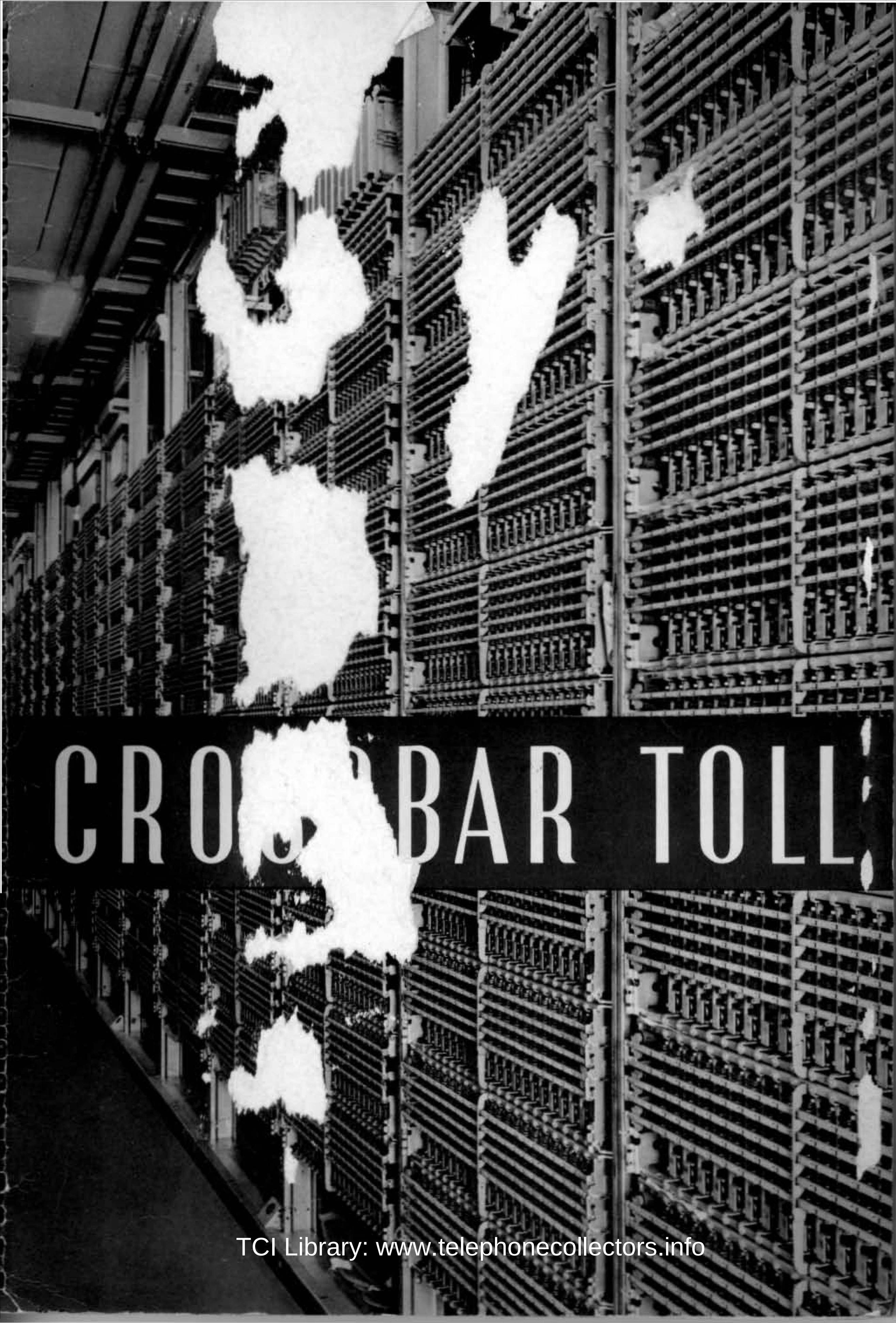


CROSSBAR TOLL

Crossbar Toll

Reprinted from

Bell Laboratories Record

Volumes 22 *and* 23

INDEX

Some of the articles reprinted in this booklet describe operating methods which had not been finally established at the time of original publication. Consequently, modifications have been or may be made in some of the details.

Philadelphia Adopts Automatic Toll Switching

By B. C. BELLOWS
Toll Facilities Director

THE No. 4 crossbar toll system which was cut into service in Philadelphia on August 22, 1943, is arranged to complete connections from trunks from outward toll positions to toll lines for outward calls; from toll lines to trunks to local offices for terminating calls; and from one toll line to another for calls switched through Philadelphia. Outward calls, and incoming calls from toll lines equipped for toll-line dialing, are switched automatically under control of dials or keysets at the originating end of the trunk or toll line. Incoming calls from other toll lines are routed to operator positions, and keysets at these positions, shown in the illustration above, control the subsequent setting up of the connection. All transmission paths through the equipment are four-wire, and telephone repeaters are cut in automatically when required. Another important feature is the use of the multi-frequency method for the transmission of switching codes.

With this new system, crossbar switches with senders and markers are used in the same general way as in the local crossbar system, with such variations and additions as the handling of toll traffic requires. The operator positions, which supplement the mechanical switching system for handling terminating and through calls from toll lines not equipped for toll-line dialing, are of the cordless type, but cord positions are used to facilitate the proper handling of traffic over badly congested toll-line groups. The system permits the use of toll-line dialing into a city where local service is given through panel or crossbar offices. The various types of calls handled through the system are shown in Figure 1.

The introduction of this system leaves the handling of outward traffic at the same positions at which it was formerly handled. Since access to toll lines is through the No. 4 equipment instead of through a manual tandem position, however, keysets or dials were added to those outward positions not formerly so equipped. In handling an outward call, the operator keys or dials a three-digit code to reach a toll-line group. If the group concerned is equipped for toll-line dialing, this code is followed by the necessary codes to control switching equipment at a distant office—the listed number if that office is the terminal office, preceded by a three-digit code if another switch is required to reach the terminal office.

On incoming traffic from toll-line-dialing groups, senders in the No. 4 equipment accept pulses from the distant offices, and control the switching of the connection to the subscriber in the Philadelphia toll center area if the call terminates there. If the call is to be switched to another toll line, the senders also control the connection, and forward pulses to the next office if the toll line selected is of the dialing type.

Incoming calls from toll lines not equipped for toll-line dialing (ringdown or straightforward) are automatically connected to the cordless positions. These are equipped with eleven rows of ten-button keys to control the setting up of connections, and various other keys and lamps to provide for other operating functions. If, for example, a call cannot be completed because the called line is busy or does not answer, a position is connected so that the proper oral report may be passed to the calling operator. Lamps indicate which report should be given. The proportion of calls handled on these positions will decrease as more toll-line groups are converted to toll-line dialing in the future.

Talking paths of all connections through the equipment are four-wire. Trunks or toll lines which are not four-wire are converted to four-wire through hybrid coils before being connected to the equipment. Gain is

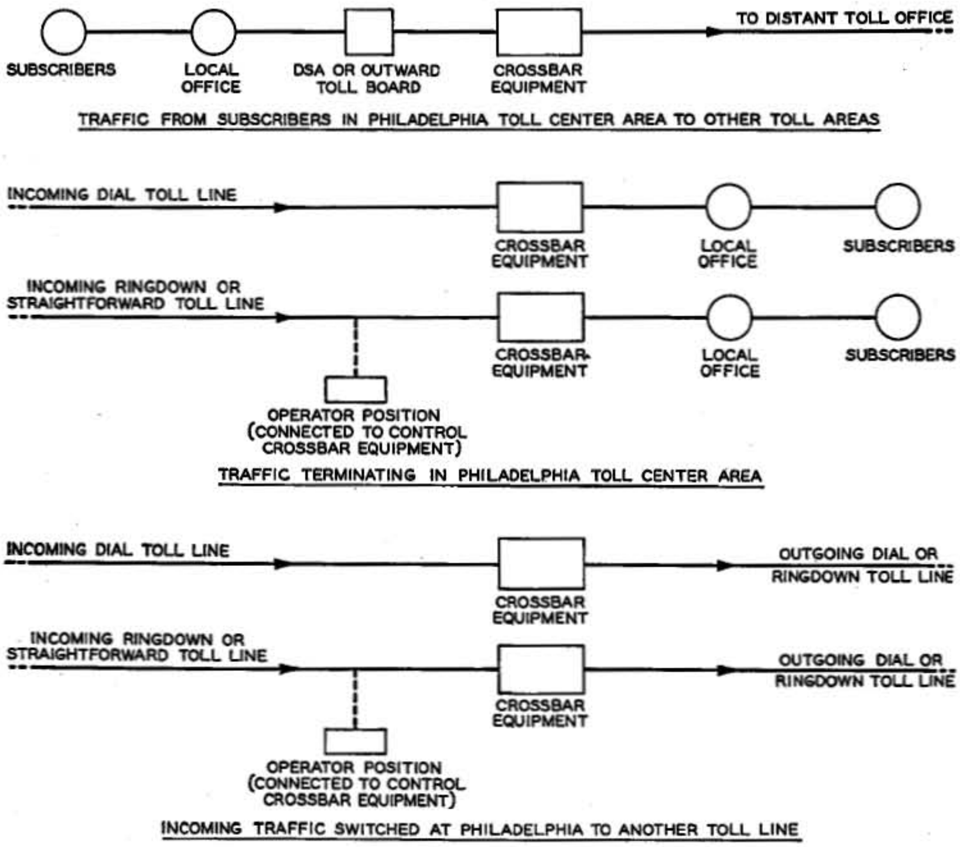


Fig. 1—Types of toll calls handled by the new No. 4 crossbar system

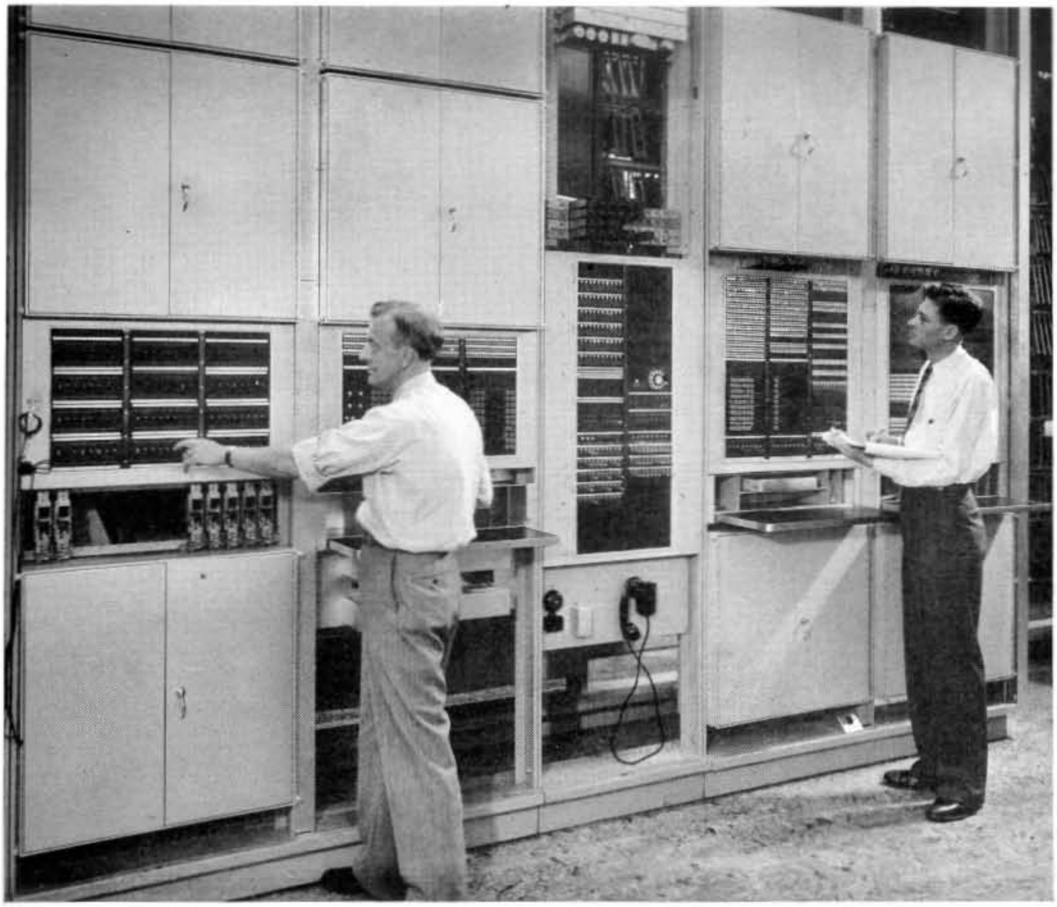


Fig. 2—The sender test frames are shown at the left and the trouble indicator frames on the right

introduced automatically in any connection requiring it through the use of switched-in repeaters.

Where two-wire switching has been used, incoming trunks of the four-wire type (including two-wire toll lines with terminal repeaters) must be reduced to two-wire before being connected to the switching equipment. In the hybrid coil arrangement which makes this transition is a network that should balance the impedance of any trunk to which connection must be made. There is a considerable proportion of the trunks on which it is economically impracticable to make the impedance uniform such as trunks to local offices and non-repeatered two-wire toll lines. A compromise value for the balancing network toward such trunks must, therefore, be used, and the gain in the terminal repeaters is thereby limited. With four-wire switching, the balancing networks are associated with individual trunks wherever hybrid coils are needed to permit connection between four-wire and two-wire terminations. They may therefore be precise, and the gain from terminal repeaters may be substantially higher.

The principal economies to be gained from using four-wire switching come from the fact that it permits making many trunks or toll lines high loss by omitting terminal repeaters or using lower grade outside plant. When two such lines are connected together, repeaters are switched in—a provision that is much more difficult to make with two-wire switching because of the balance problems previously referred to. When such a line is connected to a low-loss line, it is simply necessary to remove a pad normally used in the low-loss line, thereby using the extra gain obtained from the terminal repeater. Four-wire switching also makes it economically possible to bring the overall transmission on switched traffic nearer to that obtained when direct circuits are used.

As in local crossbar offices, automatic testing is provided where needed. There are two trouble indicators, each serving a different group of equipment. These are shown at the right in Figure 2. When trouble occurs, these indicators furnish a very complete record of the equipment concerned, and so far as practicable the nature of the trouble. These are similar to the trouble indicators provided in local crossbar offices. A very complete system of traffic registers and meters, shown in Figure 3, is also provided. These permit measuring the load carried by various parts of the equipment, thus permitting proper balance in the use of the equipment and assuring the ability to carry maximum load without objectionable service delays. One meter makes a record of calls waiting on the cordless operator positions, which is valuable in the control of proper operator assignment.

Since the estimated load is close to the capacity of the equipment, it was not considered wise to make a complete cutover at one time. The first cut transferred 1,160 toll lines and, as a result, about 100,000 calls a day are being handled through the new system. As it would have been difficult and expensive to keep some of the old manual through positions and provide for switching a call through both these and the No. 4 equipment, all toll lines carrying traffic switched through Philadelphia were included in the first cutover. The remaining 646 toll lines handle only terminal traffic, and are to points to which the traffic volume is large enough to make the provision of a separate group of toll lines for the terminal traffic desirable and economical. These lines were cut over during October.

This cutover introduces the use of multifrequency keying in handling toll traffic. When a digit key is operated, two of five frequencies in the voice range are transmitted, and the receiver identifies the digit from the two frequencies received. Keysets of this type were installed at the outward positions of the two largest outward units at Philadelphia. They will also be used for pulsing from Baltimore and New York to Philadelphia when those terminal groups are cut over. This is the fastest method for the transmission of switching codes yet used, the system being capable of handling ten digits per second. As at present applied, the speed is limited by the speed with which the operator can operate the sending keyset, which is about two digits per second.

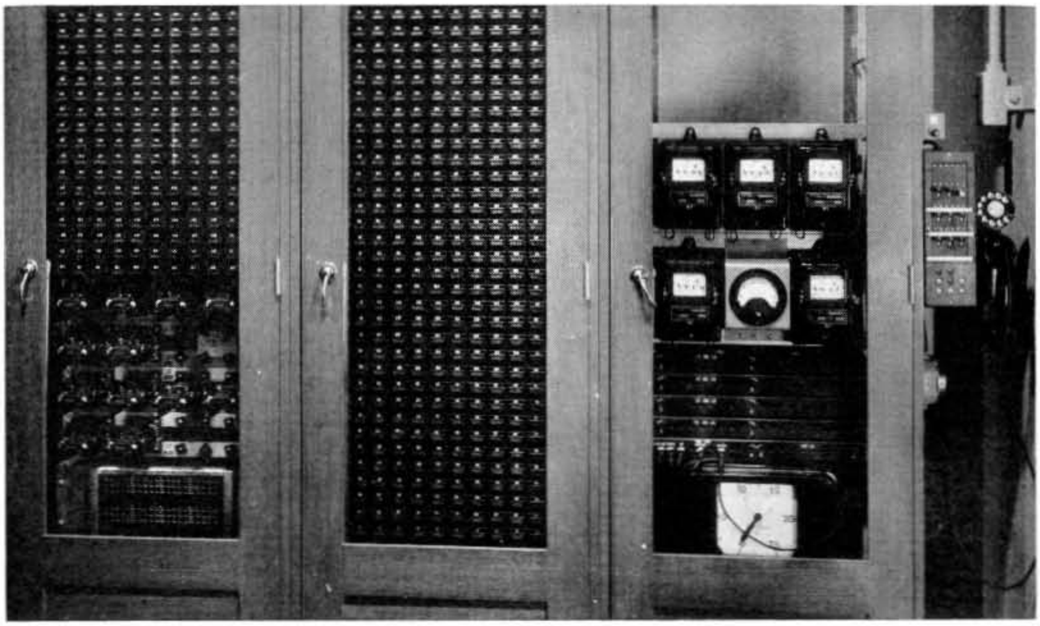
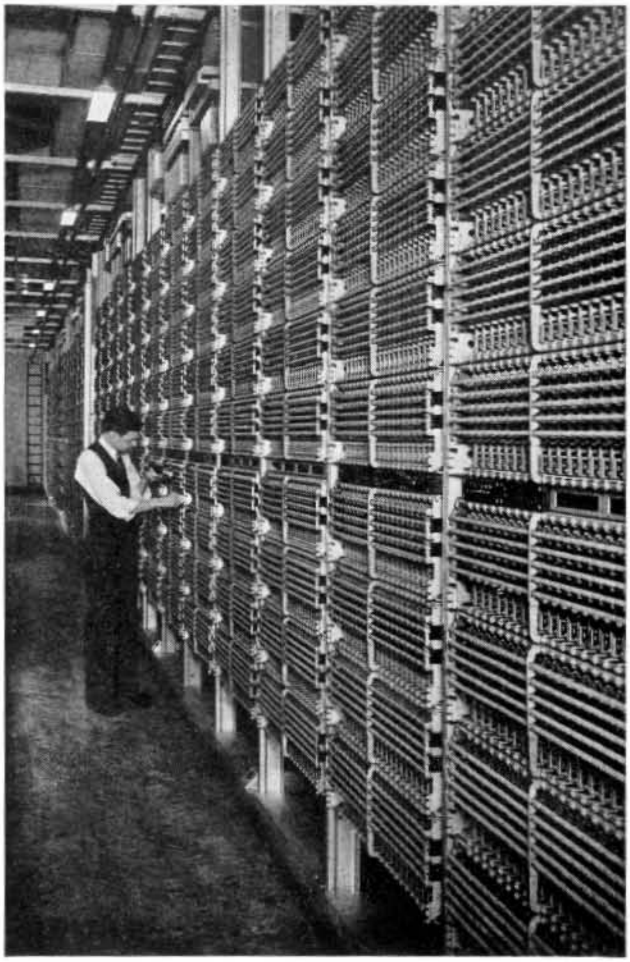


Fig. 3—Traffic register cabinet houses equipment for measuring office traffic loads

Crossbar Toll Switching System

By F. F. SHIPLEY
Switching Engineering



IN CROSSBAR switching systems, a train of two groups of switching frames is employed to interconnect incoming and outgoing lines of various sorts. Omitting all control equipment, the general arrangement is as indicated in Figure 1, where the term "lines" is used in its broadest sense to include subscriber lines, trunks to other central offices, or toll lines. In a local central office there are two trains like Figure 1. For one of them the incoming lines are from subscribers' stations, and the outgoing lines are trunks to other offices, or to other switching groups. For the other train, the incoming lines are trunks from other offices, and the outgoing lines are to subscribers' telephones. Interoffice trunks are connected to office-link frames for the outgoing train and to incoming-link frames for the incoming train and thus never appear on both ends of the same train.

A crossbar toll switching office differs in general features from a local office in that only one train is required, and in that no direct subscriber lines are involved at all. Both incoming and outgoing lines are toll lines or trunks to other offices, and since they may be either one-way or two-way, some will appear at only one end of the train, and some will appear at both. A call, for example, may come in to the crossbar toll office over a trunk from a local office for completion over a toll line to a distant center. The local trunk must thus appear on an incoming-link frame, and the toll line on an outgoing frame. If the toll line is a two-way trunk, however, it may handle a call in the opposite direction, and thus it will have to appear also on the incoming frames. The terms "incoming" and "outgoing," therefore, do not necessarily refer to entirely different sets of trunks but rather to the direction in which the call is proceeding.

Another complication of the crossbar toll office is in the wide variety of trunks that must necessarily be accommodated. There is a broad division between manual and dial trunks, but the manual may be operated either as straight-forward* trunks or as ring-down trunks, while dial trunks may be designed for dial pulsing, d-c key pulsing, or multi-frequency key pulsing, or at the distant end they may appear at operators' positions equipped for either call-indicator† or call-announcer‡ operation. All these types of trunks require different treatment

*Record, *April*, 1929, *p.* 323. †Record, *July*, 1930, *p.* 515. ‡Record, *January*, 1930, *p.* 210.

whether they are of the incoming type or of the outgoing type or both.

All outgoing calls from the local area reach the crossbar toll office either from an outward position of a toll board or from a DSA board. If the outgoing line desired is of the manual type, the outward or DSA operator will key or dial a code to cause the crossbar toll equipment to select a trunk of the desired group, and she will then pass the number desired to the distant operator. If the call is to a dial trunk, the operator dials both a code to select an idle trunk of the group desired and also the number of the line wanted at the distant end.

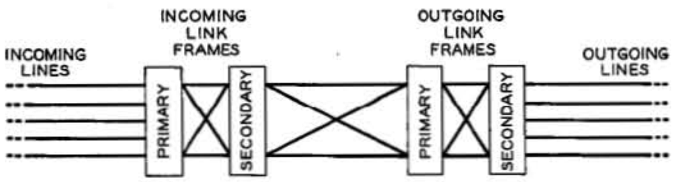


Fig. 1—A crossbar switching train consists of two frames with their connecting links

Incoming calls may be either for completion in the local area or for switching to some distant city, and either type may arrive or require completion over a manual or dial trunk. If the call arrives over a dial trunk for completion in Philadelphia, the distant operator will dial both the office code—which will guide the crossbar toll equipment in selecting a trunk to the proper office—and the subscriber's number, which will select the proper line in that office. If a call arrived over a dial trunk but were for an outgoing toll line, the operator would dial a code to guide the crossbar toll equipment in selecting the proper trunk, and would then either dial the distant number wanted if the trunk selected were of the dial type, or would repeat the number to the distant operator if it were of the manual type.

If the incoming call were of the manual type, on the other hand, regardless of whether it were for a local or through connection, it would be connected to a cordless position forming a part of the crossbar toll office. An operator here would receive the order from the distant office and write it up on strip keys—the entire number if the call were to be completed by dial, but only a three-digit code to select a trunk if it were to be completed manually.

For every call passing through the crossbar toll office, an incoming sender is connected to the calling line to assist in establishing the connection. This sender associates itself with a marker to which it passes the three-digit code to guide the selection of an idle trunk and the establishment of a connection through the incoming and outgoing frames. If the call is to be completed over a manual ring-down trunk, the sender disconnects itself after the connection has been established through the crossbar toll office, and the operator at the distant end of the incoming trunk handles the call from then on. If the call is to be completed over an outgoing toll line equipped for multi-frequency pulsing, the incoming sender, after the connection through the crossbar toll office is established, will send the proper pulses over the toll line to complete the connection at the distant end.

Had the call required completion over an outgoing dial toll line other than of the multi-frequency type, an outgoing sender would have been connected to the outgoing trunk when it was seized by the marker, and as soon as the connection had been established through the office, the incoming sender would have transferred to it the digits to control the connection at the distant end. The incoming sender would then have disconnected itself, and the outgoing sender would complete the work at the crossbar toll office.

A block schematic for the crossbar toll office is shown in Figure 2. Senders of all types are connected to the trunks through sender-link frames, which are under the direction of controllers. With incoming dial trunks, a sender-link frame connects a sender directly to the trunk, but with manual trunks, an operator-link frame connects the trunk to a cordless position with each of which a sender is directly associated. All the incoming senders have access to markers through connectors, and transmit to them the three-digit code that designates the group of outgoing trunks desired. As determined by the particular code, the markers operate a trunk block relay to reach the group of trunks desired, and test them for busy. Having selected an idle trunk, the marker establishes a connection to it and then disconnects itself.

After the marker has established a connection through the train, the incoming sender acts in one of three ways, depending on the type of outgoing trunk. With a manual ring-down trunk, it disconnects itself and allows the operator at the calling end of the trunk to pass the needed information over the trunk. With a trunk arranged for a-c key-pulsing signals, it transmits the required pulses over the line in accordance with the number it has recorded. With other dial trunks, it passes the number desired at the distant end to an outgoing sender which had connected itself to the trunk through a sender-link frame when the trunk was seized. The incoming sender will then disconnect itself, and the outgoing sender will transmit the required pulses over the line. Outgoing senders are also employed when call-announcer or call-indicator pulses are to be sent over the trunk.

As already pointed out,* one of the advantages of the new switching system is its ability to connect repeaters into the circuit when required. These, also, are connected to the trunk through link-frames as indicated on the diagram, and like the outgoing senders, they are connected automatically as required.

A feature of the crossbar toll office is the use of four-wire switching throughout. The crossbar switches of the incoming and outgoing-link frames connect four wires for the talking circuit instead of two as do the equivalent local frames, and the switchboard positions used for handling delayed calls use four-wire plugs and jacks.

One of the major advantages of the new system is the increased speed with which calls are handled. This may be illustrated by considering the time involved in placing dial calls through the office. As soon as a trunk to the crossbar toll office is seized, a sender-link frame connects a sender to the trunk. The time required for this operation is less than one second, and as soon as the sender is connected, it transmits a signal to the calling end to indicate that dialing may begin. The operator then starts dialing or key-pulsing the number. There will be three digits to select a group of trunks located in the crossbar toll office, perhaps from

*Record, *November*, 1933, *p.* 101.

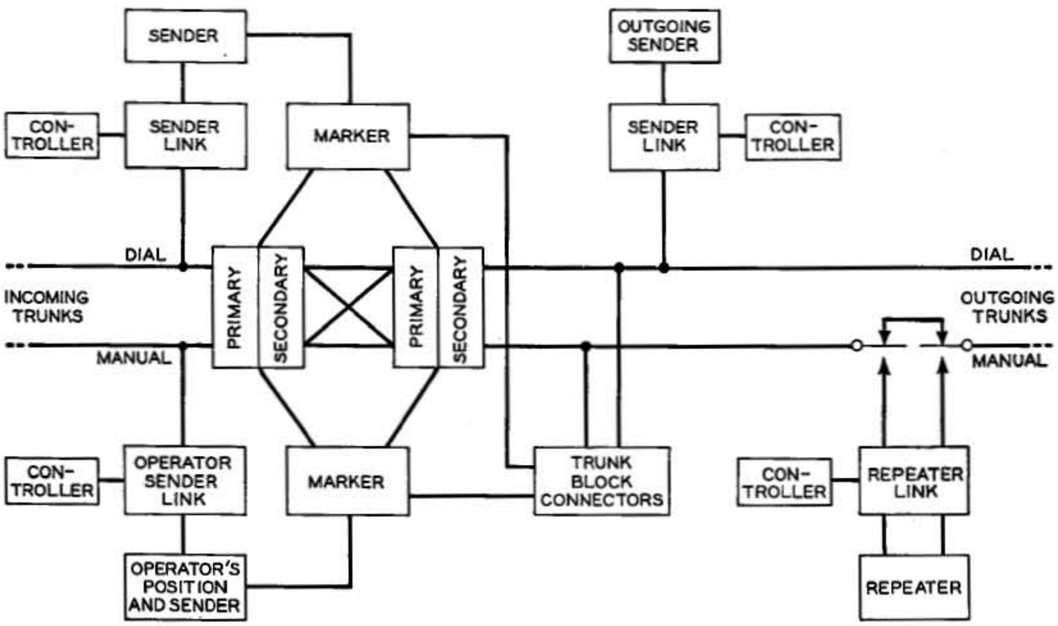
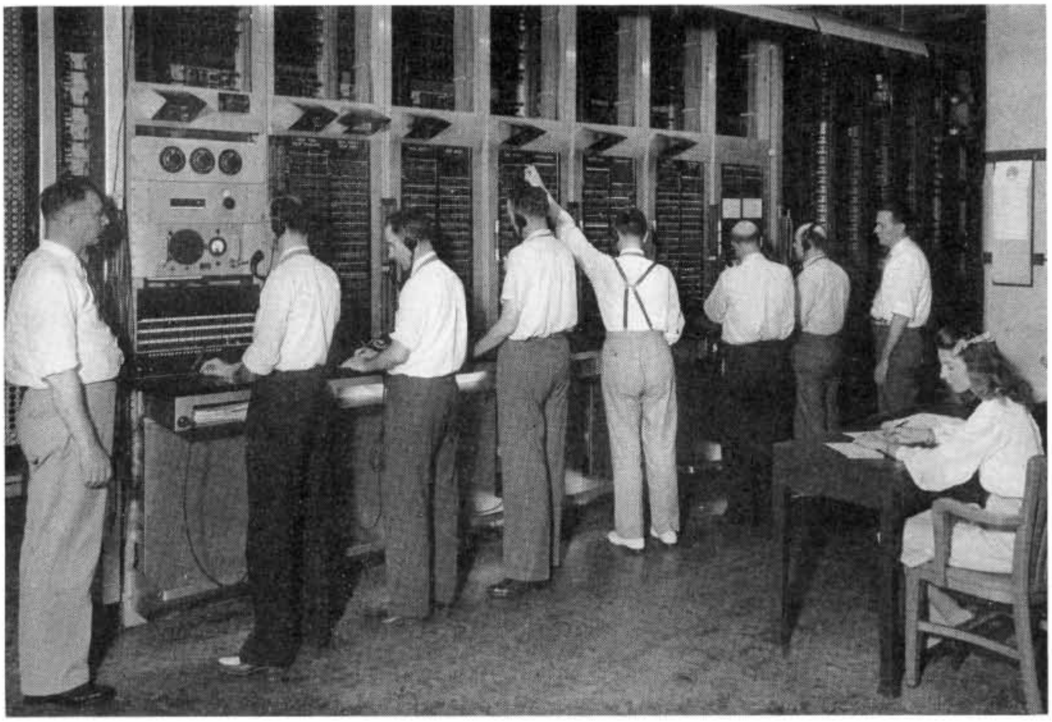


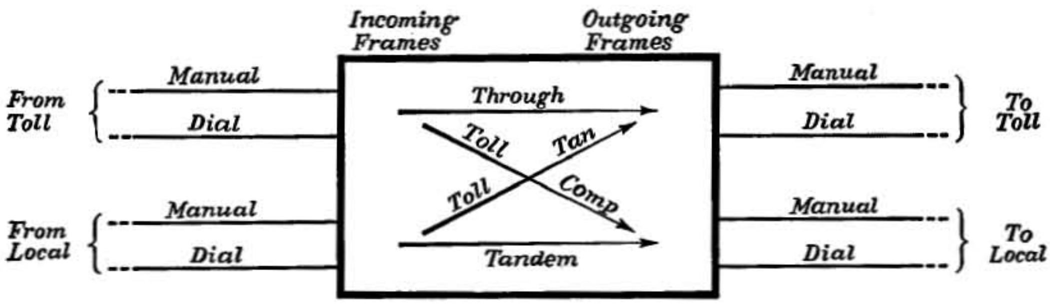
Fig. 2—Block schematic showing the main circuit components of the crossbar toll system

one to three digits to guide switching at an intermediate office, and from four to eight to select the office and subscriber in the city called. These pulses are sent at a rate of about one digit per second if they are from a dial, or at a rate of two digits per second if they are being sent by key-pulsing from the outward toll office in the local area, and as soon as the incoming sender has recorded the first three, it seizes a marker, and transmits the three digits to it simultaneously. The marker then operates the block relay for the required group of trunks, selects an idle trunk, and makes it busy to other markers. It then finds an idle path through the switching train to connect the incoming and outgoing trunks, and closes the circuit through. This has required about one second, and after the crossbar switches have operated, the marker disconnects itself to be ready to handle another call.

When the outgoing trunk was first selected and made busy by the marker, it was automatically connected to an outgoing sender through a sender-link frame. This sender is connected at about the time the marker establishes the connection through the switching train, which—as already indicated—is about one second after the three-digit code is recorded by the incoming sender. During this interval the incoming sender has been recording the remaining digits, and has not yet finished. It at once starts transmitting them to the outgoing sender at the rate of ten digits per second by d-c key pulsing, and as soon as the outgoing sender receives them, it relays them over the line to drive the switches at the distant end of the line. As soon as all digits have been recorded and relayed to the outgoing sender, the incoming sender disconnects itself, and the outgoing sender disconnects as soon at the last digit has been sent over the line. All common equipment used in establishing the connection has now been released, leaving only the connection to be used for conversation. With this overlapping operation the work at the crossbar toll office is completed in very little more time than is required to record the digits dialed.



No. 17C testboard for crossbar toll terminal equipment



Senders of the Crossbar Toll System

By R. E. HERSEY
Switching Development

SINCE their first development for the panel system, senders have been designed in a number of varieties, but their basic functions have remained unchanged. Acting as automatic operators, they record the number transmitted to them and send out pulses or other signals to guide the setting up of the connection through one or more switching frames. Their variations have been due largely to the type of pulses* used for transmitting information to them and to the kind of pulses they send out to control the connection.

With the crossbar toll system, the situation with regard to senders is much more complicated because of the wide variety of incoming and outgoing trunks with which they are to be associated. The interconnections that can be made by the new system are indicated in the diagram at the head of this article. Besides being able to handle all the types of pulsing normally employed with such trunks, senders for the crossbar toll system must also be able to send and receive multi-frequency pulsing, which has recently been developed for use over various types of toll lines. Signals coming in to a crossbar toll office may be d-c key pulses, dial pulses, multi-frequency pulses, or speech from a manual operator, while over the outgoing trunks it may be necessary for the sender to transmit dial pulses, multi-frequency pulses, call-indicator pulses, revertive pulses, or to use a call announcer, which will transmit the call by voice. It would have been possible to provide one multi-class sender for controlling all types of calls. By using various signals from the different types of trunk circuits, this sender could recognize what class of pulsing it was about to receive. Similarly the same sender might have been arranged to pulse out through the outgoing circuits as required. In spite of the advantage of being placed in one common group, such a sender would have been very complicated because of the necessity of handling so many different types of both incoming and outgoing pulses. It seemed more desirable to provide several types of senders, each to handle traffic over certain types of trunks. The association of the senders with these various types of trunks and with other units of the system is indicated in Figure 1.

In all, five types of senders are provided, three to be associated with incoming trunks and two with outgoing trunks. For each incoming call, one of the incoming senders is employed and, unless the call is to be completed over a manual trunk on either a straight-forward or ring-down basis or over a trunk to an office equipped to receive multi-frequency pulsing, an outgoing sender will also be employed. When an outgoing sender is used, the incoming sender transfers to it all of the digits received except the first three, which are used by the marker to control the connection within the office. Transfer of digits is at the rate of eight per second by d-c key pulsing, and all incoming senders are designed to transmit d-c key pulses, and all outgoing senders to receive them.

All incoming senders are also arranged for sending out multi-frequency pulses. This

*See page 3.

method will be used for pulsing over the outgoing circuits without the aid of outgoing senders whenever the terminating points are provided with senders capable of receiving multi-frequency pulses. At present, only two such services are provided: completing to local crossbar offices and to other crossbar toll offices. Ultimately, it is possible that the use of outgoing senders will be completely eliminated by the extension of the use of multi-frequency pulsing. This, however, may be a rather long look into the future.

While all three types of incoming senders are thus arranged to send either d-c or multi-frequency pulses, they are each arranged for receiving different types of signals. Dial senders are arranged to receive dial pulses, at the rate of either ten or twenty per second. The receiving circuit for these senders is similar to that of the subscriber's senders* of the local crossbar system, and the digits received are recorded on crossbar switches.

Key-pulsing senders are arranged to receive either d-c or multi-frequency pulses, and are prepared for the type of signal to be received by a signal from the incoming circuit. These senders record the digits on relays—four for each digit.

Position senders, which are the third type of incoming senders, are really part of the cordless positions. The operators at these positions receive oral information regarding the connection wanted, and then "write-up" the proper number on locking-type strip keys, which serve as the recording unit for the senders.

All of these incoming senders are arranged for connecting to the markers, into which they usually pass the first three digits received for use in determining and setting up the connection to the desired outgoing trunk. As soon as an outgoing trunk has been chosen, an outgoing sender is attached except when the call is to be handled in the straight-forward, ring-down, or multi-frequency pulsing manner.

Both of the types of outgoing senders are arranged to receive d-c key pulses as already noted, but each is arranged for sending out two different kinds of signals, and which it sends will depend on a signal received from the outgoing circuit. One type receives four or five digits, and controls the sending of either revertive or call-indicator pulses. Revertive pulses are used for completing calls to either panel or crossbar offices; call-indicator pulses for completing calls to manual offices in panel areas.

The other type of outgoing sender receives up to eleven digits, and either sends them out as dial pulses for completing calls to step-by-step systems, or connects itself to a call announcer and controls its sending of voice announcements — the latter being limited to five digits.

Both the incoming and outgoing senders and the toll-cordless positions are associated with the circuits they serve through sender links, which consist of crossbar switches. These switches are actuated by sender-link controllers, which control the connection to the proper type of sender.

Incoming dial senders are mounted on

*RECORD, *April*, 1939, *p*. 234.

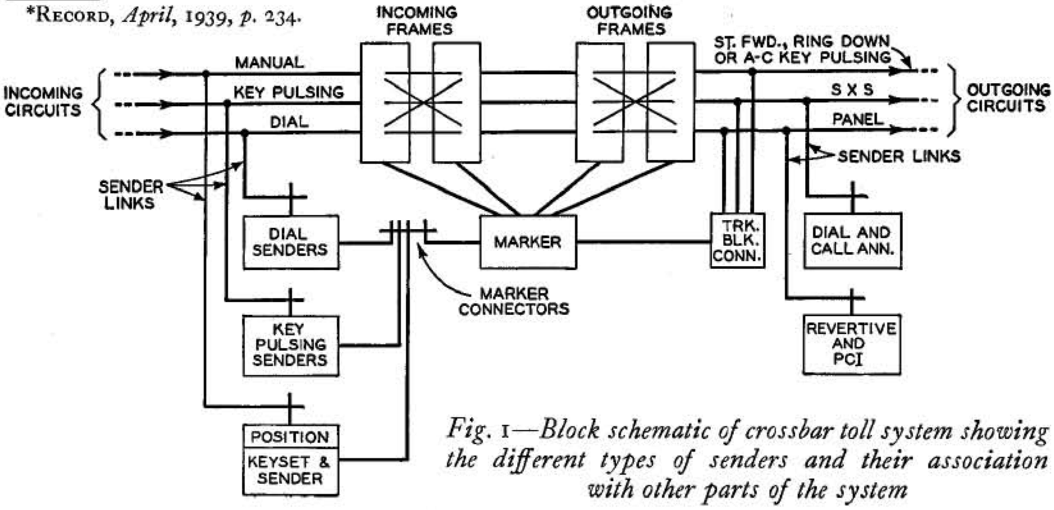
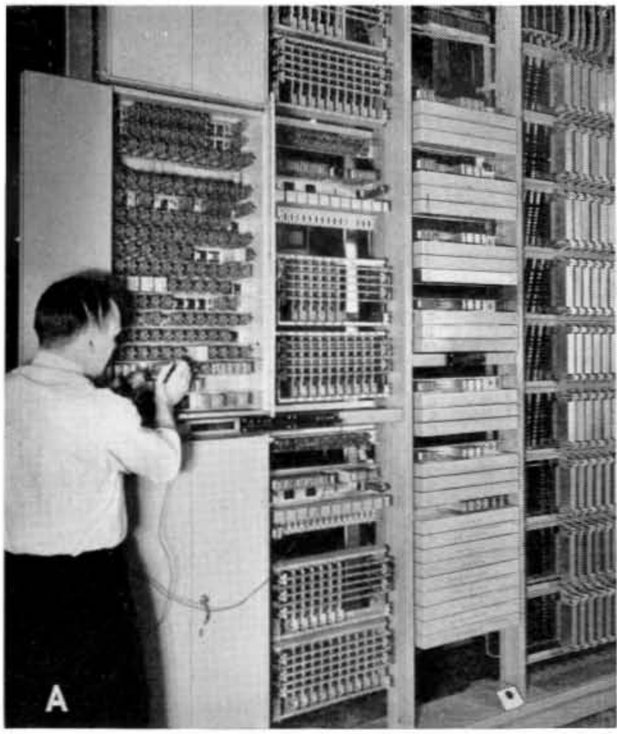


Fig. 1—*Block schematic of crossbar toll system showing the different types of senders and their association with other parts of the system*



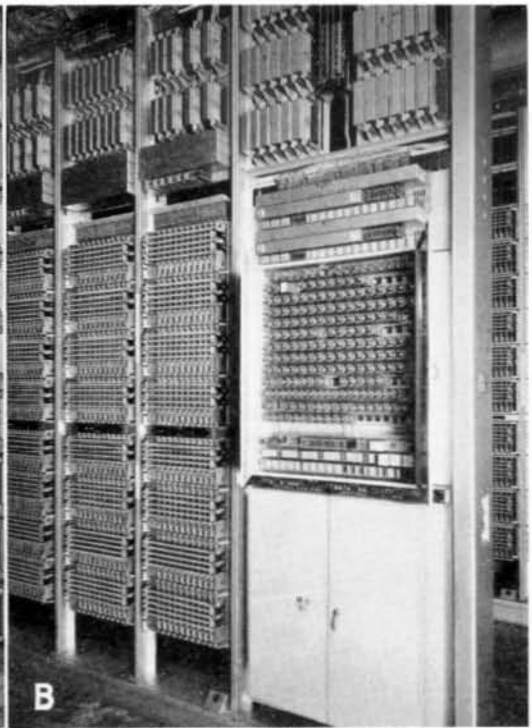


Fig. 2A—Dial senders and marker connectors in the Philadelphia crossbar toll office

Fig. 2B—Two sender-link controllers and their connectors comprise the bay at the right. The primary and secondary switches of a sender-link frame occupy two bays, as shown at the left of the controllers

Fig. 2C—A position sender at the right with the associated position relay equipment at the left

Fig. 2D—Receiving units for incoming key-pulsing senders are mounted six on a bay

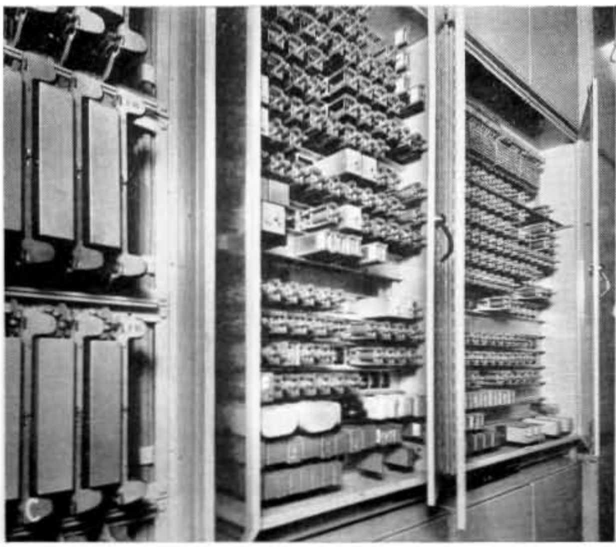


TABLE I—NUMBERS AND TYPES OF SENDERS AND THEIR ENGINEERED CAPACITY IN THE PHILADELPHIA OFFICE

Incoming Senders	*Toll Calls Per Busy Hour*
42 Dial Pulsing	8000
27 Key Pulsing	9000
34 Cordless Position	6000
Outgoing Senders	
27 Revertive and Panel Call Indicator	7000
27 Step-by-Step and Call Announcer	7000

two bays with the marker connectors on two adjacent bays. Four such bays of the Philadelphia installation are shown in Figure 2A. The cabinets on the left-hand bay—one of which is shown open—house the relay equipment for three senders, while the second bay carries certain miscellaneous equipment and the two crossbar switches on which the fourteen digits are recorded. Incoming key-pulsing senders have their multi-frequency receiving circuits on separate bays as shown in Figure 2D. Their relay equipment is in cabinets on an adjacent bay. Position senders are mounted in cabinets adjacent to their associated position relay equipment as shown in Figure 2C. Each type of outgoing sender occupies only a single cabinet. The cabinets are mounted three on a bay and each bay may include either or both types. Figure 3 shows an outgoing step-by-step sender at the bottom of the bay and a revertive sender above it. The third sender on the bay is not shown.

The types of connections that incoming and outgoing senders are required to control are indicated in Figure 4. When the call is completed to an office within the local area where the crossbar toll office is located, only the called-office code and four or five digits are required, since the trunks picked connect directly to the office called. For a call to another switching area, a switching code must be dialed or keyed ahead of the called office code and number. Similarly for a call to another switching area through an intermediate switching point, one, two, or three additional digits for use at the intermediate switching point must be dialed or keyed following the switching code. Thus all fourteen digits may be used where calls are completed through one crossbar toll office to another switching area by way of an intermediate switching point.

For the Philadelphia crossbar toll office, senders are provided in sufficient numbers to handle over 200,000 calls in a ten-hour day. The distribution of busy-hour calls for the various types of senders is shown in Table I. To permit these senders to dispose of this large number of calls, they are arranged with a number of safeguards. All senders have timing circuits to insure that they will not be held too long when they have encountered some kind of traffic delay

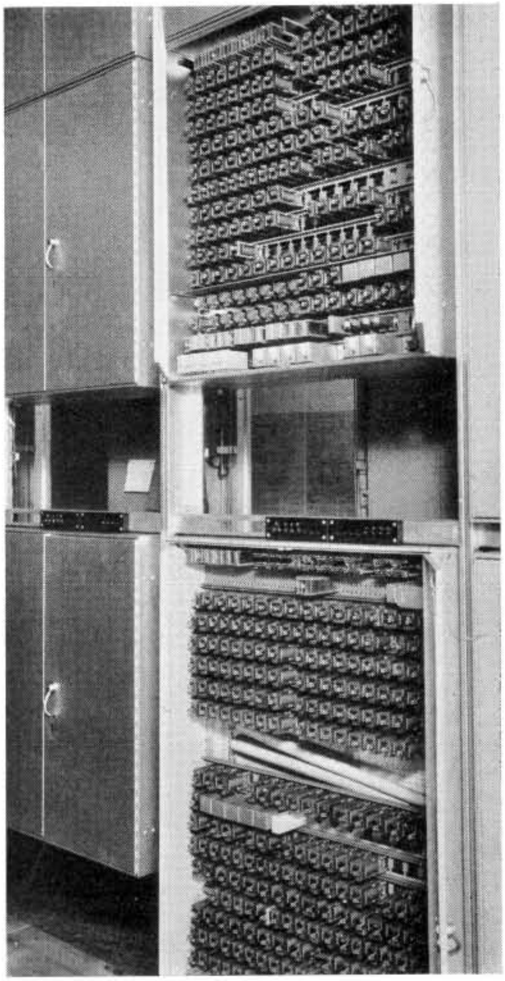


Fig. 3—Three outgoing senders are mounted on a single bay. The photograph above shows a step-by-step sender at the bottom of the bay with a revertive sender above

or trouble condition. When time-out occurs because of traffic conditions, the senders cause a re-order flash to be returned to the originating operator so that she may promptly start the call again, and are then released. When time-out occurs as a result of trouble conditions, however, the sender is held for maintenance attention. All senders are equipped with a trouble lamp and a make-busy jack. These are located on a lamp and jack bay in the maintenance center along with an automatic sender test frame for testing every function of each sender. Some types of sender troubles are automatically displayed on the trouble indicator. With these maintenance facilities, the all-important senders designed for this telephone system are rigidly tested to insure the high standard of services that are obtained with the crossbar toll system.

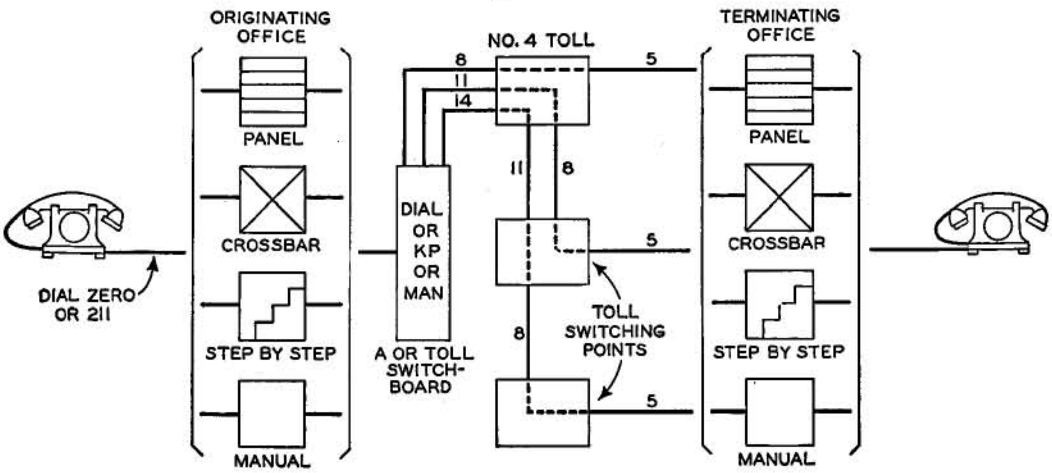
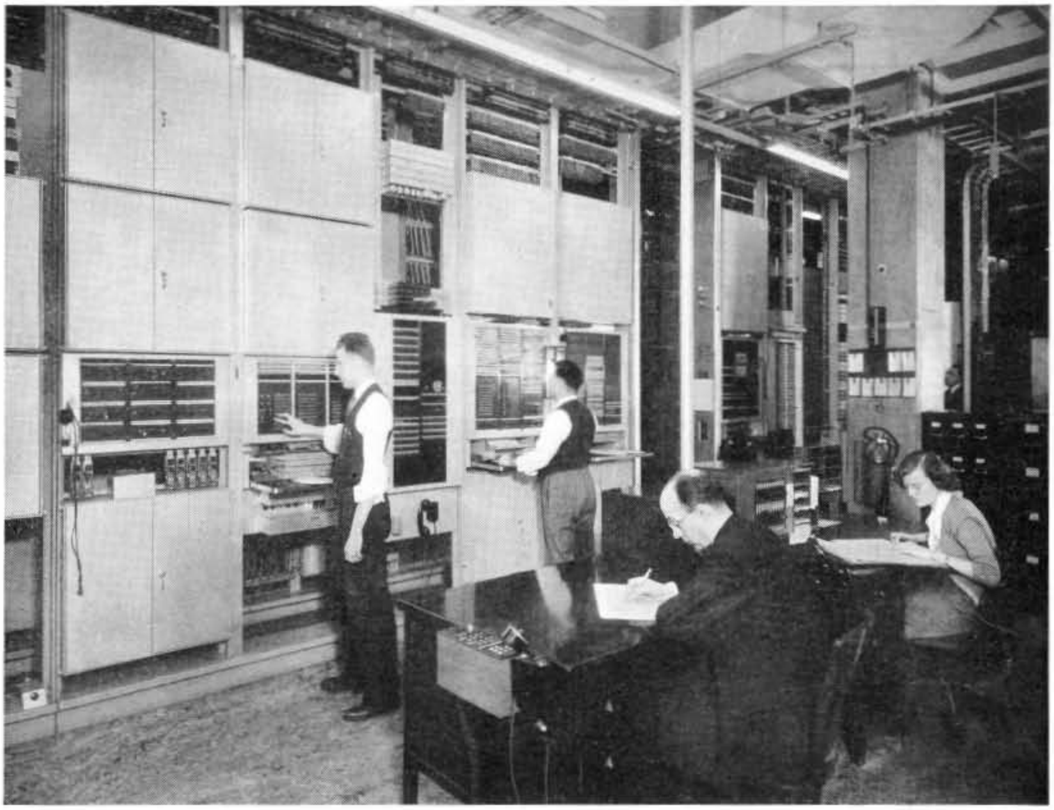


Fig. 4—Schematic representative of the types of calls handled by the crossbar toll office



Maintenance Center for the Crossbar Toll System

By C. V. TAPLIN
Switching Development

ALARMS and other indications of trouble in the automatic switching equipment of the crossbar toll system are received at the maintenance center shown in the photograph at the head of this article. Here is the major testing equipment and here also are the facilities for removing the more important circuits from service. From this point, the maintenance of the switching equipment is directed. The testing and operation of the toll lines are directed from a different point.

The need of a maintenance center for automatic switching equipment has developed with the increase in the use of relatively small groups of high usage common circuits, such as senders and markers. In offices of the step-by-step type, each switch has, in general, the same importance as every other switch, and there is relatively small need for concentrating the alarm indications, testing equipment, or the direction of maintenance activity. With the advent of panel-type central offices employing senders, the automatic sender test frame, facilities for taking senders out of service, and a floor alarm frame were usually located near the chief switchman's or wire chief's desk. This point thus became to a large degree a maintenance center, although it was not recognized as such, since generally other automatic testing equipment and facilities for removing equipment from service were not located at this point.

In crossbar offices, the introduction of markers, and the provision of terminating senders have, of course, increased the use and importance of high-usage common circuits. The markers, which do the actual work of setting up the connections, are required to operate with many other circuits, and consequently a fault in any of these circuits may cause failures of markers to complete their functions. Under such conditions, the circuits cannot be held while the cause of the failure is determined, since this procedure would in most cases interfere with service. To provide promptly as much information as possible concerning a failure and to release the circuits involved, the markers were arranged to call in a trouble indicator whenever their work could not be completed in a prescribed interval of time. Upon being attached to a marker, the trouble indicator displays on lamps pertinent information which the maintenance people can use in locating the difficulty.

Since a condition causing marker failure could occur in any of several circuits, an analysis of one or more trouble indicator displays might indicate the desirability of making tests of senders, markers, or other circuits, or of removing such circuits from service. To carry on the maintenance work efficiently, therefore, it was found necessary to locate at one point all test frames, trouble indicators, facilities for removing the common circuits from service, communication facilities, and maintenance information.

At Philadelphia, maintenance facilities consist of a sender test frame, a sender make-busy frame, a trouble indicator frame, an outgoing-trunk test frame and an outgoing-trunk make-busy frame, all located in one line. In front of these frames is the chief switchman's desk; and at one side are filing cabinets containing circuit schematic and wiring drawings, circuit descriptions, Bell System Practices applying to the circuits and apparatus used in the office, and various records that are needed.

The sender test frame requires three bays of apparatus. It has a large job to do, since it is used to test both incoming and outgoing senders. It tests and progresses automatically from sender to sender until all senders of a particular type have been tested. Provision is made for controlling the operation of the test frame in various ways by features similar to those used for sender test frames in local crossbar offices.

To the right of the sender test frame is the single bay comprising the sender make-busy frame. Its main function is to provide a location for the jacks used for removing senders from service, and for the keys used to control the feature that automatically releases the sender if it fails to complete its functions within a certain time.

To enable the maintenance people to communicate with other points within the building, and also with other central offices, communication trunks and official telephone lines are provided on the sender make-busy frame together with a telephone circuit and a dial. These facilities also appear at the outgoing-trunk test frame and the chief switchman's desk. Some additional lamps and keys, and also registers for recording the number of certain types of failures such as stuck senders, are grouped together and are located on the sender make-busy frame.

The two-bay structure next to the right is the trouble indicator frame, which accommodates the apparatus of two trouble indicator circuits: the marker trouble indicator and the controller trouble indicator. These facilities are similar, except for details, to the corresponding trouble indicators in local crossbar offices.

Jacks for taking the markers out of service are located on the trouble indicator frame. With them, the markers can be either completely removed from service or made busy to certain marker connectors. Lamps are also provided to indicate the particular marker and the circuits used by it in setting up each connection. These light only while the connection is being established.

The outgoing-trunk test frame requires only a single bay, and is used principally for testing the outgoing toll-switching trunks. This frame is somewhat similar to the incoming-trunk test frame used in crossbar offices in that it can automatically select trunks one after another and test them by directing a test call to a suitable test number in the terminating central office. The test frame is operated manually for some of its tests of toll-switching trunks and also when testing some other trunks such as those that are used by the operators.

Last in the line is the outgoing-trunk make-busy frame, which is provided as a concentrating point for the jacks used to take the toll-switching and miscellaneous trunks out of service.

The work at the maintenance center covers responding to alarms, making tests, and following up trouble reports or requests for assistance.

The activity involved in responding to alarms includes chiefly investigating trouble-indicator indications, alarms caused by stuck senders and by various other circuits whenever they do not perform their functions in a prescribed time interval, and alarms indicating blown fuses.

Trouble indicator indications are extremely important. The marker trouble indicator, for example, can be called in by trouble conditions in different circuits such as senders, marker connectors, incoming-frame circuits, and outgoing-frame circuits. Whenever the trouble indicator is called in, lamps indicate the circuits involved in the connection, the point at which the progress of the connection was stopped, and in some instances the actual trouble. In many cases, however, a single indication does not provide sufficient information, since, as pointed out previously, any one of several circuits may be responsible. As each indication appears, therefore, a record is made of the lamp display on a form provided for the purpose, after which the trouble indicator is restored to wait for the next failure. If the trouble persists, an analysis of a number of records will indicate its most likely location.

A sender which is unable to complete its functions will either release automatically or cause an alarm and light the associated lamp at the sender make-busy frame. The action of the sender in this respect is determined by the position of the key associated with the sender. If the traffic is heavy, so that all senders are required for handling calls, or if the maintenance force is very busy, the sender keys are set so as to cause the senders to be released. At other times, however, the keys can be set so as to hold senders that fail. Assuming that a stuck sender condition is to be investigated, the sender circuit is first examined to determine where the progress is stopped. If the sender does not appear to be at fault, the connection is traced to identify the circuits involved and, if possible, to locate the cause for the blocking of the call.

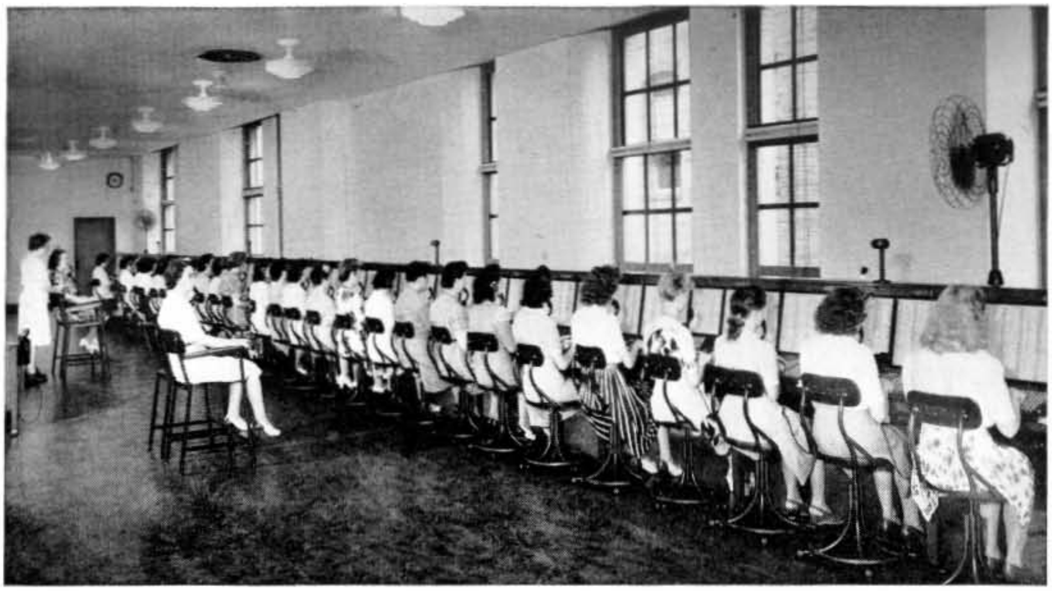
Alarms such as those indicating that other circuits have failed to complete their functions, or that a fuse has blown, are also followed up from the maintenance center.

Although the testing equipment at the maintenance center is often used for locating trouble conditions known to have caused circuit failures, a major function of this equipment is to make routine tests on a scheduled basis. It is for this purpose that the sender and outgoing-trunk test frame are arranged to test the circuits automatically one after another without attention until a trouble condition is encountered. The schedules for these tests are so arranged that all features of the circuits will be tested periodically, the high usage features receiving, in general, the most frequent tests. By making tests on a routine basis, irregular conditions are uncovered and corrected before they can seriously affect service.

Tests actually carried out at the maintenance center cover only the senders, markers, and outgoing toll-switching trunks. Tests and inspections of various other parts of the equipment are, of course, also necessary, and these are scheduled as required.

In addition to the irregularities disclosed by the trouble indicators and alarms, and by the various tests, reports of trouble are received from other sources such as the Traffic Department, the toll test board, and other local and toll offices. An investigation is made of these reports, and the trouble is cleared if it is in the crossbar toll office. If it appears to be caused outside of the crossbar toll office, the trunks to other offices will be tested, but the removal of the trouble will be handled by other groups. When failures occur on trunk cables, or when a rearrangement of trunking facilities is made, frequent requests for making trunks busy and for restoring trunks to service are handled at the outgoing-trunk test frame.

Administration of the maintenance of the equipment is carried on to a large extent by the chief switchman. In addition to the general supervision of the work, he frequently takes an active part in the analysis of trouble indications, and in directing the correction of such conditions.



Call Distribution to Crossbar Toll Operators

By F. A. PARSONS
Switching Engineering

IN THE new crossbar toll office, calls coming in over manual trunks are automatically routed to a cordless switchboard where operators set up the connection through the switching train by "writing up" the proper code on keys. In any such system, the general problem is to arrange the distributing circuits so that an idle operator can be promptly found and connected to the trunk regardless of the number of positions occupied at the time. On the other hand, the number of positions provided for any particular office and the number of them occupied for any existing load must be kept as small as practicable in order to avoid excessive operating and equipment costs.

Analysis shows that operating efficiency increases with the size of the group of operators, and thus the greatest operating efficiency is secured if all the trunks can be given access to all the positions. The amount of equipment necessary to give this universal interconnection becomes excessive, however, and economy frequently makes it necessary to divide the operators into groups, each group serving a portion of the incoming trunks. Although maximum efficiency is not secured when this is done, it can be approached fairly closely since the increase in efficiency tapers off as the groups become larger, while the cost of the equipment increases.

In the past, call distribution has been accomplished by using step-by-step, panel, or rotary switches, and the results have been very satisfactory. None of these methods could be readily adapted to the new toll office, however, because of the large number of leads per trunk that must be handled. Because of the exigencies of toll switching, a simple tap connection to the trunks is not adequate; the incoming trunk for a brief interval of the switching period must be carried to the switchboard and then back to the toll switching train, thus forming a loop. Because of the use of four-wire switching, moreover, and of other factors of the crossbar toll system, these operator loops each require sixteen leads, and this large number of leads cannot easily be obtained with any of the types of switches formerly used. In the crossbar toll office, therefore, crossbar link frames are used to distribute the calls to the operators. Since the crossbar switches make six contacts at each crosspoint, the required sixteen leads are secured by using three crosspoints for each loop.

An extensive study of all factors involved led to the decision to use a group of forty operators as a maximum, and to give as many trunks access to this group as are needed for a suitable load. Ten-by-ten crossbar switches are used in a primary and secondary arrangement for the operator link frames according to the usual crossbar practice. Since three switching elements are required for each operator's loop, three 10 x 10 switches will handle ten loops, and thus twelve secondary switches will handle forty operator loops connected to the horizontal elements. Since the switches also have ten vertical units, there will be the same number of links from the primary switches as there are loops, and a total of twelve primary switches will also be required for each frame.

In the usual crossbar frame, links run from all primary switches to all secondary switches, but the operator link frame is split in two, forming an A half and a B half, and the interconnection of primaries and secondaries applies only within each half. The incoming trunks are connected to the horizontals of the A primary switches, but each trunk is also multipled to a primary of the B switches, and thus a single group of trunks is served by both A and B halves of the link frames, and thus have access to all forty loops. Because of the splitting of the frame into two halves, only one half is needed to illustrate the arrangement of trunks, links, and loops. This arrangement is shown in Figure 1, where the six secondary switches of the half shown are at the right, and the upper and lower of the six primary switches are at the left. The lower three secondary switches supply the sixteen conductors for each of ten loops, and the three upper, for another ten loops, and thus each half frame supplies twenty loops.

Each primary switch is split so as to form five units, each with ten horizontals and two verticals, and thus the six primary switches of each half frame provide thirty such two-by-ten units. Again because of the sixteen leads required, three of the two-by-ten units are used for each loop, and thus the thirty units provide for one hundred trunks —ten for each group of three two-by-ten units. The three two-by-five units for each set of ten trunks may not all be on the same switch; two of them may be on one and one on the switch above or below it.

In Figure 1, each line represents six wires, the number that can be handled by each crosspoint of the crossbar switches. If one line is allowed to represent all sixteen wires, the interconnections for a complete frame would be as indicated in Figure 2. Here, one ten-by-ten secondary switch represents three on the actual frames, and each two-by-ten

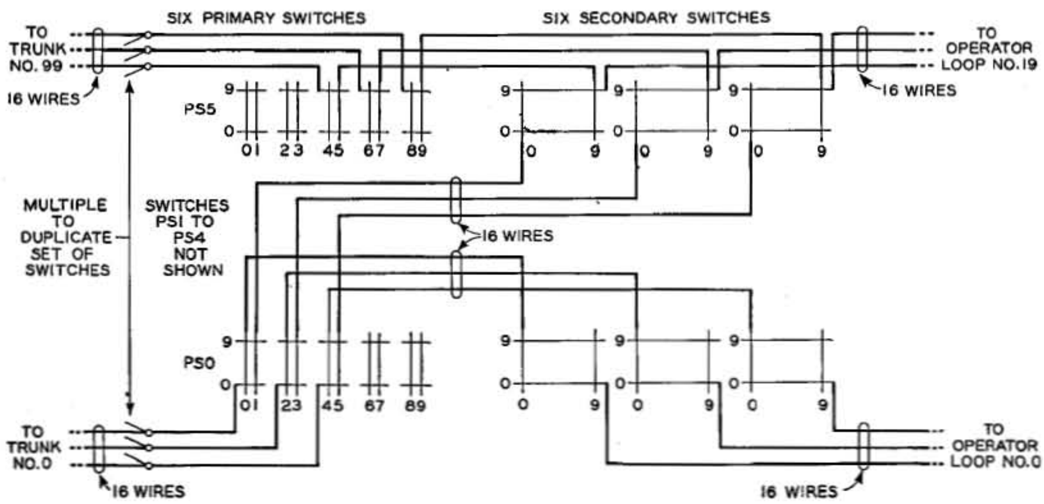


Fig. 1—One-half of operator link frame. Each line represents six wires, the number that can be handled by each crosspoint of the crossbar switches

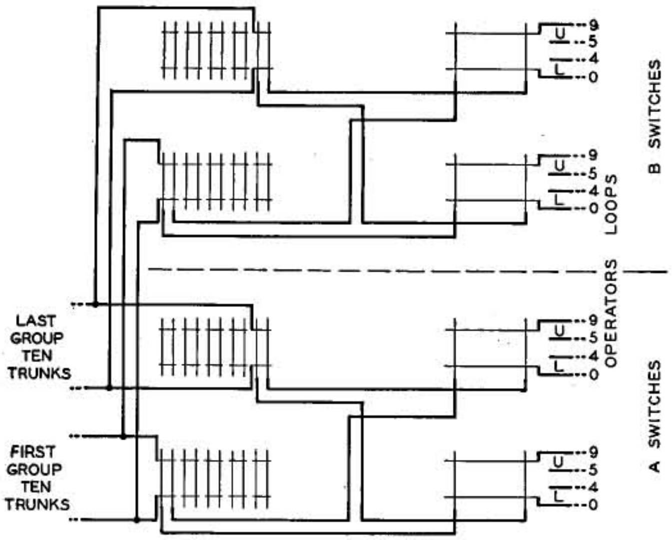


Fig. 2—Interconnections for a complete operator link frame

element of the primary switches represents three such switch elements on the actual operator link frame.

Such an arrangement gives one hundred trunks access to forty operator loops. Each operator's position, however, is served by three loops. This is done to permit an operator to be receiving a new call while the one she has just handled is being completed by her sender, or while she is holding a connection to one call that may require attention later. When the operator is actually engaged in handling a call, her three loops will be made busy, but one or two loops may be held for later attention without making the others busy.

With three loops to each of forty positions, there are one hundred-twenty loops in all. To provide this number of loops, three frames like that indicated in Figure 2 are required, and since each frame provides for one hundred trunks, a total of three hundred trunks is given access to forty positions. The three loops to each position are marked 0, 1, and 2, and all the No. 0 loops are connected to one of the three frames, all the No. 1 loops to another and all the No. 2 loops to the third. These three frames are called key-frames, and are numbered 0, 1, and 2 to correspond to the numbers of the loops they serve. Since forty operators can handle calls from more than three hundred trunks, other frames are added as needed. The horizontal terminals of the secondary switches of each added frame are multipled to one of the key-frames, but each of the additional frames serves a different group of one hundred trunks.

The use of key-frames permits a large part of the cabling to be run in permanently regardless of the number of trunks or of the number of positions that are actually occupied. When the maximum number of positions required is less than forty—only thirty-two are used for the Philadelphia installation—those secondary terminals of the key-frames that have no operator loops are multipled to terminals of one of the other key-frames that have a loop to an occupied position. This multipling is temporary, but it is needed only on the key-

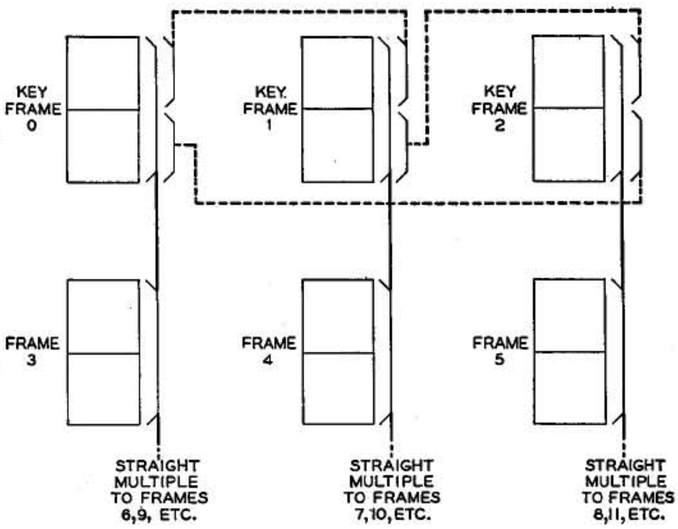
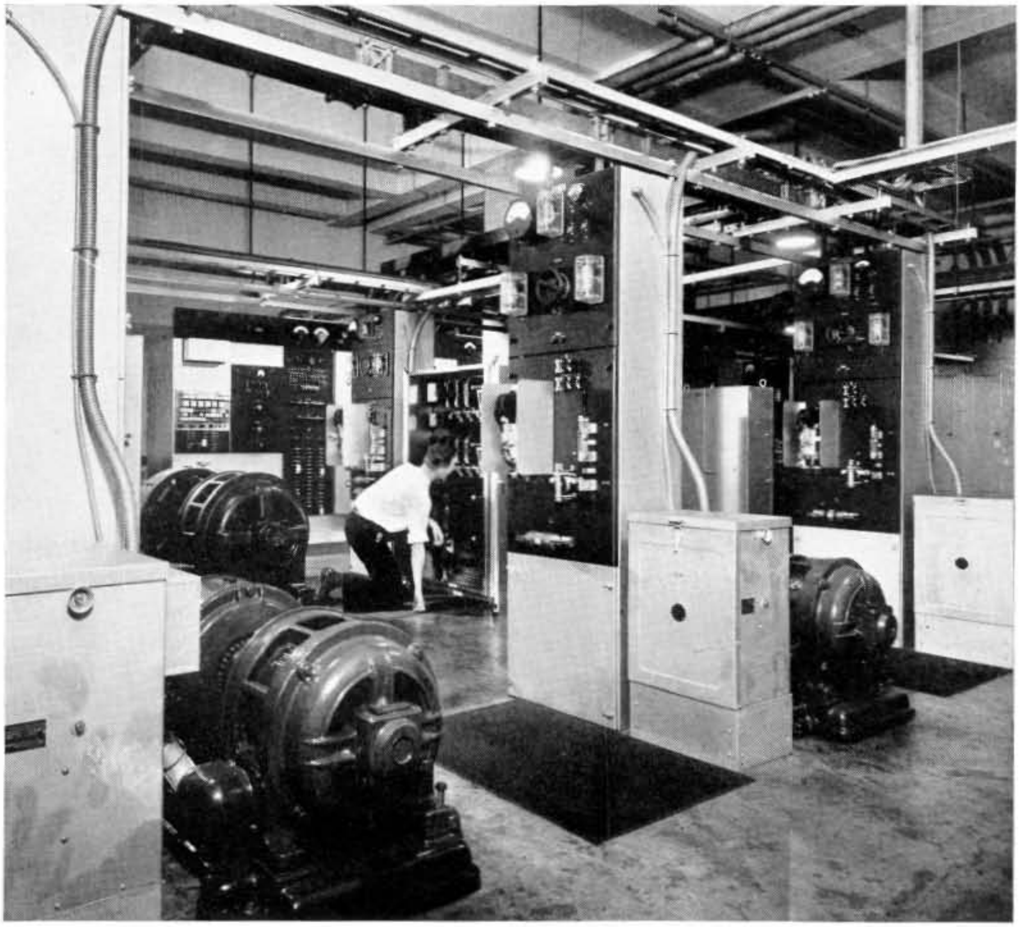


Fig. 3—Temporary multipling arrangements using the key-frame system are shown by the dashed lines. This multipling is removed when additional loops are required

frames because each additional frame is permanently multipled to one of the key-frames. This temporary multipling is indicated by the dashed lines on Figure 3 which show the general scheme of key-frames. Should these unoccupied positions later be filled, it is necessary only to remove the temporary multipling, and run the additional loops to the positions to which they have been assigned.

Forty operator positions will probably be sufficient for most of the toll crossbar installations. Some of the very large cities, however, may require more than forty positions, and to provide for them, a second arrangement has been devised that will handle a maximum of eighty positions. This is the arrangement provided at Philadelphia, for although there are only thirty-two positions at the present time, it is expected that the number will soon be greater than forty. The general scheme of arrangement for the eighty-position unit is similar to that for the forty, but six key-frames are used instead of three. These key-frames are divided into three odd and three even frames. The former handle the odd switchboard positions and the latter, the even. Thus, the forty odd positions of the board—positions 1, 3, 5, through 77, 79—will be served by the three key-frames Nos. 1, 3, and 5, while the forty even positions—2, 4, 6 through 78, 80—will be served by the three key-frames Nos. 0, 2, and 4. In this way, a doubling in size is possible without any radical difference in the general arrangement.



Power equipment for crossbar toll in Philadelphia

Loop Assignment and Selecting Order for Crossbar Toll Switching

By F. A. PARSONS
Switching Engineering

IN THE crossbar toll switching system, operators are required to handle calls coming in over manual trunks. Such calls are distributed automatically by crossbar link frames and controllers as already described.* The arrangements will accommodate a maximum of either forty or eighty operator positions, depending on the amount of manual traffic. Besides the provisions described in the earlier article, it is necessary to assign the operator loops to levels on the link frames, and to arrange the order in which idle loops are selected by the controller, so that during light-load periods, when only a few positions are occupied, all trunks will be able to reach those particular positions regardless of where they are; and so that calls do not tend to select some positions more frequently than others.

Another condition placed on the assignment of loops arises from the division of the frames into A and B halves. One of the reasons for this division was to permit half of a frame or a half of all the frames to be removed from service for maintenance. Since all trunks are multipled to both A and B primary switches, no trunks are denied access to loops when half of every frame is removed from service. The assignment of loops to the frame must take this possibility into consideration, however, so that when half of each frame is removed from service, all the calls will still be distributed uniformly among the positions.

Since each position has three loops, each of which is connected to a different one of the three key-frames, the major part of the problem can be solved by devising a satisfactory distribution of the forty loops on one key-frame. This arrangement can then be permuted on the other key-frames to insure that the three loops to one position do not appear on the A or B switches of all three frames, and so that the order of selecting loops on the three frames will be different. The problem is thus narrowed down to that of arranging the locations of the loops on the frame and to the method of selecting idle positions.

The many factors that must be considered in the solution of these problems may be divided into two groups; one is concerned with arranging the loops so that all occupied positions are equally available to all trunks, even when the A or B halves of the frames are not in service; the other is concerned with arranging a selecting procedure that will not tend to select some loops oftener than others, and that will not require ap-

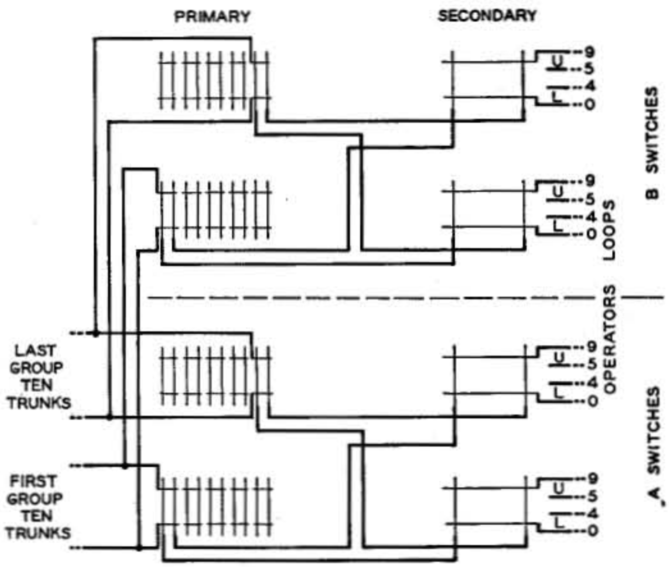


Fig. 1—Single-line diagram of operator link frame where each line represents sixteen wires and each switch element represents three on the actual frame

*See page 19.

preciably longer time in finding idle loops under some conditions than under others. These two problems, although different, are interrelated, and cannot be considered entirely independently.

In considering the loop selection, it will be simpler to refer to the single-line diagram of Figure 1, where each line represents sixteen wires, and where each switch element represents three elements on the actual frame. The one hundred incoming trunks are connected to the four primary switches, and the forty loops are distributed among the four secondary switches. At the A primary to which it is connected, each trunk has access over two links to the twenty loops connected to the A secondaries, and at the B primary it has access over two links to the twenty loops connected to the B secondaries. Each trunk thus has access over four links to all the loops. The four links available to any one trunk, however, are also available to nine others, and thus one or more of them may be busy when a particular call comes in. The selecting circuit thus must locate the idle loops and select some one of them that is accessible to one of the idle links to which the calling trunk has access.

In testing loops, the controller circuit tests half of the loops at one time, and if all of these that can be reached with a suitable idle link are busy, it then tests the other half. To distribute each half of the loops tested evenly over all the switches, one-half

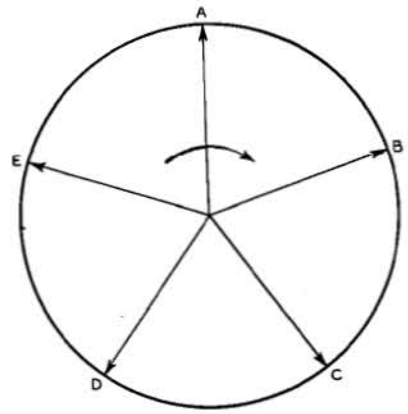


Fig. 2—By letting equally spaced radii of a circle represent the five testing groups, the possible variations in testing sequence may be determined by beginning at different radii and providing in either a clockwise or counter-clockwise solution

of them are connected to the horizontals 0-4 inclusive of all the four secondary switches, and the other half are connected to the horizontals 5-9 of all the switches. The former is called the lower half and the latter, the upper. They are indicated by the letters L and U on the horizontals of the secondary switches of Figure 1.

In a single operation the controller determines all the loops of the half tested that are idle, and by matching these against the links, it also knows which of them are accessible to the calling trunk. In the general case, however, there will be more than one available idle loop, and in the extreme case there may be twenty. It is desirable, therefore, to establish some order in which the controller makes its selection.

For this purpose, five test groups are established and they are designated groups A-E, inclusive. Since there are twenty loops tested at a time, each test group includes four. The horizontals included in these five

TABLE I—SWITCH HORIZONTALS INCLUDED IN UPPER AND LOWER TESTS

Test	*Lower Test*	*Upper Test*
A	A1-0	A1-5
	A1-1	A1-6
	A1-2	A1-7
	A1-3	A1-8
B	A1-4	A1-9
	A2-0	A2-5
	A2-1	A2-6
	A2-2	A2-7
C	A2-3	A2-8
	A2-4	A2-9
	B1-0	B1-5
	B1-1	B1-6
D	B1-2	B1-7
	B1-3	B1-8
	B1-4	B1-9
	B2-0	B2-5
E	B2-1	B2-6
	B2-2	B2-7
	B2-3	B2-8
	B2-4	B2-9

groups for both uppers and lowers are given in Table I. Here, A1-0, for example, represents the O level of the No. 1 switch of the A half frame while B2-6 represents the No. 6 level of the No. 2 switch of the B half frame. The controller is arranged to select the first idle loop beginning with the first level of some one of the five test groups. If it begins testing in a lower half, and finds no idle combination of loop and link, it releases its lower test relay, operates its upper test relay, and proceeds to select in the same order in the upper half. If no loop is found, it continues testing upper and lower halves alternately until it times out. This disconnects the controller, and the link frame will seize another controller. As a result a new testing cycle will be begun.

The order or arrangement of the five groups could be that listed in Table I, beginning at the top and running down, or it could begin with group C (A2-3), and proceed down through groups C, D, E and then back to A and B, or it could be made any other order of the five groups. Each time it is seized by a link frame, the controller makes a double shift in the testing order: it shifts from lower to upper or vice versa, and moves ahead one test group. If it started testing for one call in group C, for example, it would start for the next call with group D, and if the loop it found for the first call were in a lower half, it would begin testing for the next call in an upper half. Thus if it started testing for one call in group C and found a loop in a lower half, it would start testing for the next call in upper D. Since it is the first idle level following the beginning point that is selected, this rotation of the starting point destroys any systematic tendency to select certain levels so far as the levels of different groups are concerned. Within each group, of course, there is a tendency to select levels at the beginning of the group, but this is avoided partly by assigning the three loops of each position to different levels on their respective key frames, as described later, and partly by having half of the controllers test in one direction and half in the other.

The variations in selection brought about by five different beginning points for the selection, and by arranging half of the controllers to select in one direction and the other half in the other, are made more evident by indicating the five groups as five points equally spaced around the circumference of a circle as shown in Figure 2. The controllers that make their selections in one direction, say clockwise rotation in Figure 2, will—depending on the starting point—select levels from groups in the five orders ABCDE, BCDEA, CDEAB, DEABC, and EABCD. The other half of the controllers will select in the counterclockwise rotation, and thus will use the five orders EDCBA, DCBAE, CBAED, BAEDC, and AEDCB.

Altogether there are twelve different circular orders in which five objects may be arranged. These are shown in Figure 3. By assigning the loops in different orders on the three key-frames, the three loops for each position are selected according to different circular orders of the five testing groups.

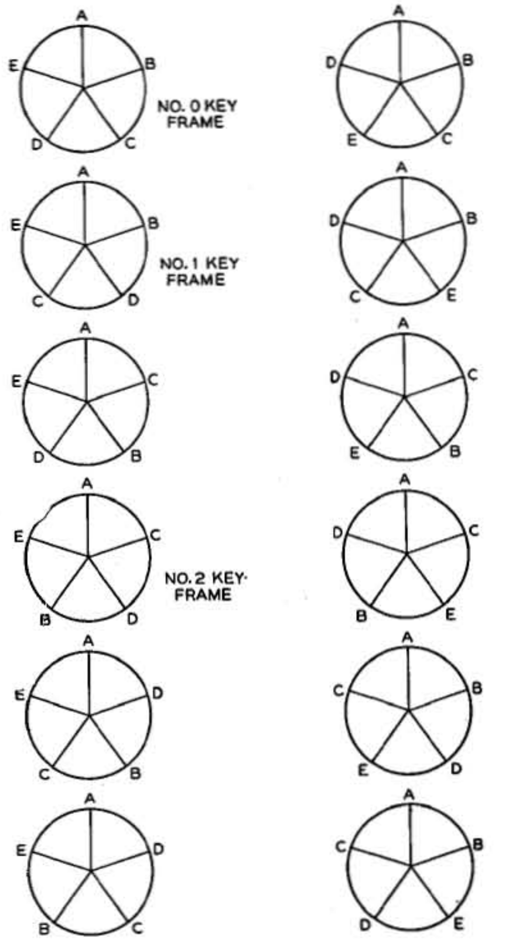


Fig. 3—Five objects may be arranged in twelve different circular orders

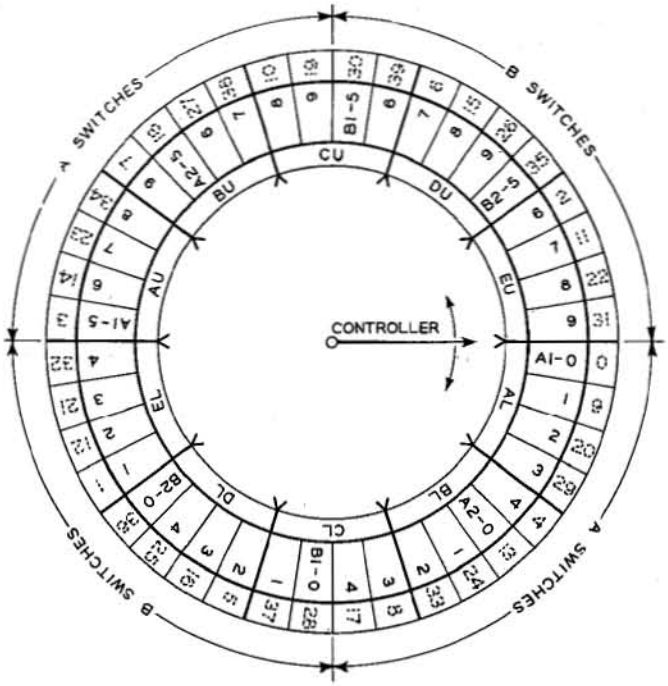


Fig. 4—Distribution employed for the zero key-frame

Since for each circular order, there are in turn ten actual orders of test—one each for the five different starting points in two directions of rotation—loops are selected in thirty different orders altogether.

These provisions for variations in loop selection at various frames and with various controllers avoid any systematic tendency to select some loops oftener than others. It is still necessary, however, to connect the loops to the switches in such a way that with the A or B halves of all frames out of service, all positions will be accessible, and when only a few positions of the board are occupied, these positions will still be accessible to all trunks without abnormal delays in locating an idle position because of too frequent switching from uppers to lowers or vice versa.

The position circuits of the switchboard are arranged so that the operator at any position can "group" with her position, the positions on each side of her. When she does this, she automatically receives calls incoming to three adjacent positions. This is taken into consideration in assigning loops to various positions on the switches, since as long as no three adjacent positions are all on the A or B halves, no position can be inaccessible because either the A or B halves are out of service. It is necessary also to consider possible systematic groupings of the operators when the board is only partly occupied, so that no such distribution of the operators will result in their all being reached through A or B switches or all through upper or lower levels. Because of these various conditions, no completely systematic distribution of the loops will serve.

The distribution actually employed for the zero key-frame is shown by the outer circle of numbers of Figure 4, which shows the complete selecting possibilities for the zero key-frame. The central arrow represents the action of the various controllers, which can start the test at any of the ten points indicated, and can proceed in either clockwise or counter-clockwise rotation. Letters in the circle just beyond the arrow represent the various test groups, thus AU stands for the upper level of the A test group, while CL represents the lower levels of the C test group. Designations in the next circle represent the switch levels. The dotted numbers in the outer circle indicate the operators' positions connected to these levels.

Equivalent wheels for the other two key-frames would be similar, but would differ in the assignment of loops to switch levels. By these means calls are uniformly distributed over the occupied positions regardless of which ones they are. Hunting time is equalized for all normal conditions, and the removal of the A or B switches in this system has no effect except to reduce the number of loops that are available.

Markers for the Crossbar Toll System

By O. MYERS
Switching Development

THE function of a marker is to find an outgoing line or trunk conforming to a code transmitted to it by a sender, and then to find and establish an idle path through a train of two crossbar frames to this line from the incoming trunk whose position is indicated to the marker through the sender. In the local crossbar* system there are always two such trains: a district link and office link frame at the originating office, and an incoming and line link frame at the terminating office. Since the grouping of the trunks and links on the office link frame differs from that of the lines and links on the line link frames, marker operation for the two trains is different, and two types of markers—originating and terminating—are employed. In the No. 4 toll office only one train of switches is involved in any one call, and the markers employed resemble the originating markers in some respects and the terminating markers in others. Besides these functions it has in common with local markers, the toll marker has certain additional ones required by toll traffic. The apparatus with which it is associated and the major paths over which it operates are indicated in Figure 1.

After a sender has recorded the code for the desired trunk group, it seizes a marker through a relay connector, and transmits the code to it. The marker performs its work in a number of successive stages. It records the code transmitted by the sender, and then operates a trunk-block relay associated with the desired group of trunks. It then tests these trunks to find an idle one. Having found an idle trunk, it seizes the outgoing frame to which this trunk is connected, and then seizes the incoming frame to which the incoming trunk is connected. On gaining access to these two frames, it finds an idle path through them, and then establishes the connection. It then notifies the sender of this fact, and asks for release. Had it encountered trouble in the course of this work, it would have momentarily connected itself to a trouble indicator, and informed it of the type and approximate lo-

*Record, *February*, 1939, *p.* 173.

cation of the trouble, and would then have signalled the sender to make a second attempt to complete the call by means of using a different marker.

With the No. 4 toll office, two different arrangements of frames are possible depending on the size of the office. In the simpler arrangement, all the switch frames form part of a single train. Both outgoing toll lines and trunks to local offices terminate on the secondary switches of the outgoing frames, and the same group of common equipment handles the traffic for both. Where the traffic is greater than can economically be handled by a single group of outgoing frames, two trains are provided: one for connecting to outgoing toll lines, and one for connecting to trunks to local offices. The markers will vary slightly depending on whether one or two trains are employed. With one train, "combined" markers are used, and these must be able to handle any type of call. When two trains are used, "intertoll" markers are used for the train completing calls to outgoing toll lines, and "toll completing" markers are used for the train completing calls to local offices. The Philadelphia installation is of the two-train type, but the operating features differ in only a few details from the markers of the "single train" system.

One of the unusual features of the toll marker is the large variety of codes that it must be able to record and act upon. The outgoing trunks to which it may be required to make connections may be divided into four major types depending on their destination. They may run to local central offices in the area in which the crossbar toll office is located; they may be toll lines to distant cities; they may be service trunks to special operators such as information; or they may be TX trunks, which run to switchboards where operators handle calls that cannot be completed at the time, generally because all trunks are busy or—on a person-to-person call—because the called person is not available. Moreover, the codes for toll trunks may have either three or four digits—three digits being used when it is not expected that there will be more than 469 toll codes, and four digits when there are more than this number. Similarly, there are three possible types of codes for TX trunks depending on the size of the office. A one-digit TX code is used when there are not more than 9 TX positions; a two-digit code, when there are from 10 to 90; and a three-digit code when there are more than 90 TX positions.

In any one marker, however, only one type of TX code will be used, but a marker may handle both three-digit and four-digit intertoll codes. All TX codes have a prefixed 11 to indicate the nature of the 1, 2, or 3-digit code that follows, and the first digit of the four-digit toll codes is a prefixed 0 to differentiate it from the three-digit codes.

Actually, the marker itself records three

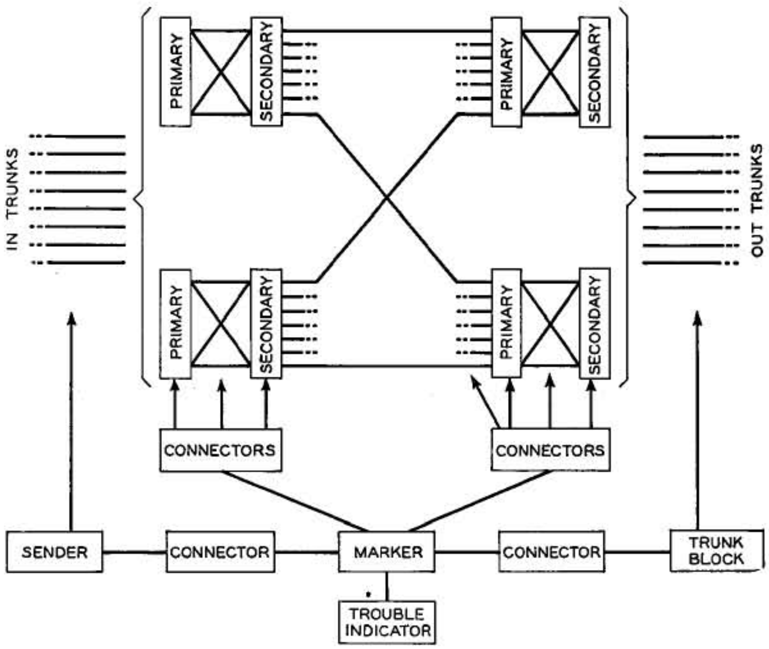


Fig. 1—Block schematic for crossbar toll train showing paths of control and association for the markers

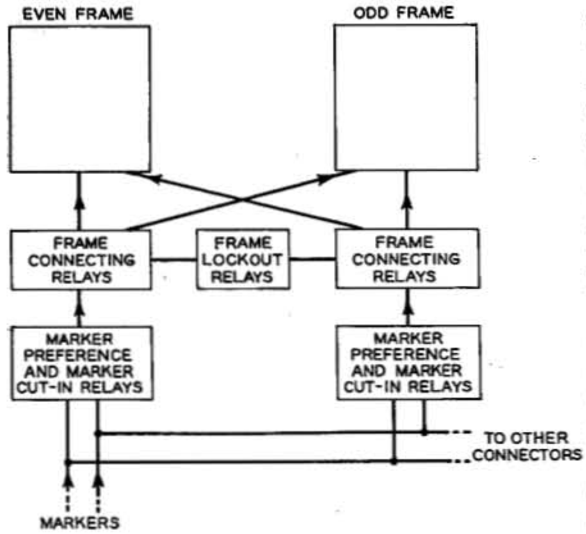


Fig. 2—Block schematic indicating the possible paths over which markers gain access to odd-numbered and even-numbered frames

digits for all codes. The prefixed digits indicating the type of code, such as the 0 for four-digit codes and the 11 for TX codes, are retained by the sender, and some other indication is transmitted to the marker to indicate the type of code. With the one-digit TX codes, the sender builds out to three digits for transmitting to the marker by adding two 0's, while with the two-digit TX codes, it adds one 0.

All markers are arranged to record and decode three-digit codes for either toll lines, local offices, or service positions. TX codes are required only in connection with calls for local completion, and thus provisions for recording and decoding them are not required in intertoll markers. All combined and toll-completing markers, however, are arranged for decoding TX codes, but they will provide for only one of the three possible types, that is, either one-digit, two-digit or three-digit.

The marker decodes the digits it has recorded by operating route relays in the same way as do the originating markers* of the local system. For each code used, the marker may provide from 1 to 12 route relays, each capable of directing the marker to a maximum of 40 outgoing trunks, the number of route relays depending on the size of the trunk groups, and in some cases upon the nature of the incoming and outgoing trunks. Thus for a single destination there may be one set of route relays for terminal-grade toll lines, and another set for via-grade lines, or there may be one route relay for trunks capable of switching in repeaters, and another for high-loss trunks not arranged for switching in repeaters.

Each route relay has twelve contacts, ten of which are cross-connectable to permit the variations required by the route. The cross-connecting arrangements are similar to those of the originating marker. Some of these contacts operate the desired trunk-block relay and indicate the trunks that should be tested. One contact operates one of a group of class relays, which in turn operates relays in the sender to condition it to fit the call in progress. Another contact tells the marker one or more of the following facts about the outgoing trunk group: that it has facilities for switching in a repeater; that it is high loss but cannot switch in a repeater; that it connects to equipment arranged to receive a-c key pulses; or that the trunk group is provided with overflow trunks. These overflow trunks return a flashing signal to the originating operator to indicate all trunks are busy, and when a trunk becomes idle the rate of flashing is changed. This prevents operators from making useless attempts to complete calls when all trunks are busy. Other contacts on the route relay are used to operate a peg-count register for traffic studies, to operate a succeeding route relay when all trunks controlled by the first relay are busy, or to perform other required functions.

The trunk block connector operated by the route relay gives access to ten block relays each serving forty trunks, and leads from the route relay indicate the particular block relay required and the position of the desired trunk group on that relay. The trunk block connectors, to which all the markers have access, are provided with lock-out circuits to prevent more than one marker from seizing them at the same time.

While the marker is operating the route relay, a group of three frequencies received from the incoming frame over a lead

*Record, *June*, 1939, *p.* 327.

through the sender identifies the incoming frame on which the incoming trunk is located. This lead is later used to operate the incoming primary select magnet. The outgoing frame on which the selected trunk is located is similarly identified by a group of three frequencies after the idle trunk has been selected. As soon as the marker has located an idle trunk, therefore, it attempts to gain access to the outgoing and incoming frames required for setting up the connection.

Access to any frame may be secured through either of two sets of connectors, each connector in turn having access to two frames—an odd-numbered and an even-numbered frame. The arrangement is shown in Figure 2. In reaching a frame, a marker can use either of the connectors that give access to it, but half of the senders cause the markers they seize to prefer even-numbered connectors, and half, odd numbers. In reaching a frame, the marker must pass through two sets of connecting relays, each associated with preference or lock-out circuits. The marker preference and cut-in relays prevent more than one marker from gaining access at a time to the frame connecting relays. These give access to either the odd or even frame of the pair, but since the frame connecting relays for the other frame of the pair also have access to both frames, a set of interconnecting lock-out relays is required so that both sets cannot be connected to the same frame at the same time.

Assume, for example, that an odd-numbered sender has seized a marker and that the marker after finding a suitable outgoing trunk finds that the trunk is connected to an odd-numbered link frame. It then attempts to seize the marker preference relays for the odd-numbered frame and does so if they are not in use. If it succeeds in getting these relays, it attempts also to seize the odd frame-connecting relays. If at that moment a connection is being established on the odd-numbered frame through the even frame-connecting relays, the marker will be locked out, and will have to wait until the frame is released. If the frame had not been busy, the frame-connecting relay would have connected it through at once.

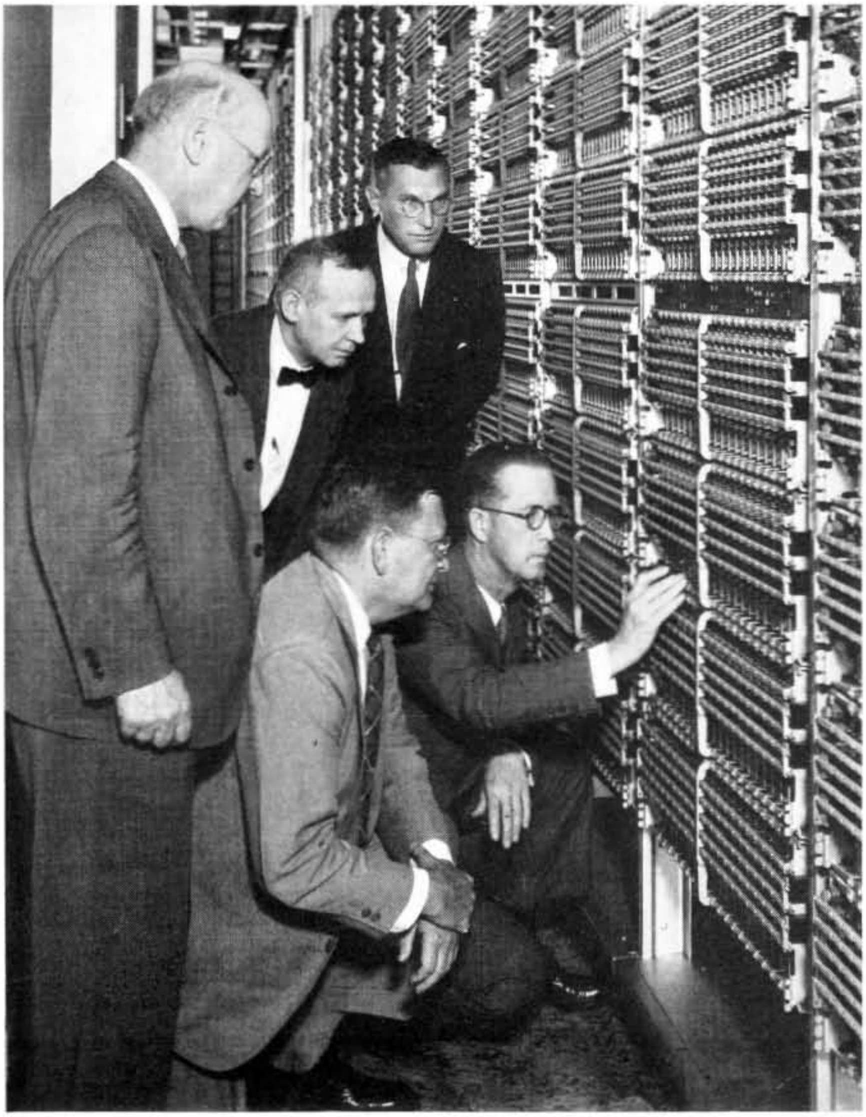
Assume, on the other hand, that the odd marker preference relays had been busy. Under these conditions, the marker seizes the even-numbered preference relays if they are idle, and then attempts to reach the odd-numbered frame through the even frame-connecting relays. These, in turn, will at once connect it to the odd-numbered frame unless it is being used by some other marker through the odd marker preference and frame-connecting relays. This paired arrangement of frames and connectors, used for both incoming and outgoing link frames, gives more dependable service since all markers still have access to all frames even though there is trouble with one of the marker cut-in relays.

After the marker has obtained connections to the incoming and outgoing frames it needs, it locates an idle path through the two frames from the calling trunk to the selected outgoing trunk, operates the proper select and hold magnets, and then signals the sender to release it. In this work, the marker tests the leads over which it operates for open circuits or false grounds, and after the connection has been established, it tests the complete circuit through the sender, incoming trunk, incoming frame, outgoing frame, and outgoing trunk, and if on any of these tests it finds trouble, it seizes the trouble indicator to report the condition. All of the marker operations are completed in about eight-tenths of a second.

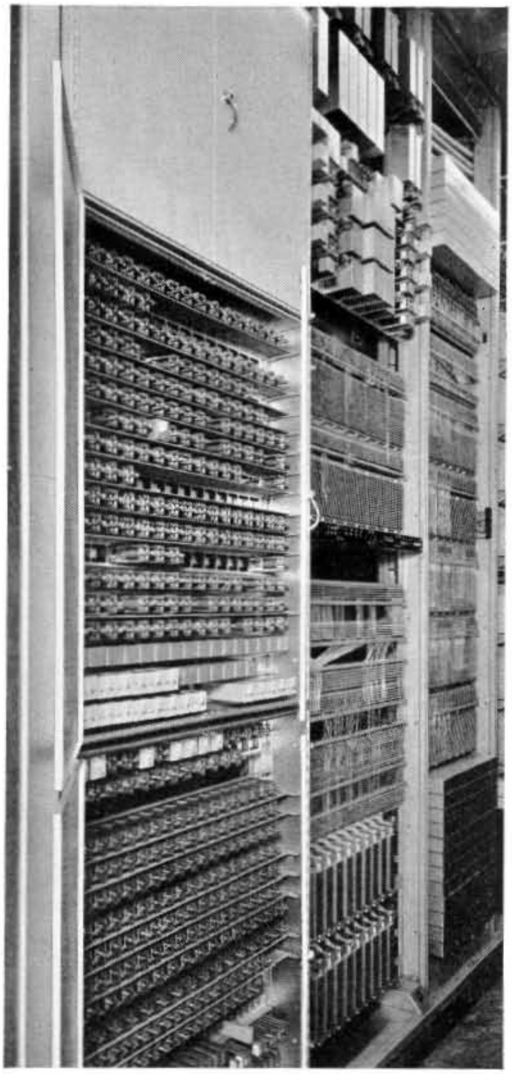
Since markers complete their functions in such a very short time, their call-handling capacity is very great, and as a result, comparatively few of them are needed in an office. This makes it important to make sure they are never delayed by equipment troubles. Steady progress in handling the call is assured by three timing circuits, one or more of which time each phase of the marker's operation, and if an unusual delay is encountered, causes the condition to be reported to the trouble indicator and the marker to be released. These three timing circuits are called the condenser time-out, the short time-out, and the long time-out. The condenser time-out allows about one-half second for each of the several marker stages, and when trouble is encountered causes release of the marker. If a marker is delayed, this timing is cancelled.

The short time-out provides five possible intervals, and for each stage in the marker's progress it selects an interval corresponding to the maximum delay the marker might normally encounter at that stage. It does not stop when the marker is locked out by a connector, and thus takes care of excessive delays in waiting for access to busy equipment, and also guards against failure of the condenser time-out circuit.

The long time-out provides an overall safeguard against failures of both of the other two and in addition gives an alarm should a marker be held busy falsely.



Taken at the time of the crossbar toll cutover in Philadelphia on August 22, 1943, *this photograph shows, kneeling, J. E. Murdoch (left), Chief Engineer, Eastern Area, Bell of Pa., and A. B. Clark, Director of Systems Development, Bell Laboratories; standing, left to right, F. J. Chesterman, Vice-President, Operations, Bell of Pa.; C. H. McCandless, Switching Development, Bell Laboratories; and C. R. Freehafer, Vice-President and General Manager, Eastern Area, Bell of Pa.*



Multi-Frequency Frame Identification in Crossbar Toll

By O. MYERS
Switching Development

TO ENABLE a marker to find and close an idle path between the incoming and outgoing trunks, it must know the frames to which these trunks are connected. Once these are known, the marker can seize the connectors associated with them and proceed to locate an idle path. Although marker action in the crossbar toll system is similar to that in the local system, the method of identifying the frames to which the incoming and outgoing trunks are connected is different.

In the local system a sender link and controller is associated with each district frame, and the controller passes the number of its associated frame to the sender by grounding two of twelve leads, and the latter passes this number to the marker. Outgoing trunks associated with one route relay of the local system are always connected to a pair of office frames, which are seized as a unit by the marker, and the frame identification is given by a cross-connection that is made at the route relay.

Neither of these conditions is true of the crossbar toll system. A sender link and controller is used in common by a group of frames, and thus does not know the number of the frame with which it is momentarily associated. Similarly, the outgoing trunks forming a group to one location are not all connected to one frame but are assigned to as many frames as possible. Facilities are provided, moreover, so that trunks can be readily patched or cross-connected from one frame and group to another, and thus even their originally assigned positions may not be held continuously. This patching or cross-connecting is done not only to provide for the normal variation in the load on various trunk groups, and to take care of temporary loads, such as those caused by sporting events, conventions, or catastrophes, but to even the load on the frames, since the call-carrying capacity of the office is greater when all frames are equally loaded.

Because of this situation, frame identification for both incoming and outgoing trunks must come from the trunks themselves. It was to meet this situation that the multi-frequency frame identification system was developed. It provides an identification for each frame by transmitting a group of three frequencies over a single lead to the marker.

The arrangement of the circuit is indicated in Figure 1. A group of oscillators is employed to generate eight frequencies spaced 170 cycles apart from 425 to 1615 cycles. These particular frequencies were selected because they are the ones that have proved satisfactory for the voice-frequency telegraph system, and suitable filters and other associated apparatus were available. For each frame, three of the eight frequencies are selected as an identification. With eight frequencies there are 56 possible combinations of three, and forty of them are used for frame identification. A sufficient number of combinations could have been obtained from six frequencies if the combinations were allowed to include one, two, or three frequencies, but by always using three, the circuit may be made self-checking, since a missing or additional frequency is readily detected.

For each frame, the three frequencies employed are combined through a resistance network, and then are passed in series through the primary coils of ten transformers. The secondary winding of each transformer connects to 30 of the 300 select magnets of a frame. The primary windings are shunted with a resistance so that an open circuit in any one winding will not interrupt the entire supply for that frame, and the select magnets are similarly shunted in order to reduce their high impedance to these particular frequencies.

Leads from the select magnets are brought to the marker during the handling of a call. The lead from the incoming select magnet is carried through the sender link and sender to the marker when the call comes in, and the lead from the outgoing select magnet is one of those connected to the marker through the block relay when the group of trunks is tested. After an idle trunk is selected, the lead from the select magnet associated with that trunk remains connected to the marker.

In the marker, the frame identification signals pass through an amplifier to increase the level of the received signals, and thence to a group of nine filters, one for each of the eight frequencies, A to H, inclusive, and one marked GU, which is used as a guard as described later. These are shown at the top of the middle marker bay in the photograph at the head of this article. Following the filters are rectifiers which convert the signal to direct current to operate relays in the translating circuit that closes a single lead to operate a relay that identifies the frame.

There are two sets of frame identifying relays, one for the incoming and one for the outgoing frames, and the same set of filters, amplifiers and translating circuit is employed for both. Between the translating circuit and the identifying relays there is a steering circuit that switches the signal from one to the other of the identifying circuits as required. When the marker starts to handle a call, the steering relays are in condition to pass the multi-frequency signal to the incoming-frame identifying relays. After one of them has operated and locked, the steering relays transfer the leads from the translating circuit to the identifying relays for the outgoing frame. As soon as an idle outgoing

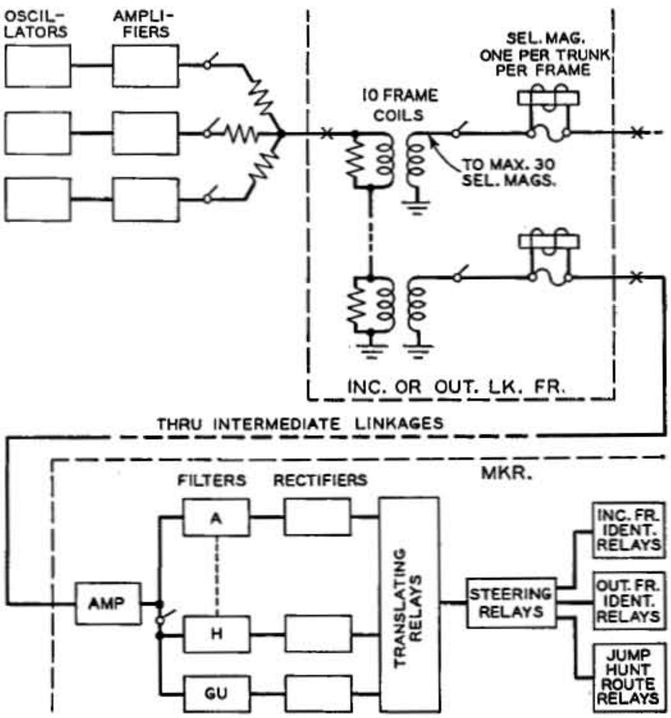


Fig. 1—Block schematic of circuit used for multi-frequency frame identification

trunk has been selected, a signal from the outgoing frame will operate one of the identifying relays for the outgoing frame. Under normal operating conditions, the steering relays merely switch the leads from the translating circuit back and forth between the incoming and outgoing frame identifying relays as successive calls are handled. At times, however, the trunks provided in a particular group are not adequate to handle the traffic. Provisions are therefore made for adding another group of trunks to the same point, and the box at the lower right of Figure 1, marked "jump-hunt route relays," is used when this is done.

Intertoll trunk groups are subject to large variations of load. Most trunk groups have spare terminals in the trunk block connector, and these are connected to jacks at the trunk assignment patching-jack frame. When not plugged up, these jacks ground the associated sleeve leads to the marker, making them test busy. When only a moderate overload exists, trunks may be borrowed from some point whose route is through the overloaded office, or they may be built up by cross-connecting or patching to reach this point. Then by patching to the spare assignment patching jacks these trunks are temporarily made part of the overloaded group. When a severe overload occurs, however, the spare trunk-block terminals and patching jacks are insufficient to provide relief, and jump hunting is used.

The marker is provided with a group of jump-hunt route relays cross-connected for various classes of outgoing trunks. Each is arranged to select as many as 40 spare terminals in a trunk-block connector. When an overload occurs which is too great to handle with the spare terminals in the overloaded group, trunks that can be made available at the desired point are borrowed from lighter loaded groups, and these are patched into the jump-hunt group whose route relay cross-connections fit. A spare terminal in the original group, if available, is patched to a jump-hunt control circuit. If there is no spare, a working terminal is used, and the associated trunk is patched into the jump-hunt group. This terminal tests busy to the marker as long as any trunk in the original group is idle or all trunks in the jump-hunt group are busy. When it becomes idle, the marker selects it, but on testing the select magnet lead for an outgoing frame identification signal, the marker receives instead the forty-first frequency combination, which tells it that a jump-hunt route relay must be operated. The marker then applies low resistance battery to the select magnet lead to operate a relay in the jump-hunt control circuit, and also rearranges the steering relays to transfer the translating relays to the "jump-hunt route relays." The operation of the relay in the jump-hunt control circuit removes the jump-hunt signal, and substitutes a new combination that tells the

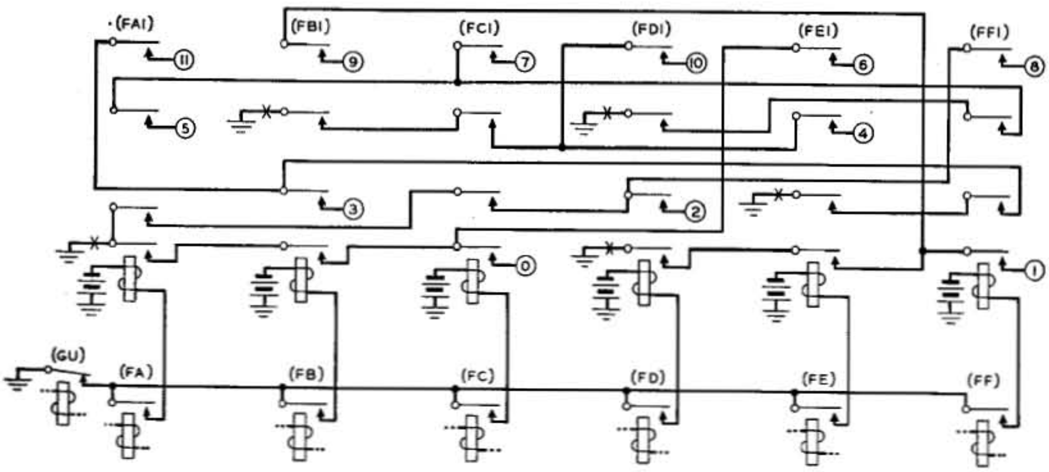


Fig. 2—Translating circuit that converts ground on three leads of a group of two to ground on one lead of a group of forty

Designation	Frequency
A	425 cycles
B	595 cycles
C	765 cycles
D	935 cycles
E	1105 cycles
F	1275 cycles
G	1445 cycles
H	1615 cycles
Guard	255 cycles

Table I—Frequencies Employed for Frame Identification

marker which jump-hunt route relay to operate. On receiving this information the marker operates the route relay corresponding to the jump-hunt group, and then returns the steering relays to the outgoing-frame identifying relays. When an idle trunk of this group is found, the frame identification signal is received in the usual way.

To translate the combination of three grounded leads of a total of eight to a ground on one single lead out of 40 that will designate one particular number is the function of the translating circuit. Its general arrangement is indicated in Figure 2. The numbered leads in the upper part of the diagram are those to the frame identifying and jump-hunt route relays, and indicate the number of a particular frame or route relay. Ground is carried through contacts of three of the relays in the lower row—one of which will be operated for each of the three frequencies received—and each of these three relays operates the relay shown immediately above it. These latter relays carry a large number of springs, and 41 chain circuits are carried through the contacts of these relays in such a way that for any of the 41 combinations of three operated relays, one and only one circuit will be closed through to ground. Relays for only six of the eight frequencies are shown in Figure 2, and some of their contact springs are omitted, but the general method employed can be seen from the relays shown. The relays and springs shown serve for decoding numbers from zero to eleven.

The eight frequencies employed for frame identification and their letter designations are given in Table I, and the 41 combinations employed, with the frame numbers they indicate, in Table II. After a jump-hunt signal has been received, and the translating circuit has been steered to the jump-hunt route relay circuit, 25 of the codes are used to designate the particular route relay wanted. The decoded numbers are shown in the right-hand column of Table II. For the most part they are the same as the frame identification numbers, but certain circuit economies were obtained by departing from this correspondence for a few of the higher numbers.

How the translating circuit works can readily be seen by following through the action of one of the codes. Suppose, for example, that the three frequencies received were those marked A, B, and C in Table I. After rectification, these three frequencies would operate the A, B, and C relays in the lower row of Figure 2, since the GU relay is normally operated. These three relays in turn would operate the three relays immediately above them, and as a result a circuit would be closed from ground on the lower spring of the FA1 relay, through the lower contacts on the FB1 and FC1 relays to lead number zero. Had the frequencies been AEF, which represents number eleven, a circuit would have been closed from ground on the second spring of FE1, through the second spring of FF1, and the fourth spring of FA1 to lead No. 11.

The select-magnet leads over which the three-frequency signals are passed often may carry disturbing voltages either induced in them or applied in the operation of other select magnets on the same frame. These would cause false signals if preventive means were not taken. The GU filter and rectifier in Figure 1, and the GU relay in Figure 2, avoid false operation by opening the operating circuit of the relays in Figure 2 whenever induced voltages are present. These induced voltages have component frequencies over a very wide range, but the greatest amount of energy is at the low frequencies. If the translating circuit is rendered inoperative while frequencies below 425 cycles are encountered, therefore, the disturbing effects of induced currents can be avoided. This is accomplished by adding a ninth filter, marked GU in Figure 1, and allowing the output from this filter to release relay GU in Figure 2. When GU is released, the ground connection for all the translator relays is opened, and thus the transmission of codes is blocked while the induced currents are present. Any frequency below 425 cycles could have been used for this guard circuit, but 255 cycles was selected as it was already available.

Two sets of oscillators are provided for each office to insure a source of the eight frequencies at all times. These are arranged so that one set is substituted automatically for the other in case of trouble. Under normal conditions each set carries the load for eighty-eight minutes and then the other set is automatically substituted for it. This insures that each set is in working order at all times. Besides this regular transfer at eighty-eight-minute intervals, the marker is arranged to make the transfer if on a second trial a frequency is missing from one of the codes. When such a transfer is made, an alarm is also given so that the trouble can be found and corrected.

TABLE II—FREQUENCY COMBINATIONS WITH THEIR FRAME AND ROUTE RELAY NUMBERS

Frequency Combinations	*Incoming or Outgoing Frame Number*	*Jump-Hunt Route Relay Number*	*Frequency Combinations*	*Incoming or Outgoing Frame Number*	*Jump-Hunt Route Relay Number*
ABC	0	0	ABG	20	20
DEF	1	1	EHC	21	..
ACD	2	2	ACG	22	21
EFB	3	3	EHB	23	..
BCE	4	4	CGD	24	22
DFA	5	5	EHA	25	..
ABE	6	6	BCG	26	23
DFC	7	7	FHA	27	..
ACF	8	8	BGE	28	24
DEB	9	9	DFH	29	..
BCD	10	10	BGF	30	..
EFA	11	11	DEH	31	..
ABF	12	12	BGD	32	..
DEC	13	13	EFH	33	..
ACE	14	14	ABH	34	..
DFB	15	15	DEG	35	..
BCF	16	16	ACH	36	..
DEA	17	17	DFG	37	..
ABD	18	18	BCH	38	..
FHC	19	..	EFG	39	..
			EFC	Jump Hunt	19

Traffic Control for Crossbar Toll

By M. E. MALONEY
Switching Engineering

WHEN the word traffic is used, the idea of congestion is implicit. The provision of a runway for every airplane, a track for every train, a sales clerk for every customer, or a trunk for every telephone call would be economically preposterous. Good traffic control consists in furnishing the facilities needed to give good service at a reasonable price, and in planning for the disposition of overloads with as little delay as possible.

If the amount and destination of traffic is known beforehand, as airways traffic usually is, the problem, although not simple, can be handled by readying equipment and personnel. Telephone traffic, however, is invisible, and sometimes capricious. Local events, weather, market changes, and many other natural or social disturbances give rise to flurries that may snowball into serious congestion if not handled promptly. It is a truism to a traffic manager that two or three additional circuits or operators provided early enough in a traffic bulge can stop the pyramiding effect and do more good than dozens can later when a backlog of calls has built up.

In designing the crossbar toll system, therefore, it was decided to provide circuits that would indicate to the traffic force the load on various parts of the system at all times so that the number of operators at the No. 4 board could be changed to meet varying conditions.

The traffic control features concerned with short and fortuitous overloads are provided by a calls-waiting signal, by busy indicators for senders and switched-in repeaters, and by means for temporarily augmenting trunk groups.

The calls-waiting circuit keeps a continuous record of the number of unanswered calls per position at the No. 4 board, and also controls warning lamps to indicate to the operators and the supervisory force when the calls are increasing. Both the warning lamps and the graphic meter that makes the continuous record are automatically controlled by signals from links that are trying to serve calls and from occupied positions. The actual number of waiting calls is not significant—it is the number waiting per occupied position that tells whether or not traffic is backing up. Also, a particular ratio—calls-waiting to positions occupied—does not have the same significance when only a few positions are occupied that it does when a large number are covered. This is because small groups of facilities, being inherently inefficient, have a margin of idle time when handling an average load, and can use this time to absorb an overload. Large groups are more efficient on average loads, which means that their idle time is small, and they cannot take the same percentage of overload that small groups can. As a result, the circuit cannot use the signals from the links and positions directly without doing some simple arithmetic. How it does this is shown in Figure 1.

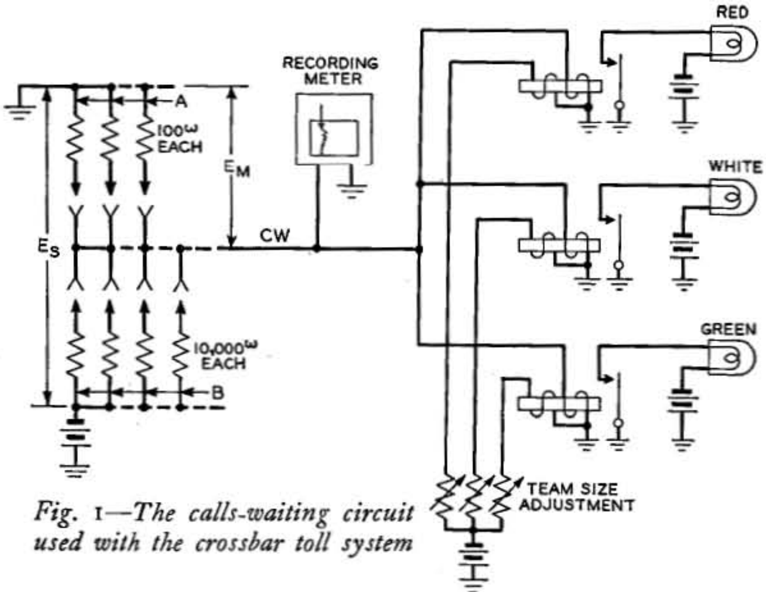


Fig. 1—The calls-waiting circuit used with the crossbar toll system

In the network at the left, one of the resistances marked A is supplied for each position and is connected into the network whenever that position is occupied. The resistances marked B are associated with the link frames that connect incoming trunks to operators, and one is connected into the network whenever a call arrives on an incoming trunk and remains there until the call reaches an operator's position. The voltage to ground of the meter lead, E_M, is obviously some function of the number of resistances A and B.

If each A resistance is one hundred ohms, and P is the number of positions occupied, the resistance from lead CW to ground is one hundred divided by P, and if each B resistance is 10,000 ohms, and C is the number of calls waiting, the resistance from lead CW to battery is ten thousand divided by C. The total resistance from battery to ground (assuming that the meter and relays have such high resistance that their effect is negligible) is the sum of these two resistances, and the current flowing is E_S divided by the total resistance. The voltage E_M is equal to this total current times the resistance between CW and ground. If the number of calls waiting per positions, which is C/P, is very small compared to 100, the voltage E_M is approximately C/P $\times$ E_S or 100, as is shown by the simple calculations in Table I, and a voltmeter with the right

TABLE I

$$I = \frac{E_S}{\frac{100}{P} + \frac{10,000}{C}} = \frac{PC\ E_S}{100C + 10,000P}$$

$$E_M = I\,\frac{100}{P} = \frac{C\ E_S}{C + 100P} = \frac{C/P\ E_S}{C/P + 100}$$

and when C/P is small compared to 100

$$E_M = \frac{C/P\ E_S}{100}$$

Table II			
Team Size	*Green*	*White*	*Red*
Under 5	1.0	2.0	3.0
5 to 10	.5	1.0	1.5
Over 10	.25	.7	1.0

range and a suitable scale will read c/p directly. In practice, c/p is so small compared to 100 that the error is negligible and smaller than the error introduced by the shunting effect of the meter and relays. The latter is noticeable when three or less positions are occupied, but tends to disappear as the team is enlarged. At ten positions, for instance, 100/p is 10 ohms, which is so much smaller than the resistance of meter and relays that the error is only about one per cent. With two positions occupied, the error is five per cent, which can be tolerated with a very light load.

The warning lamps at the right of Figure 1 are lighted when the corresponding control relays operate. The green lamp indicates a satisfactory load on the positions, and if it is extinguished for an appreciable time, the board may be over-manned. The white lamp indicates a small increase in load, and if it persists for some time the condition may be serious. Usually it is arranged to change from steady to flashing after it has been lighted for about half a minute. The red lamp indicates an immediate need for relief, and it flashes as soon as it comes on. Each of these lamps lights at a different value of c/p, but since the significance of this ratio depends on the number of positions occupied, as already noticed, provisions are made for changing the value of c/p at which the various lamps light in accordance with the number of positions occupied. This is accomplished by changing the bias current of the relays by the potentiometers labeled "Team Size Adjustment" for different numbers of occupied positions. Three steps are used: one when there are fewer than five operators at the board, one when there are from five to ten, and one when there are over ten. The settings of the potentiometers are controlled through relays by keys that are operated when the number of operators changes from one team size to another. The values of the ratio c/p for which the various lamps light for the three team sizes are shown in Table II.

A typical floor plan layout of part of an operating room is shown in Figure 2. The traffic supervisory panel, which contains the controls for the calls-waiting signals, the calls-waiting meter, and the green, white, and red lamps, is visible from the chief operator's desk, and multiple appearances of the lamps, with large beehive lenses, are installed at the head of the switchboard, where they are visible to the nearest supervisor. Multiples of these lamps may appear elsewhere in the operating room, if desired.

The graphic meter, on which the continuous record is made at the Philadelphia installation, is shown in use in the photograph at the head of this article; and Figure 3 is a close-up view of the top of the traffic supervisory panel. At the top left are the calls-waiting controls. The turn-button key labeled "cw Signal—Off-On" turns the entire circuit off and on. The "Team Size" key is set to A, B, or C in accordance with the number of working positions. The "Test" key, below to the left, cuts off the actual load circuits from the positions and links, and allows artificial values to be inserted for testing the operation of relays, lamps, and meter. These tests are controlled by the "Check" key at the upper left and the "Lamp Check" potentiometer in the center. With the check key at 0, as shown, the meter on the adjacent

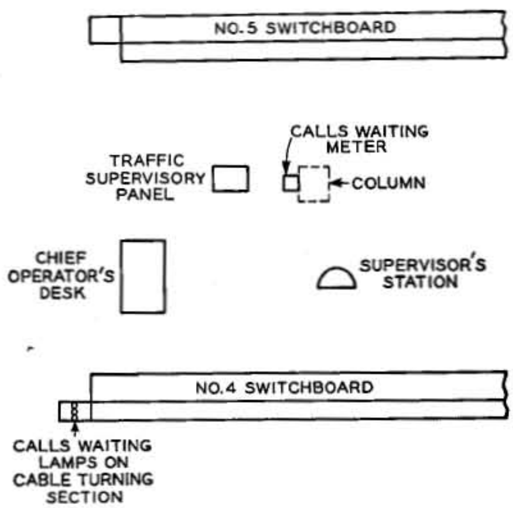


Fig. 2—Typical floor plan of operating room for crossbar toll system

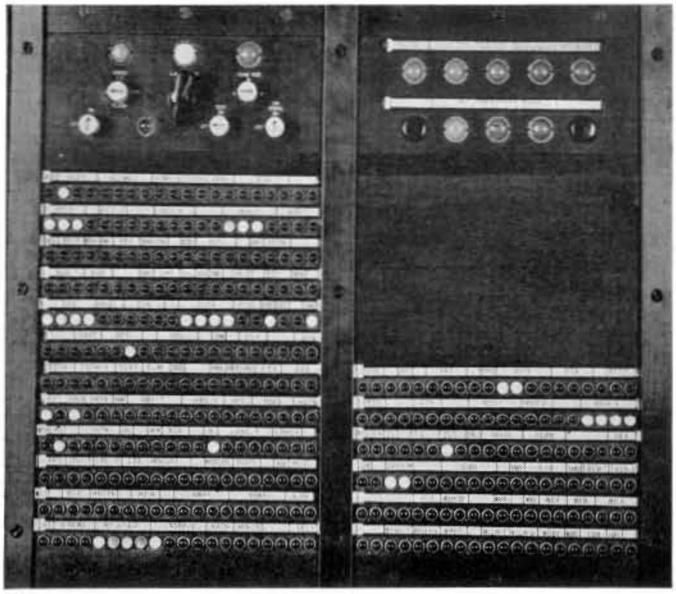


Fig. 3—Traffic supervisory panel for crossbar toll system

column should read zero, while with the key at 1.5, it should read 1.5 calls. In the LPS setting, and with the lamp check knob in the full counterclockwise position, none of the lamps in the top row will light. The knob is turned until the green lamp lights and the reading at the meter indicates whether the lamp is coming in at the proper point for the team size selected. Turning the knob further will check the white and red lamps. At the lower left are a "Flash" key and lamp. Turning this key to "Off" suspends the flashing of the red and white lamps, and while in this condition the flash lamp is steadily lit as a reminder.

In the upper right of Figure 3 are the all-senders-busy and all-repeaters-busy lamps. As their names indicate, these light whenever all circuits of an associated group are busy. The lamps in the top row from left to right are for incoming dial senders, spare lamp, incoming key pulsing revertive and PCI, and step-by-step and call-announcer senders. In the bottom row are lamps for three groups of switched-in repeaters. Strictly speaking, there is nothing the traffic force can do quickly about the amount of equipment supplied, so the amount of good that these lamps do in the operating room might be questioned. Actually, they serve to call attention quickly to load bulges, and if during what was expected to be a quiet period the plant forces have taken some equipment out of service for trouble shooting, contact cleaning, or other routine maintenance, they can throw the idle equipment back into service quickly to handle the peak. Also, an undue number of all-busy lamp signals may point out a growing load before analysis of the long-term statistics shows it.

The lower portion of the supervisory panel contains signal lamps associated with overflow trunks. From an inspection of these lamps, congestion can be spotted and steps taken to put a group on delay working if necessary. In Figure 3, all four of the overflow trunks are busy in the Chicago (CGO), Cleveland (CLEV), Richmond (RICH-V) and New York (NY #1 & 2) groups, three out of four in the Baltimore (BALT) group, and all three in the Atlanta (ATLA) group. The T and V following some of the city designations mean terminal and via. The former trunks are of a transmission grade suitable only for direct calls from an originating to a terminating switchboard, the latter must be used on all calls involving one or more switches.

If it is found that traffic tends to peak on a group for short periods, but the total amount does not justify enlarging the group, temporary relief may be obtained by a method known as assignment patching. This may be explained by reference to a simplified schematic, Figure 4. Assume that a group contains four trunks, which are shown with their test leads from the marker. The next test lead in hunting sequence can be cross-connected to a patching jack, which looks to the marker like a busy trunk because of a normal ground. When the group must be enlarged rapidly, a patch is made from this jack to a trunk jack of a spare trunk circuit. Circuit 4 then no longer tests busy, and the test leads extend to the new trunk. Before the patch is made, of course, the spare trunk circuit must be patched to the proper cable conductors, and the distant office notified to make similar arrangements. Some of the trunks may also have patch jacks so that they may be borrowed for assignment to other groups.

To provide a large number of spare terminals for each trunk group would make the number of trunk block relays excessive. Relief trunks in excess of the number of spare terminals provided can be added by jump-hunting,* although this would be resorted to only in emergencies. Jump-hunting usually requires some planning ahead, consultation with the traffic and plant departments in distant cities, and coördination of plant work in two or more localities. It is ordinarily used to provide facilities for large conventions, World's Series, and similar events where the need is foreseen. In an emergency the planning and coördination can be telescoped to give rapid relief by adding a large number of trunks.

*See page 27.

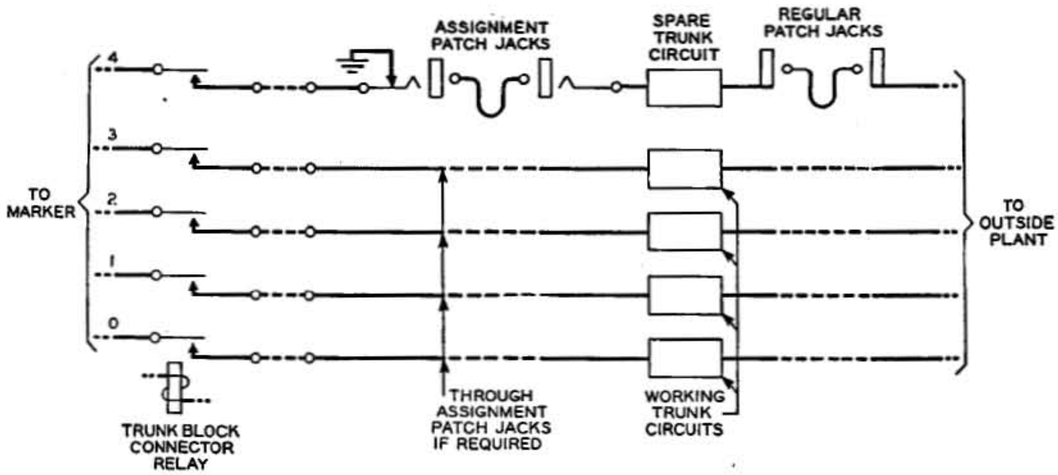


Fig. 4—Block schematic of arrangements for assignment patching

Handling Delayed Calls in Crossbar Toll

By F. F. SHIPLEY
Switching Engineering

IF ALL the subscribers connected to a central office were to place calls at the same time to subscribers connected to another office, and if there were to be no delay in completing these calls, there would have to be as many trunks between the offices as the first office has subscribers. Such a situation is conceivable, but practically the chance of its occurring is negligible, and so trunks are provided in sufficient number to insure satisfactory service under more normal conditions of traffic.

The criterion for determining the number of trunks which should be provided is the traffic during the busiest hour. Use is made of probability tables that have been calculated to show for various amounts of traffic the number of trunks necessary to insure that not more than a certain percentage of calls will find all the trunks busy. When, for example, there are on the average ten calls between two local offices throughout the busiest hour, nineteen trunks will give the desired grade of service.

The relationship of trunks and traffic, however, is not the same for toll as for local trunks. Toll lines are not only longer, but also cost more per mile than trunks between local offices. The ratio employed for toll lines varies with the length of the haul, the volume and nature of the traffic, and outside plant conditions on the route involved. On one of the schedules widely used for engineering toll lines, only eleven trunks are specified for an average of ten simultaneous calls, instead of the nineteen used for local trunks. Under these conditions, however, a much larger percentage of the calls in the busy hour finds all circuits busy.

When all circuits are busy, it is desirable that the operator be kept apprised of the condition so that she need not make repeated fruitless attempts to secure a circuit. It is also desirable to complete delayed calls as nearly as possible in the order of their filing time. This is facilitated in the crossbar toll system by overflow circuits associated with toll-line groups, and by a call-order board, known as the No. 5 toll switchboard, shown on page 45.

A simplified schematic of the overflow arrangement is shown in Figure 1. All toll-line groups have overflow trunks associated with them. Although on the same block relay, these do not form part of the toll-line group, but are tested separately. If the marker finds all lines busy, it automatically tests the corresponding overflow-trunk group—connecting the call to the first idle trunk. An overflow control circuit, associated with each group of overflow trunks, maintains a record of the all-trunks-busy condition by a lead multipled to each of the individual toll lines; and as long as all circuits are busy, it returns a slow flash to connected incoming circuits. When

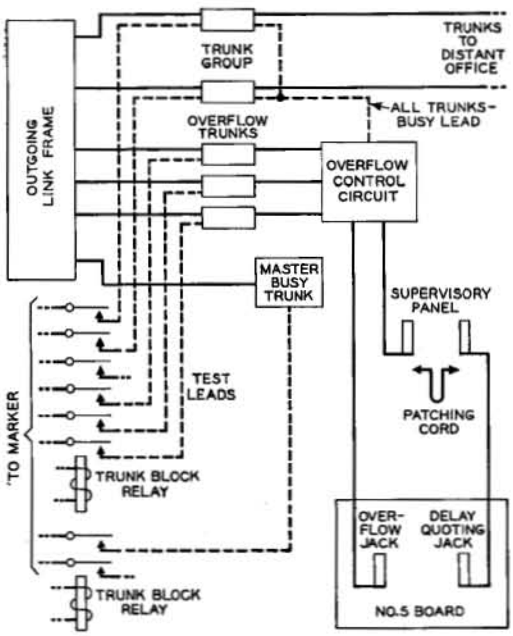


Fig. 1—Simplified schematic of connections to overflow circuit

a trunk in the group becomes idle, it returns a fast re-order flash signaling the operator to make another attempt.

The number of overflow trunks varies from one to four, depending on the size of the associated toll-line group. The intention is to allow only as many circuits to wait in overflow as have a reasonable prospect of obtaining an idle toll line within a period of about five minutes.

Besides the overflow trunks and control circuits associated with them, there is also a group of master-busy trunks that is common to the entire office. When a marker finds all the overflow trunks of a group busy, it releases the trunk block relay it was using, seizes a block relay associated with these master-busy trunks, and connects the call to the first idle one. These master-busy trunks return an irregular flashing signal to the distant calling operator to apprise her of the more extensive delay she is likely to encounter in making the call.

When an outward operator gets the slow flashing signal, indicating an overflow trunk, she usually holds the connection for a while, waiting for the quick flash indicating that a trunk has become idle. When she receives the irregular flash indicating she has reached a master-busy trunk, however, she usually turns the call over to a delayed-outward operator in her office, who will complete it as soon as she can get a trunk. As a rule, operators in distant cities who are attempting to establish a connection through a crossbar toll office do not hold toll trunks more than five minutes. If the operator reaches the crossbar toll office over a ring-down toll line, she leaves a call order with the No. 4 cordless operator as soon as delay is encountered. No further action is required on the call order if a circuit is secured within five minutes, but if a circuit is not secured within that interval, the call order is sent to the No. 5 board, the incoming circuit is released, and the originating operator sends her ticket to a delayed-outward operator in her own office.

If the distant operator reaches the office over a dial toll line, she holds the connection to overflow for five minutes, and then reaches the No. 5 operator over a code "151" trunk, and leaves a call order with her. Outward operators in the crossbar toll office area may extend the waiting period to ten minutes, but when longer delays are encountered, the calls are always turned over to the delayed-outward operators who are associated with them.

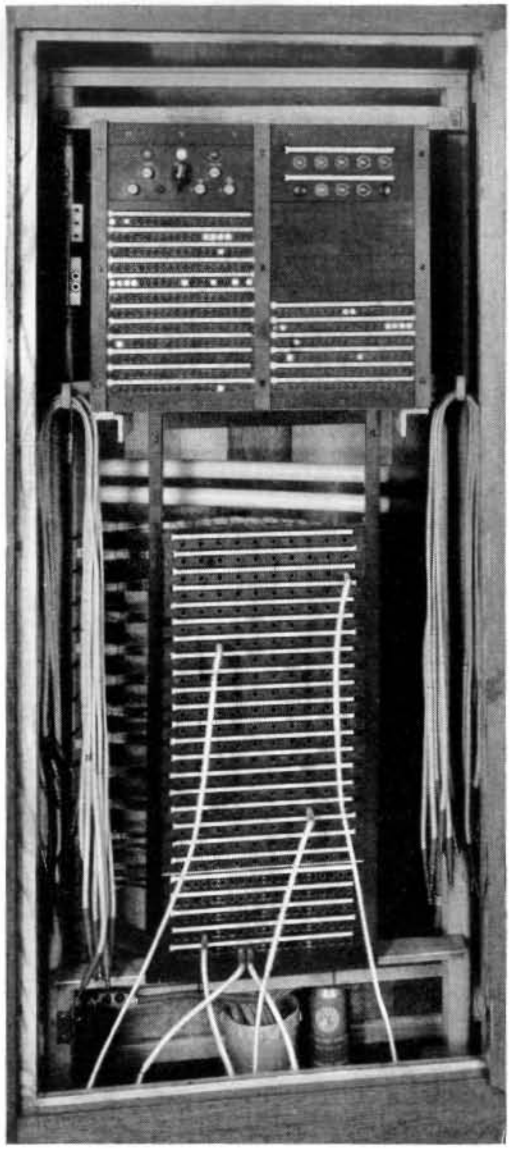


Fig. 2—Traffic supervisory panel used in connection with the handling of delayed calls in the crossbar toll system

To assist in handling calls that have encountered delays, the No. 5 switchboard has been provided. This board is of the cord type, and uses twin jacks and plugs to permit the connection to be made on a four-wire basis. Incoming trunks are known as "151" trunks, since by dialing 151 on any trunk to the crossbar toll office, a No. 5 operator is reached. The outgoing trunks from the No. 5 board run to the switch frames as do all incoming trunks. Each position has a ten-button key set with which the operators can complete calls to any outgoing trunk. Both incoming and outgoing trunks appear in jacks, and four-wire cords are provided with which the operators may complete calls between two outgoing trunks or between a "151" trunk and an outgoing trunk.

In the face of the board there are also jacks associated with each overflow circuit. These are single jacks instead of twin jacks as used for the other trunks, and each position has four cords with single plugs with which the operator may connect to them. The operator plugs into each group in which she is interested, and lamps associated with these four cords remain dark while the toll lines are all busy, and these lamps will flash at the fast re-order rate when one or more toll lines are idle.

As delayed calls come in on the "151" trunks, the No. 5 operator makes out tickets and stacks them so that they may be completed in the order in which they were received. When she sees that there is an idle trunk in one of the groups she is watching, she plugs into one of her outgoing trunks and "writes up" the number wanted on her key set. If she finds an idle line, she plugs the other end of the cord into another outgoing trunk and dials the office originally placing the call. This call is then completed through the cord at the No. 5 board—passing through the toll switching train twice.

Each overflow trunk has a lamp on the traffic supervisory panel shown in Figure 2. By noting the action of these lamps, and by keeping track of the tickets at the No. 5 board, the chief operator can estimate the delays. When she sees that the delay on a certain group will be one-half hour or more, she puts that group on "delay quotation," and thereafter a different operating procedure is followed.

In the lower part of the supervisory panel are rows of jacks. The upper rows run to the various overflow control circuits, and the five lower rows are delay-quotation jacks, which are connected to the positions at the No. 5 board. These jacks are arranged in groups: one group for a half-hour delay, one for an hour delay, and so on for the various delays that may be quoted. To put a group of trunks on delay quotation, a double-ended cord is plugged into the jack to the overflow control circuit for that group and into a jack for the particular delay to be quoted. Then calls coming into the markers for this group will be connected either to the overflow trunks directly or to the No. 5 board, depending on whether they are from local or distant operators. This is done whether there are idle trunks or not, since access to a group on delay quotation is denied to all but the operators at the No. 5 board. When a group is on delay quotation, notices stating the delay to be quoted for various trunk groups are "posted" where they can be seen by the operators at both the No. 4 and the No. 5 switchboards.

The delay-quotation jacks at the operators' positions have lamps associated with them which light every time a call comes in to an overflow group that has been patched to this particular delay-quoting trunk. After a delay has been posted, operators at the No. 5 board watch the lamps associated with the delay-quotation jacks at their positions, and whenever a lamp lights, an operator plugs in and quotes the delay. Any operators connected to that overflow circuit or to any other overflow group patched to the same delay-quoting trunk will hear these announcements.

When a group of trunks is on delay quotation, the markers are apprised of the fact by their route relays, and do not follow their ordinary procedure. A call from a distant dial operator will be connected directly to the No. 5 board where the operator will quote the delay and write a ticket for later completion. On the other hand, a call from an outward operator in the local area will be connected to one of the overflow trunks for that group, and will hear one of the No. 5 operators state the delay. The outward operator then turns the call over to her own delayed-outward operator, who may have other calls for the same group. She will inform the proper No. 5 operator from time to time as to the number of calls waiting.

The No. 5 board thus serves as a point of clearance for most of the calls that are seriously delayed. Since the operators at these boards are the only ones that have access to the group of trunks on delay quotation, and since they receive a flash as soon as the trunks become idle, they are able to complete the calls as rapidly as facilities become available and in the order in which the calls come in.

Fig. 3—The No. 5 toll switchboard for handling delayed calls

Junctor Grouping in Crossbar Toll

By G. E. DUSTIN
Switching Equipment Engineering

In the crossbar toll system, two sets of frames, called incoming and outgoing frames, comprise the toll train.* Junctors are the groups of wires that interconnect them, and they run from the secondary verticals of the incoming frames to the primary verticals of the outgoing frames. The junctors connecting one incoming to one outgoing frame form a junctor group. Since the number of frames may change from time to time as the load on an office increases, the number of junctors in a group will necessarily vary because the total number of junctors leaving any one incoming frame is fixed by the number of secondary verticals. With 20 verticals per switch and 10 switches per frame, there is a total of 200 junctors leaving each incoming frame, and they will be divided evenly among the outgoing frames. If there were only five outgoing frames, there could be 40 junctors to each, while if there were 10 outgoing frames, there could be only 20 to each. With 20 outgoing frames, which is the maximum number incorporated in a toll crossbar train, there would be only 10 junctors to each under these conditions.

This analysis gives the maximum number of junctors per group when there are 200 available from each incoming train, but the actual number required to give a desired grade of service is determined by probability theory, and will vary from 50 to 20 for

*See page 7.

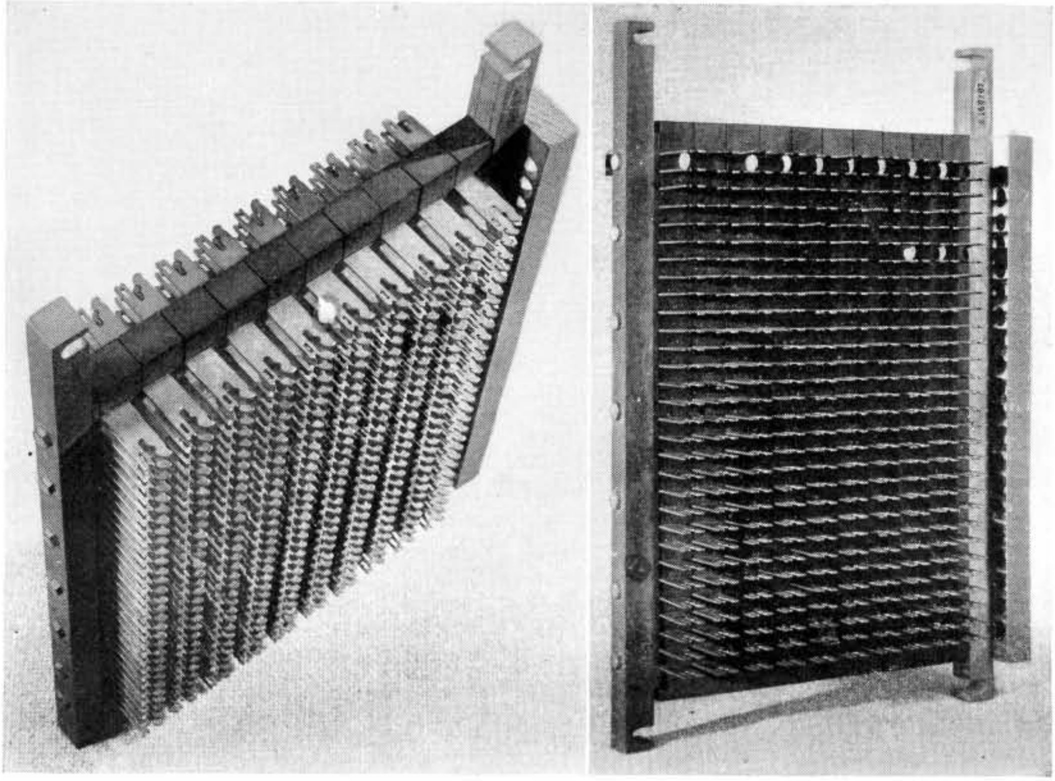


Fig. 1—Terminal strip used with the JGF, as seen from above and from the front

intertoll trains, depending on the number of outgoing frames in the train. Since with more than 10 outgoing frames the groups would have less than 20 junctors when only 200 are available at each incoming frame, extension frames are provided whenever the office requires, or may require with growth,

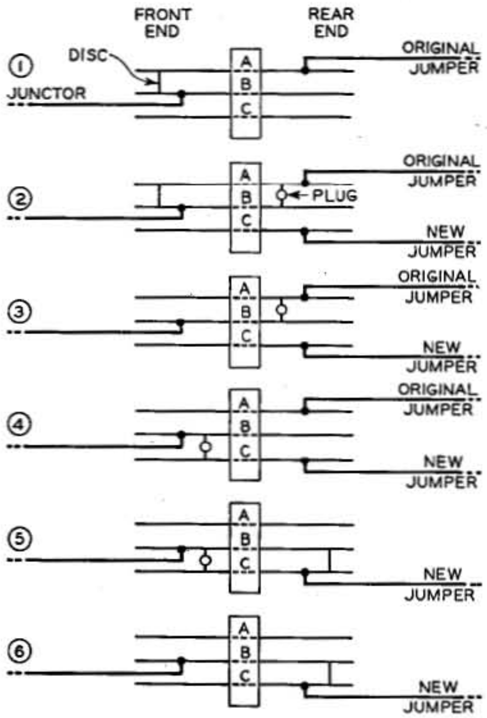


Fig. 2—Six steps in cutting in a new frame on the JGF. Only one lead of one junctor is indicated in each sketch

more than 10 outgoing frames. The extension frames make 400 junctors available at each incoming frame, but the traffic arriving at the secondary switch of an incoming frame is not sufficient to provide a load for 400 junctors. When extension frames are used, therefore, the incoming frames are arranged in pairs called "incoming groups," and the corresponding secondary verticals of each frame of an incoming group are connected to the same junctor.

A crossbar toll office might, as an example, be originally installed with eight outgoing frames with a prospect of growing to an ultimate of 20 frames. For the original installation, there could be a maximum of 50 junctors from each incoming group to each outgoing frame, but as the size of the office increased, the size of the junctor groups could be decreased because, with more outgoing frames, the number of calls from any one incoming group to any particular outgoing frame will be less. The amount of traffic any incoming frame can handle is fixed by the number of links and junctors, and this fixed amount of traffic is divided among the outgoing frames. The amount of traffic and the number of junctors to handle the traffic to each outgoing frame is thus on the average roughly inversely proportional to the number of outgoing frames. As the number of frames in an office is increased, therefore, the grouping of the junctors must be rearranged.

Using the methods of ordinary telephone practice, such changes would be provided for by wiring the junctors from the incoming groups to one set of terminal strips and those from the outgoing frames to another set. Grouping could then be accomplished by running jumpers between the two sets of terminals. With such a conventional arrangement, the amount of work involved in regrouping junctors to take care of a change in the size of the central office would be considerable, however, and would require a long cut-over time.

Consider, for example, a toll train with six incoming groups and 12 outgoing frames, which is to be increased to seven incoming groups and 14 outgoing frames. With 12 outgoing frames, 30 junctors are employed in each group, and since there is one group of junctors from each incoming group to each outgoing frame, there is a total of $6 \times 30 \times 12 = 2,160$ junctors. Since six incoming groups have terminals for 2,400 junctors, there will thus be 240 sets of terminals—40 on each incoming group—that are not used. With 14 outgoing frames, on the other hand, only 25 junctors per group are employed, and thus the total number of junctors will be $7 \times 25 \times 14 = 2,450$. Of this number, 50 will be run between the new incoming group and the two new outgoing frames, and since these can be run while the frames are being installed, they will not affect the cut-over time. Of the junctors between existing frames, $6 \times 25 \times 12 = 1,800$ need not be changed, and $6 \times 20 \times 2 = 240$ junctors from the unused terminals of the existing incoming group to the two new outgoing frames may also be run without affecting the cut-over time. This leaves 2,450 − (50 + 1,800 + 240) = 360 junctors that are involved in the cut-over. To run 360 new jumpers, including unsoldering and soldering, where each junctor has five leads, would be a long and involved proceeding if the ordinary form of terminal strip were employed. To make a quicker cut-over possible, a special form of junctor grouping frame, referred to as the JGF, has been developed.

The terminal strip, Figure 1, used with the JGF employs three terminal punchings for each junctor lead, marked A, B, and C. Each end of each punching has two prongs, one being notched for soldering and the other being slotted. Between two adjacent slotted punchings, a metal disc may be inserted and soldered in place to form a connection. How such terminals permit a rapid change of junctor grouping is illustrated in Figure 2.

Sketch 1, at the top, shows the arrangement for one lead of a junctor for the original installation. One of the leads of a junctor from an incoming group is soldered to the front end of the B punching, and a jumper to a similar set of punchings that has a cable lead to an outgoing frame is soldered to the rear end of the A punching. A disc soldered between the A and B punchings at the front end completes the connection. When an increase in the number of frames in the office requires that these connections at the JGF be changed, the first step taken is shown in sketch 2. The new jumper is soldered to the back end of the C punching, and a specially designed plug is inserted between the A and B punchings on the rear side. Then the soldered disc between the A and B punchings at the front end is removed as shown in sketch 3. Up until this time, no change of connection has actually been made, and the office is still operating on the original basis. By merely removing the plug from between the A and B punchings at the rear end, and inserting it between the B and C punchings at the front, as shown in sketch 4, the change in junctor connections is made. To make the connection permanent, a disc is soldered between the B and C punchings at the rear, as shown in sketch 5, and the original jumper is removed. This is followed by the removal of the plug from the front end of the junctor as shown in sketch 6, and this part of the work is completed.

Each junctor has five sets of punchings like those shown in Figure 2, and the plugs used have 10 contacts, and make connections for the 10 leads of two junctors at the same time. The double-pronged terminal punchings are built into terminal strips as shown in Figure 1. Each such terminal strip has 30 rows of 10 terminal punchings each, and thus each three rows provide the three terminals for each of the five leads of two junctors, and a complete terminal strip of 30 rows thus provides for 20 junctors. A

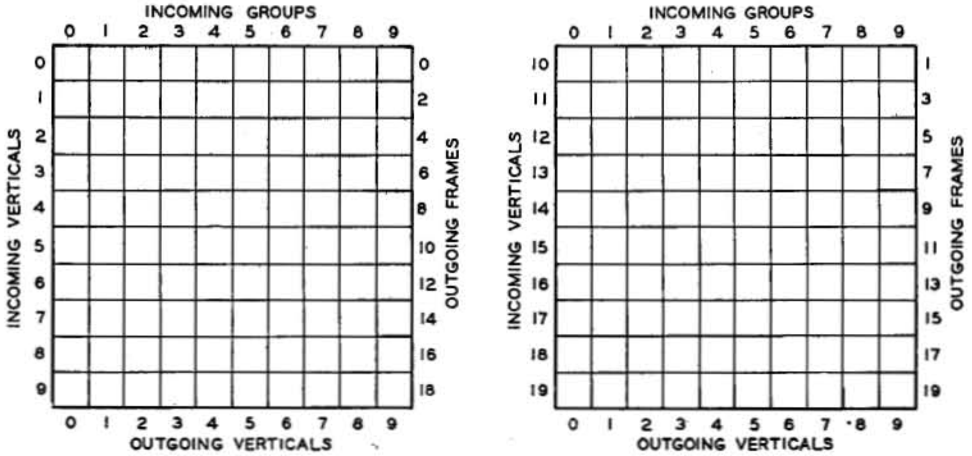


Fig. 3—Arrangement of two bays of the JGF. Each of the 100 squares of each bay represents one terminal strip with terminals for 20 junctors

Fig. 4—Left half of JGF at Philadelphia

are distributed in a somewhat similar manner, but along horizontal rows rather than vertical columns, and junctors from all odd-numbered frames are connected to one bay of terminal strips, and from all even, to the other, as indicated by the numbering at the right and bottom of the bays.

How the junctors are connected and jumpered for varying sizes of offices is perhaps best illustrated by assuming first the hypothetical case of two bays of JGF completely equipped with terminal strips for a complete initial installation of 20 incoming and 20 outgoing frames. The junctor cables from the 10 incoming groups would then be connected to the front ends of the B terminals of all the terminal strips in accordance with the numbering scheme indicated, and the junctor cables from the 20 outgoing frames would be connected to the rear ends of the B terminals. Any two corresponding columns of terminal strips on the two bays thus carry the 400

complete JGF for a 20-frame unit has space for 200 of such terminal strips arranged in two bays as indicated in Figure 3, and thus provides for 4,000 junctors, which is the maximum ever used for a single train. Junctor cables from incoming groups are connected to the front ends of the terminals, while those from the outgoing frames are connected to the rear ends. The junctors from each incoming group are connected to the terminal strips in one vertical column on each bay: the No. 0 verticals from the 20 secondary switches of each incoming group are connected to the top terminal strip of a column, the 20 No. 1 verticals to the next lower terminal stop, and so on, as indicated by the numbering at the top and left of Figure 3.

The junctors from the outgoing frames

junctor cables from one incoming group, and the horizontal rows of terminal strips of each bay carry the junctor cables to one outgoing frame. Each terminal strip thus carries the group of 20 junctors from one incoming group to one outgoing frame. For example, the terminal strip in the third row from the top and fourth column from the left of the left-hand bay carries the 20 junctors from No. 2 incoming group to No. 3 outgoing frame.

With such an arrangement, no jumpers at all would be required, since all connections between the junctor cables for incoming and outgoing frames would be made directly by the B punchings of the terminal strips. Suppose, however, that an actual office had originally only five incoming groups and 10 outgoing frames, but that an increase to as many as 10 incoming groups and 20 outgoing frames might be expected. Suppose further that the original installation were to have 40 junctors per group. Since there are only five incoming groups, the right halves of each bay of terminals would have no junctor cables from incoming frames connected to them, and since there are only 10 outgoing frames, the bottom halves of each bay would have no junctor cables to outgoing frames. The junctors on the upper left-hand quadrant of each bay would be connected directly through the B punchings, as in the first example, and would not need to be changed as the office increased in size, while the two lower right-hand quadrants would have no junctors at all connected to them. The two upper right-hand quadrants would have only junctor cables to outgoing frames, and the two lower left-hand quadrants would have only junctor cables to incoming frames.

Since the junctors in the upper left-hand quadrants would never have to be changed, there is no need of installing terminal strips in these positions at all, since the junctor cables can be run directly from the incoming to the outgoing frames. Jumpers would be run from the terminal strip in the lower left quadrants to those in the upper right quadrants, and it is these jumpers that would be subject to later change. No terminal strips would need to be installed in the lower right-hand quadrants at the time of the original installation since they would have no use. Two terminal bays, unequipped in the upper left and lower right quadrants, would thus appear as in Figure 4.

Suppose it becomes necessary to add one more incoming group—No. 5—and two more outgoing frames—No. 10 and No. 11. The junctor cable from the No. 5 incoming group would be brought to the JGF and connected to the vertical columns of terminal strips marked No. 5 on Figure 3. Since the upper five terminal strips in this column of each bay already have junctor cables to outgoing frames connected to their B terminals, which are connected by discs to the A terminals to which jumpers run to the terminal strips in the lower left quadrant, these new junctor cables from incoming frames would be connected to the C terminals to be ready for the cut-over. Since there are no terminal strips installed in the lower right quadrants, four would be set in place in the lower half of column No. 5 in each bay, and the junctor cable from the No. 5 incoming group would be connected to the B terminals.

Similarly, the junctor cables from outgoing frames Nos. 10 and 11 would be connected horizontally along rows marked 10 and 11 at the right of Figure 3 to five existing terminal strips in the lower left quadrants and to four added terminal strips in the lower right quadrants. The missing terminal strips at the junctions of the No. 5 vertical column and the Nos. 10 and 11 horizontal

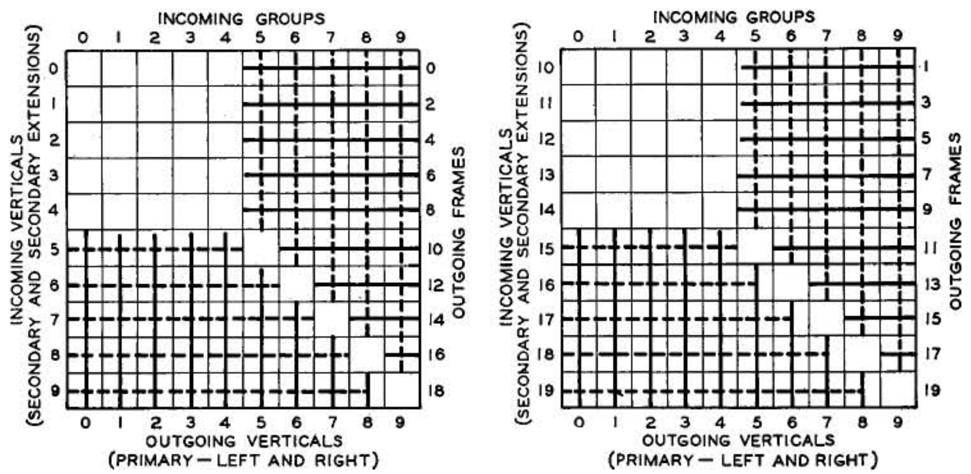


Fig. 5—Diagrammatic representation of the JGF bay as originally equipped for five incoming groups and 10 outgoing frames, and then increased to 20 outgoing frames and 10 incoming groups. Solid lines represent cables to B terminals; dotted lines, cables to C terminals

rows would correspond with the 40 junctors between the added incoming group and outgoing frames, which will never change and thus may be cabled directly.

After the cut-over, the 10 terminal strips in the left halves of the horizontal rows 10 and 11 would have no jumpers because junctor cables from incoming groups 0 to 4 on the B terminals would connect directly to junctor cables to outgoing frames 10 and 11 on the C terminals, and they would never be changed subsequently.

A similar process would be carried out for each subsequent addition. After 20 frames have been installed, there would be no jumpers on the JGF at all. Each connection would be made between the B and C terminals of the same terminal strip. This is represented in Figure 5, where the blank squares represent terminal strips not installed, solid lines represent cable connections to the B terminals, and the dashed lines represent cable connections to the C terminals.

In the above discussion, 40 junctors per group have been assumed. In ordinary practice, only 30 are used in such a situation, since 30 junctors per group will handle the traffic, and to install more would be unnecessary labor and expense. For terminating trains, as few as 10 junctors per group may be used, which means that extension frames are never required.

In finding an idle path through a toll train, the markers must locate an idle incoming link, an idle junctor, and an idle outgoing link, which together will make up the connection. The available junctors for one particular call are in the group connecting the incoming group to which the calling trunk is connected to an outgoing frame, at which trunks to the desired destination are located. Markers can test as many as 20 junctors at a time, and thus when there are more than 20 junctors in a group, they are divided into subgroups for the marker tests, and the marker tests the first subgroup, and then if no idle junctors are found there, the second subgroup. Where there are more than 40 junctors in a group, there will be a third subgroup. The first subgroup is always composed of those junctors that will not need regrouping at any subsequent enlargement of the office. These will consist of those junctors that run directly from frame to frame without passing through the JGF or those connected to opposite sides of the same terminal strips in the JGF as a result of the addition of frames.

When new frames are to be cut into service, changes must also be made in the markers, since the distribution of second and third subgroup junctors will be changed. Cut-over must be accomplished without interfering with traffic, and this is done by taking the markers out of service one at a time just prior to cut-over, rearranging the wiring that controls the testing of the second and third subgroups, and then blocking the marker so that it will test only the first subgroup junctors. After the junctor redistribution is completed by transferring the cut-over plugs as previously explained, the markers are returned to service arranged to test all junctors in accordance with the new distribution. There will thus be a brief period when the markers test only first subgroup junctors, but as these final steps of the change may be made during a light-load period, the handling of the traffic is not appreciably affected.

Multi-Frequency Pulsing

By D. L. MOODY
Toll Switching Engineering

D-C KEY pulsing was developed some years ago to permit certain operators, such as those at toll and DSA positions, to transmit numbers to senders more rapidly than is possible with a dial. When this system is used, the operator is equipped with a ten-button key set, and she presses one button for each digit successively. With such key sets, the average speed of keying by the operator is two digits per second, which is about twice the average speed obtained with a dial, and this increase in speed results in a proportionately shorter work time. The first toll installation was in Detroit in 1930, but since then the system has been extensively used in many offices throughout the country.

Where this form of pulsing is used and how the circuits are arranged has already been described.* In all applications, it is necessary that the senders into which the pulses are sent be in the same office as the key sets. The system employs d-c signals to ground, and the presence of condensers, repeaters, d-c bridges, and repeating coils, as well as differences in ground potential, prevent its use directly on toll lines and trunks. To overcome these limitations, a multi-frequency pulsing system was developed that sends out a-c instead of d-c pulses. The pulses are sent over the regular talking channels to senders usually located in the distant office, and since the frequencies employed are in the voice range, they are transmitted as readily as speech. The senders to which the pulses are sent must, of course, be arranged to receive this type of pulsing, and certain senders for the crossbar local and toll systems are so equipped. Existing local crossbar offices may readily be equipped to receive multi-frequency pulsing by adding the proper type of senders whenever conditions warrant the use of this sysem. The multi-frequency system does not take care of various supervisory signals, which must still be transmitted by other methods.

With the multi-frequency pulsing system, six frequencies spaced 200 cycles apart from 700 to 1,700, inclusive, are employed. Two, and only two, of these frequencies are used for each pulse, and each such pulse represents one digit. There are fifteen pairs of frequencies possible from a group of six, and ten of them are used for the digits from 0 to 9, inclusive, and one each for signals indicating the beginning and end of the pulsing. The remaining three possible pairs are available to meet future requirements. The various pairs of frequencies employed are wired to the key set so that, as each button is pressed, the proper pair of frequencies for that digit is sent over the line.

The first multi-frequency key pulsing system was installed at the toll board in Baltimore to permit the toll operators to complete calls for the local crossbar offices without the aid of another operator, or without requiring senders in the toll office. The development of the crossbar toll switching system, however, and the more extensive use of dial switching over toll lines that it presaged, indicated a much wider scope for multi-frequency pulsing in the future, and senders

*See page 3.

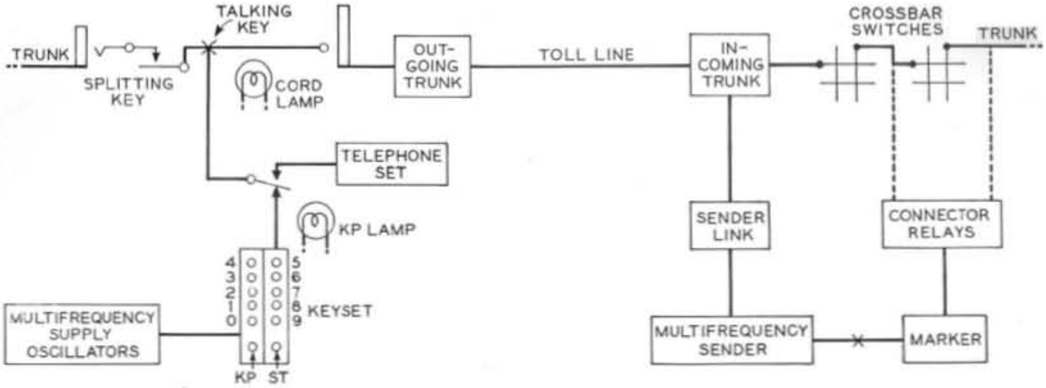


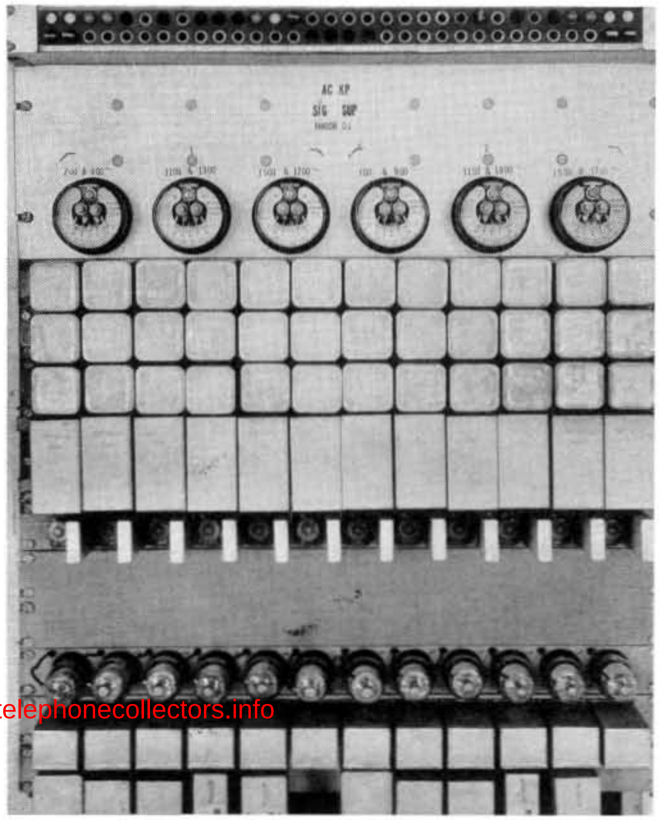
Fig. 1—Arrangement of multi-frequency pulsing between a manual No. 1 toll office, shown at the left, and a crossbar toll office, at the right

for the crossbar toll system were thus arranged both to send and receive this type of signal. Such senders transmit multi-frequency pulsing signals at the rate of seven digits per second, and thus once a number has been recorded in a sender, it can be rapidly transmitted to other senders. By installing multi-frequency pulsing equipment at the toll offices connected to Philadelphia by direct toll lines, therefore, any of these offices can directly set up connections through the Philadelphia office, and as more crossbar toll offices are installed in the future, this will become a common method of handling toll calls.

In Figure 1, a manual No. 1 type toll office equipped for multi-frequency pulsing is shown connected by a direct toll line to a crossbar toll office. When an outward operator at the manual board, which might be Baltimore, wishes to complete a call in a distant toll office, such as Philadelphia, she plugs into the line with her TALK key operated, waits until her cord lamp lights, indicating that a sender has been attached at Philadelphia, and then presses the KP (key pulsing) button of the key set. Prior to this, she has operated a "splitting" key to open the circuit to her calling trunk, and the operation of the KP button operates a relay that transfers her cord from her telephone set to her key set, and also sends a pulse consisting of frequencies of 1,100 and 1,700 cycles over the trunk to Philadelphia.

Receipt of this KP signal at Philadelphia prepares the equipment to receive the digits that will follow, and when this brief operation is completed, a key pulsing lamp in front of the operator lights to indicate that she may begin sending the digits of the desired number. The operator now transmits the called number—pressing one button for each digit. Following the last digit, she presses the ST (start) key to indicate she has finished sending. Besides informing the sender at the crossbar office that no more signals are coming, operation of the ST key

Fig. 2—Two signal supply circuits are mounted on a single panel for multi-frequency key pulsing



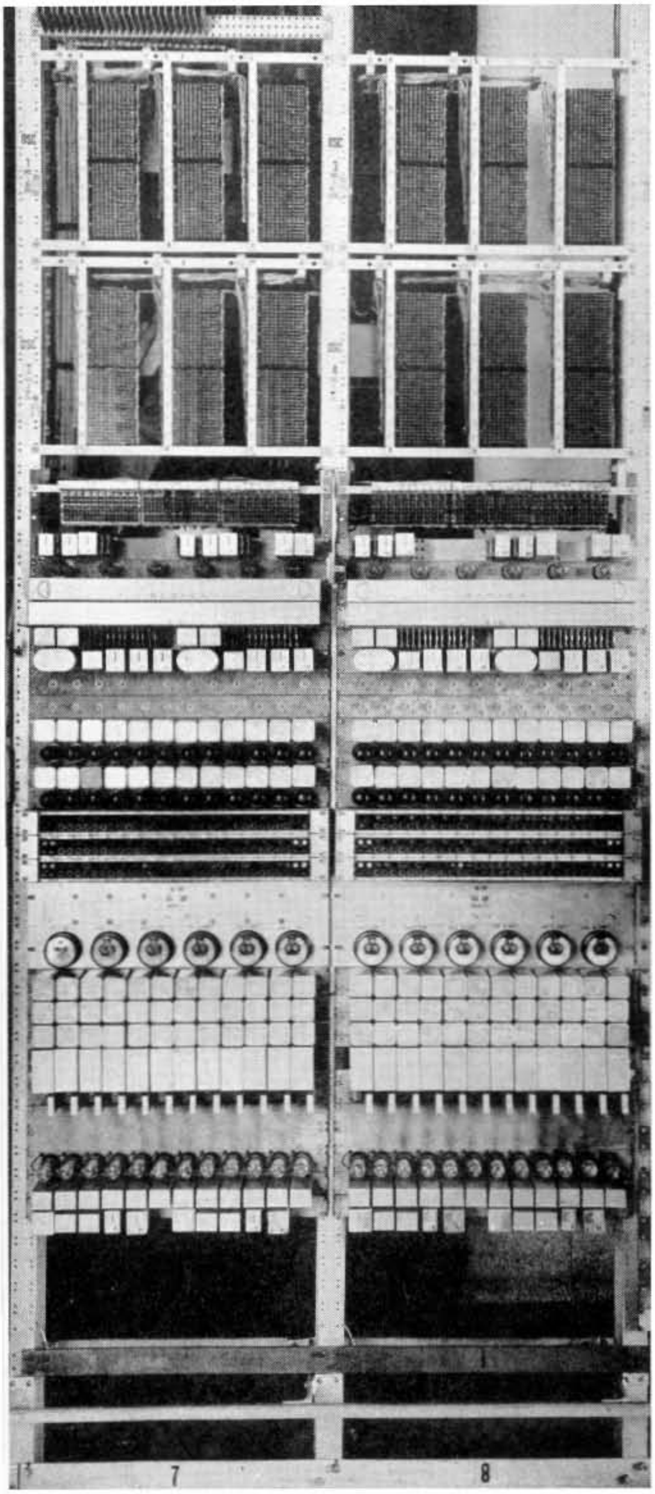


Fig. 3—Supply bays for multi-frequency key pulsing showing terminal punchings at top

also disconnects the key set and KP lamp from the cord, and reconnects the telephone set to the circuit.

When the called subscriber answers, the cord lamp goes out, indicating to the operator that the connection has been established. If the called line is busy, if the connection cannot be completed because all paths to the line are in use, if the operator presses two keys simultaneously, or if she presses the KP key twice, the cord lamp flashes, and the operator must release the connection and start making the call over again in accordance with her instructions.

Besides the ten-button key set, two major circuits are required for the multi-frequency pulsing system: a multi-frequency supply circuit and a receiving circuit. The supply circuit includes six bridge-stabilized oscillators operating at the six frequencies from 700 to 1,700, inclusive. This type of oscil-

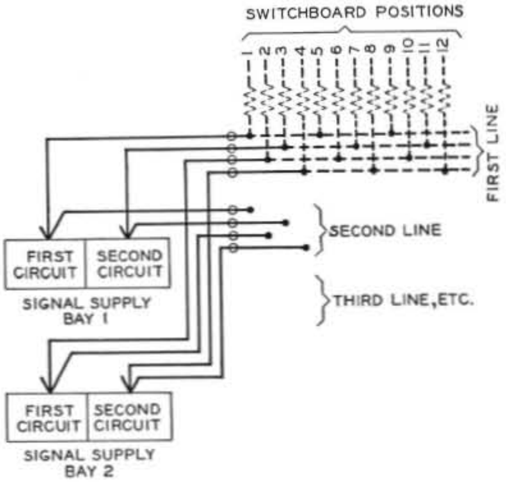


Fig. 4—Distribution arrangement to switchboard of the multi-frequency key pulsing supply

lator, which was briefly described in an insert in the RECORD,* holds both the frequency and amplitude constant with changes in load and supply voltage. This insures that the pulses sent are not only at the proper frequency, but that the amplitude of each frequency is approximately the same.

The primaries of twelve output transformers, one each for the KP and ST pulses and one for each of the ten digits, are connected across the outputs of the various pairs of oscillators, and the secondaries of these transformers are connected to the proper terminals of the key set. As each button is pressed, therefore, the proper pair of frequencies is sent over the line.

**January*, 1940, *between pp.* VI *and* VII.

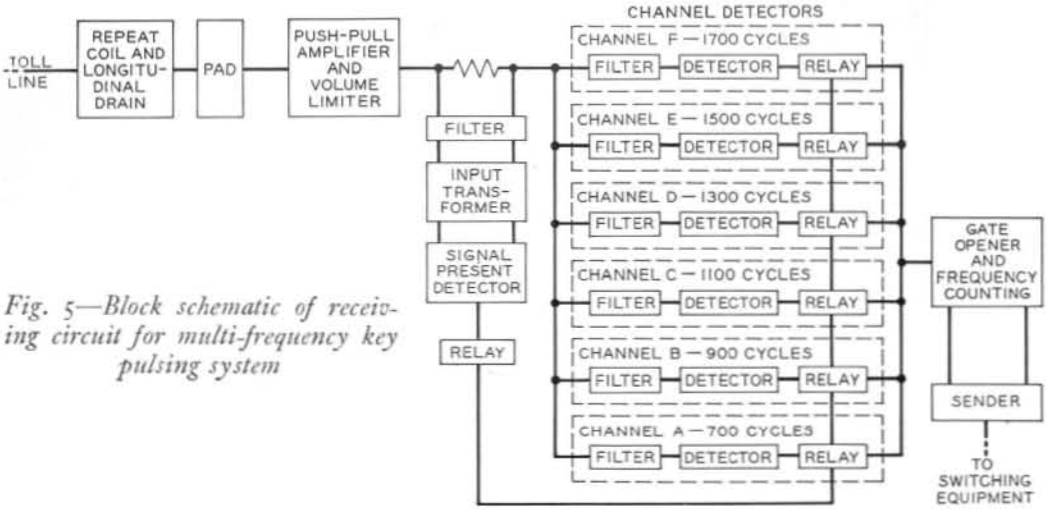


Fig. 5—Block schematic of receiving circuit for multi-frequency key pulsing system

Two of these supply circuits are mounted in a single bay as shown in Figure 2. Near the top of the bay are six voltmeter relays used with the voltage alarm. Four supply circuits are provided for each office, and thus trouble on any one of the circuits cannot affect more than a quarter of the switchboard positions. Trouble in the oscillators is very rare, however, and when it does occur, the positions affected are automatically transferred to the other supply circuit on the same bay.

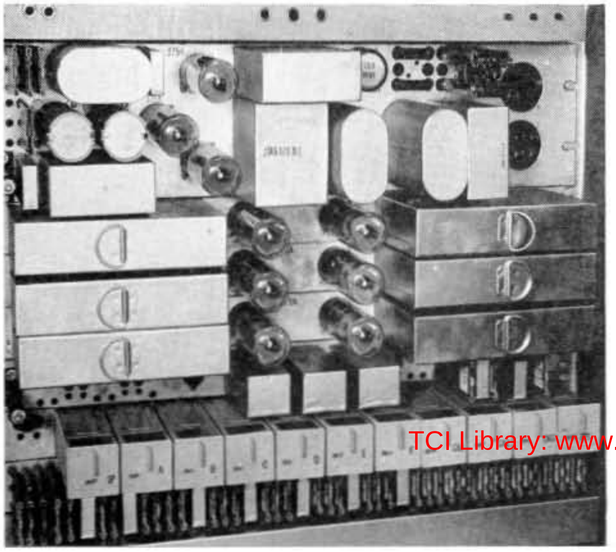
Distribution of the supply to the various positions of a large switchboard is arranged as shown in Figure 4. Each position is supplied through individual resistances which are of such a value that a short circuit at any one of the positions will not overload the oscillator or affect the operation of the other positions. To care for the occasional cross which may occur on the leads between the supply panel and the switchboard, a current alarm circuit is provided. To facilitate clearing the trouble, terminal punchings and straps are conveniently arranged at the top of the supply bays by which individual lines of switchboards can be readily isolated. These are evident in Figure 3, which shows a pair of supply bays complete.

For supplying senders or small switchboards, individual sets of leads are run directly from the supply panels to the senders or switchboard positions, and the protective resistors are placed at the supply panel. Because trouble in the supply leads under these conditions can affect only one sender or position, no current alarms are required in such installations.

The receiving circuit is shown in Figure 5. Stripped to its essential elements, it includes a repeating coil, a volume limiter, a signal-present detector circuit, six channel filters, six channel detectors with their associated relays, and a gate-opener and frequency-counting circuit.

The repeating coil reduces the effect of longitudinal currents that might falsely operate the circuit. The volume limiter is a combination amplifier and limiter that maintains the strength of the received signals within narrow limits. From the limiter, the signal divides two ways: one delivering energy to a detector used to indicate whether or not a signal is present; the other to a parallel arrangement of six band-pass filters, each connected to the input of a vacuum tube detector to operate the detector relays.

Fig. 6—A multi-frequency key pulsing receiving circuit



The filters have pass bands about 100 cycles wide centered at one of the six frequencies of the supply circuit, and step up the voltage applied to the detectors about 20 db.

Polarized relays are used to transmit the signals from the detectors to the sender. One of the windings of each relay is connected to the plate circuit of its associated detector tube, and current through this winding normally holds the relay unoperated. When a signal is received, the signal-present detector relay passes current through another winding of the polarized relay that tends to operate it, but that is incapable of doing so with full current through the first winding. Soon after the signal is received, however, a negative bias has been established on the grids of two detector tubes by the action of the current through the bandpass filters, and with the resulting reduction in plate current, the relays associated with these tubes at once operate. Since each signal consists of two frequencies, two of the channel relays will operate on each pulse and pass indications to the sender to operate the proper register relays. The gate opener and frequency counting circuit completes the path from the receiver to the sender for registering the digits.

This, in brief, is the operating procedure of the receivers, but to insure satisfactory operation under all conditions, a number of other features are included. If the first pulse received does not consist of frequencies of 1,100 and 1,700 cycles, indicating a KP (gate-opener) pulse, no connections are made from the detector relays to the sender, and digits cannot be registered in the sender. If the KP signal is repeated, or if more than two frequencies are received for any pulse, appropriate supervisory signals will be returned to the calling operator so that she may pull down the connection and set up the call anew. To insure that the sender will register the digits even with the most rapid keying by operators, the detector relays are locked operated on each digit until the sender equipment signals the receiver that it is ready for the next one.

One of the receiving circuits is shown in Figure 6. The six detector tubes are evident near the center of the panel, while the two tubes for the volume limiter and one tube for the signal-present circuit are above and to the left of them. The six detector relays are those marked A to F, inclusive, along the bottom row, where are also other polar relays used in the circuit.

Test set for No. 4 switchboard positions

Manual Calls in Crossbar Toll

By A. G. LANG
Switching Development

WITH the No. 4 toll switching system,* recently installed in Philadelphia, all connections are made by crossbar switches under the control of electrical pulses. When the incoming trunk is of the dial type, from either an office in the Philadelphia area or from a distant toll office, these pulses are received over the trunk from the originating end. For such calls, no operators are involved at the crossbar office. Many toll lines, however, are not arranged for transmitting switching pulses, and even in the larger cities some of the boards from which outgoing toll calls may be placed are of the manual type. It was necessary, therefore, to provide also a manual board from which the crossbar switches could be controlled, and for this purpose the No. 4 toll board was developed as part of the crossbar toll system. As evident from the illustration at the head of this article, the No. 4 board differs from the more usual type in having neither cords and plugs nor jacks; only keys and lamps require the operator's attention. Calls as they come in are connected to an operator's headset automatically, which she sets up by operating keys in the two large groups in front of her.

To establish a connection through the toll office, only three keys need be operated, and these are in the three columns at the left of the large bank. For through or outgoing calls leaving over manual trunks, these are the only keys that need be operated, but for calls terminating in Philadelphia and for through and outgoing calls leaving over dial trunks, the large bank of keys at the right is provided in addition for reaching the subscriber at the terminating end.

*See page 7.

Each switchboard position has three loops over which the operator may receive calls and establish connections, and calls are connected to these loops at the operator link frames.* The term loop is used because the circuit between the incoming toll line and the switches is looped to the operator positions as indicated in Figure 1 during part of the time the operator is handling the call. After the desired connection has been established, the operator's position is in most cases automatically released, with the result that the incoming line is connected to the switching equipment without passing through the No. 4 crossbar toll board.

To illustrate the operation, consider a call coming in over a manual toll line for completion to a subscriber in a dial office in a town reached over a dial toll line from Philadelphia. When the call is connected to her position, the operator is notified by lighted lamps and by zip tone in her headset, and acting on these cues she gets the connection wanted from the originating operator. On bulletins in front of the No. 4 operators are the names of the frequently called cities, together with the three-digit codes required

*See pages 19 and 23.

to reach a trunk to them through the crossbar toll system. The operator, after noting the required code, operates keys in the first three strips to select the proper trunk, and then operates keys in the large bank to select the office and line at the distant end of the trunk. She then presses a start button in the extreme right-hand column.

Operation of the three code keys caused a marker to be seized, which at once started finding an idle trunk in the desired group, and then establishing a connection to it through the crossbar switches. As soon as the trunk is found, it seizes an outgoing sender, which will be used to transmit the required pulses to the distant toll office. The marker releases immediately after it has established a connection to the trunk. At this time the code keys will also release. These operations will usually be completed by the time the operator has finished pressing the keys for the connection wanted at the distant end. When the operator presses the start key, the sender associated with her position starts transmitting the number wanted to the outgoing sender, and the loop and position, which up to this time have acted as a unit, are both separated electrically into two halves. The sender is associated with the outgoing or front half of the loop and proceeds to send out pulses to the outgoing sender. The incoming or back half of the loop, however, is disconnected from the operator's headset so that another call may be handled.

The next call will be connected to the back half of one of the other loops. The operator will receive signals and get the connection desired as before, and will start operating keys to set up the new code in the crossbar toll office. In the meantime, the sender has been transmitting pulses for the preceding call, and, as the pulses for each digit are sent, the key operated for that digit is released. As soon as all have been sent, the outgoing half of the position will be free to accept the digits of a new call. Since less than a second is ordinarily required to send the pulses for the previous call, they will have been sent before the operator has finished the three-digit code for the next call.

This division of the loops and positions into halves permits calls to be handled more speedily by enabling the operator to receive the number wanted for a call and to operate the three code keys while awaiting the completion of the preceding call. Where the call requires that only the three code keys be operated, however, the division does not come into play, and the position will automatically release as soon as the marker has established the connection through the toll office. Calls requiring a connection to a ring-

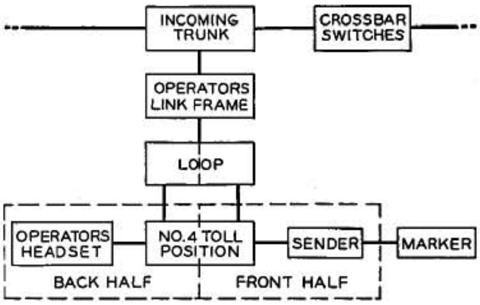


Fig. 1—From the operator's link frames, calls are extended to the No. 4 switchboard over "loops," three of which run to each position

down manual trunk are of this type, since for such calls the originating operator gives the order verbally to the distant operator after the connection has been established.

Such, in brief, is the usual operating procedure at the No. 4 toll board. There are a number of other types of calls that the operator must handle, however, and to permit her to perform her work effectively on all types of calls and under all conditions, the board is provided with a number of keys and lamps in addition to those already referred to. These are shown on the plan of the key shelf given in Figure 2.

Each of the three loops associated with the position has a connect key and three lamps: a guard lamp, a busy lamp, and a supervisory lamp. The colors of these lamps, blue, green and red, are indicated on the drawing. The connect key and the three lamps for each loop are in Column 4 of Figure 2. The busy lamp is lighted all the time a call is associated with that particular loop. The guard lamp flashes all the time the loop is connected to the back half of the position, and is extinguished after the splitting operation. The supervisory lamp gives indication of conditions on the outgoing trunk, such as that a subscriber has answered or disconnected. The connect keys are used with a locked loop as described later.

The manual trunks over which the operator receives calls or to which she may establish connections are either of the ringdown or straightforward type. The former will not transmit switchhook signals, and ringing must be applied to them to attract the attention of the operator at the distant end. Straightforward trunks, on the other hand, will pass switchhook signals and automatically call in the distant operator. The operating procedures for the two types of trunks, therefore, differ somewhat, and whether an incoming call is over a ringdown or straightforward trunk is indicated to the operator by the tone she receives when her headset is connected to the loop. For a ringdown trunk she receives a single zip tone, while for a straightforward trunk she receives a triple zip. This latter tone is also heard by the originating operator, who at once states the connection she wants. When a No. 4 operator receives a single zip indicating a ringdown trunk, she says "Philadelphia," which is a request to the originating operator to state the connection she wants.

The center pair of keys in Column 3 is for recalling the operators on ringdown trunks. The RB key (ring back) signals the calling operator, while the RF key (ring forward) signals the called end of the connection. In this same column are two other pairs of keys. Those of one pair, the DB (disconnect back) and DF (disconnect forward) keys, are used for disconnecting the connection in both directions, or merely toward the forward end. Those of the other pair, the LB (lock back) and LF (lock forward) keys, are for locking out the calling or called end of the connection and identifying them at the test board when trouble is encountered on them so that they will not be seized by the crossbar equipment until the trouble has been investigated and cleared.

When a call set up by the No. 4 operator finds all trunks in a toll line group busy, it is connected to an overflow trunk, which returns a flashing signal. If the calling trunk is of the straightforward type, the No. 4 operator is released, and the overflow signal is received by the originating operator. When the calling line is of the ringdown type, however, the overflow flash is given by the supervisory lamp at the No. 4 board, and an overflow signal is also given by a lighted

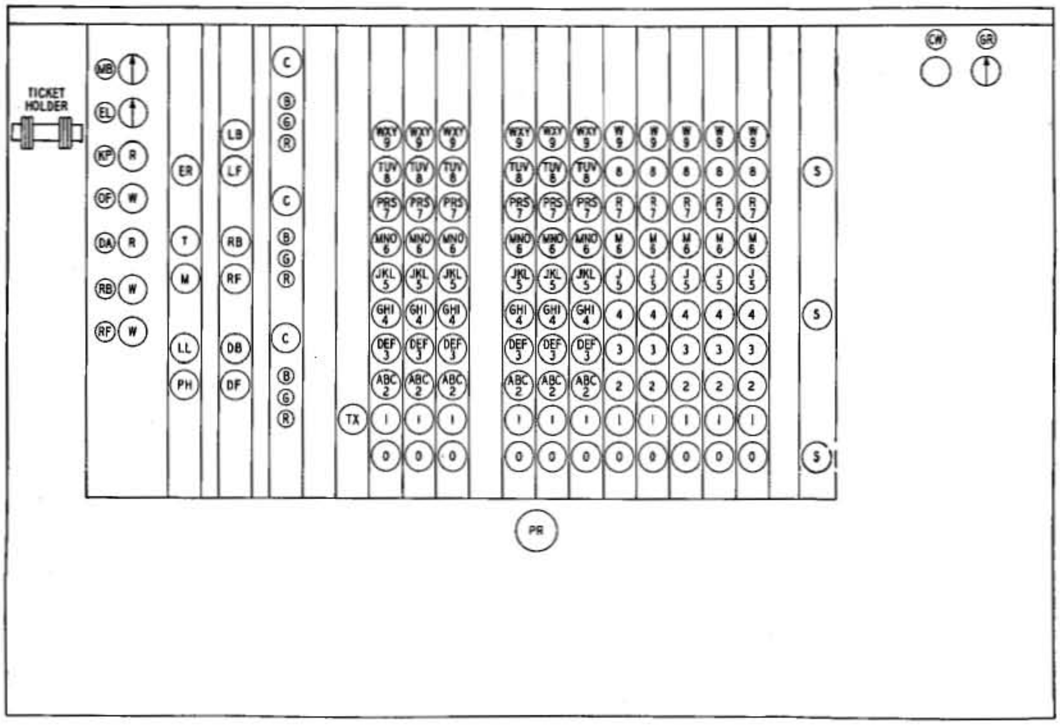


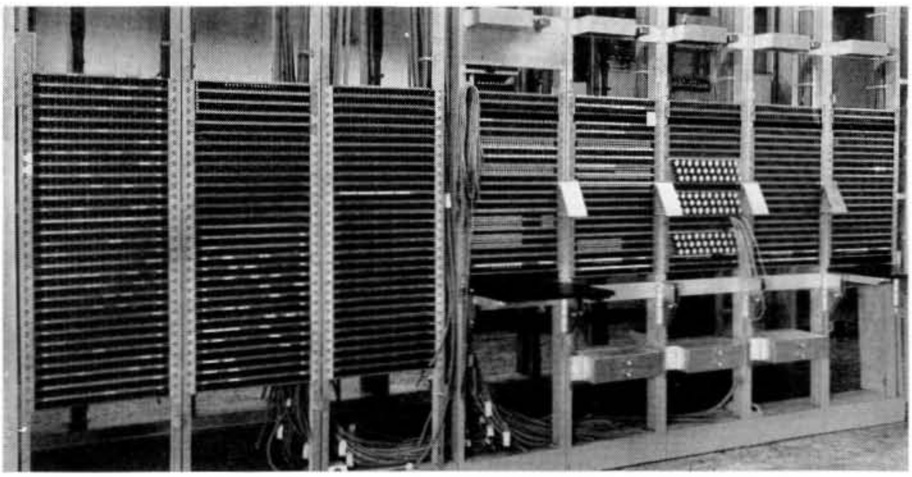
Fig. 2—Plan of key and lamp equipment at a No. 4 position

lamp, OF, as a signal that the condition must be reported to the originating operator by the No. 4 operator.

The five keys in Column 2 are rarely used. The emergency release key, ER, releases the position when it has been locked up by some trouble such as a stuck sender. The monitor key, M, permits the operator to listen, but not to talk, on a loop to enable her to make sure a connection has been properly established. After this key has been depressed, the talk key, T, must be operated if it is desired to restore the talking condition on that call. The LL and PH keys, standing for "loop lock" and "position hold," are used only when conditions make it desirable to prevent the automatic release of the loop and position that occurs under normal operating procedure. The LL key holds the loop and link between the trunk and the position so that supervisory signals may be received. While the loop is locked, the operator may disconnect her headset from it so as to handle other calls by operating PR, and may reconnect her headset by operating the connect key associated with the loop. When the PH key is operated, the position and loop are held only until the PR key is operated.

In Column 1, the RF lamp (recall forward) lights when the outgoing or forward end signals the No. 4 operator, while the RB lamp (recall back) lights when the originating end recalls. The DA lamp (don't answer) lights when a subscriber doesn't answer within 80 seconds after the position has released. The overflow lamp, OF, lights when all the trunks in the called group are busy, as already mentioned, or when all the overflow trunks are busy. The KP lamp (key pulsing) lights after the three code keys have been operated if the code registered indicates that further keying is necessary. The emergency listening key, EL, which is seldom used, connects the operator's headset to the loop when some trouble condition prevents its normal connection, while the MB key (make busy) makes the position busy. The GR key, at the extreme right of the key shelf, groups the position with an adjacent one to make more loops available to each operator during light load periods, and the calls-waiting lamp, CW, which is located to the left of it, indicates that calls are coming in faster than they are being answered.

For a large part of the calls that are switched to a local office in Philadelphia or to a distant toll office without encountering busy groups or other delays, these lamps and keys in the first three columns are not used. They are provided to permit the operator to act promptly and effectively on the smaller percentage of calls that encounter busy groups or that run into other difficulties of one form or another. For most of the calls, the operator is connected to the incoming call automatically, presses keys for the proper connection and is automatically released to be available for the next call.



Assignment patching jack and tandem patch board

Four-Wire Switching for Crossbar Toll

By L. G. ABRAHAM
Toll Transmission Engineering

CROSSBAR toll switching, installed in Philadelphia,* was designed not only to meet present conditions, but also to conform to present trends in toll-system practices. One of its novel features is the use of four-wire switching, which is here employed for the first time in the United States. This feature is expected to prove more and more advantageous as the use of four-wire circuits continues to increase. Most of the longer voice-frequency circuits are already of the four-wire type, and carrier circuits—which are the equivalent of four-wire circuits—are steadily being found economical for shorter and shorter distances as various improvements are incorporated in them. As a result, practically all lines longer than about fifty miles, at least along congested routes, will be of the four-wire type in the near future.

*See page 7.

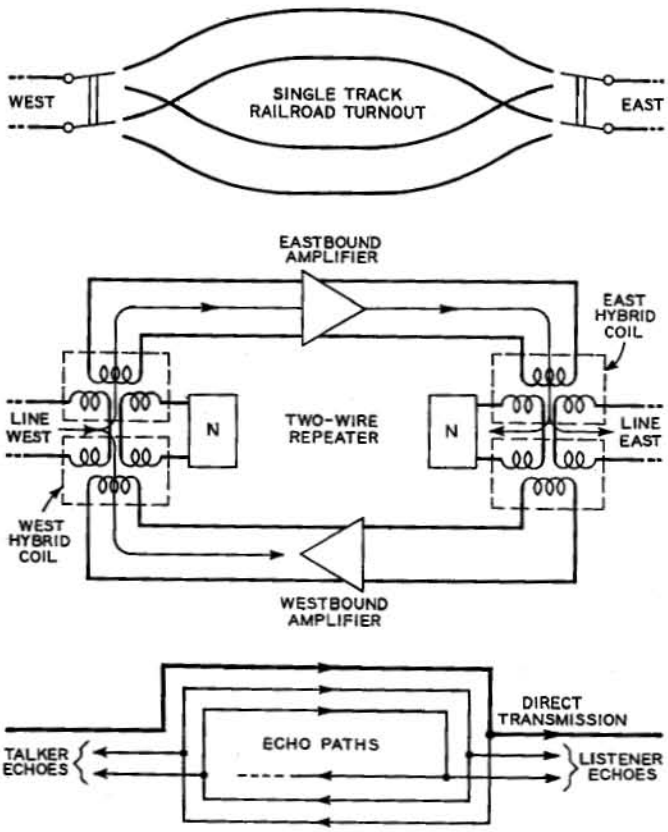


Fig. 1—A 22-type repeater, employing two hybrid coils, as shown in the middle diagram, may be likened to a railroad turn-out, shown in the upper diagram. The lower diagram shows various talker and listener echoes due to imperfect balance at the hybrid coils

This use by the telephone industry of four-wire circuits for its longer toll lines, and two-wire circuits for its shorter lines, including the lines direct to subscriber premises, is similar to railroad practice, which employs double track for the more heavily traveled routes, and single track for the less important branches. The parallel is interesting in spite of the fact that the reasons dictating the needs of a double track are not the same as those leading to the use of four-wire telephone circuits.

With railroads, the difficulties with single track arise from the necessity of permitting trains going in opposite directions to pass each other. Turn-outs are placed at intervals along the line, and by correlating train schedules with the spacing of these turn-outs, a considerable amount of two-way traffic can be handled. The heavier the traffic, however, the more numerous must be the turn-outs, and the more complicated the scheduling becomes as traffic increases, a point is ultimately reached when double track is much more economical.

Two-way telephone traffic, on the other hand can readily pass over a two-wire line, but unless the lines are short, amplifiers are required to make up for the losses suffered by the voice currents in passing over

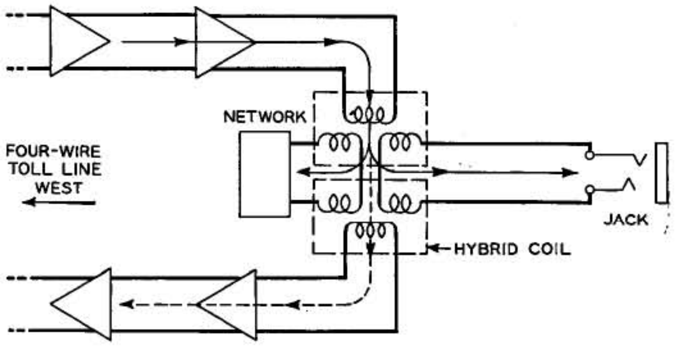


Fig. 2—With two-wire switching, a four-wire toll line must be transformed to a two-wire circuit by a hybrid coil as indicated in the diagram above

them. Since amplifiers increase the amplitude of the speech in only one direction, however, two of them are employed at each amplifying point with devices at each side of them, corresponding to the turn-out switches of the railroads, to allow the output of each amplifier to pass to the proper outgoing line without permitting it to cross to the input of the amplifier for the other direction of transmission. These devices are called hybrid coils.

A repeater with its two hybrid sets is shown in the middle diagram of Figure 1, where the resemblance of the hybrids to railroad switches at the ends of a turn-out, shown by the upper sketch, is obvious. Here the hybrid set is shown as windings on two cores. This is one of the forms commonly employed, but other forms are also extensively used. In the boxes, marked N, are balancing networks, which ideally should have the same impedances as the lines in the two directions. Under such ideal conditions, speech power in the two directions follows the paths of the light lines and arrows. That from the west, for example, divides at the west hybrid—half going to the west-bound amplifier, where it is dissipated, and half to the east-bound amplifier, where it is amplified. The amplified power then divides at the east hybrid, with half of the power going to the network and the other half to the line east.

Equal division between network and line, however, occurs only when the impedance of the network exactly equals that of the line. In practice, a perfect balance is never obtained, and as a result of the lack of balance, some of the east-bound speech passes across the east hybrid to the west-bound amplifier, as indicated by the lower diagram. Here it will be amplified, and will continue westward toward the talker as a "talker" echo. Because of unbalance at the west hybrid, part of this speech will pass across the west hybrid, will be amplified by the east-bound amplifier, and thence will continue over the line to the east as a "listener" echo. This circulation around the amplifying path may continue to form additional talker and listener echoes, but in a workable circuit the succeeding echoes rapidly become weaker and weaker. A similar phenomenon occurs, of course, with the west-bound speech.

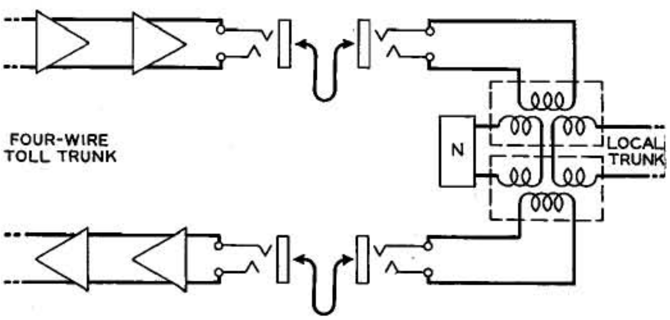


Fig. 3—With four-wire switching, no hybrid coil is required at the end of the four-wire line

How objectionable the echoes are depends on their volume relative to that of the speech, and on the time interval by which they lag behind it. The volume of the echo, with other factors fixed, depends on the loss across the hybrid coil where the echo occurs, which in turn depends on the degree to which the network balances the line.

In any normal circuit, echoes are never allowed to assume objectionable proportions, but the presence of possible echo paths places restrictions on the gain that may be used at the amplifiers, and is objectionable because of these restrictions. In Figure 1, for example, the amount of echo returning to the west talker depends on the value of the net loss from the talker to the repeater and thence back to the talker plus the loss across the hybrid coil at the east side of the repeater. This total loss must be kept great enough so that the echoes are of unobjectionable value. If the loss across the hybrid is low, therefore, the net loss over the two sides of the line must be greater. This means that the gain supplied by the amplifiers must be kept below a value determined by the loss in the section of the line to the west of the repeater.

Whenever the networks are permanently associated with their line, such as at repeaters, they may be of the precision type, and the balances will be very good. With short lines, therefore, having only one repeater, the echoes are not ordinarily objectionable because both the volume of the echo and the time interval will be small. With long lines and several repeaters, on the other hand, there are echoes from each repeater, and for some of them the time interval may be relatively long. While each echo may be no greater than with a single repeater, the greater number of them, and the longer time intervals involved, may make them quite objectionable.

It is largely because of this multiplying of echoes on two-wire lines that four-wire circuits are preferred for the longer lines. With four-wire circuits, a separate pair of wires carries the speech in each direction, and each pair of wires has its own one-way amplifiers. No hybrid coils are required at the amplifiers, and thus echoes from repeaters are avoided.

Since subscriber lines are of the two-wire type, however, and since until comparatively recently most of the toll lines also were two-wire, switching has been done on a two-wire basis. At toll offices where the circuits are switched, therefore, four-wire toll lines must be reduced to two-wire circuits, as shown in Figure 2. The balance in such situations is not very good, however, because the two-wire lines that may be connected at the right are of different impedances because of varying lengths and types of circuit. It is not practicable to change the network for each connection, and so a compromise network is used. As a result, the balance is poorer, and the loss across the hybrid is less.

By using four-wire switching, however, there is no hybrid coil at the end of the four-wire line where an echo could occur. If the line were to be switched to another four-wire line, there would be no hybrid coils at all involved at the switching office. When it is switched to a two-wire line, however, hybrid coils must be used at the end of two-wire circuits to provide a four-wire termination as shown at the right of Figure 3. Since the network under these conditions is permanently associated with the line, however, it may—except for very short lines—be of the precision type, and thus the loss in the echo path is high, and the conditions are better than those shown in Figure 2.

With a poor balance at the hybrid of Figure 2, because of the use of a compromise network, the net loss of the four-wire circuit to the switching point must thus be relatively high, and if the listener at the end of the two-wire trunk switched to the four-wire circuit at this point is to receive adequate volume, the loss in the two-wire trunk must be relatively low. With four-wire switching

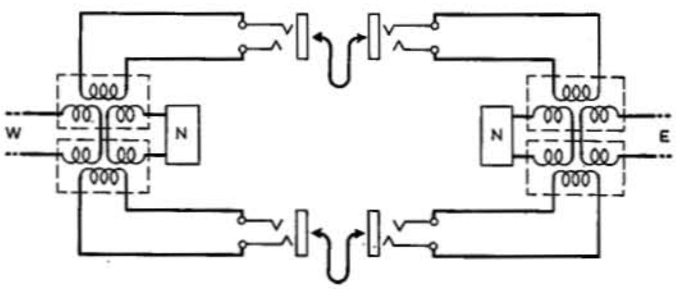


Fig. 4—When two two-wire circuits are to be connected by four-wire switching, the loss in the hybrid coils at the ends of the two-wire lines are made to cancel

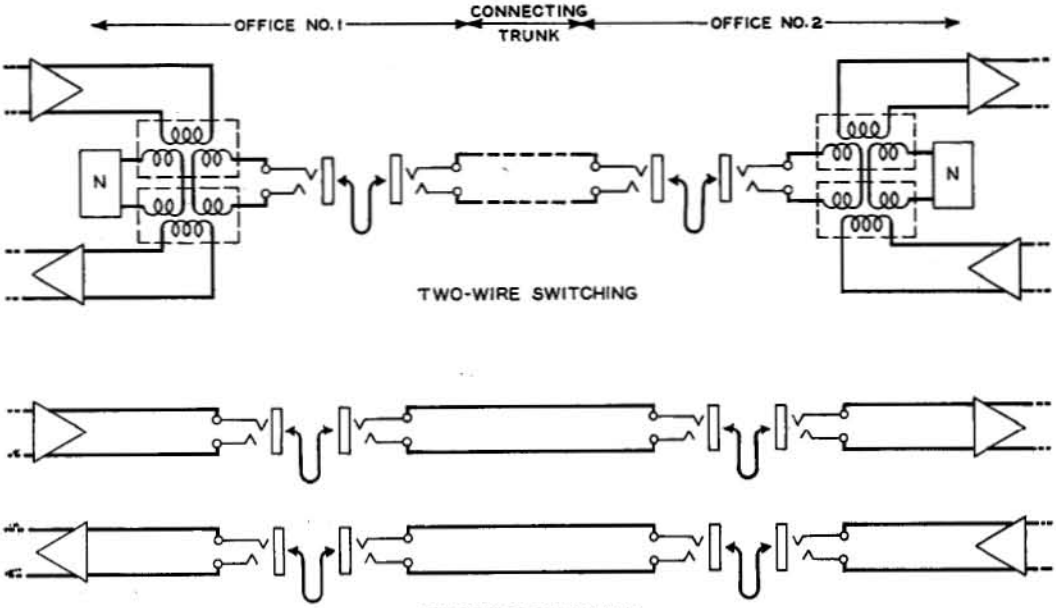


Fig. 5—Where four-wire switching is used in large cities with two or more toll offices, a through four-wire circuit is possible as shown in the lower sketch, and thus there are no hybrid coils to cause echoes. With two-wire switching as shown in the upper diagram, however, two hybrid coils are involved

as indicated in Figure 3, on the other hand, the net loss of the four-wire circuit to the switching point may be made relatively low because of the good balance of the hybrid coil of the two-wire line. As a result, the loss in the two-wire trunk may be relatively high and still allow ample volume of the speech at the listener station. Since high-loss lines may employ smaller conductors or fewer repeaters, and in general be less expensive, economies are secured by any arrangement that permits a more extensive use of them. Four-wire switching as adopted in the No. 4 toll switching system is thus advantageous in permitting a more extensive use of high-loss, and thus less expensive, two-wire circuits at the ends of toll connections.

With four-wire switching, all two-wire lines must be equipped with hybrid coils. This might seem to work a hardship on four-wire switching when two two-wire circuits are to be switched together without repeaters, as shown in Figure 4, since two hybrid coils will be required at the switching office, and a hybrid coil ordinarily introduces a loss of 3 db because speech energy coming up to it is divided into two equal parts, only one of which is ordinarily usable. With the conditions shown in Figure 4, however, speech coming in from the west divides at the hybrid—half passing over each branch—and reaches the east hybrid. By properly poling the connections at this hybrid, the energy in the two halves may be made to add in the east-bound line, and thus the usual 3 db loss in each hybrid is cancelled.

When two high-loss two-wire circuits are switched together, additional gain is required. In this case, amplifiers may readily be "switched in" between the four-wire branches of the two hybrids.

Four-wire switching will be particularly advantageous in large cities having two or more separate toll offices. With two-wire switching, the trunks interconnecting the toll offices introduce additional net loss, since gain cannot be added in the toll circuits because of the poor balances at the hybrid coils in each office. The arrangements for two-wire and four-wire switching are indicated in Figure 5. With four-wire switching, no hybrids are involved at all, and thus the loss between two offices may be offset by removing pads at the four-wire repeaters.

A further improvement from the use of four-wire circuits is possible from a reduction in the number of echo suppressors required in tandem. With four-wire circuits and four-wire switching, only one echo suppressor would be required for any one connection, while with two-wire switching they may be in the circuit between each two switching points. When only one echo suppressor is employed, "lock-outs" and other objectionable features associated with voice-operated devices are eliminated.

Taken all in all, the advantages of four-wire switching are considerable. Many terminal repeaters may be eliminated, and all that will be required in their place are a few switched-in repeaters that will be used for only a relatively few connections where two high-loss circuits are connected together. In addition, less expensive, high-loss connecting lines may be employed because available gain can be used, which is not possible with the poor balances present with two-wire switching. As the telephone plant comes to be operated more completely on the four-wire basis, there will be fewer limitations on improvements in the use of telephone conference circuits and on future developments such as automatic alternate routing of toll connections. At the same time, the reduction in echoes will result in better overall transmission.

Assignment distribution frame for crossbar toll

Nation-Wide Dialing

By F. F. SHIPLEY
Switching Engineering

ALONG with the rapid conversion from manual to dial switching for local calls, there is a growing trend toward dial switching for toll calls. The ultimate goal is to permit the subscriber either to give his toll calls to an operator who will complete them without the aid of operators at the intermediate or terminating offices or to dial his own toll calls directly. Although the arrangements now under development are intended primarily to permit the necessary dialing to be done by an operator at the calling end, the facilities and circuits will be so planned that direct dialing by the subscriber may be readily added to whatever extent future conditions should warrant. With either operator or subscriber dialing, the time required to complete long distance calls should be very short—perhaps five seconds from the time a toll circuit is secured until the called telephone is rung. To realize such an objective, a general toll switching plan must be adopted, and the direction of future development must conform with it. Such a plan has been under discussion for some time, and agreement has been reached as to its broad outlines, although considerable work remains to be done to develop instrumentalities and to fill in the many details.

At present, most long-distance traffic is handled by manual switching methods, that is, an operator is required to establish the connection at each toll office through which the call must be switched. Before the war, some progress had been made in mechanizing toll switching. Several toll dialing networks of limited scope had been established, but except for the crossbar office installed a few years ago in Philadelphia, all of them are of the step-by-step type, and toll dialing is generally limited to direct and one switch calls. Plans are now under way to insure that the expansion of toll dialing will be guided by principles in harmony with the ultimate incorporation of all networks into an integrated network of nation-wide scope.

In formulating a plan for nation-wide dialing, the first essential is that the digits used by an operator to reach a particular subscriber must be different from those used to reach any other subscriber in the country. As long as all switching was done manually, possible conflicts in numbering could be avoided merely by seeing that no two subscribers served by the same office were assigned the same number, and that no two offices in the same city or numbering area were assigned the same name. After conversion to dial operation, however, it becomes necessary in the larger cities for the subscriber to dial a portion of the office name in addition to the numerical part of the listed number, and this leads to further restrictions. Under manual operation, one office could be named Adams, and another Beacon, but a glance at the dial, Figure 1, will show that with dial operation, where the first three letters of the office name are dialed, this is not possible because the digits would be the same for both offices.

It will also be noticed that letters useful for office names appear in only eight of the holes on the dial. The "0" position was reserved so the subscriber could dial the operator for assistance with a single pull of the dial, and the first position was avoided because of the danger that a fumble of the switchhook might produce a false pulse and result in a wrong number. With only eight positions available, the number of useful office names producing non-conflicting codes proved inadequate for New York, and to obtain relief, numerals instead of letters were assigned to the third position. When this is done, it is possible to have ADams 2 and BEacon 3 or, for that matter, ADams 2 and ADams 3 without conflict. For toll routing purposes, it is proposed to set up numbering areas on a similar basis but not to change subscribers' directory numbers or their method of dialing local calls.

Under this scheme, the theoretical number of local offices that could be included in a numbering area would be 8 x 8 x 10 = 640 and, since the capacity of an office is 10,000 lines, the theoretical capacity of a numbering area would be 6,400,000 subscribers. Practically, the capacity is far below this.

Fig. 1—The telephone dial has letters used in office names in only eight of the ten finger holes

Only about 500 office codes are useful for office names, and very few offices are filled to 10,000 lines. Many offices are in small towns that will never have more than a few hundred lines.

Making proper allowances for these factors, it has been estimated that between fifty and seventy-five numbering areas should be adequate for the United States and Canada with a telephone population many times the 26,000,000 of today. How the country might be divided into such numbering areas is shown by Figure 2. The final division will undoubtedly vary considerably from this.

With fewer than 100 numbering areas, and with each area on a seven-digit basis, it is obvious that by assigning a two-digit toll code to each numbering area, nine digits are sufficient to give every subscriber a toll number not conflicting with that of any other subscriber. For routing purposes, however, it is desirable that a toll code should include something to distinguish it from a local code so that only seven digits may be used for calls to points in the same numbering area without leading to confusion with codes for distant numbering areas. It has already been pointed out that neither "1" nor "0" appears in the first two places of a local office code, and it is therefore feasible to let the presence of either of these digits in the first or second position indicate a toll call outside the local numbering area. It is tentatively proposed to use a "1" in the second place as the distinguishing mark of such a call. The first three digits for a call to toll area "75" would thus be "715."

Exclusive of party letters, the number of digits required as the basis of a nation-wide dialing plan is thus ten. The full ten digits will be used, however, only when the call received at a toll office must be switched to a distant numbering area. If the originating operator is in the same numbering area as the called point, or if she can plug into a circuit that goes directly to a toll office in the desired area, she will need to dial not more than seven digits.

To provide a code structure, however, is only the first step in working out the plan. Some of the other difficulties involved may be illustrated by considering how a multi-switch toll call would be handled if all toll

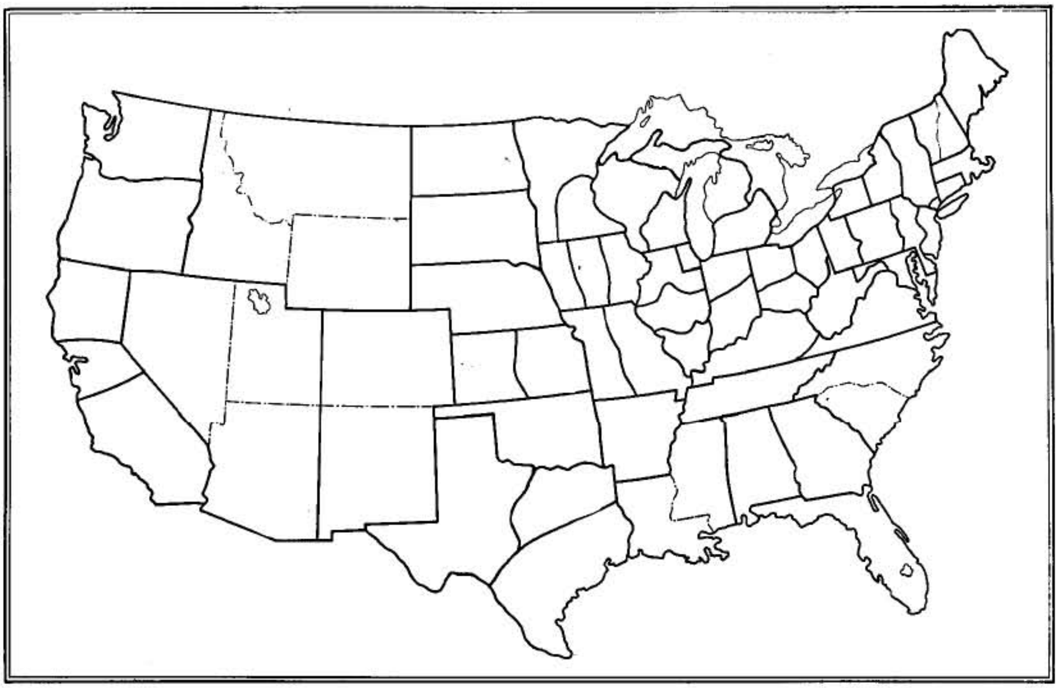


Fig. 2—One possible division of the country into toll dialing areas

offices were equipped with step-by-step switches. A step-by-step switch is driven directly by dial pulses to a level corresponding to the number of pulses in the received digit, and then hunts for an idle circuit on that level. In step-by-step toll-dialing offices, toll lines are reached from the "0" level, and two more digits are required to complete the selection of the toll circuit. Nearby tributary offices are reached from the "1" level, and two more digits are also generally required to reach them. Thus the toll code "053" would drive one switch to the "0" level, the next switch to the "5" level, and the third switch to the "3" level, where a toll line in the desired group would be found. In the process of establishing the connection through the office, however, these three code digits have been expended, and no record of them is kept to make it possible to use them again for controlling succeeding switches. When a call is dialed through a number of step-by-step offices, therefore, three digits have to be dialed for each office passed through in addition to those that are utilized in identifying the office and subscriber at the called end of the line.

This would result in a very long series of digits if step-by-step switches were used in the offices through which the call passes. Suppose, for example, that a subscriber in Portsmouth, N. H., were calling a subscriber in Vinland, Kansas, and that the routing was as shown in Figure 3, with step-by-step switches in all the toll offices. The Portsmouth operator would first have to find out the code to be used at each switching point, and then, selecting a tunk to Boston, would have to dial 053 062 078 026 138 1234. Not only would there be the delays required in finding out the proper code to dial at the various offices, but the dialing of a sequence of nineteen digits is very undesirable. This is one of the reasons why with present practice toll dialing is limited to direct and one switch calls.

How the same call would be handled under the proposed plan, with common control equipment provided where it is needed, is shown for an assumed routing in Figure 4. The Portsmouth operator instead of being required to find out the code to be used at each switching point needs only the code for Vinland, i.e., 316VI6. This code would be the same no matter where the call originated. She selects a trunk to Boston and keys 316VI61234 into a sender in Boston. The sender gives the code 316 to the marker, causing it to select a toll line to New York, and then spills the complete number into a sender in New York. This process is repeated through New York and St. Louis to Kansas City. The equipment at each switching point knows that 316 is the code for eastern Kansas, and selects the best route for getting there.

When the translator in Kansas City receives the 316 from the sender, it requires further information to enable it to select the proper route because it has direct circuits to several points in that area. It, therefore, asks the sender for the next three digits and uses them to route the call to Lawrence, telling the sender to drop the first three digits and transmit the remaining digits forward. The digits VI6 drive switches in Lawrence to the selection of a Vinland trunk and the 1234 drive switches in Vinland to the subscriber's line. The symbol for step-by-step equipment is used at Lawrence and Vinland to indicate that senders are not required at those places since the digits received there do not have to be reused.

If the toll lines from New York to St. Louis are all busy, the call is automatically routed through Chicago, where it may be routed to Kansas City directly or, if the Chicago-Kansas City toll lines are all busy, by way of St. Louis. This is possible because, as already pointed out, no matter where the code 316VI6 is received, it always means Vinland in eastern Kansas, just as within the New York local numbering area PE6 always means the Pennsylvania 6 office no matter which local office is the originating point.

Although in the example used the call was handled by an operator, it will readily be seen that the fundamental toll switching arrangements would be no different if the subscriber had dialed his own call into a sender in Portsmouth. It is contemplated that future toll developments will follow a pattern that will place no impediment in the way of long-distance dialing by subscribers.

The essential feature of the toll switching equipment that enables any place in the country to be reached with no more than ten digits is the ability to use a code for routing purposes, and then to transmit the same code forward to be used again as often as needed. Another important feature is the ability to choose one or more alternate routes automatically. Both of these features are characteristic of common control switching equip-

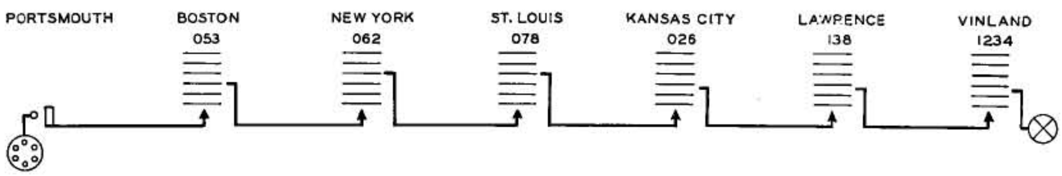


Fig. 3—Routing and codes for a toll call from Portsmouth, N. H., to Vinland, Kansas, if step-by-step switches were used at each switching point

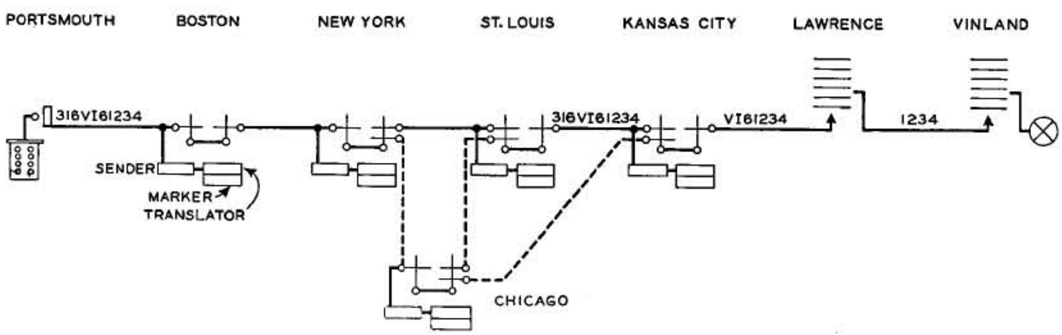
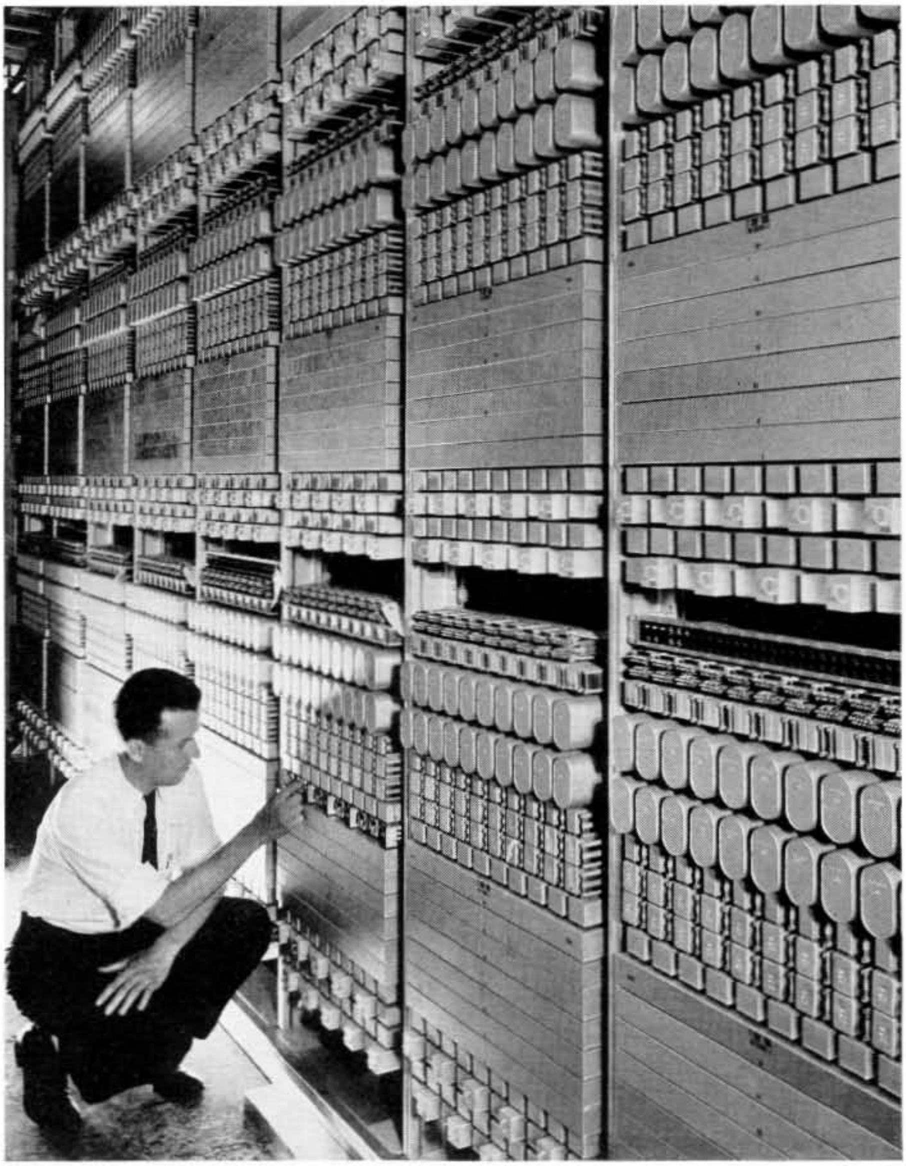


Fig. 4—Routing and codes for the call of Fig. 3 as it might be handled under the proposed nation-wide dialing plan

ment but not of step-by-step equipment. Successful operation of the plan thus requires that common control equipment be provided at many places where connections between toll lines are made. To accomplish this it is estimated that not more than about one hundred and fifty such installations would be required.

Adoption of the proposed toll-switching plan will result in simplification of routing instructions for operators, a considerable saving in operating labor, and an improvement in speed of service. The most notable effect on speed of service will be a reduction in the difference between the average interval now required for establishment of a multi-switched connection and that for a direct or single-switched connection.



Switching trunk relay equipment for crossbar toll