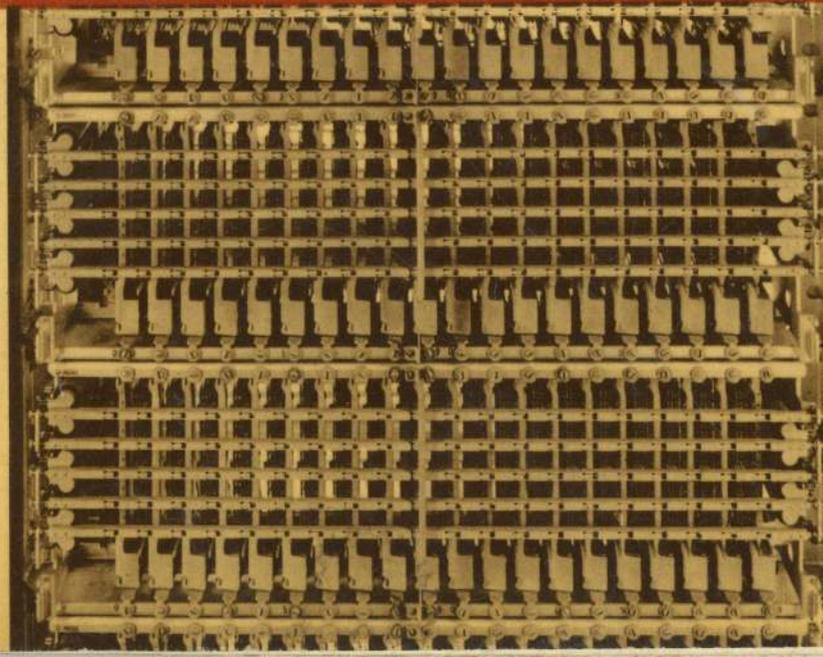
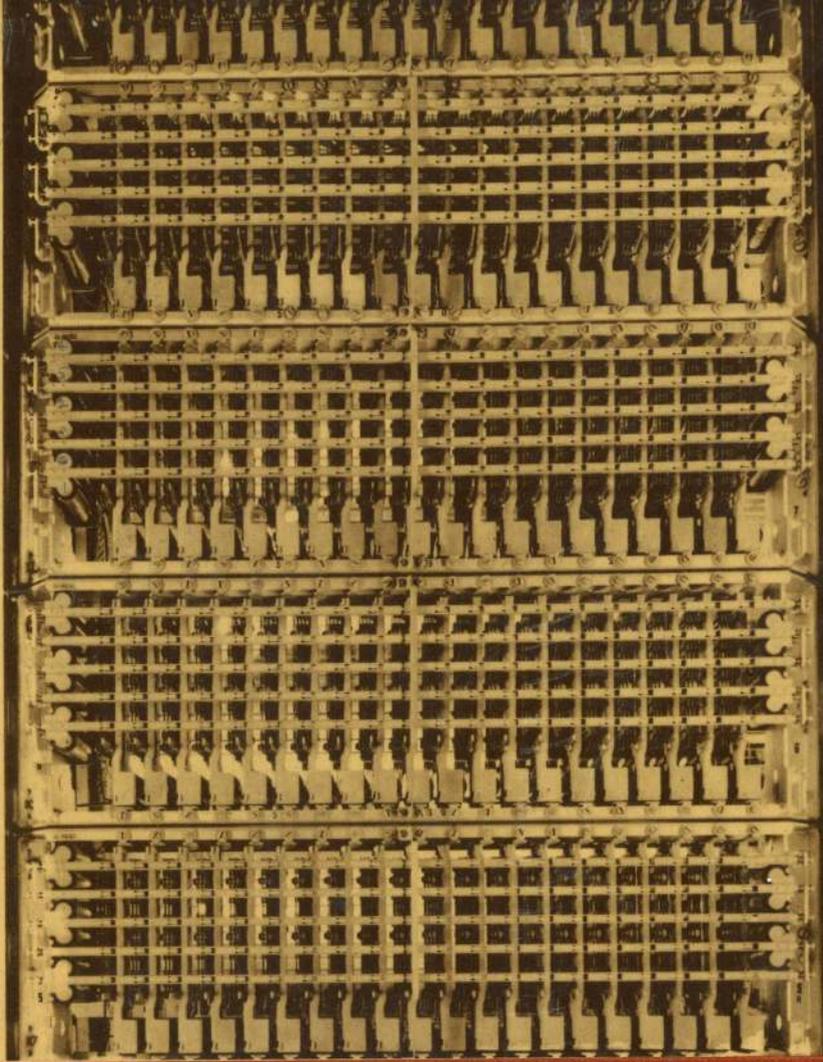


*Kaltrax*

*1944*



# CROSSBAR

CROSSBAR

# THE CROSSBAR SYSTEM

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# The Crossbar System

By R. C. DAVIS

THE crossbar switch\* has given the Telephone Systems engineer a valuable tool for use in the complex problem of completing dial subscribers' connections. This tool has been found to have advantages in many respects over switching mechanisms used in other systems, but its application also has presented many problems. Both the step-by-step and the panel systems employ selectors for establishing a connection between two subscribers. These selectors are radically different both in their construction and their method of control, but they are alike in employing a brush or wiper that moves over a large number of terminals until the desired one is reached. The crossbar switch is not of this nature at all; it is a group of magnetically operated contacts, any desired one being made by the operation of two magnets in rapid sequence. Since there is no passing of a brush over a sequence of terminals, an entirely different method of controlling selections has been developed, so that the crossbar system differs from previous dial systems not only in the type of apparatus employed, but in the method of control.

In the step-by-step system the operation of the subscriber line relay causes a line finder to connect itself to the line. The line finder has a first selector directly connected to it, and the first digit dialed by the subscriber causes the first selector to step vertically up to the level corresponding to

the digit dialed, after which it rotates horizontally to find an idle trunk to a second selector. Each successive selection is made in this fashion with the selectors directly responsive to the subscriber's dial. In the panel system the operation of the subscriber line relay also causes a line finder to find the calling line and the line finder is directly connected to a district selector. In this system, however, a subscriber's sender is also connected to the line through the district selector and a link circuit, and the digits dialed by the subscriber are recorded in the sender. The sender then is connected through a connector to a decoder, which translates the office code into brush and group selections of the district and office selectors. The sender then proceeds to set up the call through the district, office, incoming, and final selectors to the called line, after which it is released. Control of these selections is over the trunk conductors which are later used for speech transmission.

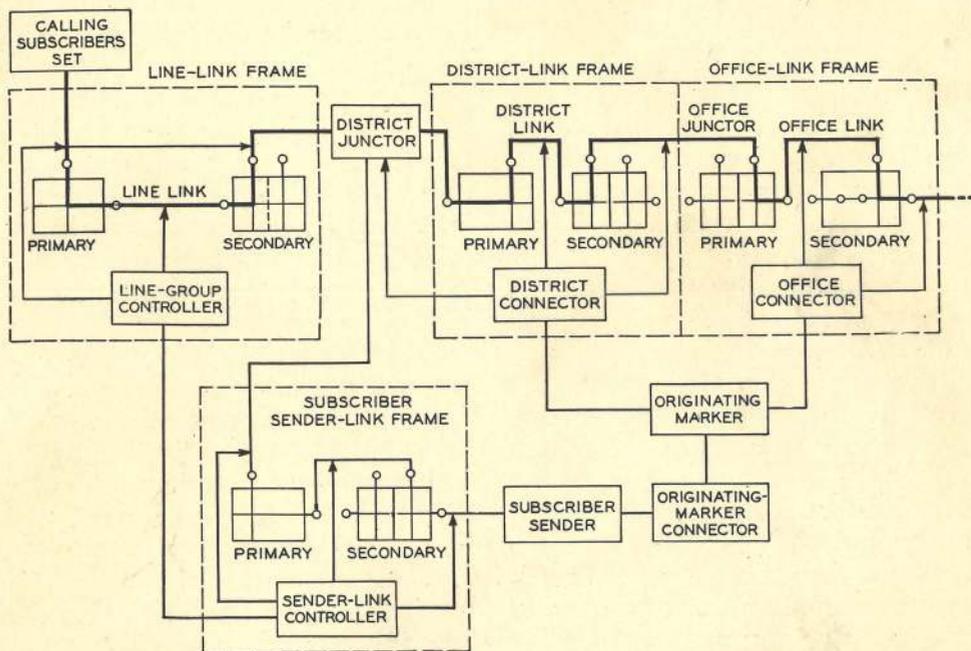
The selectors in both the step-by-step and panel systems are provided with control equipment individual to the selector for selecting the brushes or groups of bank terminals and for moving the brushes over the terminals by impulse control, directly by the dial in the step-by-step system and by the sender in the panel system. Individual equipment is also provided in these selectors for moving their brushes over the terminals to hunt for idle trunks. This necessarily means

\*Page 60, "The Crossbar Switch."

that considerable equipment is provided in these circuits which is used for only a few seconds at most in setting up the connection; and since this equipment is individual to the circuit, it is not used again until disconnect by the subscribers takes place and a new call is set up. In the crossbar system, however, economic advantage is taken of the high-speed relay-like operating characteristic of the crossbar switch by putting all of the selecting and trunk-hunting features in a few common control circuits. This greatly simplifies the individual district and incoming trunk circuits, and in addition it entirely eliminates individual relay equipment in the crossbar circuits corresponding to the office and final selector circuits in the panel system.

The switching frames of the crossbar system are known as the line-link, the district-link, the office-link and the incoming-link frames. The district, office, and incoming-link frames perform the same switching func-

tions as the district, office, and incoming-selector frames of the panel system, but the line-link frames are used for connecting the lines to districts on originating calls and for connecting the trunks from incoming frames to the lines on terminating calls, thereby performing the functions of both the line finder and final frames of the panel system. Each of these crossbar frames consists of primary and secondary switches. The connections from the primary to the secondary switches of the same frame are known as "links" and the connections between frames are known as "junctors." Each primary switch has links to each of its associated secondary switches, and the junctors outgoing from each district and incoming frame are distributed evenly over all office and line-link frames respectively. Similar primary-secondary switching arrangements are used in the sender-link frames for connecting subscriber senders to district junctors and terminating senders to incoming trunks.

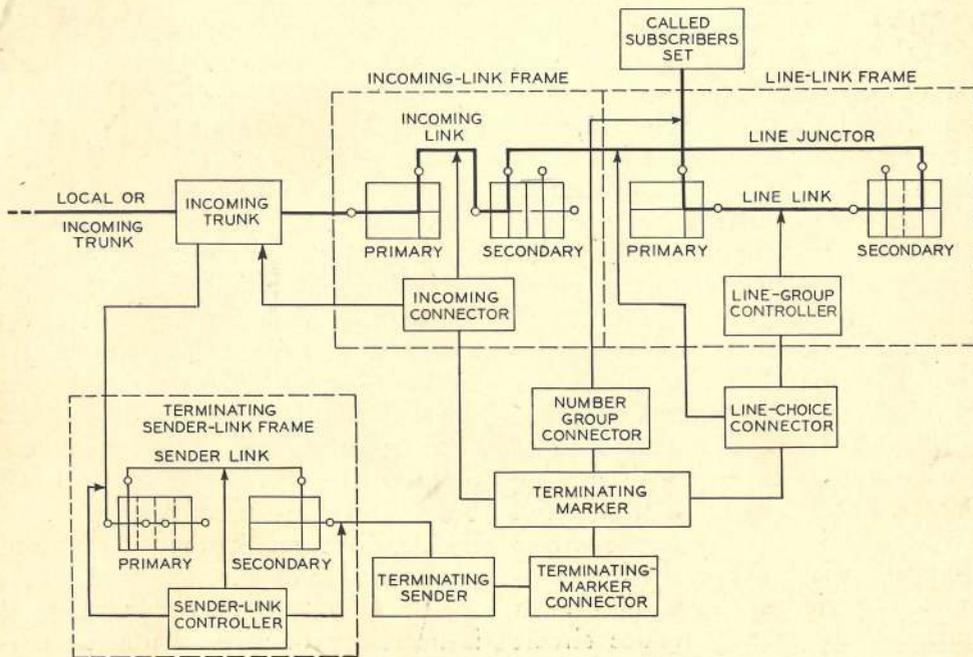


The path of a subscriber-to-subscriber call through the various elements of the crossbar system is shown in the diagram. When the calling subscriber removes his receiver, the operation of his line relay actuates a line-group and a sender-link controller circuit, each of which is common to an entire frame. These controller circuits select an idle line link, district junctor, sender link, and sender, and operate the necessary select and hold magnets to establish the connections. Approximately 0.6 second is required to complete this connection, after which dial tone is sent to the subscriber, and the control circuits are free to serve another call.

The subscriber sender in the crossbar system is fundamentally the same as the panel subscriber sender except that it does not itself control the district and office selections. The sender picks an idle originating marker and passes the code of the called office as is done in the panel system, and in addition also passes other informa-

tion on to the marker which will be needed by its added function peculiar to crossbar operation. This added function is known as a marker operation and consists of picking an idle trunk to the called office and then picking idle paths through the district and office-link frames for connecting the district junctor to the trunk selected. When these functions have been performed the marker operates the proper select and hold magnets to close the cross-points and establish the connection to the selected outgoing trunk. After getting its check signal that the cross-points are properly closed, the marker is available for the next call that comes in. The marker completes its function in approximately 0.5 second.

After the district junctor has been connected to a trunk to the called office, which we will assume is a crossbar office, the subscriber sender closes a bridge across the trunk conductors, which operates the line relay of the incoming trunk circuit and causes



a sender-link controller circuit to connect a terminating sender to the trunk through a crossbar link in a manner similar to that in which the line-group controller circuit operates. When the terminating sender is connected to the trunk, the record of the called subscriber's number is transferred to it by the subscriber sender over the trunk conductors.

The terminating sender then passes the record of the called subscriber's number to a terminating marker, which in turn tests the called line for busy and, if it is found idle, picks idle paths from the incoming trunk to the subscriber's line in a manner similar to the connecting of the district junctor to the selected out trunk by the decoder marker. The marker makes the busy test and determines on which line-link frame the line is located through a frame known as the Number Group connector frame, and then connects to the desired line-link frame through a frame known as the Line Choice Connector frame. The subscriber sender is released when the record of the called number has been passed to the terminating sender, and the terminating sender and marker are released when the connection has been established. The marker completes its function in about 0.5 second.

There are a number of reasons why those engineers who have followed the development of the crossbar system feel that it will render a grade of service superior to any previous system. The switches themselves are provided with split springs equipped with noble metal contacts so as to provide double assurance of making contact. Practically all of the control relays used in this system are also equipped with the split-ring contacts. Experience shows that such contacts very greatly reduce circuit

failures caused by contact trouble.

Marker operation, which is made especially attractive with this switch on account of its high speed of operation, is also an important element of the crossbar system. With this operating method it is possible to make a second attempt on many of the trouble conditions encountered, and on many such calls the connection can be established on the second attempt over another path with such speed that the subscriber is not aware that any trouble has occurred. In addition to serving the call on the second attempt, a record is made of the failure of the first attempt on a trouble indicator which attaches itself to the marker on all circuit failures. This trouble indicator will be of considerable aid to the maintenance man in quickly removing conditions causing circuit failures. In other dial systems where connections are established by moving brushes over bank terminals many time elements enter into the proper functioning of the system. Due to the simplicity of the crossbar switch itself and the marker method of operating it, many of these time elements are entirely eliminated. These factors are important in reducing maintenance effort.

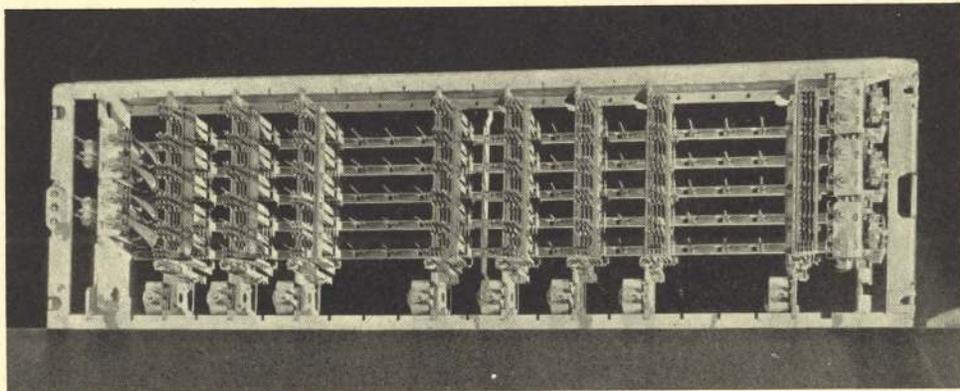
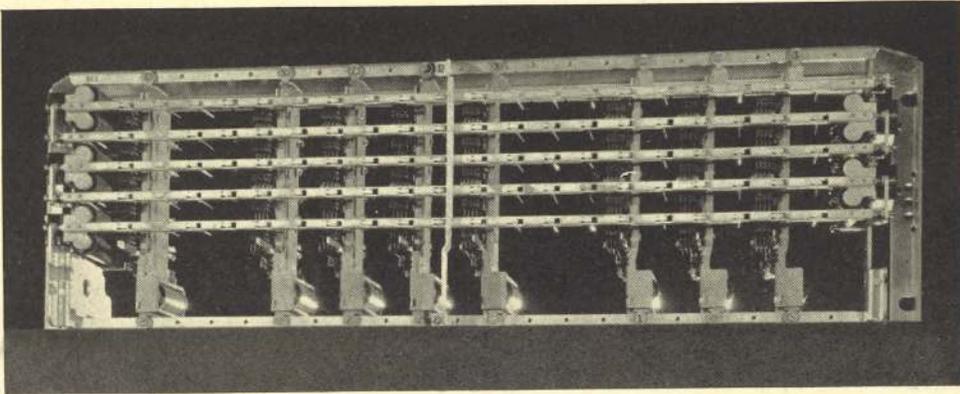
In addition there are many new operating features in the crossbar system. With marker operation, the desired trunk or line is tested before the connection is set up, which permits rerouting the call when it is desirable to do so. This is advantageous for rerouting interoffice calls to alternate trunk groups through a tandem office where the regular group is all busy, and thus permits the use of smaller direct trunk groups by routing peak-load traffic through tandem. In the step-by-step and panel systems it is necessary to wire all unused sub-

scriber line numbers to trunks to the intercepting operator, but in the crossbar system calls for unused line numbers are rerouted to intercept trunks merely by the absence of the regular jumpers on the line number terminals. It is possible to spread large interoffice trunk groups over all office frames, and large and busy PBX trunk groups over all line frames for better balancing of loads. The system can be introduced into a panel area without change in the connecting offices or subscriber sets.

The design of the crossbar switch and multi-contact relay is such that

less adjustment is necessary after they are assembled. The crossbar switch frames can be equipped with all apparatus and wired and tested in the shop, by progressive straight-line manufacturing methods, thus completing a large proportion of the work before shipment to the job.

Because of the flexibility of the sender, decoder, and marker, and the simplicity of operation of the crossbar switch, together with its precious metal twin contacts, it is quite certain that the apparatus and the principles developed will find many uses in future switching problems.



*The crossbar switch used in all the major frames consists of twenty vertical units and five crossbars, as described more fully on page 60. Each of the verticals is a self-contained unit, and the construction of the switch can be more plainly seen when some of these units are removed, as in the above photographs. The upper photograph shows the front side of the switch and the lower, the rear*

# Crossbar Trunking

By L. E. KITTREDGE

THE basic switching element of the crossbar system is the individual vertical unit of the crossbar switch. This unit consists of ten sets of contacts, and gives an incoming circuit connected to the vertical multiple access to ten outgoing paths. Any one set of contacts is closed by the operation of one of ten select magnets and of the hold magnet individual to the particular vertical unit. Since a single group of select magnets serves all the vertical units of an entire crossbar switch, these magnets cannot be put under the control of a single vertical unit, and so a control circuit common to at least all the units of a crossbar switch is

first finds the jack of the calling line and plugs into it to get the number wanted. She then finds the jack of an idle trunk to the office called, and repeats the number wanted to the B operator there. As the final step, this B operator finds and plugs into the jack of the line called.

In the panel system these steps are first the connection of the line to a sender, then the selection of an outgoing trunk, and finally the finding of the called line. At each stage the various selectors must hunt—in one or more steps—over groups of terminals to find an idle path to the next stage. In an extremely simplified form, the panel trunking scheme could be represented as shown in Figure 1, where the three sets of operations are indicated by enclosing dotted lines. Each calling line has a number of the A selectors that can serve it, and the first selection is the choosing of an idle one. Once chosen, this selector hunts for and makes a connection to the calling line, and at the same time the B selector hunts for and connects to an idle sender. This completes the first set of operations. After the sender has received the office code, the C selector on the district frame hunts for an idle trunk to an office frame, where the D selector hunts for an idle trunk to the office called—thus completing the second set of operations. At the office called, in a somewhat similar manner, the E and F selectors hunt successively for idle paths—the E selector on the incoming

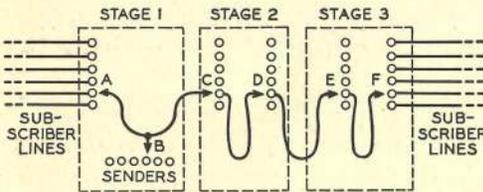


Fig. 1—Simplified representation of trunking in the panel system

necessary. Actually, a single control circuit guides the selection of all the units of one or more entire frames of crossbar switches. The many novel features of the crossbar system arise to a large extent from this use of common controller circuits.

The completion of an ordinary local call may be divided into three sets of operations. With the manual system, to take the simplest case, an operator

frame for an idle path to the final frame, and the *F* selector, on the final frame, for the line called.

It should be noted particularly that the *A* selector is chosen without knowing whether or not an idle sender is available to it. Likewise the *C* selection is made without knowing that the *D* selector can find an idle trunk; and the *E* selection is made without knowing whether or not the *F* selector will find the line idle.

In contrast with this method, which to a large extent would apply also to either the manual or the step-by-step system, the crossbar system makes sure that an idle outgoing channel is available before it seeks for an idle channel through the crossbar switches of each stage. At the first stage the line-frame controller circuit, when a call is placed, first tests for the calling line and then for an idle district junctor that has an idle sender available. Having located these two suitable end points, it proceeds to find an idle path between them through the crossbar switches. Another controller circuit for stage 2 finds the chosen district junctor, an idle trunk to the desired office, and then determines an idle path through the crossbar switches of stage 2 that is available for connecting these two circuits. This procedure is then repeated for stage 3, and only after idle paths are found is the talking path established.

In previous dial systems the various selections, both within and between the three major stages, are made one after the other in direct

sequence from the calling to the called subscriber. In the crossbar system, on the other hand, the selection of the talking path is guided by three common controller circuits, one for each of the major stages. These circuits first locate the required incoming and outgoing circuits for that stage, and then find an available

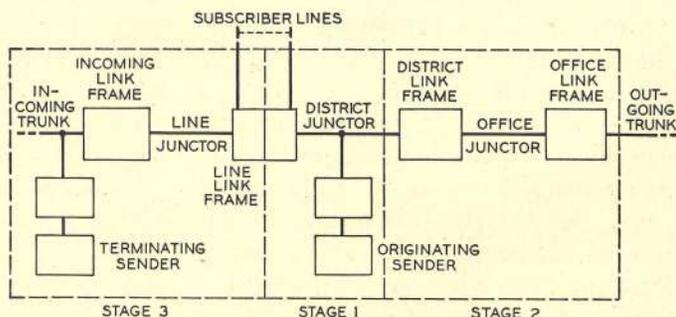


Fig. 2—Schematic of crossbar system showing the major switching frames

path through the crossbar switches comprising that stage. An additional controller is employed in stages 1 and 3 for guiding the selection of an idle sender, two of which are usually employed instead of one as with the panel system.

There are four main types of switching frames in the talking path of the crossbar system: the line link, the district link, the office link, and the incoming link. The line-link frame, however, serves both for originating and for terminating calls, and thus functionally may be considered as two frames, and in addition there are two sender-link frames. The first stage employs the originating half of a line link and originating sender link; the second stage employs the district and office links; and the third stage employs the incoming link, and the terminating half of a line link and in addition a terminating sender link for connection to a terminating sender.

These three stages may be subdivided to indicate the various frames as shown in Figure 2. A call from any subscriber's station may go to another station in that same office or to one in a different office, but in either event it passes through an incoming frame and a line frame. Stage 3 of Figure 2, therefore, might be in the same office as stages 1 and 2, or in a different one. This diagram also shows the terminating sender as well as the originating sender.

The selections in stage 1 are accomplished by the line-link and sender-link controller circuits. For the second stage selections, the originating marker is used, while the third stage uses a terminating marker. A sender-link controller is also used to attach a terminating sender.

As already noted, common controller circuits are employed instead of a selecting mechanism in the individual switching unit of the crossbar switch. A panel selector has access to 500 terminals, and thus inherently has the ability of hunting over large groups. With the crossbar unit, having only ten choices, the group would have to be very small, and thus inefficient, were it not for the selecting scheme adopted, which permits paths through several crossbar switches to be tested simultaneously.

This scheme can be most readily seen in

connection with stage 1, shown in Figure 3, where only a single frame of crossbar switches is employed in the talking path. Each line has a choice of ten paths, because of the ten-point vertical unit, and each of these paths, through the secondary switch, may be connected to any one of a group of ten district junctors. If the first path were chosen blindly, with the knowledge only that that path was not in use, further choice would be limited to only ten district junctors—the selection at each step being over a relatively inefficient group of ten.

It will be noted, however, that each of the horizontal circuits of any one primary switch runs to a different

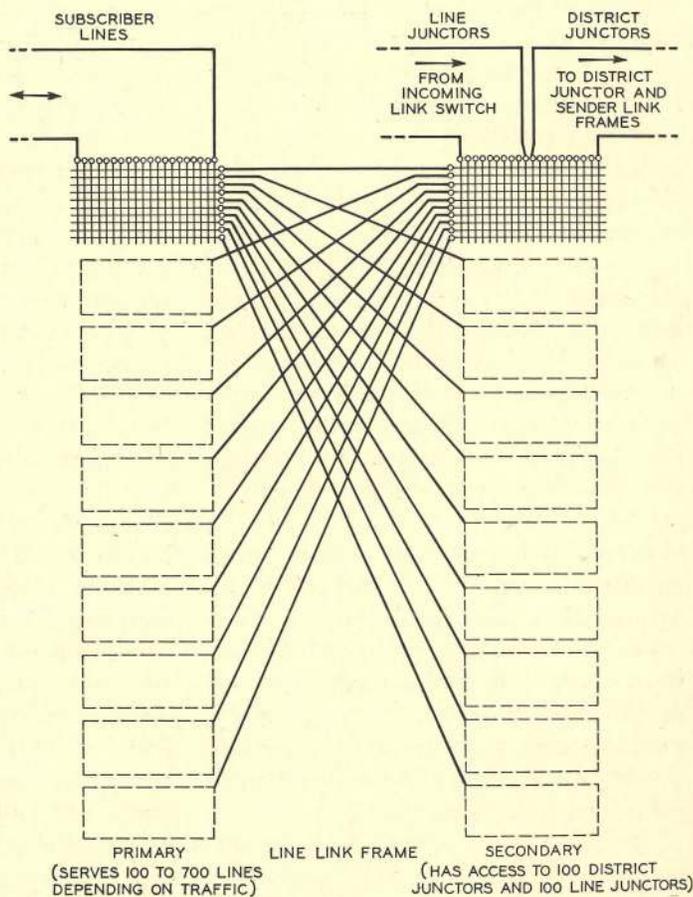


Fig. 3—Trunking scheme of the line-link frame

secondary switch in the same frame, and that each secondary switch has access to a group of ten district junctors. Each line, therefore, really has access to a hundred district junctors if, before a path is chosen at the primary switch, it is determined that idle districts will be available by way of that path at the secondary. This is what the line-group controller circuit does. Before it selects an idle line link, it determines which of them have idle district junctors available. It even goes further and determines that an idle sender is available to these junctors. The primary selection is then made so as to connect only a line link running to a group of district junctors some of which are idle and have senders available.

The controller circuit must also test for the particular line calling, to enable it to know which hold magnet to operate when the time comes for closing the circuit through. The group of district junctors selected tells it the proper select magnets on both primary and secondary switches to close. The particular junctor in the group, and thus the proper hold magnet on the secondary switch, is selected by the sender-link controller circuit, which also selects an idle sender.

The arrangement of stage two, including the district and office frames, is shown in Figure 4. Each frame has its primary and secondary switches as before. The district links are connected to the verticals of the district primary switches, and since there are twenty vertical units, there are twenty district links per switch, or 200 per frame. These district links, however, terminate on the horizontal multiple of the secondary switches, and since there are only ten of these horizontal circuits per switch, the secondary switch is split vertically so that every

link from the primary may have an independent termination on the secondary. The primary switch of the office frame is similarly split, and thus there are 200 district links, office junctors, and office links per frame.

After recording the office code, the first work of the originating marker, which is the common controller for the talking circuit of this stage, is to test the trunks running to the office called and to select an idle one. These outgoing trunks are divided between the switches of two office frames, and thus the selection of a trunk determines the particular frame, and the particular switch in that frame, that will serve as the outgoing end-point for this switching stage. The marker also determines the district junctor that has been selected, and thus knows also the incoming end-point to stage 2. Its task is then to find an idle path between these two points—indicated on the diagram by heavier lines.

The district links leaving each primary switch of the district frame are divided equally among the secondary switches of the same frame, one link going to each of the halves of each secondary switch. The office junctors, leaving the district secondaries, do not all go to one office frame but are divided equally among the various office frames. The number of junctors between any two frames will depend on the number of frames employed, since it is determined by dividing the 200 junctors from any one district secondary by the number of office frames. Since there are never more than 20 office frames, there are never less than ten paths between any one district and any one office frame. This is the arrangement shown in Figure 4—all the other verticals of the district secondaries are connected to junctors running to other office frames.

The office links are connected in the same way as the district links. While there are twenty links between primary and secondary switches of the district and office frames, it will be noted that half of them run to half-section secondaries that do not have junctors to the frame to which connection is to be made. Between any one district junctor and any one outgoing trunk, therefore, there are just ten paths for the arrangement shown—each consisting of two links together with one junctor.

To be available for use, each of the three sections of any one path must be idle. Since they all may be used by other calls in other combinations, however, it is necessary for the marker

to test each link of a path before the route is chosen. This is done by using what is functionally a three-winding relay for testing each path. If any one of the three links of a path is busy, the relay will operate, thereby indicating a busy path. Only the relays of idle paths remain unoperated, and the lowest numbered unoperated one is selected.

The switching arrangement for the third stage, including the incoming frame and the incoming half of the line frame, is shown in Figure 5. It is very similar to that of the second stage, except that the line frame secondaries to which the line junctors run have each only ten verticals available instead of twenty as with

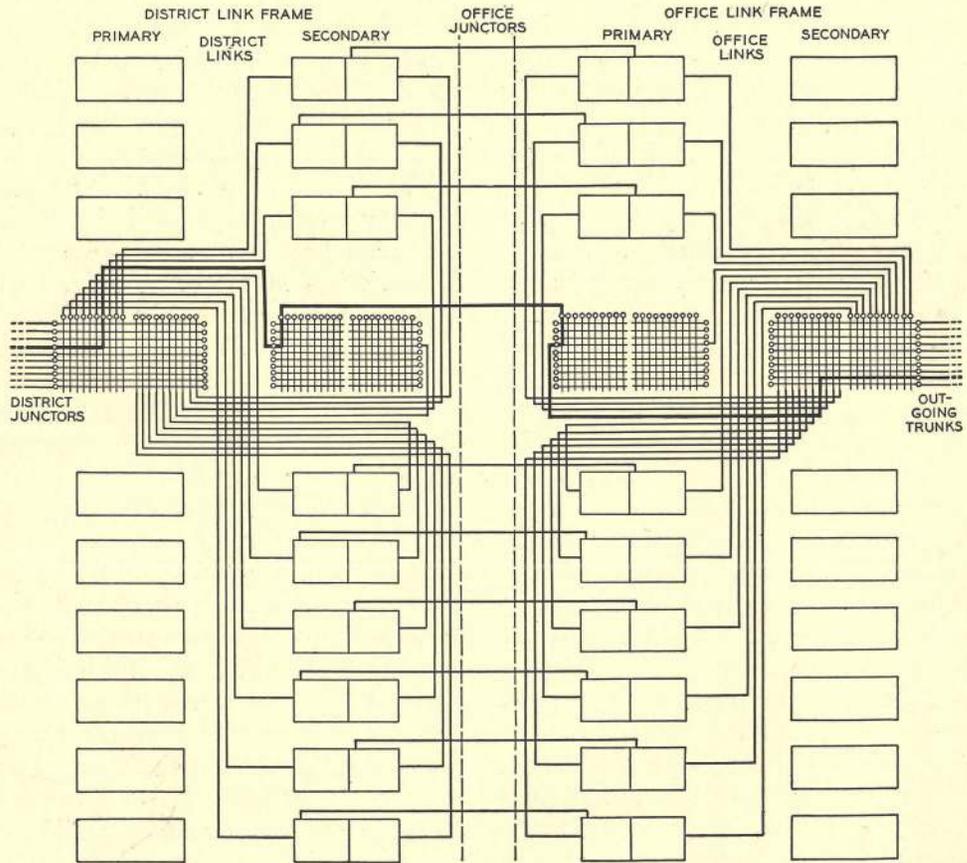


Fig. 4—Trunking scheme for the district and office-link frames

the office links, because the other ten verticals of each secondary are used for originating calls. There are at least ten paths between any incoming trunk and any particular line, however, and the testing procedure is essentially the same.

The number of frames of the various types depends to a large extent on the busy-hour calling rate for the office—that is, the number of calls placed per line during the busy hour—and on the average duration of the calls. A unit known as the CCS, standing for 100 call-seconds, is used as the criterion. Thus 500 calls each

lasting 120 seconds would give 600 CCS. The CCS during the busy hour is the determining factor, and for each office is a more or less definite figure. Each type of frame also has its capacity rated in CCS, and the numbers of each type of frame except the incoming may be roughly determined by dividing the total busy-hour CCS for the office by the CCS capacity of that particular frame. The number of incoming frames is determined by the number of incoming trunks, and these frames are frequently worked at less than their maximum capacity.

The capacity of the line frame is

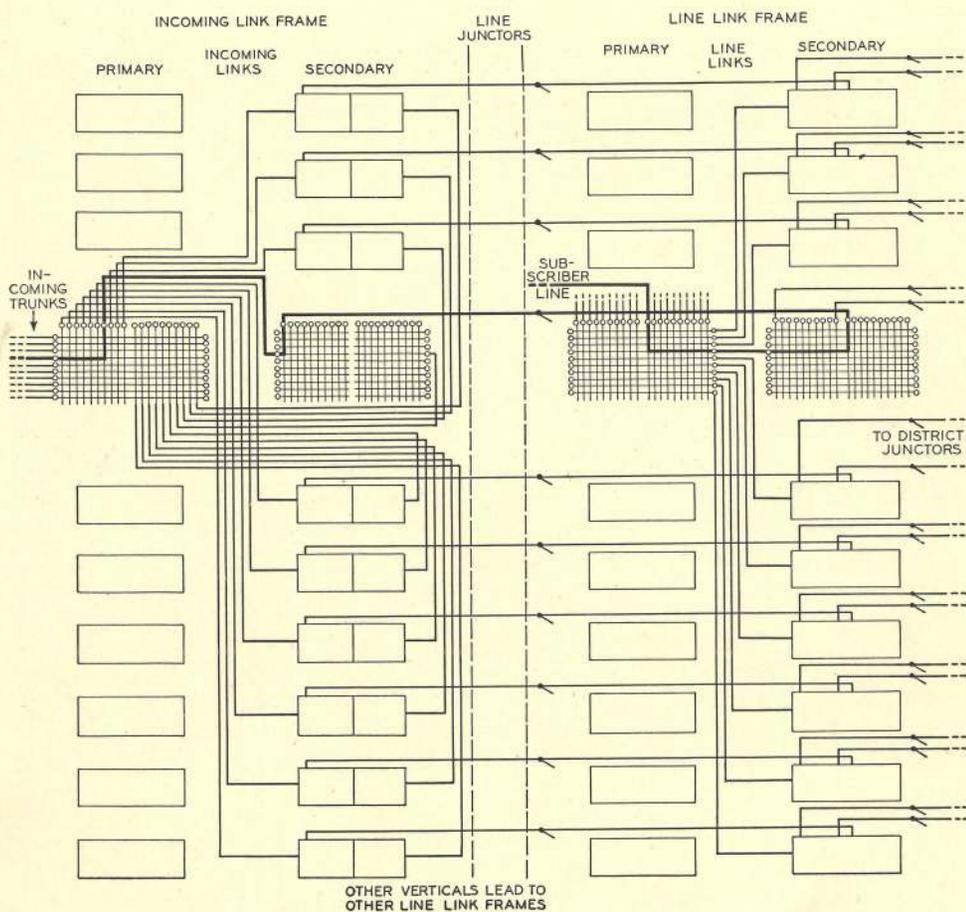
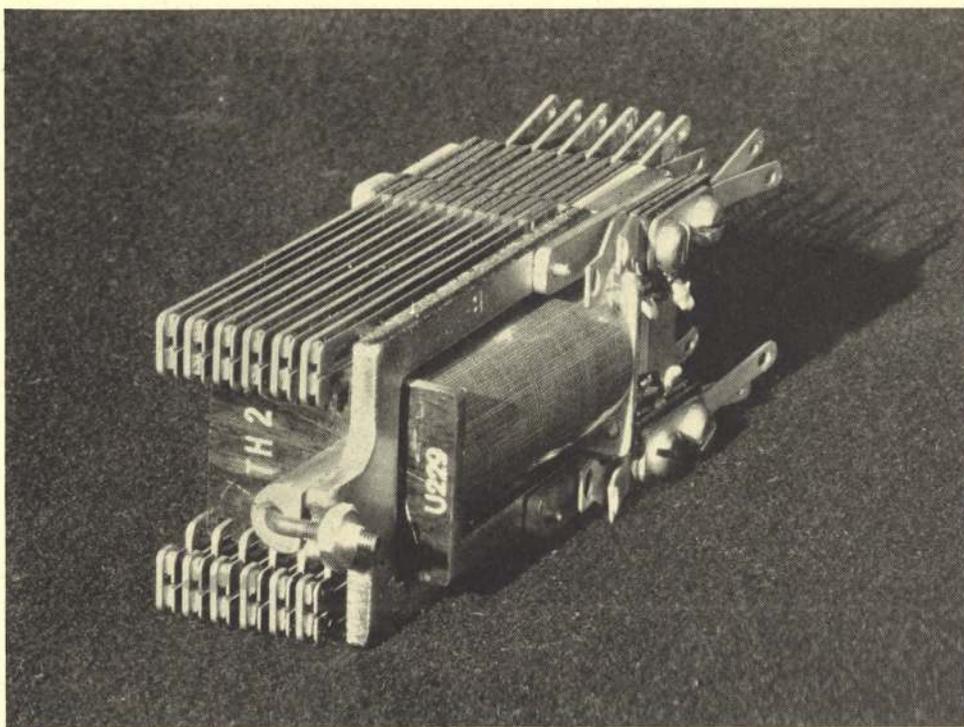


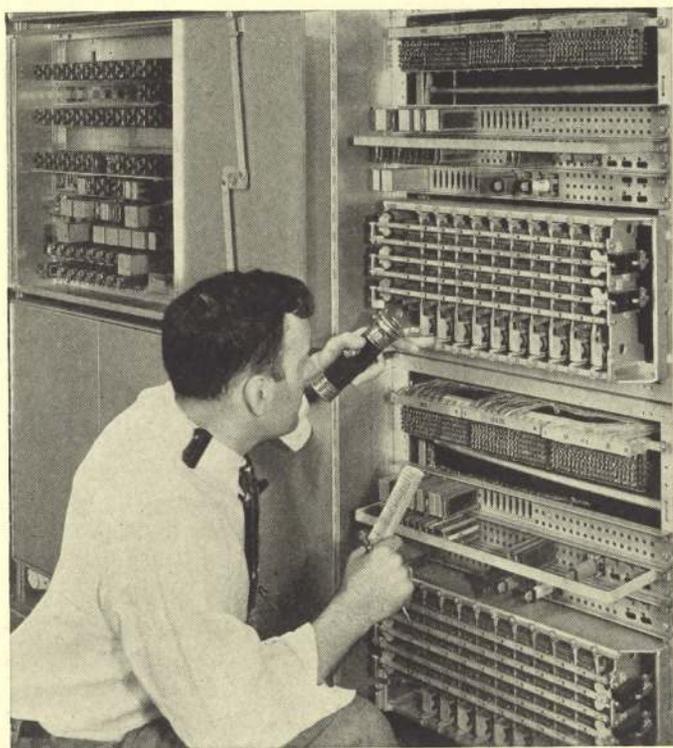
Fig. 5—Trunking scheme for the incoming-link frame and the incoming side of the line-link frame

only about half that of the incoming frame, and since, moreover, the line frame is used for both incoming and originating calls, its capacity in the incoming direction is only about one-quarter that of the incoming. To meet this situation there are about four times as many line frames as incoming, and since there are 200 terminations for line junctors on each incoming frame and 100 terminations on each line frame, each line junctor is multiplied to two line frames, so that four line-link frames will accommodate 200 line junctors. Each line-

link frame will serve from about 150 to nearly 700 lines, and additional primary switches are added to obtain a sufficient number of line terminations for the required number of lines. The capacity of 100 district junctors is about five times the originating-call capacity of the line frames, and since both district and line frames have terminations for the same number of district junctors, a five-fold multiplying is required. The capacity of the district and office frames is about the same, and consequently there is usually the same number of each.



*The U-type relay, developed primarily for the crossbar system, is distinguished by the use of a cylindrical core flattened on one end to form the pole face, and by an armature that is loosely pivoted rather than hinged. Its efficient circuit permits as many as twelve pairs of springs to be used*



## Crossbar Senders

By J. B. NEWSOM

**T**HE crossbar, like the panel system, does not employ a decimal system of trunk and line selection, and thus requires senders. The crossbar switch, however, does not "hunt" as do the panel selectors, and the equipment for testing lines and trunks for busy condition, and for finding idle paths through the crossbar switches, has been incorporated in modified decoders known as "markers." They are of two types: an originating marker, in the office of the calling subscriber, is employed to find an idle trunk and an idle path from the line to the trunk through the district and office frames; and a

terminating marker, in the office of the subscriber called, is used to locate the called line and to find an idle path from the incoming trunk to the called line through the incoming and line frames. Two senders are generally employed: a subscriber, or originating sender in the office of the calling subscriber, and a terminating sender in the office of the subscriber called. The originating sender corresponds more nearly to the sender of the panel system, while the terminating sender is generally employed, in conjunction with the terminating marker, to find an idle path between the incoming trunk and the called line.



*Fig. 1—Originating senders in the Murray Hill office in New York City*

One of the functions of any sender is to record the number dialed by the subscriber. In the later panel senders this is done by a group of relays, while in the crossbar sender, the digits are stored on a crossbar switch. This number-recording switch is of the ten-vertical type—instead of the twenty-vertical type used on the main switching frames. In the originating sender, four of the verticals are used for the three digits of the office code—two being used for the first digit—and five verticals record

the station number, four being used for the thousands, hundreds, tens, and units digits, and one—on calls to manual offices—for the party letter, where one is used. When the subscriber's dial has returned to normal after each digit, a select magnet and a hold magnet of the crossbar switch are operated to record it. In each case the select magnet operated corresponds to the digit dialed—i.e. the fifth magnet for the digit five or the eighth for eight—and the hold magnet corresponds to the position of the digit in the number. Ahead of this crossbar switch in the sender are relays that count the pulses of the various digits and operate the proper select and hold magnets. A separate vertical on this switch—together with two relays where there are more than ten district frames—is used for recording the number of the district-link frame with which the calling line has been associated.

The system is not idle while this recording is going on, however. As soon as the three digits of the office code have been recorded, the sender connects itself to an originating marker and transmits to it the office code and the number of the district frame to which the calling line is connected. The marker then finds an idle trunk to the office called and selects an idle path through the district and office-link frames between the district junctor and the chosen trunk. It then informs the sender of the type of trunk it has chosen, that is, whether it goes to a crossbar, panel, or manual office,

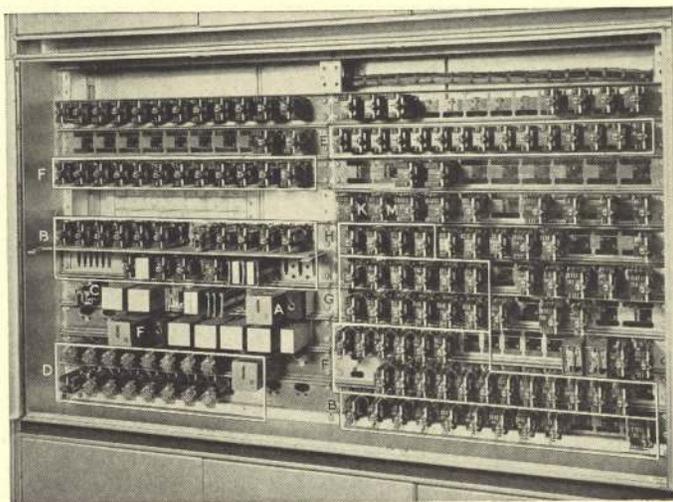
or to an operator, and whether it goes by a direct trunk or through a tandem office, and after this is released by the sender.

During this time the subscriber continues to dial, and as soon as part of the number has been recorded, the originating sender starts to pass signals over the trunk to the called office, where they are recorded by a terminating sender. This sender was connected to the incoming trunk after the latter had been seized by the originating marker. As soon as the terminating sender has completed its record, it acknowledges receipt of the number to the originating sender, which closes the talking circuit at the district junctor and then disengages. Besides acknowledging the number, the terminating sender seizes a terminating marker which locates the line called and—if the line is idle—finds an idle path between it and the incoming trunk. When this has been completed, it informs the terminating sender that the call is ready for connecting through, and the sender releases it. The terminating sender then closes the talking circuit at the incoming trunk and disengages itself. Ringing is handled by the incoming-trunk circuit and requires no attention from the sender.

This simple outline of the duties of the originating sender has assumed that the call was to a crossbar office. The circuits of the sender are arranged, however, to provide for all possible conditions, and are thus more intricate than would be required

for the functions given above. In the first place, crossbar offices are being installed in areas where panel and manual offices are already in use. The crossbar sender must thus be able to control selectors in panel offices and to generate call-indicator pulses for manual offices.

In the panel system, the sender controls brush and group selections of the panel frames by the method of "revertive" pulsing. Because of this fact, the originating sender is designed to operate on revertive pulses. Where the called office is of the panel type, the sender uses these pulses to guide the panel selectors in the completion of the call, and where the called office is of the crossbar type, the same type of pulsing is employed for transmitting the number called to the terminating sender. This permits the originating sender to transmit the same kind of signals regardless of whether the office called is of the panel or crossbar type; and a terminating crossbar sender will operate with calls incoming from either a panel or crossbar office. The originating sender includes a group of relays that count



*Fig. 2—Relay section of an originating sender*

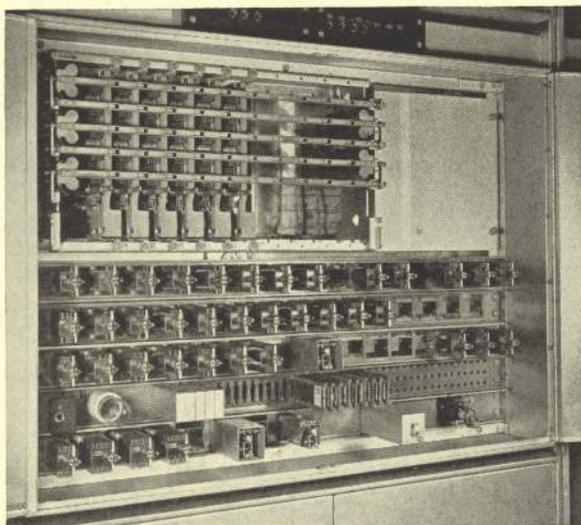


Fig. 3—A terminating sender with doors open

the revertive pulses sent to it from the terminating senders, or from the panel frames in a panel office, and interrupt the circuit after the correct number for each group is received.

A novel feature of the crossbar sender is the ability to make two or three attempts to complete a call when trouble or busy channels are encountered. Should the originating marker fail—for any reason whatever—to establish a connection to an idle trunk it will signal the sender that it has experienced difficulty, and at once the sender will release that marker, seize another, and make a second attempt. The terminating sender can also seize a second marker if difficulty is encountered in completing the call by the first marker. This is one of the many features of the crossbar system that make for more satisfactory service for the subscriber.

Both originating and terminating senders are connected to the calling circuit through sender-link frames. The originating sender is connected to the line through a sender link, a district junctor, and a line-link frame.

As soon as the line-group controller circuit has seized an idle district-junctor group, it in turn seizes a sender link, which proceeds to find an idle district junctor in that group, and connects a sender to it. When the sender is seized, dial tone is returned to the calling subscriber, and the line-group controller circuit transmits to the sender the classification of the calling line. The sender is arranged to record a maximum of twelve possible classes of service. These include coin-box lines, two-party lines, and the various other types of service that may be provided;

and the sender must know the class of line that is being used in making the call to be able to handle the call correctly.

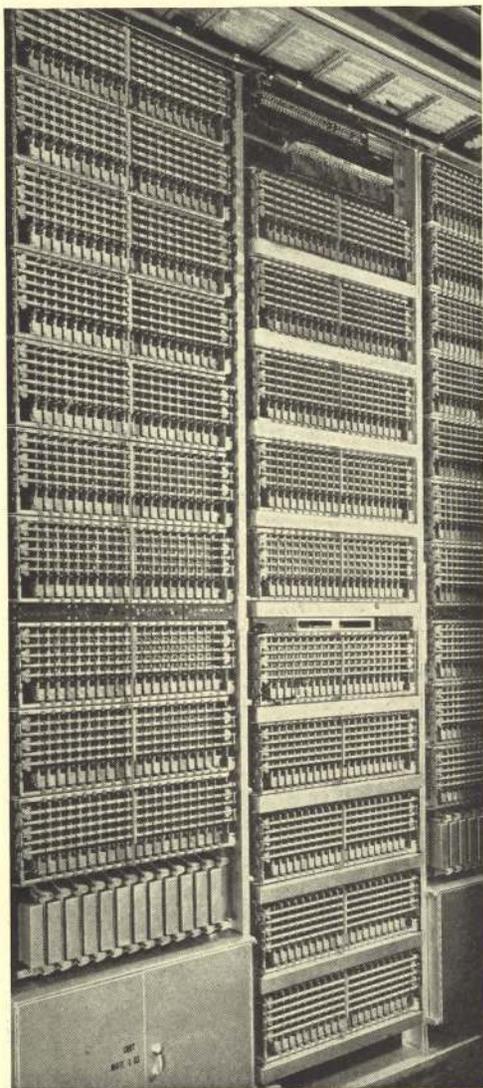
The links for the terminating senders are connected to the incoming trunk at the called office, and are seized as soon as the originating marker has established a connection to the trunk. Since the terminating sender is associated with the call only while the number of the called line is being recorded and a path through the incoming and line-link frames is being found, its "holding time," or the time it is associated with a line, is shorter than that of the originating sender, being under five seconds instead of approximately fifteen. The number required per office is thus less.

Five originating senders are mounted one above the other to form a sender frame. A row of such frames for the Murray Hill office in New York City is shown in Figure 1. As installed, the originating sender is arranged in two parts: at the left is a cabinet enclosing a large group of relays, shown with doors open in Figure

2, and at the right is the number-recording crossbar switch and some miscellaneous equipment. This part is shown more clearly in the photograph at the head of this article. The smaller amount of equipment required for the terminating sender permits the crossbar switch to be mounted in the cabinet with the relays, as shown in Figure 3. This crossbar switch in the terminating sender is equipped with only six vertical units: five for recording incoming brush and group selections, and final brush, tens, and units selections, and one for recording the frame on which the incoming trunk terminates. This latter information is transmitted to the sender when it is seized by the incoming link frame.

Except for the recording of the number dialed, the originating and terminating senders perform all of their functions by relays. Certain of these relays for the originating sender are indicated in Figure 2. The relay marked A follows the subscriber dial pulses and in turn operates the counting relays in group B. In this latter group are also the relays that operate the crossbar switch. Relay C

follows the revertive pulse sent to it by the terminating sender, or by the incoming and final selectors in a panel office, and group D counts these pulses. Group E includes the relays by which is recorded information regarding control of the call, which is sent to the sender by the marker. These relays record whether the call is to a crossbar, panel, or manual office, whether the call goes by a direct trunk or tandem office, and so on. On calls to manual or tandem offices, the sender transmits call-indicator signals, and the relays that send these are included in the two groups marked F. Group G comprises the selections-progress relays, which cooperate with the revertive-pulse counting relays to control brush and group selections for the various frames. Relays in group H control the second-trial features, while those marked K and M are the relays controlling the connection to and release of the marker. Many of these relays, such as the dial pulse counting, and call-indicating relays, are not required in the terminating sender, which thus has a less extensive circuit, as is indicated by Figure 3.



## The Crossbar Line-Link Frame

By A. J. BUSCH

nating calls. This line-link frame, like all other major frames in the crossbar system, consists of a group of primary and secondary switches, and each subscriber line is connected to one of the vertical units of one of the primary switches. The vertical units of the secondary switches are divided into two groups of ten each; one group connects to line junctors, which run to incoming link frames, and is used for terminating calls; and the other connects to district junctors which run to district frames and sender links, and is used for originating calls.

The first step the crossbar apparatus must take in establishing a connection is to find the particular line placing the call and then to connect it to an idle district junctor that has access to an idle sender. This work is accomplished by the line-link and sender-link controller circuits, the former of which associates itself with a line when a line relay operates, and remains associated until connected through to a sender. The time required for this operation is so short that only one controller is required for each line-link frame, which may serve from 200 to 700 subscriber lines.

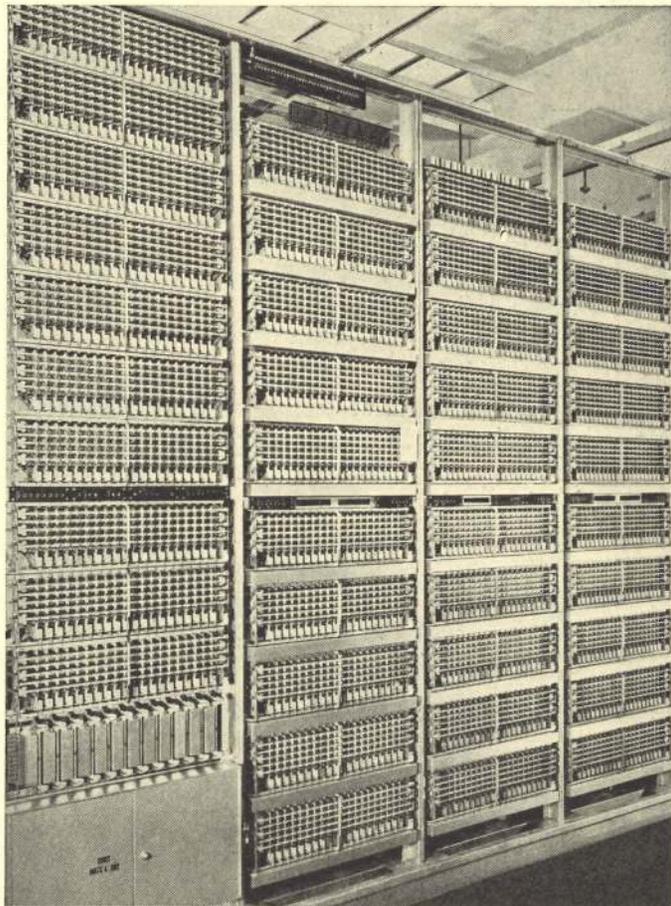
**I**N THE step-by-step and panel systems each subscriber line is brought to two switching frames. One of these, the line finder, is used when the subscriber is placing a call; the other, generally known as the final frame, is used when a call is being completed to the subscriber. The crossbar system differs radically from these earlier systems in this respect, since with it a subscriber line is connected to only one frame—the line link—which is used for both originating and termi-

The horizontal multiple connections of the primary and secondary switches of each line-link frame are connected together by line links, and since there are ten horizontal circuits for each crossbar switch, ten line links are available to each subscriber,

and 100 line links to the subscribers of each line-link frame. Since a single crossbar switch does not have more than twenty vertical units, this would provide one link for each two subscriber lines, which for ordinary calling rates is more than is needed. Where the calling rate does not warrant so liberal a provision of line links, one or more additional primary bays, referred to as the extension bays, are added, and all are served by the same group of 100 line links. The headpiece of this article shows an actual frame with only a single bay of primary switches. Beneath the primary crossbar switches, under the can covers, are the line relays, which operate when a subscriber places a call. Figure 1 shows an installation where three bays of primary switches are provided. With this arrangement, ten line links serve sixty lines. At the bottom of the bay of secondary switches is a cabinet enclosing the relays of the controller circuit, and just above this cabinet are the multi-contact relays by which this circuit is connected to the crossbar switches.

Subscriber lines connected to the line-link frame are arranged in groups of ten—one or two groups being connected to each primary switch. Where there is an odd number of groups, a crossbar

switch with only ten vertical units will be used for the last extension bay. There will be from two to seven of these groups in each row depending on the number of primary bays, and thus from twenty to seventy on a line-link frame, which has ten rows of switches. This is indicated by Figure 2, which shows the ten horizontal rows of primary switches, each with three twenty-unit crossbar switches and one ten-unit switch to provide a maximum of seven groups of ten lines. Any one group of lines may be identified by specifying its horizontal and vertical positions on the line-link



*Fig. 1—A line-link bay at the Troy Avenue Office, which employs three bays of primary switches*

frame. Thus the group marked G in Figure 2 may be identified as that at the intersection of horizontal group 6 and vertical group 4. By identifying, in addition, one of ten possible ver-

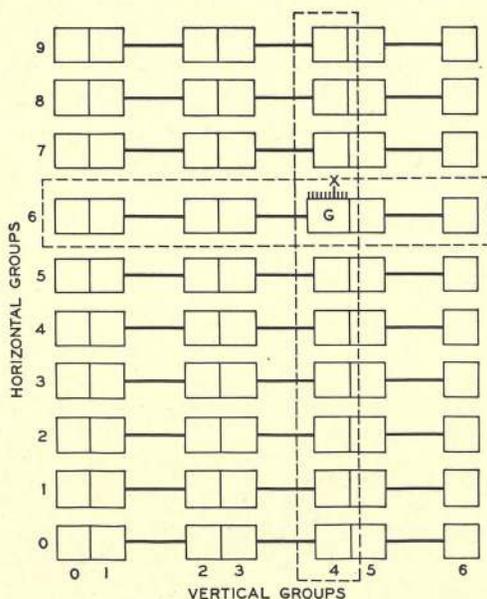


Fig. 2—Any of the seventy possible groups of ten subscriber lines can be identified by specifying the horizontal and vertical groups

tical positions within a vertical group, a particular line is identified. By providing a relay for each horizontal group, designated from H0 to H9, a similar set for each vertical group designated V0 to V6, and a set for the positions within a group designated L0 to L9, any calling line can be identified by the operation of three relays. The line marked X on the diagram, for example, would be identified by the operation of H6, V4 and L4—the line at the extreme left of each group being numbered 0.

Besides the three sets of identifying relays, certain others are required for their proper coordination. Figure 3 shows a simplified schematic of the identifying circuit, and from it the

sequence of operation may be followed. At the upper left of the diagram, the possible seven groups in each of the ten rows are indicated by the hold magnets of the first and last line of the first and last vertical groups in the bottom and top horizontal rows, and the corresponding line relays are shown. A line relay, marked L, is associated with each subscriber line, and the operation of one of these relays at once seizes the line-group controller circuit.

Three relays are employed in the identification of each horizontal group, and these are marked HA, HG, and H. There are ten such groups of relays, and each relay has a digit from 0 to 9 following the letter to identify the group. When a subscriber lifts his handset, his line relay operates. This operates HA, and, in turn, HA operates HG. This identifies the horizontal row in which the calling line is located, since a line in any other row would have operated different HA and HG relays. Operation of an HG relay connects the windings of the seven V relays to the leads from the ten groups of line relays in the row that has already been identified—the ten line relays in each group being connected to a common lead. The V relay that corresponds to the group of lines with an operated line relay will operate. The arrival of a second call before the first has been identified is prevented from interfering with the action of the line-group controller by circuit elements not shown.

Each group of lines in each horizontal row has associated with it an LR relay, and when a V relay operates, it—in turn—operates the LR relay of the group containing the calling line. The leads from the contacts of the V relays are multiplied to separate contacts of all the HG relays, and thence

run to the LR relays of each horizontal row. Since only one HG relay is operated, however, the path to all the LR relays, except in the identified row, are open. Moreover, since only one v relay is operated, only the LR relay in the corresponding vertical column will operate.

The operation of an LR relay, through ten front contacts, closes paths from each of the line relays in its group to the ten LT relays, which

are used to identify a particular line within a group. Since only one L relay is operated, however, only the LT relay corresponding to that line will operate.

Most of these relays have contacts or functions other than those shown. The dotted sections of line running to the HA, v, and LT relays indicate additional equipment, required largely to take care of conditions arising when more than one call is placed at

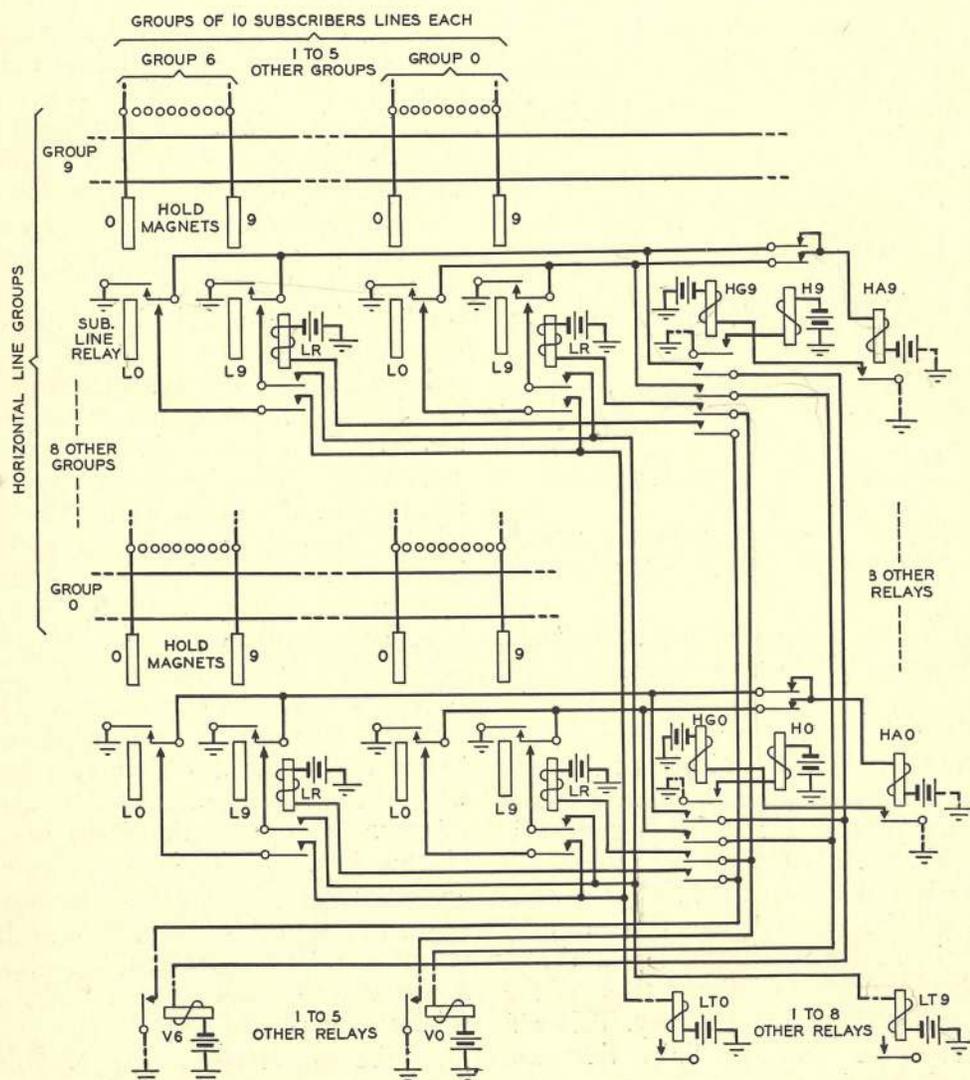


Fig. 3—Simplified schematic indicating the relays involved in line identification

approximately the same time. The H relay, included in each horizontal row in addition to the HA and HG relays, acts through the contacts shown, to isolate the vertical groups so that several v relays cannot remain operated by a single line relay.

As soon as an HG relay has operated, identifying the horizontal row in which the calling line is located,

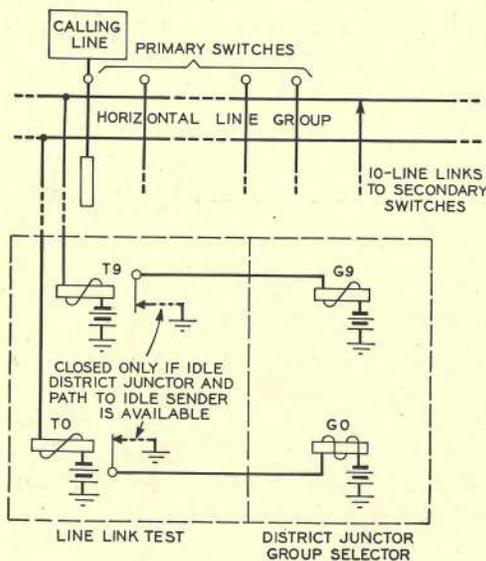


Fig. 4—Idle link identification is made by ten groups of ten pairs of relays

and thus the group of ten line links over one of which the connection will be made, the controller circuit—through another group of relays—starts to look for an idle link that can be connected through to an idle district junction for which a sender is available. The ten line links from each horizontal row run to different secondary switches, and some of them may be in use for other calls. The first step, therefore, is to eliminate those of the ten line links that are busy. This will determine the line links that are available for the call, and these particular line links, since each goes to a

different secondary switch, will designate the groups of district junctions that may be used. Some of these district junctions, however, also may be busy, and others may not have senders or sender links available, and all such junctions must be eliminated from the circuit before the final selection of the path is made.

Line-link selection is made by ten T and ten G relays as indicated in Figure 4. When an HG relay operates, it connects the ten T relays, through contacts on the HG relay not shown in Figure 3, to the ten line links coming from the horizontal row of crossbar switches with which the particular HG relay is associated, and the line links that are busy operate their associated T relays. Operation of a T relay opens the circuit to the corresponding G relay so that it cannot operate; the G relays that ultimately operate indicate the available paths.

Even though a T relay does not operate, indicating thereby that the associated line link is idle, the corresponding G relay may not operate because the circuit connected to its winding through the back contacts of its T relay passes through other apparatus, as indicated by the dotted line. This circuit will not be closed unless there is at least one idle district junction on the secondary switch to which that line link runs, and unless an idle sender is available for use with the district junctions. Those G relays that do operate thus indicate an idle line link, an idle district junction, and an available sender. Of these possible paths, the controller circuit selects one. Having made this choice, it operates the select magnets of the primary switch.

At the secondary switch, this line link has access to ten district junctions, one or more of which are idle. They

are all served by the same sender-link frame and the same group of senders, however, and the sender-link controller circuit chooses one of the district junctors and also one of the available senders as described in a previous article.\* Having made its selection, the sender controller circuit operates the select and hold magnets of the sender-link frame, and the hold magnets on the primary and secondary switches of the line-link frame. It then releases all the select magnets and restores itself to normal. This connects the sender to the calling line and dial tone is sent to the subscriber, who then begins to dial. This entire sequence and concomitancy of relay operations, which has required some two thousand words to outline in the briefest detail, requires only six-tenths of a second to complete.

In this description of the location of a calling line, it has been tacitly assumed that only one call came into the frame during the fraction of a second that is required to connect to it and to release the controller circuit. Even though a number of lines on the frame should place a call at the same instant, however, there would be no confusion or double connections; the calls would be handled, one immediately after the other, following a definite sequence. The rate at which calls come in under any ordinary conditions is not so great as to make the fractional-second wait for the handling of calls ahead of it important.

\*Page 15.

This sequence handling of calls is secured by the simple device of "chaining" the HA, V, and LT relays as indicated in Figure 5. Suppose, for example, that calls came in simultaneously on a number of horizontal rows. The HA relays of all such rows would operate, but the ground connection that will operate the HG relay is carried in a "chain" through contacts on all the HA relays. If one of the calling lines is in the zero level, HGO will be operated, but the others will not because their ground circuit is open at HAO. Had there been no call in the zero level, the ground lead would have been passed, through a back contact on HAO, to HAI.

A similar "chaining" is applied to the V relays, so that only one LR relay will operate, and to the LT relays so that only one hold magnet in any vertical group will be operated. Having found and connected to one of the calling lines, the controller circuit would start over again and establish a connection to the next.

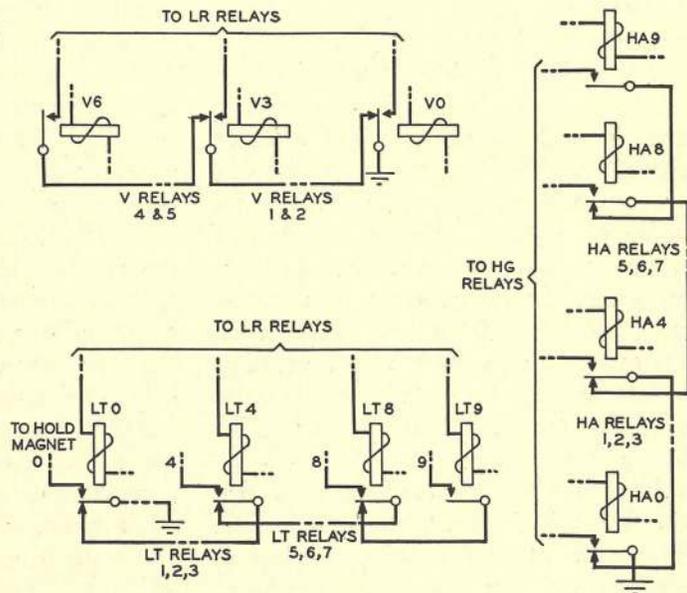
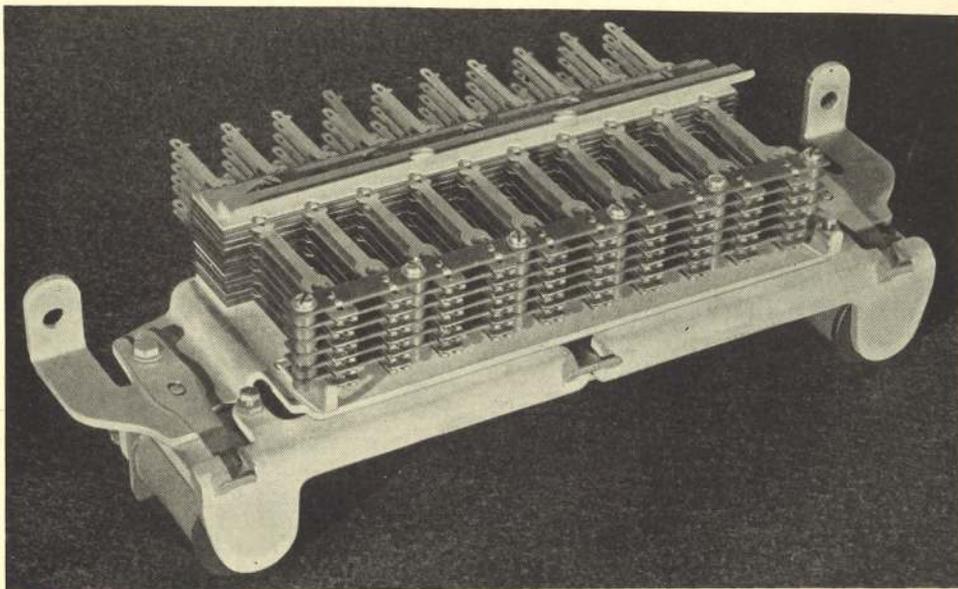


Fig. 5—Typical chaining circuits of the line-link controller



## The Multi-Contact Relay

By BRUCE FREILE

**A**S PART of the development of the crossbar system, it was necessary to develop a relay capable of closing a very large number of contacts. The multi-contact relay shown in the photograph above was the result.

The relay employs two coils and two armatures, each of which operates half the contacts. The contact springs are arranged in ten pile-ups and each may have as many as six pairs of springs—giving a total of sixty contacts per relay. The complete structure, however, may be used as two independent relays, each with 15, 20, 25, or 30 contact springs, or—by connecting the coils in parallel—as a single relay with double the capacity in contact springs.

The contacts of these relays, as with the U and Y types, are all double. The end of the moving spring is forked, each tyne carrying a contact, and the fixed spring carries two cor-

responding contacts. These latter springs have punched holes behind the contacts through which pass small insulating studs that operate the springs. These studs are fastened to the moving springs and are moved by the armature when the relay operates.

These relays are mounted vertically, so that dirt particles do not tend to lodge on the contacts. Tight-fitting can covers, not shown in the photograph, slip over the spring pile-up section, leaving the magnets and armatures exposed. Soldering terminals for the contacts project from the rear, and are arranged—like those of the crossbar switch—so that a straight length of bare wire can be used to connect together the terminals that are to be multiplied. Because of the large number of operations the relays must make, careful attention has been given to the mechanical design in order to prevent excessive wear of rubbing surfaces in the relays.

# Sender-Link and Controller Circuits

By A. J. BUSCH

**T**O ESTABLISH a connection in the crossbar system, two senders\* are used: an originating, or subscriber, sender at the office of the calling subscriber and a terminating sender at the office of the subscriber called. The sender-link frames are the assemblages of crossbar switches used to connect the senders to the calling line or the incoming trunk, as the case may be. Although the senders and their link frames of the two types differ considerably from each other, many of their functions are similar. The originating sender-link frame must first select an idle district from the group of ten districts that the line-link controller circuit has selected, and then connect an idle sender to it. The terminating sender-link frame must first find the incoming trunk being used, which is in a group that has been indicated to it, and then likewise find and connect to this incoming trunk an idle sender.

\*Page 15.

Simplified block diagrams for the two sender-link frames are shown in Figure 1. The subscriber sender-link frame is like most of the other major frames of the system in employing ten 20-unit primary crossbar switches, but differs in employing only five 20-unit secondaries. Functionally, however, the difference is greater than this, because two units are multiplied throughout to provide an additional number of leads. Each two primary switches act as a single switch, so that the primary bay has, functionally, only five 20-unit switches; and on the five secondary switches each two vertical units act as one, so that functionally there are only five 10-unit switches on the secondary bay. Subsequent diagrams and discussion refer only to functional switches.

The district junctors, coming from the secondary switches of the line-link frame, are arranged in groups of ten, and two of such groups are connected to the vertical units of each

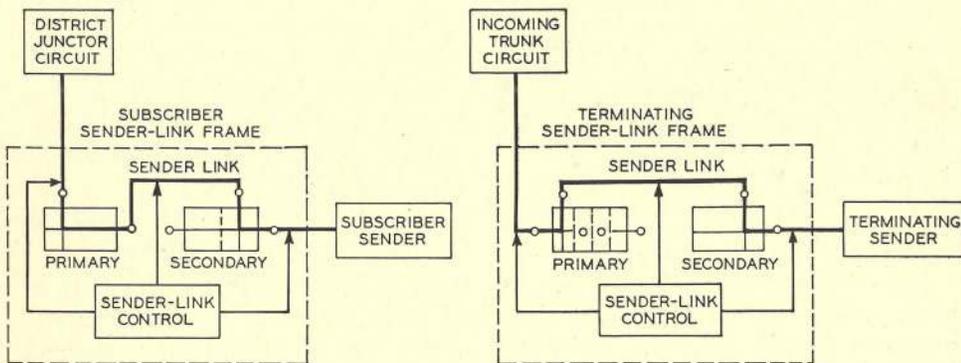
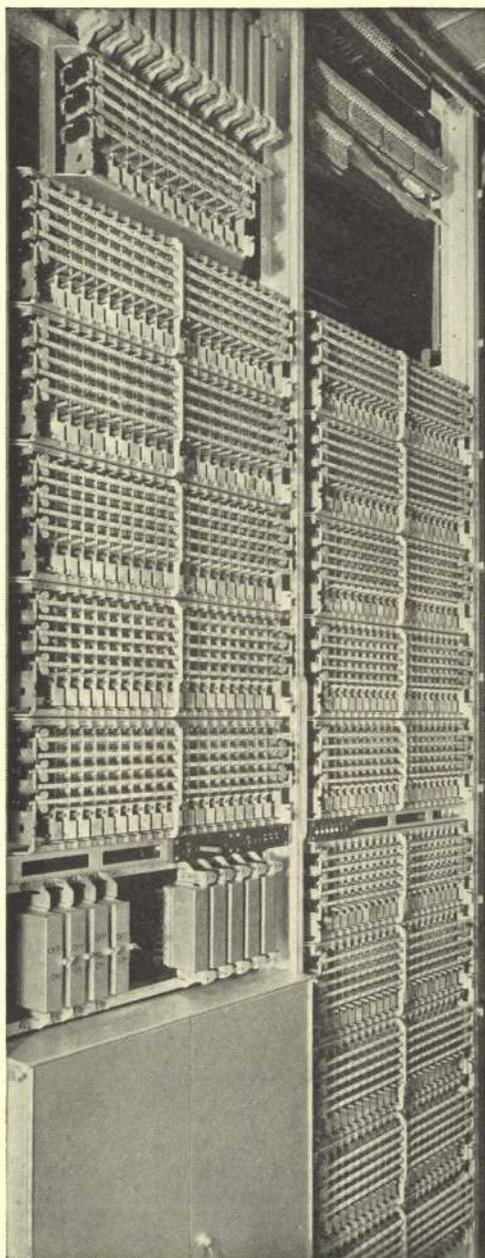


Fig. 1—Block diagrams of subscriber and terminating sender-link frames



*Fig. 2—Originating sender link*

primary switch of the originating sender-link frames, as indicated in Figure 3. Each sender-link frame thus serves one hundred district junctors.

The sender links are connected to the horizontal multiple of the primary

switches, and since there are functionally five switches, there are fifty sender links. These run to the vertical multiple of the secondary switches. These latter switches are divided in two by a cut in the horizontal multiple, and as a result the secondary switches consist essentially of ten 5-unit switches instead of five 10-unit switches. One link from each primary switch runs to a vertical unit on one of the five secondary switches. Since the horizontal multiple of the secondaries is split, one hundred senders can be connected to the secondary switches, twenty to each switch. This makes one hundred senders available to each one hundred district junctors. The senders, however, are multiplied to a number of sender-link frames, so that although one hundred senders serve a group of one hundred district junctors, the same senders are also serving many other groups of junctors. In ordinary offices there are about ten district junctors for each originating sender.

Since, for any particular call, a group of ten district junctors has been selected by the line-link controller circuit, and since any junctor of this group has access of the same group of one hundred senders, the selection by the sender-link controller of a particular junctor in the group is guided primarily by the necessity of using a junctor not already in use. One of the idle junctors is selected as indicated in Figure 5. Although the provisions are not shown in the diagram, the junctors are used in rotation as far as possible, so that over a period of time all will be used to about the same extent. A D relay is connected to each of the junctors of the particular group, but only those relays connected to idle junctors will operate. Of these idle junctors one is chosen and the

others are released for the next call.

While this selection is being made, the controller circuit also selects one of the sender groups that has at least one idle sender in it; where there is more than one such group, one of them is chosen. This sender-group selection is made by the SG relays, of which there is one on each sender-link frame for each group of senders. The windings of these relays are connected, by a group relay not shown in Figure 5, to back contacts on the secondary hold magnets of the ten sender links coming from the primary switch that will be used. If the hold magnet of a link is not operated, thus indicating that the link is idle, the back contact will be closed. From this back contact, the circuit passes to ground through other contacts that will be closed only if there is an idle sender in the group. Only the SG relays for those groups having both an idle link and an idle sender will operate; one of them is chosen and the others are

released. The operation of an SG relay operates the select magnet on the primary switch that governs the particular link selected. At this point, therefore, a particular district junctor,

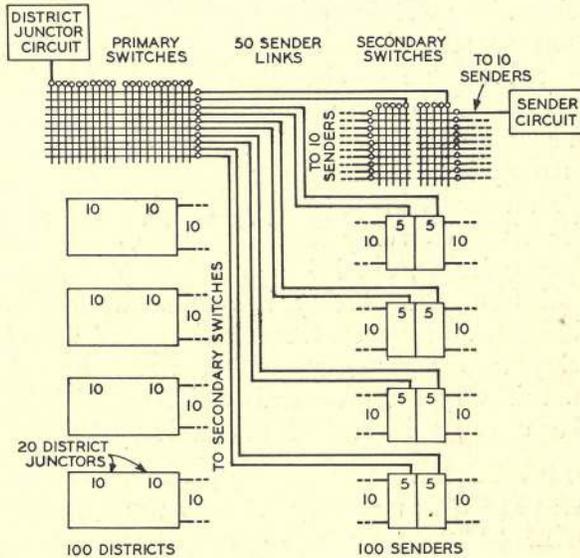


Fig. 3—Simplified schematic showing arrangement of links on subscriber sender-link frame

and a particular sender link have been chosen, and the select magnet of the link at the primary switch has been operated. It is necessary now to select a particular sender from the group of ten to which that link has access at the secondary switch location.

How this selection is made is indicated by Figure 4, which shows a simplified schematic of the principal part of the selecting circuit. When one of the SG relays is operated, it causes a C relay serving that particular group of ten senders to

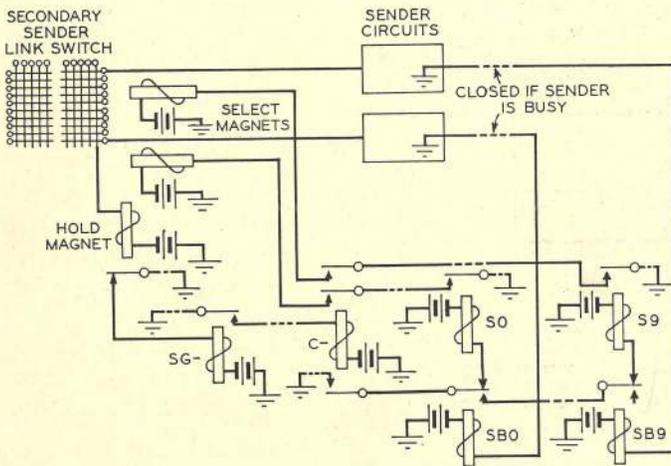


Fig. 4—Simplified schematic of the chain circuit that is used for making sender selection

operate, and—in turn—c through a front contact, extends a ground connection to the armature of the first of a set of ten sb relays. The winding of each sb relay is connected to one of the senders of the group in such a way that the sb relay is operated if the sender is busy. If the first sb relay is operated, the grounded lead from the c relay is continued through a front contact of that sb relay to the armature of the next. In this way the grounded lead from the c relay is carried successively

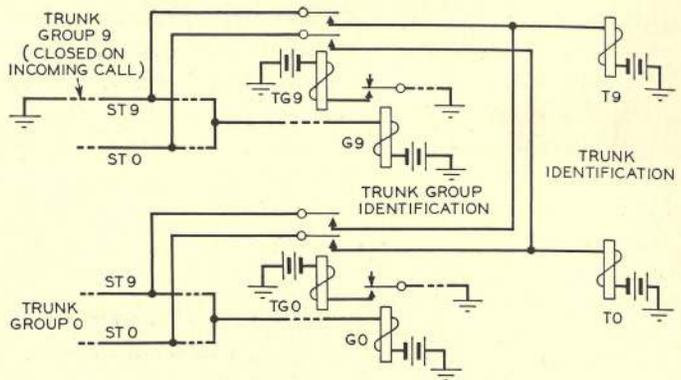


Fig. 6—Simplified schematic of trunk identification circuit at the terminating sender-link frame

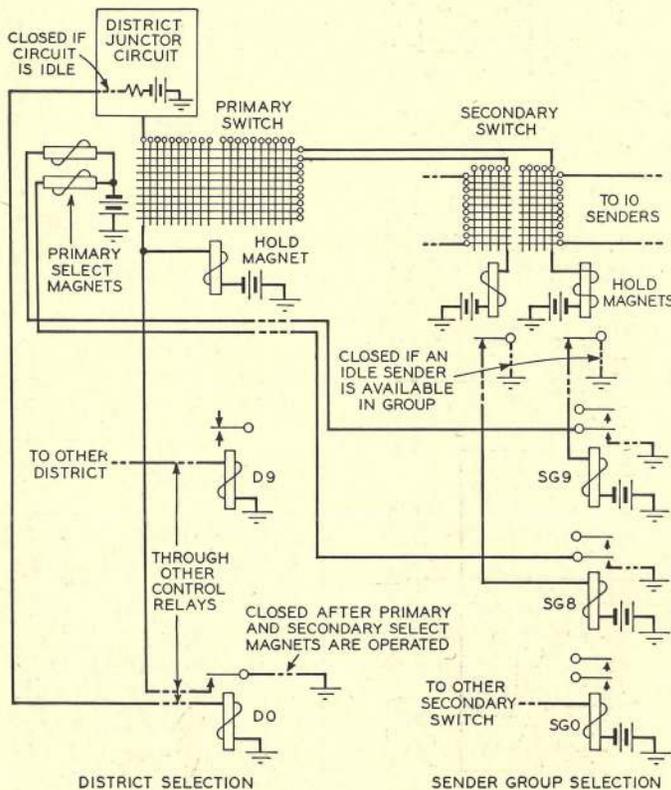


Fig. 5—Simplified schematic of circuit making district-juncator and sender-group selection

through the sb relays until it meets one that is not operated, indicating that that sender is idle. Through a back contact of this relay the grounded lead from the

c relay will be connected to the winding of an s relay, of which there is also one for each sender. This relay will be operated from the ground at the c relay, and in operating will operate the select magnet for that sender at the secondary switch. Immediately after this, the hold magnets corresponding to the selected district juncator at the primary switch and sender link at the secondary switch of the sender-link frame will be operated, and the sender will be connected through to the calling line. The select magnets are then released and the controller circuit restores to normal. Only about a half a second is re-

quired to serve a call by either the originating or terminating sender-link controller.

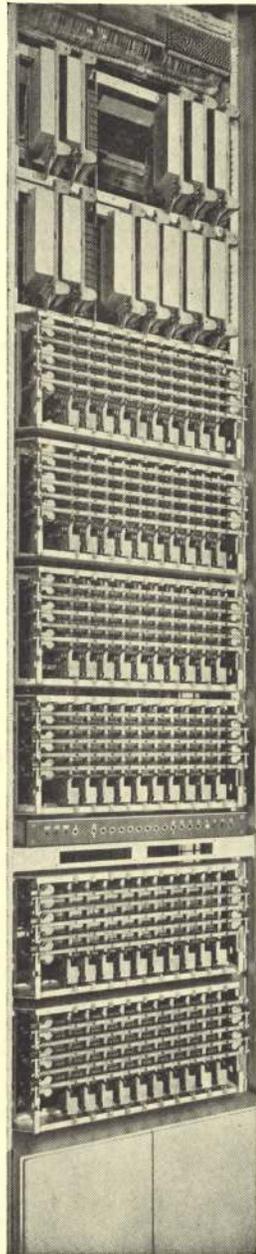
The selection of a terminating sender follows essentially the same procedure as that for the originating sender so far as the choosing of an idle link and sender is involved. At the originating sender-link frame, however, a district junctor must be selected in addition, while at the terminating sender, the incoming trunk—which corresponds to the district junctor at the originating link frame—has already been selected, and it is necessary only to identify it. This is done as indicated by Figure 6. A G relay corresponding to the group of trunks operates, and closes a corresponding TG relay which completes a connection from all the trunks in the group to a group of ten T relays. The T relay corresponding to the calling trunk will then operate. With this determined, the selection proceeds in the same way as with the originating sender-link frame.

Although the selecting procedure is essentially the same for terminating as for originating senders, the arrangement of the sender-link frame itself differs considerably. Where the originating sender-link frame, shown in the photograph at the head of this article, employs ten 20-unit primary and five

20-unit secondary switches, a total of fifteen 20-unit switches, the terminating frame consists of only six 10-unit switches, three primary and three secondary switches, as shown in Figure 8. Each secondary has ten senders connected to the horizontal multiple as does that of the originating

sender-link frame, and thus there are only thirty senders in a terminating group instead of one hundred as in an originating group. This smaller number is made possible largely by the shorter holding-time that is required for the terminating senders.

The greatest difference, however, is in the arrangement of the primary switches, since it was desired to make a single sender-link frame serve ten trunk groups, each comprising ten incoming trunks. Since there are ten groups of incoming trunks at the primary switches and thirty vertical units on the three secondary switches, there can be just three links serving each group of ten trunks. How this is accomplished is shown in Figure 8. The primary switches are divided horizontally so as to give a total of ten groups of three vertical units, each connected to a sender link. To secure a convenient wiring scheme, the upper and lower primary switches were divided into



*Fig. 7—A terminating sender link has six crossbar switches*

three groups of three vertical units and one group of one, while the middle switch was arranged in two groups of three and two of two. A unit group on the top and bottom switches each combines with one of the two-unit groups on the middle switch to form two 3-unit groups, thus giving the desired ten groups each of three links. Each

of the three links of a group runs to one of the three secondary switches and thus each link has access to ten senders. With this arrangement each sender-link frame makes thirty senders available to 100 incoming trunks, and, as with the originating frame, the terminating senders are multiplied to a number of terminating frames.

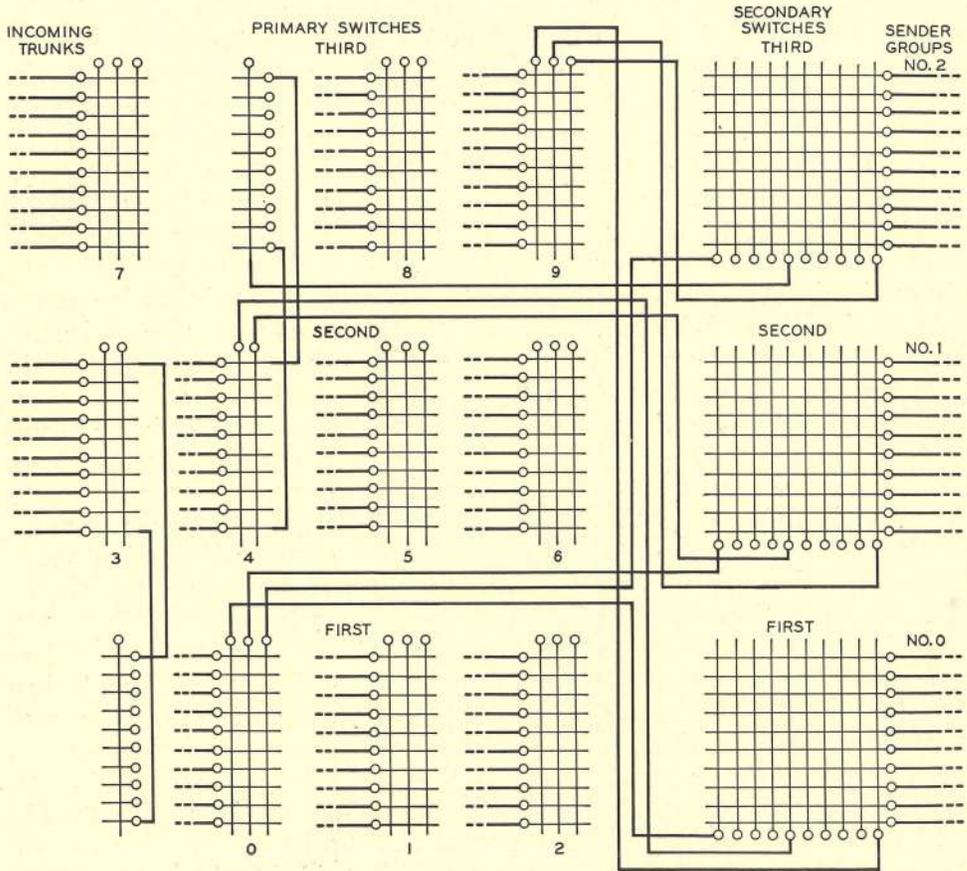


Fig. 8—Schematic layout of sender links for terminating sender-link frame

# Originating Markers

By OSCAR MYERS

**A**FTER a sender has been connected to a calling line on a crossbar-to-crossbar call, and has recorded the number wanted, a talking path must be established through four crossbar frames—two in the office of the calling subscriber and two in the office of the subscriber called. The selection of an idle path through each of these pairs of frames is under the control of a “marker”—an originating marker in the calling office, and a terminating marker in the office called. The two types of markers are similar in their general function. They both must find a suitable idle path through two crossbar frames between the circuit incoming to the frames and an outgoing circuit, which the marker itself must find. The major differences in the two types of markers spring largely from the differences in the outgoing circuits to which they must establish a connection. For the originating marker, these outgoing circuits are trunks to other offices or to the incoming frames in the same office; while for the terminating marker, they are subscriber lines.

Besides these functions of finding a suitable outgoing line or trunk and selecting an idle channel through the crossbar switches, the markers gather certain information regarding the outgoing circuit selected, and this information will be used in setting up the call. Another function of the marker is to provide cross-connecting facilities which permit the location of the lines and trunks on the frames to be

independent of the office code and line number dialed. The cross-connecting bays for an originating marker appear at the lower right of Figure 1. Two of these cross-connecting bays are shown in greater detail in Figure 2. In general each group of cross-connecting terminals includes a strip of individual terminals immediately above or below a bank of multiple terminals, appearing somewhat like the bank of a panel selector. Each strip in the multiple bank may, for example, represent the cut-in relay for a pair of office frames, and the office frames picked for any particular code would depend on the cross-connection made between the individual and the multiple terminals.

The originating marker is seized by the subscriber sender as soon as the latter has recorded the office code dialed. The marker has three sets of four register relays on which this office code is recorded. The relays of these sets are designated A1, A2, A4, and A5; B1, B2, B4, and B5; and C1, C2, C4, and C5, and the sender transfers the code digits to the marker by grounding or not grounding certain combinations of leads running to the windings of these twelve relays. The A relays register the first digit, the B relays, the second, and the C relays, the third. The sum of the numerical designations of the operated relays of each group indicates the values of the corresponding digits. Thus if the office code were 686, the relays operated would be A1 and A5; B1, B2 and

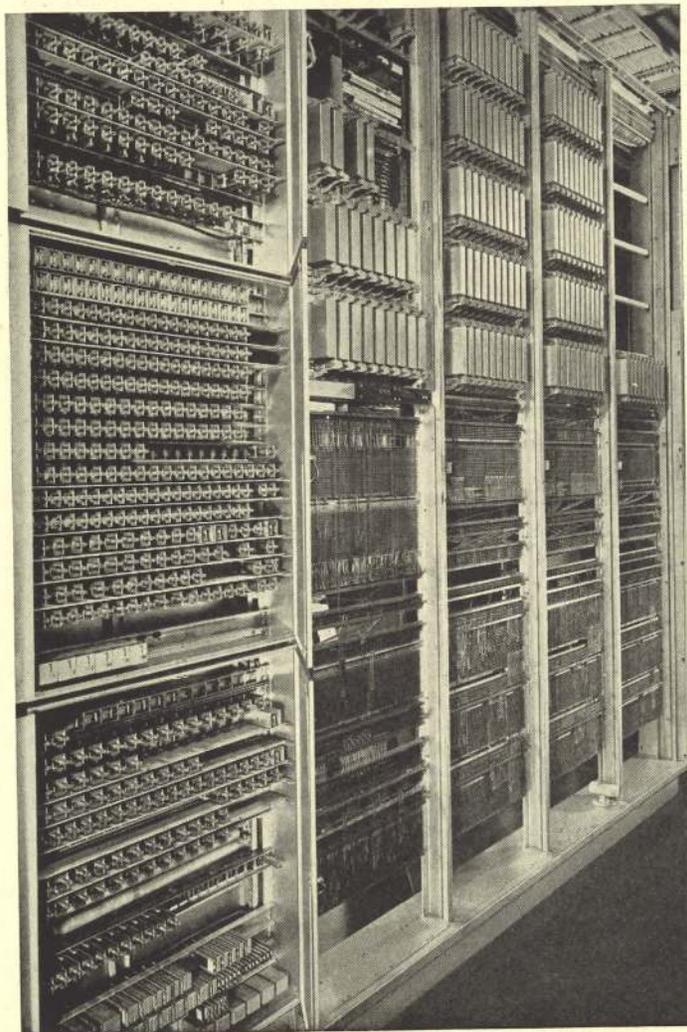
b5; and c1 and c5. Actually the sender first operates all the relays to make sure there are no open circuits in the leads, and then if there are no false grounds, releases those not needed to give the correct registration.

Zero and one are never used for the first or second digit of the office code, since no letters correspond to these digits on the dial, and thus there is a possible total of  $8 \times 8 \times 10$ , or 640,

office codes. Some of the codes are not used, of course, but for each code used a group of route relays is provided. In general a route relay is provided for each group of forty trunks or less going over the same route and serving the same class of calls. Each route relay has fifteen contacts, and its operation thus closes fifteen paths which are used for various purposes such as for establishing connections

to the group of trunks for busy test, for returning information to other circuits in the marker or to the sender regarding the handling of the call, for enabling the marker to find an idle path through the district and office frames to the idle trunk selected, and ultimately for operating the necessary select and hold magnets to connect the talking circuit through. Where there is more than one route relay in the group — because of their being more than forty trunks — one of the leads from the first route relay runs, through a cross-connection, to the next route relay of the group. If the first forty trunks are busy, the second route relay will be brought in, and the next set of trunks are then tested.

The desired route relay is selected by operating one relay of each of two groups.



*Fig. 1—An originating marker, with relay cabinet at the left, route relays at the upper right, and cross-connecting terminals at the lower right*

These are the  $TN$  and the  $H$  relays, the former closing ten contacts and the latter, fifty, as indicated in Figure 3. The winding of one route relay of each group is connected—through cross-connecting terminals—to one contact of one of the  $H$  relays. Thus each  $H$  relay, when operated, will close a circuit to fifty route relays of consecutive codes, and the  $H$  relays have numerical designations corresponding to the group of route relays with which they are associated. Thus the  $H2$  relay connects to route relays corresponding to codes 200 to 249 inclusive, and  $H2'$  connects to route relays for codes 250 to 299 inclusive.

The numbers of the  $H$  relays are 2, 2', 3, 3', and so on up to 9 and 9'—there being sixteen of them all told. The particular  $H$  relay to be operated for any one code is thus indicated by the first digit of the code plus an indication as to whether the second digit is above or below five. If the first digit is 6, either  $H6$  or  $H6'$  must be operated;  $H6$  if the second digit is less than 5, and  $H6'$  if it is five or above.

Eight circuits running from ground through front and back contacts of the  $A$  group of register relays are so arranged that ground will appear on one and only one of the circuits for each possible first digit from 2 to 9

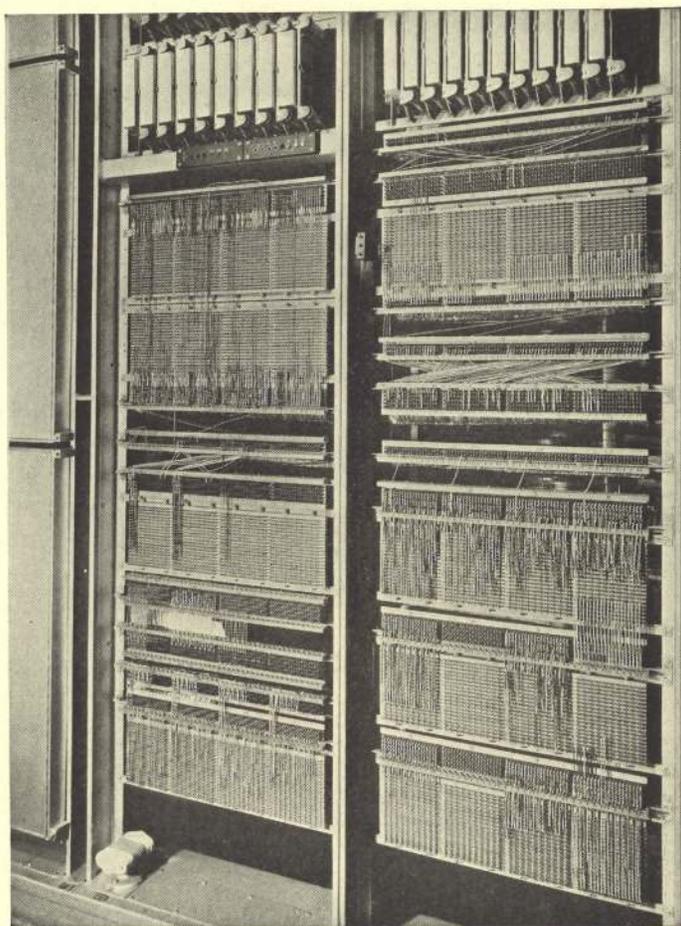


Fig. 2—A close-up view of some of the cross-connecting arrangements of the originating marker

inclusive. These leads pass to spring contacts on the  $B5$  relay, and depending on whether or not the  $B5$  relay is operated, will be extended to a front or back contact. Sixteen leads are thus provided, each running to the winding of one  $H$  relay. The possible office codes, the corresponding combinations of the four  $A$  relays and  $B5$ , and the  $H$  relay operated are indicated in Figure 4.

The five  $TN$  relays are operated by five circuits carried through contacts of relays  $B1$ ,  $B2$ , and  $B4$ . As shown in Figure 3, the ten contacts of each  $TN$  relay are multiplexed to a consecutive

set of ten contacts on each of the H relays. Thus the ten leads from TN0 will run to the lowest ten contacts on

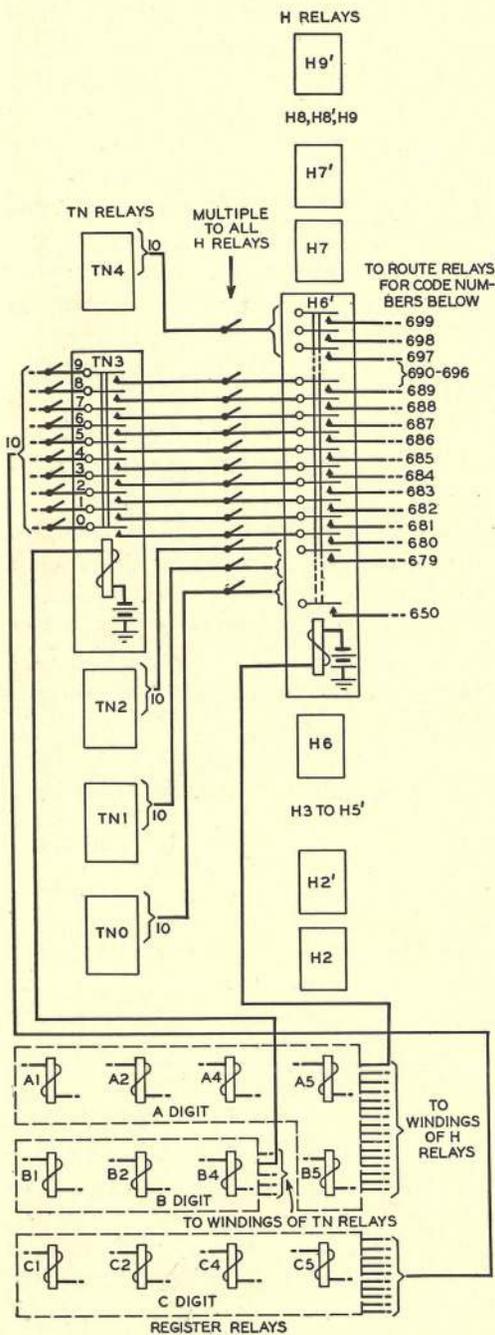


Fig. 3—Simplified schematic of the circuit for selecting and operating a route relay

each H relay, those of TN1 to the next set of ten contacts and so on. If the code called were 686, for example, the operation of H6' indicates that the first digit is 6 and that the second digit is 5 or above. Of the fifty leads to H6', however, only the ten to TN3 will be connected through. The combinations of B relays that operate the various TN relays are shown in Figure 5. TN4 will be operated when the second digit is 4 or 9, relay TN3, when it is 3 or 8, and so on. Zero and 1 are not used for the first or second digits of an office code, but they are employed for such special codes as 211, for long distance, or 411, for information, and for a number of operators' codes. For code 686, TN3 will be operated.

The ten leads from the spring contacts of the TN relays are carried to circuits running through contacts of the C register relays, and depending on the final digit of the code, one of these leads will be grounded. The combinations are shown in Figure 6. The ground on this one lead will be carried through the TN relay operated and the operated H relay to the particular route relay corresponding to 686. These operations are not carried through sequentially as described, but almost coincidentally, so that a route relay is operated almost as soon as the number-recording relays are operated.

The code 686 resulted from dialing Murray Hill-6, and the operation of the corresponding route relay, or one of them when several are required, gives all the necessary electrical information pertaining to the group of trunks running to the Murray Hill-6 office. Each group of forty trunks is distributed over two office frames to avoid all the trunks of a group being out of service should there be trouble on one frame. Each pair of office

frames has an office connector through which the circuits of that pair of frames are brought to the markers. One of the leads from the route relay runs—through cross-connecting terminals and other relays—to the “cut-in” relay of the two frames having the 686 group of trunks. Each of the office connectors has a group of multi-contact trunk cut-in relays through which the sleeve of the trunks may be connected to the marker, forty circuits at a time, for busy test. Certain of the leads from the route relays, again through cross-connections, operate the particular trunk cut-in relays for trunk group 686. The beginning and end of the desired group will be indicated by cross-connected leads from the route relays, and the marker will test only those of the desired group.

Busy testing is done by a group of trunk-test relays. The windings of these relays are connected to the sleeve leads of the trunks through the trunk cut-in relays of the office frame. The test relays connected to busy trunks will operate, and a chain circuit through their contacts will cause the operation of the select magnet of the first idle trunk. This selects and “marks” the chosen trunk. While these operations are being carried out, the district circuit has also been connected to the marker through a district connector, and the district junctor being used for the call is also “marked.” Having thus marked the

trunk and the district, the marker then tests for an idle channel between these two points through the district and office frames. There are ordinarily not less than ten of such channels and each consists of a district link, an office junctor, and an office link. The method employed tests all channels and all three links of a channel at the same time, and selects one for connecting through. Having operated the proper select and hold magnets, the marker makes a continuity test to insure that the call has been properly set up.

In the meantime grounds have been carried through the route relay and cross-connections over leads to the sender, where they operate relays that will guide the sender in controlling the call. Information conveyed in this manner indicates to the sender whether the trunks are to a panel or crossbar office, or to a tandem office or an operator; whether the trunks have proper resistance to permit the

OFFICE CODES INDICATED BY	REGISTER RELAYS OPERATED					H RELAY NUMBER
	A1	A2	A4	A5	B5	
H RELAYS 200-249	—	x	—	—	—	2
250-299	—	x	—	—	x	2'
300-349	x	x	—	—	—	3
350-399	x	x	—	—	x	3'
400-449	—	—	x	—	—	4
450-499	—	—	x	—	x	4'
500-549	—	—	—	x	—	5
550-599	—	—	—	x	x	5'
600-649	x	—	—	x	—	6
650-699	x	—	—	x	x	6'
700-749	—	x	—	x	—	7
750-799	—	x	—	x	x	7'
800-849	x	x	—	x	—	8
850-899	x	x	—	x	x	8'
900-949	—	—	x	x	—	9
950-999	—	—	x	x	x	9'

Fig. 4—Operated register relays for various codes, and the corresponding H relays operated

TWO LAST DIGITS OF OFFICE CODE INDICATED BY TN RELAYS		REGISTER RELAYS OPERATED			TN RELAY NUMBER
		B1	B2	B4	
00-09	50-59	—	—	—	0
10-19	60-69	x	—	—	1
20-29	70-79	—	x	—	2
30-39	80-89	x	x	—	3
40-49	90-99	—	—	x	4

Fig. 5—Combinations of register relays required to operate the various TN relays

sender pulsing relays to operate properly over them, and a variety of other facts. The final signal transmitted to the sender indicates that the trunk has been found and a path completed through the district and office frames, and on receipt of this signal, the sender releases the marker, which is then available for another call.

To enable the marker to handle calls at as high a rate as possible, an overlap feature is provided that permits each marker to be handling two calls at a time. After an idle trunk has been found, the marker is disconnected from the sender, since it can proceed to test for an idle channel through the district and office frames without further reference to the sender. While this is being done, therefore, this same marker may be seized by another sender, a new code registered, and the desired TN and H relays operated. Ordinarily the first call will have been completed by this time, so that the marker may proceed with the second. If the first call has not been handled, the second call will wait the very short interval until it has been.

One of the interesting features of the crossbar system is its ability to make a second trial under certain conditions should it fail to establish a connection. When the originating

marker fails to set up a connection to an outgoing trunk, either because of a trouble condition or of its inability to find an idle channel to the trunk selected, it signals the sender to release it and to call in another marker for a second trial. When the marker fails to find an idle channel through

the crossbar switches to the trunk selected, however, it tests first the trunks on the other frame of the pair. If it finds an idle trunk on this second frame, it tests for an idle channel to it through the crossbar switches, establishing the connection if it finds one. If it does not find one, it gives the second-trial release to the sender. Under these conditions the sender will call in another marker to set up the call to an overflow trunk on the office frame.

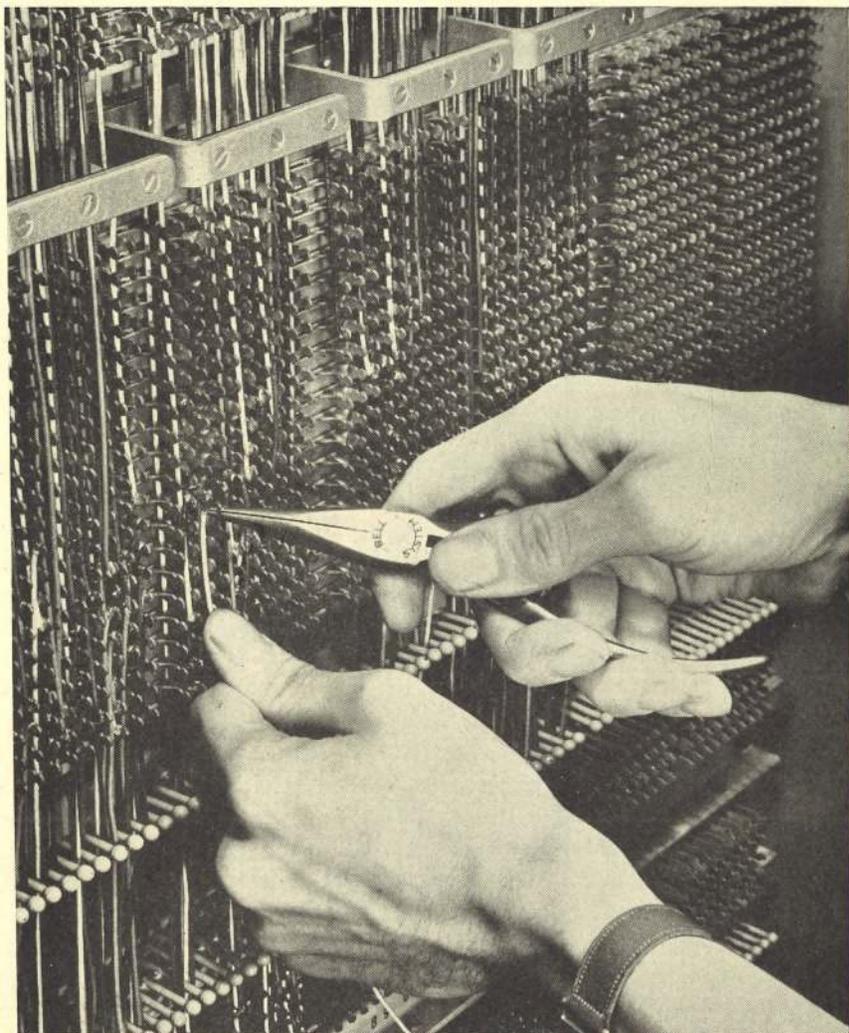
To prevent any of such troubles from seriously affecting the service, all markers are provided with a timing arrangement that, should the marker be unable to complete a call within a

C1	REGISTER RELAYS OPERATED			FINAL DIGITS
	C2	C4	C5	
—	—	—	—	0
x	—	—	—	1
—	x	—	—	2
x	x	—	—	3
—	—	x	—	4
—	—	—	x	5
x	—	—	x	6
—	x	—	x	7
x	x	—	x	8
—	—	x	x	9

Fig. 6—Combinations of the C relays for the various final digits

short interval, would notify the sender to release it and try again. The timing circuit starts to measure time as soon as the marker is seized, but the period after which it will "time out" the marker depends on what stage of the selecting progress the trouble appears. Not only, therefore, does the marker make second trials at completing calls, or—with certain types of difficulty—notifies the sender

to make a second trial with a different marker, but by the process of "timing out" prevents a call from being delayed more than a very short interval for any type of failure of the marker whatever. The originating marker is engineered to handle 4,460 calls per hour and, during a normal busy hour, will complete all its usual functions in 0.65 second, including the average delays at the district and office frames.



*A detail of the terminal strip arrangement at the block-relay frames*



## Number Decoding by Terminating Markers

By J. W. DEHN

ever, may be that of a private branch exchange, instead of an individual or party line. In such a case it is not sufficient to test only one line; since there will a group of trunks to the PBX, the marker's task is to select the first one in the group that is idle. One of the fundamental features of the crossbar system is to test a group of paths and trunks simultaneously so as to reduce the holding time of the markers to a minimum. To carry out this principle, the terminating marker is arranged to test twenty lines at a time where the number called is that of a PBX; while when it is that of an individual line, only the desired line will be tested, although the entire group of twenty consecutively numbered lines, including the desired one, will be brought to the marker.

AS HAS been explained in the preceding article, the functions of terminating markers are in general similar to those of originating markers. The differences arise chiefly from the difference in type of circuits which they control. While the originating markers must find an idle trunk out of several hundred groups of trunks, the terminating marker must be able to find one particular line out of a possible ten thousand. It must first test this line for busy, and, if the line is found idle, must then establish a connection to the crossbar switch to which that line is run, so that it may find an idle path to it from the incoming trunk, and in this manner establish the talking connection.

The particular number called, how-

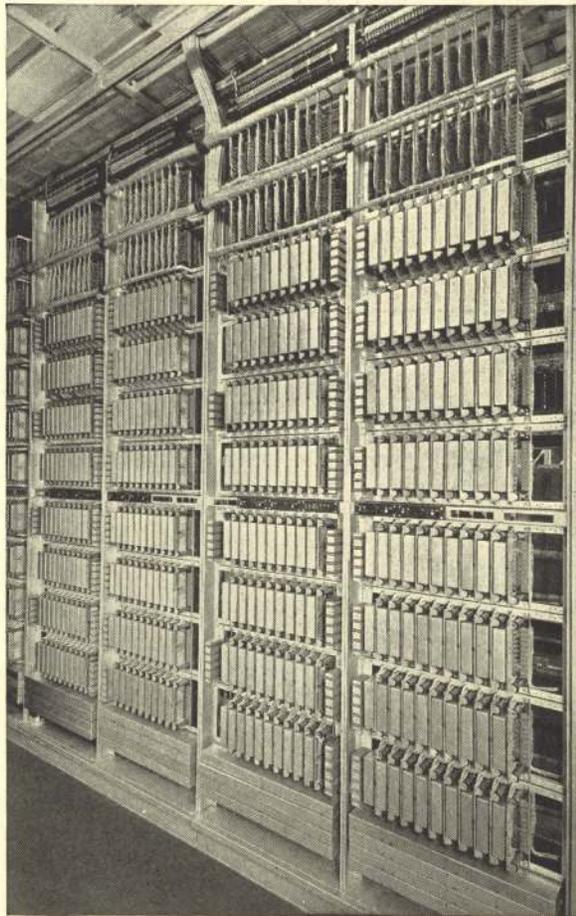
The possible 10,000 subscriber numbers of the office are therefore arranged in blocks of twenty, and a block relay is provided for each such group. In function the block relays are similar to the route relays of the originating marker, but they are controlled and operated in a different manner. The route relays are part of the originating marker, and one or more for each office code is provided in each marker. The block relays, on the other hand, are not part of the terminating marker, and there is only one for each group of twenty subscriber numbers in the office. They are multi-contact relays assembled ten in a row,

and four such rows are mounted on the upper part of a frame as shown in the photograph at the head of this article. When operated, each block relay closes sixty contacts, three for each of twenty line numbers. Twenty of these, one for each line, are in the leads used for the busy test. There may be as many as 500 of these relays in an office, and, to simplify the selection of the desired one, they are grouped into sets of five, and operated through hundred-block relays. Each of the latter has five contacts, one for the winding of each of the twenty-block relays in that hundred-block. These hundred-block relays are mounted under long can covers on the bays with the twenty-block relays.

Several of the hundred-block relays are formed into a "number group" and by means of a number-group connector can be temporarily connected to any one of the terminating markers in the office. The number-group connector relays are of the same type as the twenty-block relays, and are also assembled in rows of ten, eight rows being mounted on a frame as shown in Figure 1. Four of these relays, operated simultaneously, are required to connect a number group to one marker, and the relays for four number groups are mounted on two adjacent bays. Since each number group must have access to all of the terminating markers, of which there may be as many as ten, ten sets of four relays may be furnished for each number group. Each frame of Figure 1 has connector relays for two number groups, the

upper four rows serving one number group and the lower four the other.

This division of lines into number groups permits a number of markers to be locating lines at the same time. If two markers should receive calls for numbers in the same number group at the same time, one marker must wait for the other to set up its connection. This delay is ordinarily a small fraction of a second. To prevent unreasonable delays, however, the hundred-blocks formed into a number group usually represent only about one thousand terminating calls during the busy hour. For simplicity



*Fig. 1—Number-group connector frames in the Murray Hill-6 Office on East Thirtieth Street*

and economy in cabling, the hundred-blocks assembled into a number group are usually formed of consecutive subscriber numbers. If it is impractical to select consecutive hundred-blocks to give the desired load, however, non-consecutive hundred-blocks may be grouped, at some sacrifice in simplicity and cost of cabling.

When a marker is seized by a sender, it must determine—from the number that has been dialed—the

correct number-group connector to operate, and also the correct hundred-block and twenty-block relays to operate in this number group. This process is known as decoding, because

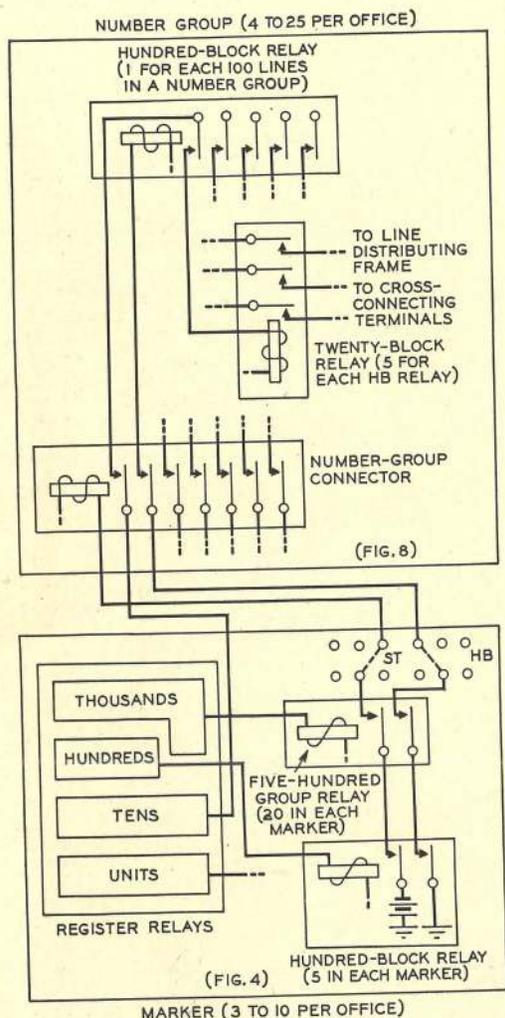


Fig. 2—Synoptic diagram of the decoding features of the terminating marker and number-group circuit

DIGITS	RELAYS OPERATED IN EITHER H, T OR U SET	RELAYS OPERATED IN Th SET
0	0	0
1	1	1
2	2	2
3	1+2	1+2
4	4	4
5	5	4+1
6	5+1	4+2
7	5+2	4+2+1
8	5+2+1	8
9	5+4	8+1

Fig. 3—Combinations of operated register relays to give the various digits

the decimal directory number it received, 2845 to take a concrete example, must be translated or decoded into terms designating a number-group, a hundred-block relay, and a twenty-block relay.

A synoptic diagram of the circuits involved in this part of the marker's work is shown in Figure 2, where reference is made to two following illustrations giving sections of the circuit in greater detail. As a basis for its action, the marker has recorded on four groups of register relays the number that has been dialed by the subscriber. The proper register relays in each group were operated by the terminating sender when the marker was seized, as described in the preceding article. These relays are similar in arrangement and function to those of the originating markers used for recording the office code, except that four sets of relays are required instead of three because the subscriber number consists of four numerals. The re-

lays of the group for the first, or thousands digit, also differ in being numbered 1, 2, 4, and 8, instead of 1, 2, 4, and 5, as are the other groups in the terminating marker and all the groups in the originating marker. The combinations of the relays within a group to give the various digits are shown in Figure 3.

Since a number group is made up of hundred-blocks, a determination of the hundred-block indicated by the registered number is sufficient to designate the number group desired. This hundred-block designation will also, of course, indicate which hundred-block relay in the number group to operate. The marker is designed to determine the hundred-block by first picking a group of 500 numbers—or five-hundred group—and then narrowing its selection to one of the five, although the two operations are carried out simultaneously, not successively. Due to the fact that there are twenty groups of 500 subscriber numbers in a 10,000 number office, the marker is equipped with twenty 500-group relays, one for each of the twenty groups of five hundred numbers. It also has five hundred-block relays, one for each of the hundred-blocks in a 500-group, and leads from contacts of hundred-

block relays are multiplied to a set of corresponding contacts in each five-hundred group relay. The arrangement is shown in greater detail in Figure 4. These hundred-block relays in the marker should not be confused with those in the number-groups. The latter are individual to a set of

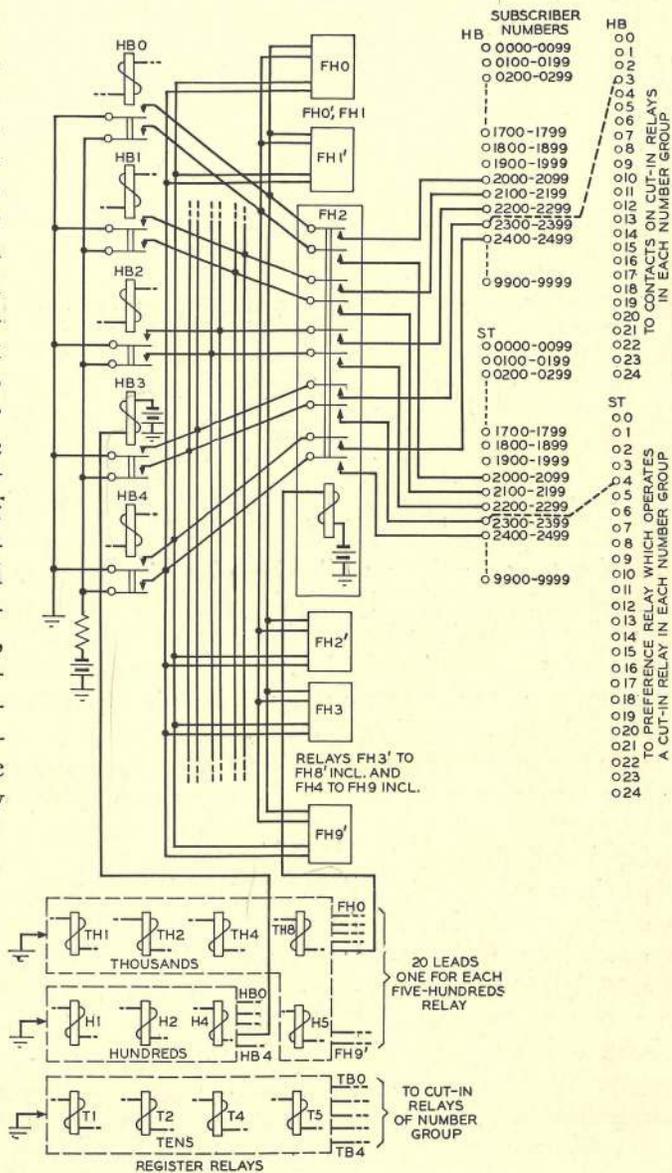


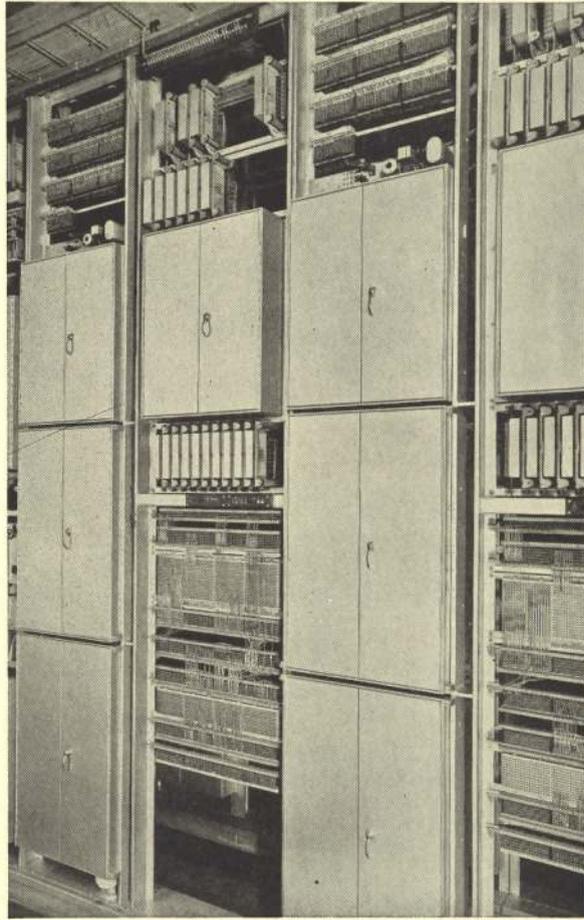
Fig. 4—Simplified schematic of 500-group and hundred-block relay circuit in the marker



tion with twenty FH relays, can be made to designate any hundred-block in the office.

The operation of one HB and one FH relay in the marker closes paths to two sets of terminal strips—one marked ST, and the other HB. These terminal strips form part of one of the marker bays as shown in Figure 7. Since there are twenty FH relays, each carrying a pair of contacts for each of the five HB relays, there are one hundred terminals in each of the two terminal sets, one corresponding to each possible hundred-block in the office. Adjacent to the one hundred ST terminals is a group of terminal strips, each strip representing a number group. Each of the one hundred ST terminals is cross-connected to the strip representing the number group containing that hundred-block of subscriber numbers, and closure of this path in the marker will cause the number group to be connected to the marker. Adjacent to the one hundred HB terminals is a similar group of terminal strips, each strip representing one of the hundred-blocks of subscriber numbers in the selected number group. Each of the one hundred HB terminals is cross-connected to the strip which will operate the hundred-block relay in the selected number group that gives access to the corresponding hundred subscriber numbers.

So far, a particular number-group connector has been selected, and a hundred-block relay in that group has been operated. Which particular twenty-block relay is operated is de-



*Fig. 7—Each terminating marker consists of two bays, one consisting chiefly of three cabinets of relays, and the other of one relay cabinet and the cross-connecting terminals*

termined by the combinations of operated relays of the tens-group of register relays in the marker. Five leads are carried from this set of register relays through the number-group connector to the number group, where they are multiplied to the five contacts of all the HB relays assembled in that number group, as shown in Figure 8. From this relay they run to the windings of the twenty-block relays—the contacts of each hundred-block relay being connected to the five twenty-block relays



# Terminating Markers: Busy Testing and Line-Choice Selection

By J. W. DEHN

**B**Y OPERATIONS described in an accompanying article,\* the terminating marker decodes the number transmitted to it by the terminating sender, and operates a block relay in one of the number groups. Forty block relays with their cross-connection banks, which permit the assignment of any line number to any line switch in the office, are mounted in a bay as shown in Figure 1. Since each block relay represents twenty line numbers, each bay represents 800 line numbers, and a sufficient number of bays are installed to take care of all the lines in the office. The operation of a block relay closes sixty contacts—three for each of the twenty subscriber numbers associated with it. Over one of these three leads, the marker will test the called line to determine whether or not it is busy. If the line is in use, the marker will cause a busy signal to be returned to the subscriber. If the line is idle, however, relays will be operated over the other two leads to direct the marker to the particular crossbar switch to which the line is connected, so that a path may be found between it and the incoming trunk. The lead used for the busy test will then be used to operate the hold magnet of the line called.

Each of the sixty moving contact springs of a block relay is strapped to the corresponding springs of all other

\*Page 40.

block relays of the number group, and is then carried through the number-group connector to the marker. Here they are distributed and connected



*Fig. 1—Block relay bays, each with forty block relays above, and line cross-connecting terminals for their NC and NF leads below*

to three moving spring contacts of twenty L relays as shown in Figure 2. The three leads for each line are marked NC, NF, and NS, followed in each case by a number from 0 to 19 to designate the twenty lines of the block relay. The L relays are also numbered from 0 to 19.

The leads from the front contacts of the block relays run to terminal strips—all the NC leads to one set, the NF to another, and the NS to another. The terminal strips for the NC and NF leads are mounted on the frames beneath the block relays as illustrated in Figure 1. These terminal strips are five terminals high and ten wide, and ten of them are mounted in a row across the frames. One such row for the NF leads is shown immediately beneath the block relays. Below it are three banks of multiple-terminal strips, each twenty terminals high. These multiple-terminal banks—somewhat like the banks of a panel selector in appearance—are built up of insulated horizontal metal strips with soldering terminals projecting in line with each terminal of the upper set of terminal strips. Below these is another row of terminal strips for NF terminals like the one above. Two strips—one above and one below the multiple-terminal banks—take care of the NF terminals from the five block relays controlled by one hundred-block relay. Eight pairs of fifty-terminal strips across the bay thus provide for all the block relays on the bay. The ninth and tenth pairs of terminal strips are used for other purposes. Below these cross-connection terminals for the NF leads is a similar set for the NC leads, the main difference being that there are only two banks of multiple terminals for the NC leads instead of the three provided for the NF terminals. Figure

3 shows the arrangement for one twenty-block relay only.

The twenty leads from each of the three multiple-terminal banks associated with the NF terminals are marked TF, HF, and RF, respectively, and numbered 0 to 19 inclusive. They are all carried through the number-group connector to the marker. Cross-connecting jumpers are run from each NF terminal to one of the terminals in one of the multiple-terminal banks. For individual and party lines, the jumper runs to either the TF or RF banks, depending on whether the called station is rung over the “tip” or “ring” conductor, while trunks to a PBX are cross-connected to the HF bank, except the last trunk in a group to any one PBX, which is cross-connected to the RF bank.

The terminals for the NS leads are on the line distributing frame. The terminals to which they are cross-connected on this latter frame are connected to one side of the hold magnets of the primary switches on the line-link frames, and there is thus one terminal for each equipped line in the office. Cross-connecting jumpers are run to associate each NS lead with the hold magnet with which the corresponding line is associated at the line switch. If the line is busy, its NS lead will be found grounded through the sleeve lead of the line. Thus when a block relay is operated, the twenty NS leads brought to the marker will be either grounded or not grounded depending on whether the lines are busy or idle.

As may be seen from Figure 2, the NS leads are extended through back contacts on the L relays—which are unoperated at this point—to the windings of S relays, and the S relays connected to busy lines will be operated by the ground on their NS leads,

while those of idle lines will be left unoperated. The number dialed is indicated by a ground placed on one of twenty leads coming from the unit-digits group of recording relays. These twenty leads follow through a chain of contacts as in the thousands, hundreds, and tens groups of recording relays, only the chain for the unit group relays includes two additional relays, one marked "tens even" and the other "tens odd." This is necessary because a twenty-block includes two sets of ten digits: in the 0-19 group for example, are digits 0-9; the first ten, 0-9, are called the even group, and the second, 10-19, the odd group. Similarly 20-29 is an even group and 30-39 an odd group, the term even and odd referring to the tens digit, and this indication is given

by contacts on the "tens even" or "tens odd" relays. These "even" and "odd" relays, in turn, are operated by a chain through relays of the tens group, the "tens even" being operated if the tens digit is even, and the "tens odd" if it is odd.

These twenty leads from the units register relays run to the moving register spring contacts of the twenty s relays, and one of them will be grounded. If the relay to which this grounded lead is connected is operated, indicating a busy line, the ground will be carried through a front contact on the s relay, and a back contact on the associated HT relay, to a line-busy relay, which causes relays in the incoming trunk to operate and return a busy tone to the calling subscriber. If the line is not busy, the s relay will not operate,

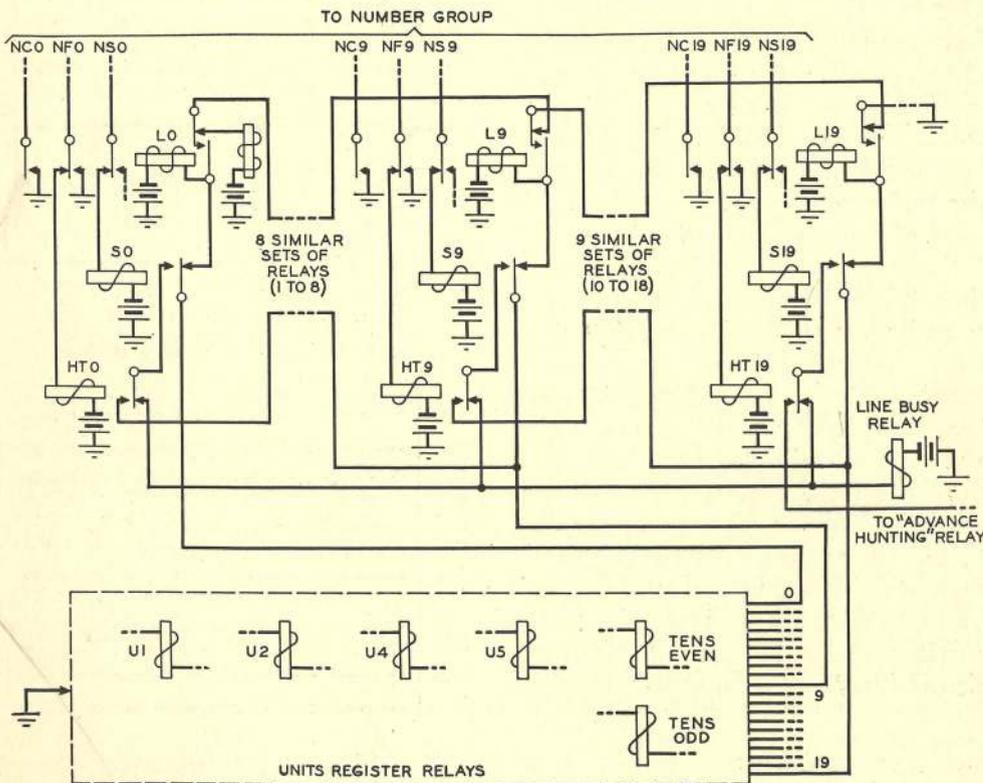


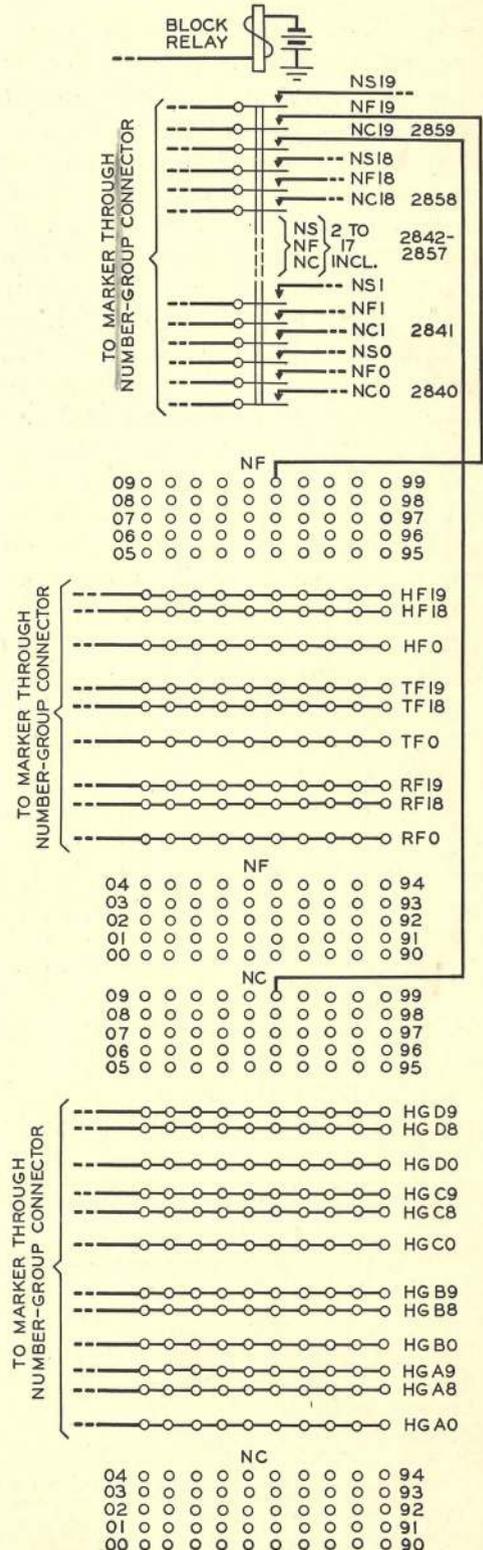
Fig. 2—Simplified schematic of the busy-test circuit of the terminating marker.

and the ground will be carried through a back contact of the s relay to operate the associated L relay.

After the number has been registered in the marker a relay is operated that grounds the twenty HF leads brought to it through the number-group connector. This relay remains operated until an L relay operates. If any of the lines of the twenty block are any but the last of a group of PBX trunks, the corresponding NF terminals will be cross-connected to the HF bank, and the ground on these latter leads will thus be carried through the block relay, the number-group connector, and back contacts on the corresponding L relays in the marker, and will operate the corresponding HT relays. All HT relays corresponding to PBX trunks, except the last, will thus be operated. This switches the leads connected to the front contacts of the s relays from the "line-busy" relay to the moving contact of the next s relay, so that instead of returning a busy signal if the first trunk is busy, the ground from the register relays will operate the L relay of the first idle trunk.

Suppose, to take a simple example, that the first trunk of the PBX had 10 as its last two digits and that there were ten trunks in the group—running from 10 to 19. Since the number dialed has 10 as its last two digits, a ground would appear on the 10 lead from the units register. This ground would be carried to the moving contact of the S10 relay, and if this trunk were busy, would be extended through front contacts of S10 and HT10 to the moving contact of S11. If this trunk also is busy the ground will be simi-

Fig. 3—Simplified schematic of cross-connecting terminals for five block relays, with one of the block relays shown above



larly extended to S12, and so on until an idle trunk is reached, when the ground would be extended through the back contact of that S relay to operate the corresponding L relay. It should be noted, however, that this testing does not pass from one trunk to the next in sequence, but that since all the S and HT relays that are to operate are operated together by the closure of the block relay—the L relay of the first idle line is also operated immediately after the block relay has operated.

If the PBX had been a large one, there would very likely be more than twenty trunks, so that they could not all be reached through a single block relay even if they started with the first line of that block. This situation is taken care of by running the lead from the front contact of the last HT relay to an "advance hunting" relay, which is associated with a group of "hunting progress" relays through which pass the leads from the tens group register relays on their way to the windings of the block relays. If all the trunks in the first block were busy, the ground from the units group of register relays would be carried through the front contact of HT19 to operate the advance hunting relay. This relay would release the block relay already operated, and bring in the block relay with the next group of trunks to the PBX called. At the same time the ground would be removed from the IO lead from the units register relays and placed on the O lead. The leads from the second block relay would now be connected to the marker, and this group would be busy tested in exactly the same manner. By this same method it is possible to test large trunk groups, bringing in one block relay after another as all the trunks of one block are found busy.

Should all the trunks in the group be busy, the ground would be extended to the line-busy relay through the back contact of the last HT relay, which will not be operated since the last trunk of a group is connected to the RF rather than to the HF lead.

The operation of an L relay, when a line or trunk is found idle, grounds both the NF and NC leads, and connects the NS lead to relays in the marker that will be used later for "closing through" the talking path. The grounds on the NC and NF leads are carried back through the number-group connector and the block relay to the NC and NF cross-connecting terminals. As already pointed out, the NF leads are cross-connected to one of the terminals of one of these multiple banks—to the RF or TF banks if it is an individual or a party line, and to the HF if it is a PBX trunk. Each multiple bank, however, has twenty rows of terminals, one for each of twenty possible line-link frames, and the cross-connection made will depend on which primary line-link frame the line is connected to.

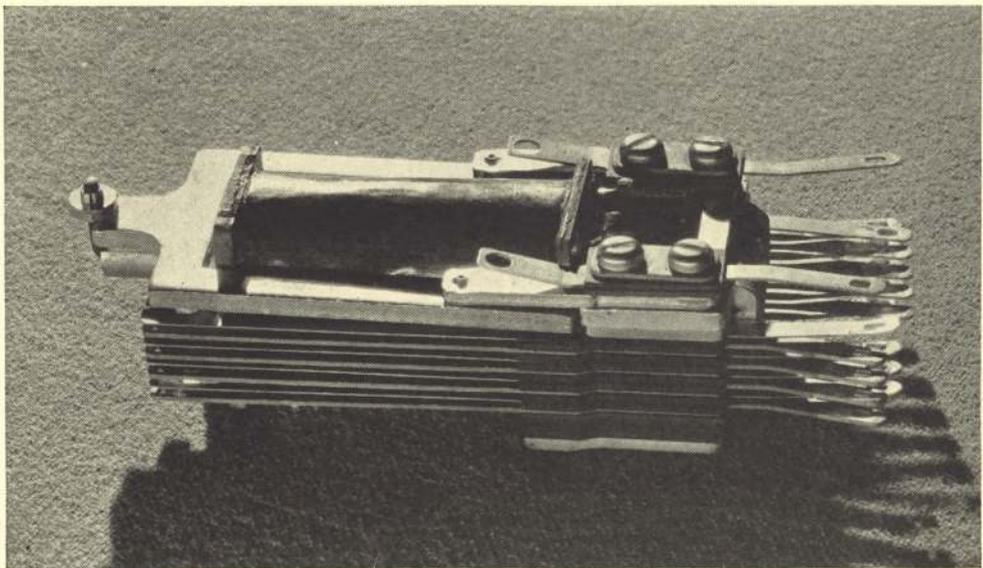
For convenience in controlling the completion of calls, the line-link frames are divided into groups of four, called "line-choices," and the control leads from only one line-choice at a time are brought to the marker through a line-choice connector. This arrangement parallels that of the number group and number-group connector. There may be as many as twenty line-choices in an office, and the twenty horizontal strips in each of the multiple banks associated with the NF terminals are assigned to the twenty possible line-choices. The cross-connection from any NF lead is thus run to the particular multiple strip that corresponds to the line-choice in which that line is located.

Leads from these multiple banks run to the marker through the number-group connector, and when an L relay operates, the group placed on the NF lead will pass over the cross-connection to the multiple strip—in either the TF, HF, or RF bank—for the line choice on which that line or PBX trunk appears, and will operate a relay in the marker that will bring in the proper line-choice connector.

It is necessary further for the marker to know which particular line-link frame of the line-choice the line is connected to, and the particular row of switches in that frame, so that it can proceed to find an idle path between the incoming trunk and the line. This information is obtained by the cross-connection of the NC lead. As pointed out above there are only two multiple banks associated with the NC leads, but each is divided horizontally into two groups, so that there is the equivalent of four multiple

banks, each ten terminals high. Each of these banks represents one of the four line frames of a line-choice, and the ten strips in each group represent the ten rows of switches on each frame. These banks are marked A, B, C, D, rather than by actual frame numbers since they represent different frames depending on the line-choice selected. The jumper from the NC terminal is thus run to the particular level in the A, B, C, or D bank that corresponds to the location of the line on the line-link frame.

The leads from these multiple banks also run back to the marker through the number-group connector. Ground appearing on one of them, from a front contact on the L relay, operates relays that allow the marker to test for idle paths from the incoming trunk to that particular row of switches, and also operate the proper select and hold magnets to connect the line through.



*The Y-type relay in its general features is like the U relay, but was designed primarily to secure accurate slow-release timing. Its armature has a spherical embossing that gives essentially a "point" magnetic contact at the pole face*

# Lockout Circuits

By F. A. KORN

IN ANY automatic telephone switching system, the time required to set up a connection is only a very small part of the total time from the beginning to the end of the call. In the crossbar system, for example, the selection of the paths through the switches and the operation of the cross points requires but a fraction of a second, while the following conversation may last several minutes. If the equipment used for establishing the connection is made part of the main switching units, its efficiency of use will be very low, since it will be used for only a fraction of a second on each completed connection. By dissociating the controlling equipment from the switching units used in the talking path, however, the control circuits may be employed very efficiently, since they may be used almost continuously in establishing one call after another.

This is the principle employed in the crossbar system. Separate controller or marker circuits are used, for example, at the various stages of the switching chain, each being associated with a call only long enough to perform its switching function. In this way these expensive controller or marker circuits are employed very efficiently, and thus become inexpensive per call.

Each such circuit must be able to connect itself to each switching unit it controls, and paths must be provided as indicated in the upper diagram of Figure 1. If the arrangement

were as simple as there indicated, however, several of the controller circuits might connect themselves to the switching unit at the same time, and interfere with each other. To avoid this, an additional circuit is interposed between the controller and the switching circuit as indicated in the lower diagram. This circuit is known as a lockout or "gate" circuit. It is arranged to permit only one controller circuit to be con-

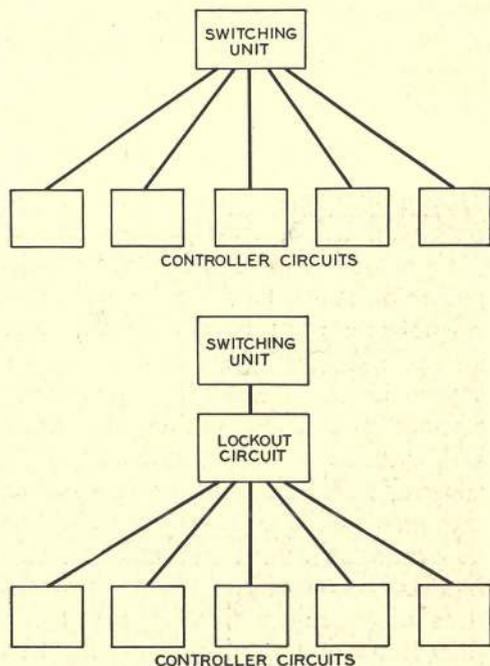


Fig. 1—Each common controller circuit must have access to the switching units it controls (upper diagram); and to prevent several controller circuits seizing the same switching unit at the same time, a lockout circuit is interposed (lower diagram)

nected to the switching unit at a time, and where a number of controller circuits are awaiting connection, to select them successively as nearly as possible in the order of their request for connection. Such lockout circuits are employed at many points in the system, and although they differ somewhat in type, depending on their location, their functions are essentially the same.

One place where such lockouts are used is between the terminating markers and the number groups.\* There may be as many as twenty-five number groups in an office and from three to ten markers. Each marker must be able to reach any number group but not more than one marker must be allowed to connect to the same number group at the same time. Each number group has a lockout circuit through which all the marker

connections must pass, and the circuit provides that only one connection be made at a time and that the markers will be served as nearly as possible in the same order in which they ask for connection.

The essential features of the lockout circuit provided for this situation are shown in simplified form in Figure 2. The relays in the top row, marked MC, are the ones that close the connection between the number group and one of the markers, while those in the bottom row are in the marker, and are operated when the marker wants a connection to that particular number group. The lockout relays themselves comprise the middle row, and are marked MP. All the relays have following numbers to indicate the marker served. It will be noticed that two circuits run through the back contacts of the MP relays. Each chain is grounded at one end. The ground GI

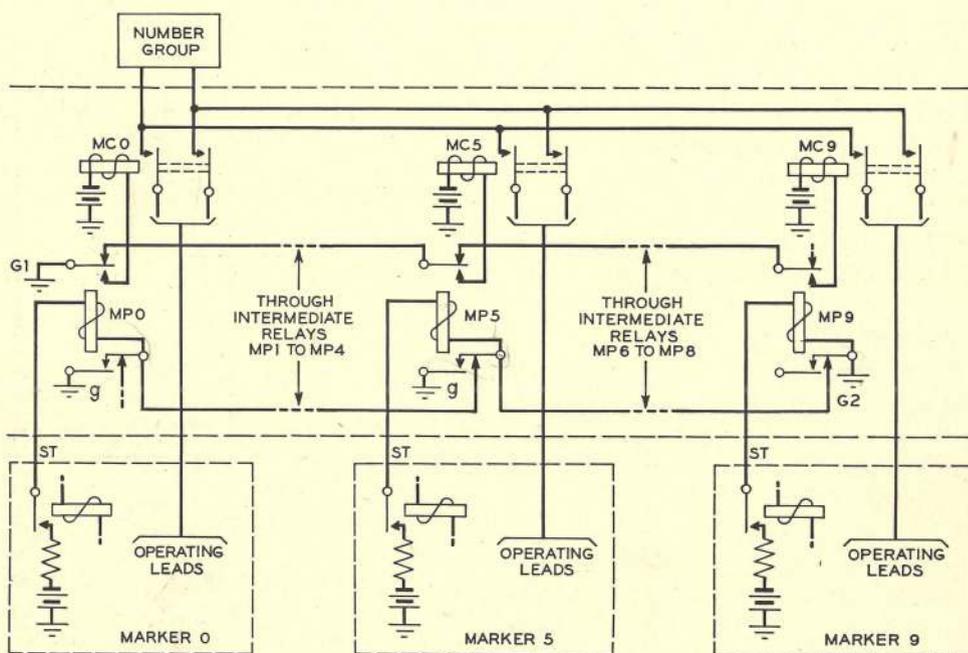


Fig. 2—Simplified lockout circuit of the type used between the terminating marker and the number group

for the upper chain is at the left and that for the lower chain at the right. In addition each relay but the last has a ground  $g$  on a front contact by which it holds itself operated.

When marker No. 5, for example, desires a connection to the number group, it closes its  $ST$  lead, which operates the associated  $MP$  relay through the chain circuit to  $G2$ . This relay holds itself operated through  $g$ , and connects ground  $G1$  through the chain circuit to the winding of  $MC5$ . This relay operates and connects marker No. 5 to the number group. By the operation of  $MP5$ , the  $G1$  chain is opened to  $MP$  relays 6 to 9 inclusive, so that even if these relays should operate, they would not operate their associated  $MC$  relays. The  $G2$  chain, on the other hand, is opened to  $MP$  relays from 0 to 4 inclusive, so that these  $MP$  relays cannot operate even though the

markers closed their  $ST$  leads. As a result of this situation, markers 6 to 9 inclusive may operate their  $MP$  relays but no further action will result, while if markers 0 to 4 close their  $ST$  leads, nothing happens.

When marker 5 finishes with the number group, which will be in less than a second, it will release  $MP5$ , and the reestablishment of the  $G1$  chain will bring in the  $MC$  relay of the next operated  $MP$  relay. When this next marker finishes with the number group, the next  $MC$  relay of higher number will be operated, and so on until all markers up to No. 9 have been served. With the release of  $MP9$ —or the highest  $MP$  relay that was operated—the  $G2$  chain will be reestablished, and any waiting markers will operate their  $MP$  relays. The lowest numbered one will operate its  $MC$  relay and in doing so will open the  $G1$

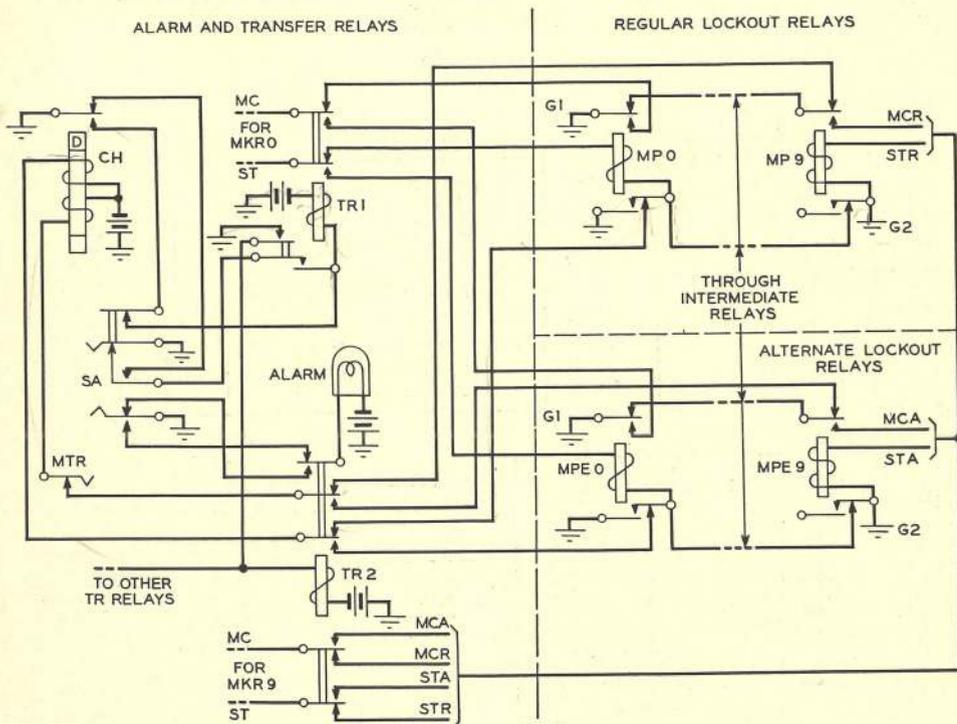


Fig. 3—Alarm and transfer circuits used with important lockout circuits

chain to the higher numbered relays, and the G2 chain to the lower numbered ones. The cycle will then proceed as before. It begins with the lowest numbered marker, travels successively through those of higher number, and then starts over again.

The two chain circuits may be looked upon as doors to a physician's reception room, with the number group acting as the doctor. The G1 chain is the door leading to the consultation office, and the G2 chain is the door from the street. When MP9 is released, the outer door is opened, and all the marker patients waiting step inside the reception room. The door to the doctor's office is then opened wide enough to admit the patient at the extreme left. After he has been served, the door is again opened to receive the next patient, and so on until all have been served. While this serving of patients has been going on, the outer door has been closing from

left to right, so that new patients can enter the reception room if they are to the right of the one being served. After the reception room has been emptied, however, the outer door is opened wide, and all waiting patients step in.

On very important circuits, where the failure of the chain circuit would seriously affect the service given, two such lockout circuits are provided, one to be switched in automatically on failure of the other. Alarms are provided to indicate when a transfer occurs, and controls to permit the transfer to be made manually to insure that both circuits are always in working order.

The essential features of this circuit are indicated in Figure 3. Under normal conditions, the operation of an MP relay opens and closes both of the chain circuits together so that current is always flowing in both or neither of them. Under the most

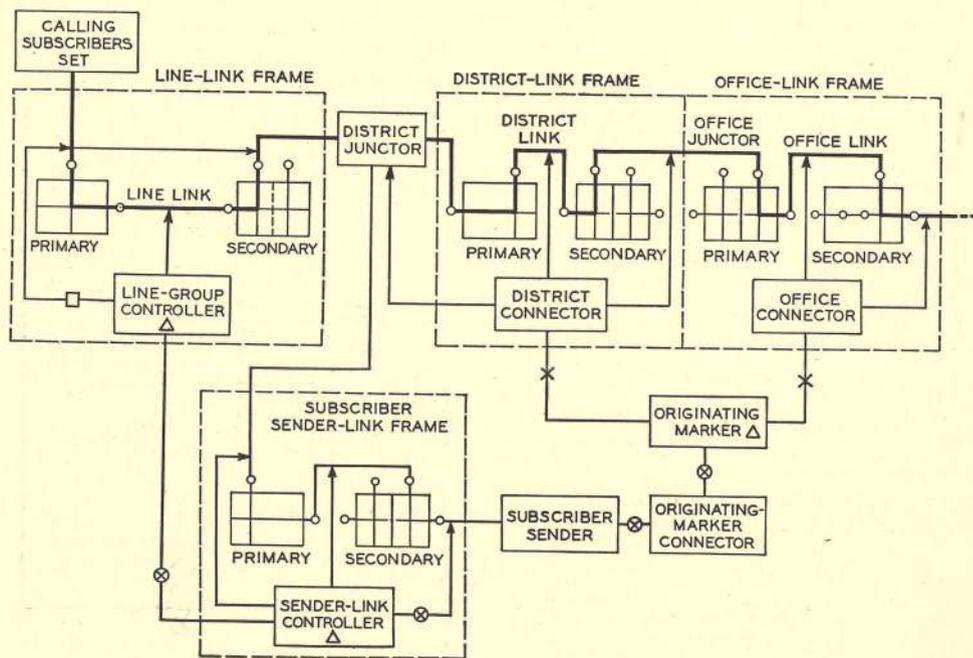


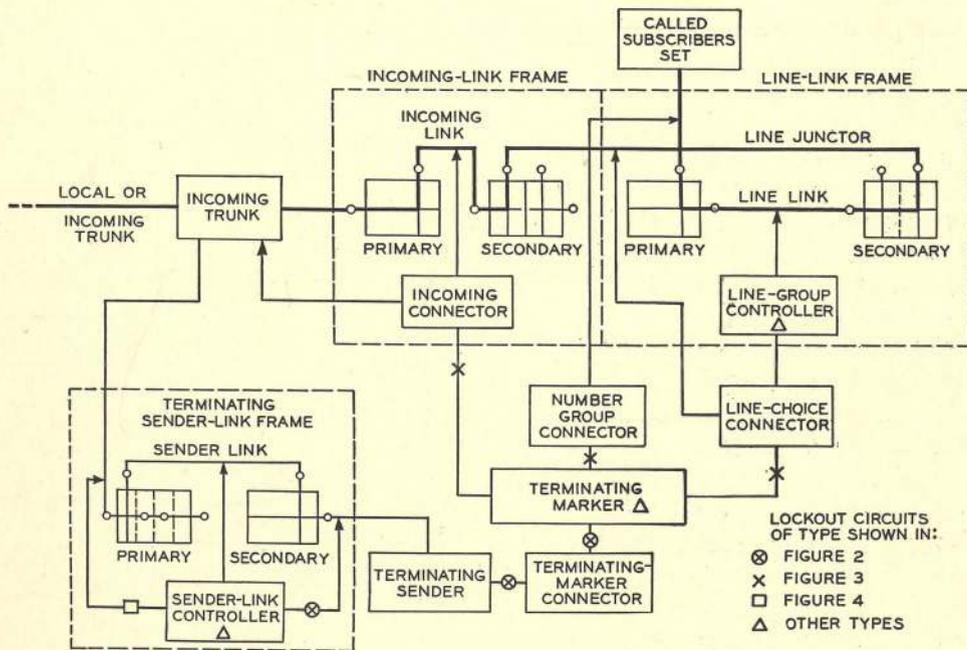
Fig. 4—Block schematic of crossbar system showing

likely trouble conditions, however, such as faulty contact, false grounds, or crossed contacts, there will be occasions when current will flow in one chain only. Under these conditions all the MC and ST leads are transferred to the other chain through two or more TR relays under control of the double-wound CH relay. One end of each winding on this latter relay is connected to battery and the other ends run, through the transfer relay TR2, to the ends of the G1 and G2 chains. The two windings on the CH relay are differentially connected so that with current in both of them, the relay remains unoperated. With current flowing in only one of the ground chains, however, as would occur under trouble conditions, mentioned above, CH operates and in turn operates TRI. This relay holds itself operated through a ground on the key SA, and also operates the other TR relays. Only TR2 is shown, but if there are not enough

contacts on TRI and TR2 to transfer the leads from all the markers, one or more similar relays will be added. In addition to transferring the MC and ST leads for MP9 and the chain leads to CH, TR2 lights a lamp and sounds an audible alarm. The maintenance man stops the alarm by operating the key SA, and then proceeds to correct the trouble on the first lockout circuit.

In the meantime the alternate lockout circuit is in use, and its chain circuits have been transferred to the CH relay, taking the place of those from the regular lockout circuit. Should the alternate lockout circuit fail, therefore, CH would again operate, and by releasing the TR relays, would bring the regular lockout circuit into use again. This transfer may also be made manually at any time by operating the MTR key, which will make the transfer regardless of which lockout circuit is in use.

A somewhat different type of lock-



*the locations of various types of lockout circuits*

out circuit is employed in the line-link controller circuit\* to determine the order of serving the lines when a number of calls come in at the same time. This arrangement is shown in simplified form in Figure 5. The lines of each frame are divided into ten horizontal groups, and a common ST lead for each group is grounded when any line relay of that group operates. Only one group can be served at a time, however, and the lockout circuit shown in the illustration provides the necessary control.

If, for example, a ground should appear on ST5—because of the operation of a line relay in horizontal group five—relay H5 would be operated, and would connect ground to the operating circuit for that group by ground from the lower contact of the GT relay and a chain circuit through back contacts on the H relays. The GT relay is also operated through a front contact of H5, and in operating, opens the ST leads from the other groups of line relays so that no other call can gain access to the controller circuit until this call is handled, which is only a matter of a fraction of a second.

A ground on any of the other ST leads would have resulted in a similar operation through one of the other H relays. Had calls come in from several of the horizontal groups at the same time, all the corresponding H relays would have operated and at once have operated GT to prevent

\*Page 20.

further calls from coming in. Although a number of the H relays operate, only the lowest numbered one will connect ground through to its operating circuit because of the chain circuit from ground on the GT relay. The lowest numbered H relay that operates opens this circuit so that ground is not accessible to the others. After this circuit has been served, however, its H relay releases and re-establishes the chain circuit to the next relay. This procedure continues until all the operated H relays have been served. The last H relay to release opens the circuit to the GT relay, which releases to allow any waiting calls to operate their H relays.

It will be noted that the action of this "gate" or "lockout" circuit is slightly different from that of Figure 2 in that the gate opens or closes completely like a portcullis rather than with the action of a sliding door. When the gate opens, on the release of GT,

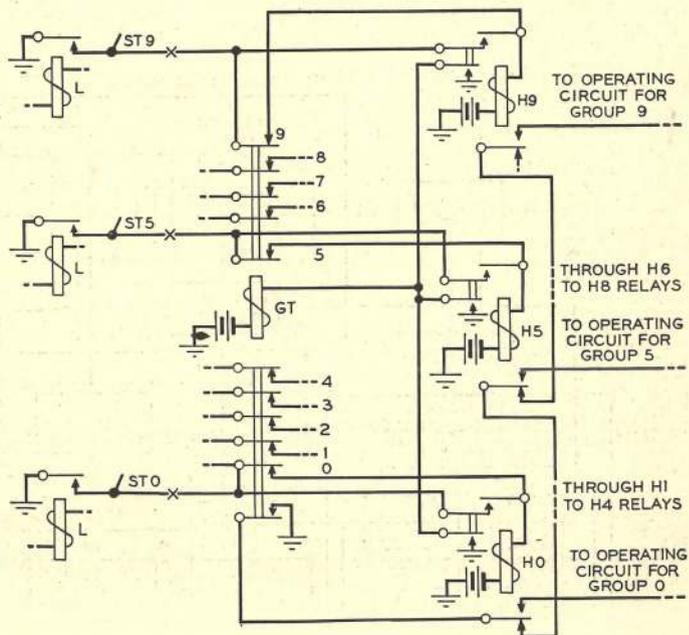


Fig. 5—A form of "gate" or "lockout" circuit employed in the line-link controller circuit

all waiting calls may enter, and when it closes—on the operation of *GT*—no more calls may enter until all those within have been attended to. With the circuit of Figure 2, however, the gate—when a call comes in—slides from the left up to that call, but remains open for calls to the right of that call to enter; it closes completely only when battery appears on the *sr* lead for marker 9. This difference is employed because of slight variations in the circuits with which they are associated.

Although the use of lockout circuits in telephone systems is not new, the common control features of the crossbar system have required their application to a much greater extent and with more elaborate circuit refinements. Applications of similar

principles, however, may be found in the start circuit of the panel line finder, and in manual systems in connection with automatic listening, where it is necessary to permit the connection of only a single trunk to an operator's telephone circuit at a time. Later, such circuits were used with the panel decoders. A duplicate set of relays with a transfer relay and alarm were added to this latter circuit to make it suitable for some of the crossbar circuits.

The two types of lockout circuits described above are used in a number of places in the system as indicated in Figure 4. Other types of lockout circuit are also used at the locations marked. In general they function in a similar manner to the circuits described, but usually are less elaborate.



*Temporary arrangements for the call-through tests at the Riverside 9 crossbar office in New York City. As a final test on a new office a group of girls place calls through the equipment in rapid succession*

# The Crossbar Switch

By J. N. REYNOLDS

THE problem of telephone switching, or how best to connect any one telephone line to any other, has always been of fundamental importance to telephone engineers. It is an extremely complicated problem, however, and may be subdivided in various manners, depending on the aspects to be particularly stressed or the degree of detail with which it is to be studied. One convenient division is into systems problems and apparatus problems. The first group arises primarily because of

apparatus used to make connections between lines and trunks. The two phases of the main problem are not unrelated, since the form of circuits and system employed may affect the type of apparatus required, and conversely the type of apparatus available affects to a considerable extent the type of system that must be provided.

In the crossbar switch there is made available a distinctly different type of switch, and one that offers very definite advantages over previous types. Its most effective utilization will require a somewhat different system of trunking and different circuits, but neither of these latter aspects need be considered in pointing out the essential nature and advantages of the crossbar switch itself. It is necessary, however, to indicate the basic characteristics of the earlier forms of switching to illustrate the specific difference of the crossbar type.

The type of switch that is used almost exclusively in manual telephone systems (using "switch" in the broad sense as any means of connecting one wire or circuit to another) is the plug and jack. A trunk or line is permanently connected to a jack, and another trunk or line is connected to a plug—either directly or through some other connecting device; and to make the desired connection, the operator picks up the plug, locates the jack of the line or trunk desired and pushes the plug into it. When mechanical methods of switching were developed, they followed the basic principle of

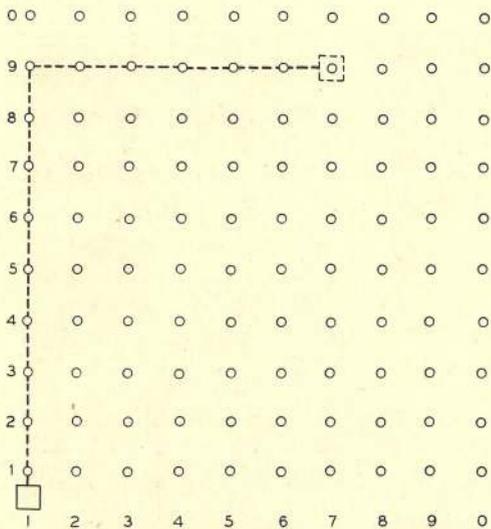


Fig. 1—The step-by-step switch includes 100 groups of terminals and one brush

the very large number of lines that must be capable of being interconnected, and considers trunking schemes and circuits. The second is concerned with the actual switching

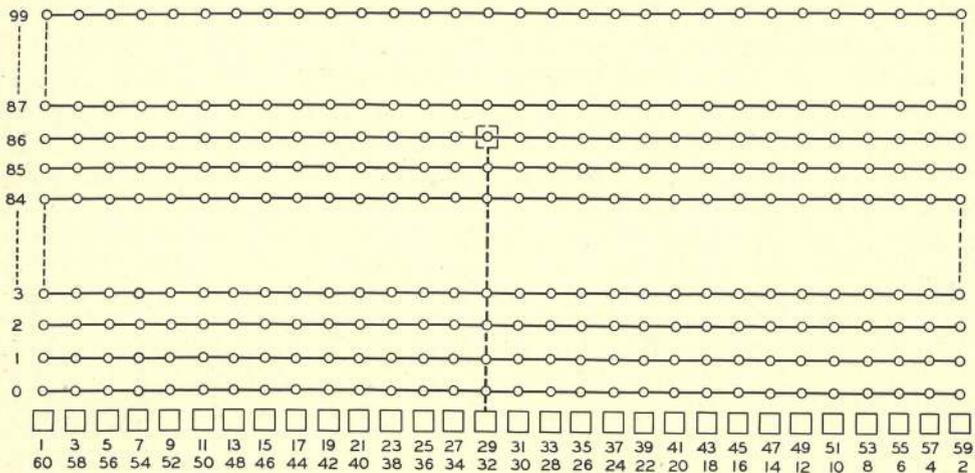


Fig. 2—The panel unit consists of 60 multiplied terminals in each of 100 rows, and a brush is provided for each of the 60 terminals of the multiple

plug and jack, but the jacks were replaced by small metal terminals arranged in compact banks, and the plugs were replaced by brushes. These were made to slide along the terminals of the bank until they reached the terminal of the desired line, when a connection would be made. Two forms of machine switching have been widely used in this country: the step-by-step, and the panel system. In the step-by-step system one brush is employed for each bank, and it moves both vertically and horizontally until the desired terminal is reached. With the panel system, the brushes move only vertically, but the banks are larger, and accommodate a number of brushes operating over parallel vertical paths.

The arrangement of the step-by-step switch is illustrated in Figure 1. Terminals for one hundred lines or trunks are arranged in a bank consisting of ten rows of ten sets of terminals each. One brush is pro-

vided for each such bank, and when not in use it rests below the bottom row of terminals at the extreme left of the bank. The terminals in the bank correspond to the jacks of the manual system, and the brush corresponds to the plug. To establish a connection the brush is moved: up by the action of a magnet, which lifts it one row for each operation; and then across the row horizontally by another magnet which moves it one contact in the horizontal direction for each operation. To connect the trunk associated with the brush of this bank to trunk 97, for example, the brush would be "stepped" up to the 9th row

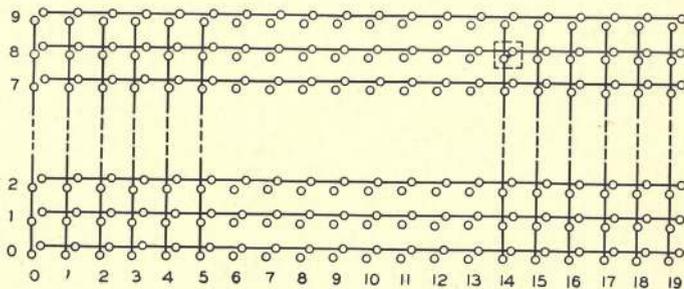


Fig. 3—In the crossbar unit two sets of terminals are mounted in place of the one set that is used in the step-by-step and panel systems and sliding contacts are eliminated

and then over to the 7th terminal.

The banks of the panel system also, for the most part, have terminals for 100 lines, but instead of being arranged in a square array they are all mounted one above the other, and the banks are thus one hundred sets of terminals high. There are sixty sets of terminals in each horizontal row—thirty on one side of the bank and thirty on the other. All the terminals in the same row, however, are connected together so that they represent only one line or trunk. Instead of one brush at the bottom, as with the step-by-step switch, there are sixty—one for each column of terminals on each side as indicated in Figure 2. The brushes on one side are assigned even numbers and those on the other side, odd numbers. Here, as in the step-by-step system, the terminals in the bank correspond to jacks, and the brushes, to plugs. The brushes are driven upward at a uniform rate by a motor-driven friction drive at the bottom of the frame, which usually

consists of five such banks, each with its own set of brushes.

Both of these systems work very satisfactorily under conditions for which they are most suitable. There are two respects, however, in which improvement seemed possible. One is that with either system a comparatively complex mechanism is required to operate the brushes. The other is that a sliding contact is required, and the terminals and brushes must be of some durable metal to withstand the wear. Unfortunately, the harder metals do not have as low contact resistance as the softer precious metals such as silver, and are more subject to the formation of poorly conducting surfaces. The crossbar switch brings improvement in both of these conditions. It avoids sliding contacts and thus facilitates the use of precious metal contacts, and it accomplishes the required connections with a much simpler mechanism. It does this by employing an entirely different and much more direct method of switching.

In the manual system, and in both the step-by-step and panel systems, which resemble it in this respect, the members of one set of terminals are banked together, and the members of the other set, which are to be connected to those of the first, are arranged to be moved up into contact with them. In the crossbar system all such necessity of motion is avoided by mounting a pair of contacts at each position in the bank, and by eliminating the

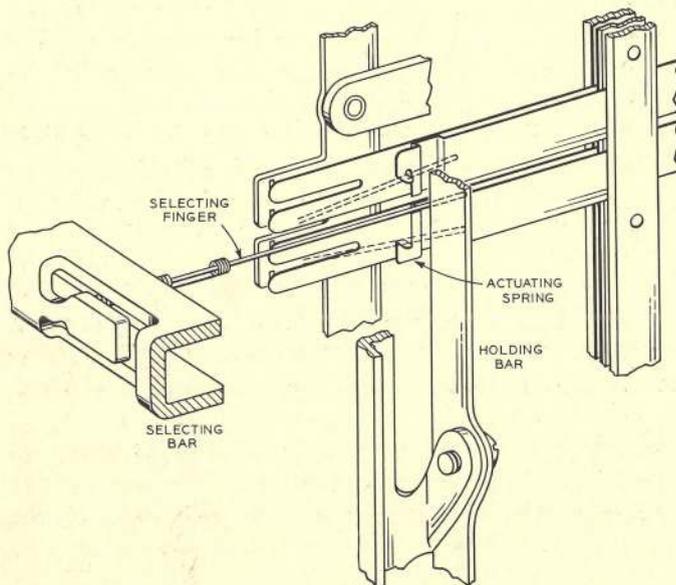


Fig. 4—Simplified schematic of the selection elements of a crossbar switch

brushes completely. The arrangement is as shown in Figure 3. One contact of each pair is multiplied with the corresponding contacts of the other pairs in the same column, and the other contact of each pair is multiplied with the corresponding contacts of the other pairs in the same row. The horizontal multiplying corresponds to that of the panel system, while the vertical multiplying is as though the brushes of the panel bank had been provided in multiple with as many brushes in each column as there were rows. Instead of moving up a brush, therefore, it is necessary only to close the contacts at the proper position in the bank to make the desired connection. The motion of the brush is avoided. The only movement required is that of a mechanical link to close the required set of contacts.

How this is accomplished is indicated by the simplified diagrammatic sketch of Figure 4. Between each pair of horizontal rows is a bar running completely across the bank, which may be rotated a small amount in either direction around its axis by the action of two magnets and armatures at one end. Wires projecting inward toward the contacts are attached to these bars at each intersection with the vertical columns. With the horizontal, or selecting, bars in their mid-positions these wires, or selecting fingers as they are called, lie between the two rows of contacts, but when the bar is rotated in one direction the fingers move up to lie across the backs of the contacts in the row above it, and when it is rotated in the other direction, the fingers are moved to lie across the backs of the contacts in the row below, as indicated by the dotted lines in Figure 4.

Along each column of contacts is a vertical, or holding, bar which—when

rotated by a magnet and armature at one end—moves a vertical bar inward to press against all the selecting fingers in that column. If none of the selecting bars are operated when the holding bar moves in, the fingers will merely be pushed down between the rows of contacts and no connection is made. If one of the selecting bars is operated, the fingers of that bar will lie across the backs of one row of contacts, and when the holding bar operates, the contact at the intersection of the selecting and holding bars that are operated will be moved into contact by the action of the holding bar against the finger which, in turn, lies across the back of the contact spring. The holding bar remains operated during the period of the call, but the selecting bar returns to normal immediately after the holding bar has operated. When the selecting bar returns to the central position, all the fingers return with it except the one held by the holding bar, thus leaving the selecting bar free for another selection with a different holding bar. The fingers are small and readily flex over the small arc of rotation of the selecting bars.

The actual appearance of a crossbar unit is shown on page 65, and in partially schematic form in Figure 5. There are five selecting bars, and thus ten horizontal rows of contacts; and there are twenty holding bars, and thus twenty vertical rows of contacts, although other numbers of holding bars may be used. The contacts themselves are similar to those of an ordinary relay and each contact in Figure 3 represents several contacts in the actual switch. Similarly each of the contact points indicated in Figures 1 and 2 really represents a group of contacts in the step-by-step or panel banks. In the crossbar system, more-

over, twin contacts of precious metal are provided, thus giving greatly increased assurance that a good connection will be made.

The gain in simplicity of operation is very obvious. In the step-by-step system, for example, the upward motion of the brush is caused by one magnet operation for each row the brush passes over, and similarly for the horizontal motion. In the panel system upward motion is caused by operating a clutch at the bottom of the frame, and then the brush is driven upward at a uniform speed by a power drive. The upward motion is actually accomplished in two steps, separated by a slight pause. In the crossbar switch, however, only two magnet operations, one immediately following the other, are all that are required.

The avoidance of sliding contacts in the crossbar system is equally obvious. The contacts are merely pressed together as in a relay when a connection is made, and no sliding in the ordinary sense occurs.

By this adoption of a new basic scheme of switching, and by the provision of a suitable mechanical method of operation, it has been possible to provide a distinctly new type of dial switching. It is much too early to make predictions as to the extent of its ultimate use or the net improvements that will accrue from its employment, but it offers opportunity for shortening the switching time and for decreasing the maintenance. Apparatus has been manufactured, and the first trial installation in a dial central office is now going forward.

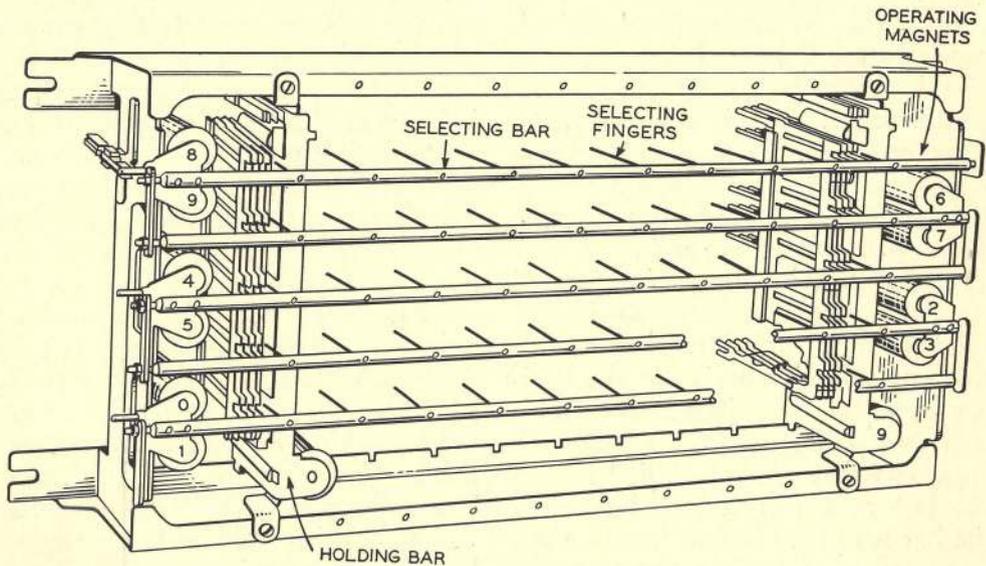
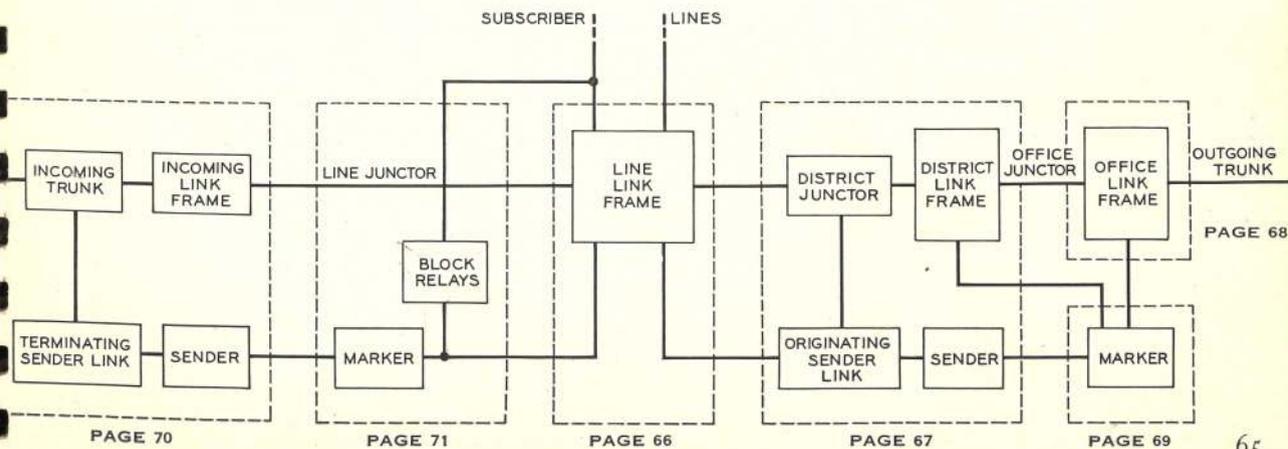


Fig. 5—Partial perspective of the crossbar switch

## MURRAY HILL SIX

On the following pages are photographs of the principal equipment units in a typical crossbar office—Murray Hill Six, which serves the busy Grand Central district of New York City. Accompanying the photographs are diagrams that show the scheme of connections; and between each two photographs is a sheet inserted to serve as an index to the apparatus groups. Leader lines on the index sheets are to be followed to the red lines on the photographs. In certain cases it is necessary to fold the sheets in the places indicated, to bring the two sets of index lines together.



*Selecting Magnet*  
5 pairs on each switch

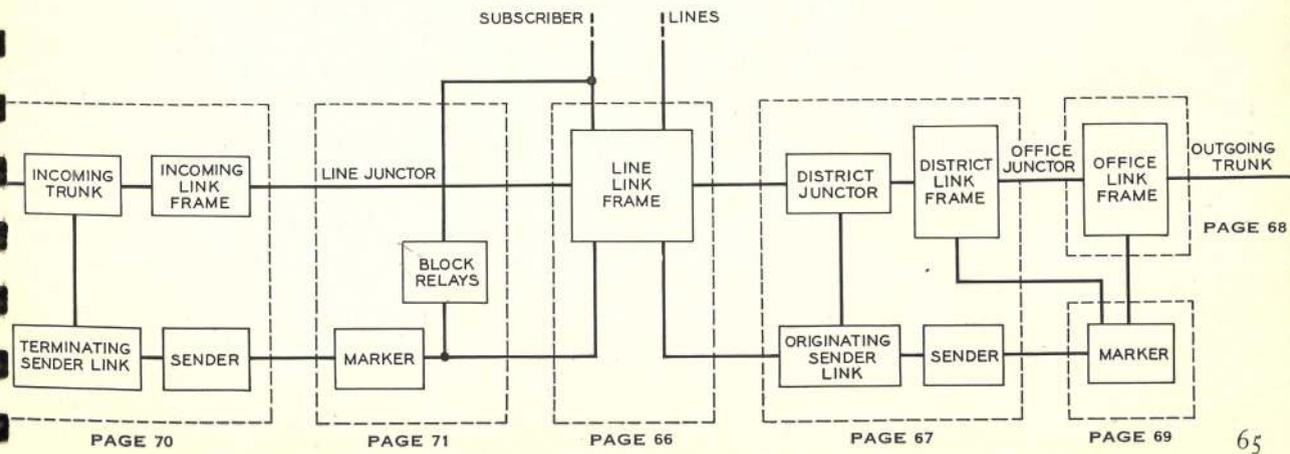
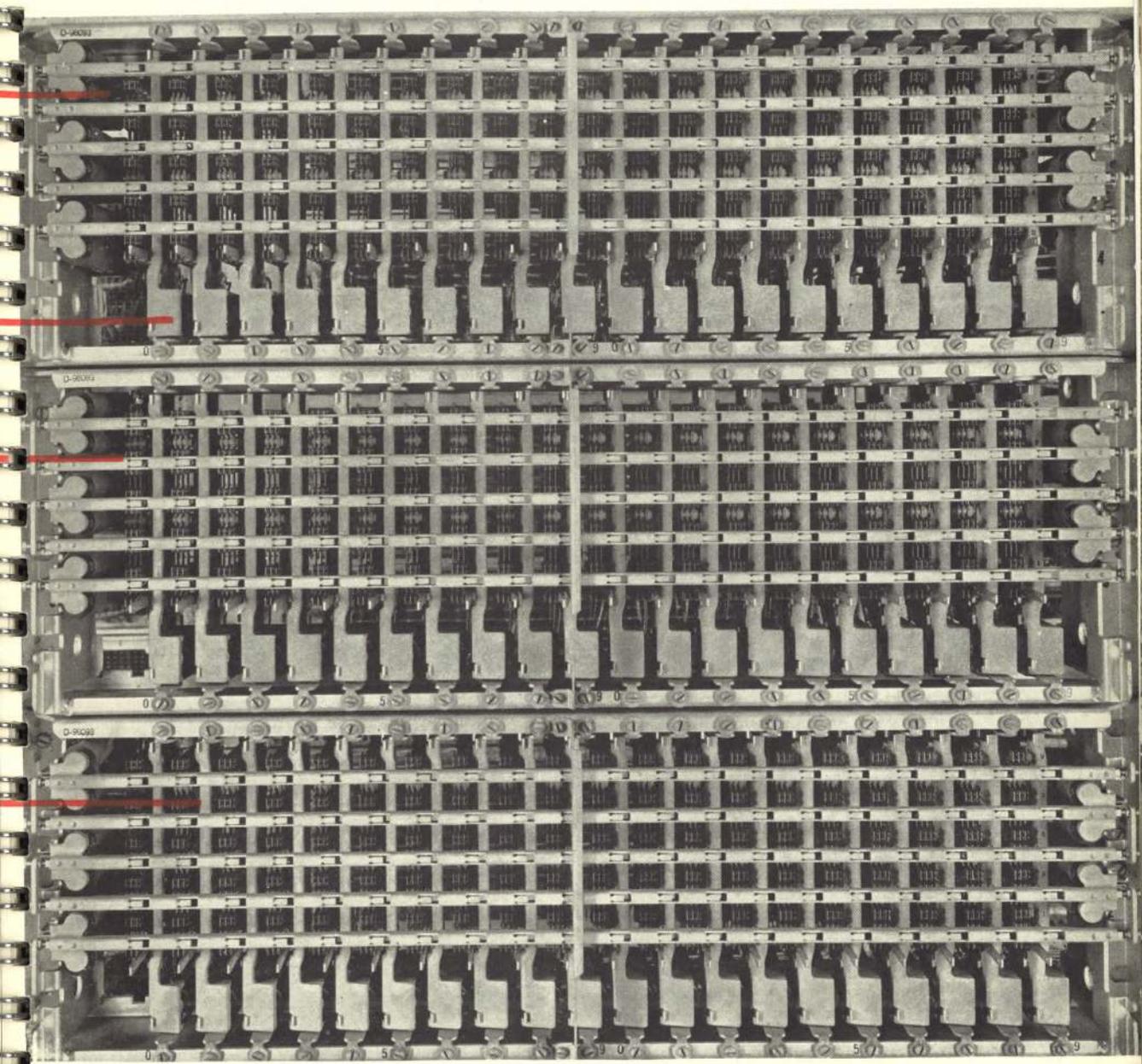
*Holding Magnets*  
20 on each switch

*Selecting Bar*  
5 on each switch, each  
with 20 selecting fingers

*Cross-point Contacts*  
200 sets on each switch

*Fig. 5—Partial perspective of the crossbar switch*

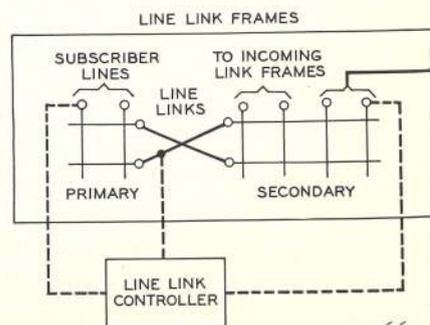
# MURRAY HILL SIX



A crossbar office differs from the previous types not only in its circuits and general switching plan, but in the type of apparatus it employs. The major piece of apparatus, the crossbar switch itself, is used for all the main switching frames, and is described on page 60. An important feature of the system, however, is the use of common controller circuits, and these are composed—for the most part—of the U and Y-type relays, shown on pages 14 and 52. These relays are in all the cabinets and under all the long horizontal covers shown in the accompanying photographs. In addition there is the multi-contact relay; these are used in large quantities on the block-relay frames, page 71, and to a lesser extent with the originating marker, page 69, but they are used to some extent with all the frames. One of their major uses, however, is as number-group and line-choice connectors.

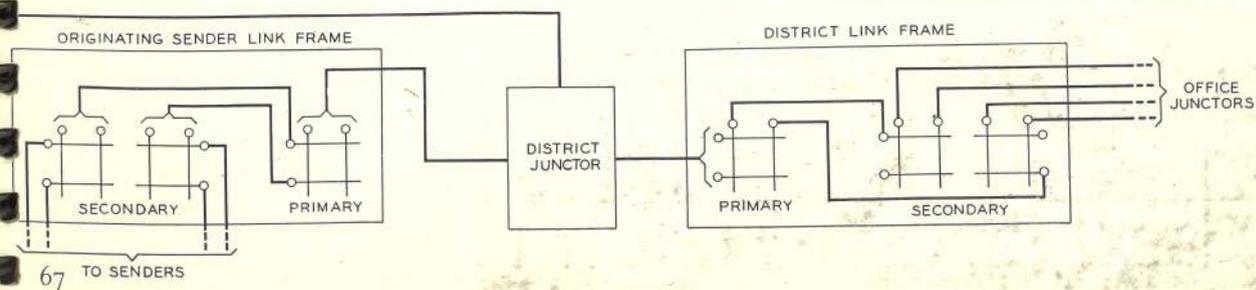
*The photograph at the left shows a line-link frame, with its common controller circuit in the cabinet at the bottom of the primary bay*

*(Opposite page) An originating sender link, the two bays at the left; district junctor circuits, the two bays of long horizontal covers; and district link frame, primary and secondary*



- Fuse Panel
- Terminal Blocks—leads for “home” and “mate” controller, and misc.
- 20 line relays (L), 2 line-test relays (LR), and 2 (HM) relays for connecting leads from hold magnets to controller
- Frame of 10 primary line-link switches
- Frame of 10 secondary line-link switches
- Make-busy jacks; alarm lamps and test jacks
- Horizontal group cut-in relays (HG) and controller cut-in relays
- “Home” controller for this frame; “mate” for paired frame

FOLD HERE →



*Originating marker cut-in relays—  
marker to frame*

*Office junctor cut-in relays  
marker to office junctors*

*District-link cut-in relays  
marker to district link*

*Marker Lock-out relays regular  
and emergency MP, E, and TR Relays,  
pp. 53, 54, 55*

*Sender sub-group relays*

*Bay of 5 sender-link  
secondary switches*

*Bay of 10 sender-link  
primary switches*

*Coin timers for district junctors*

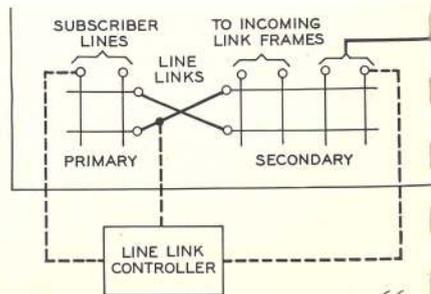
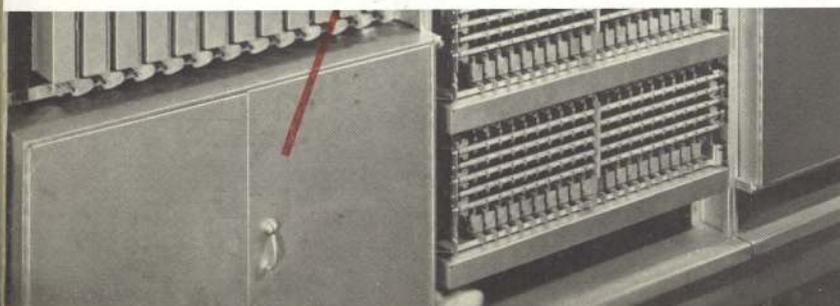
*Delayed time and automatic  
release interrupter relays*

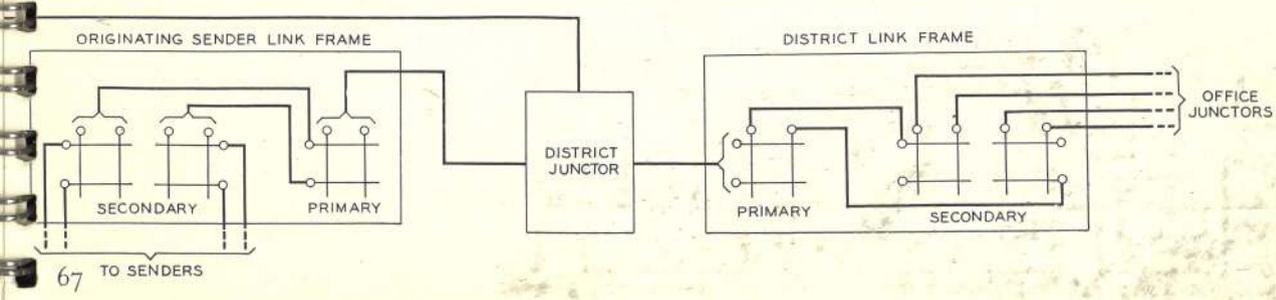
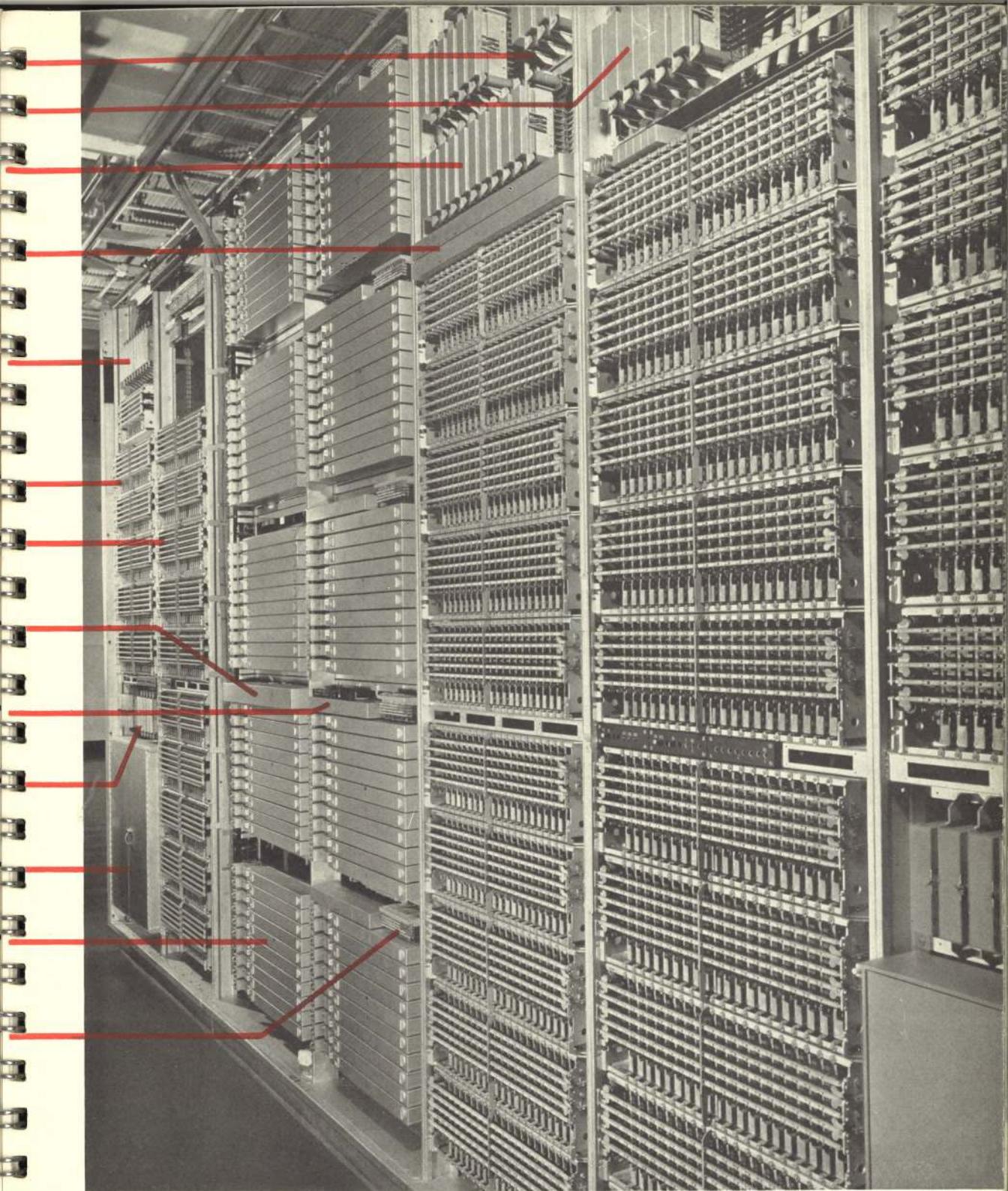
*District group cut-in relays; to  
subscriber sender-link controller*

*Subscriber sender-link controller*

*District junctors*

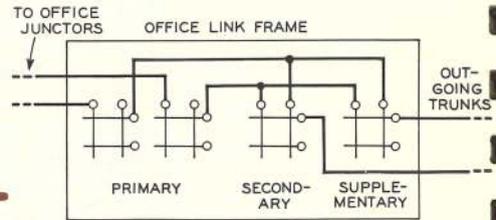
*Terminal block for district junctors*



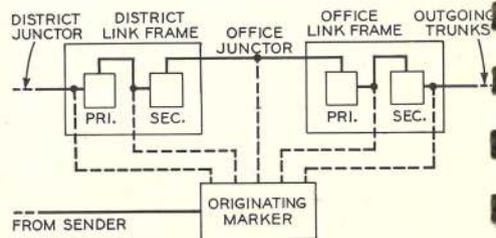


In general a crossbar switching frame consists of two bays of crossbar switches, ten in each bay. These are referred to as the primary and secondary switches. In some cases, however, additional bays are added when greater access to trunks, junctors, or lines is needed. In the office shown here—Murray Hill 6, New York City—a single supplementary secondary bay is required for the office and incoming link frames, shown on this page and page 70, respectively.

*Office link frame: primary on left, and secondary and supplementary bays adjacent*



*(Opposite page) An originating marker includes three cabinets of U and Y-type relays, at the left, and four bays of route relays and cross-connecting terminals*



Trunk level cut-in relays  
Trunks of level selected to marker

Marker Lock-out relays

Relays for control of  
secondary selecting magnets

Marker cut-in relays—  
Office frame to originating markers

Contact protection units

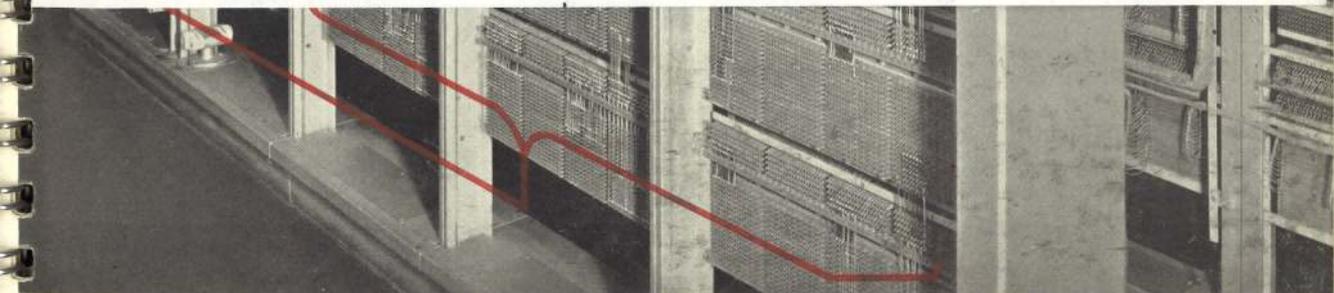
Relays for connecting office  
links to marker

Office-link primary switches

Office-link secondary switches

Office-link extension switches

← FOLD HERE



*Route Relays—  
100 on each bay*



*Sender test connector relay—*



*Trouble Indicator Connector  
Relays*



*Class of Service Relays*



*Group Relays for Large  
Trunk Groups*



*H Relays—Fig. 3, p. 36*



*Code points 600-999 repeated  
on each bay*



*Code grouping points*



*Route-relay winding  
cross-connecting points*



*Code points 200-599 repeated  
on each bay*



*Interconnector—for use  
between route-relay bays*



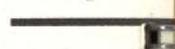
*Class-of-service  
contact points*



*Route-relay winding  
cross-connecting points*



*Talking and zone charge*



*Route-relay contact  
cross-connecting terminals*



*Pattern relay  
cross connections*



*Marker Misc. Relays  
3 Cabinets*



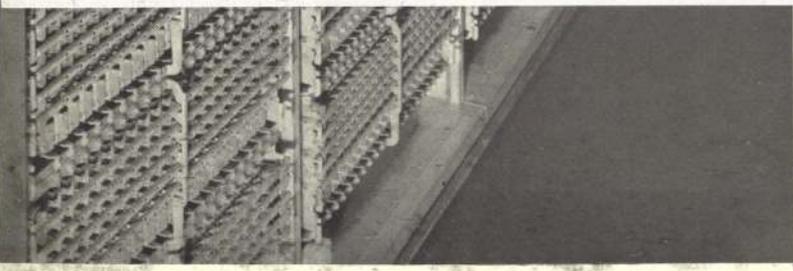
*Cross-connections for  
large trunk group relays*

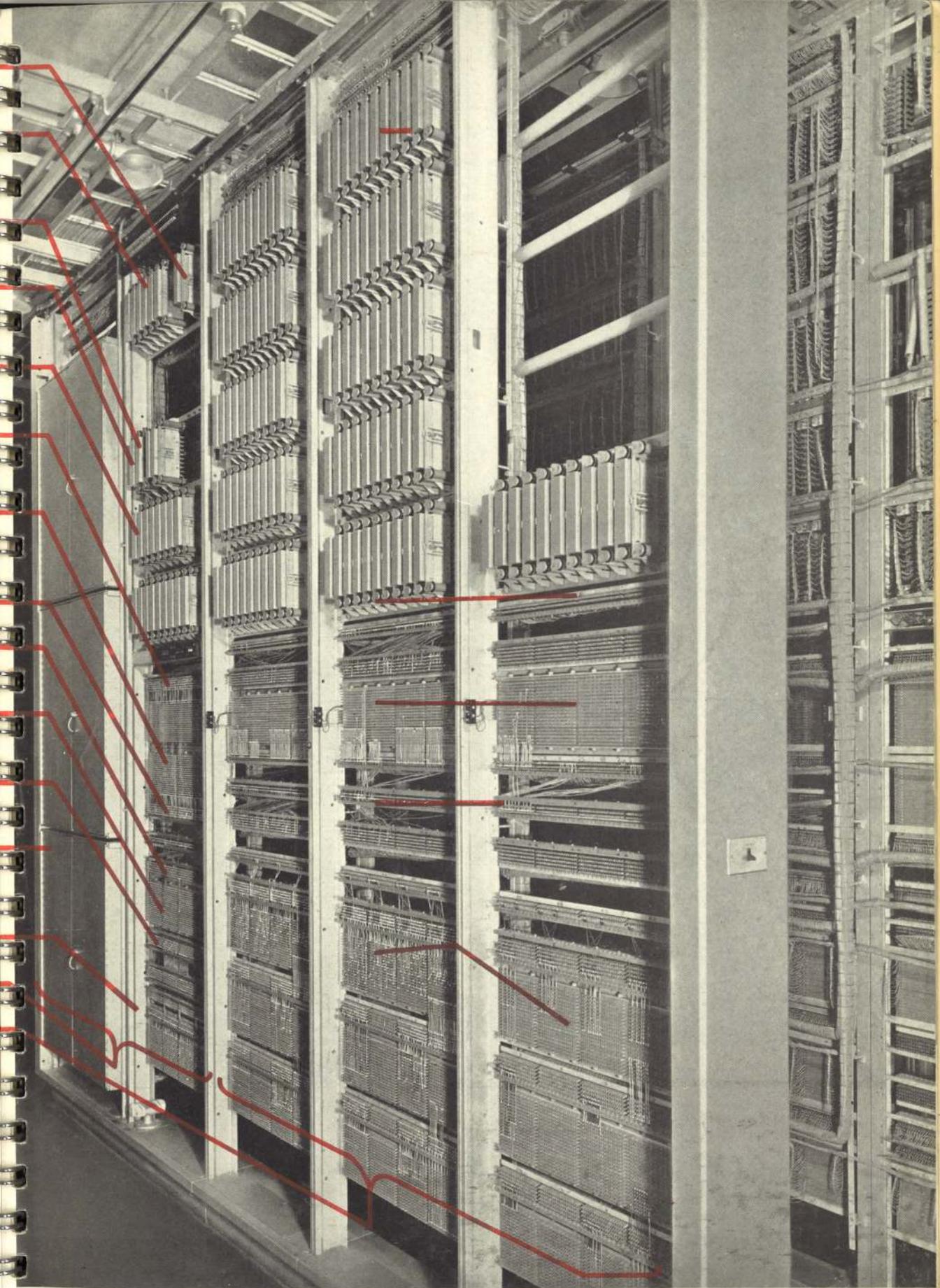


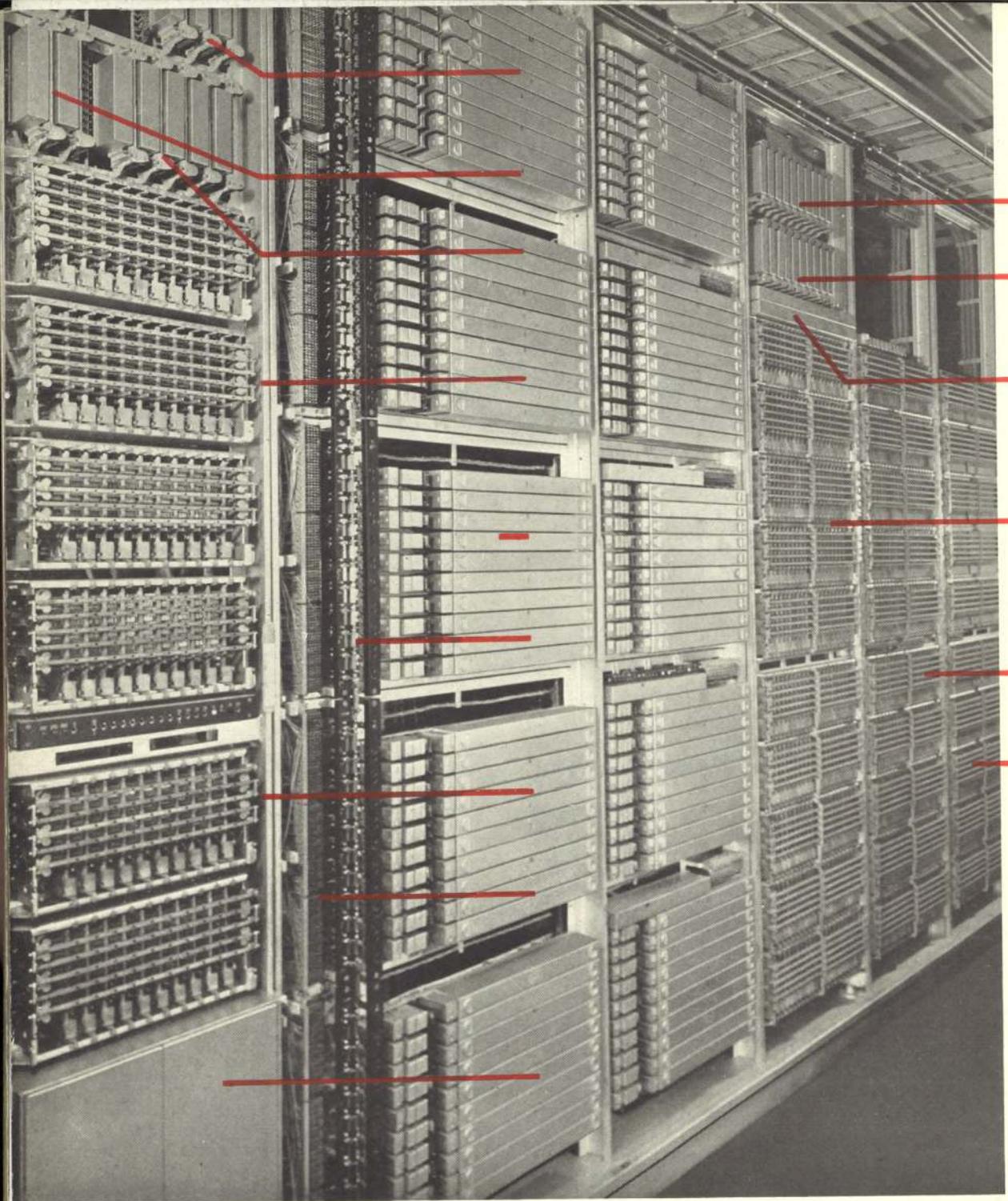
*Marker Basic Unit*



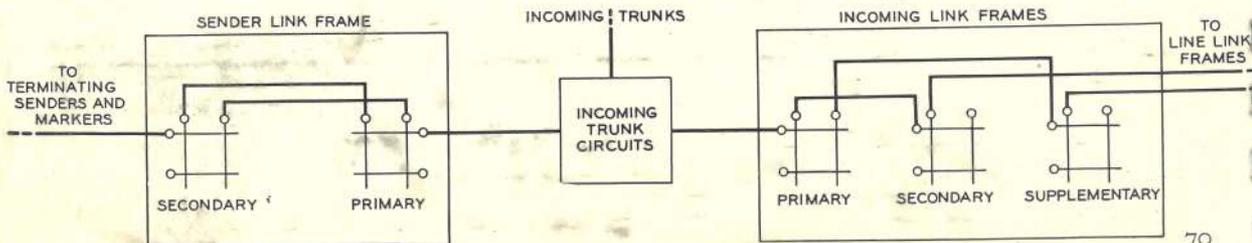
*Route Relay Bays*







*Terminating sender-link frame, left-hand bay; incoming trunk circuits—two bays of long horizontal covers; and incoming link frame—with primary and secondary and supplementary bays—at right*



Terminating marker cut-in relays connects marker to incoming frame

Incoming link cut-in relays connects incoming links to markers

Marker Lock-out relays

Incoming link primary switches

Incoming link secondary switches

Incoming link extension switches

Sender sub-group relays.  
Connects sub-group of senders to controller

Relays for connecting "home" or "mate" controller to sender-link frame

Relays for connecting sub-group of trunks to controller

3 primary sender-link switches

Incoming Trunks

Incoming Trunk fuses

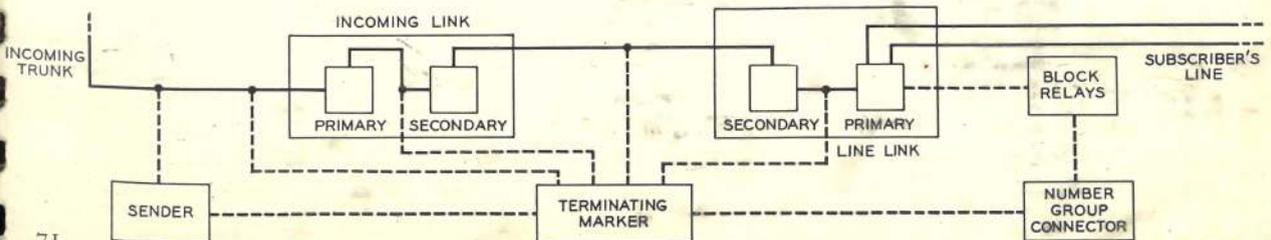
Three secondary sender-link switches

Connector blocks for incoming trunks

Sender-link controller

FOLD HERE →

location on line-link frames



Twenty Block relays  
40 relays (800 links) per bay \_\_\_\_\_

Hundred Block relays \_\_\_\_\_

NF cross-connecting punchings  
See Fig. 3, p. 50 \_\_\_\_\_

HF cross-connecting punchings  
See Fig. 3, p. 50 \_\_\_\_\_

TF cross-connecting punchings  
See Fig. 3, p. 50 \_\_\_\_\_

RF cross-connecting punchings  
See Fig. 3, p. 50 \_\_\_\_\_

NF cross-connecting punchings  
See Fig. 3, p. 50 \_\_\_\_\_

NC cross-connecting punchings  
See Fig. 3, p. 50 \_\_\_\_\_

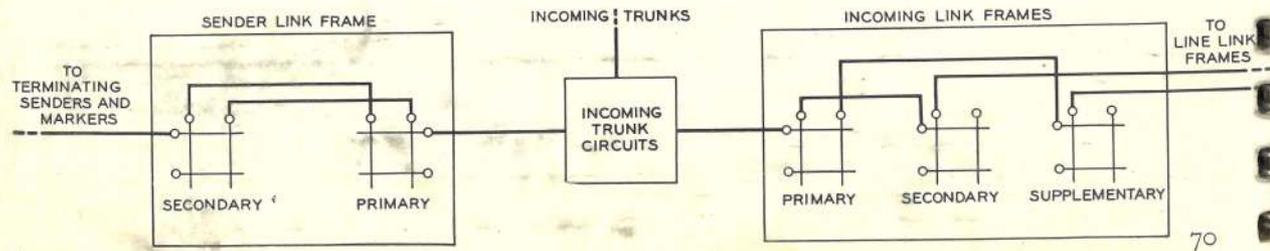
HG cross-connecting punchings  
See Fig. 3, p. 50 \_\_\_\_\_

HG cross-connecting punchings  
See Fig. 3, p. 50 \_\_\_\_\_

NC cross-connecting punchings  
See Fig. 3, p. 50 \_\_\_\_\_

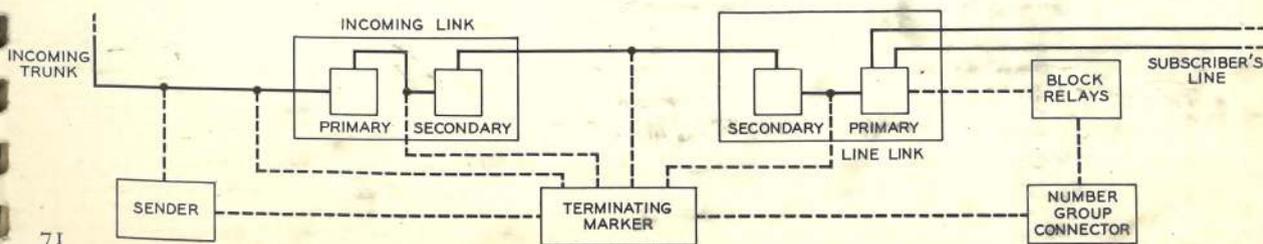
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covers; and incoming link frame—with primary and secondary and supplementary bays—at right





*Block relay bays. These are used by the terminating markers for testing lines and determining their location on line-link frames*





*This set of bays gives maintenance supervision and facilities for routine testing for the crossbar office. The major equipment bays, from left to right, are sender test, sender make-busy, originating and terminating trouble indicators, incoming trunk test, and four bays for outgoing trunk tests*

*The bays in this illustration may be identified by the letters at the foot of the bays*

*A—Originating sender test (left bay not shown)*

*B—Sender make-busy frame and plant registers*

*C—Originating trouble indicator*

*D—Terminating trouble indicator*

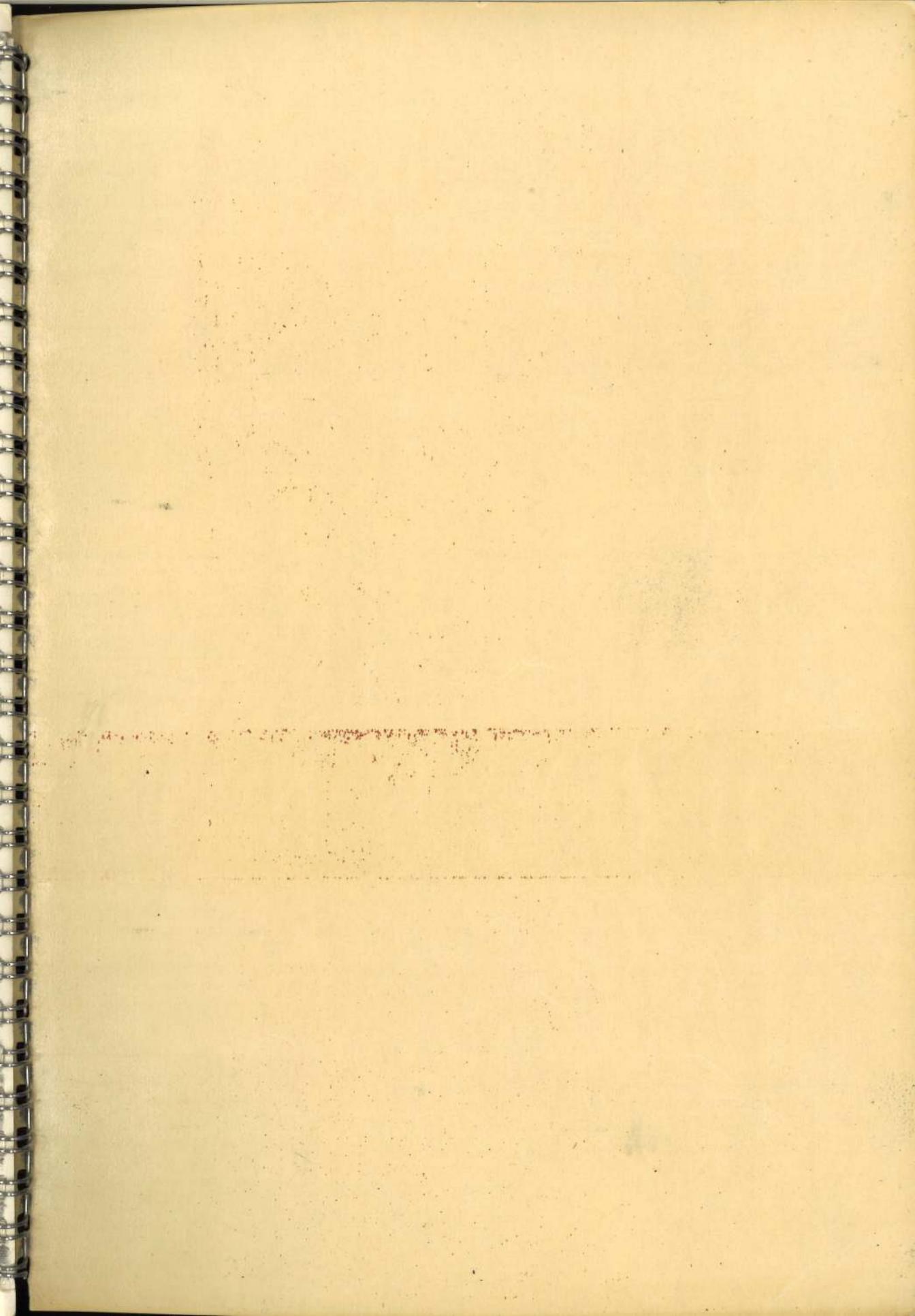
*E—Incoming trunk test frame*

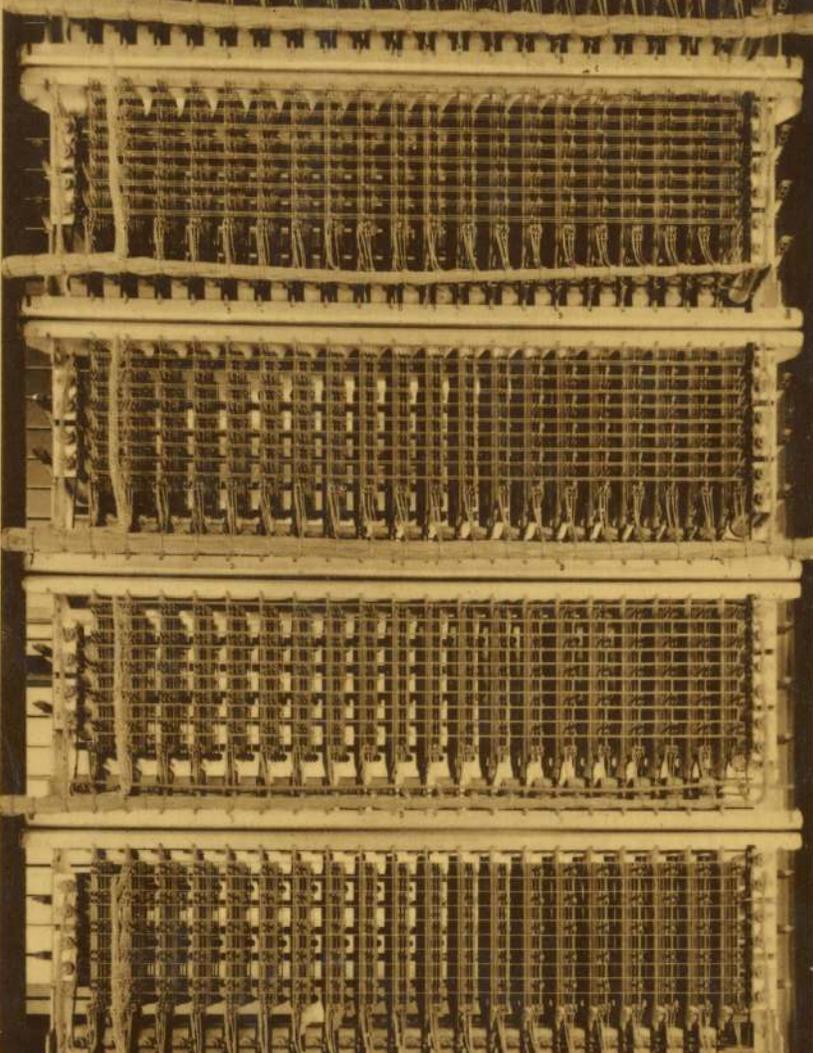
*F—Outgoing trunk test jacks*

*G, H, I—Outgoing trunk test frames*



*This set of bays gives maintenance supervision and facilities for routine testing for the crossbar office. The major equipment bays, from left to right, are sender test, sender make-busy, originating and terminating trouble indicators, incoming trunk test, and four bays for outgoing trunk tests*





# CROSSBAR

