminations. The number of these cords necessary for the efficient functioning of an operator is the most important factor governing the width of the position, a primary consideration in the design of a switchboard.

The number of cords per operator is dependent on the average time required to set up and disconnect each call (known as the average work time per call) and the average communication time per call. Whereas the former can be forecast quite accurately by the operating characteristics of the circuits, the latter is dependent on the commercial application of the service. To insure the provision of an adequate number of cords it was necessary to allow for the longest average communication time which could be reasonably anticipated. The analysis of the average work time per call together with the forecast communication time resulted in the requirement being set up for a maximum of 18 cords per operator.

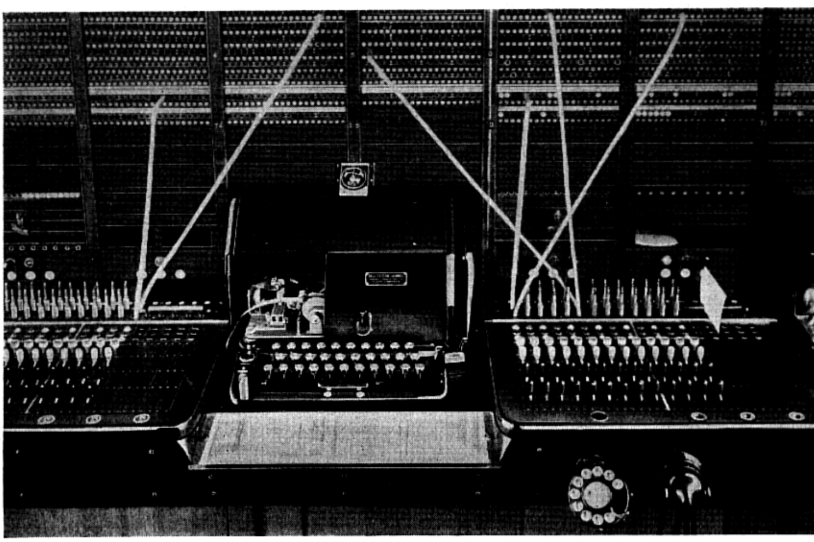

Fig. 2—Keyshelf arrangement of No. 1 Teletypewriter Switchboard.

With the requirement for the position equipment established at 18 cords (and one teletypewriter for communication purposes), the width of the position was determined to be approximately 34 inches, or the width of four panels of the jack field, each panel being $8\frac{1}{2}$ inches in width. The division into an even multiple of panels is for constructional purposes, to separate the switchboard into sections for manufacturing. It was, however, necessary to adopt a new type of keyshelf construction, shown in Fig. 2, to provide for the operator's teletypewriter.

Because of its large size, the teletypewriter was located as low as possible to minimize blocking the jack field. This required the provision of a teletypewriter shelf the lower edge of which was at the same height as the lower edge of the adjacent keyshelves. The depth of the teletypewriter made it necessary to recess it in the jack field. This recess was obtained by cutting off one stile strip and adding a longitudinal detail the entire width of the section to support the lower end of the cut stile strip. The teletypewriter shelf was placed on rollers to permit its sliding out easily for maintenance accessibility.

The teletypewriter, being the operating center of the position, has nine cords on each side to locate all 18 cords within easy reach of the operator. Because of this arrangement it was not possible to make the position boundaries coincide with the section boundaries as this would require two keyshelves of nine cords each per section with the consequent waste of equipment space for the supports between adjacent keyshelves. This loss of space was reduced by providing one 18-cord keyshelf per 2-position section and associating one half of the cords with the teletypewriter to the left and the other half with the teletypewriter to the right. This caused an overlap of the position and section boundaries so that the nine cords on the left end of each section form a part of the right position of the adjacent section to the left.

No. 1 Switchboard Multiple Equipment

The primary objective in the design of multiple equipment is the provision of line terminations in a form that will make each line readily accessible to every operator, taking into consideration the physical limitations imposed by the operator's reach. Previous experience in the design of telephone switchboards has determined that, for a subscriber switchboard, satisfactory operating conditions may be obtained in respect to the horizontal reach of the operator by the multipling of the line terminations on an 8-panel basis (using the standard $8\frac{1}{2}$ inch panel) giving a distance of 68 inches from one appearance of a line to the next. The maximum reach in each horizontal direction will then be half of this distance, or 34 inches. This was, however, reduced to a 6-panel multiple giving a maximum reach of $25\frac{1}{2}$ inches to insure operating efficiency.

In determining the maximum vertical reach for the operator, the standard practice was followed of limiting this reach to 30 inches for line terminations which are to be answered, and to 34 inches for lines to which calls are to be completed. The line terminations to be answered by the operator are kept lower than the lines for completing purposes because the operator's attention must be attracted to the line by the illumination of the line lamp. The line capacity of the switchboard is limited by the number of line terminations that can be provided within the above dimensions.

The lower line of Fig. 3 shows the inter-toll trunk and subscriber line capacities obtainable within the permissible reach limits on a 6-panel multiple basis where the complete subscriber multiple is equipped with answering lamps. The capacity shown is based on various ratios of subscriber lines to inter-toll trunks. Because of the essentially toll character of the teletypewriter exchange service, it was anticipated that there would be a high ratio of inter-toll trunks to subscriber lines and comparatively little local traffic. The traffic studies indicated that the average ratio would be in the order of seven or eight subscriber lines

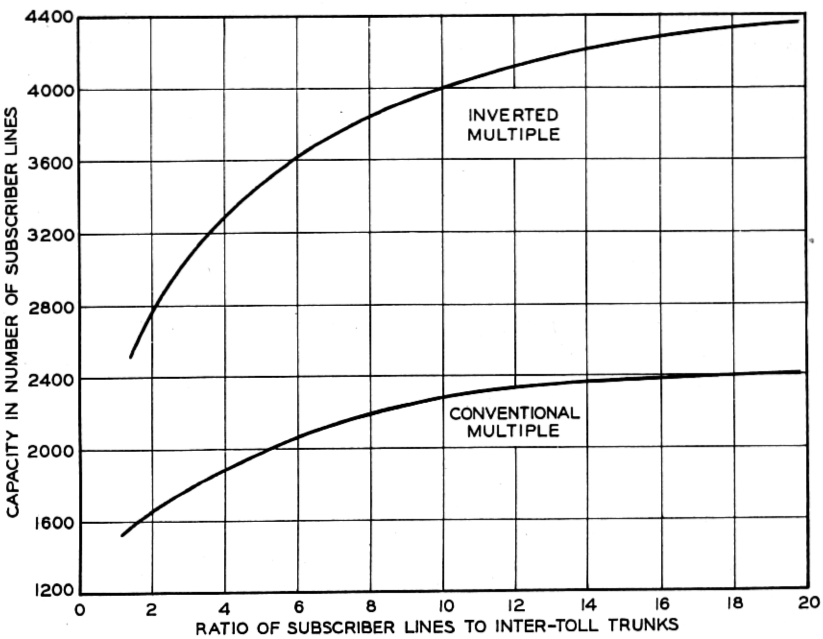

Fig. 3—Curves showing variation of subscriber line capacity for No. 1 Teletypewriter Switchboard. *A*—Inverted multiple. *B*—Conventional multiple.

to one trunk. It may be seen from Fig. 3 that, with this ratio, a capacity of only 2,200 subscriber lines is obtainable with the entire multiple equipped with answering lamps.

By providing answering lamps for only the first half of the subscriber lines and installing the second half without answering lamps in the upper portion, the total space for a given number of lines can be reduced and advantage taken of the additional space afforded by the 34-inch vertical reach permissible for calling multiple. This arrangement, known as the inverted multiple, provides answering facilities for the second half of the subscriber lines in a second line-up of switchboard in which they are equipped with answering lamps. The first half of the lines also are multipled in this line-up but on a calling-only basis; that is, without lamps. With this arrangement, calls originated by the first half of the subscribers are answered in the first line of switchboard, and those originated by the second half are answered in the second line. Any operator may complete a connection to any line as there is a full multiple of jacks in both boards. In the second line-up the two halves of the multiple are inverted as to location in order to place the lines with answering lamps within easy reach. The upper line of Fig. 3 shows the capacities obtainable with this arrangement. It may be seen that, with a ratio of 7.5 subscriber lines to one inter-toll trunk, a subscriber line capacity of approximately 3,800 is possible. It was necessary, however, to reduce this to 3,600 lines in order to obtain a division in a multiple of 600 lines to simplify the numbering of the jacks. With this arrangement 300 lines are provided in each panel without answering lamps and 300 lines with answering lamps.

This multiple arrangement is illustrated in Fig. 4, which shows schematically the cabling for the first half of the subscriber multiple (lines 0 to 1,799). It may be noted that a third line of switchboard, the inward and through board, is provided. Experience has shown that the most efficient operation is obtained if the inward and through traffic is segregated when the switchboard grows to 30 or more positions. As the subscriber multiple is used here for calling purposes only, the answering lamps may be omitted from the entire subscriber multiple, thus making additional space available for increased inter-toll trunk capacity as discussed in the following. The subscriber lines are cabled from the main distributing frame (*MDF*) to the relay equipment and from there to the *TWX* intermediate distributing frame. Here cross connections are provided to permit the assignment of any subscriber line relay equipment to any multiple jack for flexibility in assigning numbers. The distributing frame terminal strip also serves as a doubling-up point for the cable to the switchboards.

A somewhat similar arrangement used for the inter-toll trunk multiple is shown schematically in Fig. 5. The standard telegraph line facilities and terminating repeaters designed for private line service are used for the *TWX* trunks. Connections to these trunks are made at the test board distributing frame and the trunks are cabled to the *TWX* distributing frame. Here arrangements are provided for inserting a single-line repeater, which is necessary for converting the positive and negative 130-volt signals to positive and negative 48-volt signals for transmission through the switchboard. The trunk is then carried to the teletypewriter test board where a termination is provided for the purpose of testing the equipment. From the test board the trunk is cabled through the relay equipment to the distributing frame, where it is cross-connected to the switchboard multiple, the multiple for all three lines of switchboard being doubled up at the distributing

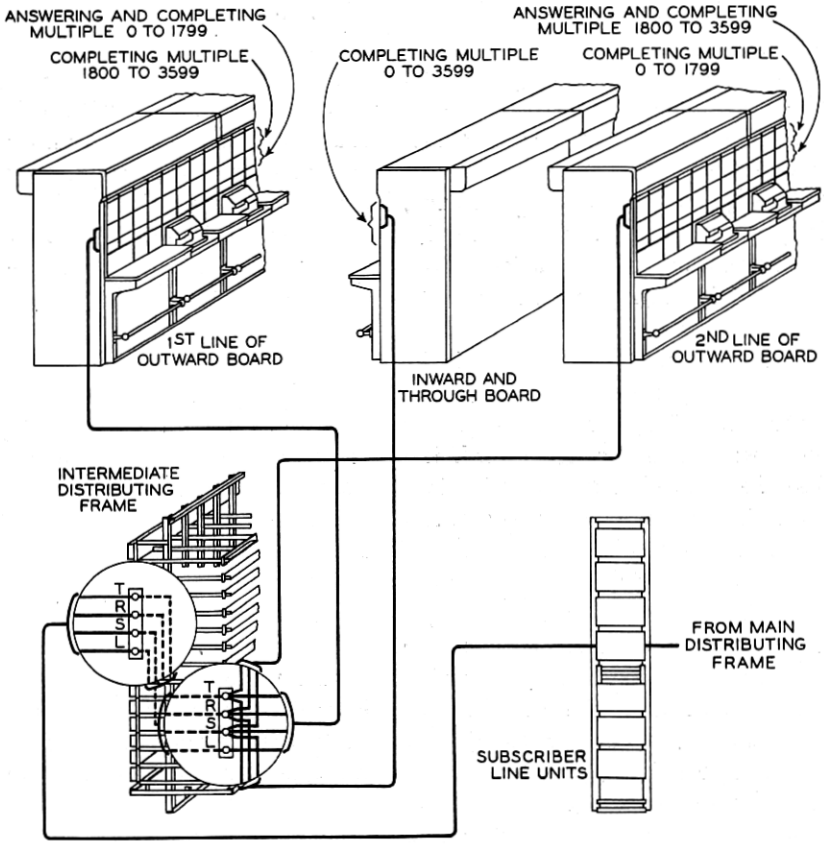

Fig. 4—Diagram of cabling for subscriber lines on No. 1 Teletypewriter Switchboard.

frame terminal strips. Ordinarily, with the inverted subscriber multiple arrangement, there will be a capacity for 480 inter-toll trunks equipped with answering lamps in the first two lines of switchboard. However, opportunity is provided for increasing this capacity by the provision of the separate inward and through switchboard. As described above, the lamps in this inward board may be omitted from the subscribers' multiple. This arrangement provides sufficient space for the installation of 840 trunks equipped with answering lamps. As all trunks are answered at the separate inward switchboard, the answering lamps may be removed from the trunk multiple in the two

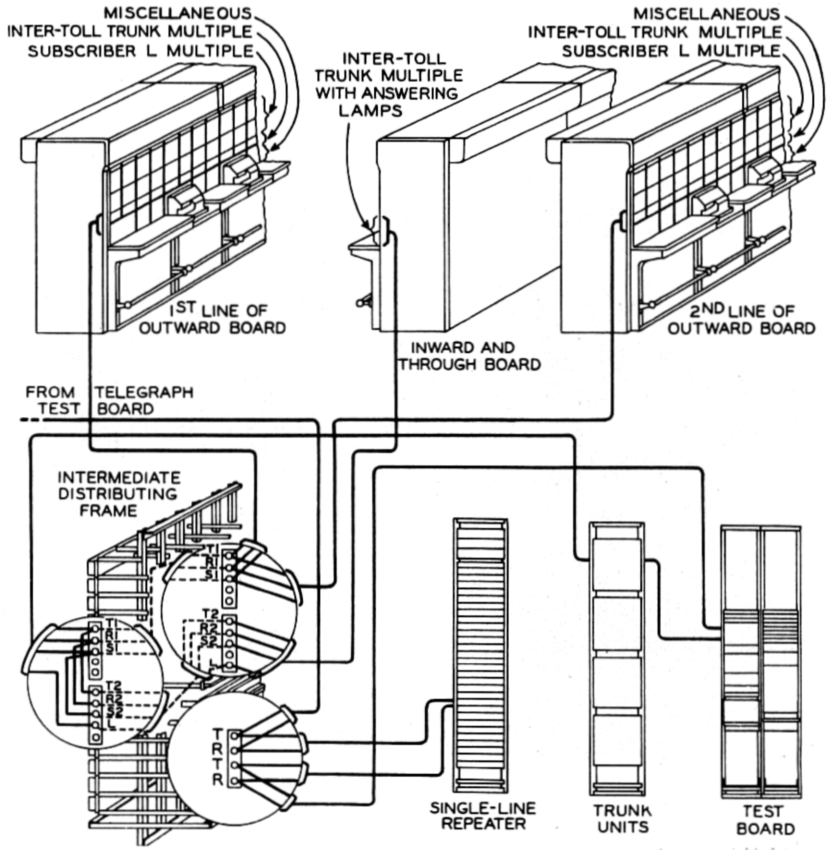

Fig. 5—Diagram of cabling for inter-toll trunks on No. 1 Teletypewriter Switchboard.

outward switchboards, thereby releasing sufficient space for the full 840 trunks without the answering lamps.

No. 3A Teletypewriter Switchboard

The design of a switchboard for the medium sized *TWX* switching points was not undertaken until the system had been in operation for about two years, temporary switching facilities having been used at these points in the meantime. Actual operating experience and traffic data were then available upon which to base the design of the switchboard, a general view of which is shown in Fig. 6.

Efficient design requires that the width of a position be kept as small as possible to avoid the excessive cost of a long switchboard multiple. Because the smaller capacity required for this switchboard did not make the vertical reach an important factor, a key-shelf arrangement different from that used for the No. 1 switchboard was adopted.

Instead of placing the teletypewriter and cords on the same level as in the No. 1 switchboard, the cords are placed above the teletypewriter. This was accomplished by the use of a sloping key-shelf permitting the cords to pass by the teletypewriter in the manner shown by the cross-sectional view in Fig. 7. With the object of keeping the vertical height of the keyshelf as small as possible, the cords are located in a single horizontal row instead of in the conventional double row. With this arrangement, the answering cord is the left cord of a pair and the calling cord is the right cord. Differentiation is obtained by using colored plug shells, black for the answering cord and red for the calling cord.

Fig. 6—No. 3A Teletypewriter Switchboard at Pittsburgh, Pa.

An additional feature resulting from this relation of the keyshelf to the teletypewriter is an arrangement whereby the position may be adjusted to include various numbers of cords. This flexibility is obtained by the location of the teletypewriter on a table separate from the switchboard, connections being made by a flexible plug-ended cord. This permits the location of the teletypewriter in front of any group of cords. A position jack is provided in each section which affords facilities for operators spaced on minimum centers of $20\frac{1}{2}$ inches, each operator having access to a maximum of 10 cords. This repre-

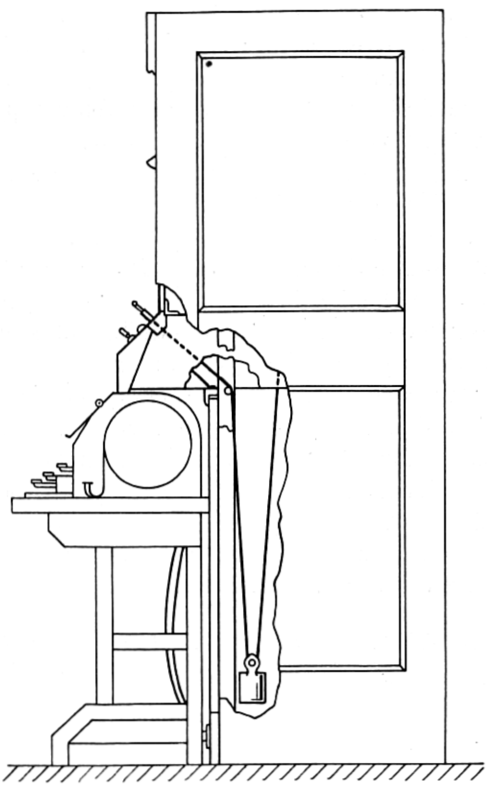

Fig. 7—Sectional view of No. 3A Teletypewriter Switchboard.

sents the closest centers which can be obtained with sufficient physical room for operating. Although the switchboards are usually engineered on the more ample operating centers of about $25\frac{5}{8}$ inches, the design permits the reduction of these centers to the $20\frac{1}{2}$ inch dimension in the event that more operators are required for unexpected increases in traffic. If traffic conditions change or the inward and through traffic is segregated, thus necessitating positions equipped with more cords, the width of the position can be increased to include the number of cords required.

The switchboard is divided into sections, each having two panels and each arranged for a position circuit. The section is an arbitrary division of the switchboard for constructional purposes and has no bearing on the position boundaries. All keys and cords in a section are terminated on terminal strips in the rear. The cord relay equipment is furnished in units of 10 circuits, each unit being equipped with terminal strips so located that, when a unit is placed in the rear of a section, the terminal strips come directly under the section terminal strips. Distributing rings above the two rows of terminal strips provide facilities which permit any relay equipment to be cross-connected to any keyshelf cord equipment.

The engineering of this switchboard is thus reduced to a very simple process. The number of cords required per operator is determined by the anticipated traffic data. From this information the width of each position is determined. The sum of the positions required to handle the peak load represents the total length of the switchboard and determines the total number of sections required. Cord units are then provided in the rear of the switchboard. The cords required for each position are then cross-connected to relay circuits on the cord units which are in turn cross-connected to the nearest position circuit. Teletypewriters are moved in front of the various groups of cords and plugged into the jacks for their position circuits. Should conditions require a different assignment of cords, they may be recross-connected to meet the new requirements and the teletypewriters moved to new positions.

No. 3A Teletypewriter Multiple Equipment

For convenience, the operator's vertical reach for lines with answering lamps has been defined as 30 inches above the standard type of keyshelf. From the lower edge of the keyself, which prevents the operator from rising to reach farther, the permissible reach is 35 inches. Deducting the space required for the teletypewriter and keyshelf equipment, there remains $14\frac{1}{2}$ inches available for multiple below the 35 inch reach limit. About $2\frac{5}{8}$ inches of this space is required for unattended line terminations and miscellaneous multiple, leaving a space of $11\frac{7}{8}$ inches for the subscriber line multiple.

This space provides for the capacities shown in Fig. 8, which are in terms of ratios of subscribers lines to inter-toll trunks. This curve is based on the use of a 6-panel multiple which, with the $10\frac{1}{4}$ inch panel required for the type 49 jack used, results in a horizontal reach of

$30\frac{3}{4}$ inches. It may be seen that, with a ratio of 7.5 subscriber lines to one trunk, a capacity of about 1,300 lines is obtainable. Because the ratio of trunks to subscriber lines is somewhat greater on small switchboards than on the larger boards, due to the relative inefficiency of smaller trunk groups, the multiple is designed on the basis of 1,200 subscriber lines and 240 inter-toll trunks which gives a ratio of five subscriber lines to one trunk.

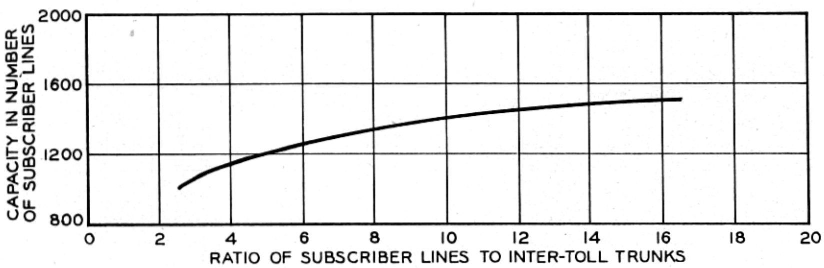

Fig. 8—Curve showing variation of subscriber line capacity for No. 3A Teletypewriter Switchboard.

Circuit Functions

The foregoing paragraphs have given a picture of the physical arrangement of the more important switchboards, and an idea of the number of subscriber lines and inter-toll trunks that can be accommodated by each. Some idea must also be given of the circuit methods by means of which connections are established between the various subscribers and supervised by the operators.

Subscriber Station and Station Circuit

The basic instrument by means of which the subscriber sends and receives his message is the teletypewriter. It is not proposed to give here a description of the teletypewriter as this is discussed in other papers. Other equipment, however, is required in addition to the teletypewriter to provide for the necessary signaling facilities for the exchange service.

A typical installation in a subscriber's office is shown in Fig. 9. The arrangement shown provides for the No. 15 (page) teletypewriter, used predominantly in the *TWX* service, mounted on a table which has been designed to provide adequate mounting facilities for the signaling equipment. This table is arranged with a removable panel known as a control panel, which is mounted in an opening in the top of the table to the right of the teletypewriter to make the key levers readily accessible to the attendant. The control panel equipment may be varied to meet the different service requirements. Space is available on a shelf on the inside for a rectifier or an apparatus box where this additional equipment is necessary.

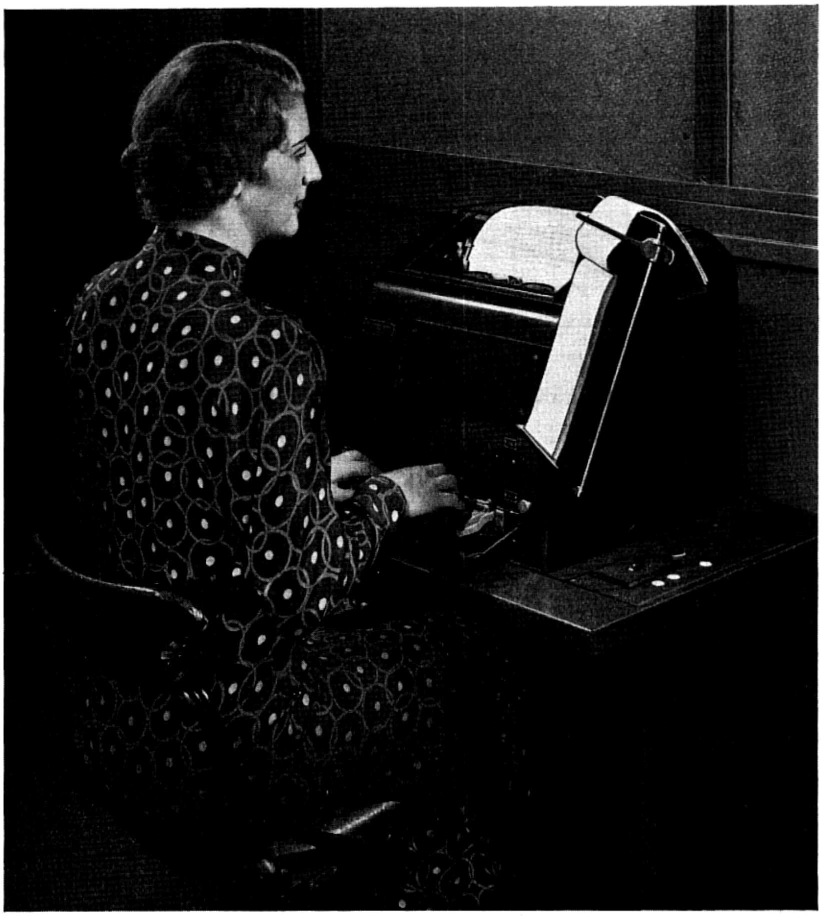

Fig. 9—Typical teletypewriter subscriber equipment for attended service.

A typical circuit arrangement for a station connected to a *TWX* switchboard is shown in Fig. 10. The station is equipped with a switch which, when operated, applies power to the motor of the teletypewriter, and also closes the loop so that a relay in the central office is energized. This relay lights the answering lamps associated with the subscriber's multiple in the face of the switchboard. An operator answers by plugging the answering plug of a cord circuit into the jack. This action by the operator connects the station line to the cord circuit, and in addition energizes another winding of the relay previously energized when the subscriber called. This relay, being differentially wound, is then released and the answering lamps are extinguished.

In addition to calling the central office the subscriber must be able to recall the operator in case new services are required during the progress of the communication. This is accomplished by the subscriber simply turning the power switch off and then on again, which causes certain relays in the cord circuit to operate and the cord lamp to flash intermittently, indicating to the operator that her services

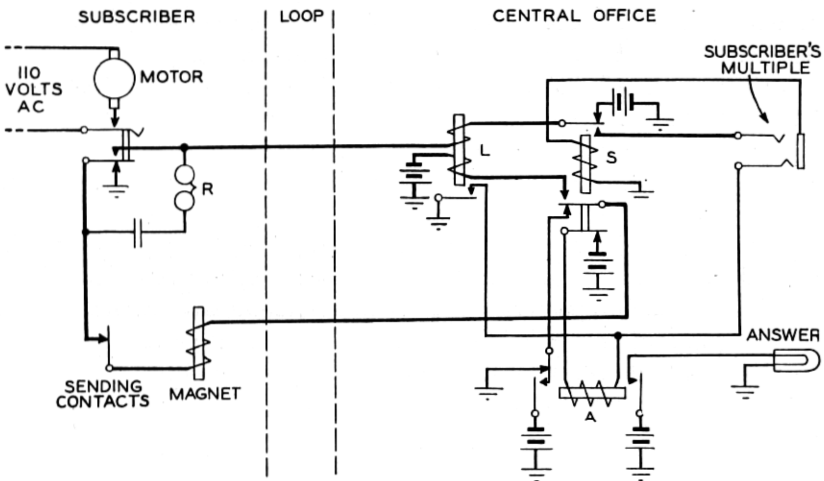

Fig. 10—Fundamental teletypewriter circuit.

are required. The subscriber must also be able to indicate to the operator when a disconnection has been made. This is accomplished by the subscriber turning off the power switch, causing the motor of the teletypewriter to stop and a lamp in the cord circuit to light.

The operator must also be able to signal the subscriber that a call is being completed to him. To provide this signal the station is equipped with a standard telephone type ringer which is energized, when the station is in the idle condition, by 20-cycle alternating current which flows over one side of the loop when the operator depresses a ringing key in the cord.

The teletypewriter lends itself admirably to the function of leaving messages on the subscriber's machine when no one is in attendance. When such service, known as unattended service, is desired, the station is similar to that already described, but additional equipment is provided for starting the motor from the switchboard. An attempt is made to complete the call on an attended basis as outlined above and, if the called subscriber does not answer, the operator asks the calling subscriber if he wishes to leave his message. If he does, she presses a key in the cord circuit, which starts the motor at the absent subscriber's teletypewriter. The operator then instructs the calling subscriber to proceed with the communication.

Long Subscriber Lines

The subscriber stations just discussed are connected to the central office by two wires, known as a loop, the maximum distance between station and switchboard for loop connections being approximately 38 miles. A network is placed in the loops where the mileage makes its use necessary to improve the transmission efficiency.

It is necessary in some instances to connect subscribers situated at greater distances from the switchboard, perhaps as much as 200 or 250 miles. Two methods are available for accomplishing this: the d-c. method using telegraph facilities, and the carrier method using telephone facilities.

With the d-c. method a standard telegraph repeater is used at the central office, and a simplified repeater is placed on the subscriber's premises. These repeaters, with suitable signaling apparatus, provide a high grade of transmission and also the same type of supervisory signals as would obtain on the shorter loop connection.

The carrier method is used to a limited extent in the few instances where telegraph facilities are not available. In this method both the central office and the station are equipped with carrier apparatus and the regular telephone facilities are used. When the subscriber operates the power switch of the station, an answering lamp is lighted before the operator of the local telephone switchboard. The local operator, knowing by the multiple marking that this is a teletypewriter station, immediately connects through to the *TWX* switchboard over the regular toll telephone facilities. When the *TWX* switchboard is reached the call is handled in the same manner as a regular d-c. telegraph connection. All the signaling facilities available for the other subscriber stations are also available here. Completion to the subscriber is also made by the *TWX* operator over the regular toll telephone facilities, and the local telephone operator at the switchboard to which the subscriber is connected rings the subscriber.

Inter-toll Trunk Supervision

To provide inter-toll trunk supervision in the *TWX* network, it was necessary to select different types of signals than those occurring during the normal transmission period of the teletypewriter; that is, the code and "break" signals.

Three types of supervisory signals are required to be sent over the inter-toll trunk. These are (1) the call signal, (2) the recall signal, and (3) the disconnect signal. There is a fundamental difference, however, between the call signal and the others in that it is applied to the trunk only when the stations are not connected. When the stations are connected the apparatus for receiving the call is removed from the trunk. The calling signal can therefore be any type of signal

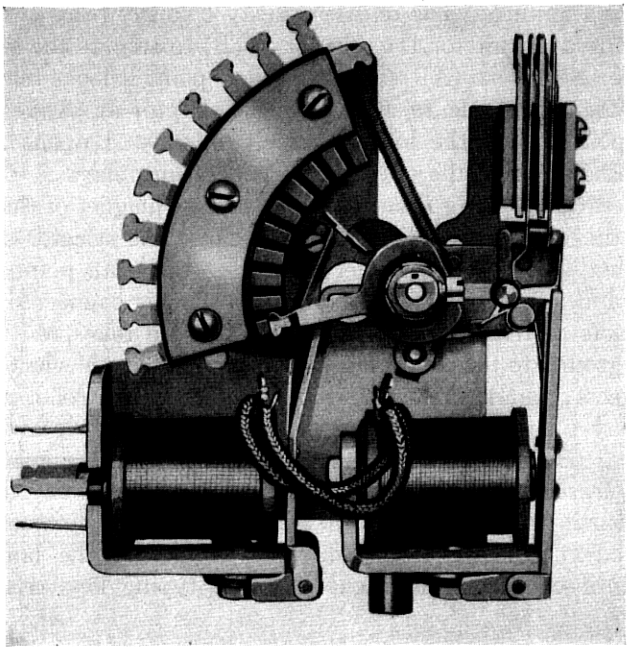

Fig. 11—Selector used for timing supervisory signals.

with the limitation that it must be such that it will not be produced by ordinary interruptions of the line, or line "hits."

The three types of supervisory signals chosen are therefore:

1. The call signal, produced by sending a spacing signal of 2 seconds.
2. The recall signal, produced by sending a spacing signal of 7 seconds.
3. The disconnect signal, produced by sending a spacing signal of 10 seconds.

To permit sending these signals, use is made of a mechanism that will measure the length of the signal. The basic apparatus used to measure this time is the selector shown in Fig. 11. By the use of this selector in conjunction with a ground interrupted 60 times per minute, it is possible to obtain a means of measuring a line "open" within a sufficient degree of accuracy.

A typical method of sending and receiving the timed spacing signals or "opens" is shown in Fig. 12. The method of sending is shown at (A), and the method of receiving at (B). To send a recall signal, the operator at (A) presses the toll signal key momentarily leaving the cord up, the sleeve relay therefore remaining operated. The closure of the toll signal key operates relay *A*. Relay *A* operated opens the loop circuit at both ends of the trunk, releasing relays *B* and *C*. Relay *B* released closes a circuit which causes the selector to step at the rate of 60 steps a minute. The release of relay *C* causes relay *D* to release and provide a circuit for the selector at (B) to step at the same rate. When the selector at (A) reaches the first point it locks relay *A* and both selectors continue to step until the selector at (A) reaches the seventh point, when the locking circuit of relay *A* opens and that relay releases, closing the circuit and reoperating relays *B*, *C*, and *D*. The reoperation of relay *B* energizes the release magnet of the selector through the off normal contacts which cause the selector at (A) to release. At (B), when the selector reaches the sixth point, relay *K* operates and, when relay *C* reoperates, ground is connected through the contacts of relays *K*, *L*, and *M* to operate relay *N*. Relay *N* connects ground to the cord lamp, lighting it. Relay *N* when operated also connects ground to relay *M* which locks under control of contact *P*. When relay *C* reoperates ground is also connected to relay *D* which reoperates. Battery is then connected to the release magnet and the selector releases. After a time relay *K*, which is slow to release, also releases causing relay *N* to release. The release of *N* connects ground interrupted at the rate of 60 times per minute to the lamp which flashes until contact *P* is opened by the typing key, releasing relay *M*.

To send a disconnect signal, the same operations take place at (A) except that, immediately after the cord key is operated, the cord is pulled down, releasing the sleeve relay, and causing the selector at both ends to continue to the tenth point. At (B) when the selector reaches the tenth point relay *L* operates and, when relay *C* reoperates, ground is applied to operate relays *M* and *N* which hold a steady ground on the cord lamp until the cord is pulled down.

These signals appear at all offices in a built-up connection. The frequency of the machines supplying the 60 interruptions per minute is accurate to within plus or minus five per cent, and the multiple connections on the receiving selector bank take up any inequalities that may exist in the speed of the machines in two different offices.

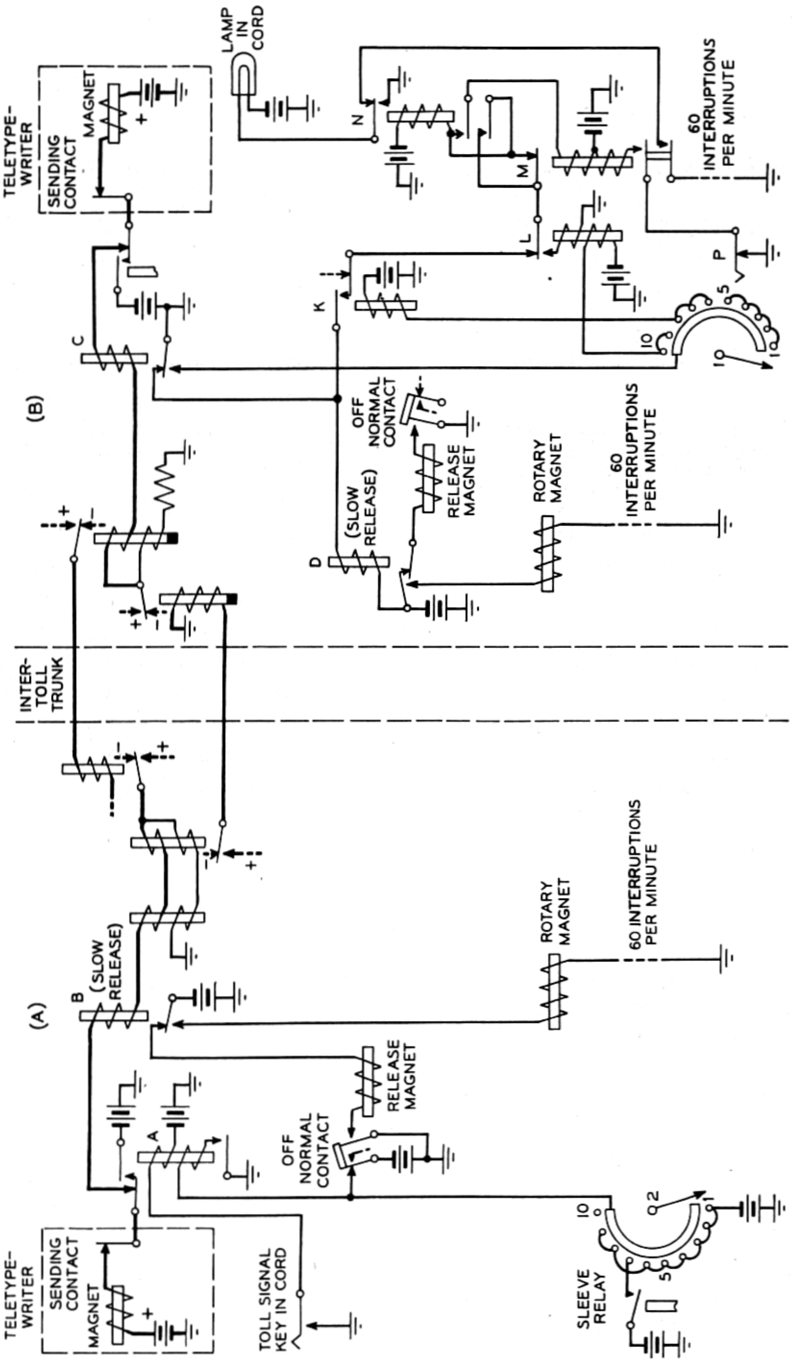

Fig. 12—Fundamental inter-toll trunk signaling circuit.

That section of the receiving selector between terminals 1 to 5 inclusive is used for the call signal which is actuated manually by the originating operator.

Cord Circuits

In order to provide each operator with sufficient traffic for operating efficiency, especially in the smaller offices and during light load periods, the cord circuits in the *TWX* switchboards are made universal, that is, adapted to handling all types of calls. This universal feature is obtained by equipping them with a simple type of repeater. By means of this repeater it is possible to provide for the maximum length of station loop and at the same time establish the following connections:

1. Subscriber line to subscriber line, known as a local to local connection.
2. Inter-toll trunk to subscriber line, or *vice versa*, known as a toll to local connection, or local to toll connection.
3. Inter-toll trunk to inter-toll trunk, known as a through connection.

In a local-to-local connection the two loops could not be connected together directly unless the repeater were provided in the cord circuit for two reasons: first, each loop may be maximum in length so that the two loops in tandem would result in the operating current being halved; and second, each loop is normally terminated on the negative side of the telegraph battery. Because it is essential, in *TWX* service, to make interconnections without requiring adjustments, all loops are padded or "built out" to the same value as the resistance of a maximum loop and each side of the cord circuit repeater is arranged to operate with each loop.

With the provision of the repeater in the cord circuit to permit interconnecting two subscriber lines, the same cord may be used for toll-to-local and toll-to-toll connections because the loop circuits of the inter-toll trunk repeaters are all terminated on the negative side of the telegraph battery and the loop resistance of each is built out to equal that of the longest station loop.

A very simplified form of the essential elements of a *TWX* cord circuit is shown in Fig. 13. The cord circuit basically consists of a repeater of the type before mentioned, a key known as the typing key, by means of which the operator may cut her teletypewriter in and out of the circuit for monitoring purposes, and facilities for receiving the recall and disconnect signals both from the subscriber lines and the inter-toll trunks.

The method of receiving these recall and disconnect signals was explained in the section on inter-toll trunk supervision, and the method used to receive those from the subscriber was pointed out in the subscriber circuit description. Many other items are included in the cord circuit by means of which the operator may expedite the setting up and removing of connections. Among these items is the busy test. When an operator is about to complete a call to a station it is necessary that she know that the station is free to receive the call. To ascertain this a means is provided so that she may make a tip busy test on the sleeve of the jack associated with that subscriber line and, if the station is busy, a position light will be lit. If no light is received the operator will plug into the jack and complete the connection.

Multiple appearances of the jacks and lamps associated with subscriber lines and inter-toll trunks are provided so that a number of

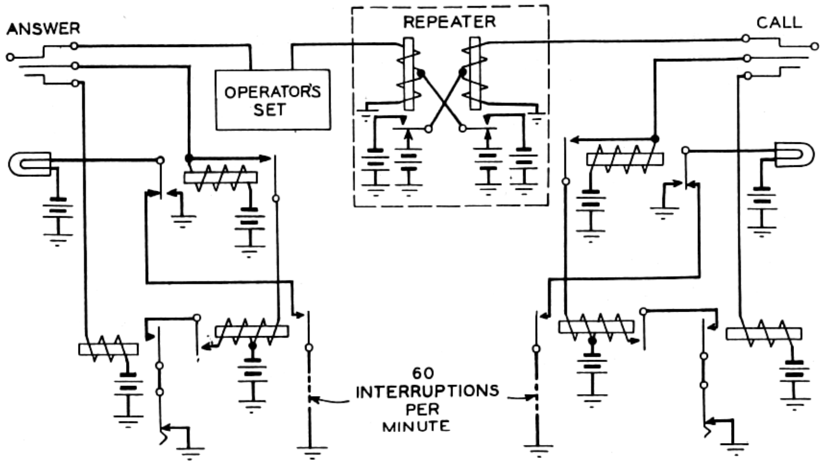

Fig. 13—Typical cord circuit.

operators may be available to answer a call from a station or an inter-toll trunk. If more than one operator answers it is necessary that they be aware of that fact, and that the first operator shall take and complete the call. A circuit is provided to indicate this.

Facilities are provided to split the cord, that is, to enable the operator to communicate in one direction without the communication being recorded in the other direction. Ringing is accomplished in a manner similar to that used in telephone practice, the No. 1 switchboard using manual start machine ringing and the smaller No. 3*A* switchboard using manual ringing. While the cord is connected to one line and the operator is attempting to complete the connection to another line, the first line is held closed in order not to mar transmission.

Conference Connections

The teletypewriter exchange system provides a means whereby practically unlimited numbers of stations can be connected in conference connections. Figure 14 shows a typical conference connection. Each link in the conference circuit is provided with a simple repeater, each of which is equipped for breaking. In this manner to and fro communication by the half-duplex method operation can be attained. The conference repeater circuits are made up in groups of five or ten, each of which is equipped with a multiple appearance so that all operators have access to the repeaters.

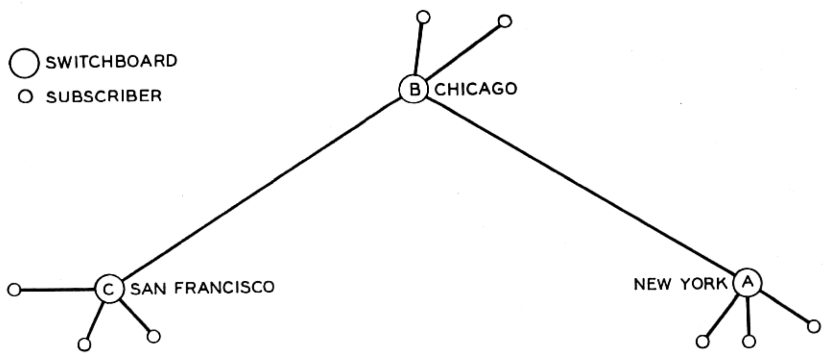

Fig. 14—Typical conference connection.

Regenerative Repeaters

It is necessary in some long circuits to improve transmission by inserting a regenerative repeater in the circuit. To make this possible and easily performed by any operator, regenerative repeaters are provided with a complete jack multiple appearing before all operators. Both ends of the repeater are available in this multiple and the repeater may be inserted where the transmission equivalent of the circuit involved makes it necessary.

Typical Built-Up Connection

In order to provide *TWX* service on a nationwide basis, certain of the connections require one or more intermediate switchboards so that one or more through operators may be involved. As an illustration of this Fig. 15 shows a connection established between a calling station in New York and a called station in San Francisco with a through switch at Chicago, a method used when all direct trunks are busy. This figure shows the manner in which the *TWX* equipment has been arranged to operate in conjunction with the telegraph line facilities. The station loop is a pair of wires such as those used for telephone service. Each inter-toll trunk consists of one or more sections of the same standard types of carrier, metallic, or grounded telegraph line systems that are employed in private line telegraph service. The signaling and supervisory apparatus is all contained in the *TWX* switchboard equipments.

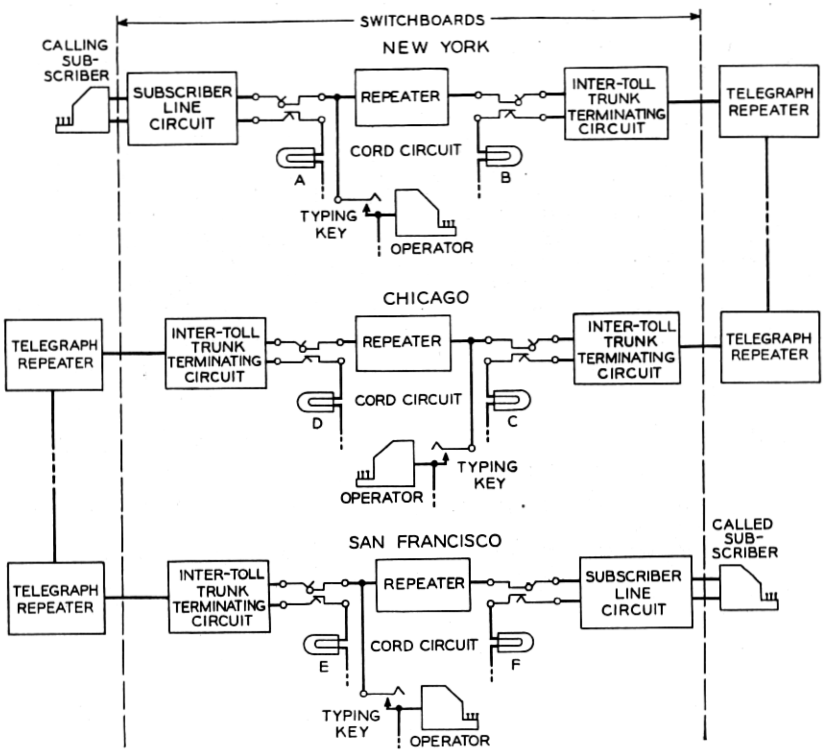

Fig. 15—A built-up connection such as would be used if all direct New York-San Francisco trunks were busy.

In the example illustrated the New York operator, being the outward operator, supervises the call and times the ticket. The following traffic table shows the important steps taken in setting up and taking down this connection:

1. *The New York subscriber calls:* Subscriber closes loop and starts teletypewriter by operating switch. Subscriber line lamps light in the New York switchboard.

2. *A New York operator answers with the cord typing key* (*similar in function to the talking key in the telephone cord circuit*) *operated:* The line lamps are extinguished. The operator and subscriber communicate.

3. *The New York operator connects to an idle trunk in the New York-Chicago multiple:* Plugs the completing end of the cord into the trunk jack and operates the cord ringing key for 2 seconds. The trunk multiple lamps at Chicago light.

4. *A Chicago operator answers:* Plugs the answering end of a cord into the trunk jack with the cord typing key operated. The trunk lamps are extinguished. The Chicago operator communicates with the New York operator.

5. *The Chicago operator completes to an idle trunk in the Chicago-San Francisco multiple:* Plugs the completing end of the cord into an idle trunk jack and operates the cord ringing key for 2 seconds. Releases typing key. The trunk multiple lamps at San Francisco light.

6. *A San Francisco operator answers:* Plugs the answering end of a cord into an idle trunk jack with the cord typing key operated. The trunk lamps are extinguished. The San Francisco operator communicates with the New York operator.

7. *The San Francisco operator completes the connection to the called subscriber line:* After making a tip busy test with completing cord to insure that the called station is idle the San Francisco operator plugs into the jack and operates the ringing key in that cord. The ringer in the San Francisco station is operated.

8. *The called subscriber answers:* The answer is received on the operators' teletypewriters at the San Francisco and New York switchboards and at the New York subscriber station. The San Francisco and New York operators release the cord typing keys leaving the communication between the subscribers. The New York operator starts timing the ticket.

9. *The calling and called subscribers disconnect:* Lamps *A* and *F* light. The New York operator completes the timing of the ticket.

10. *The outward (New York) operator sends the disconnect signal:* Operates cord key momentarily and pulls down both cords. After 10 seconds lamps *C*, *D*, and *E* light.

11. *The inward (San Francisco) and through (Chicago) operators disconnect:* Upon noting the disconnect lamp signals both operators pull down both cords.

If during the progress of the call the subscriber desires to regain the attention of the operator, a recall signal is sent. The procedure in this case is as follows:

12. *The calling (or called) subscriber recalls:* Operates power switch at the station. Cord lamp *A* (or *F*) flashes.

13. *The operator answers the recall:* Operates cord typing key connecting her teletypewriter to the circuit. The flashing cord lamp is extinguished.

14. *The outward (New York) operator recalls the inward and through operator at Chicago:* Operates recall key in cord. After 7 seconds lamps *B*, *C*, *D*, and *E* flash. The outward operator releases the typing key momentarily to extinguish the lamp.

15. *The inward and through (San Francisco and Chicago) operators challenge:* Operate cord typing keys which extinguish the flashing lamps, and then challenge by typing.

Conclusion

This paper has outlined the technique of teletypewriter switchboard operation as it stands today. Although the designs as here outlined have given satisfactory service within due limits of economy, the expansion of the system and experience in its operation will undoubtedly lead to changes in the design of both the equipment and circuits and to changes in the methods of operation to increase the efficiency and improve the quality of the service.