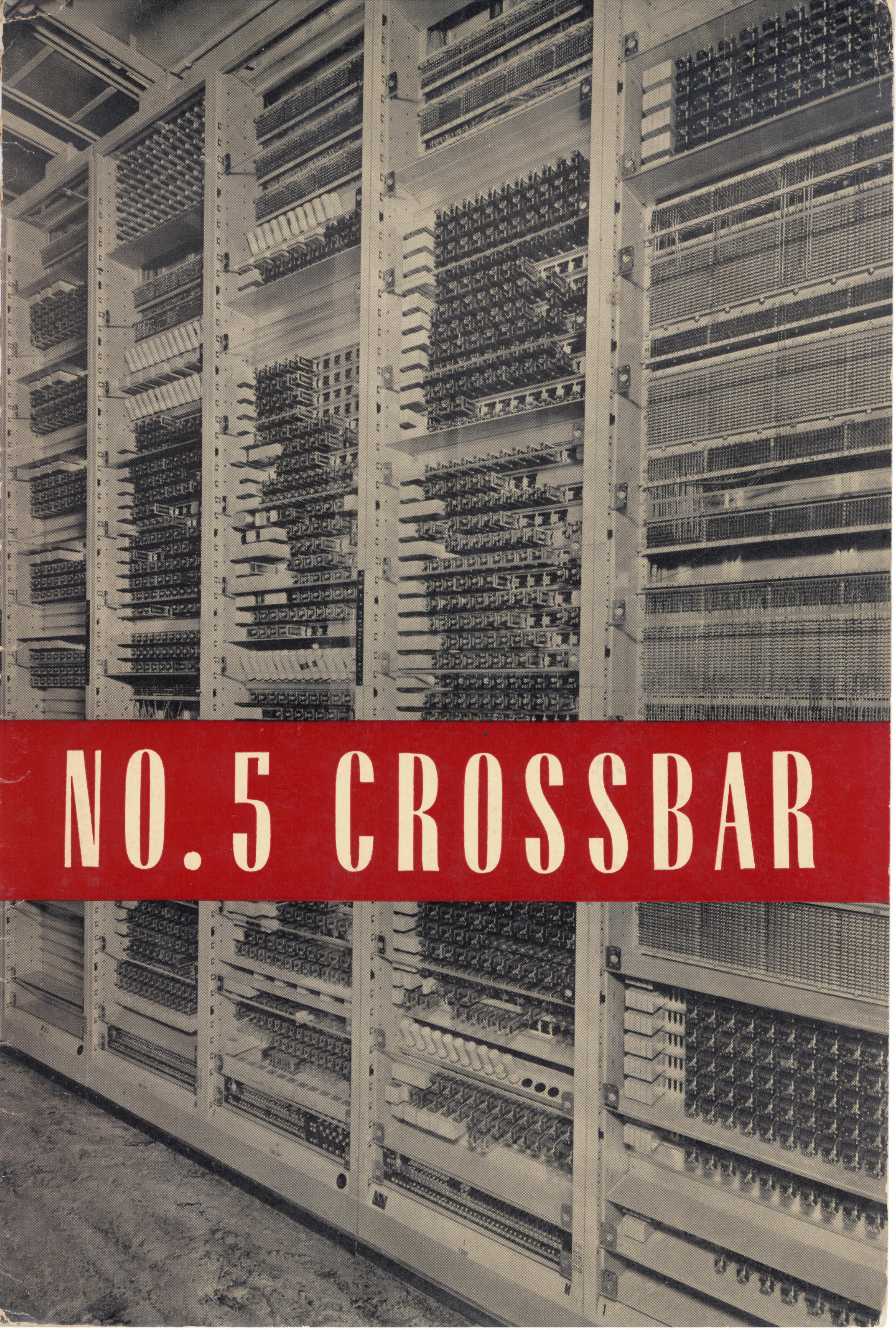
NO. 5 CROSSBAR



No. 5 Crossbar

Reprinted from
BELL LABORATORIES RECORD

Contents

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

No. 5 Crossbar

INTRODUCTION*

A little over ten years ago, the first crossbar central office was cut into service by the Bell System. Known as the No. 1 crossbar system, it was designed for large cities where the panel system had been used for almost twenty years. Since then approximately 350 crossbar dial offices of this type, serving nearly 5,500,000 subscriber stations, have been installed in the larger cities throughout the United States. During these years improvements have been made in the No. 1 crossbar system to make it more serviceable to the telephone user and to meet the new problems which have arisen.

Bell Telephone Laboratories' engineers have continued their searches for new and better telephone switching systems. One such search was for a dial system that would better meet the telephone switching requirements for areas on the outskirts of metropolitan cities and at the same time care for medium- to large-sized offices in other areas. Work on this problem culminated in the development of the new No. 5 crossbar system, and on July 11, 1948, the first office of this type was placed in service at Media, Pa., a suburb of Philadelphia.

The field of application of this new switching system is more extensive than that of any previously developed. The No. 5 system is capable of operating with all present local, tandem, and toll switching systems of the Bell System and of the independent companies which connect with it. In addition, it can serve as a tandem or toll-center switching office where this is advantageous. It can be readily equipped with features for operation as required at toll centers for nation-wide operator toll dialing and also for automatic message accounting, which permits subscriber dialing to be extended to considerable distances. No. 5 crossbar is designed for operation with as few as four digits in a subscriber number, or it can complete calls which require as many as 11 digits, (dialed by operators) three for the national area code, three for the office code, four for the numericals, and the last for the station letter of the called number on certain types of party-line service. The No. 5 crossbar system is like the No. 1 System in employing relays and crossbar switches for all switching operations; in using primary-secondary arrangements of crossbar switches to funnel the traffic from lines to trunks and from trunks to lines; in having the utmost freedom of action in routing each call; in employing registers, senders, and translator elements for only a short time on each connection; in delegating control of practically all switching and pulsing operations to the markers; and in including automatic alternate routing, second trial, and automatic trouble detection features.

It differs from the No. 1 system: in its switching plan; in its trunking arrangements; in its utilization of new apparatus; in its equipment design; in its circuit operation; and in its maintenance processes. This combination of innovations gives No. 5 unusual versatility with standardization while the extended use of the common con-

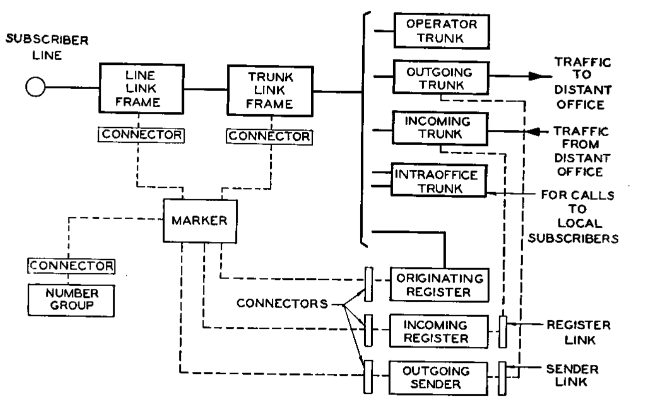


Fig. 1—Basic arrangement of the switching plan of the No. 5 crossbar system. Every subscriber line appears on one of the line-link frames, and all trunk and originating register circuits appear on the trunk-link frames.

*Excerpted from paper by F. A. Korn and J. G. Ferguson in *Electrical Engineering, August* 1950, *page* 679.

trol principle and the introduction of new maintenance concepts endow the new system with other important features, a few of which are discussed here.

The No. 5 crossbar system is different from No. 1 primarily in its switching plan, a simple block diagram of which is shown in Figure 1. Each subscriber line appears on one of the line-link frames and all trunk and originating register circuits on trunk-link frames. As in the case of No. 1, the line has but a single appearance on the line-link frame, and this serves for both originating and terminating calls. Every connection is set up from a trunk or a register to a calling or a called line through crossbar switches on trunk-link and on line-link frames. The common control equipment which is used to set up the various connections includes the markers, the connectors, the number groups, the senders and registers, and the sender and register links. Once a talking path is established, all control elements are released and only the line-link, trunk-link, and trunk circuit elements remain in the connection.

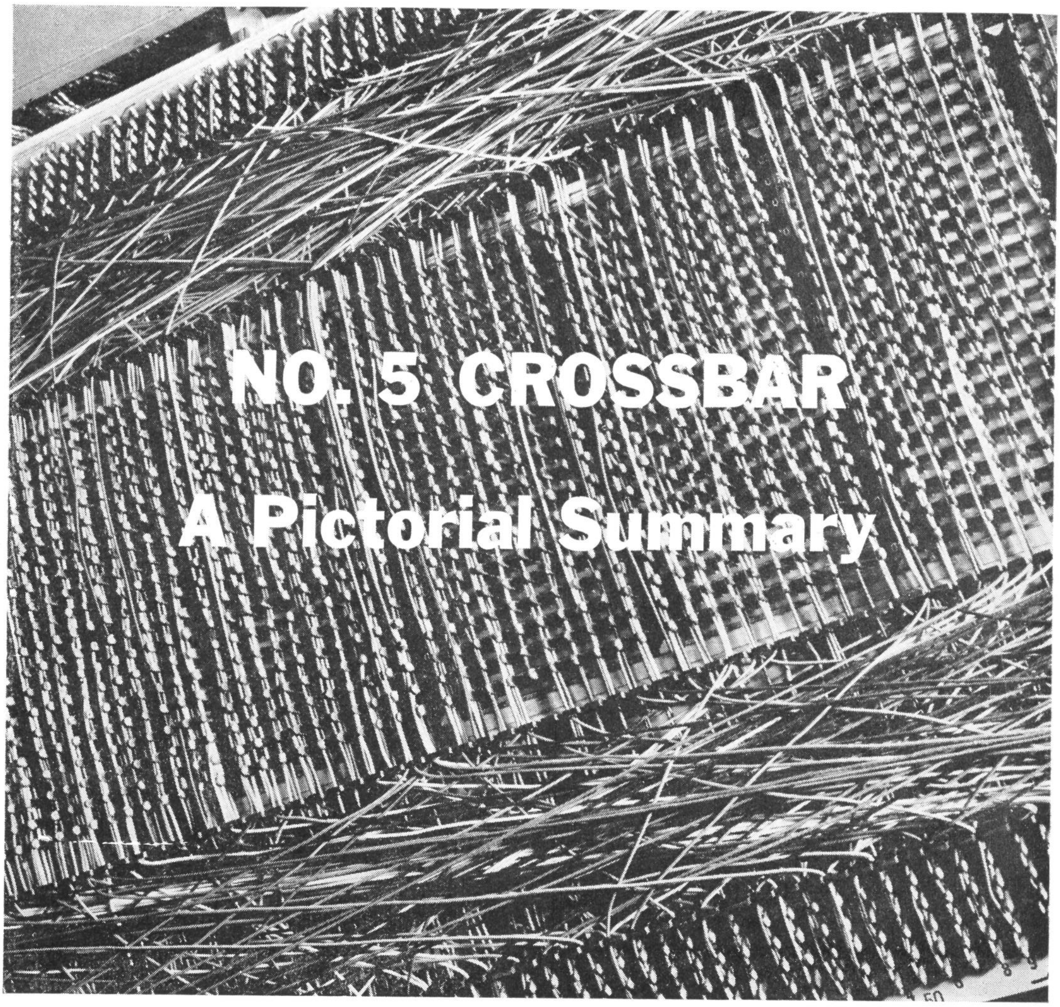
Before any talking path is set up, all needed information on calling and called parties is registered in a way which enables a marker in a uniform and flexible manner to call into the connection only those switching, signaling, transmission, and supervisory features required for the particular call. On every subscriber call, the calling line, through a connector, engages a marker to connect the calling line temporarily to an originating register through crossbar switches of the line-link and trunk-link frames after which the connector and marker are released. When all of the needed information on calling and called parties is stored in the originating register, a marker is again engaged for a fraction of a second to establish the talking connection. Knowing both ends of the connection required and with no switching equipment committed, the marker is free to set up any kind of a call with the best combination of elements.

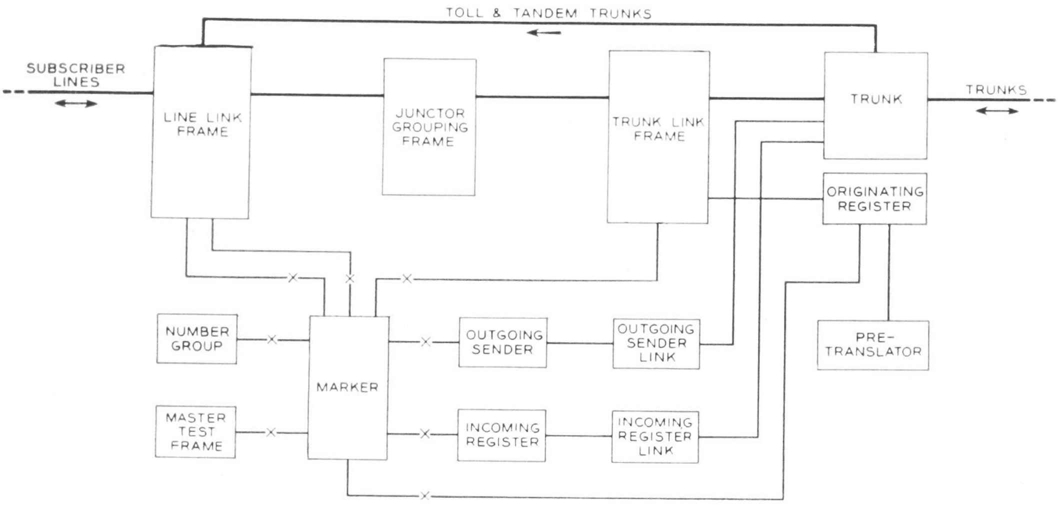
If the call is to another subscriber in the same office, the marker connects an idle intraoffice trunk circuit to the calling and called lines.

If the call is to a destination outside the office, the marker recognizes this from the information dialed and proceeds to connect the calling line to a trunk circuit in the proper group. If a sender is needed, the marker connects one of the appropriate type to the trunk circuit through a sender link. Senders receive information from the marker and transmit it in the form of pulses to registers, other senders, or directly to switches as required in the systems of the connecting offices. This information includes the subscriber's numerical digits and may include office code digits as well. Since senders must be capable of operating with the standard kinds of signaling, four types are available for dial-pulse, revertive-pulse, multifrequency-pulse, and panel call-indicator operation. Multifrequency pulsing is generally used for signaling between No. 5 offices, to and from No. 4 toll crossbar offices, to No. 1 crossbar, and to crossbar tandem offices.

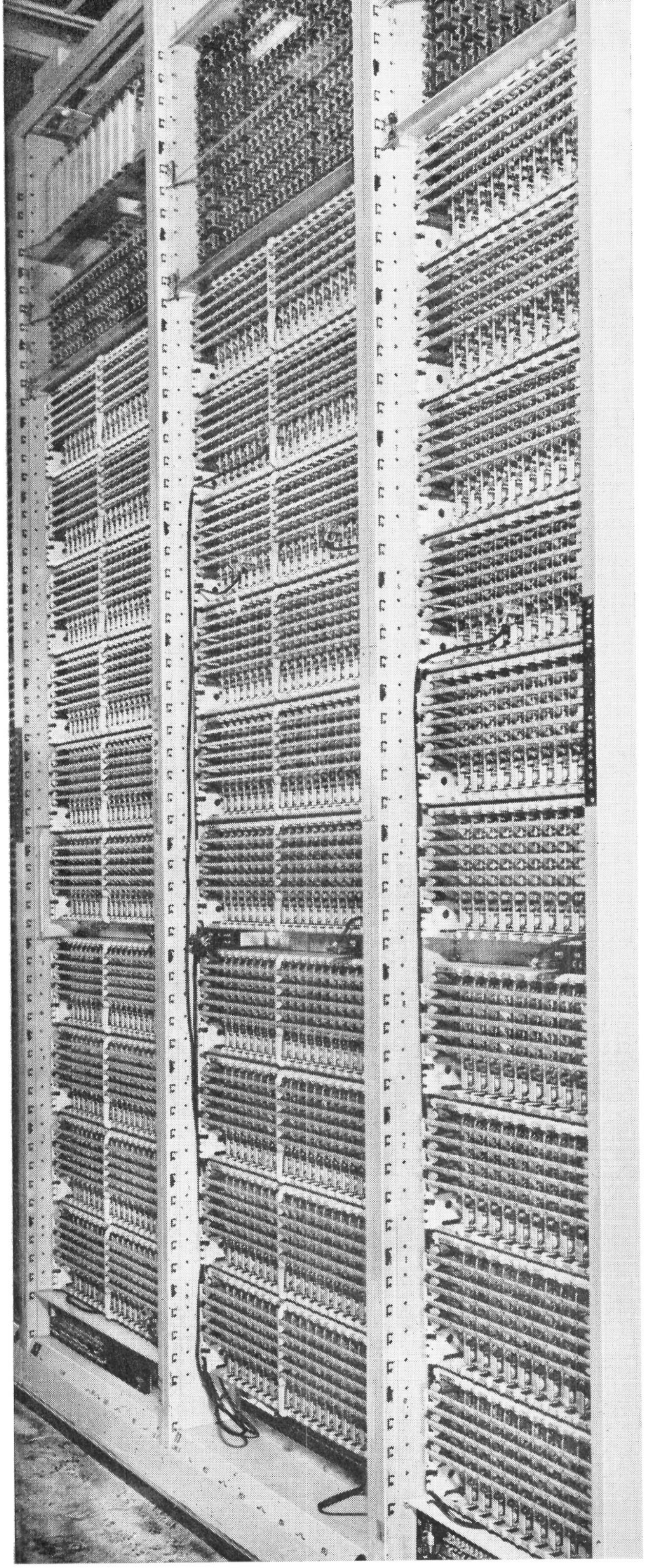
If the call is incoming from another office, the incoming trunk circuit associates itself with an incoming register through an incoming register link. The incoming registers receive information from senders, dials, or key sets in the distant offices and pass this information to the markers for establishing the switching connection either to a called subscriber line in the same office, or to a distant office when through switching of toll or tandem traffic is involved. Incoming registers, like senders, must be capable of operating with the standard kinds of signaling; hence there are dial-pulse, revertive-pulse, multifrequency-pulse, and B-switchboard registers.

NO. 5 CROSSBAR
A Pictorial Summary

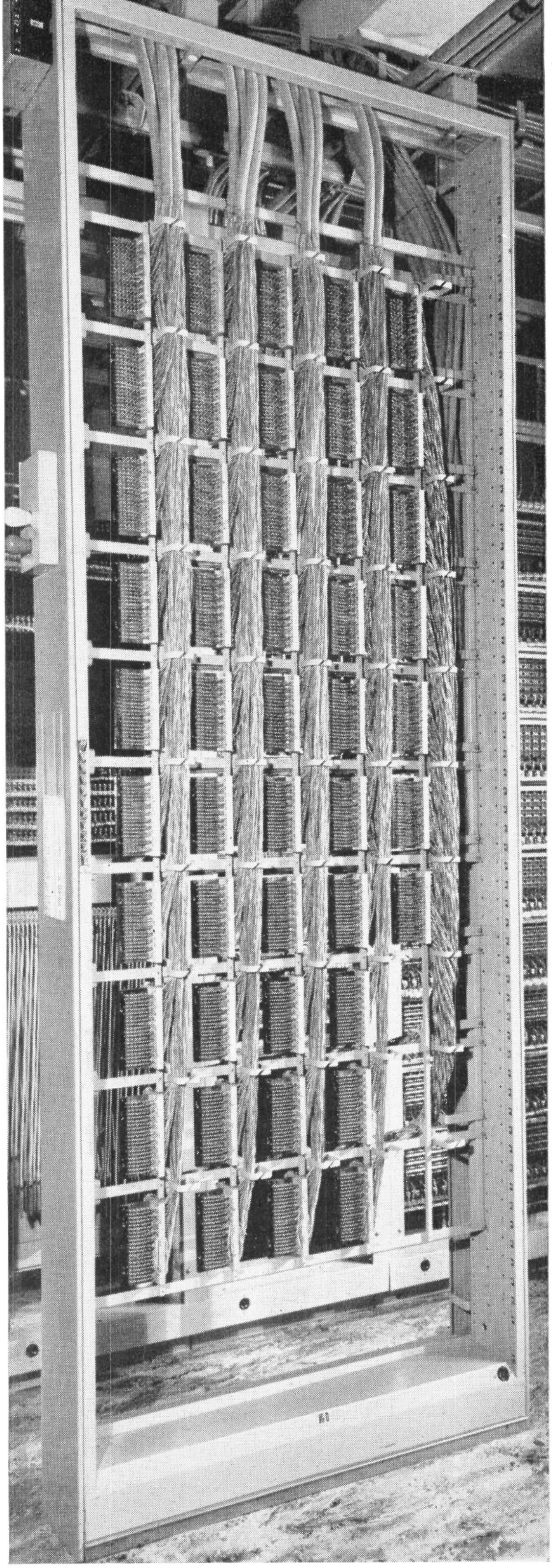




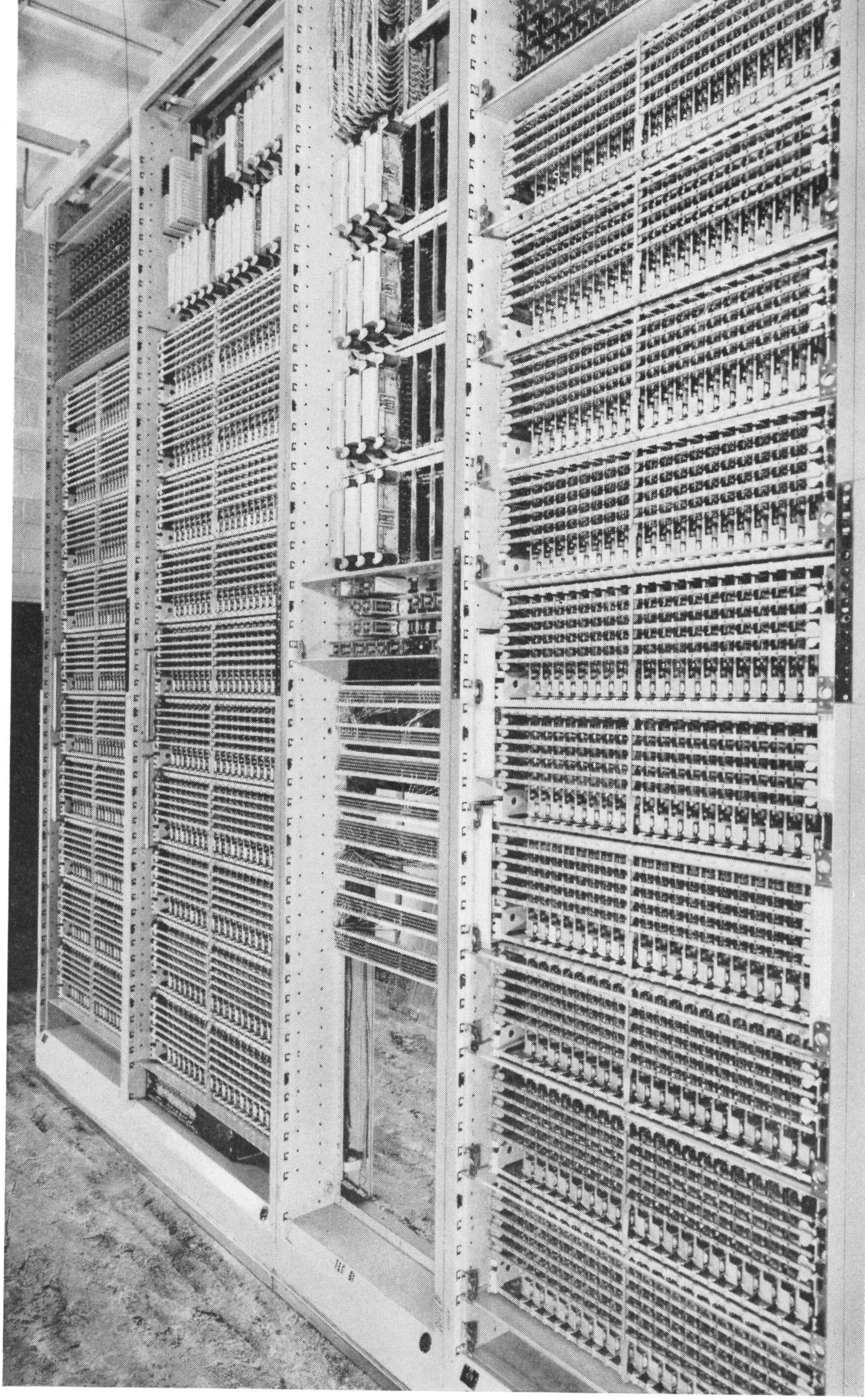
Over-all block schematic of the No. 5 crossbar system.



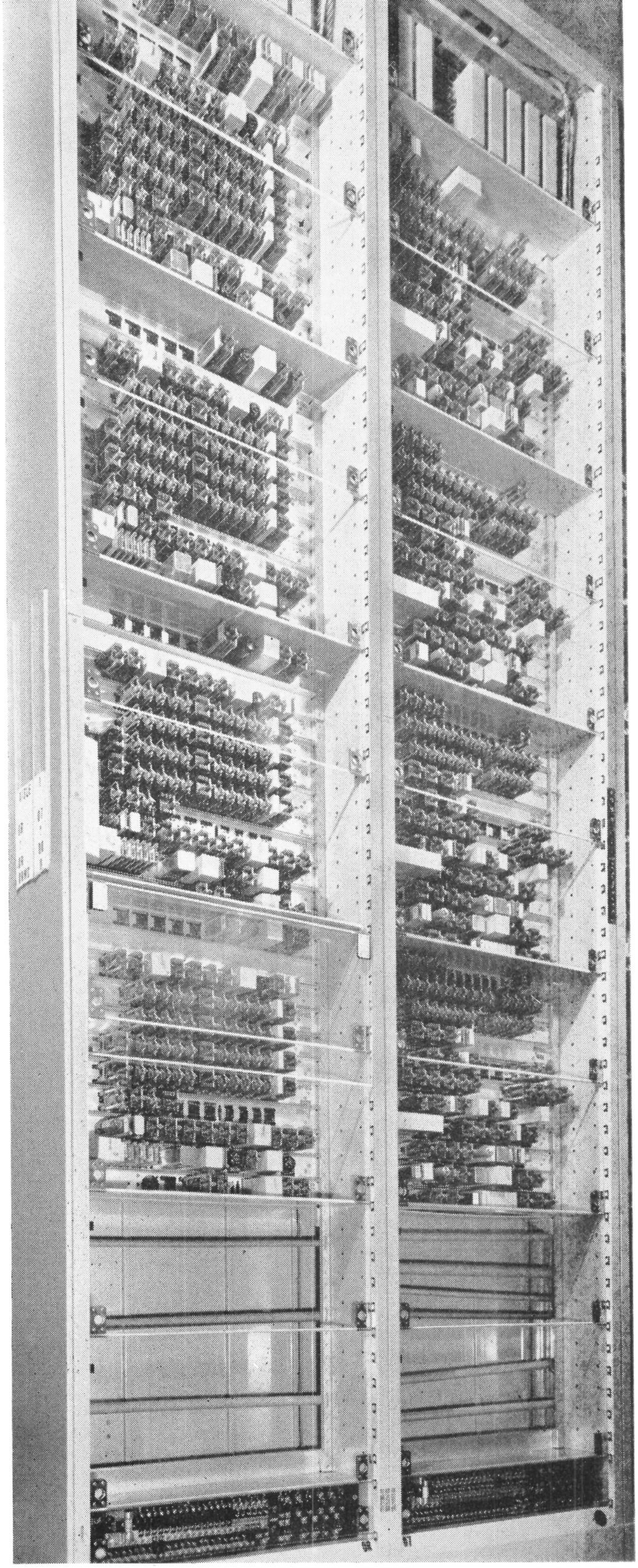
A two-bay basic frame of a line link frame, at the left, with a 100-line supplementary bay, at the right. Supplementary bays are also available for 200 lines. A complete frame may accommodate as many as 590 lines.



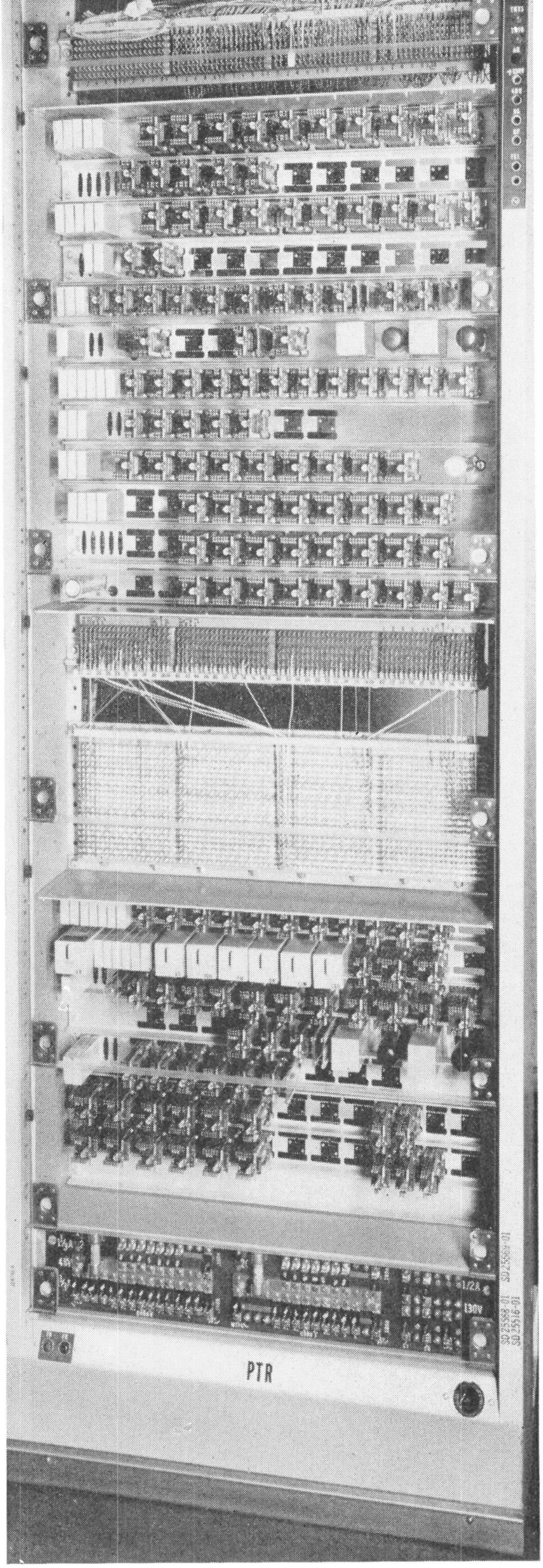
On a single junctor grouping frame, shown above, the junctors from as many as 20 line link frames are distributed to all the trunk link frames in the office.



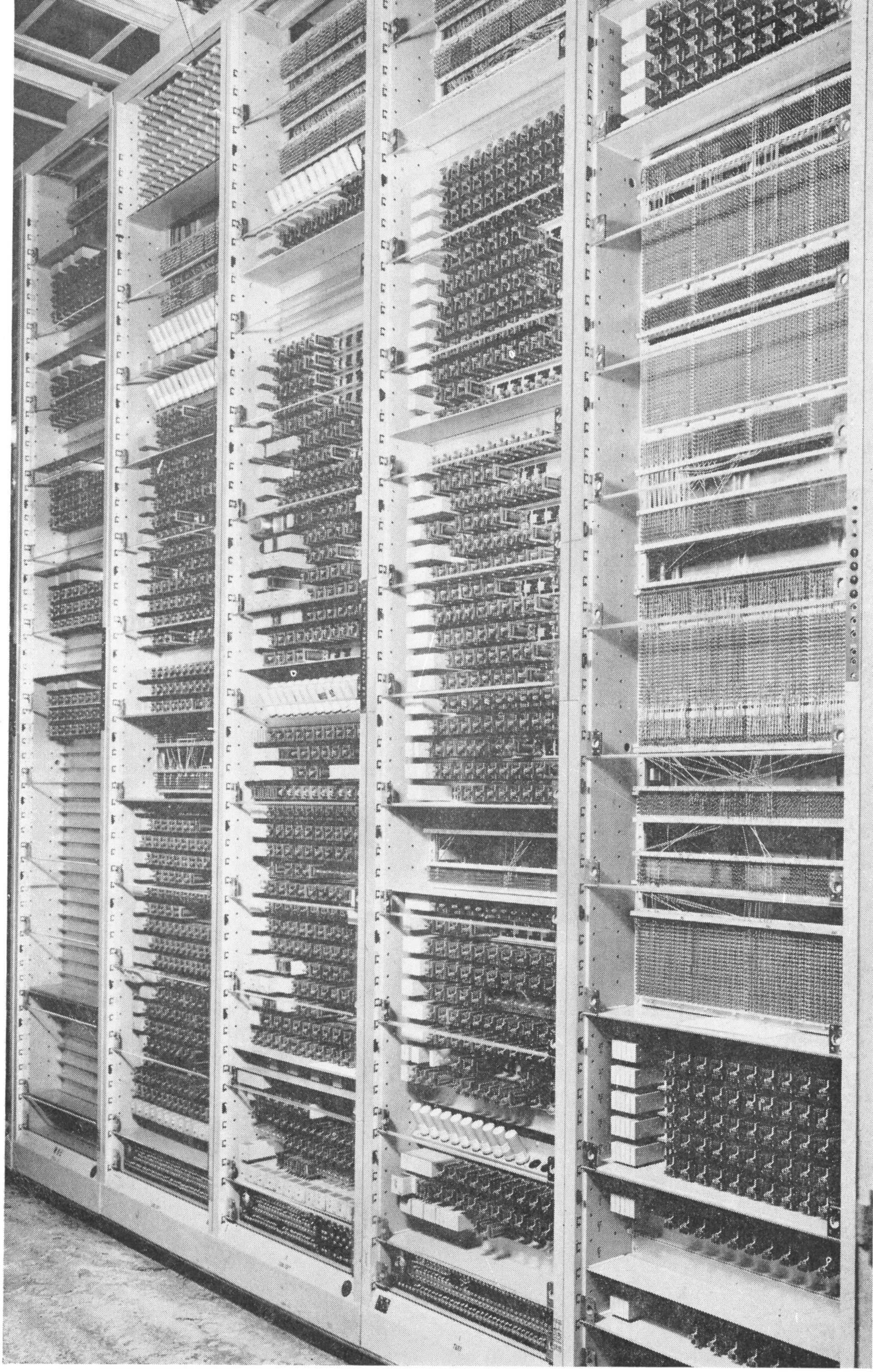
A basic trunk link frame, at the left, comprises two bays and serves for connecting any of 200 junctors from the line link frames to as many as 160 trunk or originating register appearances. Adjacent to the trunk link frame is a trunk link connector that associates that trunk link frame with the marker.



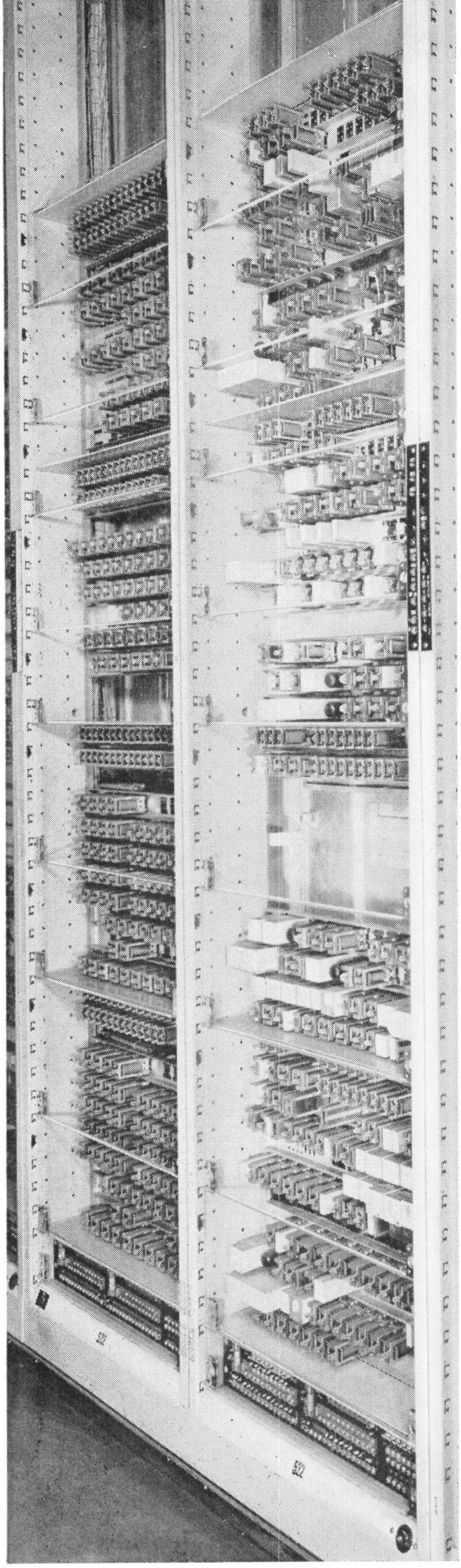
An originating register frame comprises two bays, and has a capacity of five registers, each extending across the pair of bays. In the register frame shown above, the lower position is unequipped.



A pre-translator with its connector occupies half of a single frame; two or three may be used in each installation. They furnish certain code information to the originating registers.

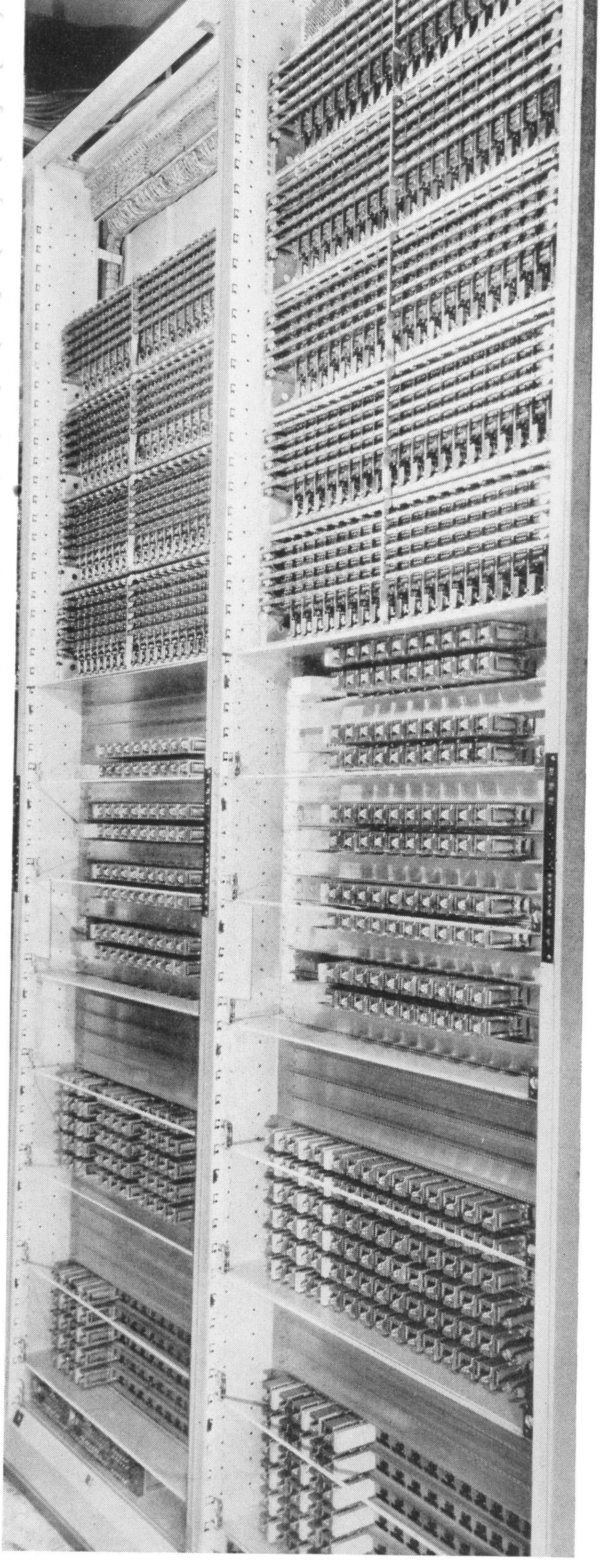


Each No. 5 crossbar marker includes the four bays shown at the right. The two bays at the right are the translator and route relay bays, while the next two at the left comprise the common equipment bays. The bay at the extreme left—the trunk frame test lead connector—will serve six markers. A class-of-service bay, not shown, serves four markers.

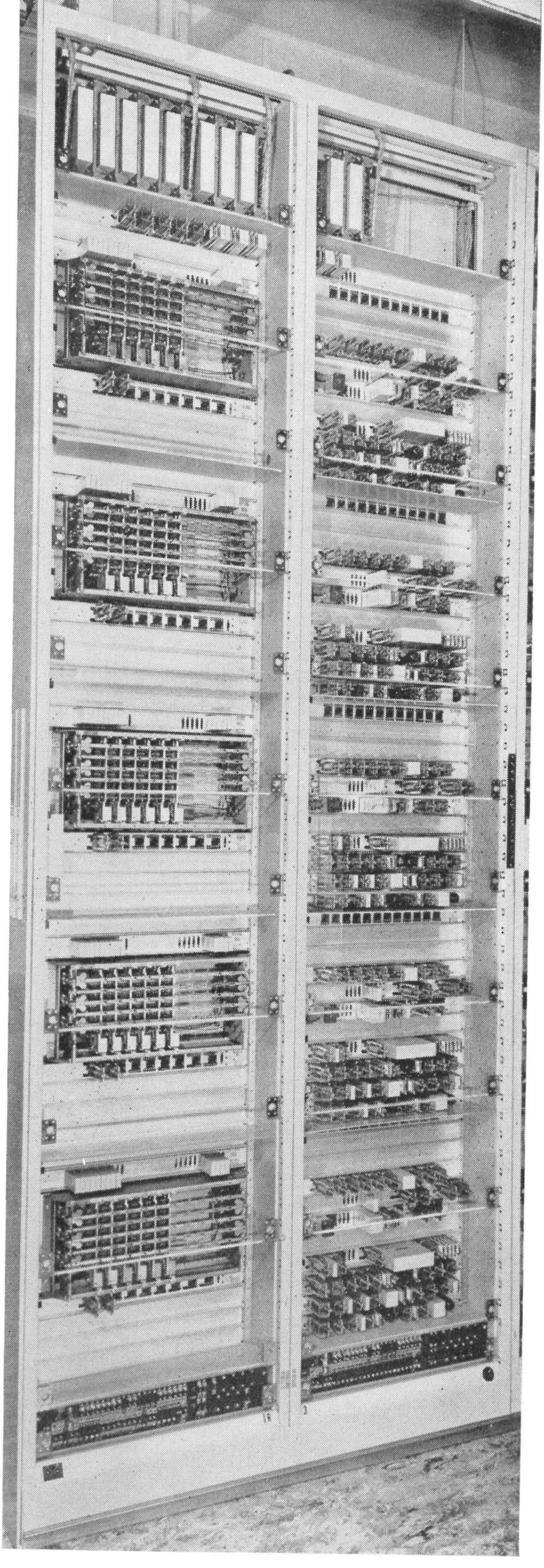


The outgoing sender frame, like the originating register frame, has space for five senders on two bays. This photograph was taken in the Switching Laboratory.

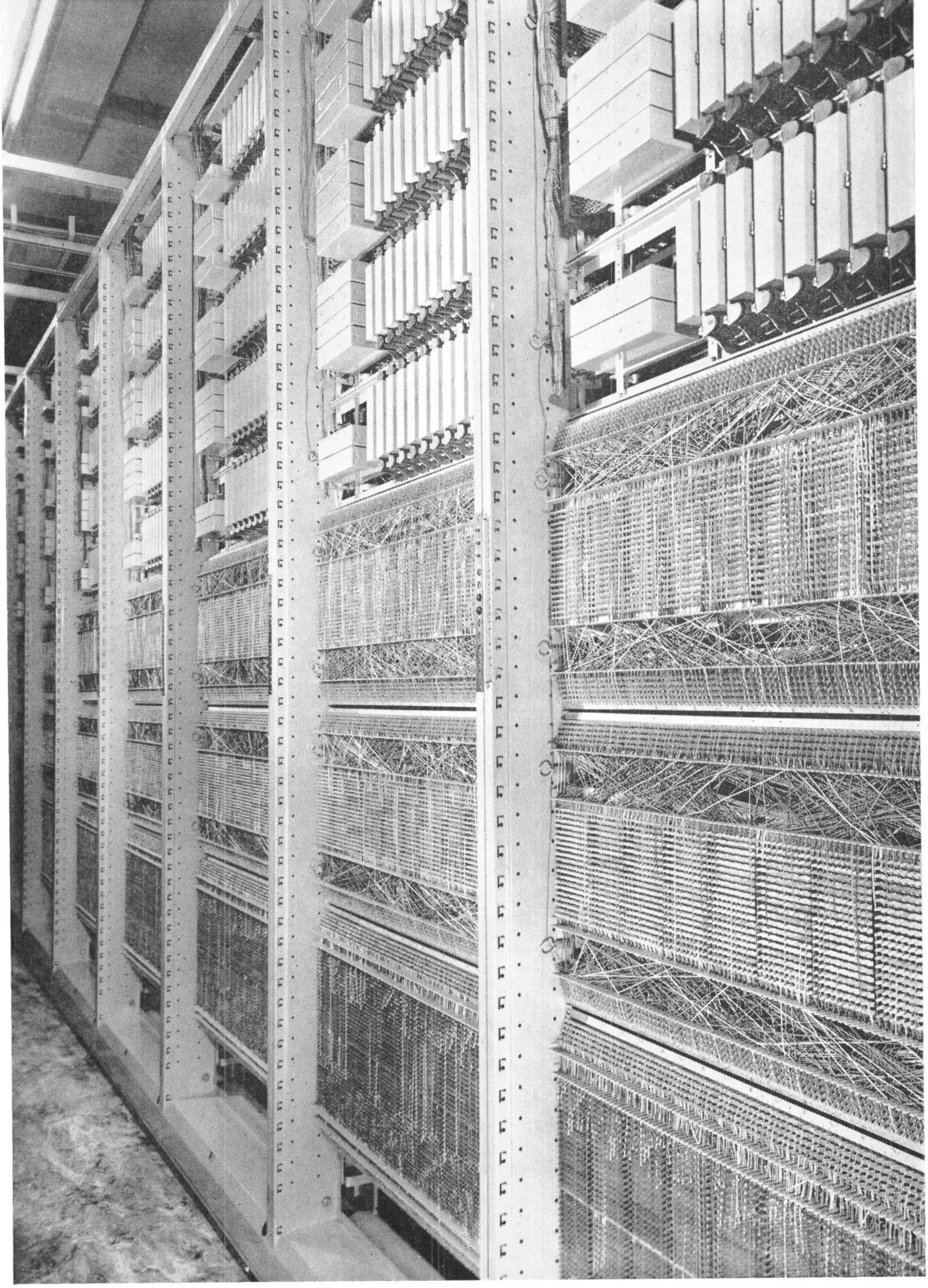
An outgoing sender link frame at the end of a line of relay rack bays. These links connect outgoing trunks, on their verticals, to outgoing senders, on their horizontals, under control of the marker.



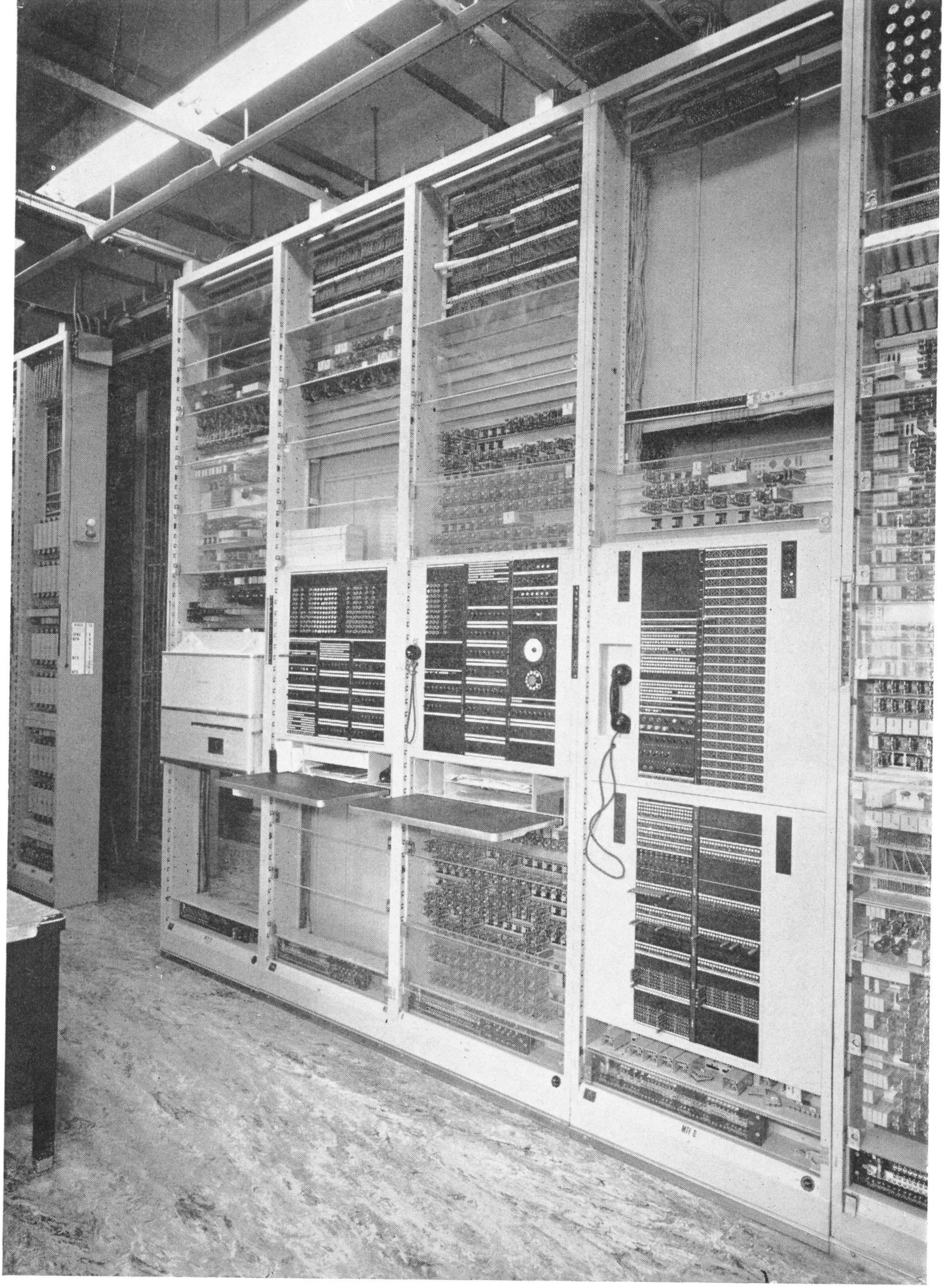
Depending on the number of trunks served by the particular type of register, incoming register links occupy from one to six bays. Above are two links serving two register groups.



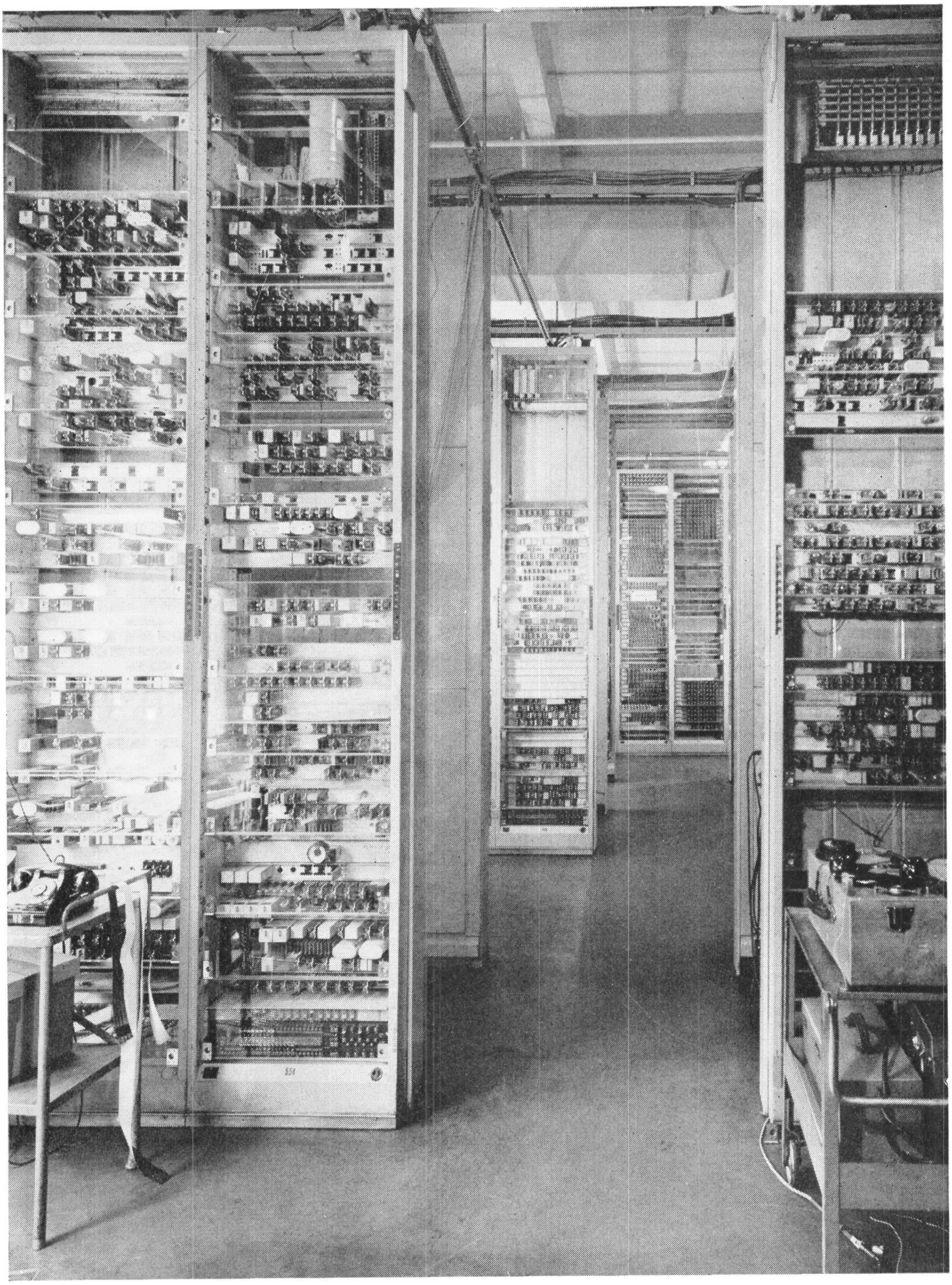
Five incoming registers are mounted on a two-bay frame, but they may be of different types. The registers on the two bays shown above are all of the revertive-pulse type.



Each number group frame, comprising the equipment between two verticals, represents 1000 subscriber numbers, and thus ten are required for an office with 10,000 numbers. When a marker has a call to complete within the office, it gives the subscriber's number to the number group frame, and receives the location of the line equipment for that number on the line link frame.



The master test frame is the central maintenance point of a No. 5 crossbar office. Here troubles are recorded, and tests are applied. At the extreme left is the trouble recorder; the next two bays are used in setting up and applying tests of the common control circuits; the right-hand bay is used principally for testing outgoing trunks, and for making various common control elements busy.



Looking down the main aisle of the No. 5 crossbar laboratory in Bell Telephone Laboratories. As the development of the No. 5 system progressed, the various frames were set up here and tested: first to determine that they perform their functions properly as individual circuits, and then to determine that they work properly with the circuits with which they are associated. As improvements are made and new features added, they are also added here.

JAMES G. FERGUSON
Switching Systems Development

Design patterns for No. 5 crossbar

No. 5 crossbar has already a broader potential field of application than any previous dial system, and it is better adapted than any to accept new services and features as they are developed in the future. The novel method of handling calls that has been devised and many of the new circuit features have already been briefly described previously.* Not less novel are some of the general equipment patterns which have been introduced to enhance the versatility of the system in providing services and at the same time insuring economy in production and maintenance.

Because No. 5 provides so many services, the deviations from office to office will be more pronounced than ever before. It is unlikely that two central offices will be identical in numbers of switch frames of the various types, or in the equipment provided on them. Some of the things which will combine to make each office different are: the numbers of subscribers, the kinds of service they require, the number of times they call, the durations and destinations of their calls, the number of central offices in the same building and in the community, and the nature, variety, and number of interconnecting circuits required to provide for the flow of traffic between the office and all other connecting offices.

All of this implies custom building, and custom building is expensive. It was unusually urgent to keep it within bounds in No. 5 by devising standardized equipment patterns which would not only provide innumerable necessary combinations of services initially, but also enable facilities to be added and traffic distribution to be rearranged to care for growth, change, and the introduction of new features. The primary objective in equipment design for the No. 5

† See page 5.

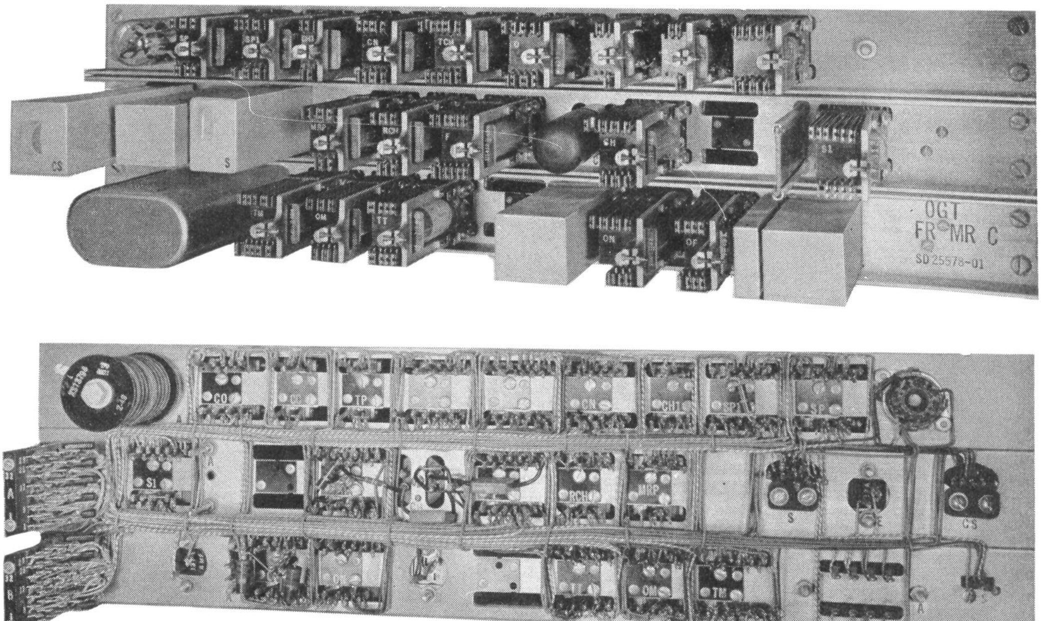


Fig. 1—Front and rear views of a typical functioned unit.

system was to exploit to the fullest extent the great flexibility inherent in the switching plan and, at the same time, to standardize all arrangements in the fewest patterns, with the fewest parts and assemblies for most economical manufacture, engineering, installation, and maintenance. In spite of the fact that flexibility and standardization are frequently incompatible, they have been combined to an unusual degree in No. 5.

Although no two offices are expected to be exactly alike, there are features within each that will be the same. Some are required in varying numbers in all offices, others are optional and specified more or less frequently. To meet this situation, a standard package was designed for each basic combination of features and these packages are used as the building blocks for all frame equipments. These standard basic units, which are generally not larger than one or two square feet in area, are re-used wherever practicable to concentrate demands on the smallest number of items.

These small subassemblies are called functional units. Frequently, an auxiliary service not required in every office employs one or two relays which cannot be economically packaged apart from a related functional unit. Each such option is coded separately for engineering and administration reasons. It may be furnished always or only as required, depending on which arrangement is more economical. All functional units can be bench assembled, wired, and tested, and straight line assembly methods can be employed where justified. Interconnecting wires, precut to length and preskinned, are run along the surface of the mounting plates which support the components and they are connected as run. A new wire with plastic insulation was developed for this purpose which reduces wiring congestion, fire hazard, and contact troubles from lint. The elimination of the wire cutting operation at the bench avoids wire clippings in the units. A typical functional unit of the type discussed is shown in Figure 1.

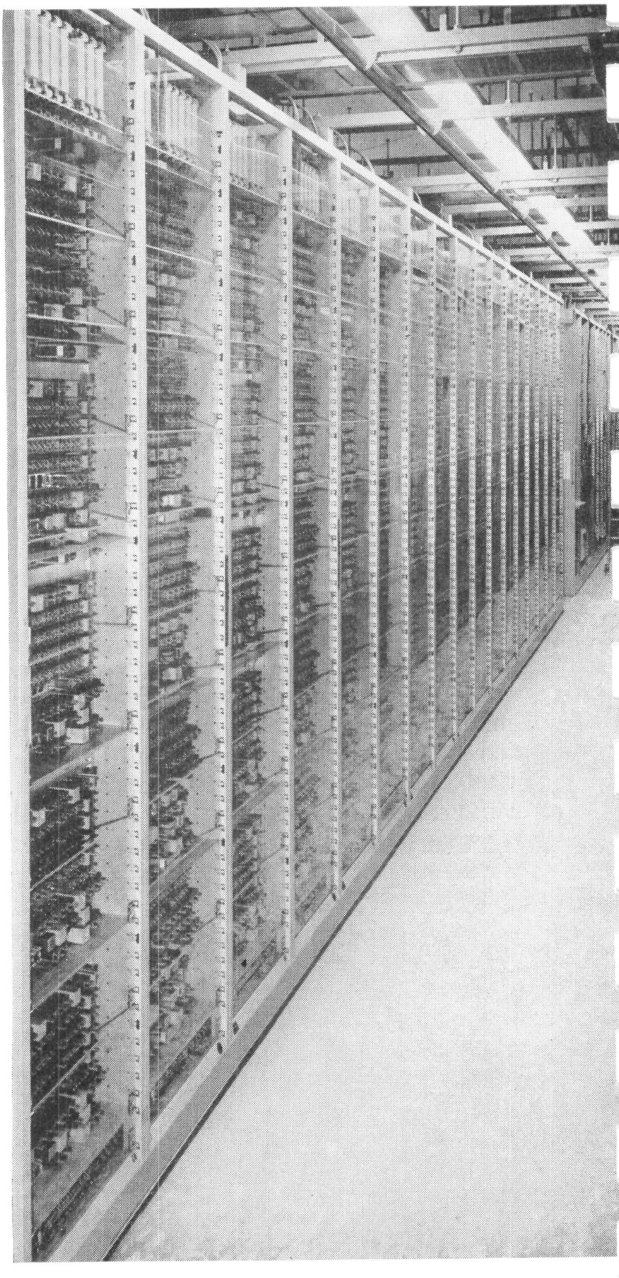


Fig. 2—Section of typical No. 5 office showing frames, covers, cabling, and lighting.

Frame equipment arrangements were similarly standardized to accommodate all needed groupings of functional units completely interconnected and tested in the factory. To make each frame as self sufficient as possible, it is equipped not only with its particular complement of functional units, but with fuse panels, test equipment, appliance outlets, talking battery filters, terminal strips, and all other items that serve it. Every frame arrangement permits the frame and its common equipment and wiring to be manufactured apart from its functional units. At a later stage in the assembly, units and frames can be brought together in a flexible manner to provide all needed services. Many combinations can thus be assembled from a few standard frames and a relatively few functional units. Each office can be engineered and manufactured with just the features it needs with as little custom building as practicable.

Patterns were developed for frameworks, fuse panels, testing facilities, and all other frame equipment and wiring to enable a few parts and assemblies of each type to be brought together in different ways to constitute each standard frame, and to permit it to serve any combination of functional units to be mounted on it. Parts, assemblies, and patterns were reduced in number by organizing the frame equipments of all types into a few families with strong family resemblances.

Where at all practicable, one frame unit combination was standardized for use on all jobs. The line link, trunk link, and number group frames are in this category. For other frames, except one type which mounts assortments of trunk and miscellaneous units, ways were found to standardize the frame equipment and wiring apart from its units, and to provide full flexibility to care for its various complements of units without too great reaction on production. Even in the one exception where the frame equipment and wiring as well as the unit complements vary widely from job to job, a pattern was developed which reduced the custom building and made it relatively easy to administer. As a result, a large proportion of No. 5 frames are fully equipped, wired, and tested in the shop, and field installation is reduced to setting up the frames on the office floor, interconnecting them with interframe cables and testing the components and the system as a whole before turning it over to the Telephone Company. A section of a typical No. 5 office is shown in Figure 2.

Another novelty of the new office is the frame construction. Heretofore, most switch frames have used angle, channel, or I-beam steel sections. In the No. 5 system, the uprights are of sheet metal formed into a rectangular box section, which is much lighter and stiffer than former types; formed sheet metal sections are also used for the other structural members. Front and rear covers of a new design are incorporated in the frame in a way that enables frame areas to be covered to any extent desired in one consistent manner. This not only avoids a variety of strip covers and sender type casings, but it frees from cover restrictions the arrangement of apparatus on units and of units on frames.

Cable rack and cabling have been simplified. Much of the effort in planning and arranging switchboard cable on the job has been avoided by adopting a basket type cable rack in which cable is laid without being confined by clips or sewing. Instead of one for each line of frames, one rack over each wiring aisle serves two lines of frames. Each frame has power feeders terminated in solderless connectors which the installer can quickly patch to supply grids in the office for battery and 110 volt service. Appliance outlets are equipped in each frame when it is assembled, and all in one line of frames are patched together and to a ceiling receptacle by flexible cable. The installer will usually have no conduit to install for these services.

Fluorescent lamps hung from the ceiling will provide improved illumination at two levels, a high level of illumination for maintenance at an individual frame and a lower level for general office lighting. This can be installed by the building contractor before the frames are ready to be put in place, and thus the Western Electric Company installer is freed of the responsibility for mounting and connecting of lights on all frames in an office except the main distributing frames.

Trunking plan for No. 5 crossbar

W. B. GRAUPNER
Switching Equipment

A basic objective of the trunking plan for any switching system is to permit interconnections to be made between the subscriber lines in the same office, and between the subscriber lines and the trunks to and from other offices. In a crossbar system, these connections are made by crossbar switches, which establish a path by interconnecting a series of links and junctors. The number of links and junctors provided must be great enough not only to handle the largest number of calls likely to be in progress simultaneously, but to make it unlikely that a call will find all connecting paths busy when the line or a suitable trunk is idle.

In the No. 5 crossbar system, the trunking plan is simple and yet very flexible. Only two types of switching frames are required: the line-link frame and the trunk-link frame. These basic frames consist of two bays of ten crossbar switches each—the two bays being interconnected in much the same manner as the primary and secondary bays of the No. 1 crossbar system. Instead of being called primary and secondary bays, however, they are called line and junctor bays on the line-link frame, and junctor and trunk bays on the trunk-link frame.

The arrangement of the line-link frames is indicated in Figure 1. The switches of the junctor bay have their horizontal multiple cut so as to give the equivalent of two crossbar switches of ten verticals instead of one switch of twenty verticals. One-half of each switch is used for junctors, and the other half, for lines. The horizontals of the right half of the ten switches in the junctor bay are connected directly across the horizontals of the line bay, and thus provide what is in effect a crossbar switch with thirty verticals. The subscriber lines are connected to twenty-nine of these verticals of each row of switches, and thus each such basic line-link frame will accommodate as many as 290 lines. The one vertical of each switch not used for lines is employed for "no test" connections.

Provision is also made for extending this horizontal multipling of the line switches to additional or supplementary bays, which may have switches of either ten or twenty verticals. To what extent supplementary bays are employed depends on how much the particular lines are used. With lines having high calling rates or long holding times, lines on the basic frame may provide sufficient traffic, and thus supplementary bays may not be required; while with lines of low calling rates, the capacity of a line-link frame may be increased to as

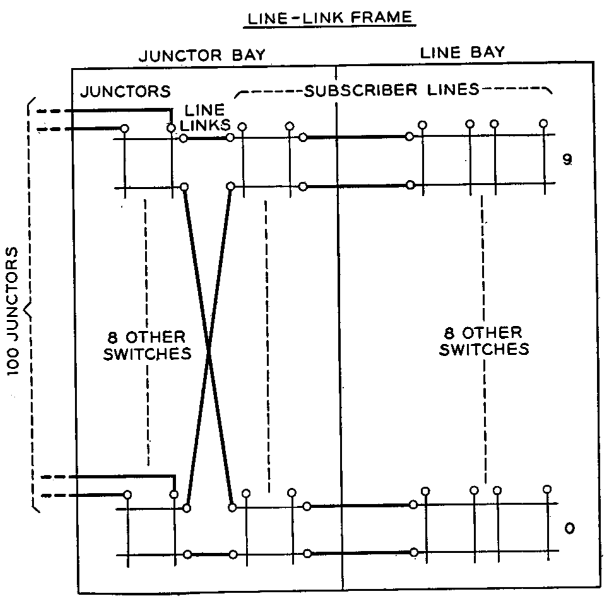


Fig. 1—Line-link frame for No. 5 crossbar

much as 590 lines by the use of supplementary bays. In each case the number of bays is adjusted to give an adequate load for the junctors by which the line-link frames are connected to the trunk-link frames.

Verticals on the left half of the switches on the junctor bay are connected to junctors. Since each of these ten half switches has ten verticals, there are 100 junctors from each line-link frame. Over them pass all calls from or to the lines associated with that frame.

The horizontals of the junctor switches are connected to the horizontals of the line switches to provide the "primary-secondary" linkage as indicated in the diagram. Here each crossbar switch is represented by its top and bottom horizontal and by its first, tenth, eleventh, and twentieth vertical, and only the top and bottom switches of a bay are shown. Each of the ten horizontals of a line switch connects to a different junctor switch in regular order, as indicated. Each line switch thus has one link to each of the ten junctor switches. In this way every line has access to every junctor.

Since the ability to meet a wide variety of conditions is one of the features of the No. 5 system, provision has been made for subscriber lines to have as many as thirty classes of service. Each such class of service identifies the type of line, such as flat rate, message rate, or coin service. Covered also by the class are the number of parties per line—single, two, four, eight, or ten—various calling zones, and other factors that affect the type of service or the rates paid. Lines of any of these classes may be connected to any line-link frame, the only restriction being that all the lines in the same vertical file of a bay, that is the corresponding verticals of each of the ten switches of a bay, be of the same class. Cross-connecting strips at the top of each line-link frame permit the class of each file of verticals to be identified to the marker.

The arrangement of the trunk-link frame is shown in Figure 2. The wiring for the "primary-secondary" linkage between the trunk and the junctor switches connects to the verticals instead of the horizontals, but the arrangement is similar in effect to that of Figure 1. In this frame, also, the switches of the junctor bay have their horizontal multiple cut to provide the equivalent of two switches of ten verticals. In this case,

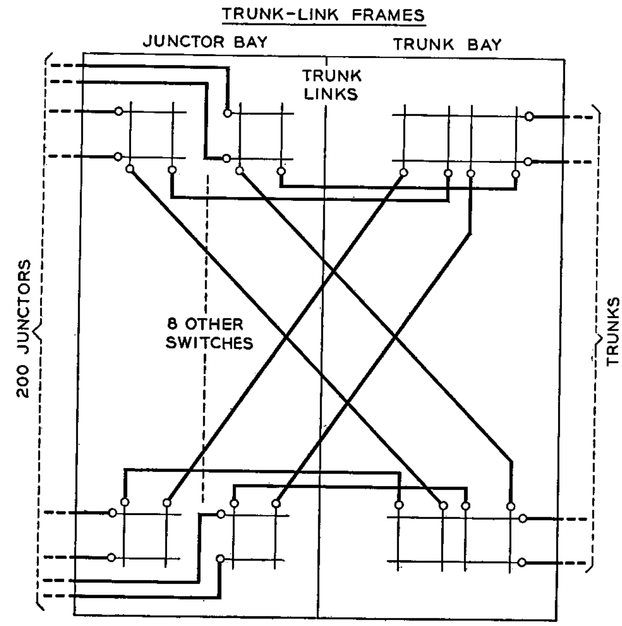


Fig. 2—Trunk-link frame for No. 5 crossbar

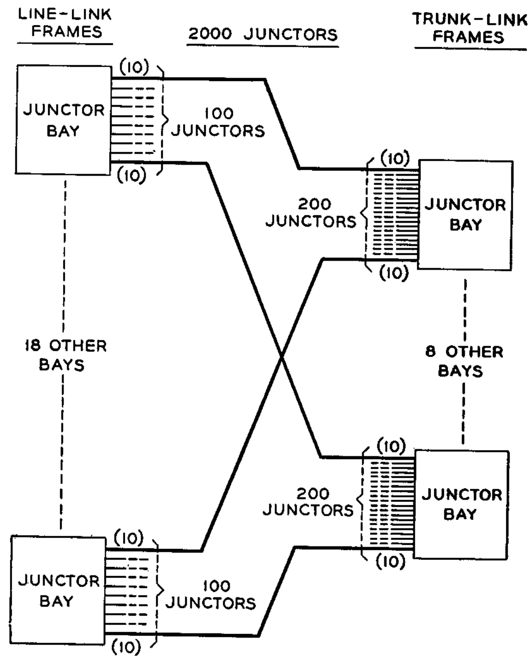


Fig. 3—Distribution of junctors

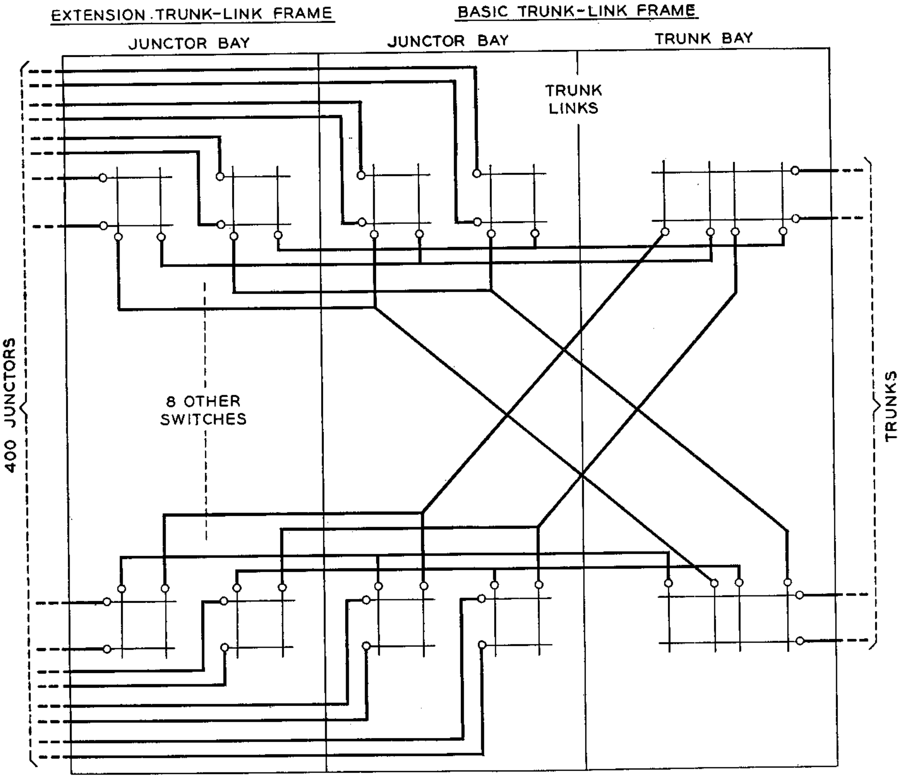


Fig. 4—Trunk-link frames where extension bays have been employed

the split is made to provide terminations for 200 junctors, which connect to the twenty horizontals of each of the ten junctor switches. Each twenty-vertical trunk switch has access to each half of the split junctor switch over one link. The trunks connect to the horizontals of the trunk switches. These latter switches are of the six-point type, already described in the RECORD;* and thus each horizontal is capable of providing terminations for two trunks. The two lower horizontals of each switch are used to select one or the other of the two trunks associated with each of the upper eight horizontals, and thus there are terminations for sixteen trunks on each switch or 160 on a bay.

Of these 160 trunk terminations, a few—perhaps five or six—will be used for originating registers; the rest will be used for outgoing, incoming, or intraoffice trunks. Not more than 120 of the terminations on a frame may be used for outgoing trunks, however, and not more than 80 for incoming or the incoming end of intraoffice trunks. Intraoffice trunks require two terminations on each frame: one for the connection going back to the calling subscriber and one for the connection going forward to the called subscriber. The trunks to a particular destination are distributed as evenly as possible over all the trunk-link frames. The marker is able to select any idle trunk on any of these frames to complete a call, so that all trunks to any destination, regardless of their number, are in one efficient group. Another advantage of this arrangement is that when trunk frames are added, in the course of normal growth, the additional trunks required can generally be assigned without disturbing the existing trunk distribution.

Since each trunk-link frame provides 200 junctors, and each line-link frame only 100, there are normally twice as many line-link as trunk-link frames. The junctors between line-link and trunk-link frames are distributed in much the same manner as are the links in each frame. Each line-link

*RECORD, *January*, 1942, *page* 114.

frame has a group of junctors to each trunk-link frame. For twenty line-link and ten trunk-link frames, the distribution is indicated in Figure 3. One junctor from each of the ten switches of a line-link frame connects to each trunk-link frame. In Figure 3, each line represents ten junctors, one from each switch of each line-link frame to each of the ten switches of each trunk-link frame. All calls, either outgoing or incoming, are connected over a circuit consisting of a line link, a junctor, and a trunk link, with the marker selecting the combination of junctor and links that is used for each call.

In the junctor arrangement indicated in Figure 3, where there are twenty line-link and ten trunk-link frames, there are ten junctors from each line-link frame to each trunk-link frame, since the 100 junctors from each line-link frame provide ten groups of ten. This is the smallest inter-frame group that will keep the probability of a call finding all possible paths busy to the low value desired. The number of junctors from each line-link frame to each trunk-link frame, however, depends on the number of trunk-link frames, since with *n* trunk-link frames, the 100 junctors from each line-link frame will be divided into *n* groups, and the number of junctors in each group will thus be 100 divided by *n*. As long as the number, *n*, of trunk-link frames is not more than ten, there will be ten or more junctors per group, and thus the requirement of at least ten per group is met. If there were more than ten trunk-link frames, however, this requirement would not be met with the type of distribution shown in Figure 3.

When more than ten trunk-link frames are required to meet the needs of an office, each junctor from a line-link frame, therefore, is multipled to two trunk-link frames, which has the effect of doubling the number of junctors from the line-link frames. Then each line-link frame can supply a group of ten junctors to as many as twenty trunk-link frames, which is the maximum number for which a No. 5 crossbar office is designed.

With twice as many line-link as trunk-link frames, there would be forty line-link frames for an office having twenty trunk-link frames, and thus a total of 40 x 100 or 4,000 junctors from the line-link frames. Since each of these junctors connects to

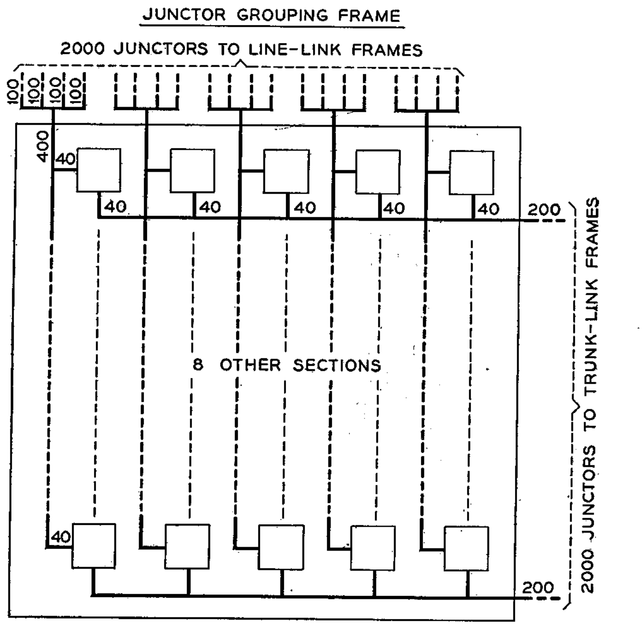


Fig. 6—Junctor grouping frame

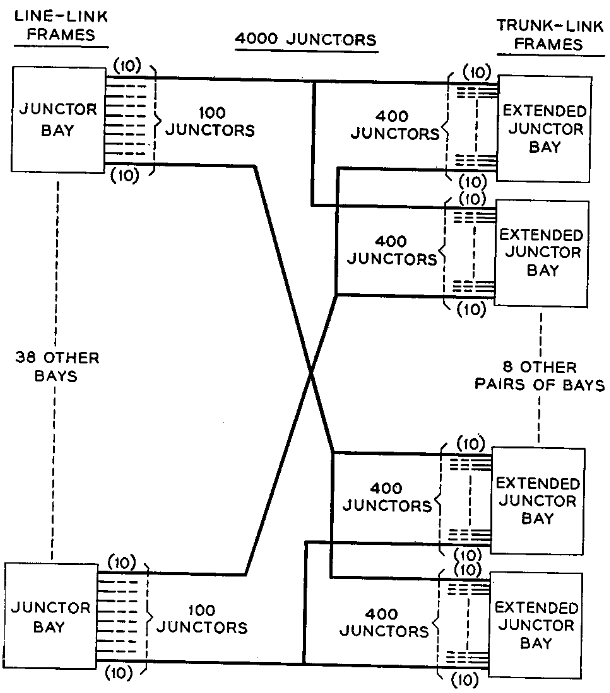


Fig. 5—Distribution of junctors when extension bays are used with the trunk-link bays

two trunk-link frames, there must be terminations on the twenty trunk-link frames for 8,000 junctors, which is 400 per frame—twice the number shown in Figure 2. To secure these additional junctor terminations, extension bays are added to the trunk-link frames, and are connected to them as indicated in Figure 4. These extension frames are arranged like the regular junctor bays of the trunk-link frames, and the verticals of the junctor bay and the extension bay are multipled. In this way terminations for 400 junctors are provided for each trunk-link frame. When such extension frames are used, the trunk-link frames are grouped in pairs, and each junctor from a line-link frame is connected in multiple to junctor terminals on both frames of a pair. This arrangement is indicated in Figure 5.

If there were always twenty line-link frames and ten trunk-link frames, the junctor terminals on the line-link frames could be permanently connected to the junctor terminals on the trunk-link frames—ten on each line-link frame being connected to each of the ten trunk-link frames. Since the number of frames in an office may vary over a fairly wide range, however, and may change from time to time, a junctor distributing bay is provided to which the junctors from both line-link and trunk-link frames are connected. Here they may be interconnected by jumpers in the best way for each set of conditions.

This junctor grouping frame consists of fifty terminal blocks arranged in five columns of ten each, as indicated in Figure 6. Each terminal block provides double ended terminals for forty junctors—one end of each terminal projecting to the front of the bay and the other, to the rear. Junctor cables from four line-link frames are run vertically down the front of the frame adjacent to each column of terminal blocks, and ten junctors from each of the four cables are connected to the terminals of each block. Junctor cables from the trunk-link frames run horizontally across the rear of the bay; the 200 junctors from each frame are connected to the terminals of

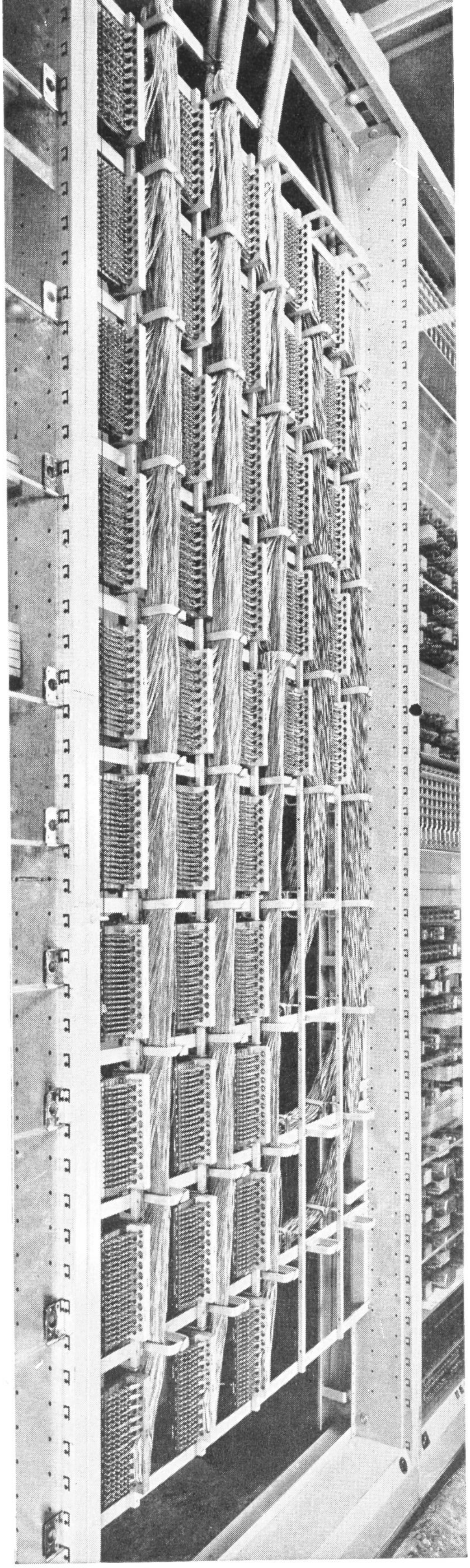


Fig. 7—A junctor grouping bay in the crossbar office at Media, Pennsylvania

each of the five blocks in one row. A front view of the junctor distributing bay in the Media Office is shown in Figure 7.

If there were twenty line-link frames and ten trunk-link frames, all the terminals would be filled and each junctor from the line-link frames would be permanently connected to a junctor from the trunk-link frame, in the manner already outlined. If there were a smaller number of frames, such as eight line-link frames and four trunk-link frames, the two left-hand columns of blocks would have junctors connected to their front end, and the four upper rows would have junctors connected to the rear terminals. The blocks in the two left-hand columns of the upper four rows would have junctors connected both front and rear, while the lower six blocks in the two left-hand columns would have junctors connected only at the front, and the blocks of columns three, four, and five of the upper rows would have junctors connected only at the rear. Jumpers are run from the upper right-hand section of the bay to the lower left-hand section to distribute the remaining junctors properly. When extension bays are used for the trunk-link frames, there would be two of these junctor grouping bays. The groups of 100 junctors from the line-link frames will be distributed to both of the junctor grouping bays, and the junctors from one trunk-link frame of each pair will go to one junctor distributing bay and those from the other frame of the pair to the other distributing bay—the junctors from the two frames of a pair being terminated on the same row of blocks.

Since the traffic capacity of the 200 junctors on a trunk-link frame is double that of the 100 junctors on a line-link frame, there are, in general, twice as many line-link as trunk-link frames. The size and number of the line-link frames required for a specific job is determined from originating and terminating peg-count and holding-time data from which the total load in CCS* is computed. By dividing the frame capacity, 1200 CCS, by the average originating and terminating CCS per line, and adding a provision for spare lines, the number of lines which a frame may serve can be determined, the actual size being governed by the fact that they are furnished in increments of 100 lines only. The number of frames of this size is obtained by dividing the total number of lines to be equipped in the office by the number per frame. Where no special requirements have to be met for terminating trunks, the number of trunk-link frames required will be one-half the number of line-link frames. Under certain conditions, trunk-link frames may be required merely to provide terminations for a large number of small trunk groups on which traffic is light. In this case, a greater than proportional number of trunk-link frames would be provided.

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*100 Call-seconds. See Record, *March,* 1939, *page* 222.

No. 5 crossbar marker

A. O. ADAM
Switching Systems Development

In the No. 5 crossbar system only two types of switching frames are employed for completing talking connections. These are the line link and trunk link frames. All connections through them are established by markers, of which there may be from three to twelve in an office depending upon the calling rate and the number of subscribers. A talking connection through these frames has three components: a line link, a junctor, and a trunk link. The line links connect the line switches to the junctor switches of the line link frame; the junctors connect the junctor switches of the line frames to those of the trunk frames; while the trunk links connect the junctor switches to the trunk switches of the trunk link frame. For any connection, there are ten line links, ten or more junctors, and ten or twenty trunk links that might be used. The marker must first determine which of the suitable components are idle, and then select one of each type to form a continuous path.

This work of the marker is required for

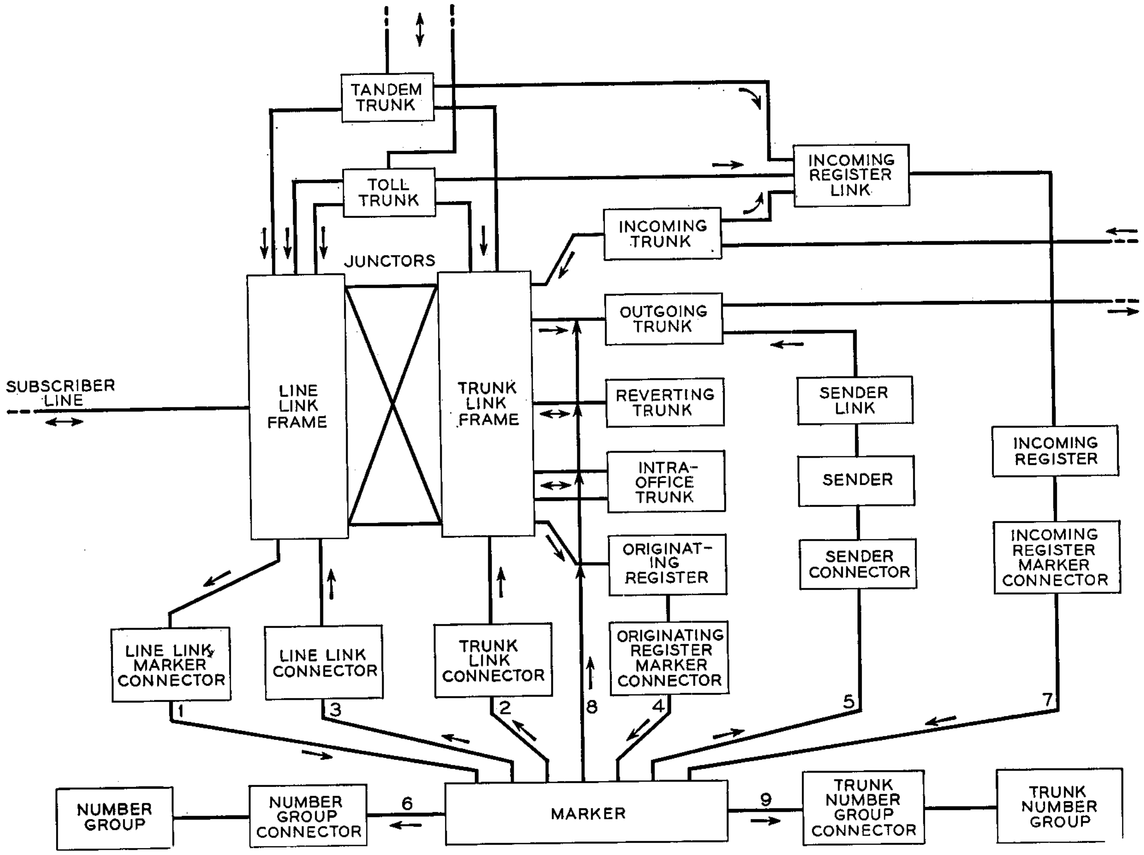


Fig. 1—Block diagram indicating the circuits that are associated with the marker at one time or another.

all types of connections, but before it can be carried out, the marker must have certain other information regarding the call, perform certain other functions, and determine the locations on the line link and trunk link frames between which a connection is to be established. Its actual procedures differ, therefore, with the kind of call, which may be any of nine types: dial tone, intra-office, reverting, outgoing, incoming, through tandem, through toll, pulse conversion, or inter-marker group.

The various circuits with which the marker is associated at one time or another in handling the various types of calls are shown in Figure 1. Since the marker performs its functions in a very short period of time—usually only a fraction of a second—there are only a few markers in any one office, and connections between a marker and the other circuits are established through connectors*. Some of these establish connections when another circuit seizes a marker, and others establish the connections when the marker seizes another circuit. Arrows on the connecting lines of the block diagram, Figure 1, indicate the direction of seizure in all cases.

Since the originating registers and the various types of trunks are all connected to the trunk link bay, the marker gains access to them through the trunk link connector and the trunk link frame. The various paths to and from the marker have been assigned arbitrary numbers in Figure 1, and these numbers will be referred to in discussing the work of the marker in handling the various types of calls.

When a subscriber lifts his handset to place a call, the operation of his line relay causes the marker to be seized over path No. 1. Such a seizure tells the marker that an originating register must be connected to the calling line so that the number about to be dialed may be recorded. Since dial tone will be returned to the subscriber by the register as soon as it is connected to the calling line, these connections of originating registers to calling lines are referred to as dial tone connections. For such a connection, the circuits employed are indicated in Figure 2.

* See page 58.

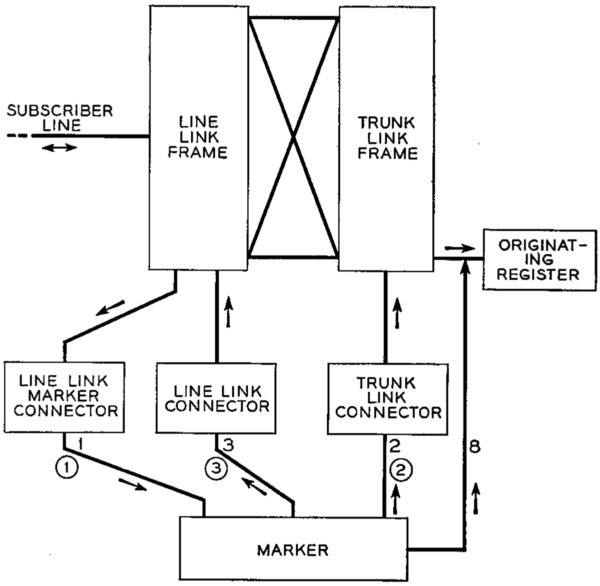


Fig. 2—Circuits associated with the marker for a dial-tone connection.

As soon as the line link frame has seized a marker over path 1, it immediately identifies itself to the marker by its frame number. Over testing path 8, the marker at once proceeds to find a trunk link frame not in use by another marker and having an idle originating register connected to it. Its method of doing this will be later described.* Having found such a combination, it at once seizes the trunk link frame through a trunk link connector, path 2, and selects one of the idle registers. During this time it has also started to find the location of the calling line on the line link frame over paths 1 and 3.

Subscriber lines are connected to the verticals of the crossbar line switches on the line link frame, and are identified by a particular vertical group, a horizontal group and a vertical file. The vertical group includes the fifty lines on the corresponding five adjacent verticals of the ten crossbar switches mounted one above the other on a line link bay. There may be from six to twelve vertical groups depending on the number of bays in the line link frame. The horizontal group includes all the lines on one horizontal row of crossbar switches, and there are 29 to 59 lines in each horizontal

* See page 45.

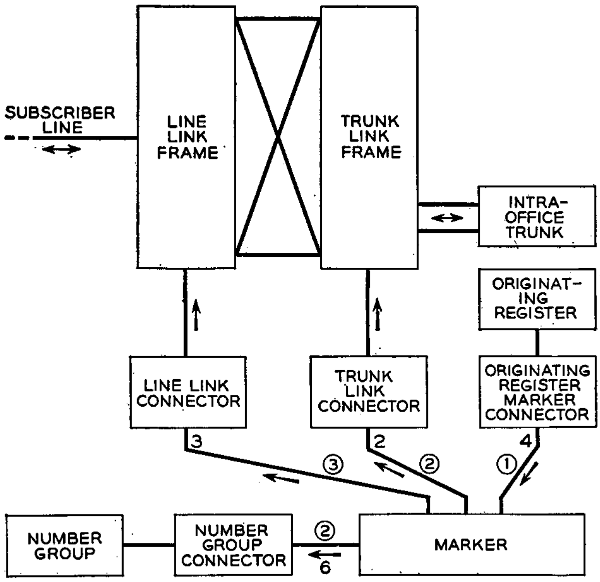


Fig. 3—Circuits associated with marker in completing a call to another subscriber in the same office.

group. A vertical file consists of the ten lines vertically above one another on a line link bay. The vertical and horizontal group identifications indicate the line as one of five on a particular crossbar switch, and the vertical file identification specifies the particular one of the five lines that are involved.

Over leads through the line link marker connector, the marker identifies a preferred vertical group and horizontal group having lines awaiting service. It also connects to the line link frame via a line link connector, path 3, and tests the five lines that are common to the particular horizontal and vertical groups it has already determined, and if more than one is calling selects only one in a prescribed order of preference.

It now has the location of a calling line on the line link frame and that of an idle originating register on a trunk link frame, and thus proceeds to find and close an idle set of links and junctors between them. Once this has been done, and the calling line location stored in the register, the marker releases, and the register sends dial tone to this subscriber.

The number the subscriber dials into the register so connected may be for a subscriber in another office, and thus require a connection to a sender and an outgoing trunk for its completion, or it may be for another subscriber in the same office or even for another subscriber on the same calling line. The latter two types of call are known as intraoffice and reverting calls, respectively, and neither requires a sender.

Whatever the type of call, the register will

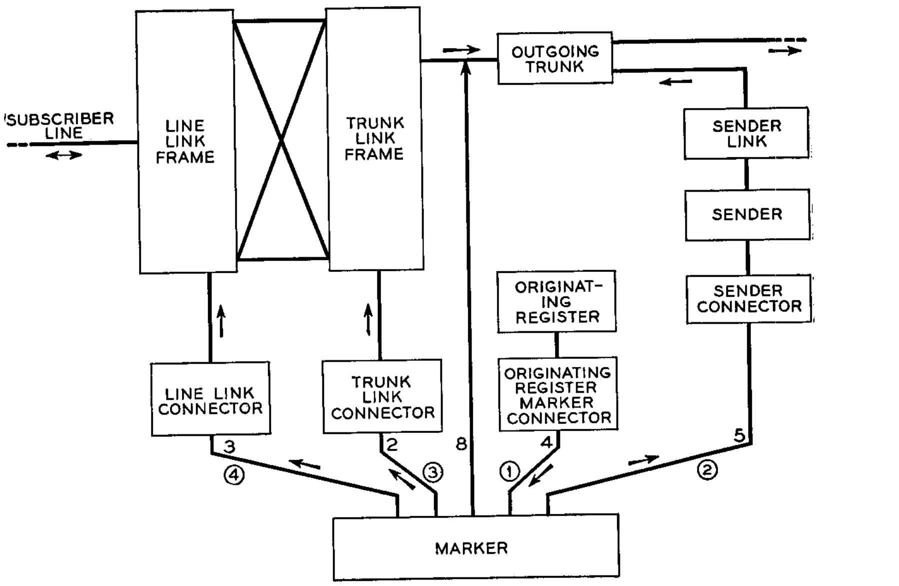


Fig. 4—Circuits associated with marker in completing a call to a subscriber in another office.

seize a marker over path 4 and request that a connection be set up. If the call is for another subscriber in the same office, the work of the marker will be as indicated in the block diagram of Figure 3, where, as in the other diagrams, the order in which the various paths are used is indicated by the numbers in circles. As soon as the marker has been seized, the register transmits to it the number dialed by the subscriber and the location of the calling subscriber's line. The marker, recognizing the office code as requiring an intraoffice trunk, at once proceeds to find and seize a trunk link frame not in use by another marker and having an idle intraoffice trunk. At the same time it seizes the number group frame over path 6 to determine the location of the called line on a line link frame. It secures this information as described later,* and then seizes the indicated line link frame, and tests to see if the line is idle over path 3. If it finds the line idle, the marker tests for idle links and junctors and connects the line to the intraoffice trunk. It then seizes the line link frame of the calling line, again, tests for idle links and junctors, and connects the line to the other end of the intraoffice trunk. Having passed ringing information to the trunk, over path 2, the marker releases.

For a reverting call, the marker proceeds as for an intraoffice call, but after finding from the number group that the called line location is the same as the calling line, it releases the intraoffice trunk it had seized, seizes a reverting trunk, and connects the line to it. After giving the trunk the ringing information it obtained from the number group, the marker releases.

Had the marker, on decoding the office digits transmitted to it from the originating register, found that the call was for a subscriber in another office, the work of the marker would be as indicated in the block diagram of Figure 4. As soon as the marker has been seized, the register transmits to it the number dialed by the subscriber. The marker, recognizing the office code as requiring an outgoing trunk, at once proceeds to find an idle sender of the proper type and a trunk link frame not in use by a marker and having an idle trunk to the desired

* See page 79.

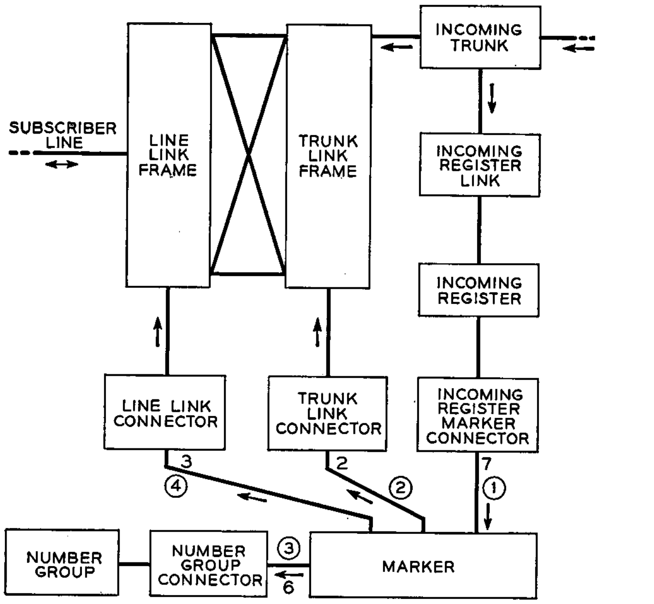


Fig. 5—Circuits associated with the marker in completing an incoming call.

office. It first seizes this sender over path 5. Then, while transmitting to it the number wanted in the distant office, the marker seizes the trunk link frame over path 2 and connects the sender to the trunk. It then seizes the line link frame of the calling line over path 3, the number of the frame and the location of the line on the frame having been given to it by the originating register. It now finds and connects an idle path through the line link and trunk link frames, tells the sender to proceed, and then releases.

All incoming calls, whether on an interoffice, a tandem, or a toll trunk, and whether for termination in the office or for extension through it, seize an incoming register on arriving. The register records the digits pulsed into the office, and then seizes a marker over path 7 and transmits the digits to it. If the call is to terminate in the office, the circuits involved are as indicated in Figure 5. As soon as a marker is seized and has decoded the office digits, it at once seizes the trunk link frame to which the calling trunk is connected. It has already received the frame number over path 7. The marker then goes to the number group to determine the location of the line being called. With this latter information, it seizes the line link frame indicated, and completes the connection through the frames as before.

Through calls, either tandem or toll, are handled as indicated in Figure 6. Tandem and toll trunks have appearances on both trunk link and line link frames; tandem trunks have one line link and one trunk link appearance, while toll trunks have two line link and one trunk link appearance. The trunk link appearance is used for calls terminating in the office, while the line link appearance is used for calls passing through the office. The added line link appearance of the toll trunks is provided to give double assurance of finding an idle path through the office for through toll calls.

For both types of through calls, an incoming register is at once seized to record the digits pulsed in. The register then seizes a marker and transmits the digits to it. Thus far the call has proceeded as described for terminating calls. On decoding the office digits, however, the marker finds the call must pass to another office, and it therefore selects a suitable sender and seizes a trunk link frame and trunk as it did in handling an outgoing call. To determine the line link location of the calling trunk, it then seizes a trunk number group frame. Having this information, it proceeds to find an idle path between this line link location of the calling trunk and the outgoing trunk already selected. It then establishes the connection, and releases.

The major difference in the method of handling a through toll call is that there are two line link frame locations. If the marker is unable to find a path to the outgoing trunk from the location it seizes first, it will return to the other trunk number group, find the second line link frame location of the trunk, and attempt to complete from that point. Provision is also made to handle a small number of tandem or toll trunks in the regular number groups at the sacrifice of line numbers.

Besides these more usual types of calls that the marker must handle, there are also intermarker group and pulse conversion calls. The former is a call between two No. 5 offices associated with different marker groups in the same building. For such a call the conventional outgoing trunk and sender are not used. Instead a combined outgoing-incoming trunk is used, and an intermarker-group sender performs the functions of both outgoing sender and incoming register, this being done without the usual pulsing.

Pulse conversion, which is described in detail on page 123, permits an operator at a DSA board equipped with a multifrequency keyset to complete calls over trunks direct to an office requiring revertive or dial pulses. For such a call the No. 5 office connects the pulse conversion trunk to an incoming MF register which in turn passes the number through the marker to an outgoing sender associated with the same trunk. This sender provides the proper pulses to the office selected by the DSA position.

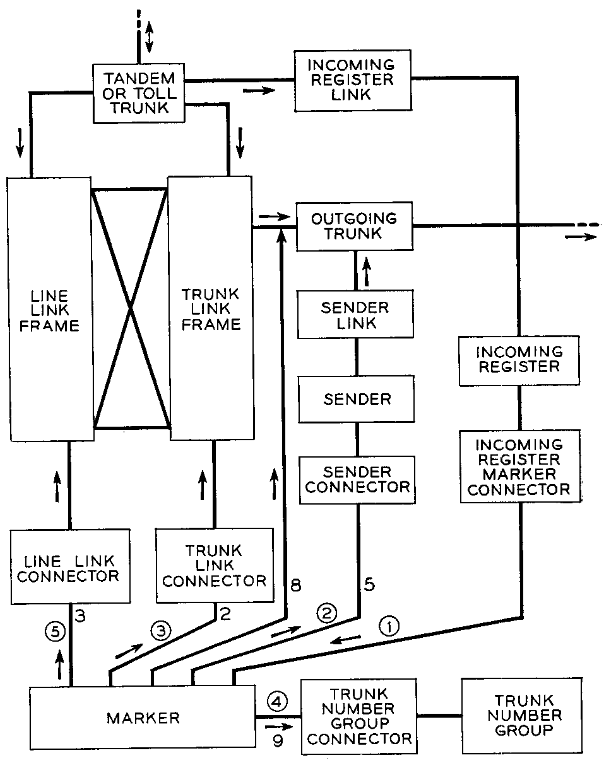


Fig. 6—Circuits associated with marker in handling tandem and toll calls.

Equipment arrangements for No. 5 crossbar markers

W. B. GRAUPNER
Switching Equipment

In the No. 5 crossbar system, a single marker performs the functions of both the originating and terminating markers in the No. 1 crossbar system. In addition, it establishes a connection between the subscriber lines and the registers that give dial tone and record the digits dialed. The equivalent connection was performed by the line link and sender link controllers in the No. 1 system. The No. 5 marker is therefore considerably larger than either of the No. 1 markers.

As with all other No. 5 crossbar equipment, the marker has been arranged on standardized frames of a size that can be conveniently handled in the shop and by the installer. Each frame is completely equipped, wired, and tested in the factory so that the installation effort is reduced to erecting and interconnecting frames and making the necessary tests to assure satisfactory operation. To aid manufacture and job engineering, the marker was designed so that associated circuit functions can be assembled in small standardized units apart from the frames with their common equipment and wiring. These standard units, with whatever optional features are needed, are then arranged on standard frames as required for a particular installation.

In grouping together associated operating features, care was taken first to segregate into small equipment units those functions whose equipment was of a repetitive or multiple nature. A relatively high demand is thus developed for these units, and the number required for each particular marker can be readily furnished initially or added as an office expands. Each of the marker frames is equipped to its capacity with those functional units having the closest association, not only for better operation and maintenance but also for economical wiring and testing in the shop.

One of the markers for the Media office is shown in Figure 1 where the bays are numbered from right to left for convenience of reference. Two frames, each having two bays, are required for each marker. One frame, bays 3 and 4, has the common control functions and line, trunk, and junctor identification and selection functions; the

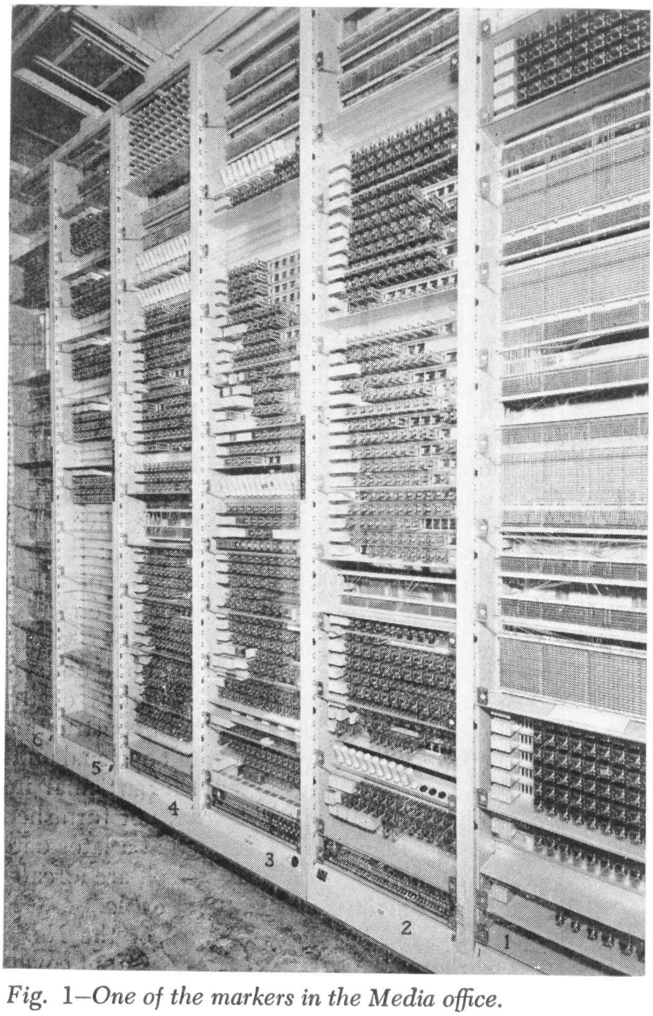


Fig. 1—One of the markers in the Media office.

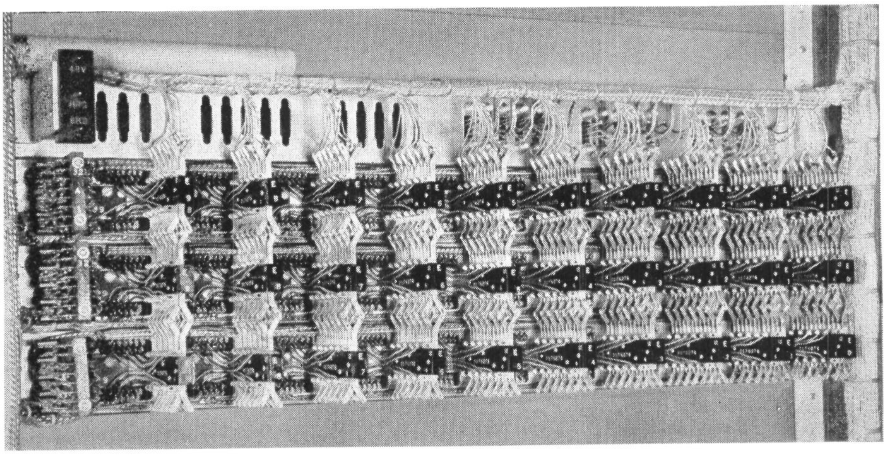


Fig. 2—Trunk test lead connector frame in the Media office.

other frame, bays 1 and 2, has the translator, route relay, and other call completing functions. An additional single bay frame, bay 5, is common to a number of markers and accommodates the relay units which connect the trunk test leads from the trunk link frame to the marker. Space is provided on this bay for 480 relays which may connect 80 or 40 routes from ten trunk link frames to six or twelve markers or 40 routes from twenty trunk link frames to six markers. When an office has more than 80 routes and six markers as an example, more than one bay of this kind is required. In the photograph, relays are provided for only fifty routes and three markers. Another single bay frame, bay 6, provides space for the class of service relay units and cross-connection fields for four markers. A third single bay frame may sometimes be required to provide route relays in addition to the 100 mounted on one of the two bay frames. Each of these five shop wired frames has terminal strips at the top of the frame for the connection of inter-frame switchboard cables which are run by the installer.

Each of the various functional units is equipped for one or more figures of the marker circuit. The use of unit construction makes it relatively easy to omit optional units which are not required for a particular installation. Any unit which is not furnished initially may easily be added at a later date by connecting to it leads which are already in the universal, frame local cable.

One of the novel features of the No. 5 marker is the use of transparent front covers on all the bays. These are evident in the photograph only by the rectangular lift plates at the bottom corners of each cover. How clearly these covers allow the operation of the relays to be observed is evident in the photograph. When adjustments or addition of equipment are required, the covers of all the bays are readily removed by lifting and tilting out.

Another novelty in the No. 5 marker is the use of 275 and 276 (mercury) relays*—evident near the bottom of bay 2, at the middle and near the top of bay 3, and three-quarters way up on bay 4. These relays must be mounted with their axes not more than thirty degrees from the vertical. To avoid the use of hinged mounting plates, which have been employed previously for apparatus that had to be mounted vertically, a sloping mounting plate was designed that will hold the relays within the required angle of the vertical, and yet permit their ready removal from the vacuum tube sockets into which they plug. These mounting plates accommodate either fifteen or thirty mercury relays—a single row being provided for the former unit and a double row for the latter. A single row shelf is evident near the bottom of bay 2, while a double row shelf is evident at the top of bay 3.

It was desired to have faster operate time than could be obtained with multicontact relays used in the No. 1 crossbar marker, and so lighter and smaller U-type relays are used in the No. 5 marker. In some cases, this means that a greater number of relays will be required, but this is offset by the faster

*Record, *September*, 1947, *page* 342.

action and more uniform mounting arrangements. To obtain particularly fast action time for some operations, the marker employs a large number of relays with 14-ohm windings; each relay requires a high wattage 90-ohm resistor in series with its winding. Instead of being mounted on their associated functional units, these resistors are provided on separate units, having twelve resistors on a plate. A number of these units are mounted together at the top of the frame. Resistors can be assigned at random from this pool to relays located anywhere on the frame, and relays may be changed or added without changing the equipment layout of the unit. In Figure 1, these resistors may be seen at the top of bay 4.

When the number of markers in an office is increased, an additional relay for connecting the trunk test leads for each route must be added to the multiple of the relays for the working markers. Since exceptional precautions must be taken to avoid interrupting the operation of important common control equipment such as markers, a special method of adding these relays was designed. The arrangement is shown in Figure 2. A vertical lead running down the rear of bay 5 connects the relays for the same route in all the markers. If there were only three markers in the office originally, there would be only three rows of these relays, each column of three relays representing the same route in the three markers. The vertical multipling lead is furnished by a newly designed, "Y" shaped terminal strip for each relay of each row. The two ends of this terminal strip slightly overlap the two-inch mounting plate, and in doing so come in contact with the terminals in the row above. A brief application of the soldering iron to these terminals connects them together, and thus completes the multiple connection. To add a unit of relays, it is necessary only to mount the unit with the relays and terminal strips in place, and solder the terminal strips to the ones immediately above, with which they will be in contact.

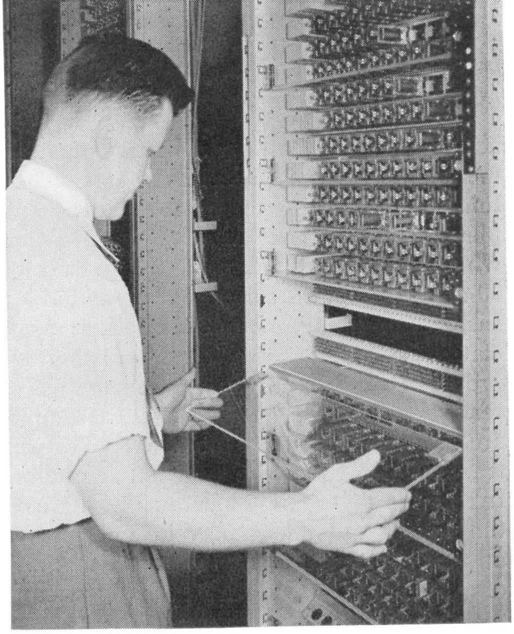
In the No. 1 crossbar system, decoding generally was based on two- and three-digit office codes. The No. 5 crossbar system, however, provides for one-, two-, or three-digit codes or a combination of these. To simplify the assignment and use of these codes, a cross-connecting field is provided in the No. 5 marker, and changes in the type of code require merely a change in the jumpers.

The local circuits for each marker are fused on three panels at the bottom of the two double-bay frames. However, a common alarm is provided, and the one fuse alarm lamp is at the base of one bay so as to be centrally located with respect to the four bays. A fuse guard lamp, to indicate that a fuse has been removed and the marker made busy, is placed next to the alarm lamp. These lamps may be seen in the small black rectangular plate near the left at the bottom of bay 2. An alarm release key is grouped with the miscellaneous circuit jacks and lamps in the vertical jack panel about half way up the column between bays 2 and 3. Test and telephone jacks are multipled to appear in every other upright for maintenance convenience.

Each marker frame—either one bay or two bay—is completely equipped, wired, and tested in the factory so that the installation effort is reduced to erecting and interconnecting frames and making the necessary tests to assure satisfactory operation. The two double-bay frames of each marker are placed adjacent to one another with the single bays common to a group of markers generally located central to the frames they serve. To assure greater security and continuity of service in cases of wiring or power failure, marker frames are generally associated with battery feeders and multiple cables in two groups, one group containing the even numbered markers and the other the odd numbered markers. To permit the cables of these two groups to be run in separate cable racks, and to obtain more direct cable runs, the markers in an office are located in two lines facing each other, with even markers in one line and odd markers in the other.

No. 5 crossbar frames

E. T. BALL
Switching Systems Development



Front view of translator and route relay frame showing method of removing front covers.

One of the many novel features of the No. 5 crossbar system is the design of the switch frame. Heretofore, switch frames for central offices have been designed primarily as supporting structures. The protecting covers and shields required for much of the apparatus have formed part of the equipment units mounted on the frame rather than of the frame itself. In general, these have taken the form of individual or strip type can covers or of cabinet type casings enclosing a group of apparatus. These types of covers impose restrictions in the arrangement of apparatus, particularly when functional

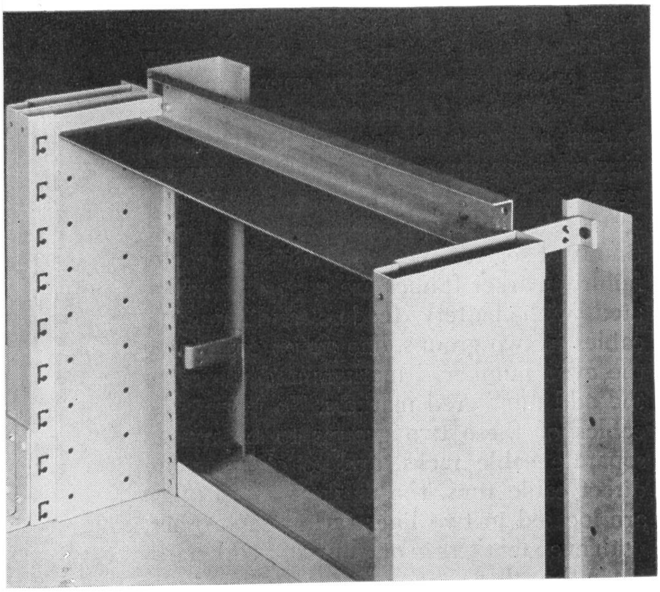


Fig. 1 (above)—Model showing some of the structural features of the No. 5 crossbar frame.

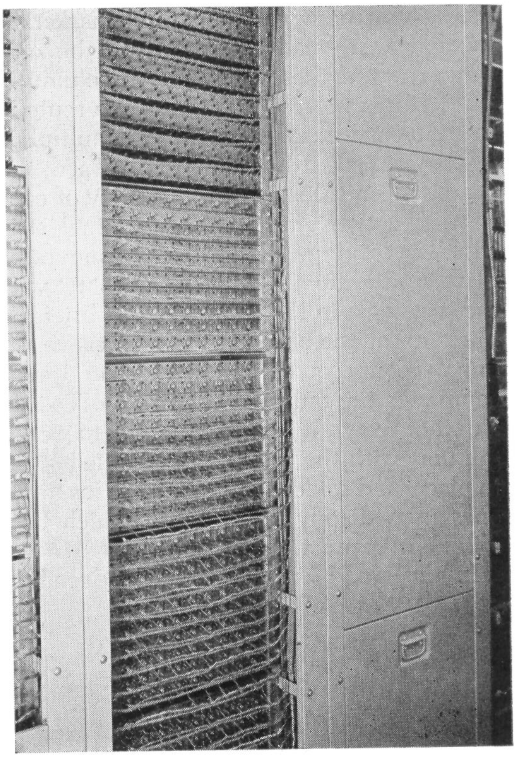


Fig. 2 (at right)—Rear of message register frame at Towson, Md., showing stile strip and covers.

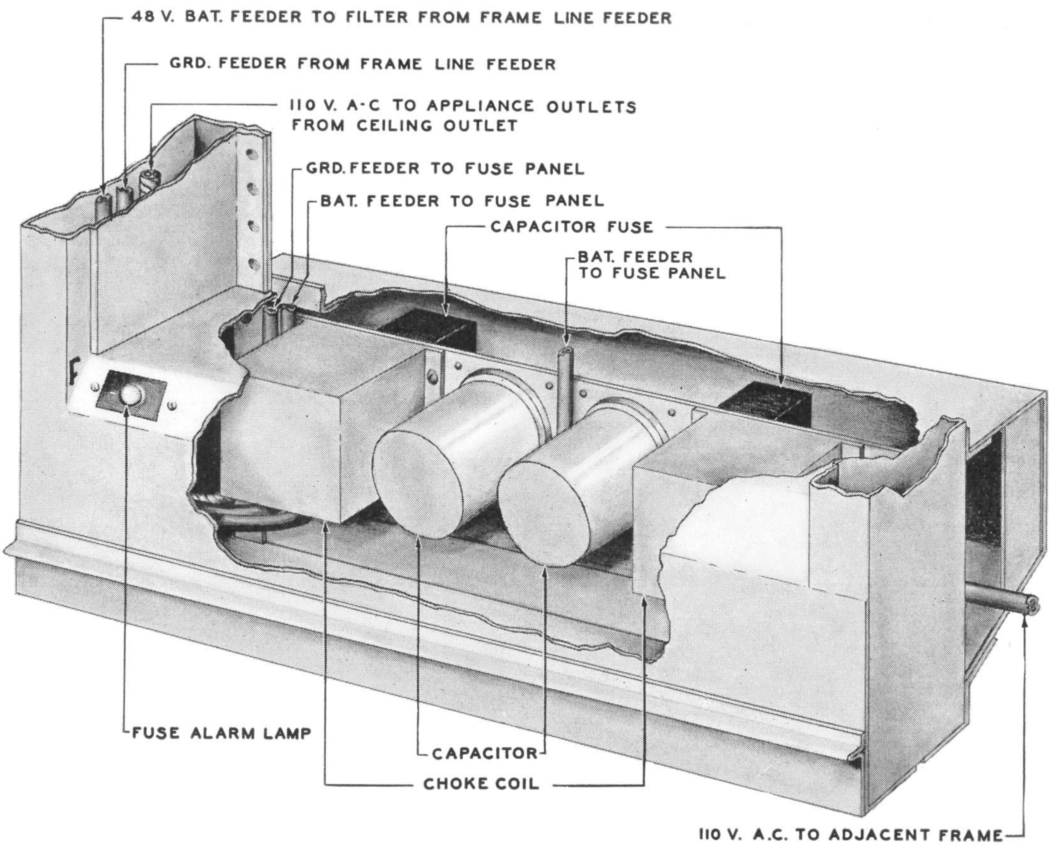


Fig. 3—Perspective drawing showing arrangement of base of the No. 5 crossbar frame.

units* are employed. To secure greater freedom in the use of functional units in the No. 5 crossbar system, covering and shielding provisions were made part of the basic frame itself. This permits a frame to be covered to the extent desired, and the covering may be readily modified at any time to accommodate changes in the arrangement of apparatus or in the amount of covering desired.

Another radical difference in the new frames is that the supporting uprights, instead of being solid steel sections, as were those for earlier types of local central-office frames, are hollow rectangular sections of sheet steel. They are deep enough to extend beyond the switches or other apparatus mounted on them, and thus permit the front covers to be simple panels hinged near the front edges of the uprights. Although the box type uprights of the new frames are only a little over half as heavy as the bulb type frame used in No. 1 crossbar, they are more than 60 per cent stiffer along both major and minor axes. In fact they are lighter and stiffer than any of the other previously used types of frames, as shown in Table I. Because of this increased stiffness of the new frames, cross bracing is not required even for the heaviest equipment. This freedom from cross bracing, together with the fact that there are no cabinets to divide up the mounting space, results in a frame that imposes no restrictions on the equipment arrangements, and has made practical the extensive unitization described in previous articles.

The shape of the box section of the new frames, and the methods of attaching the mounting plates to the uprights are shown in Figure 1: The front of the uprights are

* See page 17.

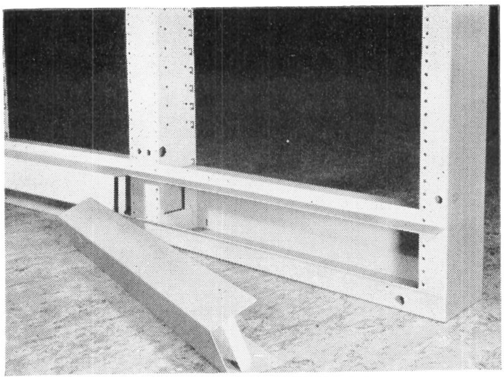
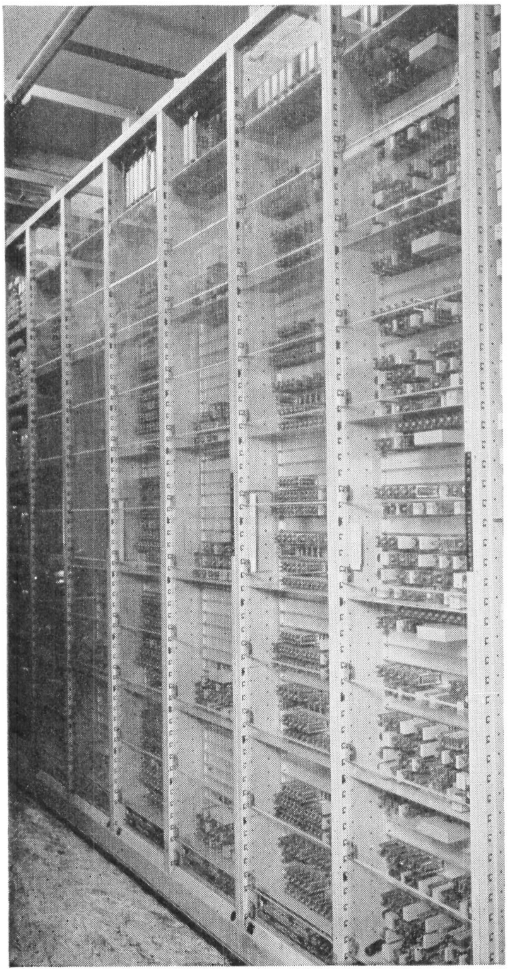


Fig. 4—Rear view of base of frame before equipment has been mounted.

TABLE I—WEIGHTS AND MOMENTS OF INERTIA OF VARIOUS TYPES OF FRAME STRUCTURES USED IN CENTRAL OFFICES

	Weight Per Ft.	Section Area	Moment of Inertia Major Axis	Moment of Inertia Minor Axis
I-Beam . . .	5.4	1.60	2.300	0.400
Channel . . .	4.1	1.19	1.600	0.200
Bulb	4.54	1.31	2.140	0.177
Cable Duct . .	3.53	1.01	1.070	0.181
Box Shape — No. 5 X-Bar	2.80	0.875	3.500	0.300

perforated and formed to support and seat the front covers. These are of transparent plastic, and are hung from the "F" slots as evident in the photograph at the head of this article. A series of round holes, also evident in the illustrations, is perforated in the inner face of each upright to accommodate slides into which may be inserted horizontal baffles or separators. These are on two-inch vertical centers so that a frame



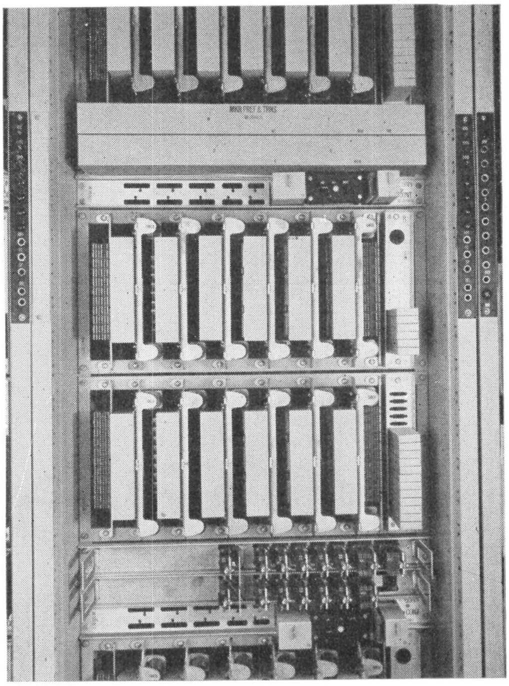


Fig. 5 (above)—On this line link connector frame, the jack strips in the face of the frame uprights are plainly evident.

Fig. 6 (at left)—A line-up of incoming register frames at the No. 5 crossbar office in Towson, Md. The transparent plastic covers may be seen in place on all frames.

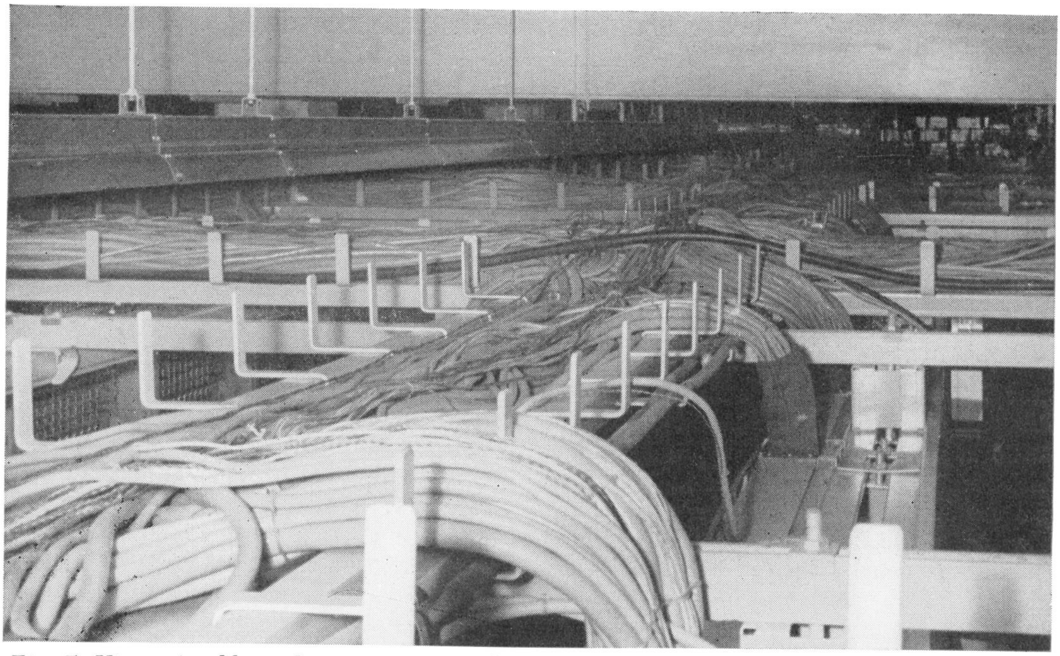


Fig. 7—View of cable racks over wiring aisle in a No. 5 crossbar office as seen from above.

may be divided up in any manner desired, each compartment accommodating a given number of two-inch mounting plates or their equivalent. In line with the front baffles but at the rear of the frame are corresponding baffles mounted by similar slides fastened to the cable brackets. Rear covers of the lift type, three per bay, are arranged to mount on fixed stiles that cover the cable ducts, as evident in Figure 2.

The frame provides for 62 two-inch mounting plates or the equivalent of other apparatus, with the bottom mounting plate 12 inches from the floor. In addition, battery filters and similar equipment requiring little maintenance may be mounted inside the base of the frame, where four additional inches of vertical mounting space is available. This arrangement is evident in Figure 6. Access to this equipment is obtained by removing the rear cover of the base, which forms the rear guard rail, as shown in Figure 3. In the front cover of the base, which is welded to the upright, are the fuse alarm

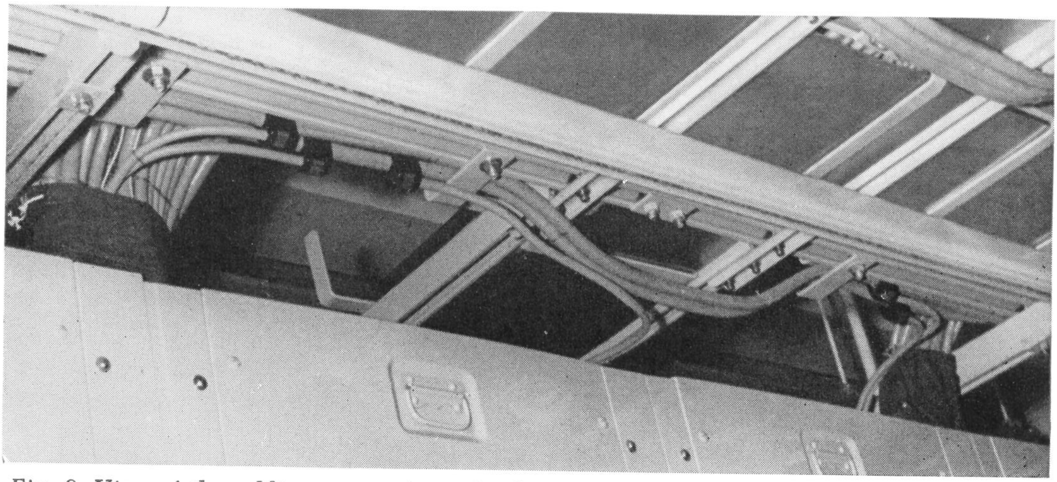


Fig. 8—View of the cabling as seen from the floor.

lamps and an appliance outlet. Both front and rear appliance outlets are connected with a common harness that is installed in the shop. It is provided with connecting leads to permit the installer to connect it quickly to the supply and to the outlet circuits of adjacent frames. The fuse panel alarm lamps are mounted in the bevel at the front of the base, where they are easily visible along the aisle. The fuse panel itself is mounted immediately above the base closely adjacent to both the alarm lamp and the filter, as may be seen in Figure 5. Advantage is taken of the hollow upright to build in accommodations for miscellaneous jacks and keys, as is evident in Figure 4. Battery and commercial power feeders are also run in the uprights.

The associated overhead cable racks are so designed that sewing and clipping of cables and much of the planning is avoided. The rack is placed over the rear or wiring aisle, and feeds two adjacent rows of frames. The rack structure consists of a pair of stringers, shown in Figure 7, to which are welded cable straps formed to provide cable space both between and above the stringers. The ends of the straps point upward to form a series of horns around which cables are broken out of the run. The cables are thrown loosely into the rack with a minimum of dressing. To conceal this and to prevent dust from slipping through the cable pileup, thin sheets of aluminum are laid in the bottom of the rack prior to cabling. In spite of this lack of dressing, the cabling presents a good appearance from the floor as evident in Figure 8.

J. W. DEHN
Switching Development

The originating dial pulse register circuit for the No. 5 crossbar system

The originating dial pulse register circuit receives information in the form of dial pulses from a calling subscriber's station and holds it for the marker to use in establishing a connection between the calling station and the line or trunk wanted. The connection between the register and line over which the register receives the dial pulses consists of three wires extended from the register circuit, through the contacts of crossbar switches of the trunk-link and line-link frames, to the line termination on the line-link frame. Two of the wires, the tip and ring, are extended over the outside line to the subscriber's station, and the third, the sleeve, is used for holding the switches in the operated position under control of the register circuit, and for other functions.

When the tip and ring connection has been established, there will be a series circuit consisting of the subscriber's instrument, the line wires, the two line windings of the dial tone transformer in the register, and a winding of the supervisory and pulsing relay L of the register, as shown in Figure 1. Relay L will operate in this circuit, and will cause the connection to be held, unless the subscriber abandons the call by "hanging up." The third winding of the transformer is connected to a source of tone, known as dial tone, which is thus transmitted to the calling station as a signal that the equipment is ready for dialing.

In most areas, the subscriber will dial a three-digit designation for the wanted central office, for example ME6 for Media 6, and then the four numerical digits of the wanted station. Three-digit or one-digit operator codes, such as 211 for the long-distance operator, and 0 for the assistance operator, may also be dialed. Variations in this pattern of digits will be described in a later article. During the return rotation of the dial, a contact opens the tip and ring circuit momentarily a number of times corresponding to the number dialed, once for one, twice for two, etc., up to ten times for zero. A governor controls the speed of the return stroke, so that these pulses occur at the rate of about ten per second. These pulses are counted by the relays at the bottom and right of Figure 1, and at the termination of a train of from one to ten pulses, this count is transferred to two of a group of five relays. The counting relays are then released and prepared for counting the pulses of the succeeding digit. A group of five relays is provided for each digit to be recorded, and thus for seven-digit numbers, seven groups of five relays would be required.

The register circuit is able to recognize the end of a digit by the fact that the dial contact remains closed for more than 0.2 second between digits (trains of pulses), whereas the closed period between the momentary openings of the dial contact within a train will always be less than 0.07 second. A slow-release relay, which will respond to the longer but not to the shorter of these intervals, is used for this purpose. Actuation of this relay causes the pulse count to be transferred to the group of five relays, the pulse counting relays to be released, and the circuit to be advanced so that the next pulse count will be recorded upon the succeeding group of five relays.

When all of the required digits have been recorded, the register engages a marker and transmits to it the called subscriber number or operator code. After the marker has se-

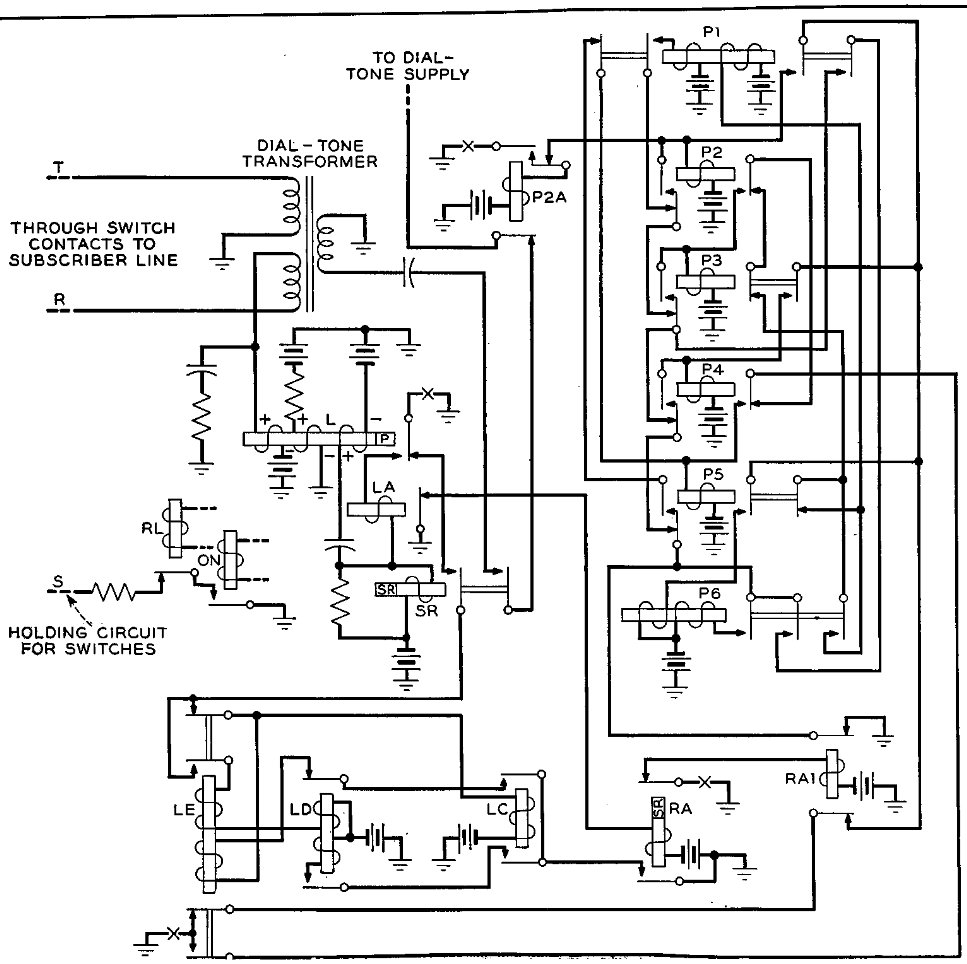


Fig. 1—Dial pulse counting circuit of the originating register.

lected a trunk in the wanted group and has decided what channel through the switches of the line-link and trunk-link frames to use for connecting the line to the trunk, it signals the register circuit to release its connection to the calling line, but it holds the connection between the register and marker so that the information recorded in the register circuit will be available until completion of the marker functions. It is necessary to release the line-to-register connection before setting up the line-to-trunk connection, because part of the apparatus is used for both connections.

When the desired line-to-trunk connection has been established, the connection between the register and marker is released, and both circuits restore to normal and are available for other calls. The register is used about fifteen seconds in the performance of its functions. This time is determined principally by the speed with which the customer dials the call. The marker takes a fraction of a second, determined principally by the time required for testing and selecting an idle trunk and channel and actuating the magnets of the crossbar switches.

Pulse counting is carried out by the LC, LD, LE, RA, RA1, and the six P relays of Figure 1. With the tip and ring wires connected together at the station, the L relay operates, operating the LA and SR relays. The latter is slow in releasing, so that it will remain operated when relay L releases momentarily during dialing, but will release and cause the connection to the line to release if the customer abandons the call by replacing the handset. Each momentary opening of the dial contact during dialing causes relays L and LA to release and then reoperate.* The first release of relay LA operates relay RA, which is slow release and remains operated until LA remains operated for a long time—0.2 second or more—at the end of the series of pulses for a digit. In its operated position, relay RA provides a locking circuit for relays LC, LD, and LE and causes the release of RA1. With relay RA1 released, the locking circuits of relays P1 to P6 are established, and the circuit is ready for counting dial pulses. Reference to Figure 2 will help in understanding the following description.

Each momentary release of the L relay closes a circuit for actuating relays LC, LD, and LE. The first release of the L relay operates relay LC, and the reoperation of L causes relay LE to operate in series with LC. The second release of L operates LD and holds LE. Relay LD in operating causes LC to release. When L again reoperates, relays LD and LE release. The third pulse has the same action as the first and the fourth the same as the second. The significant fact is that relay LE is operated by each odd pulse, and released by each even pulse.

The first operation of LE operates relay P1, and the first release of LE operates P2, which releases P1. This operation continues in such a manner that at the end of any number of pulses, the relays will be operated in the pattern shown in Table 1 on the next page.

When a digit has been completed, relay RA releases, and through contacts not shown in Figure 1 but indicated at the left of Figure 3, connects ground to two of the five register wires as shown in Table 1. These five wires are connected through the contacts of the "steering" relays—shown in the upper part of Figure 3—to the five relays of the digit being recorded. The corresponding two relays are operated, thereby recording the number dialed in the standard two out of five code.

The release of relay RA also releases relays LC and LE, if they are operated, and then operates relay RA1, which in turn releases the P-relays, thereby preparing the circuit to count the pulses of the next digit.

Contacts of the RA1 relay, indicated in Figure 3, also control the steering relays, so that the five register wires will be advanced to the register relays of the following digit. This is accomplished in the following manner. Relay AS is operated when the register is selected. When relay P2A operates during the dialing of the first digit, relay EV operates and completes the circuits of the five register wires to the five relays of the A digit. When relay RA1 operates at the end of the first digit, one of its contacts operates relay BS via contacts of EV and AS. Another contact of RA1 provides a holding circuit for AS. When RA1 releases at the beginning of the next digit, the holding circuit of AS is opened, and AS releases, releasing EV. Relay BS remains operated in a circuit through a break contact of CS (not shown), and causes OD to operate through a break contact of EV. The five register wires are now switched into the register relays for the B digit. A similar action takes place for the following digits. The contacts of the operated register relays are used to inform the marker of the called

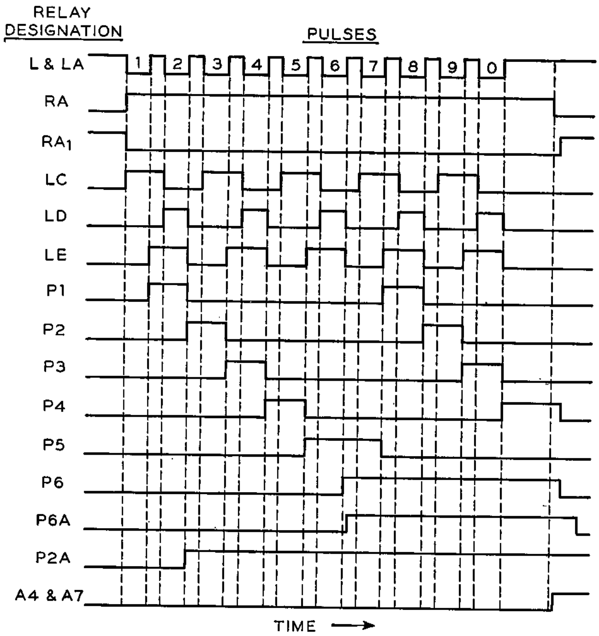


Fig. 2—Time diagram for the operation and release of the relays of Figure 1.

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*A pulse correction feature associated with the L relay was described on page 32 of the RECORD for September, 1940.

office designation and subscriber number.

In addition to recording the designation of the wanted line or trunk, the register circuit must perform certain other functions. One of these is recording and remembering certain information with respect to the calling line. These are: its location on the switches, the class of service to which the customer subscribes, and the numerical designation of the linkage used in making the connection between the line and register circuit. This information is recorded on groups of memory relays in the register circuit when the marker is setting up the connection between the calling line and the register circuit, and at the completion of dialing this information is transmitted to the same or another marker for use in establishing the line to trunk connection.

The calling line location is required, so that the marker will know which line should be connected to the selected trunk. The class of service is required for several reasons. The type of station equipment may determine which of several trunk groups to the same destination should be used. Coin and noncoin stations, for example, usually require either different trunk equipments or a universal type of trunk equipment that can arrange itself for either kind of station upon signal from the marker. Another need for class of service is to restrict groups of lines with respect to the offices they are permitted to dial, depending upon their geographical location and the monthly charge for service, and for other purposes of a similar nature.

TABLE I—OPERATION OF THE P RELAYS OF FIG. 1 AND THE GROUNDING OF THE REGISTER WIRES 1, 2, 4, 7 AND 0 OF FIG. 3 THAT RESULT FROM SUCCESSIVE PULSES.

Pulse Number	*Relays Operated*	*Reg. Wires Grounded*
1	P1	0, 1
2	P2	0, 2
3	P3	1, 2
4	P4	0, 4
5	P5	1, 4
6	P5, P6, P6A	2, 4
7	P1, P6, P6A	0, 7
8	P2, P6, P6A	1, 7
9	P3, P6, P6A	2, 7
10	P4, P6, P6A	4, 7

The number designation of the linkage in use on the connection to the register is needed, so that the marker can consider this linkage to be idle when deciding what channel to use in connecting the line to the trunk. Although this linkage is actually in use when the marker selects a channel, it will become available when the register to line connection is released, just prior to establishing the trunk to line connection.

The register is also required to identify which of the parties on a two-party line is calling. In offices equipped with message registers, this information is used to cause the operation of the proper register of the two associated with the line, and in AMA offices it informs the AMA equipment which party is calling, so that the call can be charged to the proper station.

The two parties on a line are distinguishable from each other by dissimilarities in the station instruments. When the tip station is calling and its handset is raised, contacts in the instrument close a circuit from ground through a 1000 ohm ringer winding to the line wires. There is no similar connection at the ring station. The register, having been informed by the marker that the calling line is in the two-party service class, makes two tests to identify the calling station. One test is made before dial tone is transmitted to the calling line, and a similar test is made at the completion of dialing. The two tests are made to avoid errors which might be caused by accidental depression of the buttons that actuate the switchhook contacts, thereby removing the ground at the tip station. If the results of the two tests do not match, the marker will cause a trouble card to be perforated, and will cause the register circuit to transmit busy tone to the subscriber.

To prevent registers from being held out of service unduly long, due to the failure of subscribers or circuits to perform their required functions, each register circuit is provided with an electronic timing circuit, which causes the register circuit to take appropriate action if a function is not completed in a normal time. The principal functions thus timed are the interval required to

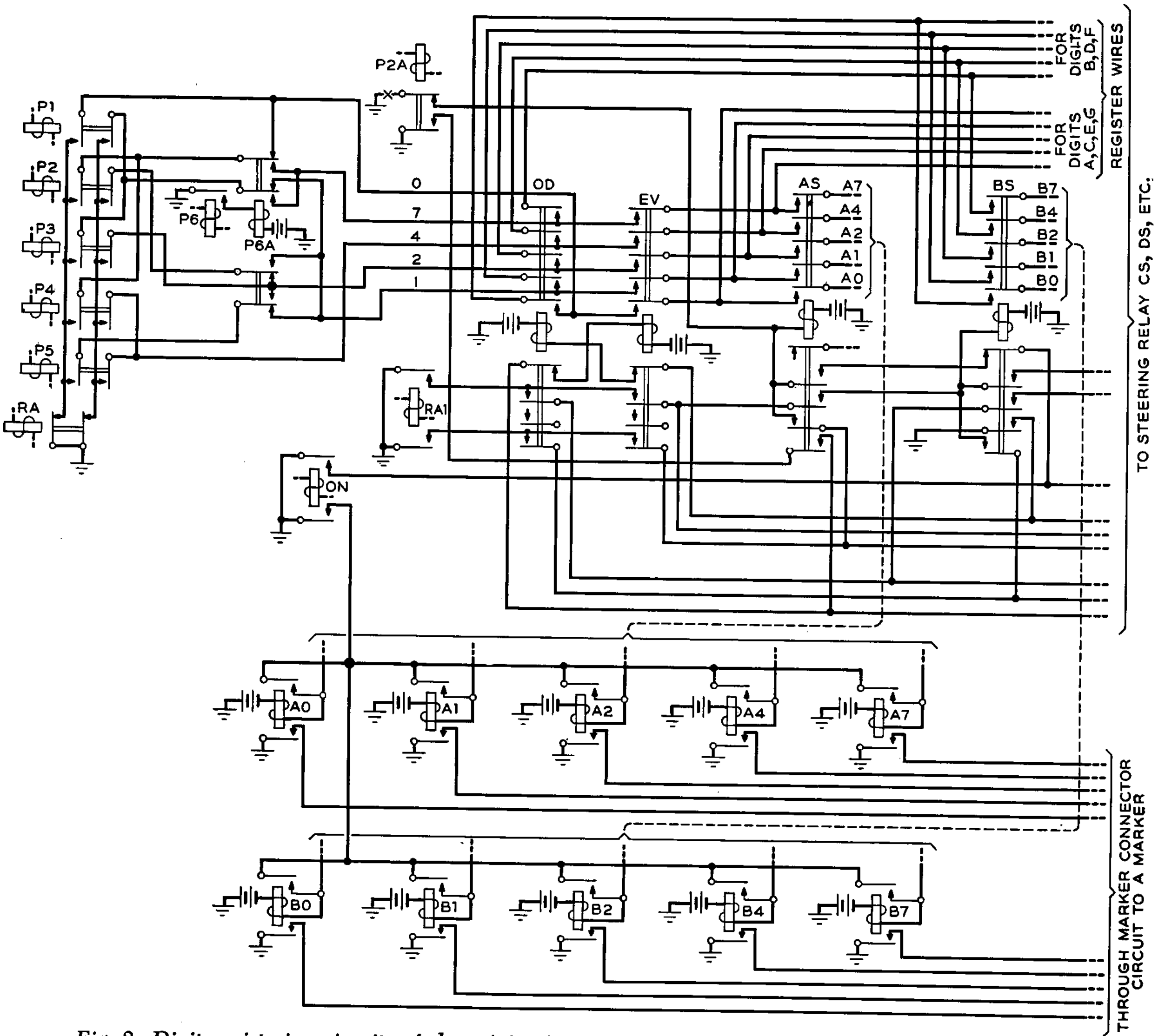

Fig. 3—Digit registering circuits of the originating register.

start dialing the first digit, the interval required for dialing each succeeding digit, and the interval required, after the completion of dialing, for completing the connection and restoring the register circuit to its normal condition.

About twenty-five seconds are allowed, after the register has been selected, for the subscriber to start dialing. If dialing is not started in this time, the register circuit requests a marker to connect the line to a permanent-signal holding trunk, and the register and marker are then released as on a normal call. In this manner the register is restored to useful service in a reasonable time even though a line gives a "permanent signal" due to the handset being accidentally off the cradle, or due to a line fault in the outside plant wires. An operator is signaled by the permanent-signal holding trunk, and means are provided for locating the line that is in trouble.

If the customer starts dialing within the time allowed, the timer is returned to its starting point and restarted. It is returned and restarted at the beginning of each digit, and allows about twenty-five seconds from the beginning of each digit to the beginning of the next. If the subscriber dials insufficient digits, or dials too slowly, the register will request the marker to connect the line to a partial dial trunk, which will transmit a tone to the subscriber as a signal to re-originate his call.

During traffic overloads, when there is a shortage of registers, some subscribers do not wait for dial tone, but start dialing before a register is attached to the line. As a result of this, some or all of the digits may not be received by the register. Also, due to accidents to the outside plant, a large number of lines may present permanent signals simultaneously, thus causing another kind of overload on the registers. In any case of register overload, the permanent signal and partial dial time intervals are reduced to about twelve, and six seconds, respectively. These intervals are sufficient for most people, and are used to restore the circuits to service quickly during overloads. During normal operation, the longer intervals are used to salvage those calls on which a customer is unusually slow.

When dialing has been completed, the timer is again restarted, and, if the connection has not been completed and the register restored to normal in about twenty-five seconds, the register will release the connection to the line and restore to normal. The subscriber will then receive dial tone from another register, and will have to dial again. It is expected that this action will not occur unless there is a fault within the register circuit or its associated circuits.

E. L. ERWIN
Switching Development

Trunk selection by No. 5 crossbar markers

In the No. 5 crossbar system* the trunks of all routes are distributed as far as possible over all the trunk link frames.† Because of this distribution of the trunks, and because some of the frames may be busy with other markers, a marker in searching for an idle trunk has to find a frame not busy with another marker—or an idle frame as it is called—that has an idle trunk of the desired group.

If markers were required to seize frames to find whether or not idle trunks were available, many unnecessary frame seizures would occur. These would not only waste the time of the marker but would delay other markers that might wish to use that frame, thereby increasing their holding time. The circuits are arranged, therefore, so that the marker may locate idle frames that have idle trunks of the desired group before seizing a frame.

Originating registers are also distributed among all the trunk link frames, and thus so far as the work of the markers in selecting trunks is concerned, the originating registers may be considered as trunks of one route. In what follows, therefore, the term trunk will be considered to include also the originating registers.

There may be from two to twenty trunk link frames in a No. 5 crossbar office, and from three to twelve markers. Each trunk link frame has capacity for 160 trunks of which 120 can be outgoing and intraoffice trunks, including registers, and after a marker has seized a frame, it must determine which trunks of the desired group are idle and then select one of these. The work of the marker in finding an idle trunk is thus divided into two steps. It first locates an idle frame that has at least one idle trunk of the desired route without establishing a connection to the frame through its connector. The marker then connects to that frame and selects and seizes one of the idle trunks of the desired route.

The arrangement of trunks, frames, connectors, and markers, and some of their interconnecting paths, is illustrated in a diminutive scale in Figure 1, which shows only three trunk link frames and two markers. The red and black lines represent those paths over which the marker tests for idle trunks and frames, respectively, before seizing, while the other paths are those used after a frame has been seized.

An FT lead (red) runs from each trunk to one of a set of FT terminals on the trunk link frame. When the trunk is idle, the FT lead will be grounded. From an adjacent set of terminals, marked FTC, leads run directly to all the markers without passing through the frame connectors. Each FTC terminal represents the trunks of a single route, and on each frame an FTC terminal is cross-connected to the FT leads of all the trunks of that group. By looking at the FTC leads to the desired route from each of the frames, therefore, the marker may determine which frames have idle trunks.

Each frame connector, as indicated in Figure 2, has an MC relay that is operated when the frame with which that connector is associated is in use by a particular marker, and when an MC relay is operated, it grounds an FB lead (black) through one of its front contacts. The FB leads from all the connectors associated with one frame are connected together and carried to all the markers. By looking at these FB leads, therefore, the marker can determine which frames are busy.

How the marker selects an idle frame that has an idle trunk of the desired route may be followed with the help of Figure 2. Each marker has a route relay—not shown

* See page 5.
† See page 20.

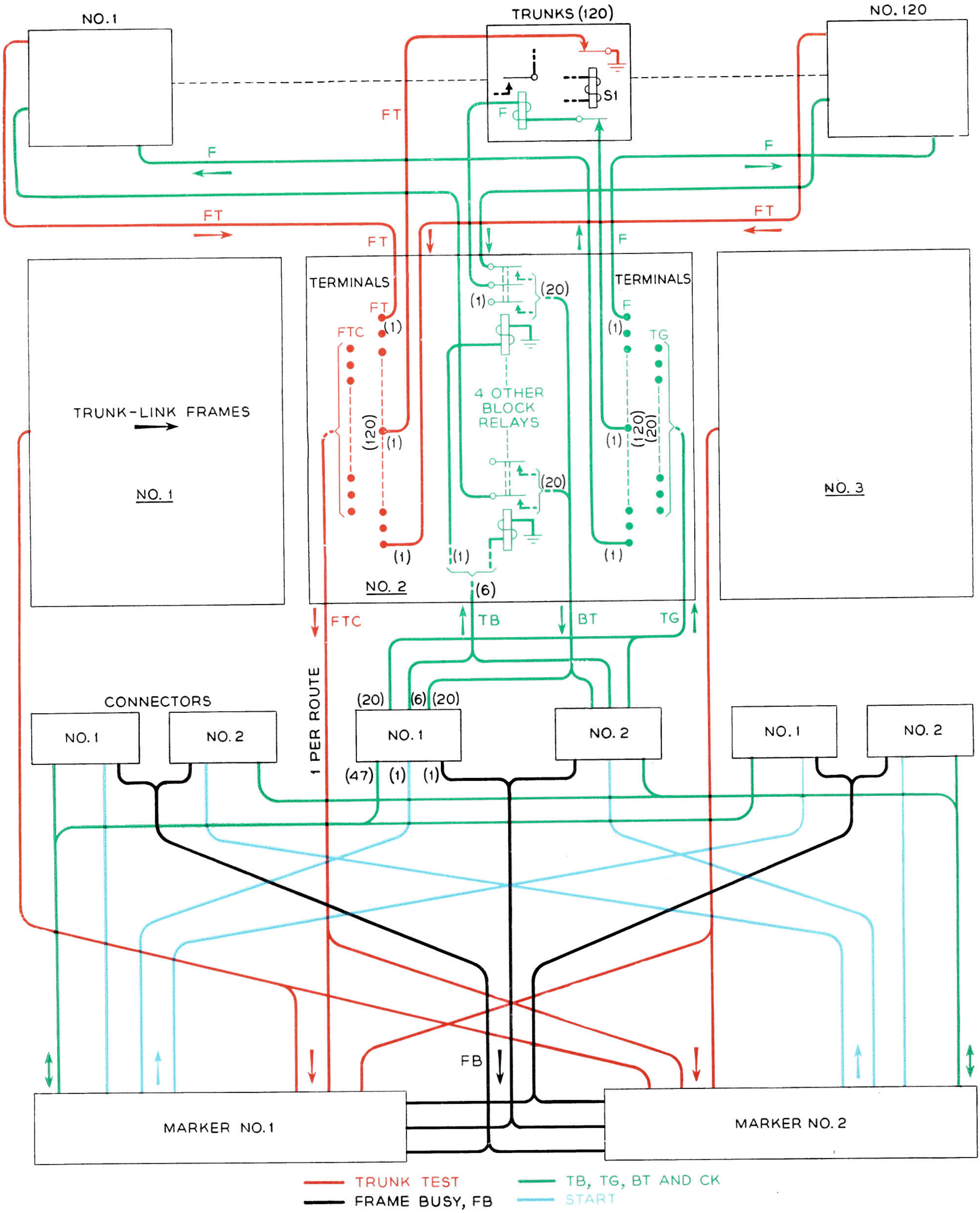

Fig. 1—Simplified diagram indicating some of the interconnections between trunks, trunk link frames, connectors, and markers in the No. 5 crossbar system.

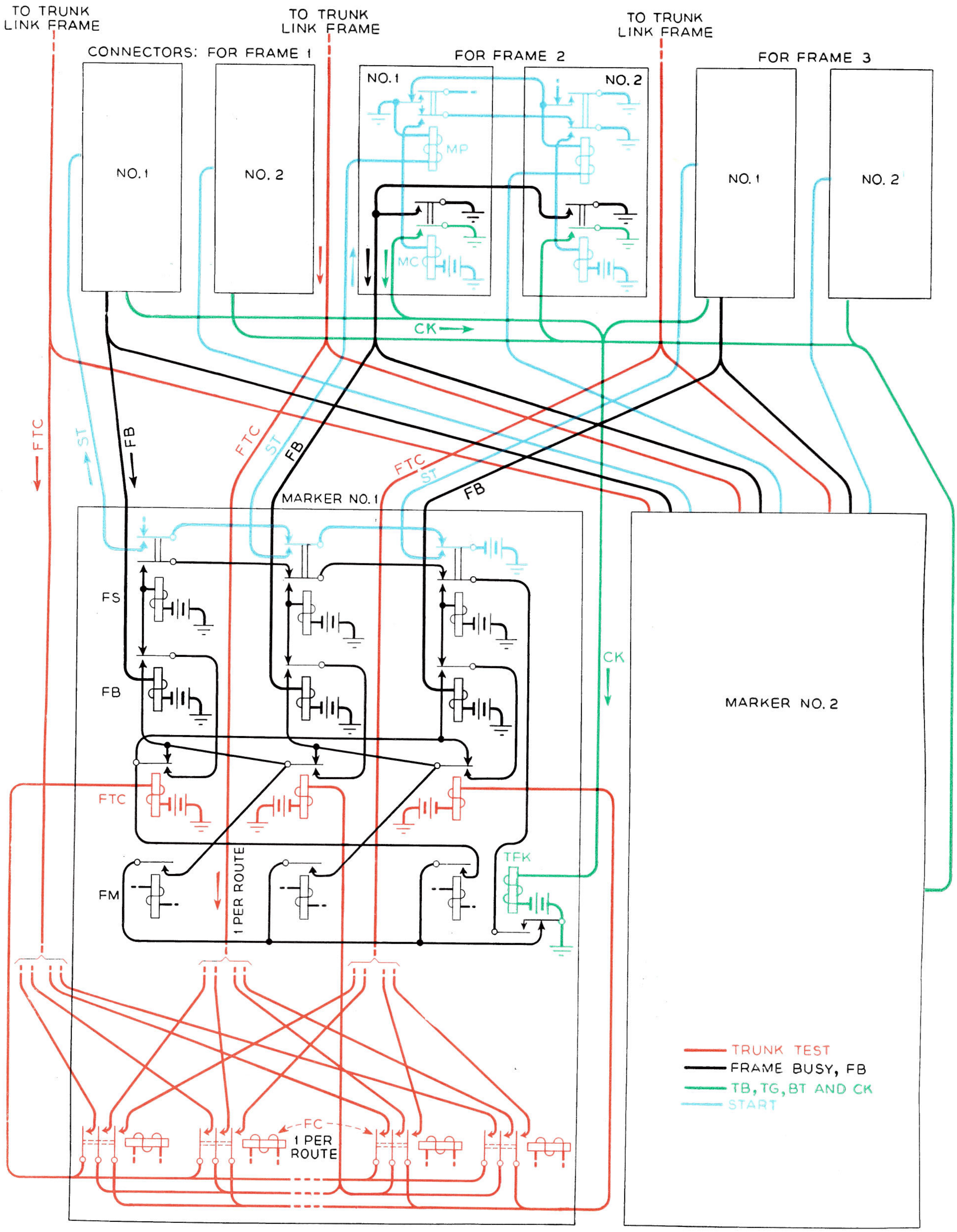

Fig. 2—Simplified diagram indicating some of the relays in the connectors and markers and their interconnections in the No. 5 crossbar system.

in the diagram—for each of the trunk routes in the office, and when a marker is seized, it operates the route relay required for the call. When the marker is seized by a calling line, it operates the route relay for the originating registers, while when it is seized by a register after a number has been recorded, it operates the route relay that corresponds to the office code data passed to it from the register. One contact on the route relay operates an FC relay in the marker, and the operation of this relay connects the FTC leads (red) for that route of trunks on all the frames to the windings of a set of FTC relays—there being one FTC relay for each frame. The FB leads from the connectors for each frame run to the windings of a set of FB relays in the marker. In addition, there is also one of these relays for each frame.

The FB and FTC relays for each frame are associated with an FS and an FM relay to form an interconnected set, and there is one of these sets of four relays for each frame. They are all interconnected as shown in the diagram. For each frame that is busy, the FB relay will be operated, and for each frame that has idle trunks of the desired route, the FTC relay will be operated. The FM are memory relays, and the FM relay associated with the frame last used by the marker will be operated when the new call comes in.

Should all the trunks of a route be busy, the marker—after a short interval—will advance to the next route, which may be an alternative route, to the desired destination or an overflow trunk, which gives an "overflow" tone to the calling subscriber. This action is under control of a timing circuit that starts operating when the frame connector relays operate. If an FTC relay operates—indicating an idle trunk—the timer will be stopped and the marker will not advance.

Ground from a back contact on the TFK relay passes through a front contact of the operated FM relay to the armature, contact of the FTC relay of the next higher numbered frame. If this relay is operated, indicating at least one idle trunk on that frame, the ground will be continued to the armature contact of the FB relay for that frame. If this relay is not operated, indicating that the frame is idle, ground will pass through its back contact and operate the FS relay for that frame, thus selecting the frame. From the interconnections between these sets of relays, it will be noticed that if the FTC relay had not been operated, or if the FB relay had been operated, the ground would have been extended to the FTC relay of the next higher numbered frame. With this circuit, therefore, the FS relay is operated for the first frame encountered—following that of the operated FM relay—that is not busy and that has idle trunks in the desired group.

When an FS relay operates, it connects battery to the start lead (blue) running to that marker's frame connector for that particular frame. This operates the MP relay in the connector which in turn operates its associated MC relay. Operation of MC grounds the FB lead (black) to indicate that that frame is now busy (occupied by a marker), connects to the marker a group of leads that the marker will use in subsequent handling of the call, and grounds a CK lead (green) to the marker. Ground on this latter lead operates relay TFK in the marker. This locks the FS relay that was operated, and removes the ground from the FM relay contacts.

If the only idle trunks of the desired route are on trunk link frames in use at the time by other markers, the marker—under control of its timing circuit—will wait a short interval for one of these frames to become idle. Should none of the required frames become available within the established time intended, the marker will cause a trouble record to be taken and then give the connector a trouble release.

Having thus selected and connected to a suitable frame, the marker now proceeds to select an idle trunk on that frame. For the purpose of finding and seizing a suitable idle trunk after the frame has been seized, the 120 possible trunks of a trunk link frame are divided into six blocks of twenty trunks each, and within each block from one to twenty groups are provided. As indicated on Figure 1, the blocks are physically represented by six block relays each with twenty contacts, and the formation of groups within each block will depend on the number of trunks of the various routes that are included in that block. Each group of a block will include all the trunks of one route on that trunk link frame. If there are many routes of only one trunk each, the block might include twenty groups, while if one route had more than twenty trunks, half of them would form a group in one block, and the remaining trunks of that route would form one group in another block but with the same group number. All the registers connected to a frame, usually five or six, will form one group in one of the blocks.

With this arrangement, the number of trunks per group may differ for each block, but in any block a group always includes only the trunks of one route, and it will include all the trunks of that route except when there are more than twenty trunks per route. In testing and seizing trunks, the marker designates one block and one group, and this combination always identifies the trunks of one route. The same group but a different block, or the same block but a different group, would, of course, identify trunks of a different route. It is

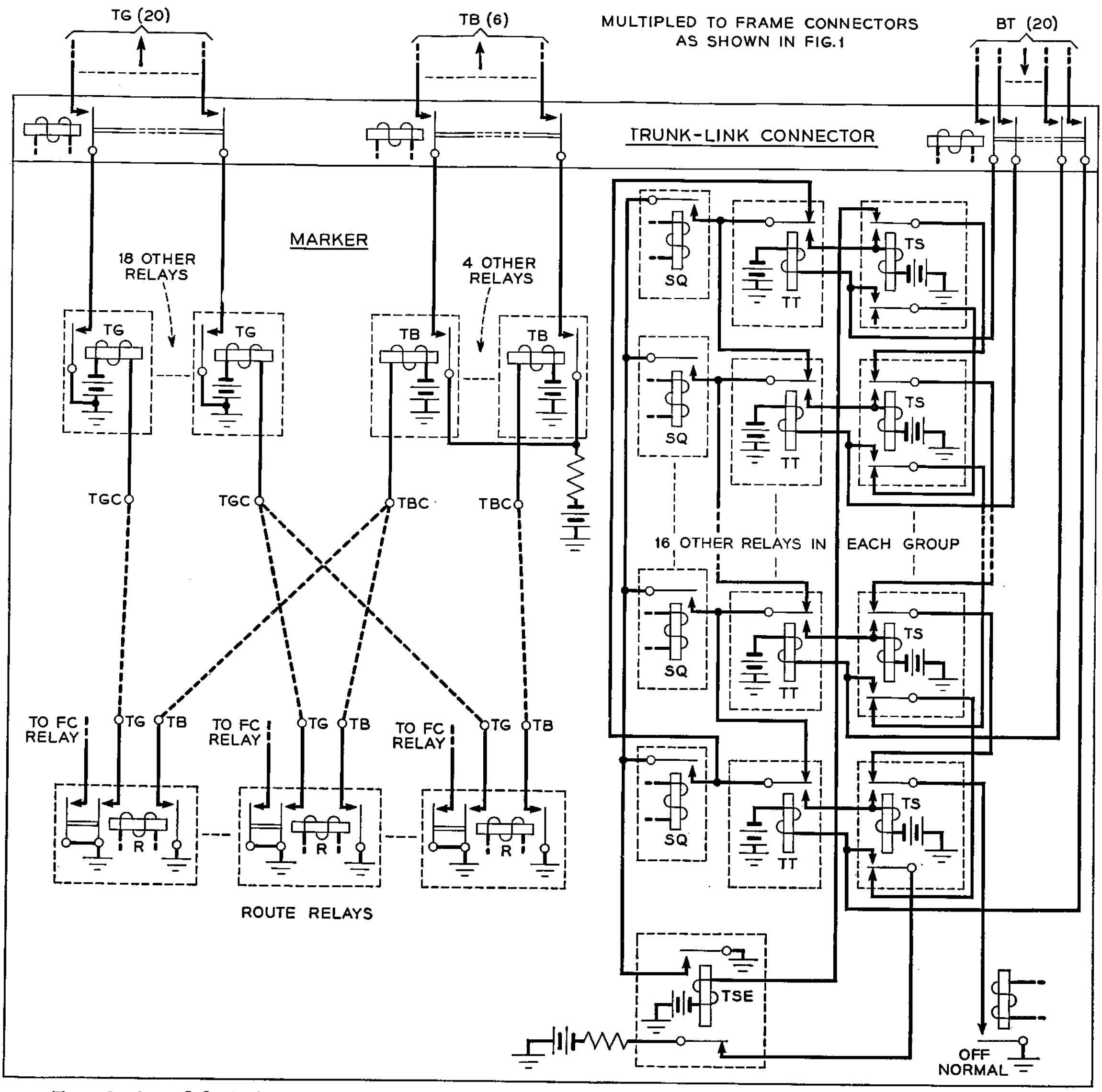

Fig. 3—Simplified diagram indicating some of the relays in the marker and trunk link connector.

because of this identifying method of the marker that the trunks are assigned as described above.

Two relays in each trunk circuit are involved in busy testing and seizing a trunk; an F relay, which is operated to seize the trunk, and an S1 relay, which remains operated as long as the trunk is in use. One end of the winding of the F relay is carried through a back contact of the S1 relay to a set of F terminals, there being one terminal for each trunk of the frame. If the trunk is in use, this circuit will be open at the S1 relay. The other end of the F relay winding is connected to one of the armature contacts of one of the block relays. This arrangement is indicated in the upper part of Figure 1.

The front contacts of the six block relays are multiplied, and brought down through the connector to the marker as a group of twenty leads (green). Each of these leads connects to a winding of a TT relay as indicated in Figure 3. The other end of the winding of the TT relay is connected to battery. Only one block relay is operated at a time, and thus the BT leads will be connected only to the F leads connected to the block relay operated.

When the route relay operated in the marker, it in turn operated a TB and TG relay as well as the FC relay referred to in connection with Figure 2. There are six of the TB relays—one for every block relay on a trunk link frame—and there are twenty TG relays; which particular TB and TG relays are operated by any one route relay is determined by jumpers run between the two sets of terminals shown in the marker in Figure 3. An operated TG relay connects ground—after a frame has been seized—to one of a set of TG terminals on the frame as shown in Figure 1. These TG terminals are adjacent to the F terminals through which the trunk test leads are connected. Each TG terminal represents, a group, and jumpers are run between the TG and F terminals to form the groups of the six block relays. Group 1 in block 1 might be six registers; in block 2, it might be three trunks to office A; in block 3, one trunk to office B; in block 4, eight trunks to office C, and so on. Jumpers would thus run from the No. 1 TG terminal to the F terminals of all the trunks comprising group 1 in all the blocks. When a frame is seized, ground from the operated TG relay would thus be applied to the F leads of all these trunks, but only the trunks associated with the particular block relay operated at that time would have their circuits completed to the TT relay and battery in the marker, and these would be the trunks of only one route. For the busy trunks of that route, moreover, the circuit would be open at the S1 relay. When a frame is seized, therefore, a TT relay for each idle trunk of the desired route will operate.

As shown in Figure 3, each TT relay in the marker is associated with an SQ and a TS relay to form twenty sets of three relays. When a marker is seized, ground from a marker off-normal relay is carried through back contacts of the TS relays in series, and operates relay TSE, which puts ground on the armature contacts of the SQ relays. These SQ relays are part of a sequence circuit, whose function is to rotate the preference, and one is operated in turn for each call that the marker handles. When a frame is seized, therefore, current flowing over the BT and TG leads and through the trunk test leads of 1 group of 1 block, operates certain of the TT relays as a result. Ground from the operated SQ relay passing through the armature contact of its associated TT relay will operate the associated TS relay if that TT relay is operated. If that particular TT relay is not operated, the ground will pass to the next TT relay above, and either operate its associated TS relay, or be passed to the next TT relay. In this way, the first TS relay with an operated TT relay will operate. Actually there are only ten SQ relays instead of the twenty indicated, but their association with multiplier relays is such as to give the effect of an SQ relay for each TT relay, as indicated in Figure 3.

The current flowing over the trunk test circuit, although sufficient to operate a TT relay, is not sufficient to operate the F relays in the trunks. When a TS relay is operated, however, it opens the circuit to the TSE relay and thus releases it, and from a back contact of TSE, battery through a low resistance is applied to the BT lead of the selected trunk. This causes enough current to flow through F to operate it, and the trunk is thus seized. Relay TS also locks itself through the off-normal ground and thus it no longer needs to be held by the circuit through TT and SQ.

These selecting operations, which have taken considerable time to describe, would appear to one watching in the marker as occurring almost simultaneously. The operation of a route relay immediately after the marker is seized is followed by the immediate operation of an FC relay, and this by the operation of a number of FB and FTC relays and one FS relay that seizes the connector and frame. As soon as a trunk link frame is seized, paths are prepared for operating one or more of the TT relays, and through contacts of one of these, a TS relay operates. That in turn operates the F relay in one of the idle trunks, thus connecting a group of leads from that trunk to the marker over which the marker gives the trunk the information needed to complete the call. The operations from the time that the route relay operates until the F relay of the trunk operates take place in about 0.09 second.

Traffic distribution in the No. 5 crossbar marker

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Switching Development

In any automatic telephone switching system, an even distribution of traffic is a desirable objective, and is always sought where other and conflicting objectives are not controlling. In the higher usage circuits, such as senders and registers, for example, relay wear and contact erosion are critical factors in determining the life of the equipment. Hence it is desirable to distribute the traffic evenly over these circuits so that their relays tend to wear at a fairly uniform rate, thus giving the maximum period of service before corrective maintenance is required. For interoffice trunks, a uniform load among the trunks of a group reduces the assignment and balancing effort in both the originating and the terminating offices. Closely related to the equalization of load among switching paths, and accomplished in No. 5 crossbar offices by the same control circuits, is the preferential assignment of the common equipment to various groups of subscriber lines. This serves to prevent undue delays to the higher numbered line groups which may occur in periods of heavy traffic.

The simplest ways of selecting switching paths give far from uniform distribution. If, in choosing an idle trunk in a group, for example, the selection process always started at the same point, the later trunks would carry materially less traffic than the earlier ones even at times of full load, and during hours of light load might carry none at all.

In step-by-step and panel systems, where the selectors hunt over their terminals in this manner, more favorable distribution can be obtained only by such mechanical means as slipped or reversed multiple,* and the improvement that can be gained is limited. Common control systems in which both selection and hunting features are centrally controlled offer better opportunities for obtaining good distribution. In the No. 1 crossbar system, four major types of control circuits are employed: the line link and sender link control circuits, and the originating and terminating marker circuits. To secure adequate control of distribution the necessary features have to be provided in each of these four circuits. In the No. 5 crossbar system, however, all the major selection and hunting features are concentrated in a single type of circuit, the marker. Thus, more complete control of distribution becomes feasible, since more elaborate distributing circuits can be justified economically in a single type of marker.

In the latter system, the trunks of each group and the originating registers are distributed as evenly as possible over all trunk link frames. In placing a call to a trunk or an originating register, the marker remembers the trunk link frame to which it placed the last previous call, and attempts to place the present call to the next higher numbered trunk link frame.

Except the arrangement for selecting a trunk link frame, the largest group from which a selection must be made is the block of twenty trunks on the trunk link frame.* Since this group besides being the largest, presents the most difficult problem, its requirements determine the design of the common preference control circuit, and it may most satisfactorily be used to illustrate the principles involved in many of the selections.

In choosing an idle trunk out of the group, the selecting circuit, in effect, tests the trunks one after the other and seizes the first idle one of the desired route it encounters. Which particular idle trunk will be seized thus depends on two factors: the trunk at which the circuit begins to test, and the order in which the testing proceeds.

* Record, *September*, 1944, *page* 514.

* See page 45.

In the actual circuit this testing of the trunks is done simultaneously, but the arrangement of the circuit is such that the same two factors of point of start and order of search determine which trunk is to be selected. To secure uniform use of the trunks, the point at which testing begins should be changed after each operation of the marker to break up any tendency to select some particular trunks more often than others. Where any trunk of the group is equally suitable for use, this rotation of the starting point is sufficient in itself to give uniform distribution over a period of time, bearing in mind that a marker ordinarily does not serve the same route on successive operations. These simple conditions do not apply to the trunk blocks in the trunk link frames however.

These blocks may include a number of groups of trunks, the various groups occupying successive positions of the twenty in the block. To illustrate the inadequacy of a rotation of the starting point, assume, for example, that a particular group of four trunks occupies positions 8 to 11, inclusive. On twenty successive searches for an idle trunk in this group the marker would test the trunk occupying position 8 first in seventeen out of the twenty times, on the average, since it would be tested first when the starting point was anywhere from positions 12 to 19 or from 0 to 8, both inclusive. Each of the other three trunks of the group would be tested first only once. Beside rotating the starting point of test, therefore, it is necessary also to break up the order of test in some situations to avoid conditions of this type.

To do this, distribution control in the marker is divided into two processes: one establishes a beginning point that is changed after each operation of the marker, and the other determines the order of search. The first process is represented in the No. 5 crossbar marker by a common sequence circuit that establishes a beginning point for the search in all groups, and changes this point after each seizure of the marker. The other is a preference circuit that establishes the order in which the search is carried out. The sequence circuit changes the beginning point at each marker seizure, while the preference circuit, beginning at a point indicated by the sequence circuit, will test in an order that will give the most uniform distribution.

The major selections requiring distribu-

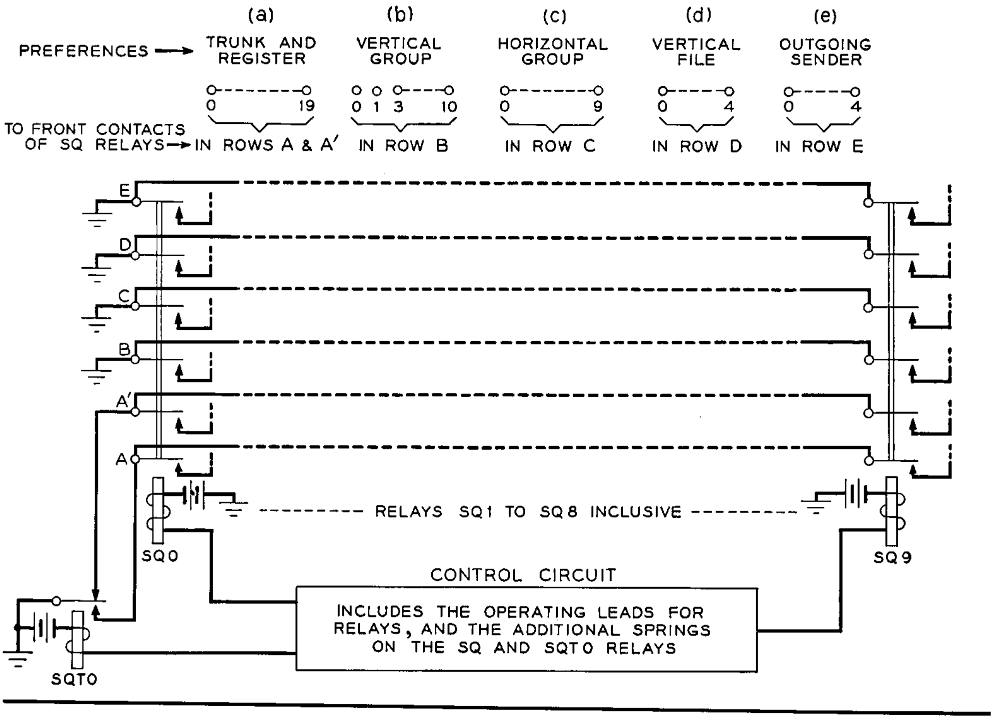

Fig. 1 — Simplified diagram of the sequence circuit of the marker.

tion control in the No. 5 crossbar marker are (1) vertical-group identification; (2) horizontal-group identification; (3) vertical-file identification; (4) trunk and originating register selection; and (5) outgoing sender selection. The first three of these together identify a calling line on a line link frame. Preference control is needed here to determine which of several simultaneous calls on a line link frame shall be served first. The fourth determines which trunk of the desired route or which originating register of those available in the preferred trunk link frame should be employed. The outgoing sender selection determines which sender of the desired type shall be selected from the preferred subgroup.

The basic sequence circuit of the marker is indicated in simplified form in Figure 1. Ten SQ relays, numbered 0 to 9, are operated one at a time by a group of six control relays in a control circuit. The SQ relays are operated in numerical order on successive marker seizures. Thus if relay SQ0 is operated on the first seizure, SQ1 will be operated on the second, SQ2 on the third and so on. For the eleventh seizure SQ0 will be operated again, and the cycle will repeat. Sets of leads representing the five functions for which a preference selection is required are connected to the front contacts of each relay, and when the relay is operated, ground is placed on these leads as shown in Figure 1. The ten leads used for horizontal group selection, for example, are connected to the front contacts of the C row of springs of the SQ relays, and thus for each seizure of the marker ground will appear on one of these leads. Since the vertical files and outgoing senders are selected in groups of five, each lead is connected to contacts on two SQ relays. The first lead will be connected to the 0 and 5 SQ relays, the NO. 1 lead to the 1 and 6 SQ relays and so on. For ten seizures of the marker, therefore, these groups are run over twice. With respect to vertical group selec-

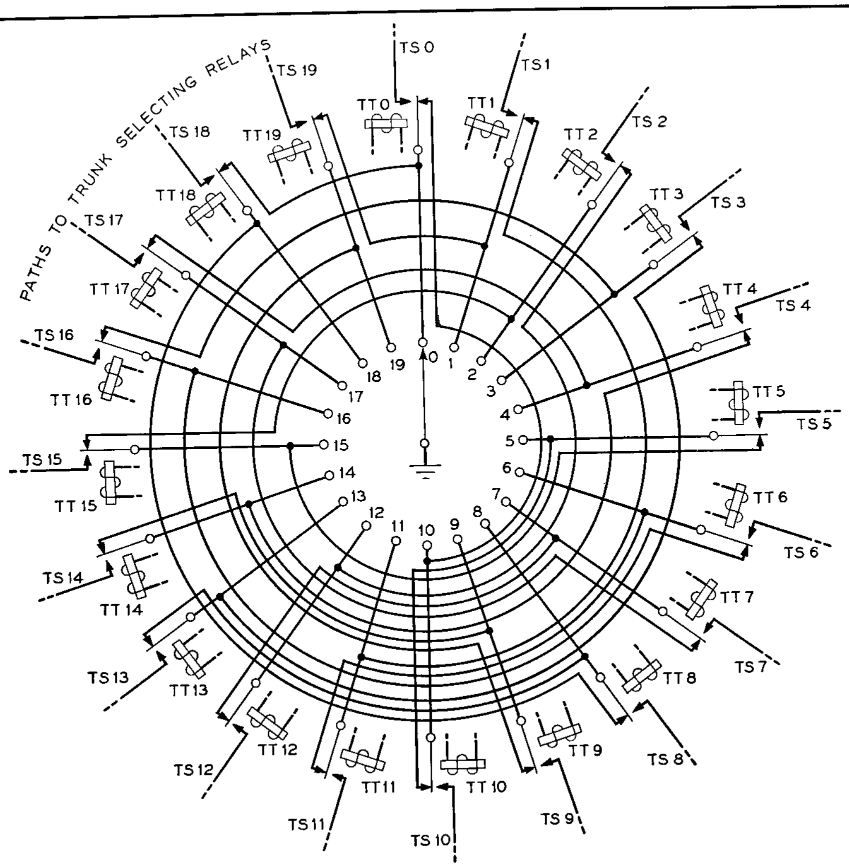

Fig. 2—Diagrammatic representation of the preference circuit for a trunk block of 20 trunks.

tion, lines which should have preference in times of emergency, such as fire, police, and ambulance lines, are assigned in vertical group 2, which is always given first preference regardless of the position of the sequence circuit. Therefore the ten leads from the sequence circuit are connected to vertical groups 0, 1 and 3 through 10, and they become effective only if there is no demand on vertical group 2. Vertical group 11, where used, is given second preference at one step of the sequence circuit.

To provide for the twenty leads for the blocks on the trunk link frames, two contacts on each SQ relay are employed. Leads 0 to 9 are connected to the front contacts of the springs of row A and leads 10 to 19 to contacts on the springs of row A′. Through a front and back contact on the SQTO control relay, ground is placed on the A row of the SQ relay for the first ten seizures of the marker and to the springs of the A′ row for the next ten seizures. In this way ground is applied to the twenty leads of the trunk and register group, one after another, on twenty consecutive seizures of the marker.

The groups of leads at the top of Figure 1 run to the preference circuits for the various selections. Although the basic principle is the same in the design of all preference circuits, the larger size for that of the trunk blocks and its greater complexity make it the best to serve as an illustration. Since the originating registers are associated with one of the trunk blocks of each trunk link frame, and since these, because of their high use, require particular care in equalizing the distribution, the distribution for the registers has been the controlling factor in arranging the preference circuit for the trunk blocks. There may be from four to eight registers on a trunk link frame and their location is such as to group them all at the beginning of one of the trunk blocks. More offices are expected to have five registers per trunk link frame than any other number, and thus this number was assumed in designing the preference circuit. This circuit for the trunk blocks is indicated in Figure 2. The twenty leads from the sequence circuit are connected to the points on the inner circle, where the arm from the central ground, rotating clockwise, represents the advancing action of the sequence circuit. The TT relays, to the springs of which the leads from the sequence circuit connect, are operated for all idle trunks of the desired group, and are released for all busy trunks and for all trunks of groups other than the desired one. The order in which trunks are tested is thus determined by the connections from the back contacts of the TT relays.

By following through these connections, it will be seen that the testing order instead of being 0, 1, 2 to 19 and back to 0 is that given by the middle ring of numbers in

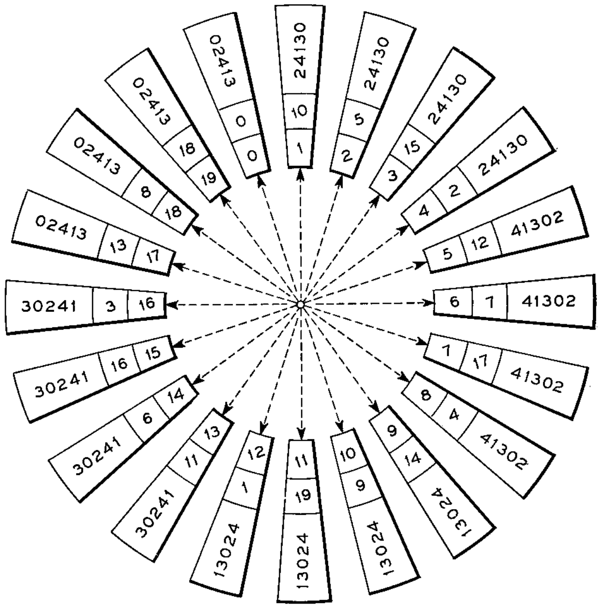

Fig. 3—Diagram representing testing order of trunks and registers.

Figure 3 reading in the clockwise direction. The inner ring of numbers here corresponds to the numbering of the TT relays and of the leads from the sequence circuit in Figure 2. If the sequence circuit had started at 0, the order of testing would thus be 0, 10, 5 and so forth as shown in the middle ring. Had the point of start been other than 0, say 12, the order of testing would be found by rotating the middle ring until 12 was opposite 12 on the inner ring and the order would then be 12, 7, 17, and so on. The order in which the five registers would be tested for the twenty starting positions is given in the outer ring of Figure 3. In position 0 of the sequence circuit, for example, five registers in positions 0 through 4 of the trunk block

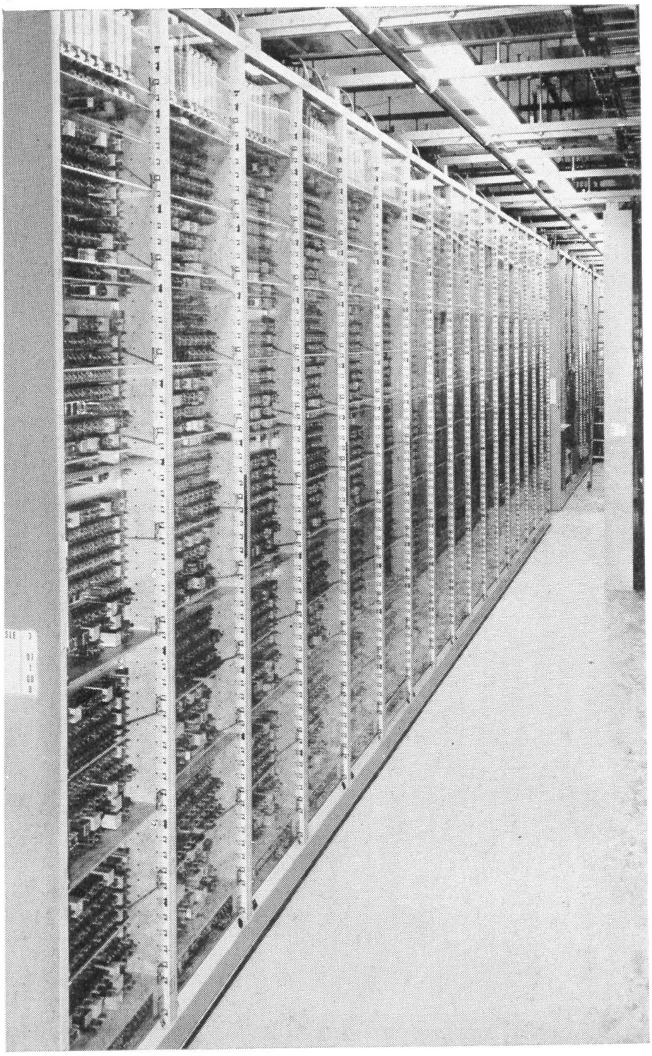

Fig. 4—A line of originating register bays in the Towson office. The distribution of calls to these registers is under control of the circuits in the marker that is described in this article.

are tested in the order 0, 2, 4, 1, 3, as shown in the outer ring. It will be noticed that each of the register appearances is first preference in four positions of the sequence circuit, second preference in four positions, third preference in four positions, fourth preference in four positions and fifth preference in four positions. Since different markers, each with its independent sequence circuit, are placing calls, and since each marker normally places different types of calls and prefers different trunk link frames on successive usages, the over-all effect is to randomize the selection of originating registers. Over a sufficient period of time, the tendency is to load the registers uniformly.

The performance of this feature was observed during two half-hour periods at the Media central office. The observations were made under rather light traffic conditions, which would tend to emphasize any maldistribution of calls among the registers. The results indicate that, with five registers per trunk link frame in service, the least used register carried about twenty per cent less traffic than the average register, and the most used register carried about twenty per cent more traffic than the average register. With higher traffic density, these deviations from average would tend to be reduced. Also, it is probable that observations over a longer period of time would show less deviation from average. Even disregarding these last considerations, the deviations indicated above represent a material improvement over the performance of comparable features in previous switching systems.

In securing optimum distribution for five registers, it is not possible to secure equally good distribution for all other groups of various sizes and positions. The order established gives the best over-all results that could readily be obtained while at the same time securing the optimum distribution for five registers.

A somewhat similar problem occurs in the vertical-group identification function, and in the sender selection function, and they are handled in a similar manner. There may be anywhere from six to twelve vertical groups on each line link frame of an office and thus a staggered preference chain is provided to give equitable service to each vertical group for any number within these limits. Similarly there may be from one to five senders of a type in a sender subgroup, and a staggered chain is used to distribute the calls uniformly among them. There are always two subgroups of each type of sender, with the preference being alternated between the two subgroups by a simple two relay circuit.

Another traffic distribution feature of the marker is that of channel selection. A channel is a path through the line link and trunk link crossbar switches from the subscriber's line to the trunk or originating register. The function of channel selection is divided into two parts, junctor group selection and selection of a channel within the junctor group. A junctor is a path from a line link frame to a trunk link frame. Junctors are arranged so that, for any size office, there are at least ten junctors from each line link frame to each trunk link frame. For the smaller sizes of office, there are correspondingly more junctors from each line link frame to each trunk link frame. For selection purposes, the junctors are divided into groups of ten or less, and calls are distributed among the junctor groups by means of a six-step sequence circuit, similar in operation to the multi-purpose sequence circuit described above. After a junctor group has been selected, the individual channel is selected in the same manner as in No 1 crossbar, the lowest numbered idle channel being selected first. This procedure represents an exception to the "even distribution" technique, in attempting to obtain the most efficient use of the channels. Provision is made, by a simple wiring change, for changing the starting point of the channel selection to equalize the wear on the switches during the life of the office.

The marker also provides flexible alternate routing arrangements for outgoing calls, so that, if the direct trunks to the desired destination are all busy, as many as three different alternate routes may be tried. This feature is of particular value in areas having a high volume of interoffice traffic. It allows a relatively efficient use of the small direct trunk groups, since the alternate routes are engineered to carry the calls which fail to find direct trunks.

There are many other subsidiary features which could be included in the discussion of traffic distribution arrangements. However, the major features that have been mentioned in this article illustrate the versatility which is made possible by concentrating the selecting arrangements in one type of common-control circuit.

Connectors for the No. 5 crossbar system

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Connectors are used for associating markers with other common control circuits and with the switching frames for brief intervals during the handling of a call. In the No. 5 crossbar system, the seven major types, indicated in Figure 1, are employed. Besides showing the circuits with which each type of connector is used, this diagram shows the number of paths closed by each connector, and also the direction of the connection, that is, whether the marker seizes the frame, or the frame seizes the marker. This difference in the direction of connection is also indicated in the name of the connector. Where the marker seizes a frame, the connector is given only the name of the frame the marker seizes. Thus there is a line link connector, a trunk link connector, an outgoing sender connector, and a number group connector. When it is the marker that is seized by the frame, on the other hand, both the word marker and the name of the frame are included in the name of the connector. Thus there is an originating register marker connector, an incoming register marker connector, and a line link marker connector. For the line link frames, both types of connectors are required, and thus there are both line link connectors and line link marker connectors; the former is used while the marker is setting up connections between line link and trunk link frames, and the latter only when a subscriber lifts his handset to place a call.

Paths through the connector are established by operating multicontact relays,* each such relay closing 60 contacts. Since each connector closes more than 60 paths in establishing a connection, there will be more than one multicontact relay per marker in each connector. These relays have two operating magnets, and by separating the operating circuits of each relay, the equivalent of two 30-contact relays is available. Advantage is taken of this for the line link marker connector and the number group connector—the former requiring one and a half relays per marker, and the latter two and a half.

Two different circuit patterns are used for associating the multicontact relays to

*RECORD, *May*, 1939, *page* 301.

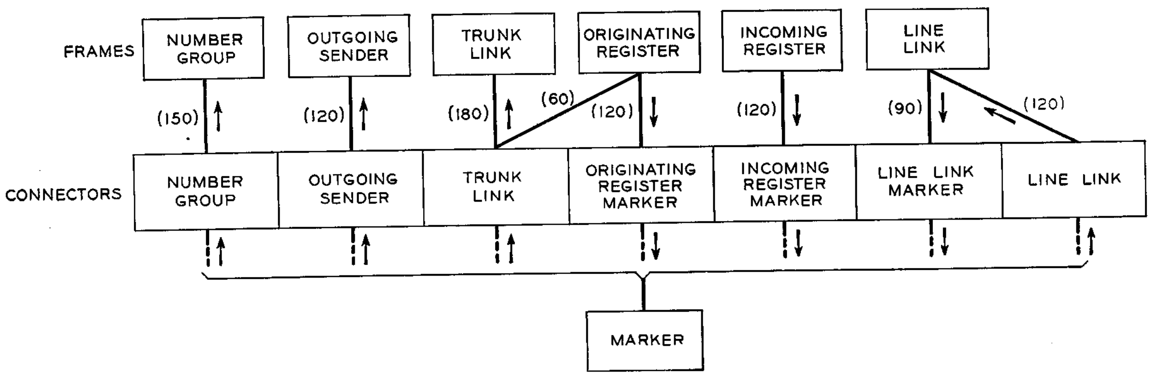


Fig. 1—The seven principal types of connectors used in the No. 5 crossbar system with the circuits with which they are associated and the number of paths they close.

form a connector, as shown in Figure 2. The arrangement shown at (a) is called a single-ended connector, while that at (b) is a double-ended connector. The latter is used only for registers and senders. Only one multicontact relay is shown connected to each marker, but as pointed out above, there will always be more than one of them depending on the number of paths that must be closed. With the single-ended connectors, which are used for line link, and number group frames, the connector multiple is connected to the armature contacts of all the multicontact relays and extended nection of 240 leads to each marker. The single-ended connector multiple for 180 leads is extended directly to the associated trunk link frame. The double-ended connector multiple for the remaining 60 leads is extended to the multiple side of the multicontact relays on the originating register frames which represent originating registers associated with that trunk link frame.

The reason for the provision of two types of connectors is that as soon as a line link, trunk link, or number group frame has been released by one marker, it is free for seizure by another. After a register or

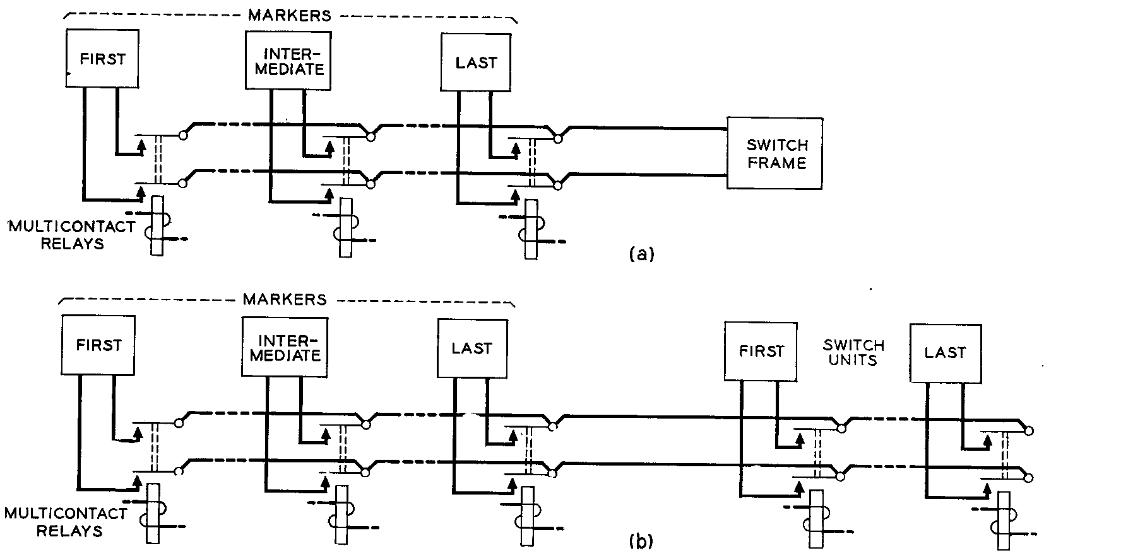


Fig. 2—Two types of connectors are employed: single-ended connectors arranged as indicated at (a), and double-ended connectors as arranged at (b).

to the switch frame the connector serves. There is thus one connector for each frame. With the double-ended connectors, on the other hand, used only for senders and registers, the connector multiple is connected to the armature contacts of both a group of multicontact relays for the markers and another group for the circuits to be connected to them. With this type of connector, therefore, a single connector will serve a group of similar circuits.

The trunk link connector, in conjunction with the originating register circuit, is both a single-ended and double-ended connector. There are multicontact relays for con- sender has been disconnected from a marker, however, it will not, in general, be free for connection to another, since it will be busy recording the digits dialed by a subscriber or transmitting pulses over an outgoing trunk. Double-ended connectors are thus used for registers and senders to permit the connector, after it has been released by one register or sender and a marker, to be at once reused for another connection. If single-ended connectors were used for these equipments, there would be relatively long intervals while the sender or register was performing its other functions when the connector was not in use.

The two sets of multicontact relays used with double-ended connectors are mounted in different locations. Those that connect the marker to the connector multiple are on the connector frames, as are those of the single-ended connectors, while those that connect the registers or senders to the connector multiple are on the register or sender frames, described later.*

Because of the similarity of the connector circuits and the large number of them required, the connector frames were designed to be built up of functional units in accordance with one of the basic features of the No. 5 crossbar system. The principal unit includes six multicontact relays

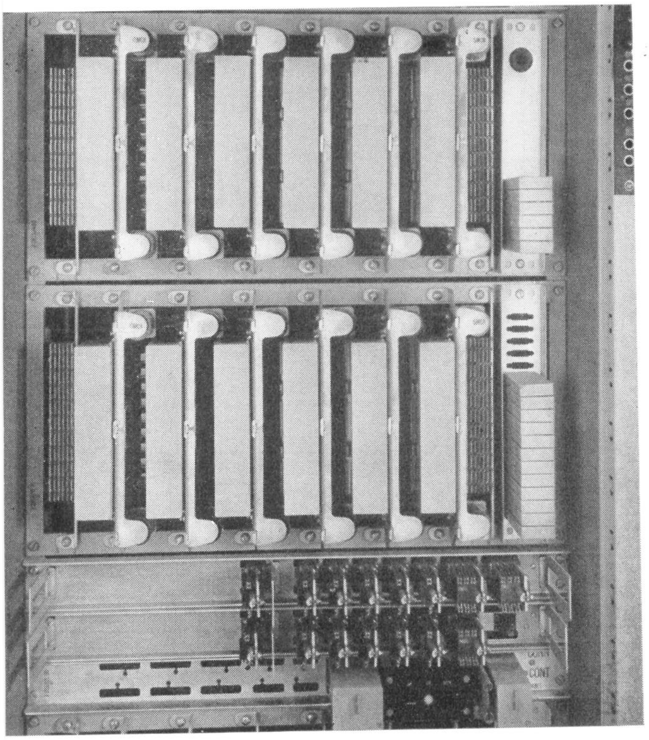


Fig. 3—Front view of a line link connector which employs two multicontact relay units.

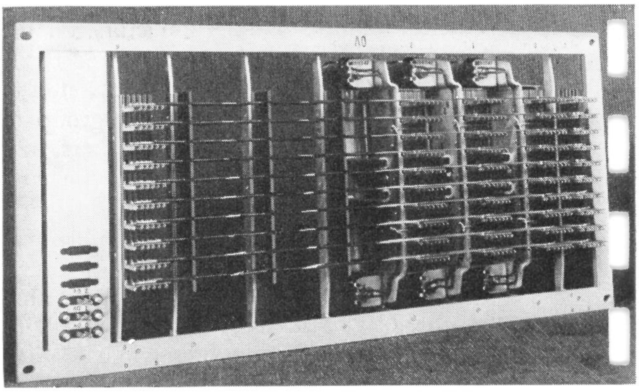
spaced on 2¾ inch centers to provide ample space for soldering the leads from the markers. Two of these units are shown in Figure 3. Terminal strips are mounted at each end of the unit, and the bare copper wires that connect the armature contacts of all the relays are connected to the terminal strips at each end as shown in Figure 4. The small cans to the right of the right-hand terminal strip in Figure 3 enclose contact protection networks.*

From one and a half to four such units—depending on the number of paths to be closed—will serve six markers, which is all that many of the No. 5 offices will require. For offices that require less than six markers, some of the positions for the multicontact relays will be left vacant, as shown in Figure 4. For offices requiring more than six markers, supplementary connector frames are provided, which may be furnished to serve either three or six additional markers. When such frames are used, the terminal strip at one end of the unit on the basic connector frame is wired to the terminal strip at one end of the unit on the supplementary frame to form a single connector.

Besides the multicontact relays, each connector requires a set of preference relays and a set of control relays. A preference relay unit requires one, two, or three mounting plates depending on the type of connector. Connectors through which markers seize the frames have two sets of preference relays, a regular set and an emergency set. The latter is brought into service automatically in the event of failure in the former. Control units consist of one or two mounting plates, and one unit is provided for each connector.

Six sets of terminal strips are located at

Fig. 4—Rear view of a multicontact relay unit partially equipped.



* See page 79.

*Record, February, 1949, page 50.

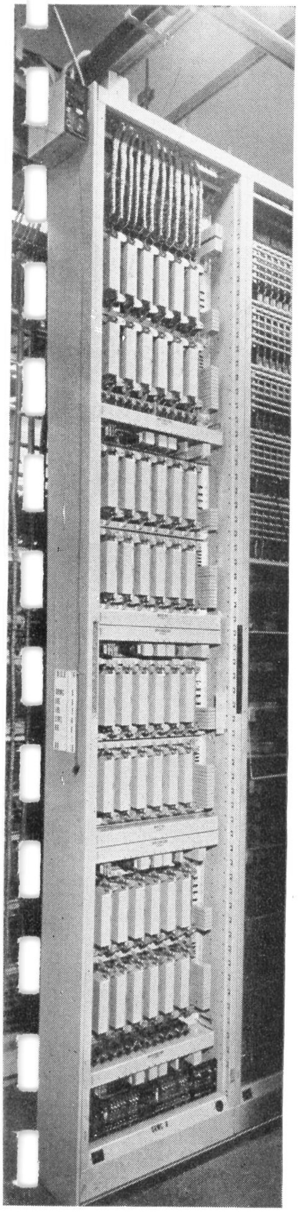


Fig. 5—An originating register marker connector frame.

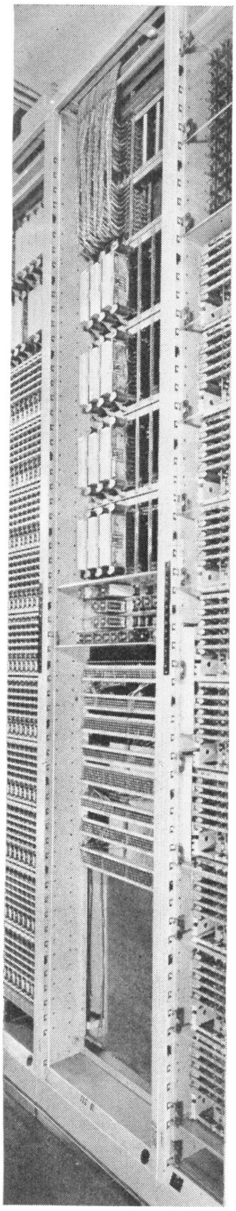


Fig. 6—A trunk link connector frame at the Media office.

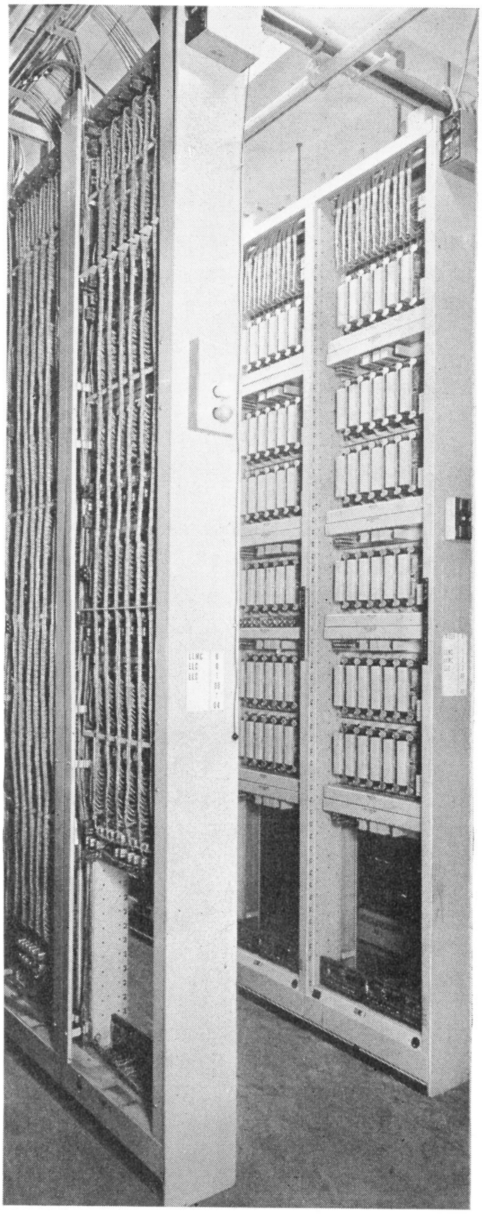


Fig. 7—Front and rear views of a line link marker connector in the Towson office near Baltimore.

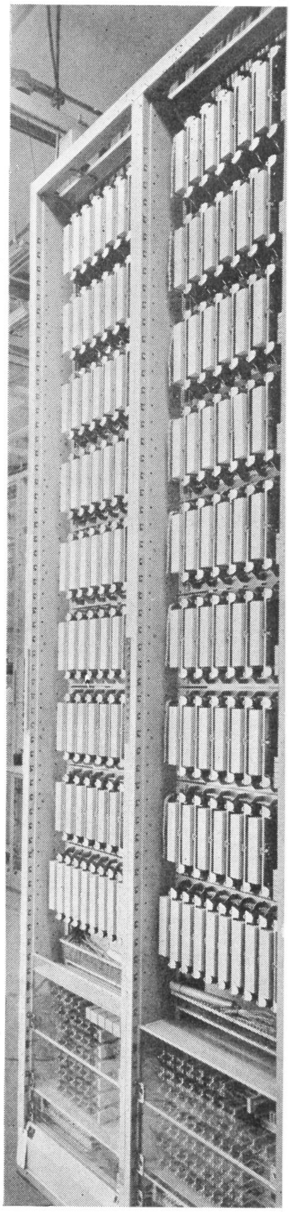


Fig. 8—A master test connector frame at the Towson office.

the top of each connector frame. The marker leads are cabled to the front of these strips, as may be seen in Figures 5 and 6. On the rear of the frame, vertical local cables extend the marker leads to the multicontact relays for all connectors on the frame, as evident at the left of Figure 7. One set of terminal strips, together with a vertical local cable, is furnished as a unit at the time that each marker is equipped.

Each of the connector frames is a standard 23-inch single bay sheet metal frame, but because of the different number of paths closed by the various connectors, and of differences in the amount of auxiliary equipment required for certain frames, the number of connectors per frame is not the same for all types. The originating register

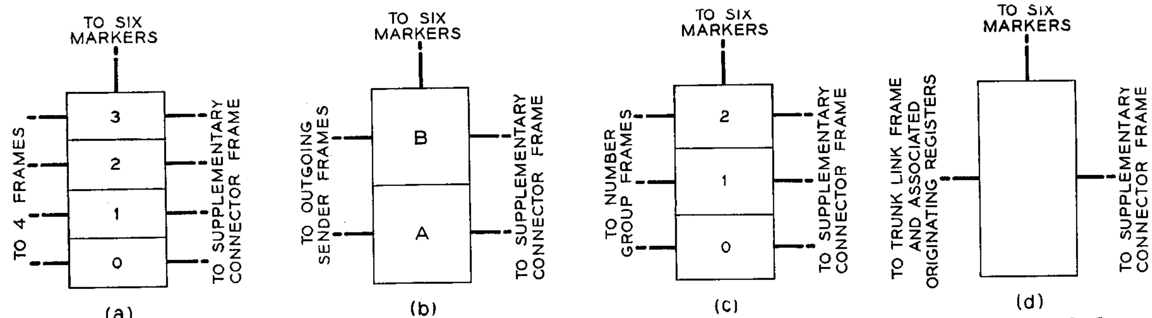


Fig. 9—Either one, two, three, or four connectors may be mounted on a single frame as indicated above.

marker connector, the incoming register marker connector, and the line link connector all have four connectors per frame, each consisting of two multicontact relay units. The arrangement of these frames is indicated diagrammatically at (a) of Figure 9. Figure 5 shows an originating register marker connector frame, which in its general arrangement is similar to the other two of this group. A closeup of part of a line link connector frame is shown in Figure 3. The preference and control relays are on the three mounting plates immediately below each pair of multicontact relay units.

Four connectors per frame are also used for the line link marker connectors, but since these connectors require only one and a half multicontact relays per marker, there are only six multicontact relay units per frame as shown in Figure 7.

The outgoing sender connector also closes 120 paths, and thus requires two multicontact relay units to serve six markers. Since a group of cross-connecting fields and a number of auxiliary relays are required in association with the outgoing sender connector, only two connectors are mounted on a frame as indicated in (b) of Figure 9.

Number group connectors close 150 paths and thus require two and a half multicontact relay units per connector. Four connectors would thus require ten multicontact relay units, but since with terminal strip and control equipment a bay will not accommodate more than eight, only three connectors are mounted on each number group connector frame, (c) in Figure 9.

The trunk line connectors close 240 paths and thus require four multicontact relay units for each connector. Since several sets of cross-connecting terminals are associated with these connectors, only one connector is mounted per frame as indicated at (d) of Figure 9. A trunk link connector bay in the Media office is shown in Figure 6. Since this office has only three markers, the multicontact relay units are each equipped with only three relays.

Besides the seven connectors used in setting up service calls, a master test connector is required in each marker group of the No. 5 system. This connector circuit is arranged to connect markers, pretranslators, and the automatic monitor circuit to the trouble recorder. Test calls may be made from the master test control circuit through the master test connectors to markers and pretranslators.

The master test connector frame consists of two bays to accommodate the connector equipment for the first six markers, and is shown in Figure 8. For marker groups exceeding this, one or two supplementary master test connector frames are required; the first serves markers 7 to 9, and the second serves markers 10 to 12. The supplementary frames are single bays of equipment.

For offices arranged for AMA, an auxiliary master test connector frame is required in addition to the master test connector frame. This is a single-bay frame that accommodates the multicontact and U relay equipment used for connecting transverters, AMA recorders, and the master timing frame to the trouble recorder.

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Switching Development

Senders for No. 5 crossbar

One of the features of the No. 5 crossbar system that distinguishes it from other common control switching systems is that intraoffice calls—calls originated by and completed to subscribers within the office—are established without the use of senders. Neither are senders required on incoming calls. All calls outgoing, however, except those requiring operator assistance, require a sender. Where the called and calling offices are in the same building but are served by different marker groups, intermarker-group senders may be used, but for all other calls outgoing senders are used.

The chief function of the outgoing sender is to transmit the number to the called office, and since No. 5 crossbar is designed to connect to all existing types of offices, provisions must be made for multi-frequency pulsing, dial pulsing, revertive pulsing, and call-indicator pulsing. This could have been done by providing a single design with a multiplicity of classes, but to reduce the complexity of the design, four general types of outgoing senders are provided, and are designated according to the method used for transmitting the number. Thus there are multi-frequency, dial pulse, revertive pulse, and call-indicator pulse senders.

Unlike the No. 1 crossbar senders, the senders of the No. 5 office do not receive and record the digits one at a time as dialed by the subscriber, but receive them all simultaneously through the marker from either the originating or incoming registers. While the number is being recorded, the sender also records, under control of the marker, class marks denoting any special handling of the call such as fast dial speed or compensation to be added to the loop. The sender also receives from the marker information for the initial entry on the automatic message accounting tape in offices where this system is used. It records this information at the same time it receives the called number and class information, and transmits it to the automatic message accounting circuits as soon as it receives a "go ahead" signal from the marker. This latter signal indicates that the marker has connected the calling line to a suitable outgoing trunk, and that the sender should proceed with its part in completing the connection.

A set of five relays is provided in the sender for recording each digit of the called number, but two, and only two, relays of each set are used to record any one digit. For some types of calls, only four digits are included in the called number, while for nation-wide dialing, eleven digits may be required. The senders may thus include from four to eleven sets of recording relays. The five relays of each set are marked 0, 1, 2, 4 and 7. For digit 0, relays 4 and 7 are operated, but for all other digits, the sum of the two operated relays indicates the digit. Thus 0 and 1 are operated for digit 1, 0 and 2 for digit 2, 1 and 2 for digit 3, and so on. This 2-out-of-5 method of recording provides a check on correct operation, since if fewer or more than two relays are operated, it is evident that an error exists, and a trouble record will be made.

In the registers, digits are also recorded on 2-out-of-5 sets of relays and in the same order in which they are dialed. A particular set of recording relays, therefore, does not always record digits of the same significance. For a call to a local office in an area with only two-digit office codes, for example, the fourth set of relays would record the second digit of the number in the office called. In an area with three-digit office codes, the fourth set of relays would record the first digit of the number in the called office, while with nation-wide dialing systems, the fourth set of relays would record the first digit of the office code. Because of this lack of functional identity, the sets of recording relays are designated A, B, C. and so on, up to L, but excluding I, when the full eleven sets are required.

These digits are transferred from the register to the marker and from the marker to the sender in the same order in which they were dialed, and in both marker and sender are recorded on similarly designated sets of relays. In general, however, the sender does not transmit all the digits it records. To an office in the same area reached over a direct group of trunks, for example, only the subscriber's number is transmitted, even though the office code had been recorded, since the marker has selected a trunk to that office. Although the markers could have been designed to transfer to the will begin with the B digit; while if the No. 3 delete relay is operated, it will begin with the D digit, and so on. Thus, if the number CH3-2468 has been transferred to the sender, the marker, after selecting a trunk to the CH3 office, would operate the No. 3 delete relay in the sender. When the sender is given the "go ahead" signal, therefore, it will begin its transmission with the fourth digit, 2. When automatic message accounting is not provided, however, and when there are no routes to a toll or tandem office, the senders are not equipped to record the digits for the office code.

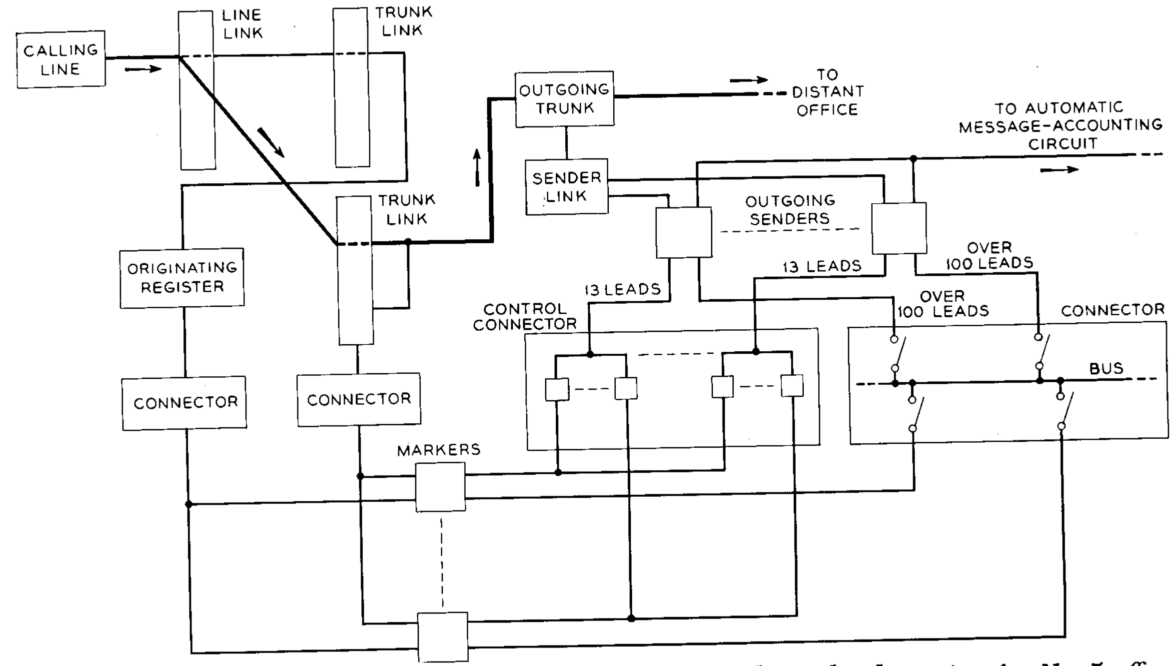

Fig. 1—A block diagram showing lines of association of the sender with other units of a No. 5 office.

sender only the digits it required, or to shift the order in which it transferred them so that in the above example the called station-number digits would have come first, it was found simpler to allow the marker to transfer the complete set of digits it received and in the same order, and then to indicate to the sender the point in the recorded chain of digits at which it should begin sending. This is accomplished by delete relays, of which there may be as many as six in the sender. If the marker operates the No. 1 delete relay, the sender

The first three delete relays are commonly used, but the higher numbered ones are employed chiefly to take care of situations that may occasionally arise with nation-wide or extended-area dialing. The marker can also order the sender to add one arbitrary digit or to prefix "one-one" as special codes under certain conditions.

The lines of association of the sender with other units of the system are indicated in Figure 1. When a subscriber lifts his handset, a marker is seized and connects the calling line through the line-link and trunk-link frames to an idle originating register, which returns dial tone and then records the number dialed. The register then seizes a marker, transfers the digits to it, together with certain other information, such as the equipment location of the calling line. The path through the link frames, over which the register was connected to the calling line, is broken down after the trunk has been selected. The marker, knowing from the office code digits the type of sender that will be needed, seizes an idle sender of this type, and transfers the digits to it. Communication between the marker and sender is established over two sets of channels, a connector, and a control circuit. The connector, when fully equipped, includes more than 100 leads and is common to all senders and to all markers. Over these leads all the digits and certain other information, such as the class and automatic message accounting information, are transferred simultaneously. Only a fraction of a second is required for the transference of this information and for checking the recording, and then the channel is released for use by other markers and senders.

The control channel between the marker and the sender, when fully equipped, includes thirteen leads. It is individual to each sender and each marker and is held until the marker is satisfied that the proper connections have been made to the sender. This channel is also used for passing certain class information pertaining to the trunk which the marker obtains from the trunk-link frame on which the trunk appears and which may not be obtained in time for passage through the common channel.

The marker, at the same time it records the number in the sender, selects an idle outgoing trunk to the called office and causes the trunk to be connected to the selected sender through the outgoing sender link. This connection places the sender under control of supervision in the outgoing trunk, and when the marker has connected the calling line to the outgoing trunk over the line-link and trunk-link frames, it gives

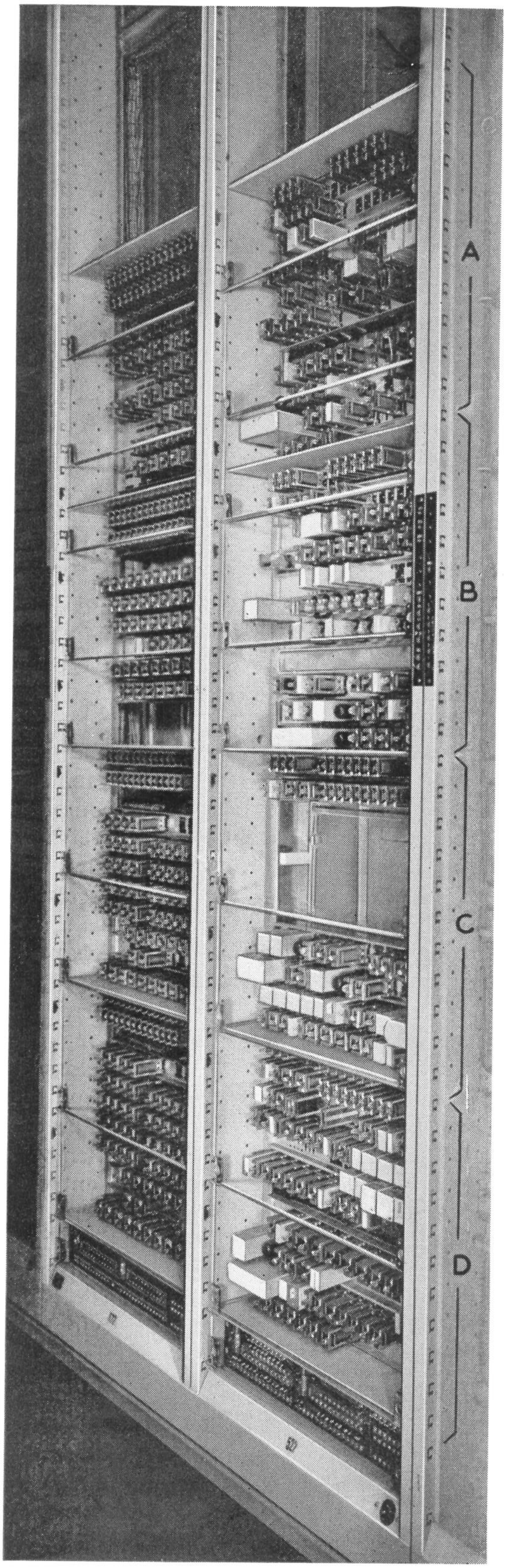

Fig. 2—A sender frame of the Laboratories' installation of No. 5 crossbar: A—call-indicator sender; B—revertive sender; C—multi-frequency sender; and D—dial-pulse sender.

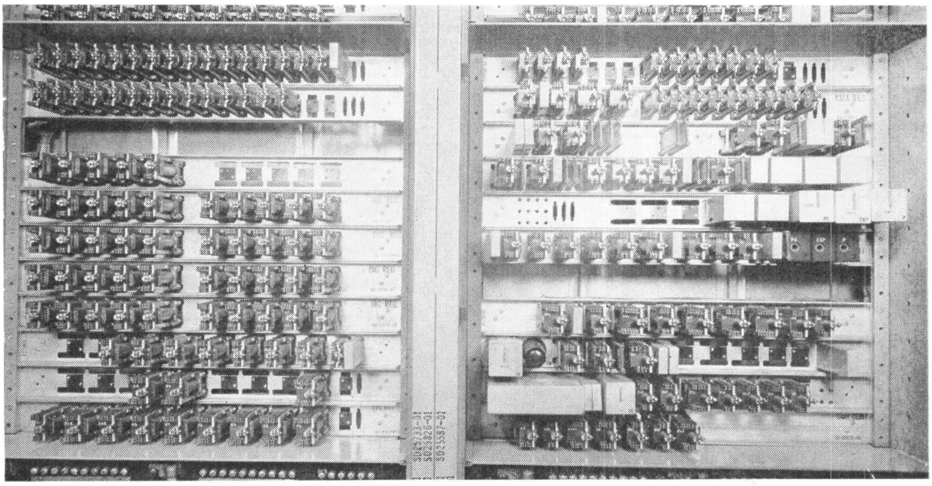

Fig. 3—*A dial-pulse sender with the front covers of transparent plastic removed.*

the sender a "go ahead" signal, and releases. At this time, the sender starts an AMA initial entry, if one is required, and starts timing an interval for allowing the distant end of the trunk to become normal. This is necessary since the trunk may have been seized immediately on appearing idle. The time between selection of a trunk by the marker after being released from one call, and the connection to a sender for another call, is insufficient to allow the complete release of the trunk supervisory relays at the called office, and the sender allows approximately one-half second before closing the trunk tip and ring conductors as a seizure signal. When this interval has elapsed, the sender connects the tip and ring leads to its supervisory circuit, and when this circuit detects the proper polarity, the number is transmitted and the sender released.

Outgoing senders are arranged so that when an AMA record is required for the call, the transmission of the number will not be completed until the initial entry is completed. This is done on all except the call-indicator sender by delaying the transmission of the last digit, but on call-indicator senders by delaying the transmission of entire number. Usually, except for the call-indicator sender, the initial entry is completed in sufficient time so that it causes no delay in the call's completion.

The multi-frequency sender offers the fastest means for transmission of the number and, consequently, this sender is used whenever the called office is provided with means of receiving the multi-frequency pulses. At present, such services are available for crossbar No. 1 and No. 5, crossbar toll, and crossbar tandem offices. Transmission of multi-frequency pulses is at the rate of approximately seven digits per second.

Dial-pulse senders are used for completing calls to step-by-step offices, and can be used for completion to No. 5 crossbar and to crossbar toll and crossbar tandem offices. Transmission of dialed digits is at an average of either one or two per second, depending on the capability of the terminating office to receive them.

Revertive-pulse senders are used for completing calls to panel offices and to No. 1 crossbar offices that are not equipped to receive multi-frequency pulses. The revertive-pulse sender is arranged to transmit only the four numerical digits of the number, but this is transmitted in five selections of the type required for guiding the panel selectors to the proper terminal. Revertive-pulse senders are arranged for operation in areas having office codes of two digits, three digits, or combinations of two and three digits.

Call-indicator senders are used for completing calls to manual offices equipped with call-indicator equipment, and to panel-tandem offices, which are similarly equipped. These senders are arranged for operation in areas having office codes of two digits or three digits, and the marker informs the sender whether to delete or to transmit the office-code digits.

A close-up view of the dial-pulse sender is shown in Figure 3, and of the multi-fre-

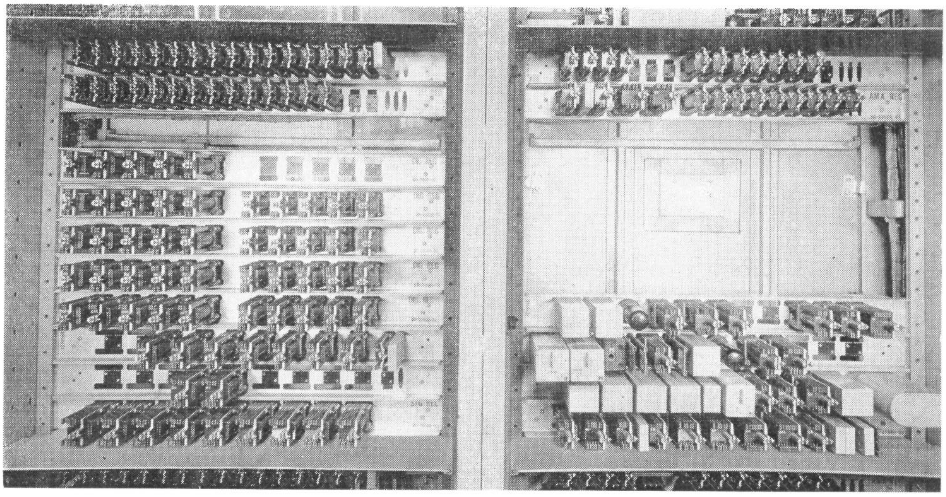

Fig. 4—A multi-frequency sender with the front covers of transparent plastic removed.

quency sender in Figure 4. The two rows of relays across the top of both bays of each sender are those used for the automatic message accounting system. In the left-hand bay section of each sender, the five rows of relays beneath the AMA are the digit register relays, while the delete relays are in the row next lower, and the steering relays that control the digit register are in the bottom two rows. In the right-hand bay section of the dial-pulse sender, the first row beneath the AMA relays includes the class relays; the next three rows include the dial-pulse generator, counting, and control relays; and beneath these are the general control relays. For the multi-frequency sender, the frequencies are generated in a separate circuit. Means for connecting these frequencies for each digit are included with the general control relays in the four lower rows.

The holding time of an outgoing sender on a normal call is only a few seconds, and as few as ten multi-frequency and ten dial-pulse senders are usually capable of handling the outgoing traffic for a 10,000-line office. To prevent a sender from being held for a long period, in case a trouble condition is encountered that prevents completion of the call, each sender has a timing circuit which allows each call sufficient time for normal completion. If the call is not completed within this interval, the timing circuit functions to give the calling party an overflow signal and then to release the sender. Under certain conditions, the sender can be held for maintenance attention after a timeout. All senders are equipped with make busy jacks and trouble lamps, and these are located at the maintenance center. All outgoing senders have provisions for connections to the automatic monitor, register, and sender-test circuit for automatic monitoring of service calls and for testing to insure that their respective functions are performed satisfactorily.

Sender link frames for No. 5 crossbar

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When a call from a No. 5 crossbar office requires pulsing to another office, a marker must connect a sender to the outgoing trunk to pulse out the digits for the called number. Depending on the type of office to which the trunk is connected, any of four types of pulsing may be required, and a different type of sender is used for each. After the marker has received the called number from a register, it selects both a trunk link frame that has an idle trunk circuit to the desired destination and an idle sender of the proper type. Since the trunks to any one destination will in general be distributed over a number, and perhaps all, of the trunk link frames, and since the senders of each type must be available to all trunks of that type, it is necessary to provide a flexible means of connecting any sender to any trunk that requires its type of pulsing. This is accomplished by having the trunks and the senders appear on crossbar switches of a sender link frame.

Such a frame carries a maximum of ten crossbar switches having trunks connected to their verticals and senders to their horizontals. All the trunks assigned to one switch are associated with the same trunk link frame, and there may be as many as four of these switches associated with trunks connected to one trunk link frame. Senders are arranged in groups depending on their type of pulsing, and all senders of a group are multipled to all switches of all sender link frames that have trunks requiring that type of sender. The only exception is where there are more than ten senders of one type. Under this condition, the senders are divided into two groups, and each group will be associated with a different set of trunks. Omitting this latter arrangement, the association of trunk link frames, senders, and sender links is indicated in Figure 1.

Since flexibility is desired in associating trunks and senders with sender link frames, there is no fixed pattern of connecting the trunks to the verticals of the sender link switches or of connecting senders to their horizontals except that, as already mentioned, any one sender link switch serves trunks of only one trunk link frame, and any one sender is always assigned to the same horizontal of all the sender link switches to

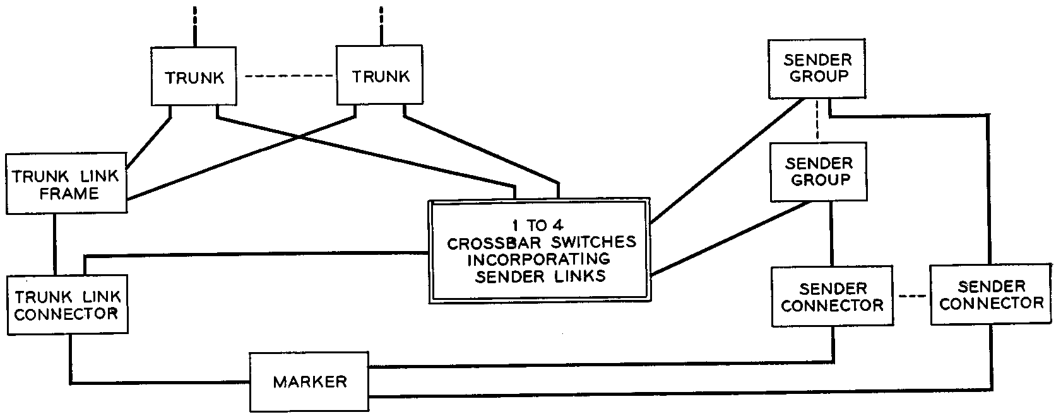


Fig. 1—Block diagram showing connecting paths to the sender link switches from the various trunks, sender groups, and trunk link connectors.

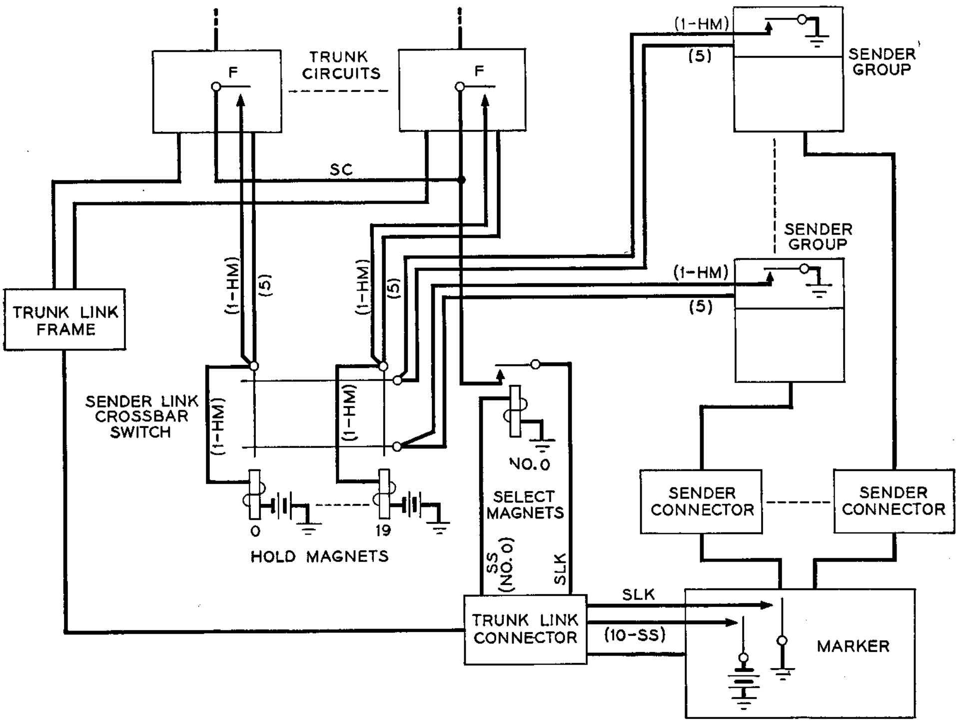


Fig. 2—Paths over which the select and hold magnets of the sender link switches are operated.

which it is connected. The marker has no direct access to the sender link switches but operates the proper select and hold magnets through the trunk link connector and sender it has selected for use. How this is accomplished is indicated in Figure 2, which shows one of the four possible crossbar switches comprising the sender link for one particular trunk link frame.

After the marker has seized a sender, it obtains from it the horizontal level to which that sender is connected on the sender link switches. The marker has ten SS leads running to the connectors for all the trunk link frames, and from the connector these leads run to the select magnets of the sender link switches associated with that trunk link frame. The No. 0 SS lead is connected to the No. 0 select magnet of all of the sender link switches associated with the trunk link frame selected; the No. 1 SS lead is connected to all the No. 1 select magnets, and so on. After the marker has received the proper level number from the sender, it connects battery to the corresponding SS lead, and as a result the corresponding select magnets of these sender link switches are operated.

The marker connects ground to an SLK lead, which is also extended to the sender link switches through the trunk link connector. Through contacts associated with the operated select magnets, this SLK lead is connected to an SC lead that is multipled to all the trunks appearing on the same switch.

The sender link switches are of the six-wire type—each crosspoint consisting of six contacts. Two of the contacts connect to the tip and ring conductors of the trunk and are used for pulsing; the other four are used as control leads between sender and trunk. Each hold magnet of the sender link switches is connected to an HM lead that forms one of the six leads connecting the trunk circuit to the vertical of a sender link switch. After the marker has seized the trunk, the SC and HM leads are connected together in the trunk circuit. As a result, the proper hold magnet is operated from the ground on the SLK lead in the marker, through the trunk link connector, the contacts associated with the

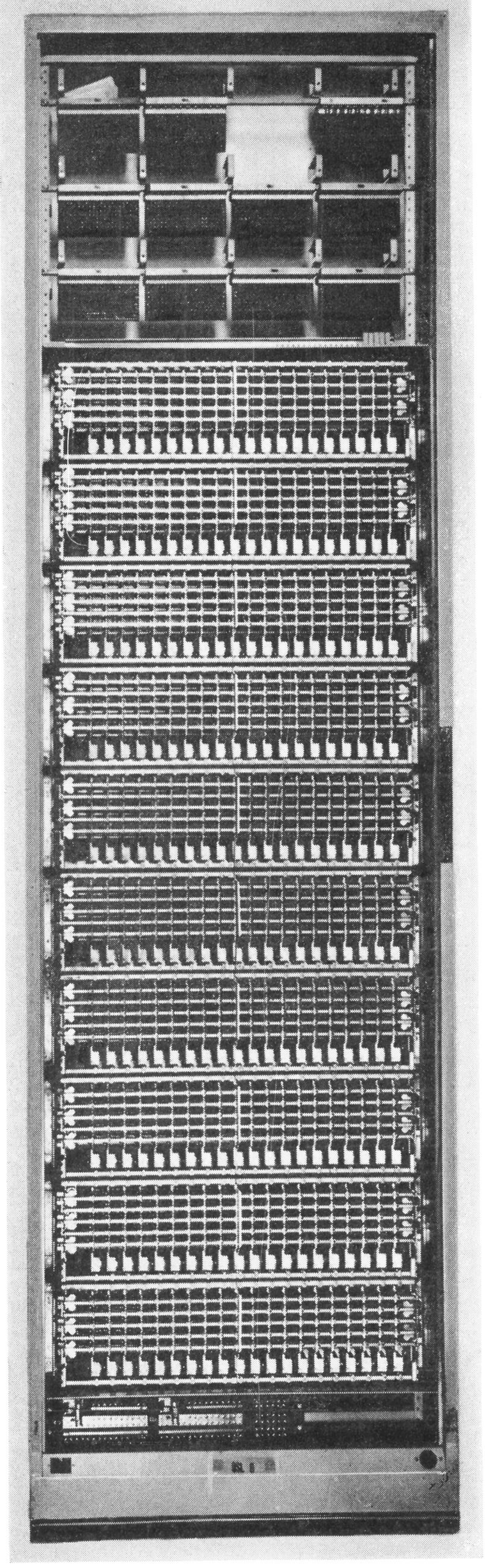
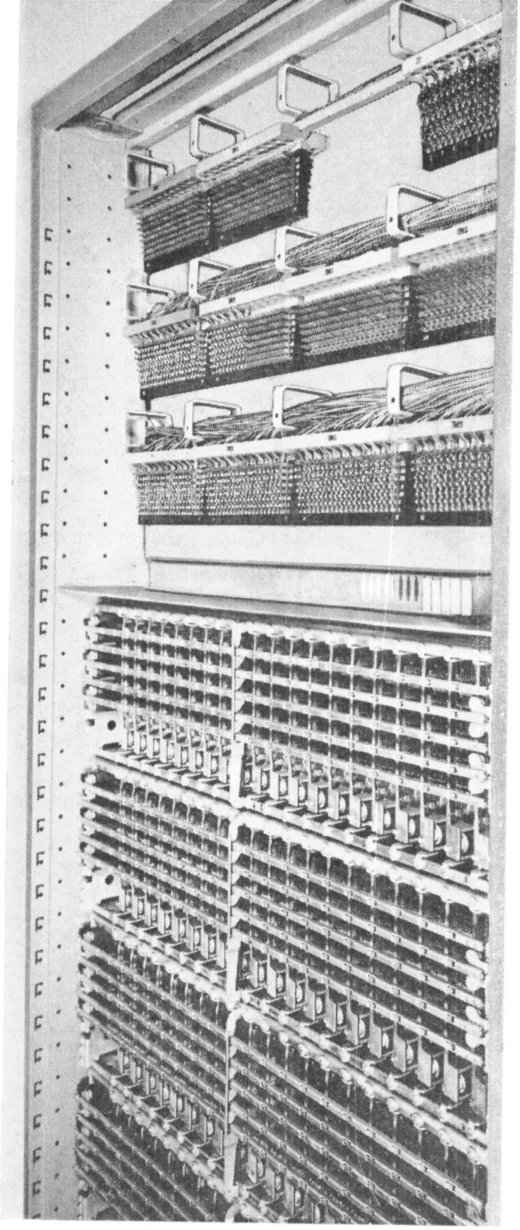


Fig. 3—Front view of an outgoing sender link frame for the No. 5 crossbar system.

select magnets that have been operated on the sender link frame, over the SC lead to the trunk, and thence over the HM lead to the hold magnet for that trunk. As a result of operating the hold magnet, the proper sender is connected to the selected trunk through the six crosspoint contacts. The sender then grounds its end of the HM lead to keep the hold magnet operated after the marker has released, and to notify the marker that the connection has been established.

The marker has already transmitted the pulsing information to the sender, and after it has ascertained that the connection between sender and trunk has been properly made, it disconnects itself from both the sender and trunk link frames. After the sender has transmitted its pulses, the connection between trunk and sender is released.

Sender link switches are mounted on standard frames that have fuse panels on the bottom and terminal strips at the top. The latter are used for connecting the trunks to the switch verticals, and the SLK lead and the ten SS leads to the trunk link connector. On one of the side uprights of the frame is a jack strip used for maintenance. Each such frame will mount ten switches, and as many frames are used as are needed to take care of all of the trunks. Since the only restriction on the assignment of the ten switches of a sender link frame to trunk link frames is that one switch cannot be associated with more than one trunk link frame, a single sender link frame may provide twenty trunks for each of ten trunk link frames, forty trunks for each of five trunk link frames, or any other division that does not assign the twenty trunks of one switch to more than one trunk link frame. Additions may be made at any time either by adding switches to existing frames or by adding new frames. A front view of one of the frames in the Western Electric shop is shown in Figure 3 and the upper part of the frame in the Media office is shown in Figure 4. The eight terminal strips in the two lower rows and the two at the left in the top row take care of the 200 trunks that may be served by a single sender link frame, while the terminal strip at the upper right is for the SLK lead and the ten SS leads. Jumpers from the rear of the trunk terminal strips run directly to the switch verticals and may be readily changed when



a trunk is moved from one sender group or one trunk link frame to another. Leads from the senders are cabled directly to the horizontals of the switches.

Because of the method of operating the select and hold magnets of the sender link switches, it is not necessary to restrict one switch to one type of trunk or one type of sender. The major limiting factor is the total number of trunks of one type and the number of senders required to serve them. If, for example, there were only five senders of each of two types, both groups of senders could be connected to the horizontals of the same sender link switch, and thus two types of trunks could be served by that switch. When a single switch must serve two types of trunks, each having access to ten senders, the horizontal multiple of the switch is cut. This permits one part of the switch to serve one group of trunks and the other part another group.

To make the senders more accessible to the markers, the ten possible senders on the levels of one sender link switch are divided into two subgroups, and each subgroup is served by a separate sender connector. This permits two markers to use senders of the same type and complete calls on two trunk link frames at the same time.

Fig. 4--Upper half of an outgoing sender link frame in the Media office.

Incoming register link for No. 5 crossbar

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Calls incoming to the No. 5 crossbar system* from other offices terminate on incoming trunk circuits, which have appearances both on a trunk link frame for completion of the talking path to the called subscriber, and on an incoming register link frame for connection to an incoming register. A separate group of register link frames is required for each of the various types of registers, such as dial, multifrequency, and revertive pulsing, and for each ten registers of the same type. Incoming register link frames mount five twenty-vertical crossbar switches together with their control relays as shown in Figure 1. One hundred incoming trunks, one per switch vertical, have direct access to a group of ten incoming registers, each register being multipled to one horizontal on each of the five switches. To this basic frame a supplementary frame of five additional twenty-vertical switches may be added to increase to two hundred the number of trunks connecting to the same ten registers. A further increase in trunk capacity may be obtained by associating a second basic frame and its supplementary frame with the same registers. The number of trunks and registers varies with traffic, but the combination of capacities of one hundred or two hundred trunks and ten registers satisfies the average office.

Reduced to its simplest form, such a frame could be represented as shown in Figure 2. It differs from the sender link frame in the No. 1 crossbar system and from most crossbar frames in consisting of only a single switching stage instead of using a primary and secondary switch for the completion of a connection.

* See page 5.

A single-stage link frame seemed essential because of the rapidity with which a register must be connected to trunks carrying subscriber-dialed traffic from a step-by-step office. On calls from panel or crossbar offices, the pulses indicating the number wanted are transmitted by a sender, and they are

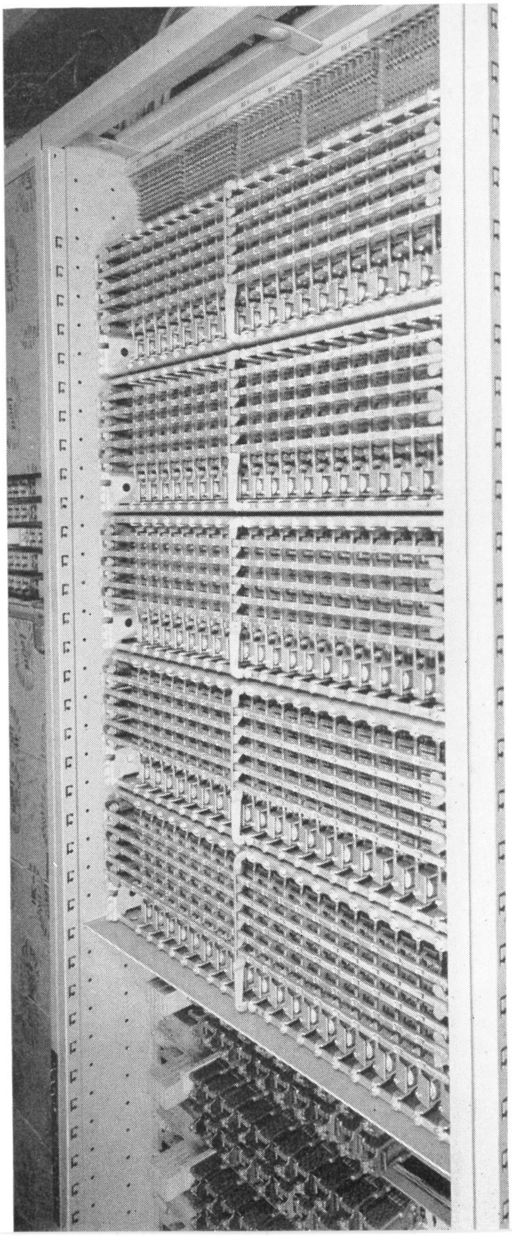


Fig. 1—Incoming register link frame for No. 5 crossbar system.

not transmitted until the sender gets a signal indicating that a register is ready to receive them. With subscribed-dialed step-by-step traffic, however, the pulses are sent directly from the subscriber's dial, and those for the first digit of the called number follow immediately after those for the last digit of the office code. The only time available for connecting an incoming register to the circuit, therefore, is part of the interdigital time between the last digit of the office code and the first digit of the subscriber's number.

The twenty trunk circuits connecting to one switch on the basic register link frame, or the forty trunk circuits connecting to one switch on the basic frame and the switch on the same level of the supplemental frame,

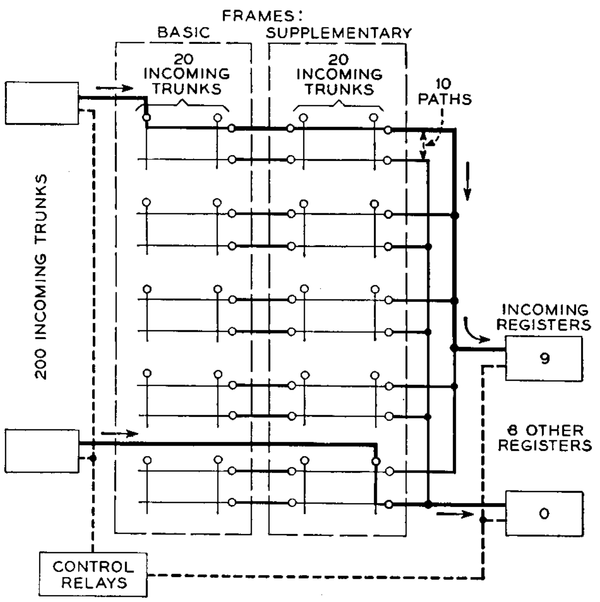


Fig. 2—Block schematic indicating the arrangement of trunks and registers on an incoming register link frame.

are called a horizontal group. The complete link frame is thus divided into five horizontal groups. Although all trunks of all the horizontal groups have access to all of the ten registers associated with the frame, each horizontal group of trunks is given a different order of register preference. The control circuit that connects the trunks to the registers consists in effect of five separate control circuits—one for each horizontal group. Simultaneous calls appearing in different groups may therefore be connected to registers simultaneously, but simultaneous calls in the same group cannot be. One or the other of them is given preference, and the other must wait the fraction of a second required to connect the first to a register.

In the control circuit for each horizontal group there is a trunk preference, TP, relay for each trunk of that group, a register busy, RB, relay and a register preference, RP, relay for each of the ten registers, and the twenty hold and the ten select magnets for the crossbar switches of that group. There is also a TF, a CL, and sometimes a TN relay through which the register receives additional information. These various relays are interconnected as indicated in Figure 3. For the sake of simplicity it is assumed here that a supplementary frame is not employed, and thus there are only twenty trunks to be considered in a horizontal group, and relays are shown for only the fourth horizontal group and only for the fourth register, which is the first preference for that group. Since there are ten registers and five horizontal groups, there are in all fifty RP relays—one for each horizontal group for each register. In Figure 3, only the five RP relays for register No. 4 are shown; each of the other registers has a similar group of five RP relays. Register busy relays in horizontal group 4 are indicated for all ten registers. A lead from a back contact of each of these relays runs to the No. 4 RP relay for each register, but only the RP relay for the No. 4 register is shown in the diagram.

To illustrate the action of the circuit, assume a call comes in on trunk No. 10, and that register No. 4—the preferred register for horizontal group 4—is not busy. The No. 10 TP relay will operate, and through its No. 2 spring will connect ground—through a back contact of the No. 4 RB relay—to the winding of the No. 4 RP relay of register No. 4, and this RP relay will operate. Through a front contact on the No. 2 spring of the No. 4 RP relay, battery applied in the register will operate the No. 4 select magnet on the crossbar switch of horizontal group No. 4. When the magnet operates, a connection will be established from ground in the register to operate the hold magnet for No. 10 trunk. In the meantime, relays TF and CL, and TN if one is required—for trunk frame, class, and trunk number identification—have been operated through the No. 4 spring on the RP relay. These relays each close twelve sets of springs to make the necessary identifications, and through a set of cross-connecting terminals they are associated with leads from front contacts on springs 5 and 6 of the TP relays. From front contacts of the TF and CL relays leads run to the register to convey the required information.

It will be noticed that when the RP relay operated, it opened the operating path to the windings of all the other RP relays for that register. Should a call in one of the other horizontal groups attempt to seize that register, it will thus be unable to do so. Immediately upon selection, the register operates its RB relays associated with the other four horizontal groups so that calls coming in by way of these other groups will not attempt to seize the No. 4 register. After the hold magnet has been operated, the register—through circuits not shown—releases its RP relay that had been operated and operates its RB relay in the horizontal group from which it was selected. After this time, all calls from

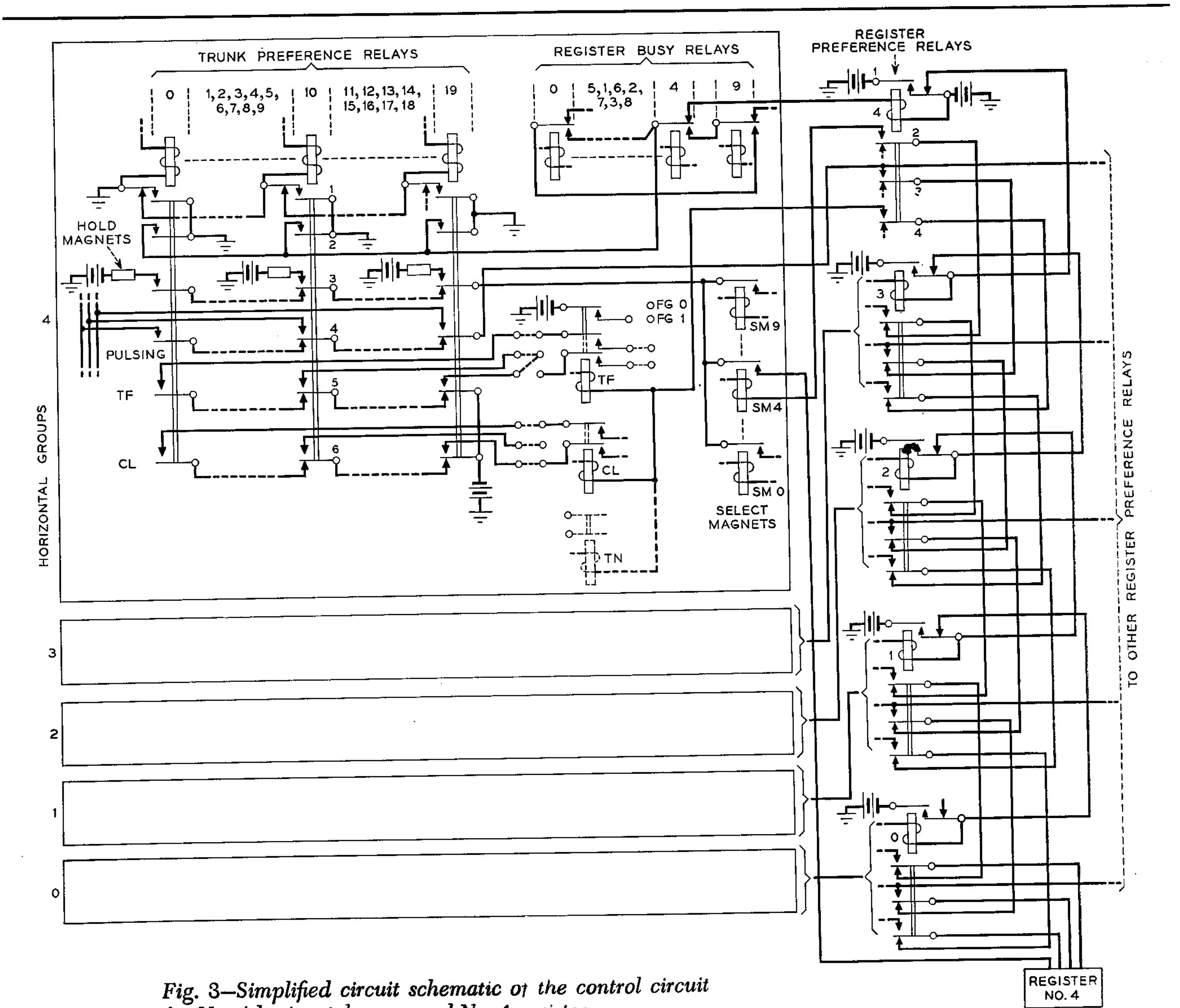


Fig. 3—Simplified circuit schematic of the control circuit for No. 4 horizontal group and No. 4 register.

that horizontal group will be passed to one of the other registers because of the operated RB relay.

In the fraction of a second between the operation of the No. 10 TP relay and the operation of the No. 4 RB relay, a call coming in on a higher numbered trunk of the same group—11 to 19, inclusive—could not operate its TP relay because the circuit to its winding would be open at the No. 1 spring of the No. 10 TP relay. A call on any of the lower numbered trunks—0 to 9, inclusive—could operate its TP relay, but the hold magnet for that trunk could not be operated since its circuit is opened by the No. 3 contact of the No. 10 TP relay. By these means complete lockout is secured.

When the hold magnet is operated, six leads are connected to the register from the trunk circuit. One of these is used to keep the hold magnet operated. Two are used for pulsing, two for passing information between trunk and register, and one over which the marker will operate a relay in the trunk circuit to identify the trunk when it completes the talking path through the trunk link frame. The select magnet and relays TP and RP are released after the crosspoints are closed so that other calls in the same horizontal group may be handled.

Reference was made earlier to the need for a quick connection when subscriber-dialled calls originate in step-by-step offices. Although with the frame idle, the connecting time of this link involves only the operating time of the control relays and one crossbar switch, even this interval of about 0.1 second may be too long on some connections. Because of this, a by-link circuit has been incorporated that permits dialing to proceed before the switch crosspoints are closed, thus reducing the time to about 0.04 second. The by-link path is closed through the No. 4 springs on the TP and the No. 3 springs on the RP relays as soon as the trunk preference and the register preference relays operate. The by-link path and the regular pulsing path through the crosspoints are in multiple so that there is no discontinuity in the reception of pulses when the crosspoints close. This by-link path, being part of the control circuit, is released as soon as the switch path is established, and is thereby made immediately available for use with the next call.

Some calls may arrive while the link is being used to set up one or more calls which have preference in the chain. When this occurs or when the dial pulses are received too soon for the register to have been attached, the trunk circuit will send back an overflow or paths-busy signal to the subscriber.

As mentioned in the article already referred to, the No. 5 crossbar system is arranged to serve as a tandem office or a toll center to switch calls through it to other distant offices. In such cases the incoming trunks have connections to both line link and trunk link frames, the former for calls passing through the office. The register link then has the additional function of indicating to the register, for use by the marker, the line link location in the form of a trunk number. The circuit for passing this information is not shown, but is similar to that for trunk frame and class, that is, by cross-connection from the trunk preference relay through another connector relay TN shown dotted in Figure 3. The equivalent of the three digit number, which is required to identify any one of the two hundred trunks, is derived on a link location basis. Because of the additional contacts needed for this purpose on the trunk preference relays, auxiliary relays are provided, one for each tandem trunk, and the contacts on these relays are cross-connected to a tandem connector relay. One set of contacts is connected to indicate whether the trunk is on the basic frame or the supplementary frame, thus indicating in which hundred the trunk is located. The frames are further subdivided into even and odd tens in each horizontal group. One of two leads from each horizontal group, therefore, identifies the second digit, and one out of ten leads identifies the unit or third digit.

The five horizontal groups of crossbar switches can be seen in Figure 1 at the top of the frames and below them some of the trunk preference relays in the control circuit.

Incoming register circuits for No. 5 crossbar

R. K. McALPINE
Switching Development

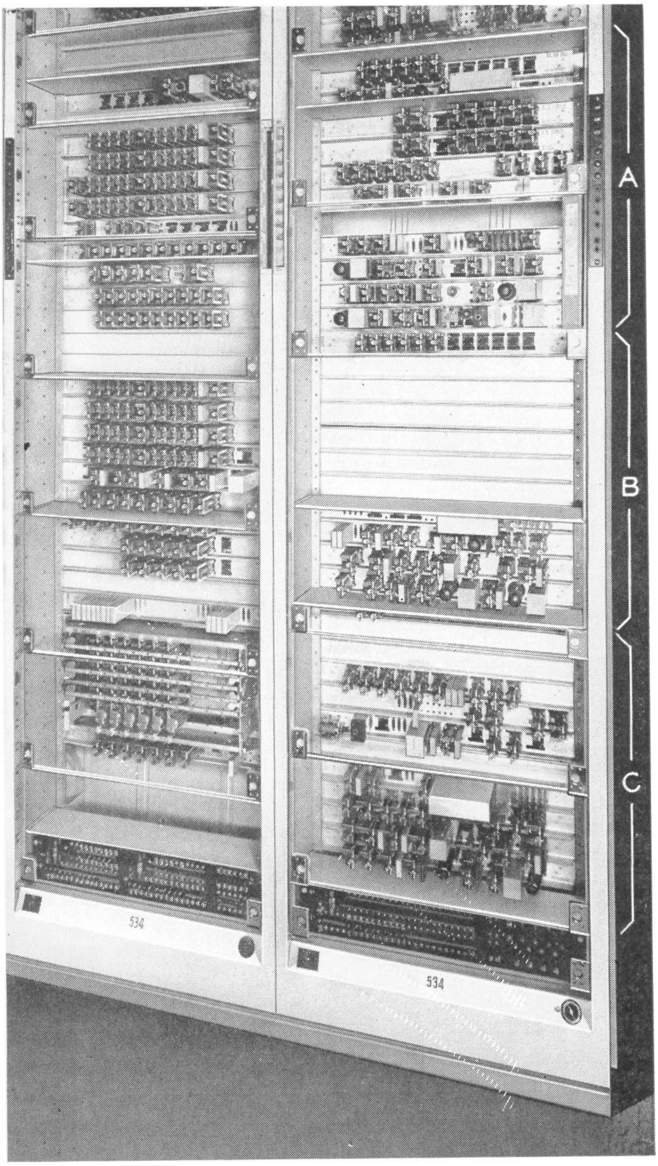


Fig. 1—A frame of incoming registers installed in the Laboratories for test: a dial-pulse register at A; a multi-frequency register at B; and a revertive-pulse register at C.

In a No. 5 crossbar office, a call coming in from another office can be completed to the called line by a marker in a fraction of a second. A much longer time is usually required, however, to receive from the incoming trunk the number of the called line, since the several digits of the number are pulsed one at a time over the two wires of the trunk. To avoid holding the marker during the pulsing time, a circuit is required to receive and remember the various digits, and then to transmit all of them to the marker at once, using as many paths as needed. Such circuits are called incoming registers. In general function and purpose, they are thus like the originating registers.*

When an incoming trunk receives a call from its distant end, it signals a link circuit†, which connects it to an idle incoming register. The link transmits to the register a trunk class signal, a frame number, and, for tandem trunks, a number-group location. Class indications give such information as whether the register should send dial tone over the trunk; the number of digits to be received; whether the trunk is arranged for local, tandem, or toll service; any restrictions which may apply to the trunk in completing to various groups of lines; and whether the trunk is of a special purpose type used by certain operators or test men. Some of these items will affect register functions, but most of them are merely recorded to be passed on to the marker after the line number has been received. The frame number is the number of the trunk-link frame where the trunk appears. It is required by the marker in connecting the trunk to a local subscriber. The number group location is used by the marker to obtain the line-link frame location of a

* See page 39. † See page 72.

tandem or toll trunk. Such trunks appear on both the trunk-link and line-link frames. The latter connection is used when the call is to pass through the office, and the former when it is to be completed to a local subscriber. The register records this information, checks for any possible double connection in the link, and then signals the trunk that pulsing may commence.

Incoming registers may receive pulses from a step-by-step subscriber's dial, from a sender, or from an operator's dial or keyset. Three types of pulsing are encountered: dial pulse, from a dial or sender; revertive, from a panel or crossbar sender; and multi-frequency, from a keyset or sender. Other types may be added as required without affecting the marker. A separate type of register is used for each type of pulsing. A frame with the three types of registers is shown in Figure 1 as installed in the Laboratories for test purposes.

Each dial-pulse digit is a train of from one to ten open-circuit pulses sent from the calling office; each revertive digit is a train of shunting pulses sent from the called office and stopped by a signal from the point of origin when the correct number has been sent; each multi-frequency digit is a single pulse containing two out of five frequencies in the audible range. A dial-pulse register need merely count pulses and recognize the end of each digit, while a revertive register must generate pulses, count them, and recognize an open circuit signal which marks the end of a digit. These functions are performed by relays within the registers; pulse generation as described in connection with revertive pulsing,* and counting as described for the originating registers.† Multi-frequency registers are not at present equipped with relays to sort out the a-c frequencies contained in their pulses, but instead employ an electronic multi-frequency receiver, shown in Figure 2, which amplifies the pulses, limits their amplitude, checks for spurious and missing frequencies, separates and detects the frequencies, and furnishes the register with d-c pulses on two at a time out of five leads. A sixth frequency and its associated lead are used only for start and stop signals and not for numerical digits.

As each successive digit is received, the register records it for future reference. Dial-pulse and multi-frequency registers use five relays to record each digit, two relays operating for each numeral from 0 to 9. This scheme matches both the two-out-of-five arrangement of frequencies in multi-frequency pulses and the pattern of grounded leads by which the digits will be transferred to the marker. Its main advantage is that it is self-checking, since ordinary trouble conditions would result in one or three out of five instead of two—a difference easily recognizable. These registers may be equipped for from four to eleven digits, depending on traffic requirements. In a single-office unit with only local incoming traffic, four digits are sufficient, while a No. 5 unit used as a combined local office and toll center may require eleven digits to accommodate a three-digit national dialing code, a three-digit local area code, four numerical digits and a party letter. Revertive pulse registers at present re-

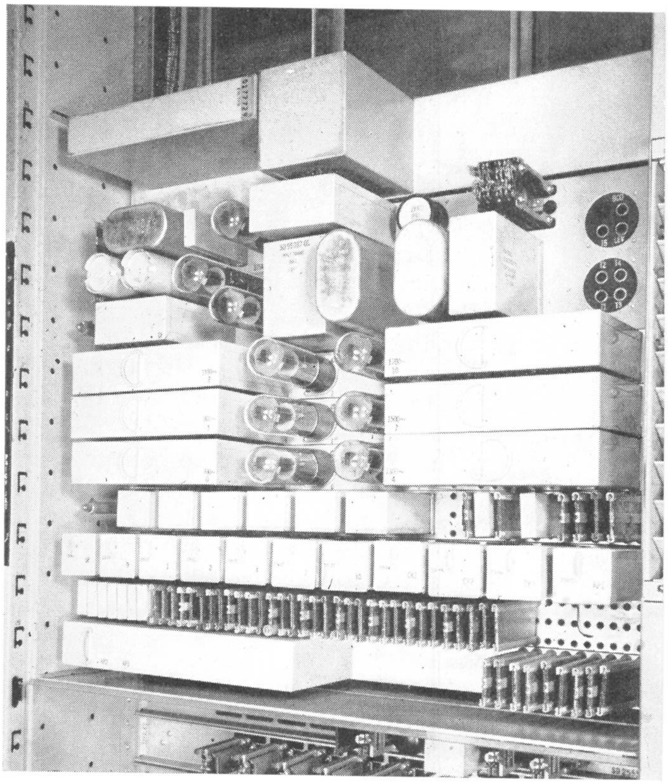


Fig. 2—A receiver for the multi-frequency register.

* Record, *August*, 1943, *page* 448.
† See page 39.

cord only the pulses designating the four digits of a line number, although plans envisage additional digits for tandem operation in the future. Instead of recording the digits on sets of two-out-of-five relays as in the other types of registers, however, the revertive-pulse registers record them on a crossbar switch, using apparatus and circuits essentially the same as those used in terminating senders of the No. 1 crossbar system.

To determine when the last digit has been received is no problem for revertive and multi-frequency registers, since the former are arranged for a fixed number of digits, and the latter always receive an end-of-pulsing signal after the last digit. Dial-pulse registers, however, may receive any number of digits from three to eleven and do not receive any end-of-dialing signal from the trunk. Dial-pulse registers, therefore, must look for every possible clue as to the number of digits to be received. On calls from local trunks, the trunk class indicates the expected number of digits—either four or five depending on the class. On tandem and toll trunks, an office code always precedes the line number. However, there may be both two and three-digit codes within the numbering area, and some offices reached by tandem may have some lines with party letters. Still more variation occurs on toll calls, since they may be directed to either subscribers or toll operators in either the local area or some distant area.

To take care of these variations, the dial-pulse register has facilities for looking at the first one or two digits of the office code, which may indicate the number of digits in the code and also identify the code sufficiently to tell whether the called office has party letters. If it has or may have, there is still no assurance that a letter will be dialed on this particular call, but the register will allow time for a possible additional digit. On toll trunks, the code may be either a local area code or a toll code. The register can recognize the difference by looking for a toll-indicating zero or 1 in the first or second position. Local-area codes are treated as are those received on tandem trunks, but most toll codes may be followed by an indefinite number of digits. When such a toll code is recognized, therefore, the register times after every digit received, and recognizes the last digit by the lack of dialing within the succeeding few seconds. An exception is made for certain toll service codes that are never followed by any digits. Such codes, recognized by 1's in certain positions, indicate the end of pulsing without timing after the third digit.

When the register is satisfied that all digits have been received, it must pass them to a marker. The register signals a marker connector circuit, which seizes an idle marker and connects it to the register by a large number of wires. Using these many paths simultaneously, the register is able to tell the marker in a few milliseconds all the information which it has accumulated in perhaps as many seconds. Trunk class, frame location, number-group location, and the several digits go into the marker all at once, enabling it to complete the call immediately and to free itself so quickly that it can handle thousands of calls per hour.

Register and sender frames in No. 5 crossbar

O. J. MORZENTI
Switching Equipment

Registers and senders* in the No. 5 crossbar system,† although performing the opposite functions of receiving and transmitting switching information, respectively, have many points of similarity. The time of action for each of them, unlike the marker, is largely controlled by apparatus outside the central office. With an originating register, for example, the time required is at least that necessary for a subscriber to complete dialing the desired number; with an outgoing sender, the governing factor is the speed at which the equipment in the distant office may be actuated. They both must "register" or store the dialed number. They both must count pulses, and "steer" them into the proper digital sequence. They are both required to time their various operations to assure proper functioning. They are alike also in both requiring access to markers for exchange of information for brief periods. This access is provided through connectors consisting of multicontact relays. All of these similarities have permitted the design of registers and senders to follow a uniform pattern.

* See page 63.
† See page 5.

Despite their common features, senders and registers of the No. 5 crossbar system are called upon to serve under such widely varying conditions that there are many points of dissimilarity also. Thus to meet immediate Bell System needs, there are five types of registers—one originating and four incoming—and four types of senders. Each

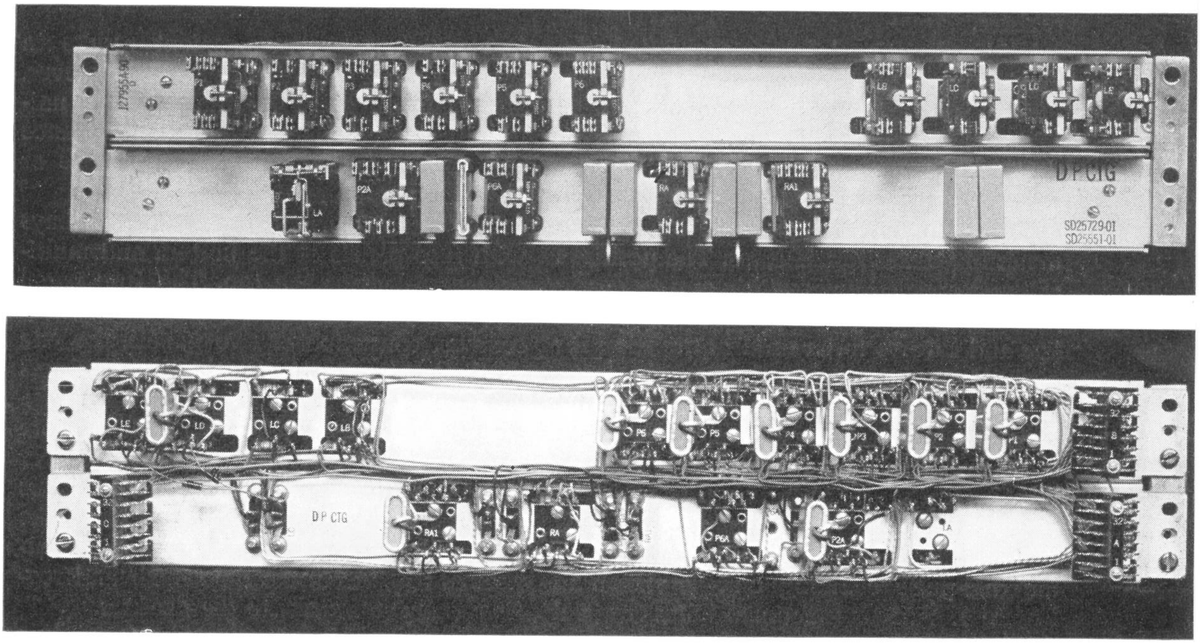


Fig. 1—A dial-pulse counting unit for the No. 5 crossbar system. Front view above and rear view below.

of these has a variety of optional features which are required in different combinations for different offices, depending upon the numbers of digits, lines, frames, classes of service, types of pulsing, the need for automatic message accounting, etc. An idea of the degree to which this differentiation is carried is shown in Table I, wherein the three categories, originating registers, incoming registers and outgoing senders, branch out into the nine types of registers and senders. These in turn are comprised of sixty-eight major features represented by functional units, of which thirty-four are always required in the system and thirty-four are optional.

In keeping with the standardization and simplification of manufacture that has been stressed in the design of the No. 5 system, it was desirable to reduce the wide variety of functional units and to arrange for their combinations in the fewest and simplest standardized patterns. The numbers of functional units have been reduced wherever practicable by making one unit serve in two or more places. Fourteen of the units are common to several types of registers or senders. For example, of the twelve possible types of units entering into the make-up of an originating dial-pulse register, six are also used in the incoming dial-pulse register.

With all optional features included, the maximum number of mounting plates required is twenty-two (for the originating register) and the minimum is fifteen (for the incoming revertive-pulse register). To secure greater standardization, it was felt desirable to fix on a space of twenty-two mounting plates for all cases. The positions of the functional units within any sender or register are also fixed to permit standard jigs and fixtures to be used in the shop for over-all operating tests. Each of the functional units has terminal strips at one end for loose-wired cross-connections between functional units. This loose wiring is readily run from standard drawings to interconnect whatever assembly of units is required for each office. A typical functional unit—the dial-pulse counting unit—is shown in Figure 1. Various functional units grouped to form a complete register for a particular office are shown in Figure 2. Figure 3 shows the register arrangement for a hypothetical central office requiring all of the functional units.

Since no register or sender requires more than twenty-two mounting plates, five of them may be arranged on a two-bay frame, with eleven mounting plate spaces in each of the bays. For the smaller registers or senders, or those equipped with only a few options, this arrangement results in vacant spaces. This loss of space, however, is more than offset by the resulting uniformity in manufacture and maintenance and in the ease with which additions or changes may be made.

The frame consists of two 23-inch bays with fuse panels at the bottom and multicontact relays at the top. The fuse panel arrangement is universal for all registers or senders, consisting of two panels, the one on the left bay caring for the even registers or senders and the one on the right bay, for the odd ones. Each panel is fused from a different frame feeder, so that if power should fail on one, only half the registers or senders will be put out of service. The multicontact relays at the top serve as connectors to concentrate the sender and register connector paths to the markers.

Cable forms are run up the outer edges of each frame at the rear to interconnect

TABLE I—NUMBERS OF FUNCTIONAL UNITS AND OPTIONS FOR REGISTERS AND SENDERS

	Total Number of Functional Units	*Basic Units (Always Required)*	*Optional Functional Units*
Originating Register			
Dial Pulse	12	4	8
Incoming Registers			
Dial Pulse	13	6	7
Multi-Frequency .	8	4	4
Revertive Pulse...	5	4	1
Central "B"......	5	4	1
Outgoing Senders			
Dial Pulse.......	6	4	2
Multi-Frequency .	5	3	2
Revertive Pulse...	7	3	4
Panel Call Indicator	7	2	5
Total	68*	34	34

*Of these 68, there are fourteen functional units used in several applications; thus there are only 54 discrete and different units.

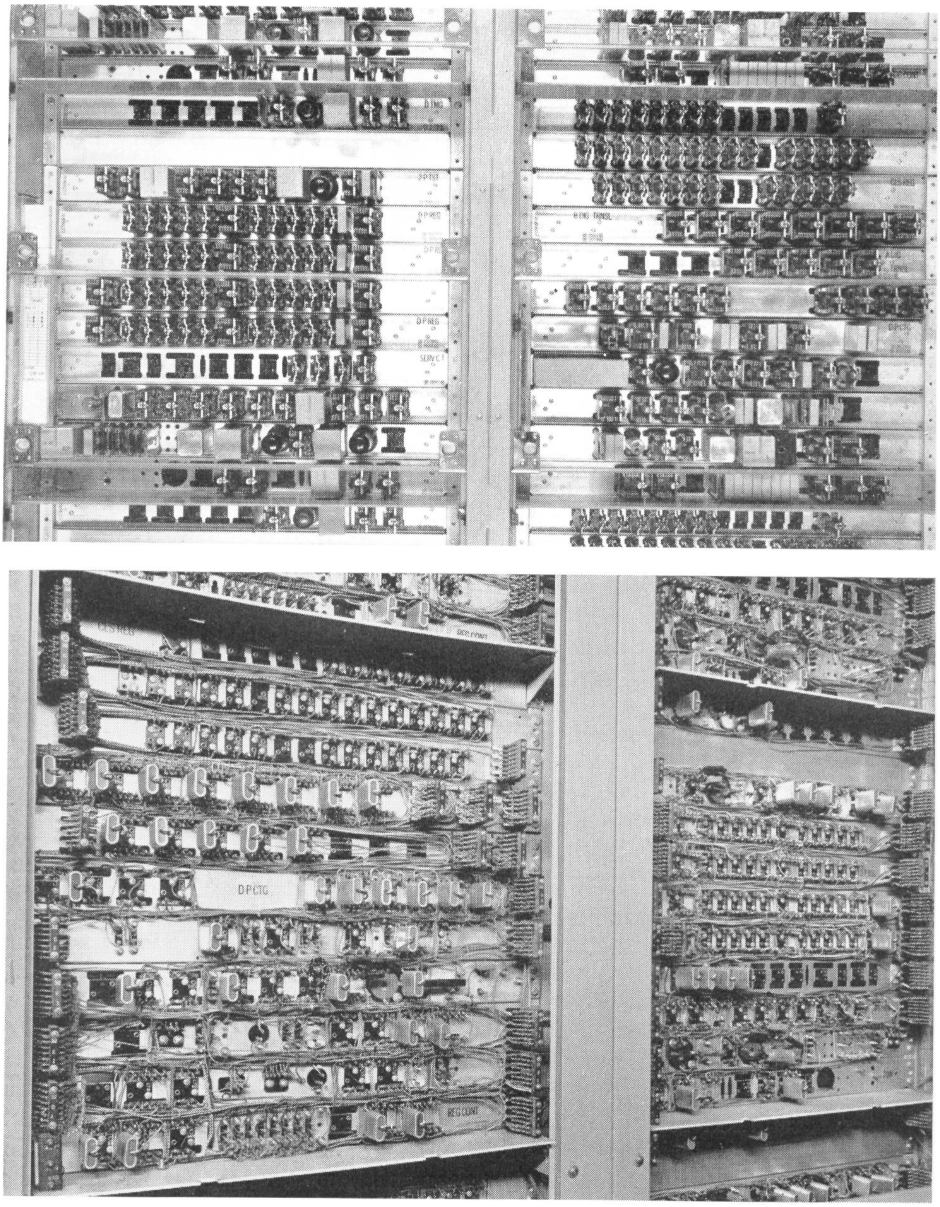


*Fig. 2—An **originating** register for the No. 5 crossbar system. Front view above and rear view below. The counting unit of Fig. 2 occupies the fifth and sixth mounting plates from the bottom on the bay at the right.*

the fuses at the bottom, the connectors at the top, the testing facilities in the frame upright, and the frame terminal strips to the sender or register equipments. They have leads brought out at the various mounting plate levels to connect to any combination of functional units which might be furnished. If one cable form included all the wiring needed for all types of registers and senders, it would, in any specific case, provide many leads not required, and add unjustifiable cost. After considerable study, ways were found, however, to standardize three frame cables to care for all conditions. One accommodates five originating registers; one accommodates any of the four types of incoming registers in any combination; and one accommodates any of the four types of senders in any combination. The single type of frame structure with standardized fuse panels, connectors, and other equipment common to a frame, thus becomes one of three possible types when the local cable is installed: an originating register frame, an incoming register frame, or a sender frame.

Front and rear views of a typical register frame are shown in Figure 4. The permanent cable may be seen at each side in the rear view. The flexible wiring between the two bays is that connecting the various functional units, previously discussed, that comprise a complete register.

Besides securing a flexible frame arrangement that requires only three types of frames for mounting any type of sender or register, on the other hand, receives its digits very quickly, and thus will be ready for connection to a marker much oftener. Therefore, a single connector cannot serve as many multi-frequency registers as it can dial-pulse registers.

At the top of each frame are five groups of sometimes two and sometimes three multicontact relays, one group for each possible register or sender on the frame. The arma-

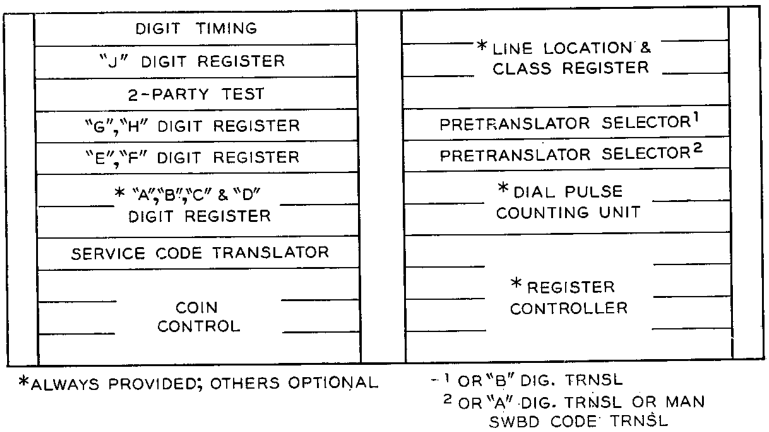


Fig. 3—A chart showing a fully equipped originating register (all units named and optional units and apparatus so indicated).

register, it has been necessary also to provide flexibility in grouping the registers and the senders for connection to the markers. Senders and registers are connected to markers to transfer information to them or to receive it from them. As stated previously, only a very short time interval is required for each transfer of information. The sender or register may be busy with a call for a much longer time than this, however, and thus a single connector can serve a number of registers or senders. Just how many will depend to a large extent on the type of register or sender. A dial-pulse register, for example, requires considerable time to receive a long train of digits from an outlying office in comparison with the time it requires to pass this information on to the marker through the connector. Thus, while the register is occupied in receiving the digits, other registers could be using the connector, and in the example chosen, this connector might serve as many as a dozen such registers. A multi-frequency ture contacts of all five groups are multipled together for connection to the marker. If used in this manner, all five groups of multicontact relays would be part of a single connector. By mounting terminal strips at each end of the row and at two or three points within the row, however, it is possible to cut the multiple of the armature contacts at some point and thus split the connector. The terminal strips are so placed that the multiple may be cut to assign one register to one connector and four to the other, or two to one and three to the other. Of the registers or senders on a single frame, therefore, all five may be on one connector, one may be on one and four on the other, or two may be on one and three on the other, and thus essentially complete flexibility is secured. Further flexibility is obtained by multipling connectors on different frames. Thus a single connector is able to take care of registers or senders on several frames. The same connector, however, cannot serve both registers and senders.

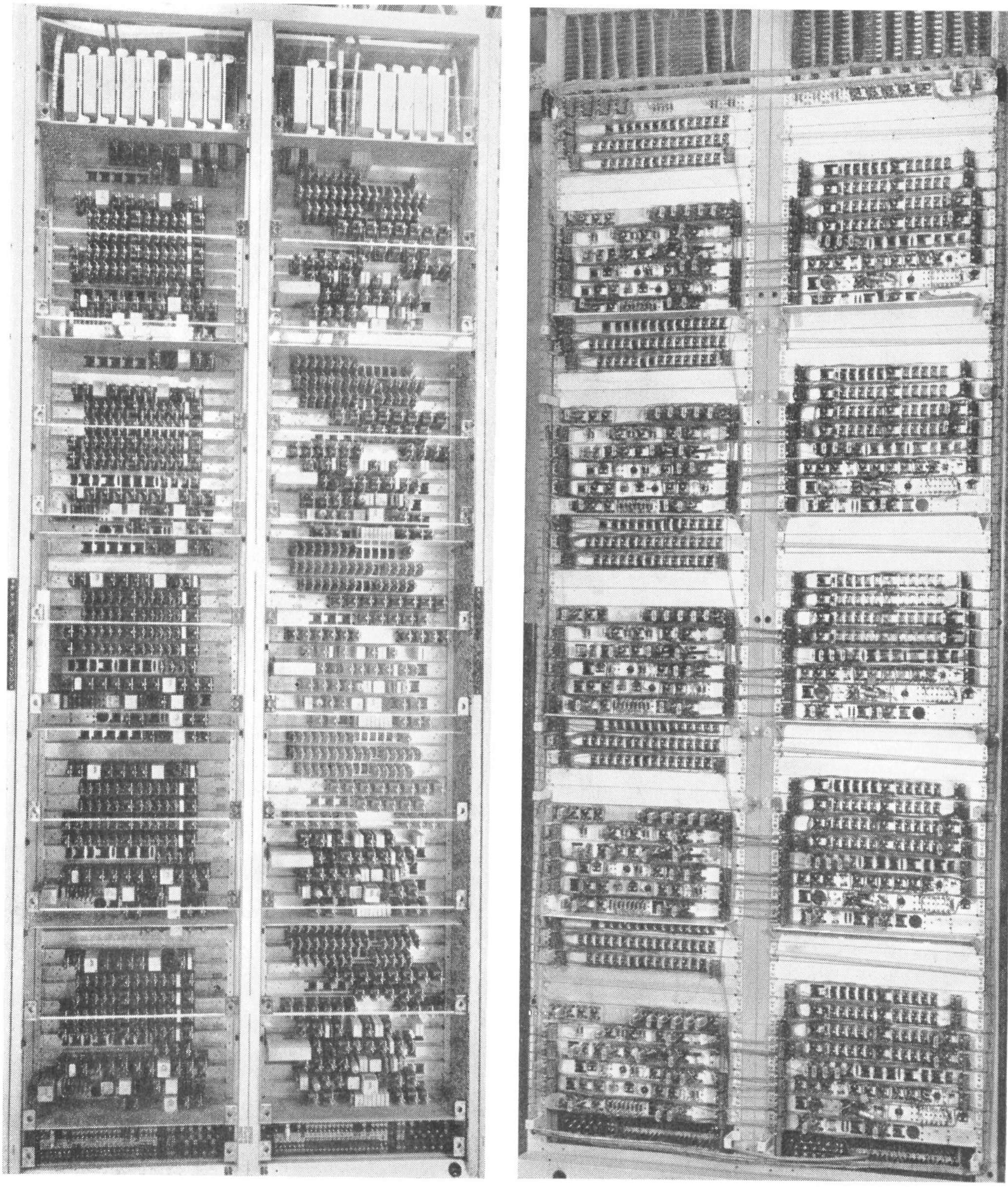


Fig. 4—Front view of an originating register frame in the Towson Office at the left, and rear view of a similar frame at the Hawthorne plant of the Western Electric Company at the right. The permanent cable may be seen at each side of the rear view. The flexible wiring between the two bays is that connecting the various functional units comprising a complete register.

Because of the provisions made in the design of the No. 5 system, there is flexibility at every stage of the assembly. Functional units may be selected as desired to build any type of register or sender. The three types of frames with their common equipment are manufactured as separate entities. Frames and their registers or senders are then brought together in any combination. Finally, both senders and registers are grouped as required by traffic to supply suitable loads for the connectors. It is features of this type that make No. 5 adaptable to many types and sizes of office.

Number group frame for No. 5 crossbar

O. J. MORZENTI
Switching Equipment

As in the No. 1 crossbar system, there is no permanent or prearranged association of directory numbers with switch positions on the line link frames of a No. 5 crossbar office.

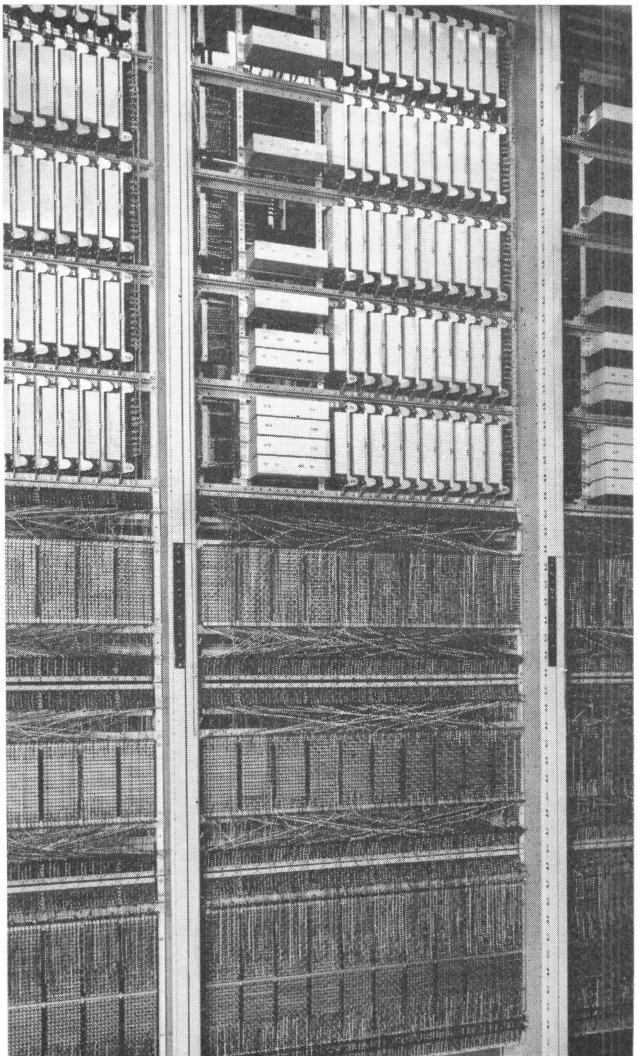


Fig. 1—A number group frame of the No. 5 system.

A marker upon receiving the number for a terminating call must therefore ascertain which one of the many switch verticals in the office is associated with that particular directory number so that a connection may be established. The marker obtains this information from the number group frame. This frame, in a manner of speaking, is a large central file, kept up to date with the latest directory number assignments, to which each marker in turn applies for the necessary information, asking, in effect, on which line link frame and where on that line link frame will the line corresponding to this directory number be found. While getting this information, the marker must also be told the type of ringing required for this number—or the ringing combination as it is called. After this information is received, the marker disconnects itself from the number group, and proceeds to establish connection to the called line.

The position of a particular number on a line link frame is identified by giving the line link frame number, the horizontal group, the vertical group, and the vertical file, while the type of ringing is given as one of fifteen possible ringing combinations. A horizontal group represents the lines associated with all the crossbar switches in the same level of a line link frame, and there are ten such horizontal groups on each frame. A vertical group represents five verticals in the same vertical column on all ten switches of a frame. Any particular frame may have from six to fourteen vertical groups: six when no supplementary bays are used, and fourteen when the full complement of supplementary bays is used. A vertical file represents a single column of verticals, and there are thus five vertical files in each vertical group.

A number group frame, as pictured in Figure 1, is arranged to serve 1000 consecutive directory numbers. Thus, a 10,000-number office would have ten such frames, the first serving numbers 0000 to 0999, the second 1000-1999, etc., up to the last for numbers 9000-9999. The upper part of the frame is filled with relays which receive the directory number from the marker. They in turn extend leads from the marker to three cross-connecting fields occupying the lower half of the frame, where the actual translation from directory number information into equipment location is made. The bottom field serves to identify the line link frame number and is known as the "LL" field. The middle, or "RF," field, identifies the ringing combination and vertical file. The top, or "VHG" field, identifies the vertical and horizontal groups.

Each of these cross-connecting fields consists of an array of terminals in numerical sequence representing directory numbers, and an array of terminals representing specific equipment locations or ringing combinations. A translation is accomplished by means of a jumper wire which connects a particular directory number terminal to the terminal associated with its equipment location or ringing-combination terminal. Figure 2 shows the simplest form such a translating scheme may take, wherein these cross-connections are shown for directory number 2435 to LL 25 (line link frame 25), RF 024 (ringing combination 02, vertical file 4) and VHG 078 (vertical group 7, horizontal group 8). The marker, through paths WL, WF, and WG "wets" or places a potential on the proper directory number terminals, those of number 2435 in this example, whence the jumpers extend this potential to the equipment location terminals. The marker receives this potential back over leads FU, FT (frame units, frame tens), RC, VF (ring combination, vertical file), and HG, VG (horizontal group, vertical group) and thereby recognizes the translation.

A marker gains access to the proper number group frame, in competition with other markers, through its associated number group connector. The choice of number group frame is dictated by the thousands digit of the called directory number. Thus, the number 2435 would be found in number group frame 2; the marker summons that particular number group and is then concerned only with number 435 within that group. For transmitting this number to the number group frame, three sets of ten leads are employed: an HB set to indicate the hundreds digit; a TB set to indicate the tens digit; and a U set to indicate the units digit. As a result of a potential placed on one lead in each of these sets in the marker, relays in the number group connect three other leads from the marker, designated WL, WF, and WG, respectively, to the terminals in the three directory-number arrays representing the particular number wanted. Thus, if the marker has placed a potential on the NO. 4 hundreds lead, the NO. 3 tens lead, and the NO. 5 units lead, the WL, WF, and WG leads will be connected to terminal NO. 435 of each of the three directory-number arrays. The WL lead will be connected to the array associated with the LL field; the WF lead to the array associated with the RF field; and the WG lead to the array associated with the VHG field.

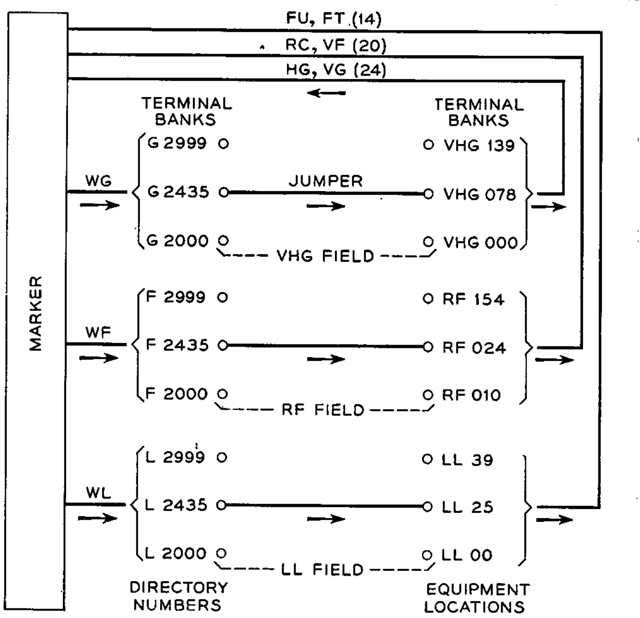


Fig. 2—Simplified diagram of the method of translating from directory numbers to the information the marker needs in locating a line.

How this is accomplished is indicated in Figure 3. There are ten hundreds block relays, and each of the ten leads over which the marker transmits the hundreds digit will

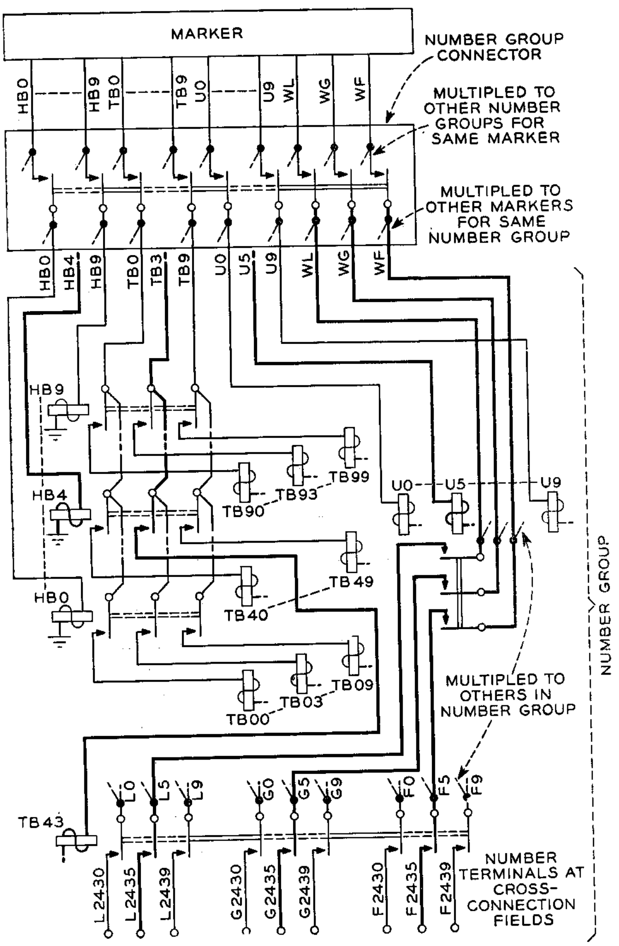


Fig. 3—Simplified schematic of relay circuit in number group that extends battery on WL, WG *and* WF *leads from marker to called directory number terminations of cross-connecting field.*

be connected to the winding of one of them. Each of the hundreds block relays has ten springs, and the ten leads over which the marker transmits the tens digit are connected in multiple to the springs of all the hundreds-block relays. The ten front contacts of each hundreds-block relay are connected to the windings of ten tens-block relays. In all there are 100 tens-block relays —ten for each of the hundreds block relays. Each tens block relay thus represents ten consecutive directory numbers. The NO. 43 tens-block relay, for example, represents directory numbers from 430 to 439, inclusive, since it is operated only when the NO. 4 hundreds lead and the NO. 3 tens lead have potential on them. Each tens-block relay has thirty springs, or three sets of ten, and each set is connected to one of the three arrays of directory number terminals already mentioned.

Multicontact relays are used for the tens-block relays. Each of such relays has sixty contacts and two operating magnets, but by controlling the magnets independently, each multicontact relay becomes the equivalent of two thirty-contact relays. Fifty multicontact relays are thus required to furnish the 100 tens-block relays, and they are mounted in five rows of ten each on the upper part of the number-group frame as may be seen at the upper right of Figure 1.

Besides the hundreds-block and tens-block relays, designated HB and TB for convenience, there is a group of ten units relays, and the winding of each is connected to one of the ten units leads from the marker. Each of the units relays has three springs, and the WL, WF, and WG leads from the marker are connected in multiple to the three springs of each relay. From the front contacts of the ten units relays there are thus a total of thirty leads, three from each—and these thirty leads are connected in multiple to the thirty springs of each tens-block relay. When a units relay is operated, therefore, the WL, WF, and WG leads will be extended to all the tens-block relays, and through the particular tens-block relay operated will be extended to the three arrays of directory number terminals. In the example taken, only the NO. 43 tens-block relay is operated, and if the NO. 5 units relay is operated, the WL, WF, and WG leads will be extended through the NO. 43 tens-block relay to the terminals of the three directory number arrays that represent NO. 435. Of the 1000 terminals in each of the three arrays, therefore, only terminals numbered 435 will be connected to the WL, WF, and WG leads and will thus have potential on them. Three jumpers then extend this potential to the terminals representing the equipment location and ringing combination and thence back to the marker.

The frame number is indicated to the marker over two sets of leads: a set of four FT leads to indicate the tens digit of the frame number, and a set of ten FU leads to indicate the units digit. This implies that for

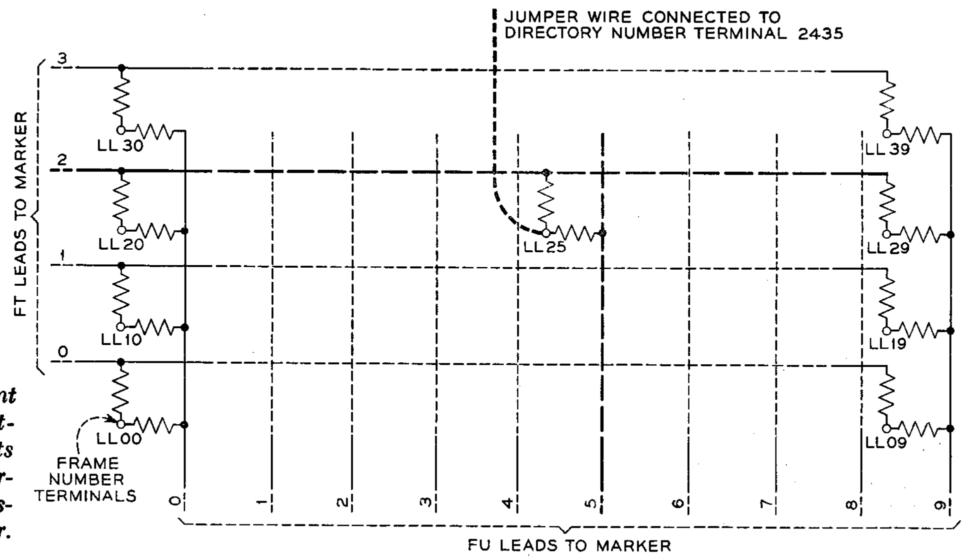


Fig. 4—Arrangement of resistance networks that permits two pieces of information to be translated by one jumper.

a line link frame number, it is necessary to convey two pieces of information—the frame tens and the frame units numbers. At first glance it would seem that two cross-connections would be required, one for each piece of data, instead of only the single cross-connection shown in Figure 2. By use of a resistance network as shown in Figure 4, however, it is possible to couple these two pieces of data with only one jumper connection. Here each of the line link frame number terminations, to which the directory numbers are cross-connected, is associated with the frame tens and units leads to the marker through a pair of resistances. Thus when a potential is applied through the relay tree, through the jumper wire associated with 2435, and thence to line link frame terminal 25, a current will flow through the FT2 resistance to the FT2 lead into the marker, where it is recognized as a frame in the twenties, and current will also flow through FU5 resistance to the FU5 lead into the marker, where it is recognized as a frame with a five units digit. These two facts inform the marker that it is frame 25.

An arrangement similar to that of Figure 4 is used for combining the vertical and horizontal group information. The possible 140 combinations can be accommodated by ten HG leads for the horizontal groups and fourteen VG leads for the vertical groups. Similarly for vertical file and ringing combination information, the 75 possibilities are cared for by twenty leads, five VF leads for vertical files, and fifteen RC leads for ringing.

There is still another function that the number group must perform for the marker. Some of the lines of any number group may be PBX trunks. The directory number given the marker will ordinarily be that of the first of the terminal hunting group, and this particular trunk and perhaps several adjacent ones may be busy while others in the group are idle. If the number group gave the location of the first trunk to the marker, the marker—after disconnecting from the number group—might find the trunk busy and would have to reconnect to the number

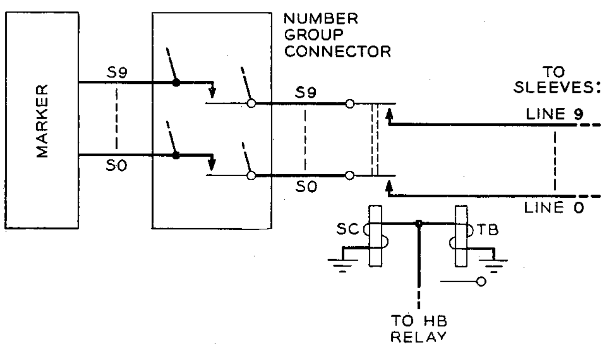


Fig. 5—Simplified circuit indicating method by which marker tests for idle PBX trunks.

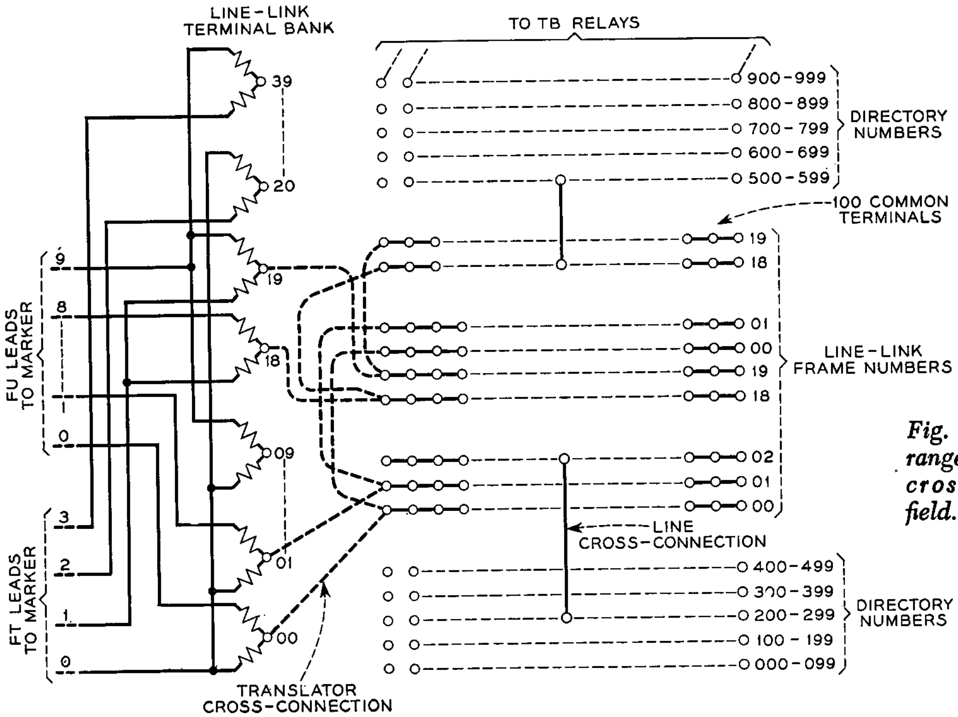


Fig. 6 — Typical arrangement of the LL cross-connecting field.

group to get the location of another trunk of the group. To avoid this loss of time, facilities are provided in the number group to permit the marker to test for an idle trunk before leaving the number group, and then to determine the location of only the first idle trunk found.

This is accomplished by extending the sleeve leads of all PBX trunks to the number group, and providing ten additional leads between the number group and the marker over which these sleeves may be tested. As shown in Figure 5, an SC (sleeve connect) relay is paralleled with each TB relay that has PBX trunks associated with it, and thus the SC relay is operated at the same time as the TB relay. There are ten springs on each SC relay, and the sleeve leads from the PBX trunks are connected to their front contacts, or to as many of them as may be required. The springs of the SC relays are connected, through the number group connector, back to the marker.

All terminal hunting groups have ringing combination NO. 10, and when the marker gets this code from the number group, it tests the ten sleeve leads, and then transmits a units code for the first idle trunk found. Where there are more than ten trunks in a PBX group, SC relays will be associated with all the TB relays that have trunks of that group, and provision is made for advancing from one to another if all trunks associated with one TB relay are busy.

The principal objective in the equipment design of the number group frame was to arrive at a flexible grouping of the LL, RF, and VHG terminal arrays so that they may be varied in size as the demand for terminals requires. Figure 6 shows a typical arrangement of the LL cross-connecting field, arranged for 20 line link frames. As with the RF and VHG fields, the 1000 directory number terminals are arranged in ten rows of 100 each, five rows above and five below the equipment location terminals. The LL field has 4000 terminals in forty rows of 100 each. Each row consists of ten groups of ten common terminals, multiplied together so that the 100 terminals of the row are common. In the illustration, since only 20 line link frames are involved, two such rows may be multipled to represent one line link frame. Had forty frames been involved, each row would have represented a single frame. Similarly, had there been ten frames, four

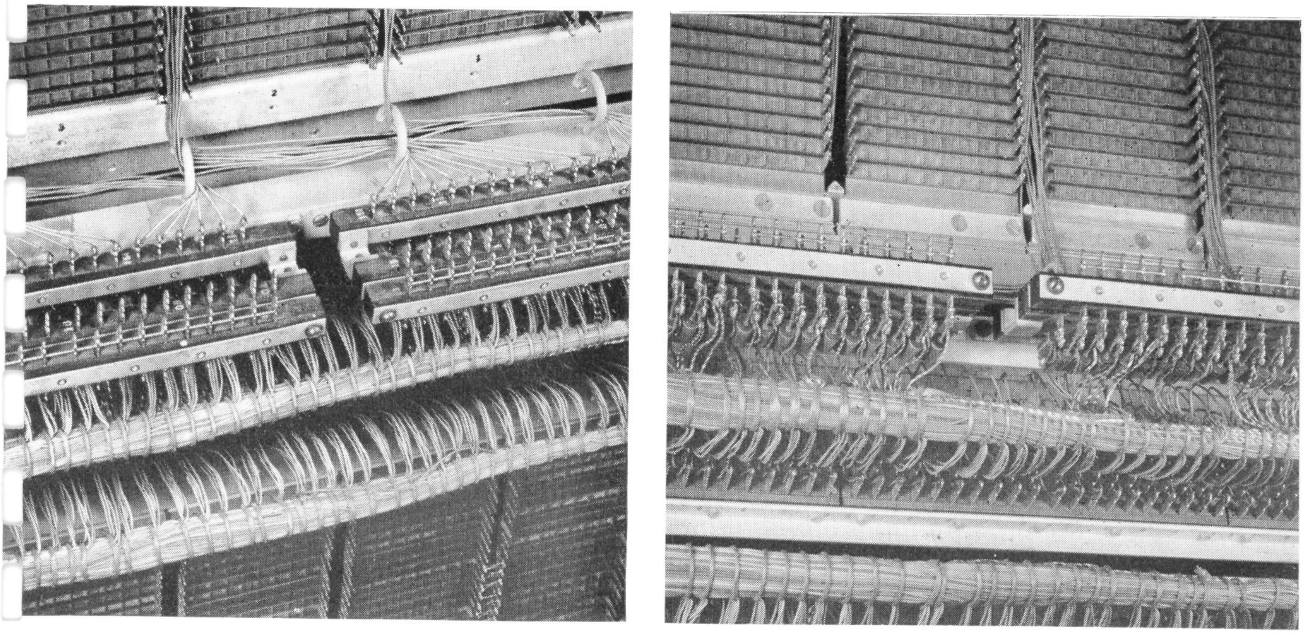


Fig. 7—Rear of number-group frame. Left, looking down on the terminal strips; right, looking at terminal strips from beneath. The resistors are just below the strips and are barely visible in the lower illustration

rows could be multipled to represent a frame, keeping in mind, however, the pattern required for future expansion. These rows, or multiples of rows, are then connected to the translator resistor networks, which are mounted on the rear of the frame in groups of 20. Figure 7 shows these connections and resistors, with the multipling of terminals in the RF field. These facilities are provided on the rear of the frame where they do not interfere with running jumpers on the front of the frame to associate line with directory number assignments. The RF and VHG fields have 2000 terminals in 20 rows, arranged for variable multipling in similar fashion to the LL field.

These arrangements make possible a fairly standardized design for economical manufacture, and yet provide the needed flexibility to meet many job variations.

Ringing selection in No. 5 crossbar

M. C. GODDARD
Switching Development

In supplying telephone service under the wide range of conditions encountered, it is often necessary to connect more than one subscriber to a single line From the point of view of the number of subscribers per line, five types of lines are available at present for No. 5 crossbar: single party, two party, four party, eight party, and ten party. Four party lines may be either of two types: one having full and the other semi-selective ringing. With full selective ringing, each subscriber hears ringing only when his station is being called, while with semi-selective ringing, each subscriber hears the ringing for his own and one other station. On individual, two party, and four party full selective lines, therefore, each subscriber hears only his own ringing, while on four party and eight party semi-selective lines he hears also the ringing for one other party, and on ten party lines he hears the ringing for four others. Coded ringing is used to identify the party called, and the five codes indicated in Figure 1 are employed in the No. 5 crossbar system.

This group of codes has been arranged so that it may be used for all these types of lines. Individual, two party, and four party full selective lines use only code one. Eight party and four party semi-selective lines use codes one and two; only ten party lines use all five codes.

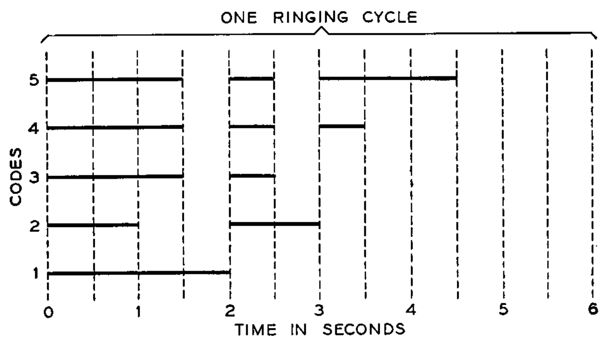


Fig. 1—The five basic ringing codes used by the No. 5 crossbar system.

On party lines, half of the subscriber stations are arranged to be rung over the "ring" conductor, and half over the "tip" conductor. On eight party lines and four party full selective lines, a further limitation in the ringing a subscriber hears is made possible by superimposing the interrupted 20-cycle ringing on either negative or positive d-c. All ringing is superimposed on a d-c component to permit the tripping relay to operate when the subscriber answers, and the normal d-c component is negative; only for eight party and four party full selective is the positive superimposed ringing employed. To specify a ringing code completely, therefore, it is necessary to state the side of the line to which the ringing is applied, whether it is negative or positive superimposed, and the particular one of five codes of Figure 1 that is employed. There are thus in all fourteen types of ringing used at present in No. 5 crossbar, and they are indicated in Table I.

Although very few central offices serve lines of all these types, they frequently have more than one type of line, and the proper type of ringing must be selected for each call. Means must be provided at a central office for selecting and applying ringing to any line, but since this equipment is used only for a brief period in each call, it would in general be uneconomical to associate these circuits with each line. In the step-by-step system they are associated with the connectors, while in the panel and No. 1 crossbar systems, they are associated with the incoming trunk circuits. These latter systems rarely have eight or ten party lines, and thus the equipment for selecting ringing consists of only a few relays. In the rare cases when eight or ten party lines are required, the additional ringing selecting equipment is associated with only the few lines that require it.

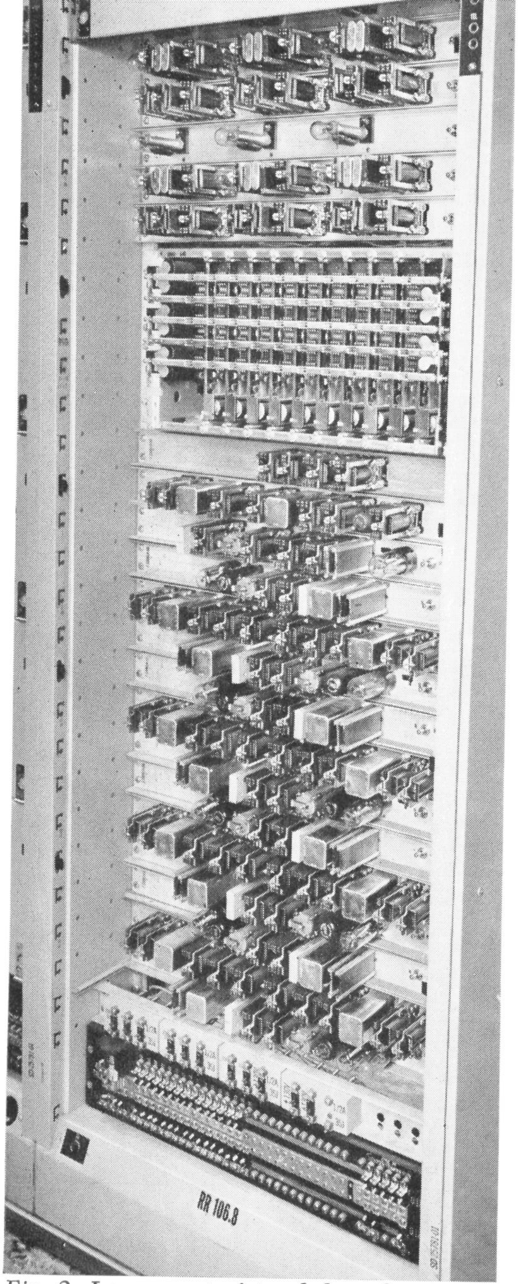


Fig. 2—Lower part of trunk bay showing one ringing switch.

The field of use for No. 5 crossbar offices, however, includes the suburbs of metropolitan centers, and these offices may commonly serve eight or ten-party lines in addition to one, two and four-party lines. The selecting equipment is associated with the trunk as in the No. 1 system, but all fourteen types of ringing are made available to each trunk. Instead of using a relay circuit, however, a crossbar switch is used to apply the ringing. The trunk circuits are installed on twenty-three inch relay racks. A ten-vertical crossbar switch is used for each ten trunks requiring ringing. Each trunk circuit is associated with a switch vertical to select any one of the required types of ringing. A complete bay of this type will carry twenty or thirty trunks maximum, depending upon the amount of equipment in the trunk circuits, and will thus use either two or three crossbar switches. The lower part of such a bay is shown in Figure 2. The crossbar switch shown serves the ten trunks mounted beneath it—two trunks being mounted on each set of three mounting plates.

A simplified schematic of the circuit employed is shown in Figure 3. Levels 0 and 1 are used to apply ringing to either the tip or ring conductors of the line and ground to the other. When crosspoint 0 is closed, ground is applied to the tip conductor and ringing to the ring conductor, while when the No. 1 crosspoint is closed, ground is applied to the ring conductor and ringing to the tip. Levels 2 to 8, inclusive, select the seven types of ringing supplied by the ringing power plant: negative superimposed code 1, positive superimposed code 1, negative superimposed code 2, positive superimposed code 2, and negative superimposed codes 3, 4, and 5.

TABLE I—THE FOURTEEN TYPES OF RINGING OF THE No. 5 CROSSBAR SYSTEM

Code	Polarity	Side of Line	Ind. Line	Two Party	Four Party Semi	Four Party Full	Eight Party	Ten Party
1	—	R	X	X	X	X	X	X
1	—	T		X	X	X	X	X
1	+	R				X	X	
1	+	T				X	X	
2	—	R			X		X	X
2	—	T			X		X	X
2	+	R					X	
2	+	T					X	
3	—	R						X
3	—	T						X
4	—	R						X
4	—	T						X
5	—	R						X
5	—	T						X

Under direction of the marker, the crosspoint for either the No. 0 or No. 1 level is operated and also the crosspoint for one of the levels from 2 to 8 depending upon the type of ringing required by the party being called. Closure of the crosspoints of any of

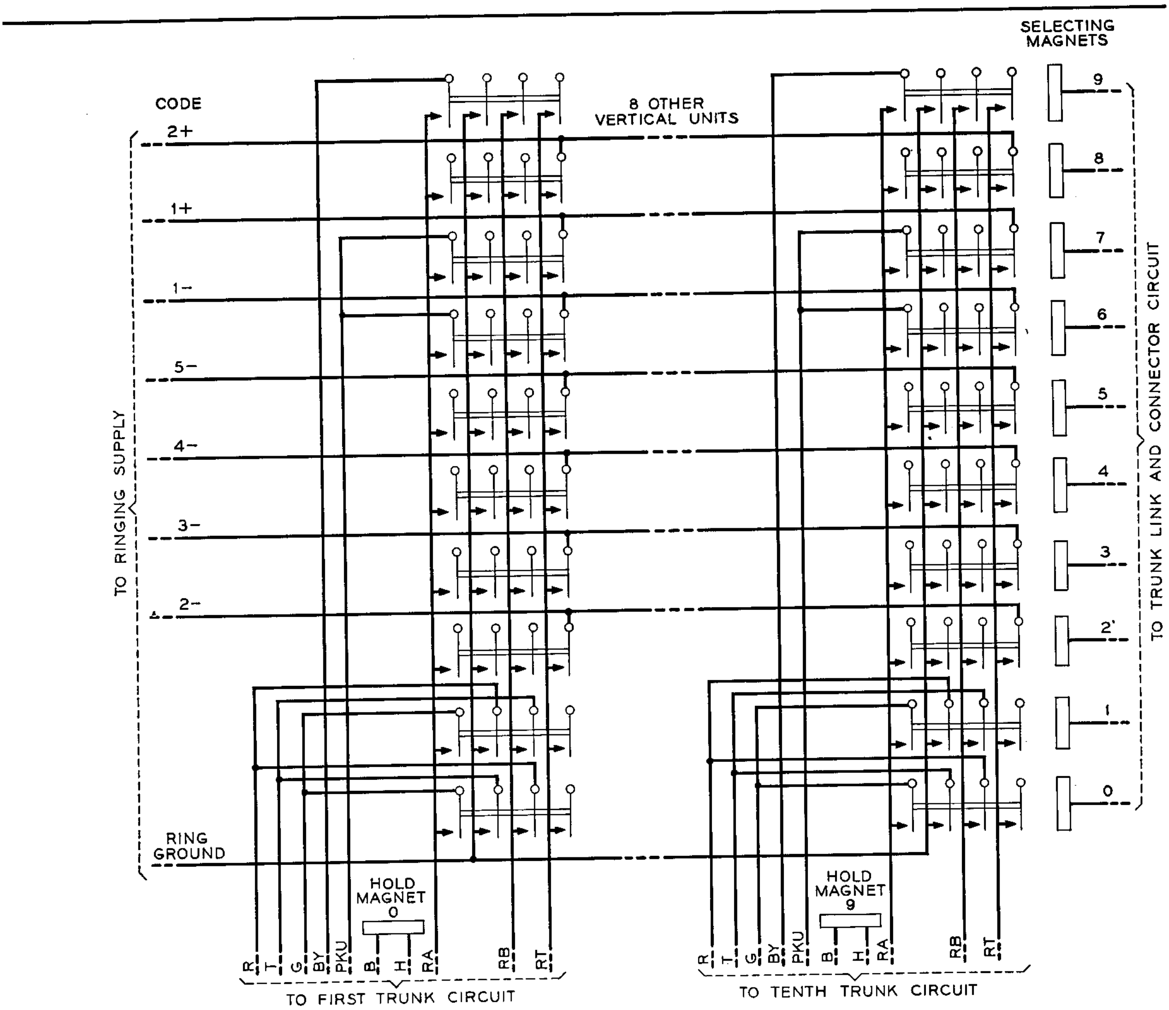


Fig. 3—Simplified schematic of ringing circuit in a No. 5 crossbar office.

the levels from 2 to 8 connects the selected code ringing supply to the RT lead to the trunk. Here it passes through the ringing trip relay and back to the crossbar switch over lead RB. Through the crosspoints of the No. 0 or No. 1 level, the RB lead is connected to either the ring or tip conductor of the subscriber's line, and ground is connected to the other lead of the line. Also through the contacts of the No. 0 or No. 1 crosspoint, ground from the trunk circuit over the G lead is connected to the RA lead, whence it returns to hold the trunk in the ringing condition until ringing is tripped or the call is abandoned.

When a line requires code 2, 3, 4 or 5, ringing is connected to a line only at the start of a complete ringing cycle so as to avoid a partial code from being sent over the line, which might be misinterpreted by the subscriber. This means that there may be a delay of a few seconds before ringing is started. With code 1 ringing, however, there is no possibility of the code's being misinterpreted since it consists of only one ring, and if the first ring were shorter than the others, no confusion would result. For either 1— or 1+, therefore, the code ringing supply is connected at once without waiting for the end ot the ringing cycle. This is brought about by using other contacts of the No. 6 and No. 7 crosspoints, which apply codes 1— and 1+, to connect the ground on the RA lead to the PKU lead. Lead RA is grounded by the closure of the crosspoints on levels 0 or 1, and this ground on the

PKU lead tells the trunk to start ringing without waiting for the end of the cycle.

Level 9 on the crossbar switch is not required for applying ringing, and is therefore employed—in conjunction with No. 0 or No. 1 crosspoints—to indicate busy and overflow conditions. If the line called is found busy, the marker, instead of operating one of the ringing code crosspoints, will operate the No. 9 crosspoint and also the No. 1 crosspoint. Closing the No. 1 crosspoint connects ground from the trunk over lead G to the RA lead, and closing the No. 9 crosspoint connects this RA lead to the BY lead. Ground on the BY lead will operate the BY (busy) relay in the trunk circuit.

If the line had not been busy, but the marker had not been able to find a path to it from the trunk link frame, it would have operated the No. 0 and the No. 9 crosspoints. Closure of the No. 9 crosspoints operates the BY relay in the trunk as before, but closure of the No. 0 crosspoint has connected ringing ground to the tip lead of the trunk. Under these conditions the TC relay is operated in the trunk as well as the BY, giving an overflow instead of busy signal.

Since the ringing selection switch is wired for all types of lines up to and including eight and ten party, there are no ringing options to be selected in furnishing trunk circuits and associated ringing selection switches, and the engineering and installation is simplified. The only variation in an office is in the types of ringing supply. Systems with eight party lines or four party full selective lines require superimposed positive ringing codes and superimposed negative, but where there are none of these lines, superimposed positive codes are not required.

Message register operation in No. 5 crossbar

F. K. LOW
Switching Development

A feature of the No. 5 crossbar system* is the use of cold cathode gas-filled tubes to perform certain operations. Large numbers of them are employed for operating subscriber message registers in offices where these are required. Owing to the differences in the trunking plans of the two systems, the d-c method of control employed for registers in the No. 1 crossbar system was not practicable with the No. 5 system. Accordingly, an unusual type of control circuit utilizing cold cathode tubes has been developed to fit the simplified plan of the latter system.

Telephone message registers have been used for many years with certain classes of subscriber lines to indicate the number of calls completed. They are small magnetically operated counters that are operated once for each call completed, and in some cases once for each unit charge a call entails. Although automatic message accounting is being made available for the No. 5 crossbar system, it will be employed in general only in the larger areas where many outlying offices at varying distances result in a wide range of charges. In many offices there will continue to be a need for message registers, and circuits for operating them on both single and two-party lines are thus included in the No. 5 crossbar system, as they were in the No. 1 system.

If the method employed for operating the message registers in the No. 1 crossbar system were used in the No. 5 system, however,

* See page 5.

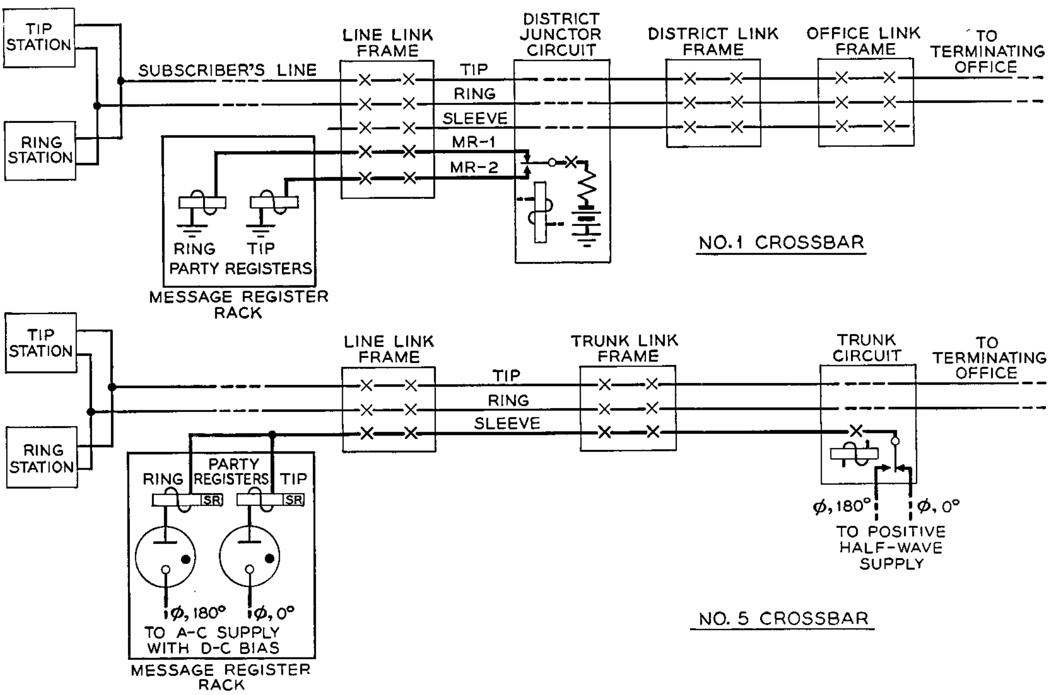


Fig. 1—Simplified circuit indicating method of operating message registers: above, in the No. 1 crossbar system; below, in the No. 5 crossbar system.

the crossbar switches on the line link and trunk link frames would have had to be equipped with five sets of contacts at each of the crosspoints instead of three. In the No. 1 system the registers are operated from the district junctor circuits over two leads—one for the two possible registers associated with a two-party line. These leads pass through the line link frames to reach the registers, and thus the crossbar switches on these frames must have two sets of contacts in addition to the three for the tip, ring, and sleeve conductors. This is indicated in the upper diagram of Figure 1.

In the No. 5 crossbar system, on the other hand, the message-register operating voltages are applied in the trunk circuits as indicated in the lower diagram of Figure 1, and the leads over which the registers are reached pass through the trunk link as well as the line link frames. If the method of the No. 1 system were employed, therefore, the crossbar switches on the trunk link as well as on the line link frames would have to be equipped with five sets of crosspoints instead of three. This has been avoided by a method of operating the message registers that requires no additional crosspoints on any of the switching frames.

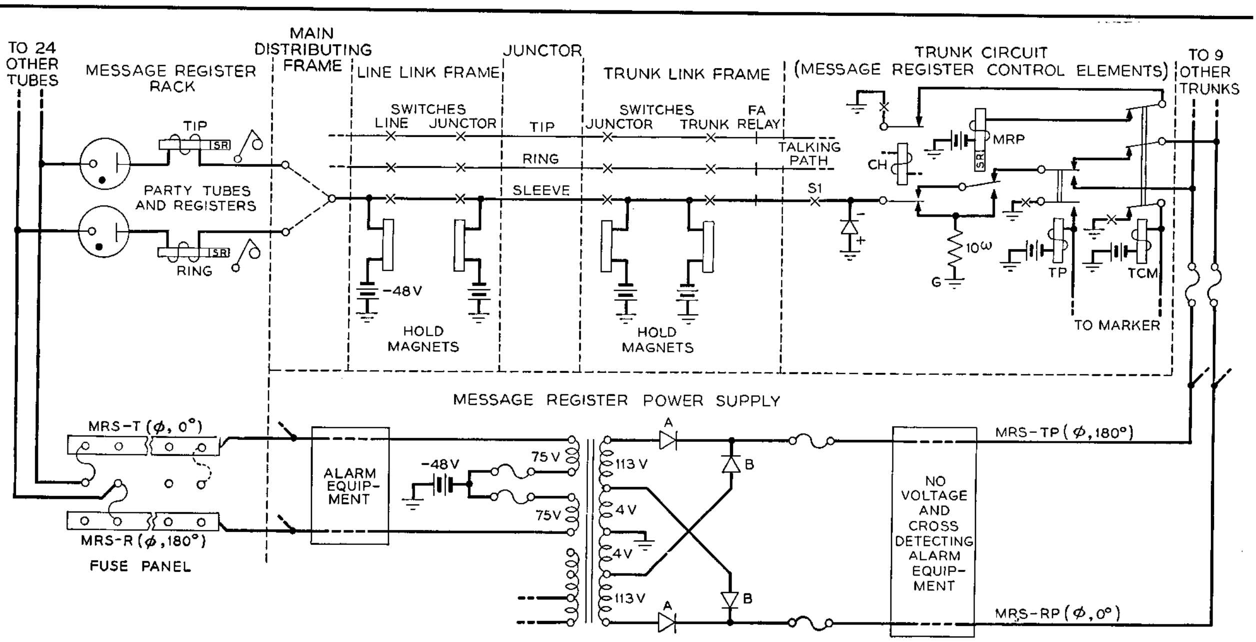


Fig. 2—Message register operating circuit in the No. 5 crossbar system.

Instead of using extra leads for operating the message registers, the sleeve lead is made to do double duty. Besides being used for operating the hold magnets of the crossbar switches and giving busy indications to the marker, it is also used for operating the message registers through 413A cold-cathode gas-filled tubes. The two registers associated with the line are both connected to the sleeve lead, but because of the cold-cathode tubes in series with them neither will operate on the potentials applied to the sleeve lead for operating hold magnets or giving busy or idle indications to the marker. They will operate only when a properly phased half-wave ac voltage is applied to the sleeve lead in the trunk circuit. Two voltages are made available for applying to this sleeve lead. They are alike in magnitude but differ in phase by 180 degrees. Each of the two registers on a line will respond to only one of these voltages, and a relay in the trunk circuit connects the proper voltage to the sleeve lead under control of the marker.

Which party has originated the call, and which register should thus be operated after the call is answered, is determined by substantially the same means in both the No. 1 and No. 5 crossbar systems during the first phase of the call, when the line is connected to the dial pulse receiving equipment (not shown in Figure 1). When a call is originated by a tip station, a d-c path to ground is provided while for a call from a ring station there is no d-c path to ground. Message register control circuits in both the No. 1 and No. 5 systems use this difference to determine whether it is a tip or ring party that is calling.

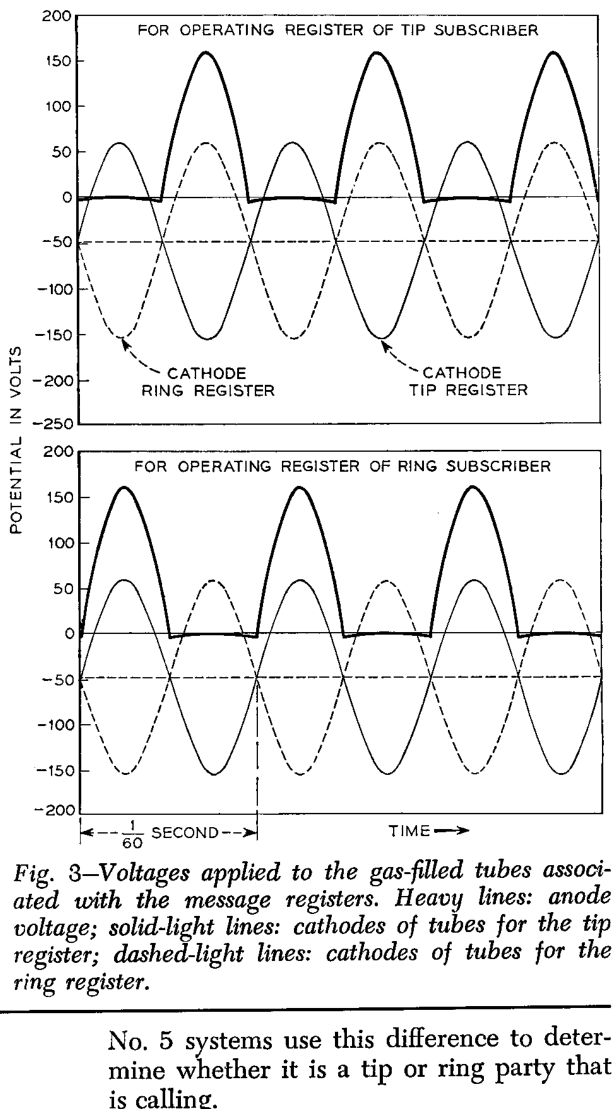


Fig. 3—Voltages applied to the gas-filled tubes associated with the message registers. Heavy lines: anode voltage; solid-light lines: cathodes of tubes for the tip register; dashed-light lines: cathodes of tubes for the ring register.

Standard sheet metal frames are used for mounting the registers and their associated cold-cathode tubes as shown in Figure 5. Each frame accommodates five hundred registers and tubes. A locking bar is fastened along one upright of each frame, and a key is required to open or remove the lucite covers from the message register frame.

The method of operating registers is achieved as follows:

The detailed plan of operation of the new message register circuit is indicated in Figure 2. Each message register is connected between the sleeve lead of the circuit with which it is associated and the anode of a gas-filled tube—a 413A. In Figure 2 only the two registers associated with one line are shown, and they both connect to the sleeve lead of that line. The cathodes of the gas filled tubes for all the registers connect to a 75-volt rms a-c supply with a negative 48-volt bias. As indicated in the diagram, there are two of these supplies, equal in voltage but differing 180 degrees in phase. The tubes for all tip subscribers connect to one supply and those for all ring subscribers to the other. The voltage on the cathodes of the tubes is indicated by the dashed and light solid curves of both the diagrams of Figure 3. Since a 75-volt rms sine wave has a peak value of 106 volts, these curves swing from −154 to +58 volts.

When a line is not in use, its sleeve conductor is connected to −48 volt battery through its holding magnet on the line link frame, and thus this voltage appears on the anode of all tubes while the lines are idle. This voltage is indicated by the light dashed horizontal lines in Figure 3. The gas tubes will not ionize and pass current unless the anode is about 200 volts more positive than the cathode, and thus under these conditions, no current passes through the tubes.

When a call has been placed and the line is connected to a trunk by operation of the crossbar switches, the sleeve is held grounded in the trunk circuit. This increases the anode voltage from minus 48 to 0, indicated by the light solid horizontal lines of Figure 3, and the peak voltage across the tube thus becomes 154. This is still too low to ionize the tube, however.

To operate a message register, the trunk circuit momentarily connects to the sleeve lead for that line one or the other of two positive half-wave supplies. These are derived from the same source that supplies the cathode voltages by the method indicated in the lower part of Figure 2. These two voltages have the same peak value of 165 at the supply transformer, but a drop of about 5 volts across the rectifiers A reduces it to about 160 volts at the register. Rectifiers A block the negative half cycle, but a tap on the winding for the voltage of the opposite phase connected through rectifiers B supplies a voltage of about 5 volts peak during the suppressed negative half cycle. The resultant voltage applied to the sleeve conductor—and thus to the anodes of both tubes of that line—when a tip subscriber is to be charged is shown by the heavy curve in the upper part of Figure 3, and that applied for a ring subscriber to be charged is shown by the heavy curve in the lower diagram. These two heavy curves are identical in magnitude but differ in phase by 180 degrees.

From the lower curves of Figure 3, it will be noticed that the voltage on the anode of the tip party tube is never more than 154 volts above the cathode, and thus the tube does not pass current. The voltage on the anode of the ring party tube, however, rises to 314 volts above the cathode every half cycle. As a result, this latter tube passes current and the ring subscriber register is operated. While a tube is passing current, there is a drop of about 70 volts across it, and thus the voltage across the register is reduced by this amount. This is indicated in the diagram of Figure 4 for the operating cycle of the ring subscriber. The shaded area on this diagram is a voltage-time graph per cycle for the ring register, and is proportional to the energy per half cycle that is available to operate the register. No current will start to flow until the voltage across the tube is about 210 volts, which is assumed to be the ionizing voltage for this particular tube. At this moment—as soon as current is passing—the voltage across the register becomes 140. Following the sine wave, it then increases to 244 volts and then drops to 0. About a hundredth of a second later, during the next positive half cycle, a similar spurt of current will flow through the register, and these spurts of current recurring every sixtieth of a second operate the register and, because of the copper sleeve that is placed around its core, hold it operated as long as the anode voltage is applied.

This operate current for the register is applied by the trunk using the circuit indicated at the upper right of Figure 2, which shows the conditions after the line has been connected to the trunk but before the register is operated. If a charge will be required for the call in progress, relay TCM will have been operated by the marker, and in turn will have operated relay MRP. Whether it is a tip or ring subscriber that is calling will also have been determined by the marker, and if a tip subscriber is calling, relay TP will be operated; if a ring subscriber is calling, or if it is a single party line subscriber, TP will not be operated.

After the called subscriber has answered, and a charge is to be made for the call, relay

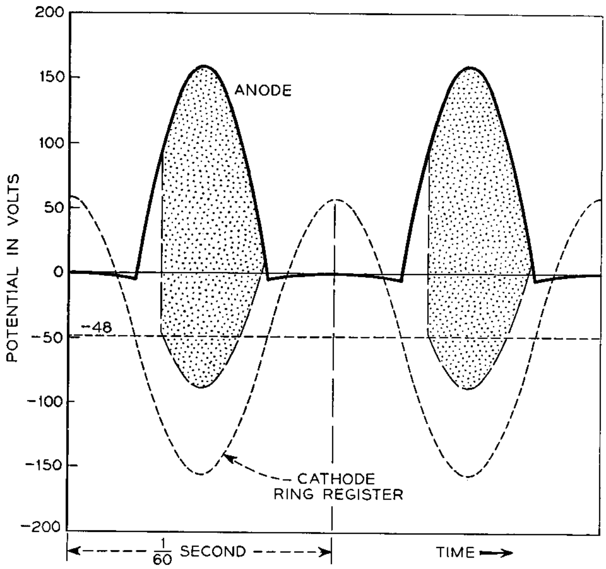


Fig. 4—Enlarged diagram of about two cycles of the voltages shown in Figure 3.

CH is operated. This transfers the sleeve lead from the holding ground at G to lead MRS-RP of the power supply through front contacts of MRP and TCM and a back contact of TP. This establishes voltages on the registers for this line as indicated by the lower curves of Figure 3, and the message register for the ring subscriber will operate while that for the tip subscriber will not.

The circuit to the winding of relay MRP is opened when CH operates, and since MRP is a slow-release relay, the message register operating current is applied only during the release period of this relay, which is ample time to operate the register. After the release of MRP, the sleeve lead is returned to its normal holding ground at G. While the message

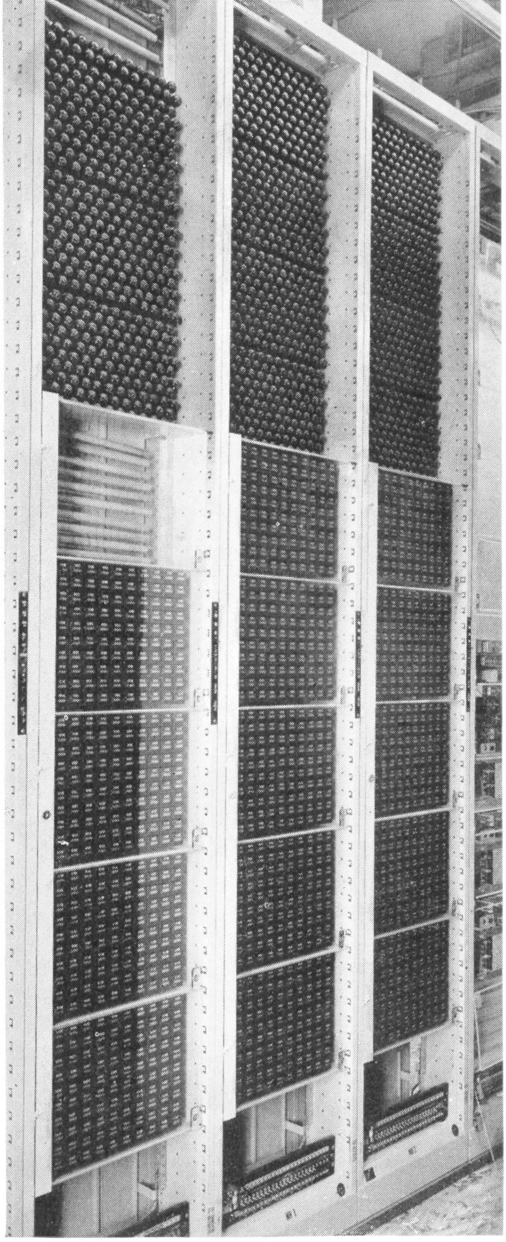


Fig. 5—Message register equipment.

register is being operated, the hold magnets are held operated from ground at the center tap of the transformer in the lower part of Figure 2. The varistor shown in the trunk circuit keeps the hold magnets operated while the sleeve lead is being transferred to the anode power supply by the operation of CH and while it is being transferred back to the hold ground by the release of MRP. It also prevents an undesirable negative discharge of the holding magnets from being impressed on the gas tubes during this switching.

At the end of the call, the trunk circuit removes the sleeve ground, thus releasing the crossbar switch hold magnets. Where they are required, trunk circuits may also be provided with equipment for timing the duration of conversations and for advancing the message register an additional step after each measured time interval. In such cases, a motor driven contact controls the relays that apply the operating voltages for the message registers.

A special fuse panel at the bottom of the message register frame, evident in Figure 5, provides either tip or ring party voltage to each group of twenty-five tubes and permits changing the assignment of any group from tip to ring supply without recabling or restamping. This is done by providing one lead to carry the superimposed a-c supply to each tube group. This lead may be connected to either tip supply or ring supply by connecting its associated fuse to either the tip supply bus bar or ring supply bus bar of the fuse panel as shown in Figure 2.

T. V. CURLEY
Switching Development

Operator connections in No. 5 crossbar

Calls from subscribers in a No. 5 crossbar office to other subscribers in the same office, and for the most part other subscribers in other offices in the immediate area, are completed mechanically under control of the subscriber's dial. Although these mechanically completed calls constitute most of the traffic originating in the office, there are many occasions when a dial subscriber requires the assistance of an operator to complete a call, and a considerable number of trunk equipments are needed to serve these operator-assistance calls.

Operator's assistance is sometimes required to complete calls to manual offices, and also, at the present time, to complete long distance calls. Even though all offices were of the dial type, however, and even should subscriber dialing for toll calls become universal, there still would be occasions when an operator's assistance was needed. Such conditions as the provision of telephones for the blind often make it necessary to furnish manual service even in dial offices. Certain types of emergency calls also require access to an operator.

For all such outgoing operator calls in crossbar or panel areas, either a recording-completing or a special-service trunk will be used when the subscriber dials 211 or 0.* With previous types of offices, two different types of trunks were generally used, but for the No. 5 office a single circuit has been designed that is used as either a recording-completing or a special-service trunk—the former terminating in a toll position and the latter in a DSA position. It is common practice to combine the DSA and toll boards, and thus dialing either 0 or 211 may reach the same switchboard, but in considering the handling of the calls this fact may be ignored.

For originating calls of any type in a No. 5 crossbar office, a marker is connected to the line by the lifting of the handset, and in turn connects an originating register to receive the number to be dialed. The marker then releases. After recording the digits, the register calls in a marker to establish a connection between the subscriber's line and a suitable trunk, as determined from the code dialed. So far, the operation is the same for all types of dial calls; the difference is in the type of trunk the marker connects to the line. If the code dialed were 211 or 0, either a recording-completing or a special-service trunk will be connected. On calls from manual lines, where the subscriber does not dial, the steps taken are essentially the same except that the marker, when called in by the lifting of the handset, recognizes that a manual line is calling and indicates this fact to the register it selects. The register, in turn, after seizing a marker to complete the connection to the trunk, will indicate to the marker that a DSA operator is required.

Besides making provisions to enable a subscriber in a No. 5 crossbar office to reach an operator, there must be provisions for operators at DSA or toll boards to reach a subscriber in a No. 5 office. Incoming operator-assistance trunks will thus be required as well as the outgoing trunks.

Both outgoing and incoming trunks between a No. 5 crossbar office and toll and DSA operator positions are of several types, as indicated diagrammatically in Figure 1. Outgoing trunks may be for use with coin or non-coin lines, and in either of these forms they may or may not be arranged to give a class-of-service signal to the operator. This class-of-service signal is used to identify a particular class of subscriber when an out-

*In areas predominantly step-by-step, codes of the type 11X are commonly used.

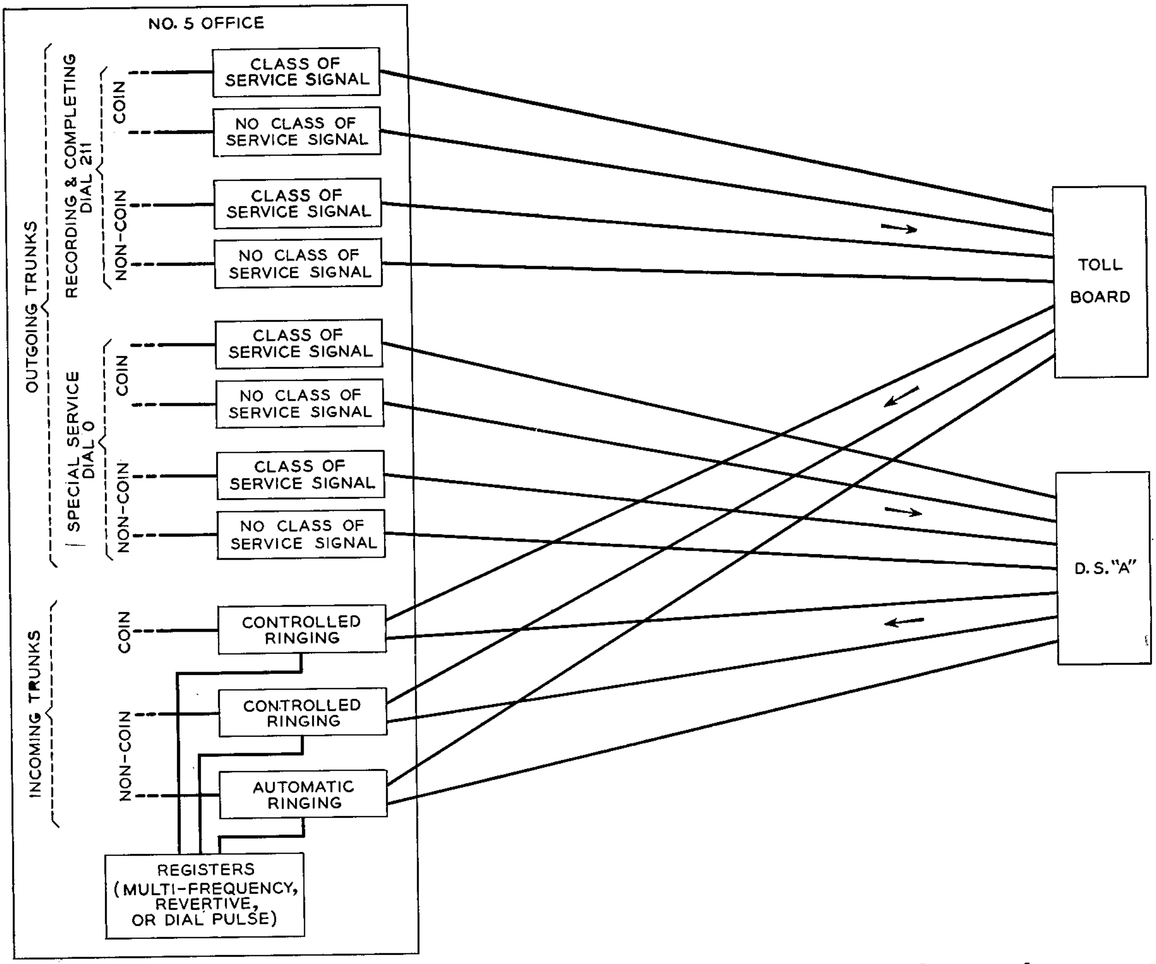


Fig. 1—In each of the three major classes of operator-assistance trunks—recording-completing, special-service, and incoming—there are subgroups for coin and noncoin lines which are further subdivided depending on the type of ringing provided and on whether or not a class-of-service signal is used.

going group of trunks serves two or more classes of subscriber service. With non-coin trunks, the class-of-service signal is used to indicate that the call is from a manual line, such as is provided for an incapacitated subscriber, while with coin trunks it may indicate that the call is from a manual coin-box line.

All of the outgoing trunks of the above type include provisions for ring-back. They differ in this respect from outgoing trunks to dial offices since the operator may need to recall the subscriber before the call is terminated. With coin trunks, continuous ringing voltage may be applied across the line under control of the operator whether or not the subscriber has hung up. With non-coin lines, two types of ringing are provided. One, used principally for PBX trunks, rings under off-hook conditions, since even though the subscriber has hung up, the trunk will be in the off-hook condition as long as the PBX operator is plugged into it. The other type, used primarily in emergencies, applies all ringing voltages to the line successively regardless of whether the line is in the on-hook or off-hook condition. This latter type of ringing and its purpose have already been described in the RECORD.*

There are also several types of incoming trunks used for operator-assistance calls. They differ in their ringing provisions and also in being arranged for coin or non-coin

*RECORD, *March*, 1941, *page* 206.

traffic. Coin incoming trunks are not arranged for automatic ringing, but only for controlled ringing. After the trunk is seized and a marker has subsequently established a connection to the called line, the marker sets up the proper ringing conditions.† Ringing will not be applied, however, until the ringing key at the switchboard is operated. This permits the operator to seize and hold the line at once, but not to ring until she is ready to bring the subscriber into the connection.

Non-coin incoming trunks may be arranged for either controlled or automatic ringing. With the latter type of ringing, the subscriber line is rung as soon as it is seized, and after the subscriber answers, the ringing switch remains connected with the trunk for further use. With controlled ringing, for both coin and non-coin trunks, the ringing switch remains connected with the trunk until final disconnection, and may be reused under control of the operator. All of these incoming trunks may be connected to any of the three types of registers: multifrequency, revertive, or dial pulse.

In the trunk diagram of Figure 1, only certain of the features that differentiate the various types of trunks are indicated. In addition to these features, all of the coin trunks—either outgoing or incoming—have provision for collecting and returning coins. For outgoing trunks this is obviously necessary, but it is also needed sometimes with incoming trunks, such, for example, as when the charge is to revert to the called subscriber. The return of the original coin used to reach the operator is under control of the originating register, and the coin is returned automatically on calls dialing 0 or 211. Subsequent return or collection of the coin, however, is done by the trunk under control of the operator.

In addition to the differences mentioned above, operator-assistance trunks are available in two forms commonly referred to as two-wire and three-wire trunks. The latter form is used when the switchboard is in the same building as the No. 5 office, and the former when it is in a distant building. With the switchboard in the same building, three wires—tip, ring, and sleeve—are carried from the trunk circuit to the switchboard, and the third or sleeve lead provides an extra path for supervisory signals and for holding switches and relays operated. Circuits to distant offices, however, have only two wires—tip and ring conductors—and thus the trunk circuits used at both ends of the circuit must have additional relays and other elements to substitute for the third conductor. Two-wire trunks are thus somewhat larger and more expensive than three-wire trunks.

Operator-assistance trunks are used in considerable quantity; a 10,000 line office will usually have more than 100 of them. The quantity varies over a wide range, depending upon the percentage of the traffic that is not handled on a full-mechanical basis.

†Record, *April,* 1941, *page* 170.

Cold-cathode-tube test set

V. L. JOHNSON
Switching Development

In the panel and crossbar dial systems, many timed periods are required to permit certain circuit operations to be carried out, and to give an alarm if these operations are not completed by the end of the period. In the past, these time intervals have been provided by power-driven, cam-actuated interrupters. With the introduction of the No. 5 crossbar system, however, the power-driven interrupters were replaced by circuits employing cold-cathode tubes. Time delays are obtained by utilizing the time required to charge a capacitor in series with a high resistance. The potential on the capacitor is applied to the control anode of the tube, and when this potential builds up to a value sufficient to cause the tube to ionize, a relay in the tube circuit operates.

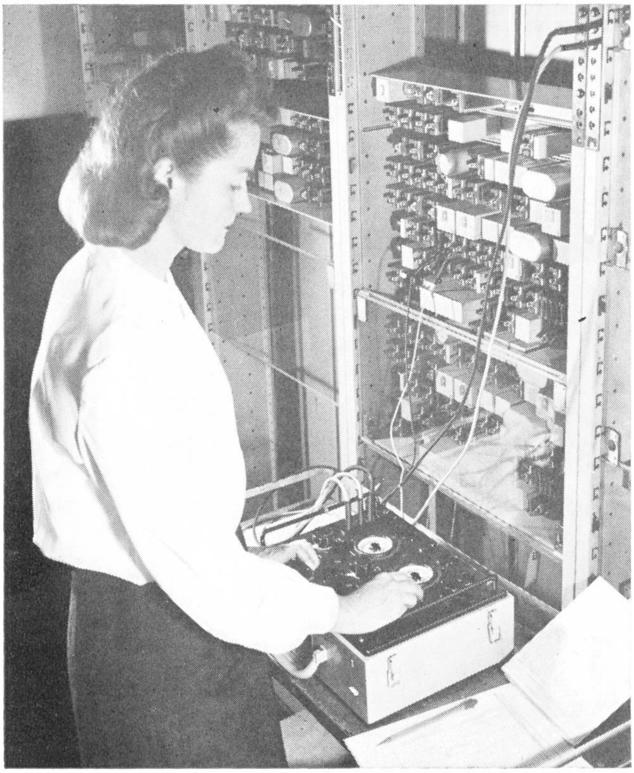


Fig. 1—Cold-cathode-tube test set in use in the Systems laboratory

The voltage at which individual cold-cathode tubes will ionize and conduct current varies considerably, resulting in corresponding variations in the time delay obtained with different tubes. To prevent excessive time variations that would result from the use of tubes with ionization voltages greater or less than the specified tolerances, a test set has been developed for checking these tubes. The principal equipment of the test set consists of a voltmeter, a milliammeter, potentiometers, keys, and sockets for mounting the various types of tubes to be tested, all of which are encased in a standard metal test set box as shown in Figures 1 and 5. Jacks provide access for testing wired-in tubes and for connecting to the necessary testing battery by patching to frame jacks furnishing the required −48 and +130-volt potentials. Binding posts are provided for making direct connections to tubes with lead-in wires.

Most of the testing connections are set up by operating either of two keys to one or the other of two positions. The SG key is used for testing the starter gap, and the AG key for the main anode gap. With triodes, tests may be made on the starter and anode gap successively, but for diodes only the AG key is used. Each of these keys has an ionization test position marked ION, and voltage drop test position marked DROP. Figure 2 shows the circuit established for testing the starter gap. The only change made by moving the SG key from the ION to the DROP position is to change the voltmeter connections so as to read the potential across the starter gap rather than that from the starter anode to ground.

With the SG key in the ION position, the SG-V potentiometer is turned until the tube starts to pass current, which will be indicated by a sudden increase in the reading of the milliammeter. The potential to ground on the starter anode may then be read on the voltmeter after the RLS key has been operated to extinguish the tube and

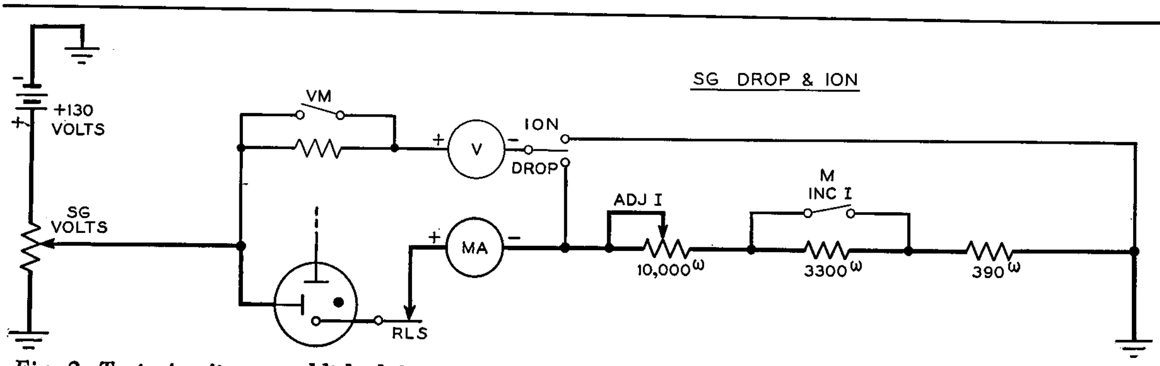


Fig. 2—Test circuit as established for testing the starter gap

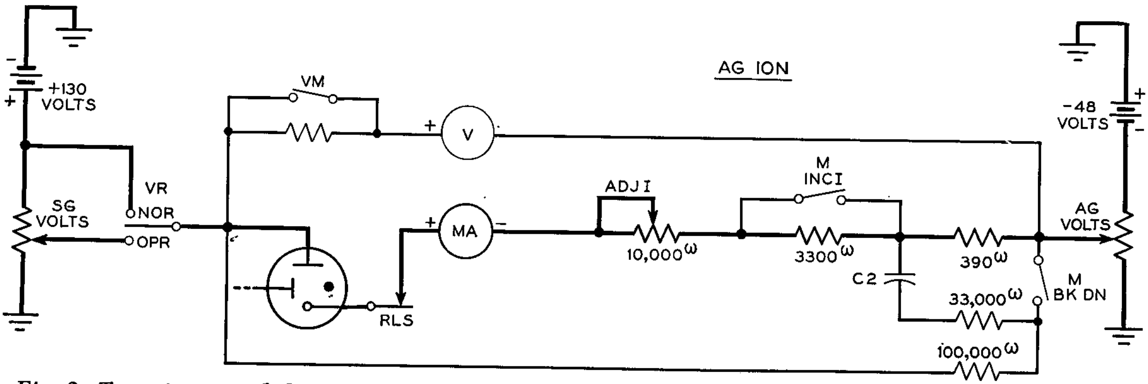


Fig. 3—Test circuit with key in "ION" position

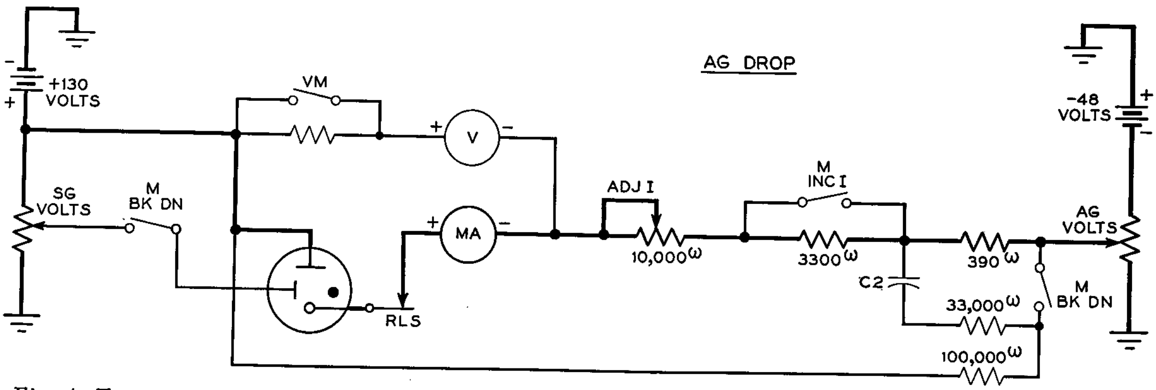


Fig. 4—Test circuit with key in "DROP" position

reduce the current to zero. To measure the drop across the starter gap, the SG key is moved to the DROP position so that the voltmeter is connected directly across the starter gap. In either position, the potential of the starter anode to ground may be adjusted to the desired value. The drop across the starter gap cannot be measured on tubes that are permanently wired in a circuit, since the anode is connected directly to positive battery, and the anode current would prevent such measurements.

Current through the tube for the starter and anode drop tests may be adjusted by the ADJ-I potentiometer. When more current is required than may be obtained with this potentiometer, the M key may be moved to the INC-I position, thus shorting out a 3,300-ohm resistor in the cathode circuit. There are thus two ranges over which the current may be adjusted, and over both ranges the ADJ-I potentiometer is used to obtain the

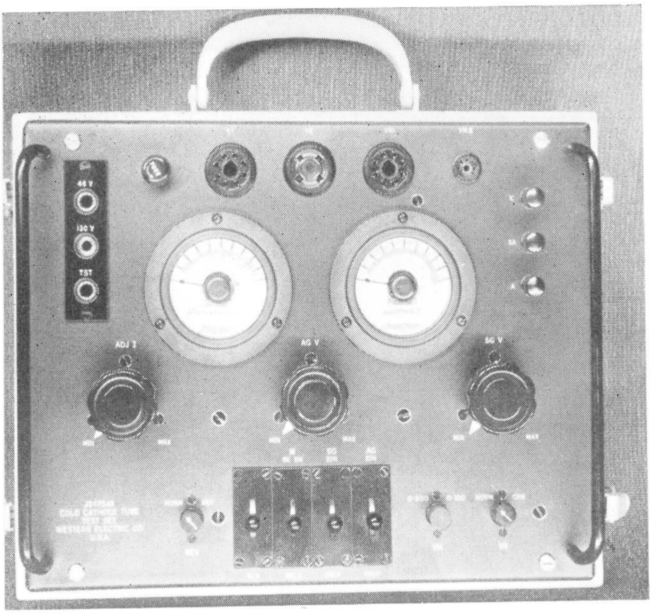


Fig. 5—Front view of cold-cathode-tube test set

exact current required. The voltmeter also has two ranges: 100 and 200 volts. Normally, the 200-volt range is connected in, but by operating the VM key, a resistor in series with the voltmeter is shorted out to give the 100-volt range.

When the AG key is operated to the ION position, the circuit is as shown in Figure 3. Normally, the anode is connected directly to the +130-volt battery, and the cathode —through the milliammeter and the cathode resistor—is carried by way of the AG-V potentiometer to the −48-volt battery. This latter potentiometer will be adjusted to the non-ionizing potential across the anode gap, and the tube should not ionize, since this is a non-operating test on the tube. For testing voltage-regulator tubes, the VR key may be operated, which changes the connection of the anode from the 130-volt battery to the SG-V potentiometer, and thus gives wide control over the anode potential. On these tubes, the potential should be adjusted to the point where the tube ionizes.

When the AG key is moved to the DROP position, the circuit is as shown in Figure 4. This is similar to Figure 3, except that the voltmeter is connected directly across the anode gap, and the anode is always connected directly to the +130-volt battery. Operation of the M key to the BK-DN position, however, will connect the SG-V potentiometer directly to the starter anode, and thus ionize the tube when the potential across the anode gap is not sufficient.

This M key closes a second contact in the BK-DN position that gives a transient voltage to start ionization. This key is used only on VR two-element tubes to insure a potential across the anode gap high enough to ionize the tube. The arrangement is shown in both Figures 3 and 4. With the M key normal, the C2 capacitor is charged to +130 volts through a large resistor. When the M key is moved to the BK-DN position, this capacitor is suddenly discharged and thus momentarily increases the voltage across the anode and cathode gaps and causes the tube to ionize. When the key is restored to normal, the capacitor will slowly recharge through the 100,000-ohm resistor.

These various keys and controls are evident in Figure 5, which shows the front of the test set. Across the top are four receptacles for various types of tubes, while at the upper right are binding posts for connecting to tubes with lead-in wires. At the upper left are jacks for battery connections and also a test jack for connection to wired-in tubes.

In a line directly beneath the two indicating meters are the three potentiometers already referred to. Beneath the central potentiometer are four keys: the AG, SG, M, and RLS keys, reading from right to left. The latter key opens the cathode circuit and thus de-ionizes the tube preparatory to making a new test and also permits reading ionizing voltages. The VR and VM keys are at the right of this group, while at the left is a reverse key that reverses the connections to the cathode and starter anode for testing bi-directional three-element tubes.

As used in the new No. 5 crossbar offices, the set may be kept at some convenient location and tubes carried to it for testing, or the set may be carried to the frames where the tubes are located when tests are to be made on tubes that are permanently wired into the circuit. Figure 1, on page 481, shows a test of this latter type being made in the No. 5 crossbar laboratory. Complete with cords, the set weighs only twelve pounds and thus is readily carried about a central office as needed.

Maintenance facilities for the No. 5 crossbar system

O. H. WILLIFORD
Switching Engineering

In a No. 5 central office, new maintenance devices and techniques are employed, and the use of automatic trouble detecting facilities is increased. Also there is a greater degree of automatic coverage of the outside plant than in previous systems. Practically all the controls for maintenance equipment are concentrated in one location, called the maintenance center; the one at the Media office in Pennsylvania is shown in Figure 1. The equipment includes primarily a trouble recorder, an automatic monitor, a master test circuit, and a jack bay for outgoing trunks. Here also are means for extending the alarms* to a distant office during unattended periods.

The trouble recorder† functions automatically to keep a punched-card record of troubles that occur on service calls, both for the major part of the central office equipment and for the associated outside cable plant as well. The automatic monitor checks on a sampling basis the performances of the pulse-receiving equipment of all register circuits, and the pulse-sending equipment of all senders, and causes the trouble recorder to make records of irregularities disclosed. The master test circuit provides for simulating service calls under controlled conditions. This aids the maintenance personnel in the final diagnosis of an indicated trouble condition, and also permits insurance tests to be made of those parts of the central office equipment that do not have access to the trouble recorder. It also permits tests to be made of subscribers' line and outgoing trunk conductors, and associated incoming trunk circuits in distant offices. This includes a rapid test for continuity and polarity of outgoing trunks. The alarm extension facilities can keep an attendant at a remote central point informed of the occurrence of each trouble, and indicate to him its classification as to urgency of corrective action.

Automatic recording of trouble is aided by the nature of the No. 5 system wherein markers become associated with all major circuits in the process of establishing connections. Self-checking features, which are basic elements of markers, also check the associated circuits, and where faults are detected, they are recorded. Markers become associated with line circuits for originating and terminating calls, when checks for continuity and the absence of false ground are made, and through associated senders on outgoing calls they receive indications of open outgoing trunks. Such failures are recorded on the trouble recorder when encountered. Under key control, the trouble recorder may also record the identity of lines on which permanent signals occur.

The automatic monitor is provided to disclose irregularities in the pulsing features of registers and senders. This is one of the new devices in crossbar switching, and its performance is being followed with interest. Its circuit consists essentially of pulse-receiving equipment and two sets of digit recording relays. It associates itself automatically with registers on service calls and records on one set of recording relays the digits pulsed into the register by the subscriber, and on the other set, the digits passed from the register to the marker. It similarly associates itself with senders, and on one set of recording relays records the digits sent to the sender by the marker, and on the other set, the digits pulsed out by the sender. With both senders and registers, after pulsing is completed, the two sets of monitor recording relays are compared, and if mismatch occurs, the trouble recorder is caused to make a record of the details of the call. This record includes the identity of the as-

* See pages 126 and 131.

† See page 112.

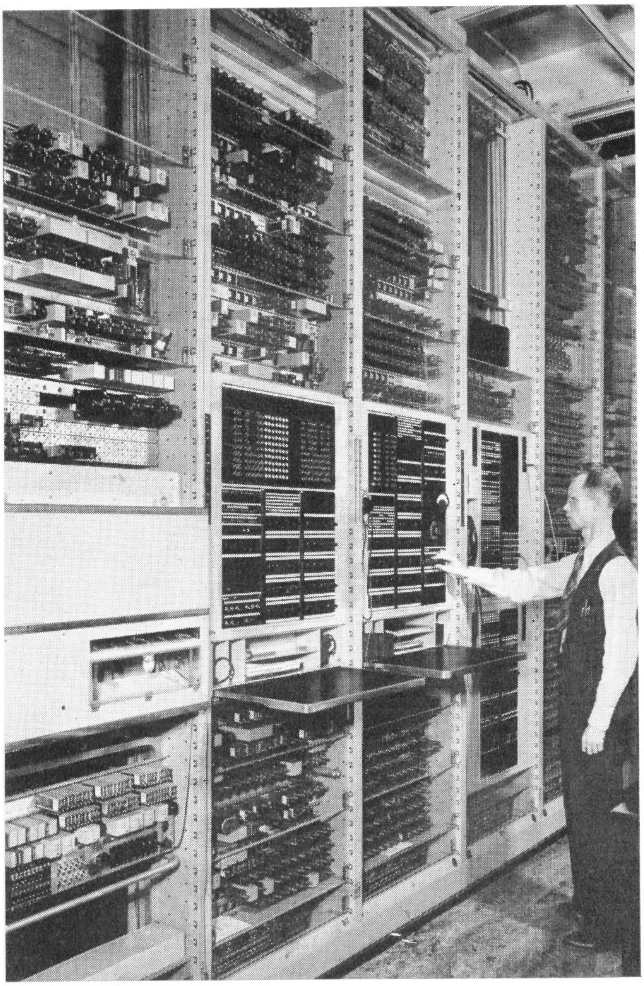


Fig. 1—Maintenance center of the Media No. 5 office.

sociated line or trunk, since some types of failure might be due to faulty line or trunk conditions. One monitor circuit cannot, of course, monitor all calls, but it works continuously, and over a period checks a substantial percentage of the calls each register or sender handles.

The No. 5 system is designed to permit a degree of unattended operation and therefore it is expected that there will be scheduled periods when an office is attended and others when it is not. Since the trouble recorder is automatic, it will record troubles which occur while the office is unattended as well as while it is attended. Also, during the unattended periods, alarms will be transferred to an attended office, and the seventy codes available permit the nature and seriousness of the trouble to be readily appraised. A repair man would at once be dispatched to the unattended office should any serious trouble arise, but normally the troubles will not be of a nature to require immediate attention.

When the maintenance force returns to the office at the next maintenance period, the punched cards stored in the trouble recorder give details on the troubles that have arisen, and thus they can readily be located and remedied. For this purpose the master test circuit is available. Its control panels carry keys and push buttons to permit the markers, registers, senders, and trunks to be selected as desired for a test call, and lamps on the control panel indicate the progress of the call. The automatic monitor can also function as a test circuit, and will be called in by the master test circuit in testing registers and senders. Troubles occurring in the major circuits while under test will be registered on the trouble recorder. The trouble recorder may also be controlled to give a record of the establishment of test calls which complete satisfactorily, to supplement lamp signals. Start and release control of this master test circuit can be extended to any point in the office where a maintenance man may wish to observe the performance of the equipment under these conditions.

While the office is attended, the master test frame is the observation and control point for the office. Here progress lamps display continuously the flow of traffic through the office, and an experienced man can often tell by the pattern of these lamp flashes in space and time whether or not all is well in the office. Audible and visual alarms will indicate the occurrence of irregular conditions in either the inside or outside plant under operating conditions. Individual circuit make-busy jacks are also concentrated here so that circuits with indicated troubles can be quickly isolated from service. Access by the master test circuit to circuits plugged busy is not prevented.

Both the trouble recorder and master test circuit are designed for use with automatic message accounting equipment where this is provided. It is necessary only to add a small relay unit to the master test circuit to adapt a master test frame for automatic message accounting maintenance. The trouble recorder was also designed in anticipation of the future automatic testing of subscriber lines for low insulation resistance. When this is provided, subscribers' lines can be tested automatically when desired, and the trouble recorder will record the identity of lines found to have less than an established minimum insulation resistance.

The possibility of unattended operation for extended periods of time lies in no small measure in the many operating safeguards that have been built into this system. The extensive use of second-trial and alternative-choice features prevents localized troubles from interfering with the completion of calls through the office, and circuits have been designed to prevent the pyramiding of trouble that has sometimes occurred under overloads in previous offices. These designs include a more liberal provision of timing intervals in the markers. This permits timing the switching functions in smaller increments, thus providing less circuit delay when failure is encountered, and advance by timeout is required. Every precaution has been taken to localize trouble when it does occur. The more extensive use of double contacts, the elimination of relay types and contact combinations that have required abnormal maintenance in previous experience, as well as a more liberal use of contact protection, greatly contribute to the freedom from trouble in the No. 5 office.

The Automatic Monitor

J. W. BRUBAKER
Switching Systems Development

In the panel and crossbar systems that preceded No. 5 crossbar, the senders, which perform the functions of both the register and sender in the No. 5 system, are maintained by circuits that originate test calls to each sender to check its various features—advancing automatically from sender to sender unless a trouble condition is disclosed. In the No. 5 system the objective has been to indicate troubles in senders and registers while they are handling service calls.

To meet this objective, the automatic monitor was designed to connect on a random basis to the registers and senders as they are selected for service calls. If connected to a register, the monitor independently records the called number pulsed into the register from the line, and checks it against the number that the register passes to the marker. If connected to a sender, the monitor records the number pulsed out over the trunk by the sender, and checks it against the number passed to the sender. If the numbers do not check, a trouble record is made.

This monitor forms part of a larger circuit known as the automatic monitor, register, and sender test circuit.* These latter facilities, which will be described in a subsequent article, are used to locate both the troubles reported by the monitor and those indicated by other methods. The monitoring and testing facilities are combined into a single circuit because a number of the circuit units are used for both. Actually the test facilities comprise the greater part of the circuit.

The monitor is arranged to check three general types of circuits: originating registers, incoming registers, and outgoing senders. It progresses from one type of circuit to the next in the order named under control of a ten-step allotting circuit, which steps once for each monitored call. Cross-connections in the allotting circuit provide flexibility in apportioning the monitoring between the three types of circuits. This is usually done in proportion to the number of circuits of each type in the marker group. A typical division of the ten calls would be six on originating registers, two on incoming registers and two on outgoing senders. Since during light load periods there may be no interoffice traffic for long intervals, the allotting circuit is arranged to advance one step if no calls are received for one minute to prevent the monitor from waiting for sender or incoming-register calls during such periods. By key selection, monitoring can be confined exclusively to originating registers, incoming registers, or outgoing senders. Should a register or sender be suspected of trouble, the monitor can be caused to monitor every call that the suspected register or sender handles.

Each time a marker starts to establish a dial-tone or outgoing-sender connection, it requests the use of the monitor, and if the monitor is idle and if its allotter at that time is in the position to monitor on an originating register or outgoing sender, the marker will gain access to the monitor. If an originating register is called for, the marker—having gained control of the monitor—operates a relay in the register that establishes a direct connection between the register and the monitor. In addition to certain signaling leads, this connection includes the tip and ring leads incoming to the register from the subscriber's line. A dial pulse amplifier is bridged across these tip and ring leads in the monitor. The amplifier is a vacuum-tube circuit with a high-impedance input so that it will not disturb the pulsing capabilities of the register. As

* See page 105.

the subscriber dials, the pulses are amplified, counted, and registered by the monitor independently of the originating register.

When dialing is completed, the originating register selects a marker to set up the connection called for. The operation from this point on is illustrated by the block diagram of Figure 1. When the register is connected to a marker, a direct connection for a limited number of signaling leads is established between that marker and the monitor, which has remained connected to the register. At this time the monitor selects the master test frame connector and causes the marker also to connect to this connector. This connection between the marker and monitor through the master test frame connector is used principally to permit the monitor to record the called number that the register is passing to the marker. The line location of the calling subscriber's line is also recorded in the monitor at this time so that pulsing failures caused by unfavorable subscriber line or dial conditions can be associated with the line causing the trouble. The relays and leads which connect the marker to the master test frame connector are part of those used when the marker connects to the trouble recorder to make a trouble record.*

When the monitor has recorded the information it receives from the marker, the connections to the monitor both direct and through the master test frame connector are released, and the monitor starts checking the called number. It has two sets of register relays; on one set is recorded the number the monitor received from its dial pulse amplifier, and on the other set is recorded the number that the originating register passed to the marker. If the two numbers are identical, comparable relays in each set will both be operated or unoperated, and a check circuit through all relays will be completed. If this check is satisfactory, the monitor waits for the marker and originating register to restore to normal, and then releases and awaits a new call.

Should the number check fail, the monitor selects the master test frame connector for connection to the trouble recorder. The trouble record card will indicate the called number that the monitor registered, and the called number that the register passed to the marker. In addition the card shows the location of the calling line, the originating register location, and the marker number. When the trouble record is complete,

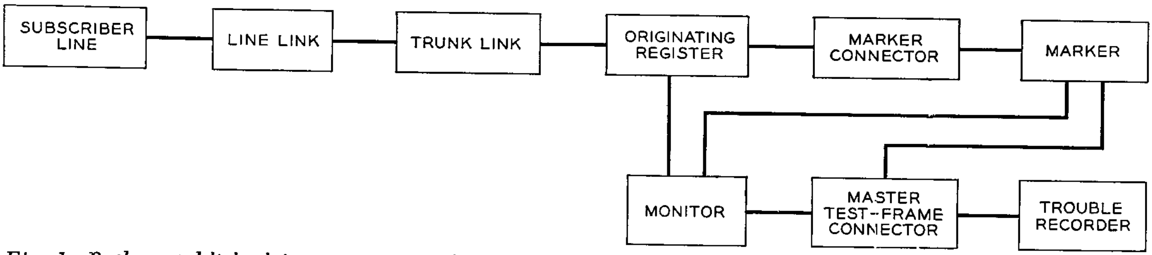


Fig. 1—Paths established for monitoring the action of an originating register.

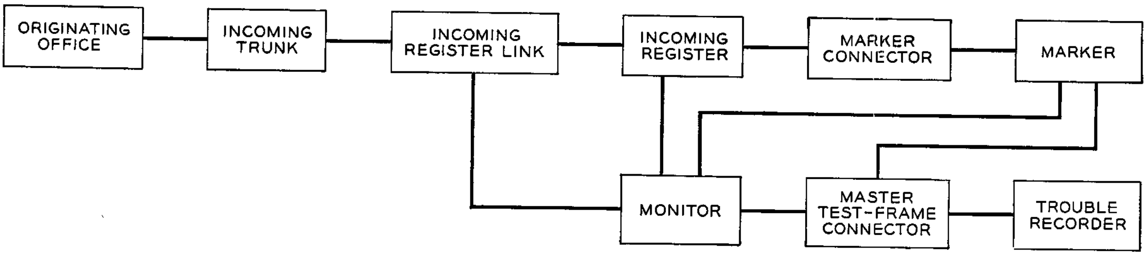


Fig. 2—Paths established for monitoring the action of an incoming register.

* See page 112.

the monitor restores to normal and awaits a new call. Trouble records may be due either to register trouble or to improper line and pulsing conditions. Since both the register and the line are identified on the trouble record card, repeated trouble records should indicate which is at fault.

The connections which are established for incoming register monitoring are shown in the block diagram of Figure 2. When an incoming trunk is seized, it is connected to an incoming register by the incoming register link circuit. As the connection is being established, the use of the monitor is requested by the link, and if the monitor is available, it is associated with the register by operation of a relay in the register. If the incoming register is of the dial-pulse type, the operation from this point on is as described for an originating register except that the location of the incoming trunk instead of the subscriber's line will be shown on the trouble card.

In addition to dial-pulse incoming registers, a No. 5 office may also have revertive and multifrequency incoming registers. For receiving multifrequency pulses, a high impedance amplifier is bridged across the tip and ring to the incoming register. The output of this amplifier is connected to a standard multifrequency receiver associated with the monitor, which detects the incoming frequencies, and operates corresponding register relays.

With revertive-pulse incoming registers, the monitor inserts a low resistance relay in series with the pulsing circuit. The output of this relay is counted and registered in the monitor. In revertive pulsing, the thousands and hundreds digits are translated at the originating office and transmitted to the No. 5 office as three numbers, or "selections," while the tens and units digits are transmitted without translation. In both the incoming register and the monitor the initial three selections are retranslated into the thousands and hundreds digits, since communication between circuits within a marker group of the No. 5 system is on the basis of the digits as dialed.

For outgoing sender monitoring, the marker requests the use of the monitor as soon as it recognizes that the call will require an outgoing sender. The block diagram of Figure 3 illustrates the connections involved. At the time the marker selects the monitor, a direct connection for a limited number of signaling leads is immediately established between the marker and the monitor. The monitor also connects to the marker through the master test frame connector. Through this latter connection the monitor receives the called number, which is being passed to the marker from the originating register, and also the signals passed from the marker to the sender, which may require the sender to modify the number sent it. On

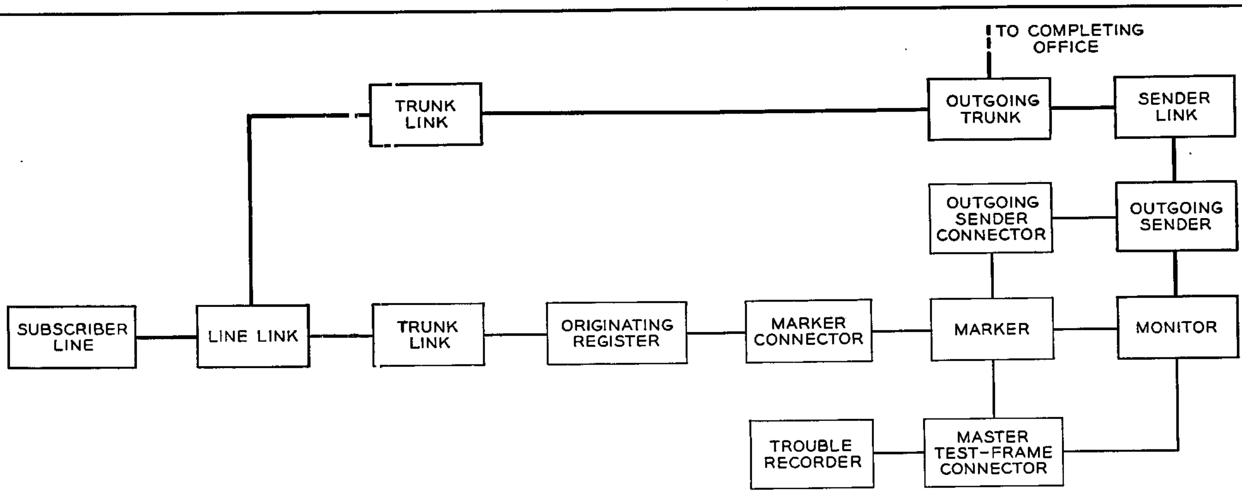


Fig. 3—Paths established for outgoing sender monitoring.

a direct call to another office, for instance, the office code will not be pulsed out, and the marker will indicate this to the sender. The marker may also direct the sender to prefix a one-one, an additional digit, or both ahead of the number passed to the sender. Such signals from marker to sender are recorded by the monitor, since it must readjust its checking circuit to take into account any difference between the number which is passed to the sender and the number which is pulsed out. In addition to the called number, the monitor records the location of the outgoing trunk used on the connection. When all necessary information has been recorded, the paths between the marker and monitor both direct and through the master test frame connector are released.

When the marker connects to the outgoing sender, a relay is operated in the sender that establishes a direct connection between the sender and the monitor. After the marker has completed its functions, it releases, and for the remainder of the time, while the sender is pulsing out, the connections are as shown by the heavy lines in the diagram.

Through the direct path to the sender, the monitor connects to the tip and ring over which the sender outpulses. The pulses sent out by the sender are picked up, counted, and recorded in essentially the same manner as described for registers. There are four types of outgoing senders, multifrequency, dial pulse, revertive, and panel call indicator. Monitoring on the latter sender requires a special amplifier to repeat the PCI (panel call indicator) type of pulsing. After the sender has completed pulsing, the monitor checks the pulsed out number against the number passed from the register to the marker. A trouble record is made if the numbers do not check.

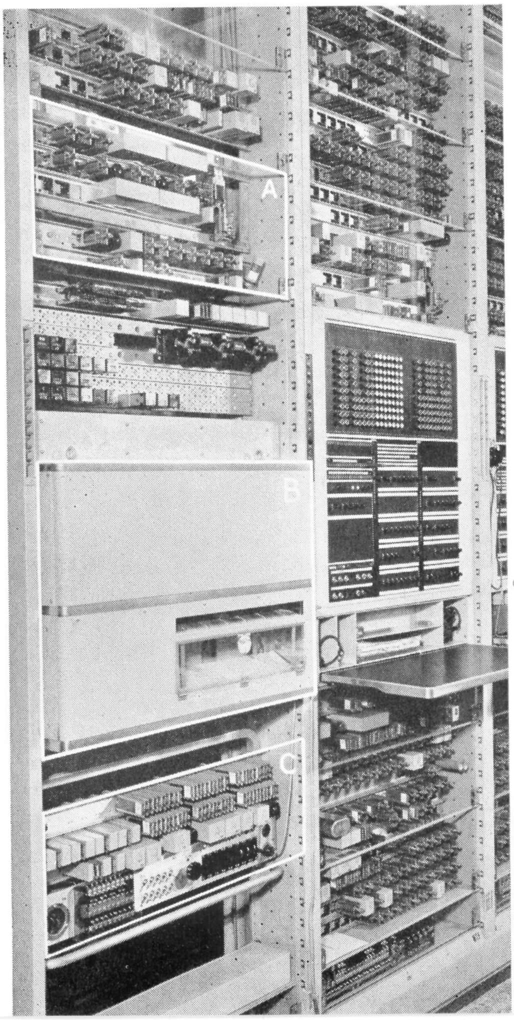
In the initial No. 5 crossbar installation at Media, records indicate that there are approximately 35,000 daily usages of outgoing senders, originating registers, and incoming registers. There are approximately 2,000 monitor usages per day. Thus about one call in every seventeen handled by a register or sender is monitored. Larger offices will, of course, have more senders and registers, but one monitor is still considered adequate to sample sender and register operation and to bring any faulty operation to the attention of the maintenance forces.

Trouble recording for the No. 5 crossbar system

A. C. MEHRING
Switching Systems Development

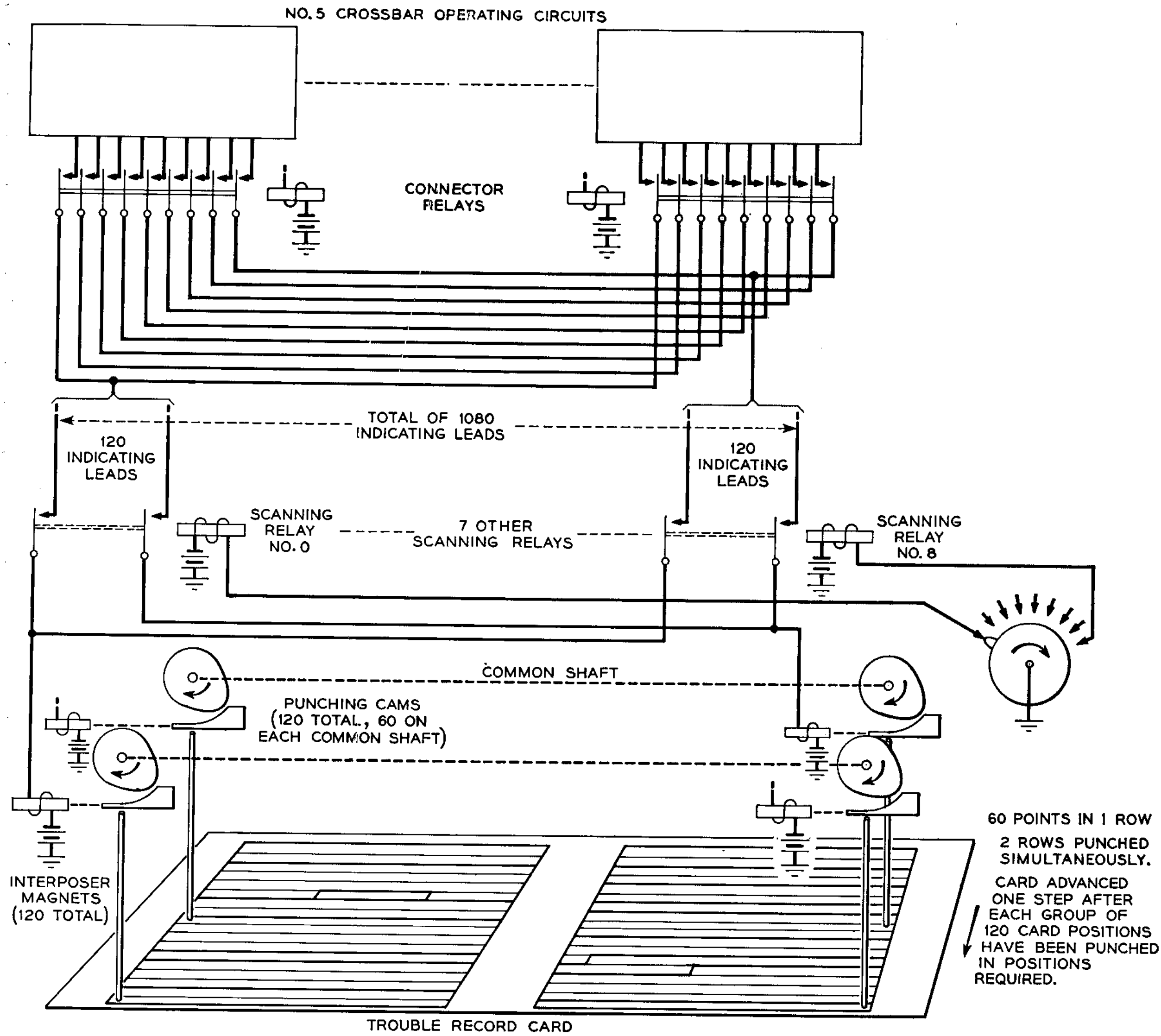
In the No. 1 crossbar system, trouble indicators are employed to give information that will assist the maintenance force in locating troubles as they arise. When such a condition occurs, lamps in various groups light up, and a maintenance man records the information they display. With continually recurring trouble conditions, this recording alone requires considerable time. When trouble conditions recur in rapid sequence, moreover, it is impossible to record all of them; under some conditions only a small percentage may be recorded. Since these records are used as a guide in clearing the trouble conditions, it has been desirable to provide a much faster recording method so that a higher percentage of the troubles would be recorded, and so that records could be made when the office was unattended. To make this possible, a trouble recorder perforator and associated circuits, shown in the accompanying illustration, have been provided as a part of the maintenance center in the No. 5 crossbar office.

At the maintenance center in Media, the trouble recorder occupies part of the left hand bay. The trouble recorder circuit is at A, the trouble recorder unit at B, and the perforator test circuit at C.



For each trouble it handles, this recorder punches a trouble record card, one of which is shown on pages 114 and 115. There are 1080 positions on this card arranged in eighteen lines of sixty positions each. Those points in the central office from which an indication is required when locating troubles are given designations and assigned positions on this card. As a trouble record is being taken, all of the points associated with the circuit that indicated a trouble are tested; where a positive signal is received, the trouble recorder perforates a hole in the corresponding position on the trouble record card referred to above.

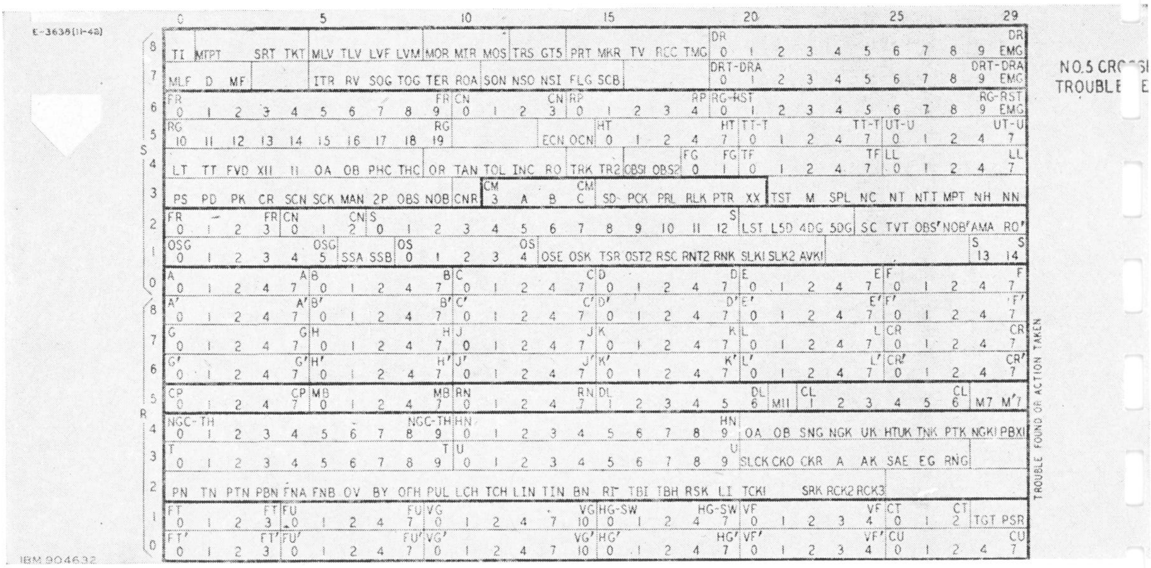
In the recorder there is a bank of 120 punches mounted in such a way that they can punch any or all of the sixty positions in each of two lines on the card. The first and the tenth lines from the bottom of the card are punched first, and then the card is shifted to permit the second and the eleventh to be punched, and so on. The complete



Simplified diagram indicating the arrangement of the trouble recorder and its associated circuit.

punching operation is thus made in nine steps to cover the eighteen lines on the card. The entire punching operation requires about one second. Which holes are punched in each operation is controlled by an interposer magnet for each of the 120 punches. These magnets act to interpose a link between the punches and the operating cams, and holes are punched simultaneously by all the punches for which the interposer magnet is operated. There is thus only a single punching operation for each two lines of the card.

The information punched on a record card consists of six major groups: (1) the equipment included in establishing the connection; (2) the type of connection being established; (3) how far the various circuit operations had progressed before the trouble occurred; (4) information as to the specific test that has indicated trouble; (5) information which is helpful or necessary in determining the source of the trouble, such as the identification of the calling line, the called line, the trunk, and the channel through which the connection is established; and in



Card used for recording trouble.

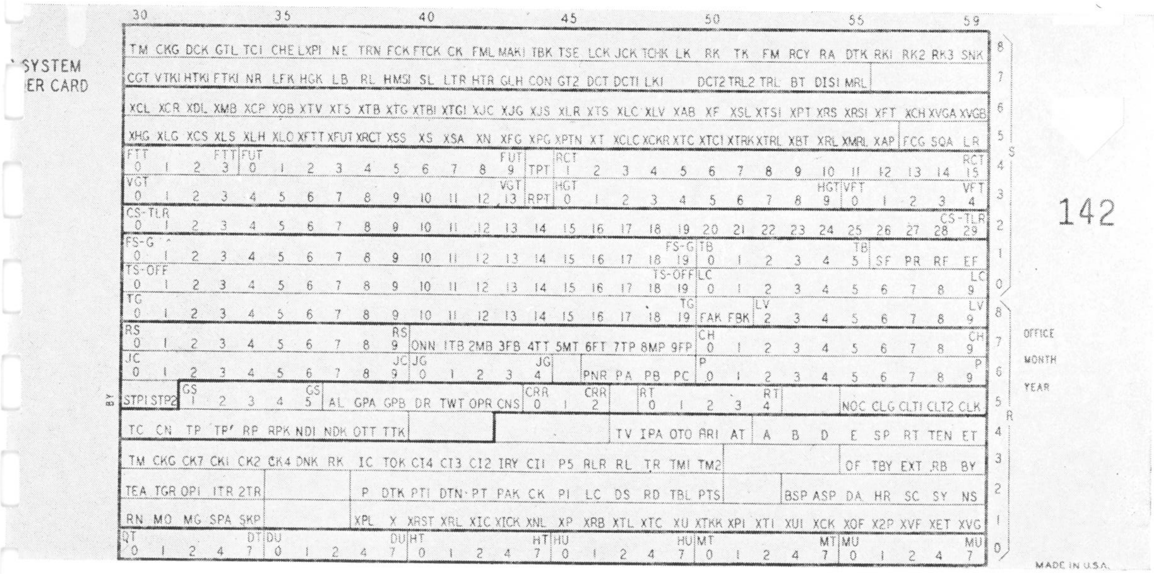
some offices (6) the time the trouble occurred.

This information is derived from a number of sources but chiefly from the marker and the automatic message accounting equipment when the office includes it. In the No. 5 crossbar system the greater portion of the control of a connection is associated with a marker. Each marker circuit is provided with a system of checking features so that it can detect the presence of a trouble condition within itself or within the circuits with which it is associated. Should trouble be detected by a marker, the marker will stop its circuit operations, and request the trouble recorder to make a detailed record of the information the marker contains and also of certain information of the circuits associated with the marker. A similar process is carried out by the transverter, the recorder and the master timing circuits of the AMA equipment, and by the automatic monitor register and sender test circuit.

Connections between these operating circuits and the trouble recorder are made chiefly by multicontact relays under the control of the master test frame connector circuit. Each multicontact relay will connect sixty leads, but since a circuit such as a marker will require many more than sixty leads to record the required information, there will, in general, be several multicontact relays comprising a connector to a marker or other circuit. There will be one connector for each circuit that may make a trouble record: one for each marker, one for each AMA transverter, one for each AMA recorder, and so forth. From one side of the connectors, leads run to the operating circuits that originate the trouble record, while from the other side the leads are multiplied to a set of 1080 wires—one for each specific piece of information that may be recorded. This arrangement is indicated in the diagram on page 113.

Between this set of 1080 leads and the interposer magnets of the recorder are nine scanning relays each connecting 120 of the group of 1080 leads to the 120 interposer magnets. When the recorder is seized, the proper connector is operated to connect the recorder to the circuit that has indicated a trouble condition exists. This puts the trouble information on the set of 1080 leads. The scanning relays then operate one after another in rapid sequence to extend these leads so that the perforator may punch the information on the card. After this, the connector is released and the recorder is ready to punch another card.

In general, the troubles are recorded in the order in which they occur, but a preference circuit is provided so that in the case of two simultaneous troubles, the master test frame



connector circuit will give preference to one of the requesting circuits and will exclude the others. When some unusual condition causes a number of troubles to appear in rapid sequence, all of them will not be recorded, but since a complete recording operation, including the punching of the card and recycling the perforator to the normal position, requires only a little over a second, it has been found that most of the troubles will leave a record.

In addition to providing means of recording information when a trouble condition occurs, the trouble recorder perforator and circuits are arranged to record as well the results of certain tests initiated at the master test frame.

Besides providing information to guide the maintenance force in clearing trouble that has arisen, these trouble record cards also provide permanent records of the various trouble conditions that have existed in the No. 5 office. It will be possible by examining these trouble records and noting those troubles which continually recur to work toward their elimination.

Register and sender testing in No. 5 crossbar

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A number of features are included in a No. 5 crossbar office to insure that the occasional faults arising from the continual operation of electromechanical apparatus over long periods of time will not cause repeated failures in establishing connections. These include self-checking features in the marker that test for open and crossed circuits on each call it handles, the automatic monitor[1], and a trouble recorder[2] that makes a punched card record of the nature and location of troubles reported to it. They are located at a maintenance center[3], with a number of other test circuits and facilities that are used as required. In addition to these various facilities, provisions have been made for testing registers and senders. The test facilities are combined with the monitor circuit and much of the equipment is used in common. The control of the test circuit is at the maintenance center.

Since the marker's checking features and the automatic monitor keep a continual watch on the behavior of registers and senders, the register and sender test circuit is not made automatic in its initiation of tests, but is under control of the maintenance force at the maintenance center. They use it as varying conditions require. A trouble record on a register or sender, for example,

[1] See page 108; [2] page 112; [3] page 105.

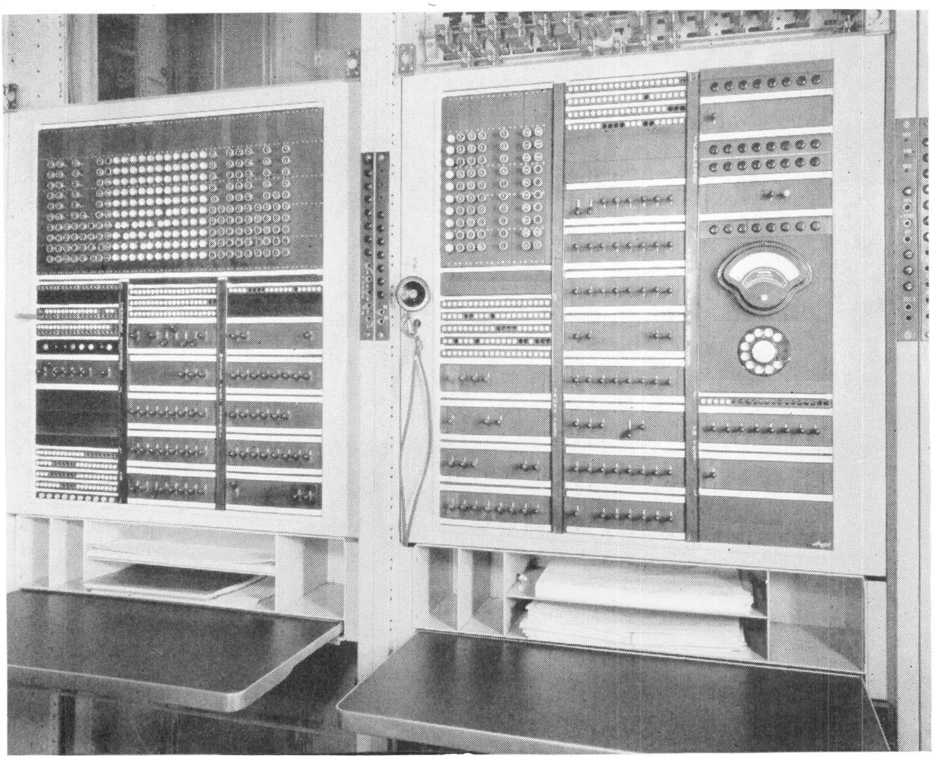

Fig. 1 — Positions at the maintenance center used for controlling the register and sender test circuit.

might indicate that certain registers or senders should be tested.

When a test is to be made, the test conditions are set up on keys on the panels shown in Figure 1. This would indicate to the circuit the number to be called, the particular register or sender to be tested, the method of pulsing, and the type of line or trunk calling. Once these conditions have been set up, the operation of a start key sets the circuit in operation. The tests are run through automatically by the test circuit, and the progress of the test is indicated by lamps. If the call goes through successfully, an OK lamp is lighted, while if trouble is encountered, lighted progress lamps will indicate the stage of operation at which it occurred. Under certain conditions, the trouble recorder is called in to make a record of the conditions found.

In running through its tests, the test circuit calls in a marker to establish connections through the line link and trunk link frames, and to select registers, senders, or trunks in the same general manner as for service calls. The major difference is that the marker may be required to select a particular register or sender rather than any idle one, and that the marker is informed it is handling a test call and will act accordingly. In addition to its other tests, the register and sender test circuit checks the recording of pulses by the register and the outpulsing by senders, and where the work is similar, it uses corresponding elements of the automatic monitor. To provide a margin of safety, all pulsing tests are more severe than encountered on service calls.

The various circuits called into action in testing an originating register are indicated in Figure 2. In each office there is a line link vertical to which the register and sender test circuit has access, and after the test conditions have been set up and the start key operated, a marker is seized and this line location and the particular originating register desired is transmitted to it. The marker then establishes a connection through the line link and trunk link frames to the desired register, operates relay M in the register, and then disconnects. Relay M connects the register to a set of test leads from the test circuit that is multipled to all the registers in the office. In this way there is established a circuit through a line link and trunk link frame to the register and back to the test circuit as indicated by the solid lines in the diagram. Over this circuit the various test conditions are applied. Following this, the register seizes a marker to transmit to it the number pulsed into the register from the test circuit. The marker, recognizing that this is a test call, establishes a connection to the test circuit, over the master test frame connector, so that the digits and other in-

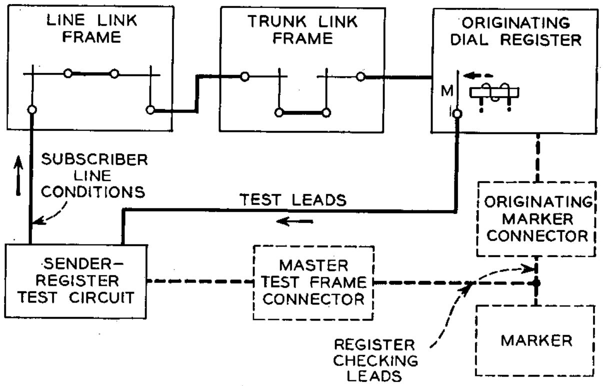

Fig. 2—Block schematic of circuits brought into action in testing originating registers.

formation transmitted to the marker can be recorded in the test circuit and checked against the information transmitted to the register. If the information were not properly recorded by the register and transmitted to the marker, the trouble recorder would be called in to make a record. Other troubles will be indicated by lamps. If all tests are satisfactorily completed, the OK lamp will light and the connection will be broken down.

For testing senders, the circuits employed are those indicated in Figure 3. Following an initial procedure similar to that described above, a marker is seized and establishes a connection to the desired trunk and selects the desired sender, and the trunk connects to the sender through the sender link. Relay TT is operated in the trunk to transfer the T and R leads of the trunk from the circuit to the distant office to the test circuit. Relay M in the sender is also operated to connect the sender to the test circuit over a special set of leads as was done for the originating

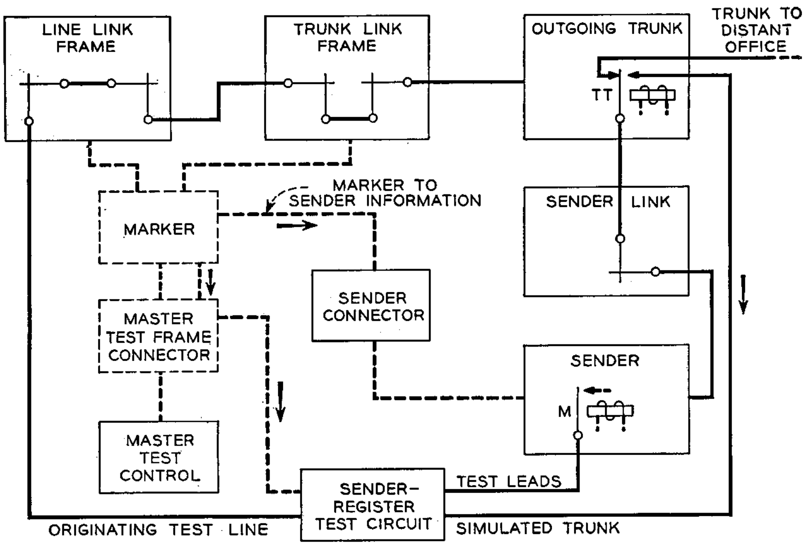

Fig. 3 — Block schematic of circuits used in testing senders.

register. Outgoing pulsing information is then transmitted to the sender by the marker and is received by the test circuit through the master test frame connector. After this, the control circuit shown by the dotted lines is released. The sender test circuit then applies various tests to the sender, records the pulses sent out by the sender, and checks the results against the known information. Pulsing troubles result in a trouble record card. Other types of troubles will be indicated on lamps.

Figure 4 illustrates in a similar way the connections established for checking incoming registers. The marker is not used for establishing the connection, but a preference circuit within the test circuit secures access to the desired register through the incoming register link circuit. The test circuit applies the desired test, and the register then calls for a marker. Recognizing this as a test call, the marker stops progress, calls in the master test frame connector, and permits the test circuit to record all the information the register is transmitting to it. This connection, shown by the dotted lines, is established only momentarily. The test circuit then matches the register results against the known information, and gives an OK lamp if everything is satisfactory, a trouble card on pulsing failure, or a trouble lamp on other types of trouble.

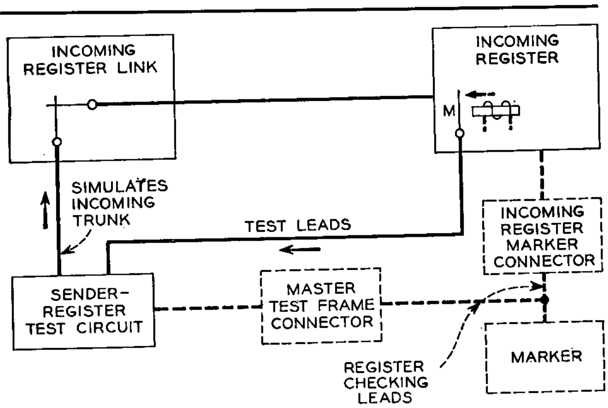

Fig. 4—Block schematic of circuits used in testing.

The relays, amplifiers, resistances, and other circuit elements are mounted on standard frames. One frame is used for the monitoring apparatus, and a double frame for the test equipment used for all registers and senders employing dial or multifrequency pulsing. An additional frame is required when revertive pulsing or call indicator pulsing is required. The keys for controlling the tests and lamps for indicating the progress and results of the tests are mounted adjacent to the master test control circuit keys and lamps as shown in Figure 1. The monitor register and sender test apparatus is shown on the middle panel of the right-hand frame. The progress lamps are located at the top of the panel.

Permanent signals in No. 5 crossbar

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Switching Systems Development

Ever since the first central office went into service, "permanent signal" has been one of the most prevalent conditions requiring the attention of the maintenance force. When a subscriber wishes to place a call, he must first send a signal to the central office to attract the attention of the operator or, more commonly at the present time, the automatic circuits, so that the connection he desires may be set up. This signal is now sent merely by lifting the handset from its cradle. When the handset is replaced at the termination of a call, this signal disappears, and thus normally the signal is present only while a call is in progress. Sometimes, however, the signal becomes permanent. Perhaps the subscriber started to place a call and then just after the handset was lifted, the baby cried, and the solicitous parent inattentively laid the handset on the table instead of putting it back on its cradle, and ran to her child. When the operator answers, no one is on the line and yet the signal remains there—a permanent signal now exists.

Although a receiver off the hook or a handset off the cradle is the most common source of a permanent signal, it is not the only one. Any line or equipment trouble results in a permanent signal if it grounds or shorts the line in a way that gives essentially the same condition as a receiver off the hook. Permanent signals on a large number of lines is often the first indication of a cable failure.

A permanent signal prevents any calls from being connected to the line since the line is in effect made busy by the permanent signal. As a result, not only is the party responsible for the permanent signal prevented from receiving calls, but on multiparty lines all subscribers are similarly restricted. Its effect on a central office and the apparatus there depends on the type of office. In a manual office, little harm is done. The answering lamp of the line in front of the operator remains lighted, and the line itself is made busy, but other lines and equipment are not affected. In a step-by-step office, each permanent signal ties up certain of the selectors, and with a large number of permanent signals existing at the same time, the reduction in the number of available selectors may become serious. In a panel or crossbar office, any appreciable number of permanent signals would be very serious if preventive steps were not taken, since each permanent signal would tie up a common control circuit, of which there are comparatively few in the office. This situation is avoided by the use of "time out" circuits that release the common control after a comparatively short interval. In panel and No. 1 crossbar offices the methods adopted for dealing with a permanent signal have been guided to a large extent by the fact that a maintenance force is generally available in the office. In the No. 5 crossbar office, however, there may often be no maintenance force in the office for comparatively long periods, and a different philosophy had to be adopted in designing methods of dealing with it.

In panel and No. 1 crossbar offices, the method of dealing with a permanent signal consists of two stages. The first comprises a number of tests made by the operator, such as testing for a grounded line, and ringing on the line or applying a howler tone to attract the subscriber's attention so that the receiver will be replaced if it is off the hook. If all these efforts fail, an interval of between 15 and 45 minutes is allowed before further steps are taken. If the permanent signal has not disappeared at the end of this interval, the circuit is turned over to a test man who can determine the nature of the trouble by measurements on the line and can take steps to have it cleared. These two stages are retained by the No. 5 crossbar equipment, but the over-all supervision is made automatic, and since the operator to whom the line is first turned over may be in an office distant from the No. 5 crossbar office, a signaling system must be provided to transmit information back and forth between the No. 5 crossbar and the distant office.

When an originating register is connected to a subscriber line in a No. 5 crossbar office, it connects dial tone to the line and starts a timing circuit. If dial pulses are not received within approximately 25 seconds, the register calls in a marker and informs it that a permanent signal condition exists on the subscriber's line. The marker then connects the line to a permanent signal holding trunk, and disconnects it from the register. This takes the line out of service and prevents it from making further use of the common control circuits until the trouble has been cleared.

These permanent signal holding trunks are connected to the trunk link frames as are outgoing, incoming, and intraoffice trunks, and usually two are provided for each frame, although more or fewer may be provided if conditions make it desirable. One of these permanent signal holding trunks is indicated in Figure 1, which shows in block form the general method of dealing with a permanent signal in a No. 5 crossbar office.

As soon as a line is connected to it, a permanent signal holding trunk at once takes a number of steps that will lead to the ultimate removal of the permanent signal conditions. It extends the line terminals to the master test frame at the maintenance center of the No. 5 office and lights a lamp there to indicate the number of the permanent signal holding trunk involved, and whether the trouble is on a PBX line, a coin line, or a noncoin line. This information is given to the permanent signal holding trunk by the marker and will be used in clearing the trouble, since different types of lines require different treatments. The holding trunk also extends the line to a test and selector circuit where it will be available for test from the local test desk.

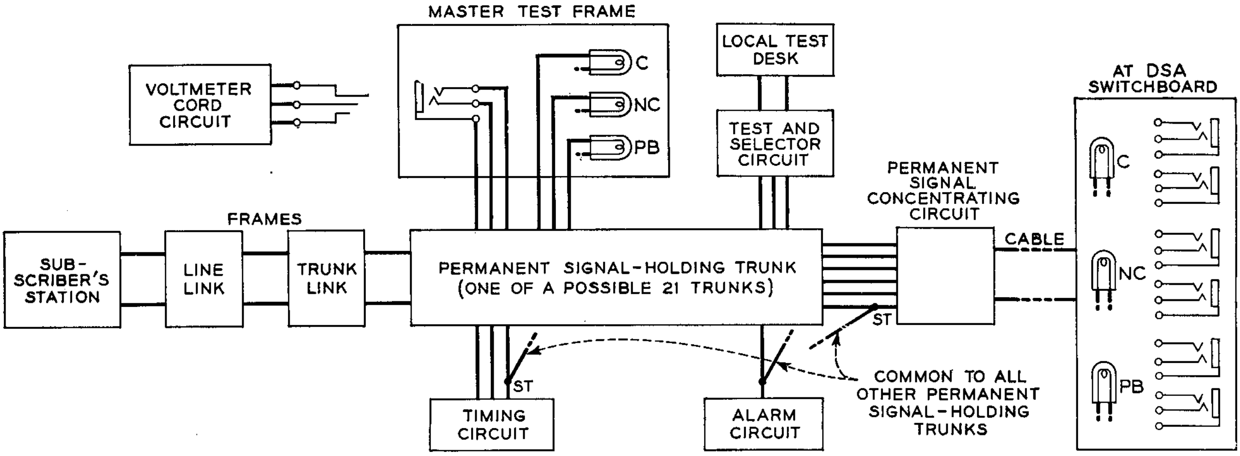

Fig. 1—Block schematic indicating method of handling permanent signal in a No. 5 crossbar office.

Since the first attempt to clear the permanent signal condition will be made by an operator, the holding circuit also extends the line to a concentrating circuit through which it will be extended to a DSA operator. This concentrating circuit can serve as many as twenty-one lines and connect them one after another over a single trunk to a DSA operator for test. It also serves another purpose. The DSA board may be in an office a considerable distance from the No. 5 office, and if howler tone and the other tests the operator makes were applied at the DSA board, the line attenuation to the subscriber station would be too great to allow them to be effective. They are actually applied in the concentrating circuit therefore, but under control of the DSA operator. The concentrating circuit also permits simplification in the holding trunks, since certain of the control features are included in a single concentrating circuit instead of in a large number of holding trunks. At least two concentrating circuits are always supplied, and more may be used where conditions warrant it.

Besides extending the line to these various points, the holding trunk also places a high tone on the ring conductor of the line to make the line readily identifiable. At the same time it starts a timing circuit to provide an interval adjustable between 15 and 45 minutes before demanding active attention from the maintenance force. During part of this period an operator will attempt to attract the attention of the subscriber by ringing on the line or applying howler tone. She may also make certain simple tests to determine the cause of the trouble and to remove it if possible, as already mentioned.

As soon as a line is connected to the concentrating circuit from a holding trunk, the concentrating circuit passes a signal to the DSA board which lights a lamp associated with a pair of jacks at one of the positions. There are three lamps and three pairs of jacks—one lamp and one pair of jacks for each of the three types of lines already mentioned. All the jacks have access to the line from the No. 5 office, but only the lamp associated with one pair of jacks is lighted by the concentrating circuit. The operator plugs into one of the jacks under the lighted lamp and then, if she hears no distinguishable sounds and is unable to get a reply, proceeds to apply her tests. If the permanent signal disappears during one of these tests—indicating that the subscriber has hung up—the operator's type-of-line lamp goes out and the operator takes down her plug. This, together with the disappearance of the permanent signal on the line at the No. 5 crossbar office, disconnects that line from the concentrating circuit and holding trunk and restores all conditions to normal. Should the operator not succeed in clearing the trouble, she still will take down her plug, but under this condition the holding trunk remains connected to the affected line, but the concentrating circuit and switchboard is released.

To permit the concentrating circuit to indicate to the DSA operator the type of line involved, and also to receive the results obtained from the tests that the operator applies, it must be possible to pass six different signals from the concentrating circuit to the DSA board. To permit the operator there to control the application of the various tests at the concentrating circuit, it must be possible to pass seven different signals from the DSA board to the concentrating circuit. Since only one pair is used between these two points for each concentrating circuit, a special sig-

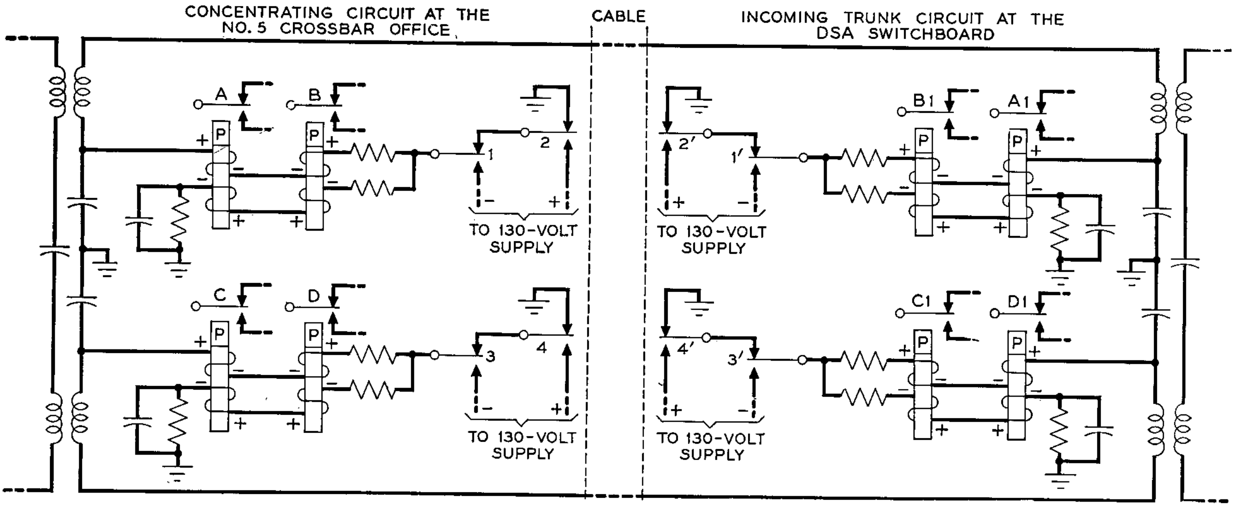

Fig. 2—Method by which six different signals may be passed from the concentrating circuit to the DSA operator and seven different signals may be passed from the DSA operator to the concentrating circuit.

naling circuit had to be developed. This is shown in simplified form in Figure 2.

This circuit permits as many as eight d-c signals to be sent in each direction over a single pair without interfering with voice transmission over the pair, and signals may be sent in both directions at the same time. Four polarized relays are used at each end of the circuit—two in series being connected to each side of the line at each terminal. To either or both of these pairs of relays—through contacts 1, 2, 3 and 4 or 1′, 2′, 3′ and 4′—either positive or negative battery is applied to transmit the signals. With positive voltage applied at contact No. 2 at the concentrating circuit, for example, only relay A1 at the DSA board will operate. Because the current is of the wrong polarity, B1 will not operate, and A and B will not operate because opposing currents pass through both the windings of each. If at the same time a positive potential is applied at contact 2′ at the switchboard, relays A and A1 will operate because of current flowing through their lower windings while no current is flowing through their upper windings. By using combinations of these relays, eight different signals can be received at the switchboard: A1, B1, C1, D1, A1 and C1, A1 and D1, B1 and C1, and B1 and D1. Similarly, eight different signals can be received at the concentrating circuit from the switchboard by using the same combinations of A, B, C, and D.

The operator will have concluded her tests before the end of the timing period that was started when the holding trunk was seized. At the end of the timing period, the holding trunk starts flashing the lamp at the master test frame that it had lighted when it was first seized. The lamp is changed from steady to flashing as soon as the trunk has timed out, but it may flash at either of two rates. It flashes at a lower rate when a connection has been made to the trunk either by the clerk at the repair service desk or by the maintenance man at the master test frame, but it flashes at a higher rate when such connections have not been made. When the trunk times out, it also gives an alarm in the No. 5 office. If there is a maintenance force in attendance at this time, the number of the line and of the permanent signal holding trunk will be reported to the repair service desk.

For economy reasons, permanent signal holding trunks, which are twelve-relay circuits, are provided only in sufficient quantity to handle the normal traffic. When an abnormal number of permanent signal conditions occur at the same time, all permanent signal holding trunks will become busy. Under these conditions, the marker will connect the subscriber line to a common overflow trunk circuit. This common overflow circuit consists of only five relays and is very liberally provided. It not only handles overflow from the permanent signal holding trunks but also the overflow from certain other trunk circuits. When the marker connects a subscriber line having a permanent signal condition to a common overflow circuit, however, it operates a class relay in the trunk which supplies high tone on the ring conductor, and also extends the line conductors to a jack located at the master test frame, and lights a lamp associated with the jack.

When an abnormal number of permanent signal conditions occur at the same time, it is necessary to attract the attention of the maintenance personnel since they may be due to a cable failure. Each permanent signal holding trunk when connected to a subscriber line and each common overflow trunk circuit when connected to a subscriber line on which there is a permanent signal, connects a resistance ground to a permanent signal alarm circuit. This alarm circuit is an integrating type of circuit and only functions when a definite preset number of low resistance grounds are connected to it at the same time. Thus, when an abnormal number of permanent signal conditions occur at the same time, the permanent signal alarm circuit causes an audible and visual alarm circuit to function, thus bringing this condition to the attention of the maintenance personnel. Should the maintenance force not be in attendance, the alarm will be extended to the distant maintenance center, and the nature of the trouble will be indicated as has already been described.*

*See pages 126 and 131

Pulse conversion in No. 5 crossbar

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Most DSA[1] and toll switchboards are equipped with pulse-sending apparatus to permit them to complete calls directly to dial offices. Depending on the types of offices in the direct switching area, this pulse-sending apparatus may be a dial or one of several types of key sets. When some of the offices to which the operator may have to complete calls require one type of pulsing, and others another type, a group of senders is commonly associated with the switchboard that will accept the pulses sent out by the operator's dial or key set and then send out to the distant office the type of pulsing it requires. Such an arrangement is generally more satisfactory than to provide two or more pulse-sending devices at each position of the switchboard and require the operator to determine the type of pulsing needed for each call she completes. These senders form a separate group for use exclusively by the switchboard.

With the introduction of the No. 5 crossbar office with its inherently great flexibility, however, it has been possible to provide arrangements that permit the No. 5 crossbar equipment, where it is in the same building as the switchboard, to be used for calls of this type, and thus the provision of a separate group of switchboard senders becomes unnecessary. Since the function of the crossbar circuits in such applications is primarily to accept one type of pulsing from the switchboard and convert it to another type for transmission over a trunk, the process is called pulse conversion. Ordinarily the amount of this type of traffic is comparatively small, and it may thus be handled by the No. 5 office with little if any increase in the size of the register and sender groups.

When an operator plugs into one of the trunks requiring pulse conversion, the procedure so far as she is concerned is the same as though she had plugged into a trunk not requiring pulse conversion. No special traffic instructions are required. The trunk circuit itself, however, is arranged to seize automatically an idle incoming register,[2] which will record the pulses from the operator's key set and certain other information. The register then seizes a marker and transfers the information to it. The marker, in turn, causes an idle sender[3] of the proper type to be connected to the trunk

[1] RECORD, *December*, 1945, *page* 466. [2] See page 5. *March*, 1950, *page* 104. [3] See page 63.

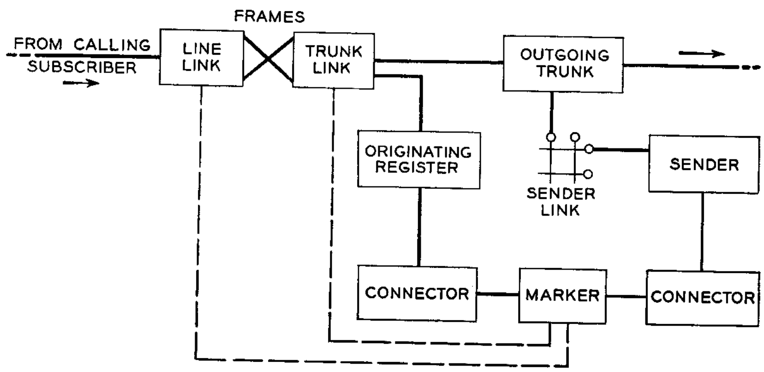


Fig. 1 — Block diagram of major circuits involved in handling an outgoing dial call.

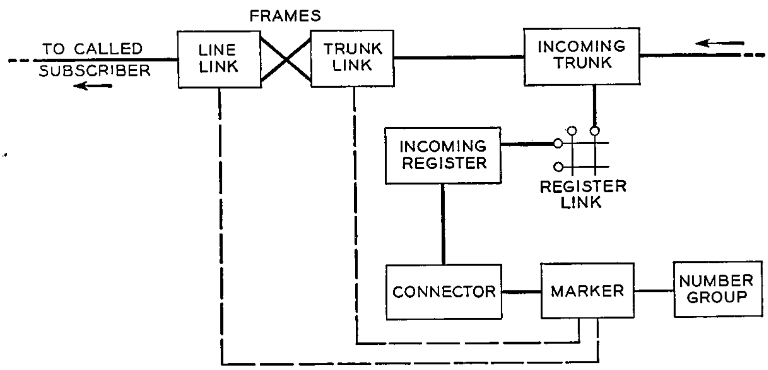


Fig. 2—Block diagram of major circuits involved in handling an incoming dial call.

into which the operator has plugged, and transfers the required information to it. The sender transmits pulses of the proper type over the trunk, connects the trunk through to the switchboard, and then disconnects itself. The register and marker will have disconnected themselves shortly after the association of the sender. The marker is held for only about a quarter of a second, and the sender only long enough to transmit the necessary pulses over the trunk.

All this sounds very straightforward and regular, but as a matter of fact, the marker in handling a pulse conversion call must follow a different procedure from many of those it carries out in completing an ordinary No. 5 crossbar call. The difference lies in the fact that the marker must first treat the pulse conversion call as though it were an incoming call, and then as if it were an outgoing call. This is possible largely because in the No. 5 crossbar system a single type of marker is capable of handling both incoming and outgoing calls.

The steps taken by a No. 5 crossbar marker in handling an ordinary outgoing call are indicated in Figure 1. The marker is seized by an originating register, which has previously been connected to the calling line by this or another marker. It then connects to an idle trunk-link frame that has an idle trunk of the desired route, and seizes one of them. Having selected and seized a suitable sender for completing the call, the marker connects it to the selected trunk. After transferring the needed information to the sender, it then disconnects. Before disconnecting, however, it had also found an idle path from the calling line on the line-link frame to the selected trunk on the trunk-link frame, which is always one of its major functions in handling a call through the No. 5 crossbar office.

Its procedure in handling an incoming call is indicated in Figure 2. In this case, the calling incoming trunk seizes an idle incoming register, and the register, after it has recorded the information regarding the connection desired, seizes an idle marker. The marker then connects to the trunk-link frame to which the calling trunk is connected, and to a number group circuit to determine the location of the line called. It then connects to the line-link frame indicated and finds an idle path from it to the trunk-link frame. It is then free to disconnect.

In handling a pulse conversion call, the marker, as previously mentioned, goes through some of the steps it follows for incoming calls, and some it follows for out-

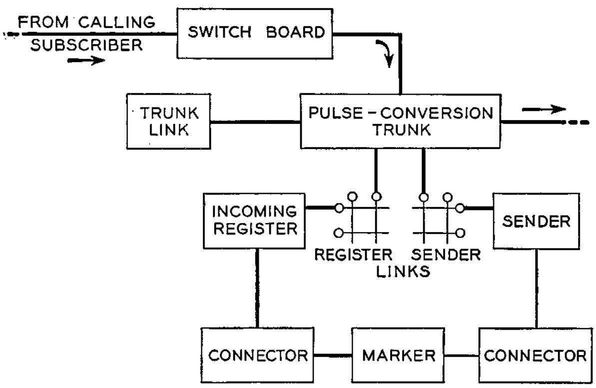


Fig. 3—In handling a pulse conversion call, the circuits used for incoming and those used for outgoing calls are both employed.

going calls, but it never has to connect to line-link frames or find idle paths between a line-link and a trunk-link frame. Its procedure is indicated in Figure 3.

The pulse conversion trunk partakes of the characteristics of both an out trunk and an incoming trunk: it is connected to a register link as is the incoming trunk and to a sender link as is the out trunk. An incoming register is seized when the operator plugs into a trunk, and after the pulses have been recorded, the incoming register selects an idle marker and transfers the information to it. The marker selects and seizes a suitable sender, and then—by way of the register link, the conversion trunk and the trunk-link frame—it operates the proper hold magnet in the sender link to connect that trunk to the sender already selected. It then transfers its information to the sender, and disconnects.

On all these drawings the paths over which the marker is seized and those that are pre-established without selective action on the part of the marker are shown by heavy solid lines. Those paths that the marker selects are indicated by light solid lines, while the auxiliary paths over which the marker gains access to the various circuits are indicated by dashed lines.

For an ordinary outgoing No. 5 crossbar call, the marker selects the trunk and the sender to be used with it. For an ordinary incoming call it selects only the path between the line-link and trunk-link frames. With a pulse conversion call, on the other hand, it selects only the sender, since the trunk has been selected by the operator, and the trunk in turn selects the incoming register. The marker is seized by the incoming register and gets the information from it as with an incoming call, and then selects a sender as in handling an outgoing call. It does not have to make a trunk selection nor find idle paths between a line-link and a trunk-link frame, however, and thus the work it does is not as extensive as with an ordinary crossbar call. Furthermore, the main switch frames of the No. 5 office are not held busy after the call has been established. The demands placed on the No. 5 office by this service are thus not great, and yet considerable economy is secured by eliminating the necessity for a special group of senders for the manual board.

Alarm system for No. 5 crossbar

C. E. GERMANTON
Switching Development

To give warning of conditions that might adversely affect telephone service, Bell System telephone offices have alarm systems which indicate by both audible and visual means the equipment in trouble. The indicators are so arranged that a maintenance man, regardless of what part of the building he might be in at the time, can find his way to the equipment in trouble with a minimum of effort. Alarm systems used previously in crossbar, and in the later panel and toll offices, have achieved this objective by using a system of bells, chimes, and colored lamps strategically placed whereby the floor, the main aisle, the aisle, and finally the circuit in trouble are indicated. In the No. 5 crossbar system, the same result is achieved but with a simplicity of design that makes possible economies in manufacture, installation, and job engineering. The components for the system are fabricated in the shop, and only a minimum of cabling is required to complete the system on the job.

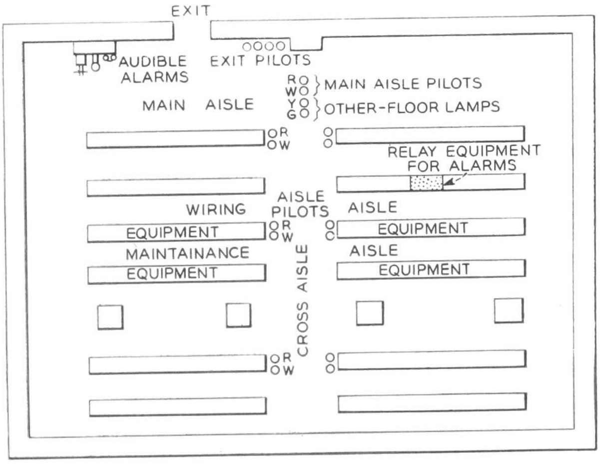
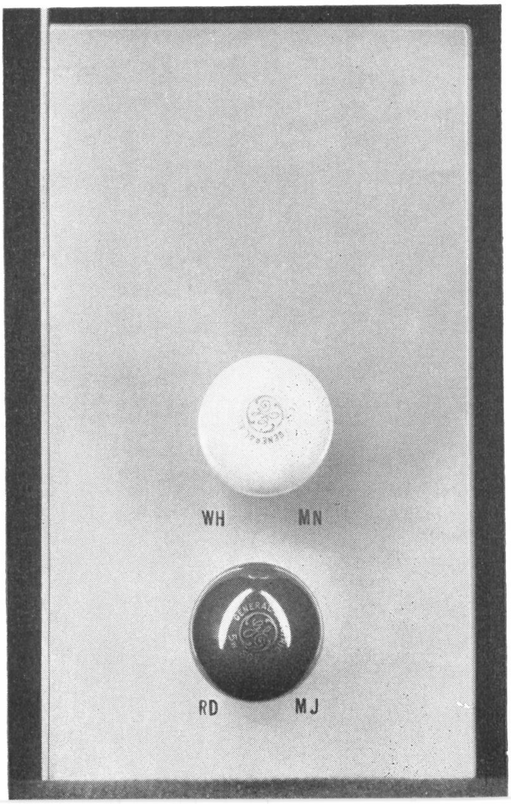


Fig. 1—Arrangement of alarm pilots in a hypothetical central office

Components do not depend on the types or number of circuits requiring alarm, and the special engineering required for each installation is reduced to a minimum. For any one building, the entire alarm equipment consists of a small aisle pilot unit having a red and a white lamp and two relays; a cluster of four lamps—red, white, yellow, and green—for each main aisle; a vertical lamp holder near the exit door having one lamp for each of the other floors in the building; a panel having a six-inch vibrating bell, two telephone ringers with distinctive gongs, and a large tone bar or chime signal; and relay control equipment consisting of one two-inch mounting plate for each floor of the building. Of the group of four lamps in each main aisle, two—the red and white—are the MAIN AISLE PILOTS that indicate trouble in some tributary aisle. The other two—green and yellow—are the

Fig. 2—The aisle pilot unit used in the No. 5 crossbar system



OTHER FLOOR lamps, which indicate the existence of trouble on one of the other floors in the building.

A hypothetical central office layout indicating the positions of these lamps is shown in Figure 1, and an aisle pilot unit in Figure 2. In addition to these lamps, there are individual lamps mounted on various switching and equipment frames that indicate the particular bay, panel, or circuit in which the trouble has arisen. Whenever a trouble arises that lights one of these individual lamps, an aisle pilot for that aisle, the main aisle pilot on that floor, and of the latter lamps is lighted, he will go to the exit, and the particular exit lamp lighted will indicate the floor on which the trouble has arisen. These exit lamps are arranged in a vertical row with one socket for each floor, the top representing the top floor and so on down. On each floor no lamp is in the socket for that floor, and thus the floor on which the trouble exists may be determined from the position of the lighted lamp relative to the socket that has no lamp. After he reaches the floor where the trouble has occurred, the main aisle and aisle pilots will guide him to the proper aisle, and the

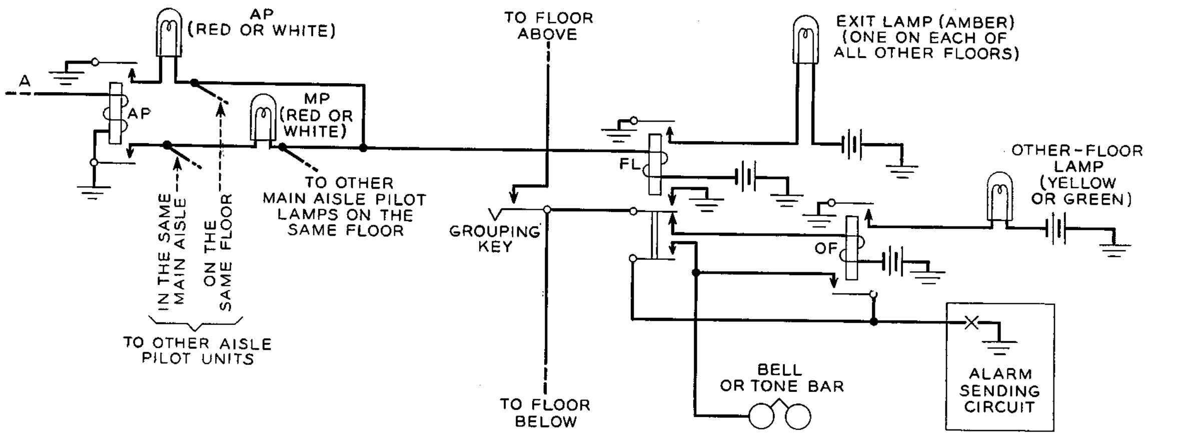


Fig. 3—Simplified schematic of the alarm circuit for No. 5 crossbar

the exit lamps on all the other floors also light, and an audible signal is sounded on the floor where the trouble has occurred. Lighting of the OTHER FLOOR lamps, and giving audible signals on other floors, is optional, and depends on whether or not a grouping key on each floor is operated. When these keys on all floors are operated, any trouble will also light the OTHER FLOOR lamps on all floors except that on which the trouble has occurred, and will sound the audible alarm on these floors. With the grouping keys all operated, therefore, a maintenance man on any floor will hear the alarm when trouble arises anywhere in the building.

By looking at the OTHER FLOOR lamps, he can tell whether the trouble is on the floor he is on or on some other floor, since an OTHER FLOOR lamp will be lighted only when the trouble is on another floor. If one lighted individual lamp on the frame will indicate the equipment causing the alarm.

The circuit by which the proper lamps are lighted when trouble occurs is indicated in Figure 3. When trouble arises, the local lamp will be lighted and battery through a resistance will be connected to lead A at the left of Figure 3. A connection to this same lead will be made for all troubles of same grade, major or minor, arising in that aisle. Battery on this lead operates the AP relay, thus lighting both the aisle pilot lamp for that aisle and the main aisle pilot lamp and operating the FL relay. The operation of this latter relay connects ground to the exit lamp multiple and thus lights all the exit lamps for that floor, sounds the audible signal on that floor and also connects ground to the grouping key. If the grouping key on any floor is operated, the audible signal will sound and the OTHER FLOOR lamp will light on the floor above. Conversely, an alarm on the floor above will sound the audible signal and light the OTHER FLOOR lamp on this floor. If all the grouping keys are operated, audible signals will sound and OTHER FLOOR lamps will light on all floors except the floor on which the trouble occurred.

Switching-trouble alarms are arbitrarily divided into two categories called major and minor alarms, and there is a circuit like Figure 3 for both types. Each circuit has lamps of a particular color associated with it. For major alarms, the individual circuit or fuse panel lamp, the aisle pilot, and the main aisle pilots are red, while for minor alarms, the corresponding lamps are all white. The OTHER FLOOR lamps are yellow for major alarms and green for minor alarms. A distinction is also made in the audible signals; for major alarms the audible signal is a tone bar operated by a relay interrupter, while for minor alarms it is a telephone ringer. The exit lamps, which are all amber, serve for both types of alarms, and are lighted by the FL relay of both the major and minor alarm circuits.

The main power supply equipment is usually all located in the basement, and since it does not require a series of locating lamps, provided by the circuit in Figure 3, it has its own alarm circuit providing both major and minor alarms. It is tied in with the Figure 3 circuit, however, to the extent that for major alarms it lights the yellow OTHER FLOOR lamp and rings a six-inch gong on all floors whether or not the grouping keys are operated. For minor power alarms, it lights the green OTHER FLOOR lamp and rings the regular minor alarm bell on one of the floors which was arbitrarily designated as the floor from which power alarms are supervised. Of course, the grouping keys will also transmit minor power alarms to the other floors. For either major or minor alarms, it lights a separate amber exit lamp on each of the switching floors.

Also not part of Figure 3 are the alarms from the fuses that supply the alarm circuits themselves. A failure of one of these fuses rings a specially toned telephone bell on each floor, but no pilot lamps are lighted except in the alarm control equipment unit, since the blown fuses might prevent the pilot lamp from lighting and thus no dependence could be placed on them. The location of the alarm control equipment is always known to the maintenance man, and thus the sounding of the specially toned bell is sufficient to indicate where the trouble has occurred.

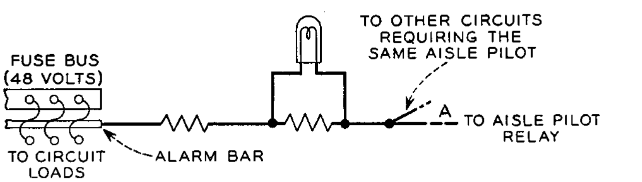


Fig. 4—The standard fuse alarm arrangement

Since in a 10,000-line central office there are about 15,000 fuses that may give an alarm, they are potentially the source of the greatest number of alarms. Experience has shown, however, that fuse alarms are of comparatively rare occurrence.

Alarm type telephone fuses connect the individual circuits to a common power bus, and when they blow, they establish a con-

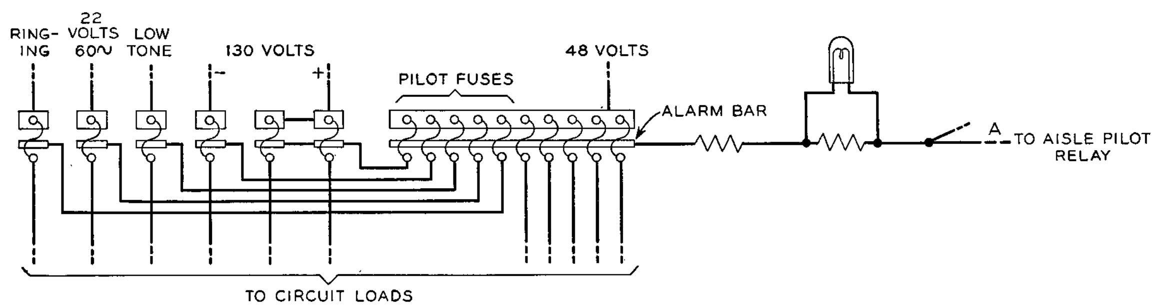


Fig. 5—Pilot fuse alarm system employed where more than one type of power supply is required

nection from the power bus to an alarm bar as has already been described in the RECORD.* This arrangement, together with a commonly used type of circuit to connect the alarm bar to the fuse panel lamp and the alarm system, is shown in Figure 4. Lead A connects to lead A of Figure 3. Such an arrangement has been used for many years, but it has been necessary heretofore to limit the number of fuse panels that can be connected to the same aisle pilot relay—relay AP of Figure 3. This is because with a number of simultaneous alarms, the current through the winding of the AP relay is the sum of all the individual alarm currents, and as a result with many simultaneous alarms, the relay not only overheats but may reduce the voltage across the lamps below the point for satisfactory illumination. By a careful selection of the type of lamp, the relay winding, and the two resistors in the lamp circuit, however, the permissible number of simultaneous alarms has been so greatly increased that all restrictions on the number of fuse panels have been removed. The panel lamps, indicated in Figure 4, are always red

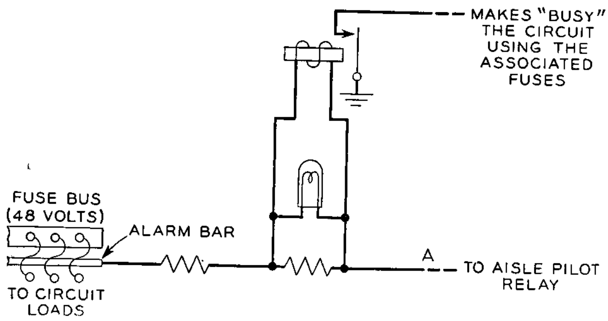


Fig. 6—A make-busy type of fuse alarm

since blown fuses in this system are arbitrarily classed under major alarms.

Telephone offices require a number of power supplies other than 48-volt battery, and heretofore a relay has been used for each panel for each type of supply since the panel lamps had to be lighted through relay contacts. For the No. 5 crossbar alarm system, however, the arrangement indicated in Figure 5 is employed. It is

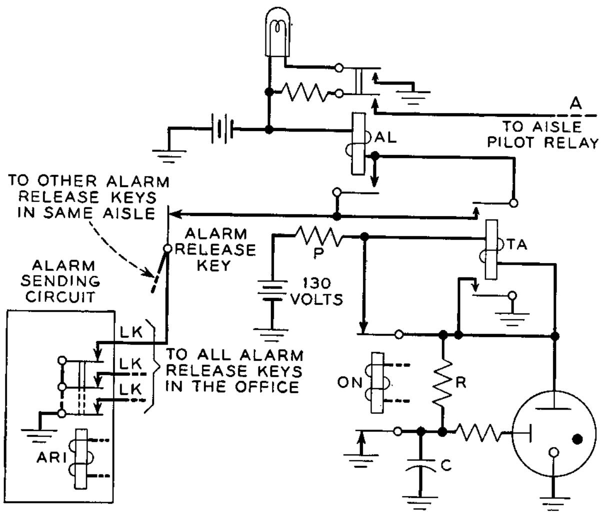


Fig. 7—A typical time alarm

known as the "pilot fuse" method since it employs a fuse in the regular 48-volt section of the panel as both a relay and indicator to give the alarm when a fuse in any other part of the panel blows. Five types of power supply besides 48-volt battery are shown in Figure 5, and the alarm contact or stud for each of the fuses in these five sections of the panel is connected to a separate pilot fuse in the 48-volt section of the panel. When a fuse blows and connects its particular power supply to its alarm stud, the pilot fuse is placed directly in series between the 48-volt battery and the other power supply. As a result, the pilot fuse blows and gives an alarm in the regular manner.

Some circuits, such as the marker or transverter, have a large number of fuses since it is not desirable to design them with a single fuse large enough to carry the entire load. However, should even one fuse blow, the effectiveness of the circuit is impaired and since the circuit is involved in a large percentage of the calls handled by the office, it is of the utmost importance not only to indicate an alarm if a fuse blows, but also to prevent the circuit from being selected for further use until the defective fuse is replaced. For such circuits, therefore, the arrangement shown in Figure 6 is employed.

A relay is connected in shunt with the

*RECORD, *October,* 1925, *page* 78; *September,* 1933, *page* 27; and *February,* 1939, *page* 178.

panel lamp, and if any fuse blows, not only will the regular alarm be actuated, but, in addition, the relay will operate and make this circuit busy. The relay has practically no effect on the fuse alarm, and thus does not affect the high reliability of the original arrangement. If a failure should occur in the wiring to the relay or in the relay winding, or if the adjustment of the relay is faulty, the regular fuse alarm in the system is still operated.

In addition to fuse alarms, many circuits are arranged to indicate other types of trouble, particularly an inability to complete functions within a reasonable time. To measure such time intervals, a condenser-timed cold-cathode-tube circuit is usually employed. One type of circuit is shown in Figure 7. When the circuit is selected, relay ON operates and remains operated during the entire in-use time. This removes the ground connection from capacitor C and allows it to charge from the 130-volt battery through the P resistance, the winding of relay TA, and resistance R. As the capacitor charges, the voltage between the control anode and the cathode increases. When this voltage is high enough to cause ionization, current will flow between the main anode and the cathode, thus operating relay TA. The operation of TA in turn operates relay AL, which lights a local alarm lamp and connects battery to lead A, which in turn connects to lead A of Figure 3. Through circuit components not shown in Figure 7, relay ON is then released, thus releasing TA, stopping the flow of current through the tube, and restoring the circuit to its original condition. Relay AL has locked itself in, however, and will remain operated to remember the trouble until it is manually released.

Another common source of alarms is the trouble recorder, since each time a trouble record is made, an alarm is given. These also are classified as major and minor, and light indicating lamps leading to the master test frame.

Since the No. 5 system was designed to serve small as well as large areas, it was planned to extend the alarms a large portion of the time to off-premises personnel. It has been necessary, therefore, to provide for transferring the alarms to a distant office where a maintenance force will always be available. All the alarms, therefore, are connected to an alarm sending circuit, which is indicated in both Figures 3 and 7. The alarm sending and receiving circuits, which are capable of identifying as many as seventy distinct types of trouble, are described on page 131.

C. E. GERMANTON
Switching Development

Interoffice transfer of alarms in No. 5 crossbar

Since it was expected that many No. 5 crossbar offices would be maintained by off-premises personnel at least part of the time, such as nights and week-ends, it was necessary to design suitable circuits to transfer alarms* in unattended offices to some center where a maintenance force was available. Such a system has been designed, and was first used with the No. 5 crossbar office in Media, Pa. It has since been adapted for use with the panel system and with the No. 1 crossbar system, and should it be found desirable, it could be arranged for use with the step-by-step, community dial, crossbar tandem, and panel sender tandem systems.

In a trial of the transfer of alarms from a No. 1 crossbar office, it was found that a considerable amount of information was desirable, and twelve cable conductors were used. In addition, it was found that it should be possible to enable the transfer circuit from the receiving end whenever transfer had been neglected at the sending end. It should also be possible to determine whether the transfer had been enabled even if no alarm conditions existed, and to release locked-in temporary alarms so as to determine whether or not the trouble condition was of a continuing nature.

*See page 126.

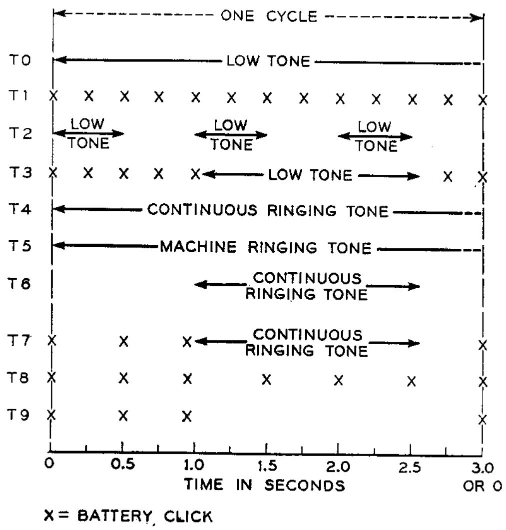


Fig. 1—Tone and click combinations

Another requirement was that any failure in the transfer circuit should not result in a no-alarm signal, or should not signal an alarm of less importance than that existing at the time. If the cable conductors were opened or grounded, for example, if a fuse blew, if a contact failed due to dirt, or if a wire were broken off, an alarm should be sounded, while if an alarm were being transmitted, it should be changed to a more important class if possible but never to a less important one.

These requirements were all met by an alarm sending and an alarm receiving circuit connected by only two interoffice conductors. Over these two conductors may be transferred as many as seventy different types of alarm conditions. At the sending end of the system, positive or negative 130-volt battery or open circuit may be applied to each of the two transfer leads under control of relays. At the receiving end of the system, each transfer lead connects to one side of the winding of a three-position polarized relay; the other side of each winding is grounded. Since each relay has three positions, there are nine combinations of positions for the relays taken together. These relays control a circuit which causes a specific lamp to light and an audible signal to sound for each of eight of the combinations. The ninth combination with no lamp or audible signal is used to indicate that the circuit is in good working order. One of the eight lamps and audible combinations is used to indicate a failure in the alarm circuit itself. This leaves seven indications to be associated with various types of trouble conditions that may arise in the particular office that is being supervised.

Besides these two relays, a telephone receiver is bridged across the circuit through a repeating coil, and at the sending end provisions are made for applying any of ten possible tone or click combinations, which may be superimposed on the d-c current through the transfer leads. These combinations are shown in Figure 1. For each of the seven alarm positions of the relays, therefore, there are ten possible tones. There are thus seventy possible trouble conditions that may be given in addition to the signals for transfer-circuit failure and for the all-clear condition.

A simplified schematic of this transfer arrangement is shown in Figure 2, where the relays are in the positions they assume when no alarms are being transferred. Relays FA, L, L1, and A are operated at the sending end, while at the receiving end polarized relay T is operated to its positive position and relay R to its negative position. Under these conditions, the d-c signal relays and the tone and click circuit are disabled, and thus alarms arising in the office are not transferred.

When the alarms are to be transferred to the distant point, the transfer key TR is operated, thus releasing the A relay. This supplies enabling battery to both the tone and d-c relay circuits and disables all audible alarms in the local office, but makes no other changes so long as there are no alarms to be transferred. Should a maintenance man now listen at the receiver at the maintenance center, he would hear a low tone, which in conjunction with the no-lamp condition would indicate that a transfer had been made, that the circuit was in good working condition, and that there were no alarms. When alarms occur, they operate relays in the d-c and tone sig-

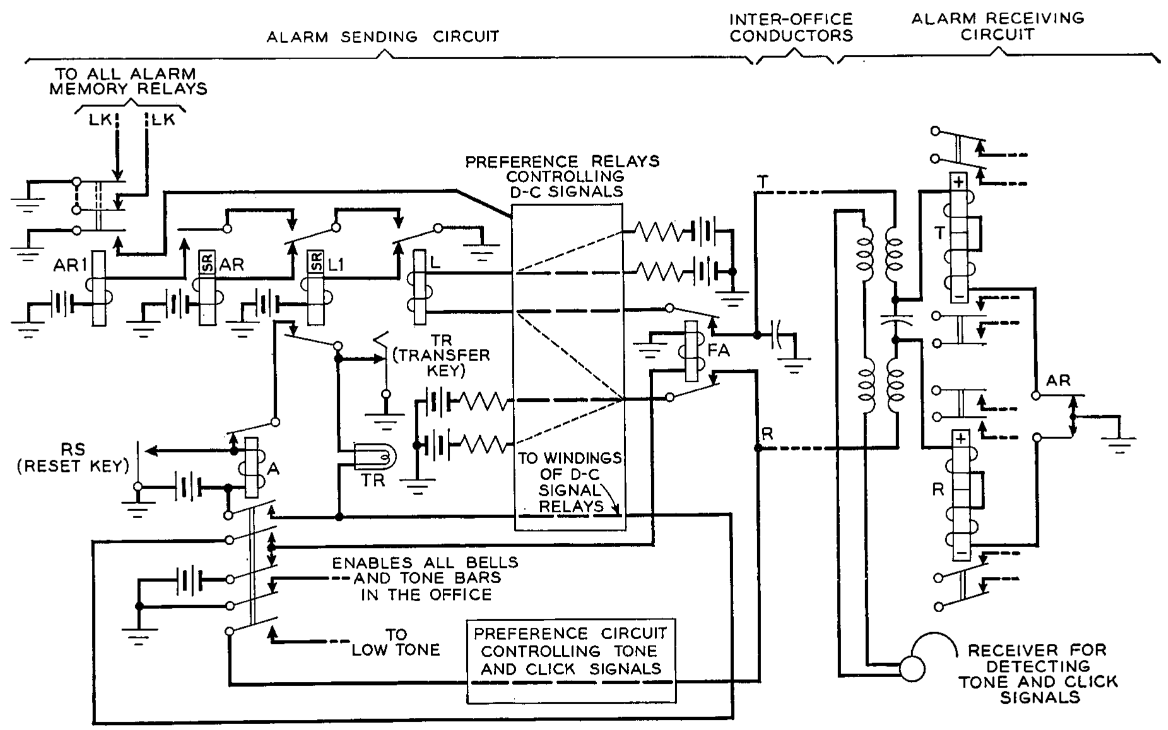


Fig. 2—Simplified sketch of the alarm sending and receiving circuits

LEAD	ALARM CONDITION								
	ALARM TRANSFER FAILURE	TROUBLE RECORDER SEIZURE		ALARM					NORMAL
		1 ST TRIAL	2 ND TRIAL	MAJOR POWER	MAJOR SWITCHING	PERMANENT SIGNAL	LOAD	MINOR	
T	OPEN	–	OPEN	–	OPEN	+	+	–	+
R	OPEN	OPEN	–	–	+	OPEN	+	+	–
	8	7	6	5	4	3	2	1	0

DECREASING SEVERITY ⟶

Fig. 3—D-c signal combinations

nal circuits to send the proper signals to indicate the type of trouble existing.

When the maintenance man returns to the unattended office, he releases key TR. This causes lamp TR to light. Then he momentarily operates the reset key RS. This operates relay A which locks itself in through the transfer key, extinguishes lamp TR, removes battery supply from the tone and d-c relay circuits, and enables the local audible alarms. The extinguishing of TR lamp is a check that relay A operated and remained locked after RS was released.

It is not sufficient, however, only to provide for sending the required alarms. Every possible contingency must be foreseen and provided for. One obvious one is that the maintenance man might neglect to operate the transfer key when he left the No. 5 office. Under such conditions, the transfer may be accomplished from the receiving circuit by operating the AR key at the extreme right of Figure 2. A maintenance man at this point would know that the transfer had not been made by absence of tone when he listened on the telephone receiver, and knowing from the schedule of nonattendance at the distant No. 5 office that transfer should have been accomplished, he would at once operate key AR. This opens the transfer circuit and thus releases relay L which in turn releases relay LI. The release of LI in turn releases relay A and thus effects the transfer.

When transfer has been accomplished in this manner from the receiving end, the TR lamp at the sending end will be lighted through a back contact of relay A and the TR key. When a maintenance man returns to the No. 5 office, therefore, this lighted TR lamp will show that transfer was made from the receiving end, and he will momentarily operate the RS key to reoperate relay A and thus enable the local alarms. When relay A operates, the TR lamp will be extinguished.

Key AR need be operated only momentarily, since once relay A has released, it will not be reoperated by closure of LI because normal connection to the winding of A is made through one of its front contacts. Once released, relay A can be reoperated only by operation of the reset key RS.

The primary function of key AR, however, is to open momentarily the locking paths for all memory relays—in this way determining whether some alarm received is of a temporary nature or whether it continues or recurs. Examples of the former are a trouble recorder seizure, momentary failure of the regular power service to the building, or an overload of the switching equipment such as may result from a flurry of calls in case of a fire in the neighborhood. The slow-release relays LI and AR in Figure 2 insure that the locking leads LK are not opened if relay L releases momentarily when the alarm signals change, and that these leads do not remain open continuously in case of a cable failure.

Since there is always the possibility of two or more alarms occurring simultaneously, and since only one alarm can be transferred at a time, it has been necessary to associate preference circuits in the tone and d-c signal circuits to select only one of possibly several alarms for transfer. Under such conditions, it is desirable to select the most important alarm, that is, one requiring the most prompt attention. The nine possible combinations of conditions that can occur on the transfer leads to the maintenance center are thus arranged in a preference sequence as shown in Figure 3, where the importance decreases from left to right. At the extreme right is the normal condition, indicating that the transfer circuit is normal and that no alarms are being transferred. At the extreme left, on the other hand, are the conditions that would exist if the power fuses on the alarm circuit had blown, or if the transfer leads were open. Since, under this condition, no alarms at all would be transferred, this is the worst condition possible. Between these two extremes are the seven conditions used for various classes of alarms.

TABLE I—CHANGE IN ALARM GIVEN IF EITHER TRANSMITTING LEAD IS OPEN

	T	*R*
0	6	3
1	4	7
2	4	3
3	8	–
4	–	8
5	6	7
6	–	8
7	8	–
8	–	–

These seven alarm conditions have been so selected that should an open occur in either of the transfer leads, the resulting alarm indicated at the receiving office would be of a more serious nature than the alarm existing when the trouble occurred. This is shown in Table I. At the left are listed the various classes from zero to eight, corresponding to Figure 3. The next column to the right indicates the alarm class that would result were the tip lead opened, while the third column indicates the alarm that would result were the ring lead open. A dash indicates that no change occurs, since the battery signal has already been removed from that lead. It will be noticed that in all cases the importance of the alarm is either unchanged or increased, but is never decreased by the opening of the circuit. The absence of tone would give a clue if this trouble is caused by severance of a conductor. However, the trouble may be due to a dirty contact or a broken wire, in which case the tone may still be audible. A factor of safety resides in the fact that any alarm which is transmissible over one lead is severe enough, unless of short duration, to warrant dispatching a maintenance man to investigate its cause.

If while relay A is operated, a momentary break should occur that would release it, the transfer of alarms becomes enabled and the audible alarm devices in the building are disabled. This feature does not appear desirable at first glance but the alternative—to disable the transfer under a similar failure condition—would be dangerous, since the alarm signals would then not reach any maintenance people. The present arrangement insures that in case of such trouble, the alarms are transmitted to the distant point where maintenance personnel are always in attendance. In addition, the pilot lamps at the originating point will light, which, without the audibles, will be indication of an alarm sending circuit failure.

At the receiving end of the transfer arrangement, the lamp and audible signals remain locked-in, even if the received signal has been retired. If the signal should be changed before attention can be given, all lamps and audibles remain locked-in. In addition to the alarm release key already referred to, there is an audible cutoff key which, when operated, will silence the audible and extinguish the lamps unless an alarm signal is still in effect, in which case the corresponding lamp remains lighted. If the alarm signal is subsequently replaced by the normal signal, the lamp is extinguished and the circuit is again normal. If, however, the lamp signal is changed, the original lamp is extinguished, a new lamp lights, and the audible is sounded.

No. 5 crossbar AMA translator

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In the No. 5 crossbar system, the subscriber lines terminate on verticals of crossbar switches on the line link frames. They are identified for switching purposes by the number of the frame on which they appear and their position on that frame. This position on the frame is defined by specifying the horizontal group, and the vertical group and file in which the vertical is found. The scope of the divisions of the frame is shown in Figure 1. There are ten horizontal groups and from six to twelve vertical groups on each line link frame. Each vertical group consists of five vertical files.

The series of numbers specifying the line link frame, vertical group, horizontal group, and vertical file, is known as the equipment number, but there is no fixed relation between this equipment number and the directory number. The reasons for this lack of relationship have to do mostly with keeping an even distribution of traffic through the frames and with providing flexibility for changes in assignment of directory numbers.

Since the marker obtains the equipment number in the process of handling an originating call, it is readily available to the AMA equipment. However, directory numbers rather than equipment numbers are required by the AMA equipment in billing the charges for a call. A translator is therefore required to convert the equipment number to a directory number. This translator is an electrical directory with the equipment numbers appearing in an orderly array each with its associated directory number.

After a subscriber picks up his handset to place a call, the marker seizes the calling

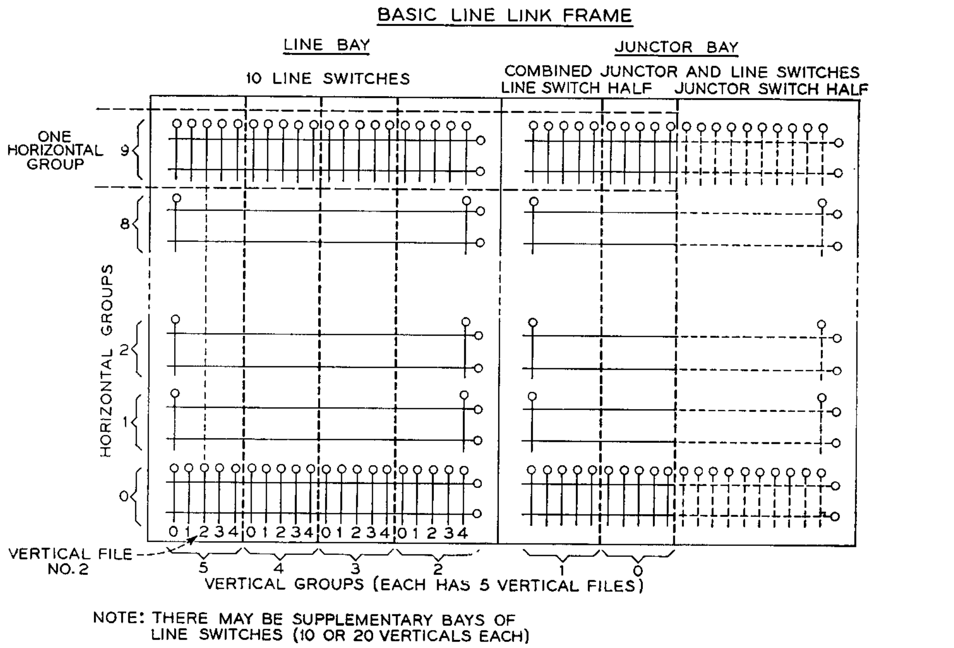


Fig. 1 — Division of lines on a line link frame into vertical groups, horizontal groups, and vertical files.

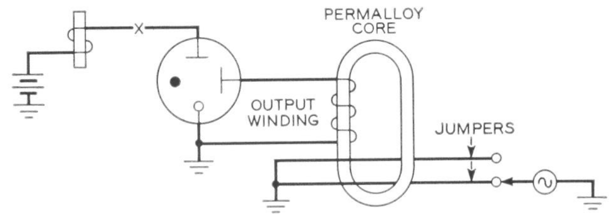


Fig. 3—Simplified diagram indicating method of using the coil shown in Figure 2 for translating.

line link frame, finds the calling line, connects it to an originating register, and tells the register the equipment number. The register records this number and, if the call is from a two-party line, determines whether the tip or ring party is calling. After the subscriber has dialed, the register obtains a marker and gives it the calling equipment number, including tip or ring party identification, and the called directory number. The marker in turn passes this information to the outgoing sender, which records it. After the marker completes this job, the sender controls the selection of the called number and at the same time obtains a transverter, which is part of the AMA equipment, and gives it the information. The transverter uses this information to obtain a translator to which it passes the equipment number. From this information the translator determines the directory number and returns it to the transverter, which causes it to be placed on the AMA tape in the form of five digits: one to indicate the office, and one each to indicate the thousands, hundreds, tens, and units digits of the subscriber's directory number.

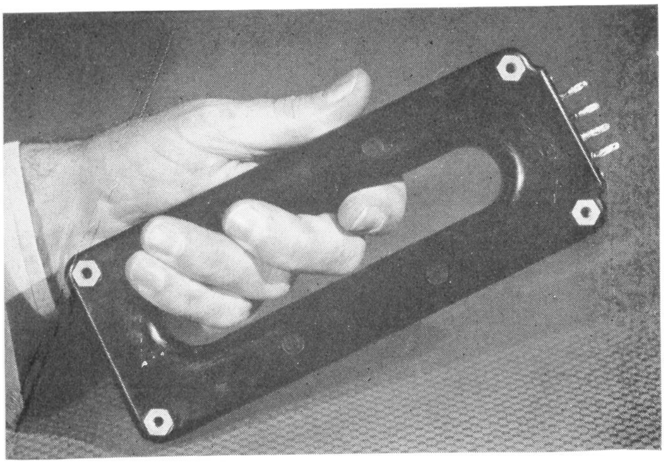


Fig. 2—The coil used with AMA; one of the essential elements of the "Dimond" ring translator.

The new element of the translator is the coil shown in Figure 2 and is shown schematically as applied to a circuit in Figure 3. The winding of the coil is connected to the control anode of a gas filled tube. If a surge of oscillating current is sent through one of the jumpers, an oscillating voltage is induced in the winding. This voltage ionizes the tube, thus allowing it to pass current between the cathode and the main anode, and operate the associated relay.

The method of using these coils in the AMA translator is shown in Figure 4. At the top of this figure is the surge circuit which generates the jumper current. Below is a relay tree that selects one of the terminals in the equipment number terminal bank. There is one terminal in this bank for each equipment number.

From each terminal, a jumper is threaded through one coil in each of the five rows of coils and terminated in ground. The coil used in the top row indicates the number of the office in which the calling line is located. The coils used in the other four rows are chosen in accordance with the thousands, hundreds, tens, and units digits of the associated directory number.

When the transverter is connected to the translator, it operates relays in the relay tree which select one of the thousand equipment number terminals and connect it to the surge circuit. When this connection is made, a path is closed from ground through the jumper, the relay tree, and the back contact of relay SST. This ground suddenly changes the potential of point A from minus 48 volts to ground. This voltage change is carried through a coupling condenser to the control anode of the SST tube which is caused to pass current, thus operating relay SST. Relay SST now closes a discharge path for the oscillatory discharge of capacitor C through inductance L to ground. The discharge circuit is closed by the mercury contact relay SST rather than by the contacts of the tree circuit because the high current (about 3 amperes peak) in the surge might damage ordinary relay contacts, especially if there is any contact chatter. Any chatter which occurs in the relay tree contacts subsides during the operating time of relay SST.

The surge current in the selected jumper induces a voltage in the output windings of the coils through which the jumper passes. The associated gas-filled tubes fire from this voltage, and cause relays in the transverter corresponding to the directory number to operate. The translator connector then releases, disconnecting the transverter from the translator.

The relay tree is shown schematically in Figure 5. By using the line link frame number and the vertical group number, the transverter grounds one of the twenty G leads to operate the proper G relay. Tip parties and ring parties are assigned to separate translators. The transverter also operates one of the VF relays corresponding to the vertical file number of the calling line, and operates horizontal group relay in accordance with the horizontal group number.

The G relay uses fifty contacts to select from the thousand equipment number terminals the particular fifty of the vertical group of the calling line. The VF relay selects ten of the fifty terminals selected by the G relay, and the horizontal group relays select one of the ten terminals selected by the VF relay. Thus, by this process, one terminal out of 1000 is connected to the surge circuit, whereupon the operation proceeds as above.

Since the jumpers are changed rather frequently and since the terminals in the equipment number terminal bank are fairly closely spaced, it is felt to be worthwhile to design the translator so that inadvertent shorts between adjacent terminals will not cause severe reaction. With all the jumpers connected to a common ground bus as indicated at the bottom of Figure 4, such a short might result in the failure to translate the equipment numbers for a large number of lines, and the fault might be difficult to find. Suppose, for example, there were a short between the equipment number terminals for jumpers A and B. An attempt to translate the equipment numbers associated with either of these terminals would, of course, give the translation of both because of the short. This in itself is not too serious since only two lines are involved and the trouble could soon be located. The serious feature of such a short is that the short forms a closed loop consisting of the two jumpers. As a result, a surge in any jumper passing through one or more of the coils threaded by either of the shorted jumpers will induce a surge in the closed loop and thus besides operating the proper tubes for the translation will also operate those associated with the jumpers of the closed loop. With the short between jumpers A and B, for example, when jumper D is energized, a surge voltage is induced in jumper A because it threads tens-coil No. 6 in common with the D jumper. A current is therefore induced in the A and B jumpers, which energizes several coils besides the desired ones. This does not cause charging irregularities, however, because the transverter recognizes the operation of more than the correct number of tubes as a trouble condition. It would not accept the translation but would call in a trouble recorder. The fault would be difficult to locate, however, because the equipment number of the line that caused the trouble recorder to be called in may not be anywhere near the equipment numbers whose terminals are shorted in the bank.

To avoid such a situation, the formation of closed loops by shorts must be prevented. To this end, ground is provided through a bank of 1000 terminals physically arranged just as are those of the equipment-number terminal bank. Jumpers are run between corresponding terminals of the two banks. The method of supplying ground to the terminals of the ground bank is indicated in Figure 6. The ESW relay is operated by the horizontal group relays of the relay tree whenever the equipment number being translated is in an even horizontal group. Similarly the OSW relay is operated if the horizontal group is odd. The VF relays are the same relays as the VF relays shown in the relay tree. When a translation is to be made, the ESW or OSW and VF relays together supply ground to only a certain fifty of the thousand ground-supply terminals, and no two of these fifty are adjacent. ESW and VFO, for example, ground the even terminals in the bottom row of Figure 6.

With this arrangement there can be no

closed loops due to shorts between adjacent terminals in the equipment number terminal bank. If the shorted terminals are horizontally adjacent, then one must be in an odd horizontal group and the other in an even and, therefore, only one of the jumpers can be supplied with ground because of the ESW and OSW relays. If they are vertically adjacent then only one can be supplied with ground because only one VF relay is operated, and each horizontal row of terminals is supplied from a different VF relay. With no closed loops there can be no tubes falsely operated, and therefore the circuit will translate satisfactorily in spite of the short.

Not only does this scheme prevent false operation, but it causes a trouble record to be made indicating that a short exists. If jumpers A and B are crossed either in the equipment-number or ground-supply terminal banks, then when the A jumper or any other jumper on the same ground sup-

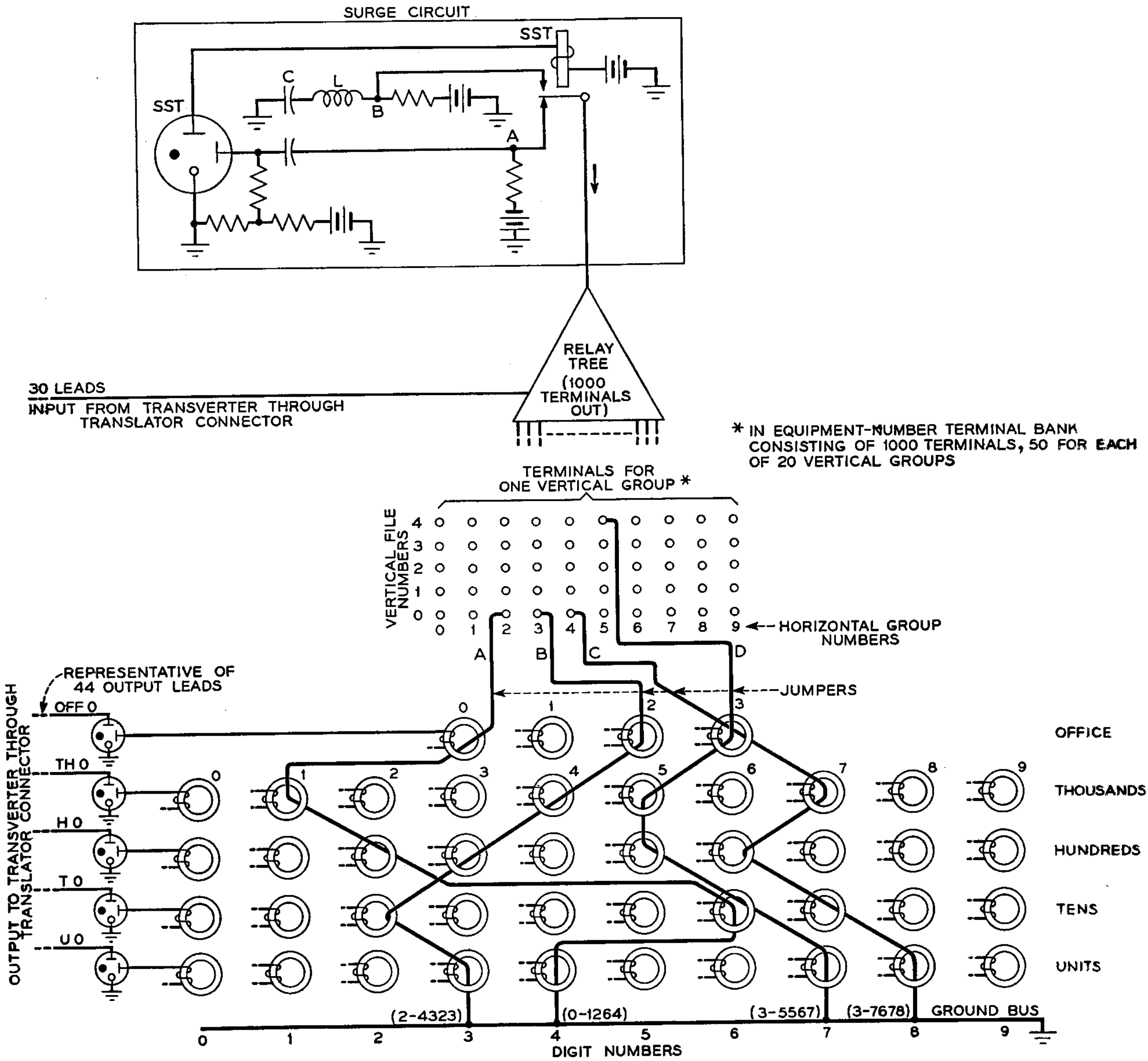


Fig. 4—Simplified circuit schematic of the AMA translator. This schematic shows jumpers set up to identify terminals of directory numbers 2-4323, 0-1264, etc.

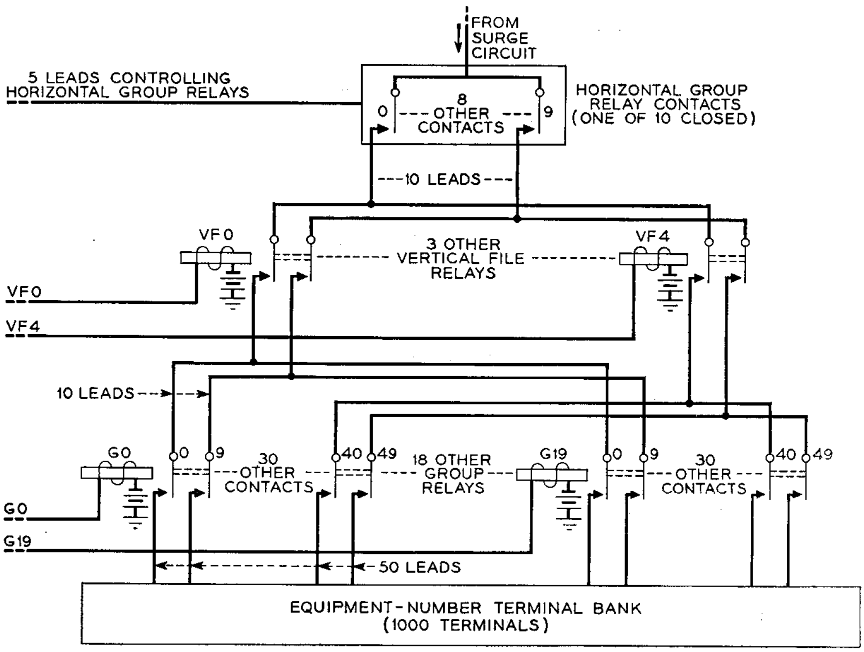


Fig. 5—The relay tree of the translator, which distributes the surge to the terminal for the equipment number that is to be translated.

ply lead is selected, the ground furnished by the VFO and ESW relays will close a circuit through the short and through the back contact of relay OSW to operate the cross-detecting relay in the transverter. This causes a trouble record to be made but does not interfere with the translation.

It may be wondered why it is necessary to indicate when a short exists since it does not interfere with the translation. The answer is that a single short cannot cause a closed loop but two shorts may. For this reason it is desirable to indicate a short as soon as it occurs so that it can be cleared

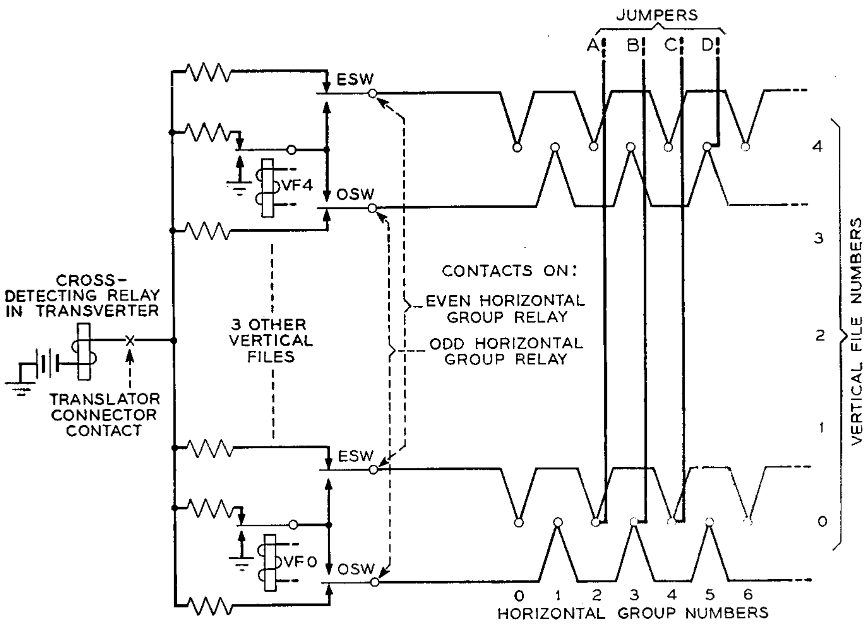


Fig. 6—Simplified sketch indicating the method of distributing ground to the terminals of the ground bank.

before another occurs which, in combination with the first, might cause translation failures on a large number of telephone lines.

A translator frame is shown in Figure 7. At the top, not shown in the photograph, is the translator connector, which has a capacity for five transverters. In the middle of the frame are the relays making up the relay tree. The bulk of these are the multi-contact G relays. Below the relays are the terminal strips making up the equipment-number terminal bank. The coils are mounted next. The tubes are mounted immediately behind the coils. Near the bottom is the ground supply terminal bank. The whole assembly of coils and terminals is within easy reach of a maintenance man standing on the floor.

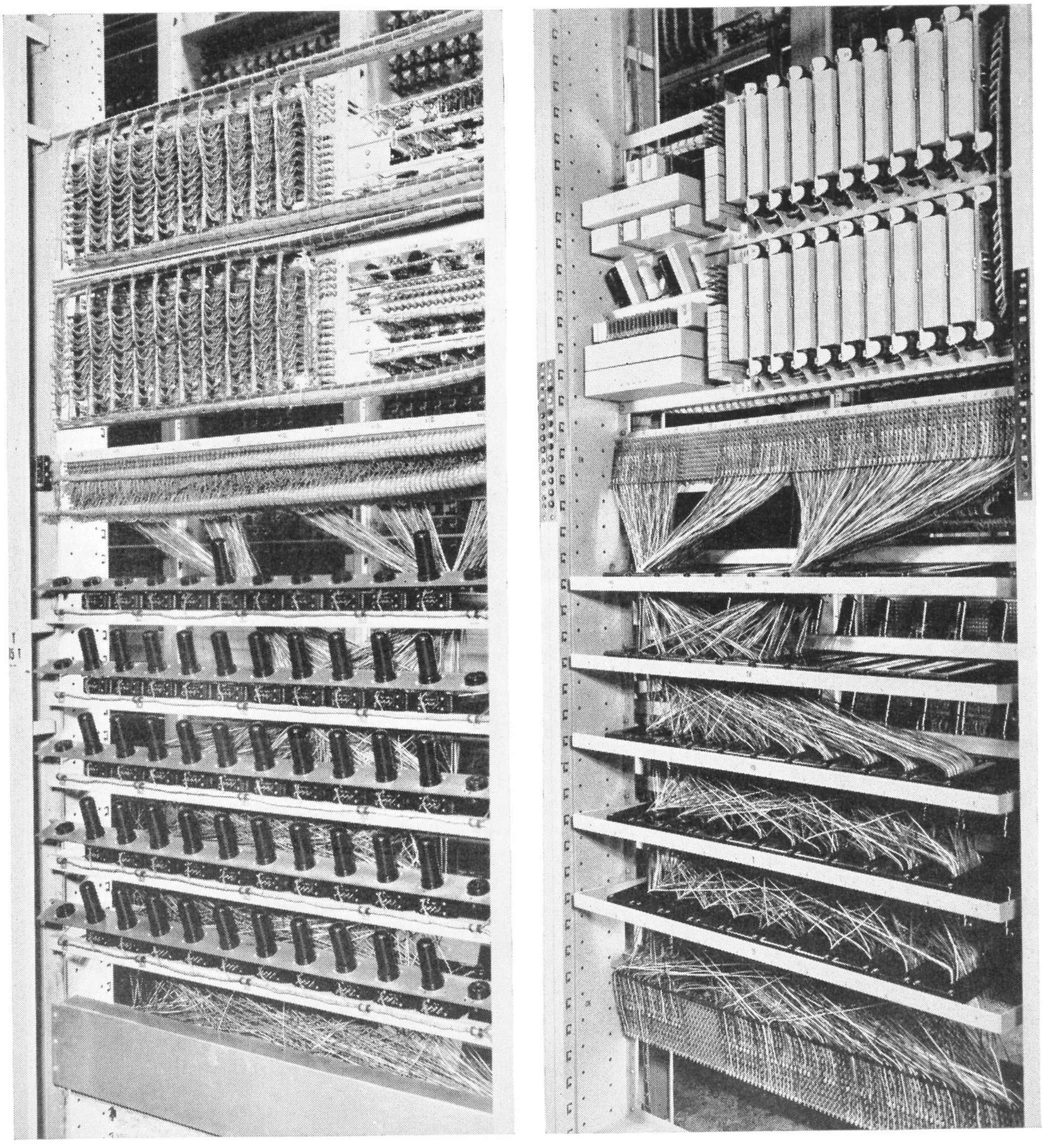


Fig. 7—Lower part of a translator frame; tube side at left, and coil side at right.

One of the difficult equipment and apparatus problems was the design of the coil structures and the general layout in such manner that the jumper could be readily removed. With the arrangement finally devised, the jumper can be removed by loosening both ends and pulling. One reason for terminating the jumpers in the same relative locations in both terminal banks is to make this possible without tracing the jumper through the coils to find its ends. The coils, one of which is shown in Figure 2, are enclosed in bakelite cases with smooth rounded jumper windows to reduce friction. It was found that an oblong window accommodates more jumpers than a round window of the same area. The maximum that can be placed in the coil is 600.

As a further aid in changing jumpers, the terminals in the equipment number and ground supply banks are of a new solderless type. These are shown in Figure 8. Each consists of a slit punching into which the stripped end of a jumper is slipped. A complete turn of the jumper is then made around the terminal so that any movement of the jumper will not disturb the electrical connection. The pressure between the jumper and terminal is very high, insuring a good, low resistance contact. Tests show that this terminal allows a reduction in connection and disconnection time.

The basic type of translator employing the kind of coil described above is known in the Bell System as a ring translator because of the shape of the coil. Its main advantage over more conventional types of translators is that it reduces the number of jumpers and connections. This saving in jumpers represents appreciable savings to the Telephone Companies because on the average each jumper is removed and re-run once each three years.

The same translator circuit as described above is used in the No. 1 crossbar system, although the equipment details are slightly different. The basic ring translator scheme has also been applied to computers.

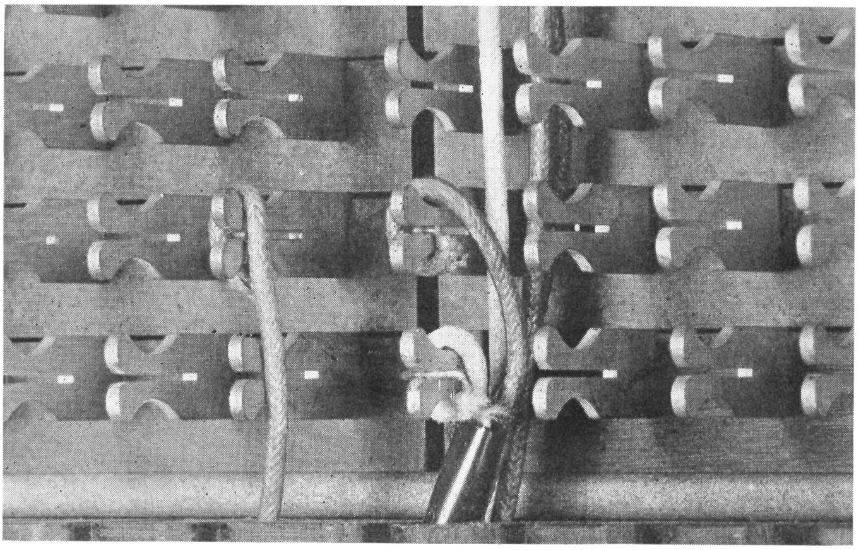


Fig. 8—A close-up of one of the terminal banks of the translator showing the new type of terminal employed.

Pretranslation in No. 5 crossbar

R. C. AVERY
Switching Development

An originating register in the No. 5 crossbar system does not seize a marker until it has recorded all the digits dialed by the subscriber, and it must therefore have some indication of the number of digits the subscriber will dial. In areas where the same number of digits is always dialed, the register is arranged to seize a marker as soon as this number of digits has been received.

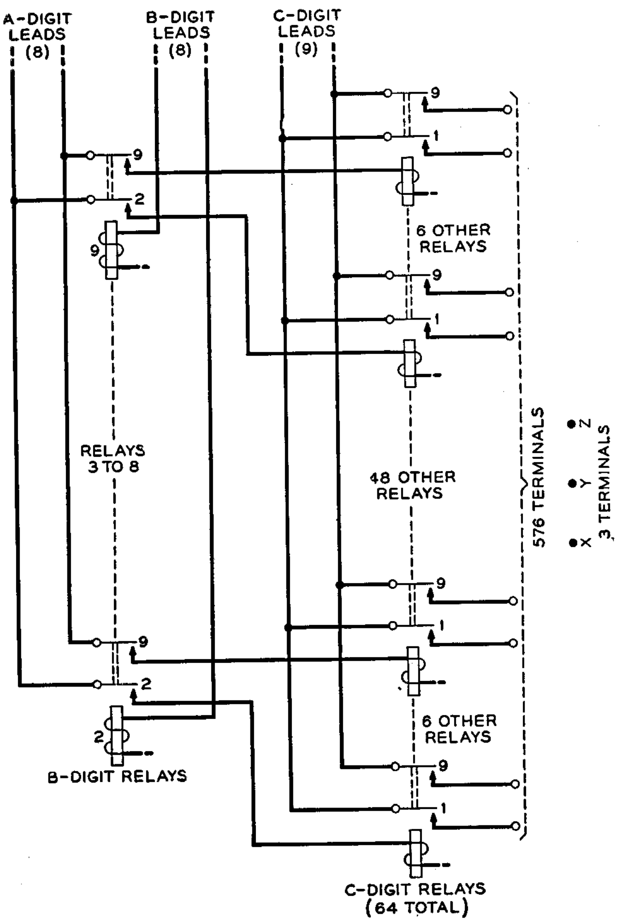


Fig. 1—The type of circuit usually employed in the past for translation as applied to the 576 codes which are treated in a novel manner by the pretranslator.

In many areas, however, the number of digits to be dialed varies for different called offices, and the register must have some way of determining from the office code how many digits to expect. This process is called pretranslation.

Where the numbering arrangement is simple, the register may be arranged to do the necessary pretranslation itself. In the Vineland, New Jersey, office, for example, only three-digit office codes with a four-digit line number are used except for lines in a manual office, for which the code 9 without numericals is dialed. To reach a DSA or toll operator, a 0 or a three-digit code is dialed. All registers are arranged to recognize an initial 0 for an operator and to call in a marker at once, and they can readily be arranged to do all the pretranslation where the conditions are as simple as at Vineland.

In more involved situations, however, it is more economical to concentrate the pretranslating functions in common pretranslator circuits, which are accessible to the originating registers through pretranslator connectors. In the Freeport-Baldwin office on Long Island, for example, a three-digit office code and four numericals are used to reach stations in a number of dial offices, whereas an additional digit is required for party lines in several nearby manual offices. It is not practicable to identify the particular lines of an office that require party letters or a fifth numerical digit, and thus when the office code indicates such an office, the register must allow a "station delay" interval of about four seconds after receiving the seventh digit to allow time for an eighth digit to be dialed.

The average holding time of the originating register is about 13.5 seconds without station delay and 17.5 seconds with it. To provide this delay on all calls, and thereby eliminate the need for pretranslation, would increase the completion time of calls to offices which do not require the delay by about

30 per cent, and more registers would be needed. In general the cost of the additional registers would be greater than the cost of pretranslation. The pretranslator developed for this purpose is designed to translate both two and three-digit office codes, foreign-area directing codes in the series 112 to 119 followed by an office code and a number, and service codes such as 211 and 411 that do not require additional digits. It is seized through a pretranslator connector as soon as three digits have been received by the register, and the three digits have been transmitted to it.

Separate small relay circuits are available when required for translating foreign-area office codes beginning with 11, and for dealing with 0 as the final digit of the code. The register itself acts directly when the first digit is 0. The greater part of the pretranslator circuit, however, is employed for translating codes having any number from 2 to 9, inclusive, for the first and second digits—or the A and B digits as they are referred to—and any number from 1 to 9, inclusive, for the third or C digit. The 576 (8 x 8 x 9) codes of this type are translated into one or another of three indications. These may be referred to as X, Y, and Z. An X indication tells the register to seize a marker after seven digits have been received. A Y indication tells it to allow a station delay interval after

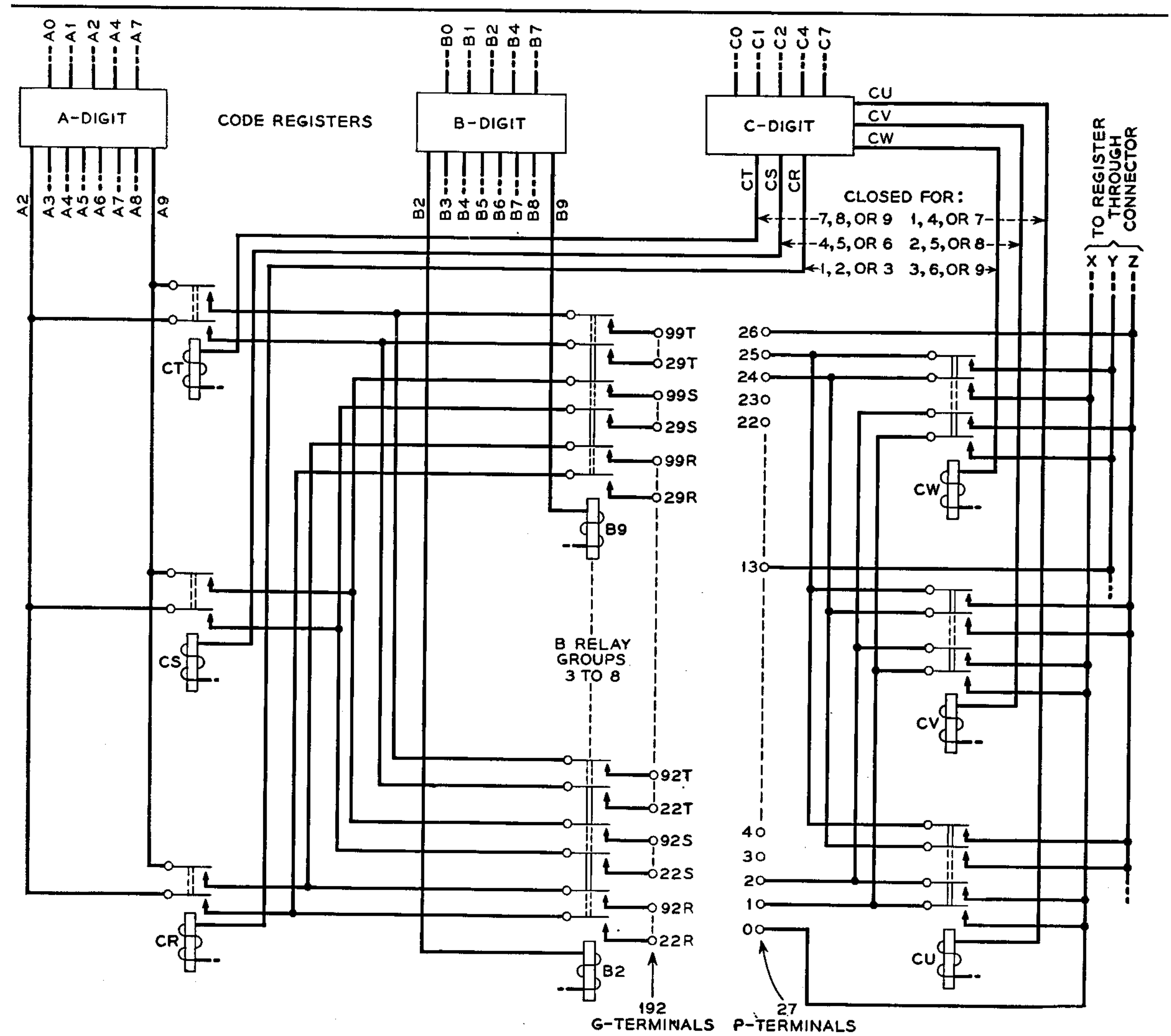


Fig. 2—Simplified schematic of circuit employed for translating in the pretranslator.

the seventh digit to give time for an eighth digit to be dialed, while a z indication, which is given when the office code is one not assigned, tells the register to seize a marker after three digits have been received.

Although translation is now commonplace in telephone systems, the method for translating the 576 codes to one of three indications employed by the No. 5 crossbar pretranslator is novel. It permits the translation to be made with much less equipment than would have been required with the more usual method of translation.

Had the usual method of translation been followed, the circuit would have been of the general type indicated in Figure 1. Each of the three digits of the code are transmitted to the pretranslator by the register as ground on two out of five leads. For translation by the method of Figure 1, these indications are converted to ground on one lead of each of three sets—one set for the first, or A digit, one for the second, or B digit, and one for the third, or C digit. At the left of Figure 1 are eight B-digit relays, which are operated by the eight B-digit leads. The eight A-digit leads are multiplied to the armature springs of these B-digit relays. There are thus 64 leads leaving the front contacts of the B-digit relays, and each of these is connected to the winding of a relay closing nine contacts. The nine C-digit leads are multiplied to the nine armature springs of each of these latter relays. There are thus 576 (9 x 64) front contacts on the C-digit relays, and they are connected to a bank of 576 cross-connecting terminals — one for each code. Adjacent to these terminals would be three others as shown—or three banks of multiplied terminals—for the three possible indications to be returned to the register. Jumpers would be run between the bank of 576 and the bank of three terminals to associate each of the 576 codes with its proper X, Y or Z indication.

TABLE I—THE TWENTY-SEVEN POSSIBLE COMBINATIONS OF THREE THINGS—X, Y, AND Z—TAKEN THREE AT A TIME.

P	U	V	W	P	U	V	W	P	U	V	W
0	X	X	X	9	Y	X	X	18	Z	X	X
1	X	X	Y	10	Y	X	Y	19	Z	X	Y
2	X	X	Z	11	Y	X	Z	20	Z	X	Z
3	X	Y	X	12	Y	Y	X	21	Z	Y	X
4	X	Y	Y	13	Y	Y	Y	22	Z	Y	Y
5	X	Y	Z	14	Y	Y	Z	23	Z	Y	Z
6	X	Z	X	15	Y	Z	X	24	Z	Z	X
7	X	Z	Y	16	Y	Z	Y	25	Z	Z	Y
8	X	Z	Z	17	Y	Z	Z	26	Z	Z	Z

With this arrangement there are in all 640 relay contacts and 579 cross-connecting terminals. With the circuit actually used, however, only 288 relay contacts and 219 cross-connecting terminals are required. This great reduction in the amount of equipment was brought about by using the translator circuit indicated in Figure 2.

With this circuit, three codes are translated as a group with one jumper, and thus only one-third as many jumpers need be run as for the arrangement in Figure 1. In spite of this, there is complete flexibility since the translation of one code of a group of three may be changed without affecting the other two codes of the group. Since there are 576 codes in all, there are 192 groups of three codes, and each of the terminals in the column marked G in Figure 2 represents a group of three consecutive codes. The translating jumper wires from these G terminals are not run to the X, Y, and Z terminals but rather to a bank of twenty-seven P terminals, each of which represents one of the twenty-seven patterns in which three codes may be translated into any of three indications.

The three consecutive codes in any one group may be represented by U, V, and W, where U represents the lowest numbered code of the group and W the highest. The three columns to the right of column P in Table I represent the twenty-seven possible translation patterns for three codes into three indications. In pattern No. 0, for example, all three codes of the group are translated to an X indication. In pattern No. 5, the U code is translated to X, the V code to Y, and the W code to Z. The column labeled P in Table I represents the number of the P terminal that corresponds to each pattern. If for a particular group of codes the U code requires translation to X, the V code to Y, and the W code to Z, the G terminal for that group would be jumpered to P5. If it were desired to change the V code of this group to a Z translation without affecting the U and W codes, the jumper would be moved from P5 to P8, which represents pattern X, Z, Z as

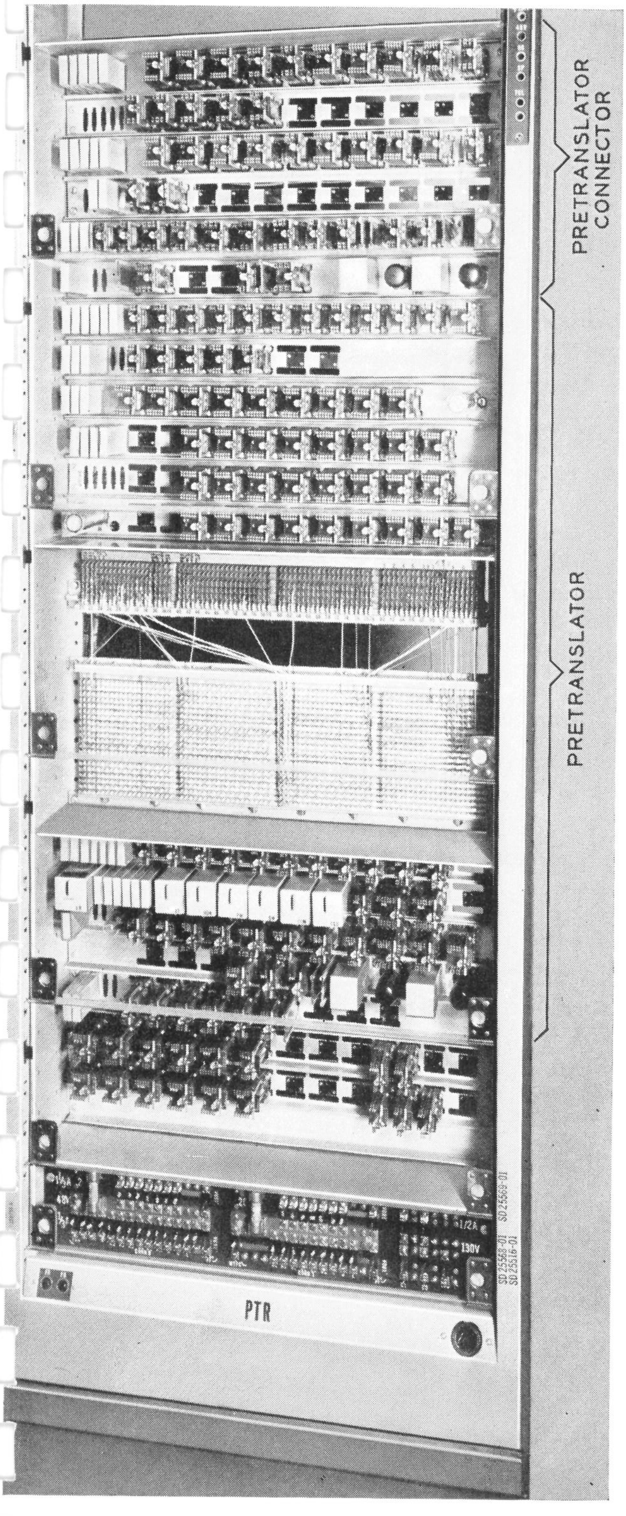


Fig. 3—Lower part of a pretranslator frame. The whole frame is arranged for two pretranslators and two pretranslator connectors.

may be seen in the table. These translating jumpers between the G and P terminals are the only variables between the input to the pretranslator and the X, Y, and Z leads, by which the translated information is returned to the register.

To convert the code recorded in the pretranslator to ground on only one of the G terminals, eight B-digit relays are used as in the circuit of Figure 1, but the A-digit leads, instead of being connected directly to their armature springs as in that circuit, are multiplied to the armature springs of a CR, a CS, and a CT relay. The twenty-four leads from the front contacts of these three relays are multiplied to the armature springs of the eight B-digit relays. Since a single U-type relay will not operate twenty-four contacts, two B relays are operated in series by each B-digit lead.

Relays CR, CS, and CT are operated from the circuit that records the C digit of the code. If the C digit is a 1, 2, or 3, relay CR is operated; if it is 4, 5, or 6, CS is operated; while if it is 7, 8, or 9, CT is operated. For each possible combination of the A and B digits in a code, there are thus three code groups: an R group when the C digit is 1, 2, or 3; an S group when it is 4, 5, or 6; and a T group when it is 7, 8, or 9. This group letter is included in the designations of the G terminals, which run from 22R to 99T. The G terminals to which the contacts of the B2 relays are connected, for example, will be the twenty-four numbered from 22R to 92R, 22S to 92S, and 22T to 92T—all those, in other words, that have a 2 as the B digit.

To distribute the twenty-seven P terminals to one or another of the X, Y, and Z leads, the three relays, marked CU, CV, and CW, are employed. Here also two relays operated in series are used for each designation, since one would not handle the number of springs that are required.

Whether a P terminal should be connected to X, Y, or Z depends on whether the particular code being translated is the first, second, or third of the code group. Since this fact is determined by the C digit, the operation of relays CU, CV, and CW is made to depend on whether the code is the first, second, or third of its group. Thus CU is operated whenever the C digit is 1, 4, or 7, CV when it is 2, 5, or 8, and CW when it is 3, 6, or 9. It will be noticed in Table I that for P0 all three codes of the group are translated as X; that for P13 they are all translated as Y; and for P26, they are all translated as Z. These three terminals thus do not need to be carried through the CU, CV, and CW relays since the code is given the same translation whether it is the first, second, or third of the group. These three terminals are thus connected directly to the X, Y, and Z leads. Each of the remaining twenty-four P terminals is connected to one armature spring on each of the CU, CV, and CW relays, and the front contacts of these relays are connected to the X, Y, and Z leads as indicated in Table I.

Terminals P1 to P8, inclusive, are connected to the first eight armature springs of each of the three relays; P9 to P17, inclusive, but excluding P13, are connected to the next eight armature springs of each relay; and P18 to P25, inclusive, are connected to the last eight armature springs of each relay. The front contacts of the CU relay are then connected to the X, Y, and Z leads in accordance with the U column of Table I. Similarly the front contacts of CV are connected according to the V column of Table I, and the front contacts of CW according to the W column.

Suppose, for example, that in code group 32S the first code, 324, requires translation as an X, the second code, 325, requires translation as a Y, and the third code, 326, as a Z. The G terminal 32S would thus be jumpered to P5, which gives this distribution as may been seen in Table I. If code 326 were now transmitted to the pretranslator, ground would appear on the No. 3 A-digit lead and the No. 2 B-digit lead. The No. 2 B relay would operate because of the ground on the No. 2 B-digit lead, and the CS and CW relays would operate because the C digit was 6. The ground on the No. 3 A-digit lead would thus be extended through contacts of CS and B2 to G terminal 32S, thence over the jumper to P5, and thence through a contact on CW to the Z lead.

Two of these pretranslator circuits and two pretranslator connectors are mounted on a single frame. The lower part of such a frame, with one pretranslator and one connector, is shown in Figure 3. Both circuits are protected by time alarms as are other common control circuits, and are arranged for the second trial feature. The pretranslator has access to the trouble recorder so that records of failures may be made. A number of additional safeguards have been provided in the design of these circuits to minimize the likelihood of trouble.

The pretranslator circuit operates in about 0.160 second, and is rated at 15,000 calls per hour—probably the highest usage of any telephone circuit. One pretranslator can carry the traffic in most offices, and two are sufficient for a marker group in any case. One additional circuit is provided for maintenance, however, and thus there will always be at least two pretranslators in an office. There are always as many connectors as there are pretranslators.

Traffic registers for No. 5 crossbar

W. WAGENSEIL
Switching Systems Development

In dial as well as manual central offices, registers are provided for measuring traffic. Each register is a small electro-magnetic counting unit with number wheels which turn one position each time a pulse of current is sent through the winding by the operation of other equipment in the office. Registers show the number of calls originated and completed and the loads handled by various groups of equipment units or operators, and give indications of congestion. The general data showing trends in subscribers' usage are useful in shaping business policies, and the more detailed data are needed for central office administration and engineering. The latter include assignments of lines to balance loads and thereby obtain full use of the equipment; scheduling of operators; and ordering of new equipment of proper types and amounts to care for growth or traffic shifts.

Because the Traffic Department is particularly interested in the data provided by traffic registers, they like to have them located in operating rooms at a convenient height from the floor for easy reading, with all registers of a type grouped together. Furthermore, it is desirable to purchase only as many registers as are required for each office at any given time. It is also desirable to have the traffic register cabinet blend in with new operating room appointments and occupy as little space as possible.

To meet these requirements and to obtain manufacturing economies, a new circuit and a new traffic register cabinet, shown in Figure 1, have recently been designed. The new steel traffic register cabinet mounts directly against the wall and will be used in new offices instead of the earlier wooden traffic register cabinets, shown at the left in Figure 2. These were located two and one-half feet away from the wall to permit access to the permanent cables connected to the rear of the registers. With the old arrangement a traffic register distributing frame, shown at the right in Figure 2, was required in the terminal room to connect the various registers to the desired circuits by cross-connecting jumpers. This distributing frame is not required where the new cabinet is provided.

With the new arrangement, one basic register unit is used. It is shown in Figure 3 and only as many of these units as are needed are ordered by the Telephone Companies. On each unit are ten registers, ten register pin jacks, and one supply pin jack. One end of each register winding is surface wired to its individual register jack. The other terminals of the ten registers are strapped together and connected to the supply jack. These register units are mounted on the cabinet framework that also mounts a field of pulse jacks. Switchboard cable leads are permanently connected to the pulse jacks from equipment requiring traffic registrations. As shown at the right in Figure 1, inexpensive Western Electric Company single-conductor cords are used to connect any traffic register via its jack to any equipment via its jack-field pulse jack. Similar cords are used to connect the battery supply jack for each group of ten registers to one of the battery supply jacks of the jack field that provides either direct battery or battery under control of one of the switches mounted immediately above the registers. The traffic registers themselves are of the new 14 type that operate in such a short interval of time that pulse-help relays are not ordinarily required. For some registrations, however, such as sender group busy registrations, it is necessary to have auxiliary relay equipment, which is mounted on

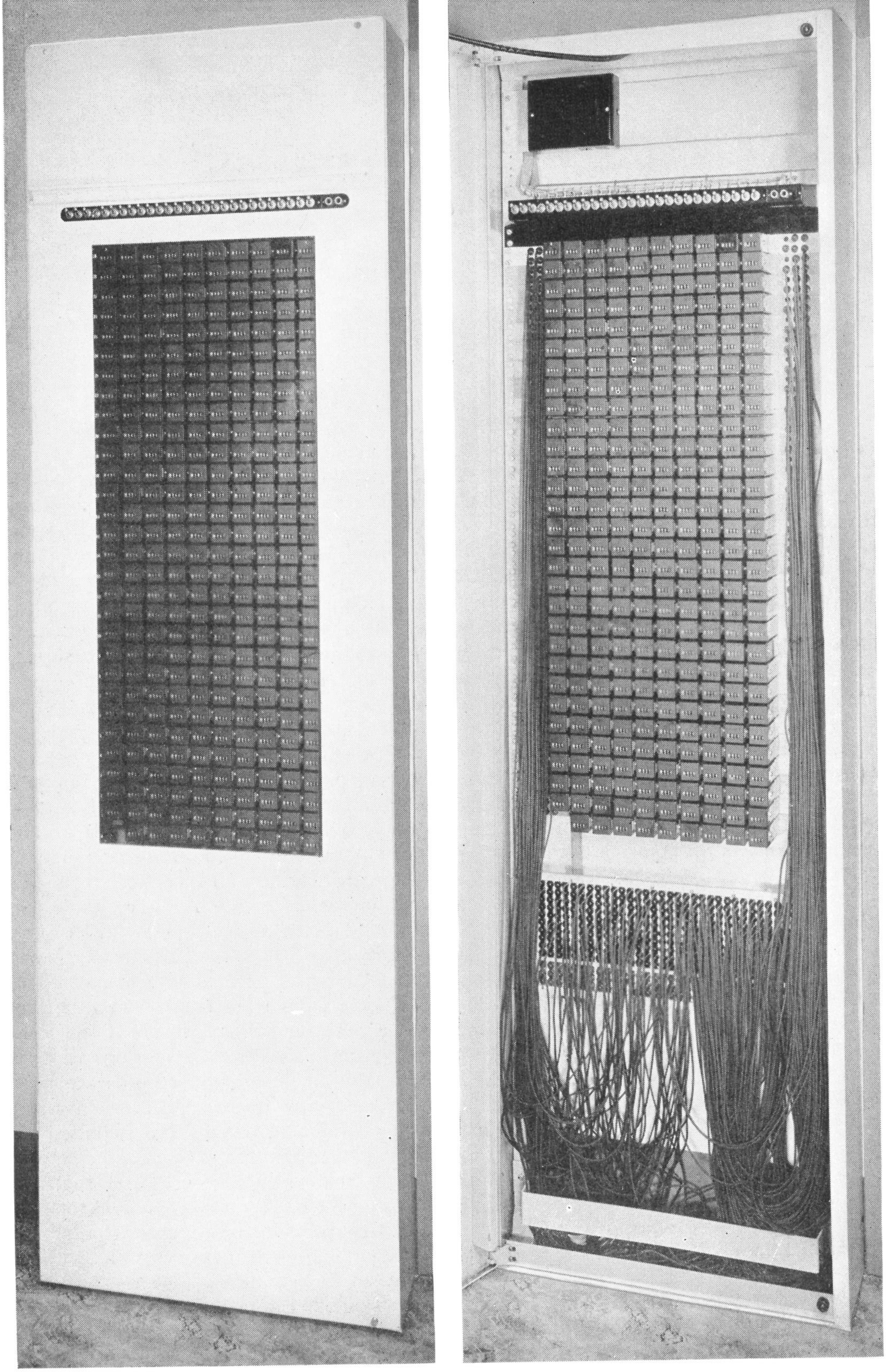
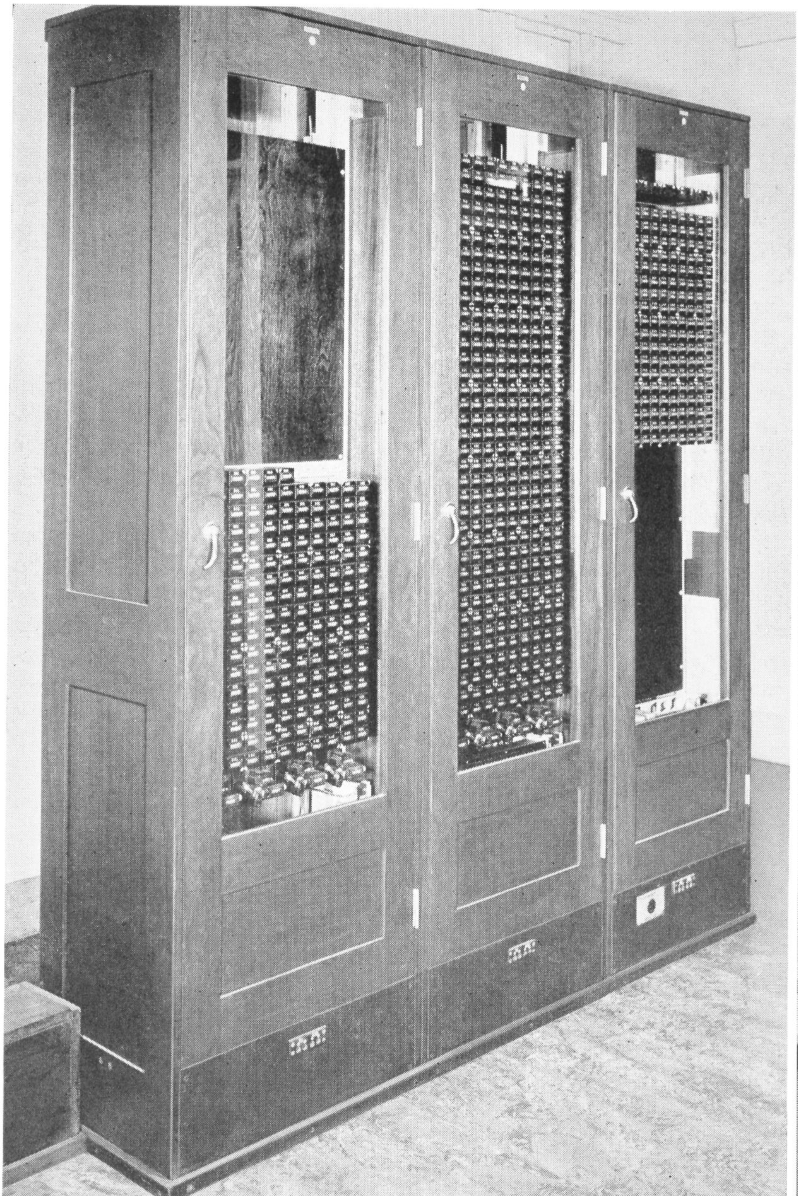


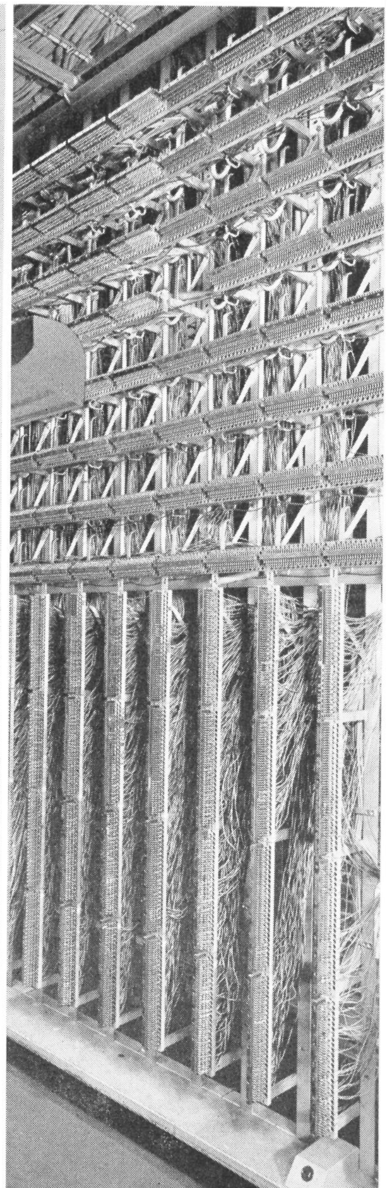
Fig. 1—Left, one of the new traffic register cabinets with doors closed. Right, opening the door of a traffic register cabinet gives access to the cords by which the various registers are connected to the required circuits.

a miscellaneous relay rack frame in the terminal room.

The use of 14-type registers and inexpensive cords makes it possible to meet the Operating Companies' requirements for a traffic register cabinet, one which occupies a small amount of space, contains only the number of registers required for the office at a given time, and can be located in the operating room with all of the registers at a convenient height for easy reading. The traffic register cabinet is only 7¾ inches deep and can be maintained entirely from the front. It is thus mounted against a wall with no provision for access to the rear of the cabinet. It will accommodate any number of registers from ten to three hundred. The Western Electric Company provides only as many register units as are required for each office without penalizing either

Fig. 2—Left, a traffic register cabinet of the earlier type. Right, part of a traffic register distributing frame.





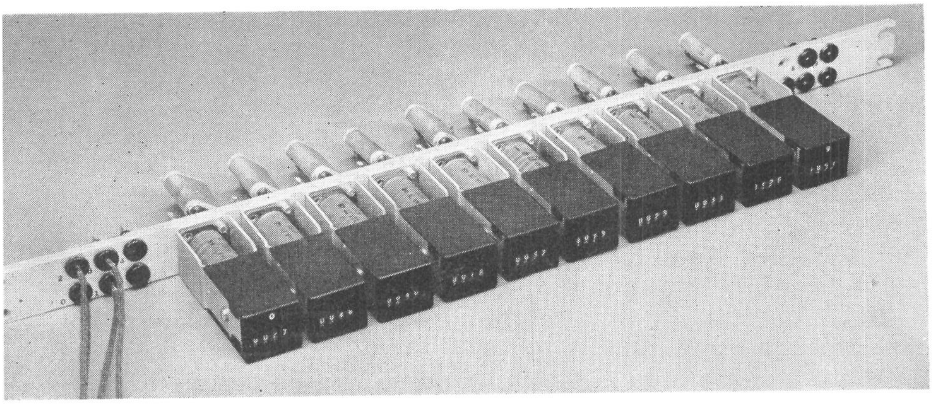


Fig. 3—A traffic register unit includes ten registers and their connecting jacks.

large or small offices. The installer or maintenance man assigns or reassigns incoming cable leads to different registers by changing patch cords as required so that all registers of a type are always grouped together and so that the most often read registers will be located at the most convenient height. A record of the permanent assignment of switchboard cable leads to jacks in the jack field, and of the patch cord connections, is kept on a card hung on the rear of the door of the traffic register cabinet. Because side panels are provided only on end cabinets, any register can be patched to any lead terminated either in the cabinet where the register is located or in an adjacent cabinet.

The new arrangement provides other desirable features. The maintenance man can remove an entire plate of registers for inspection or maintenance without interrupting service and without bending any local cable forms. Registers that are connected to equipments that operate often can be disconnected during periods when readings are not being taken by operating the switches immediately above the registers. This prolongs the life of these registers. The installer can easily provide for either right- or left-hand opening of the cabinet door. Both the door and the side panel may be painted the same color as the wall to which they are secured, thus making them inconspicuous. Jacks connecting to a talking line are located next to the switches so that one traffic employee can pass the register readings to a second employee, the recorder, seated at a desk.

When the central office building does not contain an operating room, the traffic register units, the jack field and the keys are mounted on a standard 23-inch relay rack frame in the switch room. This contributes to the uniformity of the basic arrangement.

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