# MECHANOELECTRONIC TELEPHONE SWITCHING SYSTEM

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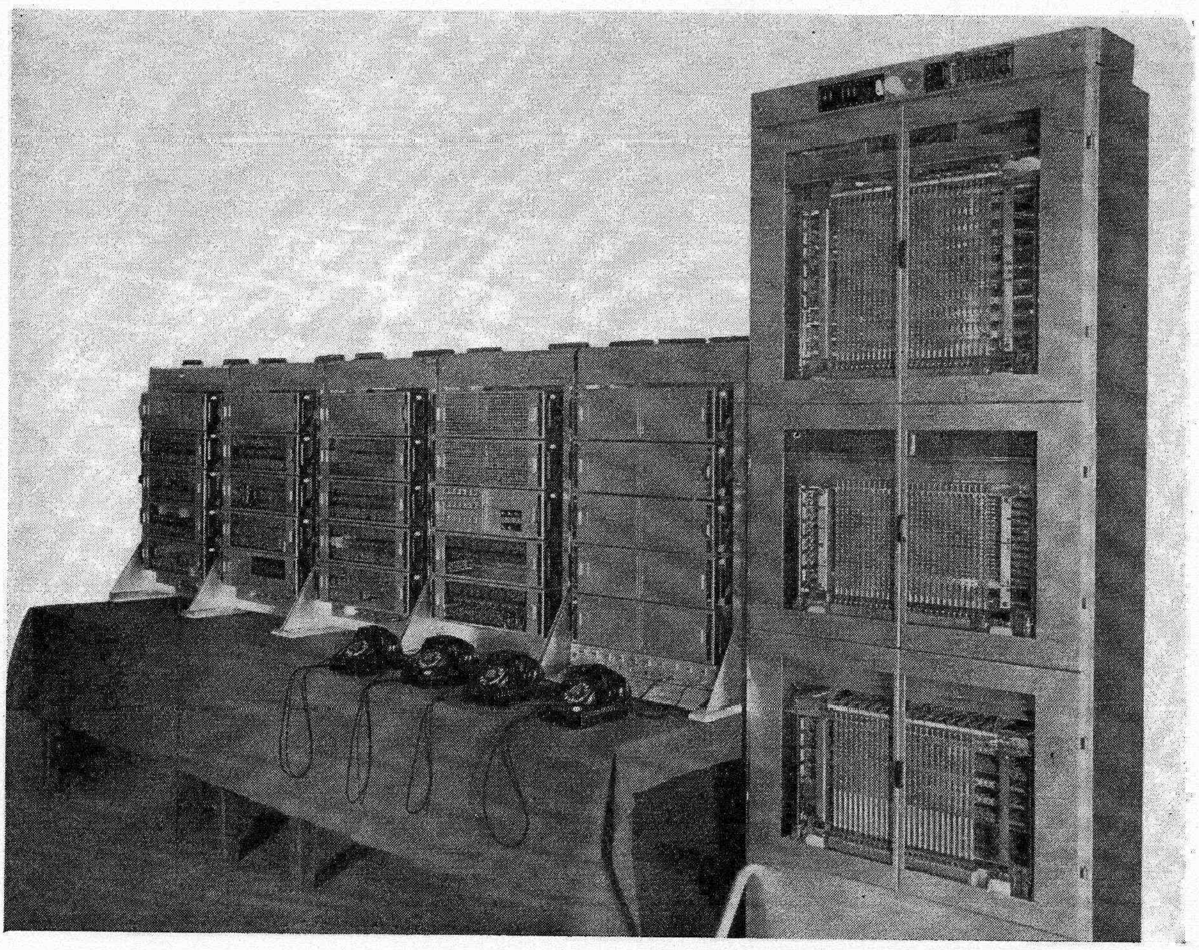
DEVELOPMENT of modern machine switching systems for telephone service has been influenced by three distinct factors.

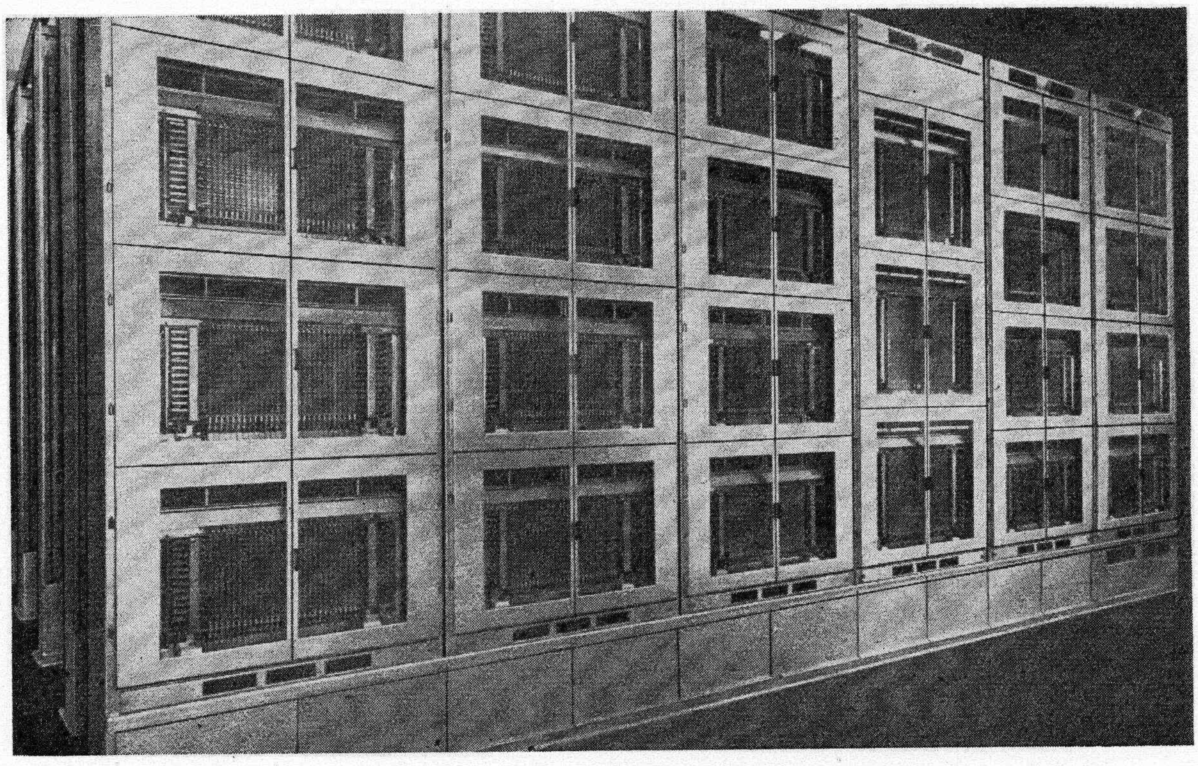
The first concerns fundamental apparatus design. It is an established fact that switches having ordinary sliding contacts are liable to cause disturbances in the talking circuit. After a certain time of use, the surrounding atmosphere forms on contact surfaces a thin film that is highly sensitive to vibrations and causes appreciable voltage variations. Although means are available to improve this condition, notably by periodic cleaning of the contact surfaces and by reduction of the disturbing vibrations, nevertheless the fact remains that a high-quality electric connection between two conductors can best be obtained by providing precious-metal contact surfaces. With the advent of automatic long-distance switching, the contact-noise phenomenon has become more prominent.

The crossbar switch invented by J.S. Reynolds in 1913 was the first attempt at switch design providing precious-metal, pressure contacts. However, it was not brought into actual use until some years later.

The development of all-relay switching systems took place parallel to this. Possibly, it is the combination of the crossbar switch and all-relay switching system methods that suggested



Demonstration model of the system.



Multiswitch bays in the Ski exchange, Oslo, Norway.

the application of the Reynolds type switch as a multiswitch, associated with the link and the marker that provides the directive control of the equipment and that performs the functions of hunting and selecting.

Another stimulus that instigated new trends of thought was the dynamic progress of electronic techniques and their growing reliability. The application of electronics to switching is attractive for its speed and absence of mechanical wear, implying easier maintenance. Switching engineers are not obliged, however, to accept electronic means as the only solution of their problems as they have other thoroughly tested electromechanical and electromagnetic devices at their disposal. They are, therefore, inclined to accept electronics only if it offers concrete advantages, such as simplification, smaller space occupancy, reduced maintenance, higher-speed operation, et cetera.

Yet another impulse was created by the rapid extension of long-distance dialling by the subscriber, which gave rise to a variety of problems. Multiple registration of the fee due on the subscribers' meters as adopted by several European administrations, although attractive on account of its simplicity, may not provide a complete solution for the call-charging problem of the larger countries. Long-distance dialling has, therefore, brought to the foreground the problems of identification, ticket printing, automatic call charging, and completely automatic billing. Accuracy being of prime importance for these services, simple and reliable means are indispensable. Where the function of identification of the calling subscriber's number had to be added to existing exchange equipments, the ways and means used were often rather complicated. With new systems, however, the requirement of perfect accuracy should be guaranteed and be obtained with simplicity and economy.

The mechanoelectronic *(ME)* switching system is based on a newly developed multiswitch of the crossbar type in which connections are established by operating vertical and horizontal bars. The contact metal used is gold. The multiswitch has a capacity of 100 outlets, which eliminates the necessity of working switches in pairs or links. The capacity of the switch is sufficiently large to permit single-stage selection whereby complicated circuit arrangements, switching schemes necessitating the establishment of one call at a time through several selecting stages, and common markers, are rendered unnecessary. The switch is of compact design and both multiples, inlets, and outlets are of the jack-in type. In a following section, a description is given of the multiswitch and of the manner in which the three basic problems of contact quality, multiple design, and space occupancy have been solved. As the switch is of the passive type, all hunting and selecting operations are performed by auxiliary circuits.

All functions of calling, hunting, selecting, testing, discriminating, and identifying are performed by electronic means, for which pulse techniques are used. One electronic pulse generator is required for each exchange. The functions mentioned are performed by explorers and comparators, operation of which is based on coincidence of pulses applied to gate circuits. These electronic methods produce extremely high speeds of selecting and hunting.

The combination of a large-capacity multiswitch and electronic contral places the *ME* system among the most modern available.

An order for a 2000-line trial exchange was received from the Norwegian telephone administration. This equipment was installed at Ski in the Oslo area and successfully cut over during the spring of 1954. This exchange permits both the administration and manufacturer to gain valuable experience on the behavior of electronic controls applied to switching systems by which further progress in the telephone switching art will undoubtedly be achieved.

### 1. *Fundamental Principles*

The *ME* system employs multiswitches of the crossed-contact type as the switching element. Depending on traffic and switching purposes, there is a choice among 3 capacities; 3, 12, and 18 panels on each of which are 2 subswitches. Switches with wiping contacts are not used.

The system is of the indirect type in that registers are utilized to receive the digits dialled by the subscribers and then assume complete directive control of selection.

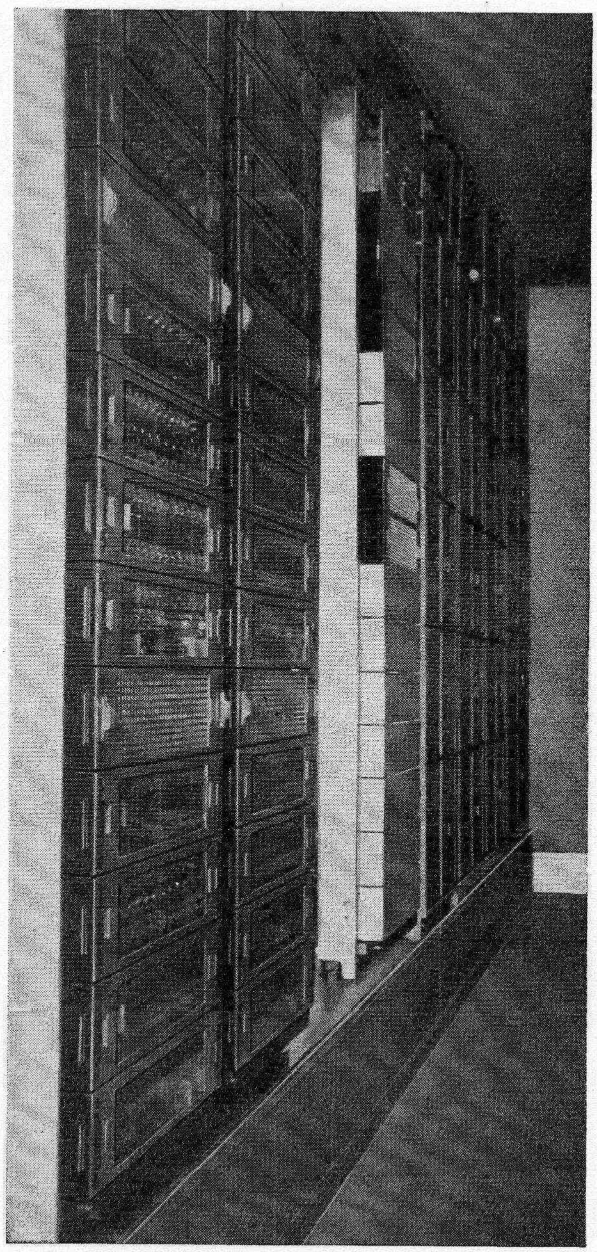
Extensive use is made of electronic means for the establishment of connections. As the multi-switch incorporates pressure contacts instead of wiping contacts, as used in many existing machine switching systems, it cannot conveniently hunt or select. These functions are performed by auxiliary circuits called governors.

This auxiliary equipment need be connected to the equipment carrying the effective traffic only during the selection period. As a consequence, a minimum of equipment is engaged during the conversation period. To illustrate this, a local call in an exchange forming part of a multioffice area holds in use only 6 subswitches and 12 relays. These relays form the cord circuit ; neither the line circuit nor the line-finder or selector circuits include any relay equipment.

The circuits have been designed to ensure continuity of operation. The mechanical apparatus is of sound construction, wear is negligible, and all parts are easily accessible.

Auxiliary apparatus of well-known design such as relays, capacitors, resistors, cold-cathode gasfilled tubes, and vacuum triodes are used. All apparatus is mounted on jack-in units, inserted in folded-sheet-steel bay frameworks of the type designed for the *7E* machine switching system.

Owing to the application of electronic switching principles and the negligible time a selector takes to perform its functions, the system operates at high speed.



Ski exchange electronic control equipment.

Simultaneous operation of switches for different calls is a normal feature. Whether these switches belong to the same switching stage or to different stages, provided they are not located on the same multiswitches, they function independently. It is obvious, however, that of the different switches forming part of one multiswitch only one can be operated at a time owing to the basic mechanical principle of a crossbartype switch. It is important, however, to mention that the electronic control equipment associated with a multiswitch can concurrently carry out selection, hunting, and testing operations for severall calls at a time.

The *ME* system will interwork with any other type of automatic telephone switching system. The equipment performing the adaptational functions forms parts of the local and incoming register circuits exclusively.

For interoffice selection, voice-frequency binary-code sending equipment of the type developed for the *7E* system is used, permitting high-speed transmission of numerical information via any number or kind of tandem exchanges without impulse repetition, impulse correction, or impulse regeneration. This ensures extremely reliable interoffice working. The same signalling system has also been adopted by the Comité Consultatif International Téléphonique for its European rapid-toll plan.

The latest type of circuit cross-connection or grading is incorporated. It is the so-called homogeneous grading developed on the basis of experimentally obtained traffic results. Two-stage selection can be provided permitting large junction groups to be operated on a full-availability basis, thus ensuring maximum junction efficiency and economy.

The needs and particular conditions applying to a number of operating telephone administrations throughout the world have been carefully studied so they could be provided for in a telephone system having universal application.

The present development has advanced only to the design of exchanges of 2000 to 10,000 lines for multioffice city areas.

However, it will be followed by the development of exchanges of smaller capacity. The multiselector will also be applied to the solution of many other switching problems.

## 2. *Operating features*

**A.** Improved method of detecting and signalling false calls resulting from permanent loops, grounded lines, and the like.

**B.** Testing by auxiliary switching equipment of the class and condition of a called line. A large number of conditions can be distinguished. The circuits permit various combinations of 32 different conditions and classes. The class of a line depends on cross-connections and may readily be changed.

**C.** On calls to busy lines, all selector and junction equipment is released and only finders and a cord circuit are held until the calling subscriber releases.

**D.** Lines may be placed in the absent-subscriber condition by remote control from an operator's position. Calls directed to such lines are automatically rerouted to an operator.

**E.** Identification of the calling number for automatic toll-call charging and calls to special services such as the telegraph office ; for tracing false, malicious, police, and fire calls ; and for those to combined-line-and-recording positions. This feature has been designed as an integral part of the system.

Compared with previously known methods of identification, the novel methods employed offer several advantages.

**F.** Private-branch-exchange hunting facilities for lines with consecutive numbering, with nonconsecutive numbering, and for nonnumerical groups.

**G.** Absentee service with a record of calling numbers printed at the premises of the absent called subscriber.

**H.** Provision for repeated time-and-zone metering and for automatic call charging on rural and toll calls.

**I.** Possibility of holding the calling subscriber's line with switchhook supervision by a combined-line-and-recording operator with possibility for reringing.

**J.** For the detection of malicious callers, a line may be provided with a means by which the called subscriber can prevent the calling line from releasing ; its number will be displayed at an operator's position.

**K.** Improved transmission. The supervisory and bridge relays used in the cord circuit and incoming selector circuits are not used for the transmission of dial impulses, permitting them to have high impedance and great sensitivity. This results in an extremely low speech attenuation (0.3 decibel compared with 0.7 decibel in other systems) and provides the possibility of operating with junctions having loop resistances of several thousands of ohms. Further, great care is taken to obtain a high degree of balance to ground of all supervisory bridges by selecting pairs of relays with equal characteristics. The balance obtained is of the order of 99.8 percent.

**L.** High-speed operation. The electronic equipment hunts at 5000 steps a second and selects a circuit within a wanted group at 455 steps a second. The operation of a multiswitch takes only a fraction of a second.

**M.** Direct-reading traffic-recording equipment as used for the rotary systems may be provided. Traffic-metering contacts are available in every circuit.

**N.** Pay stations of various types may be used. A special signal is given to the operators to whom a call may be routed for the purpose of coin control.

**O.** Party lines of various types may be introduced. The type described in this paper requires a party suffix to be added to the line number ; it is based on a number per line. Arrangements may be made also for handling party lines on a number-per-station basis.

**P.** Delayed release. The cord circuits are arranged for immediate front release ; the calling party's line is set free at once when he restores his handset. Should the called party not release, the cord circuit is forcibly released after some 20 seconds.

Should be called party release and the calling party fail to do so, the connection is forcibly released after some 20 seconds. This prevents a subscriber from blocking another line for an indefinite period of time. The line of the subscriber who failed to release creates a call and is subsequently routed to the false-call desk.

**Q.** Hold-over feature. The well-known hold-over feature of the rotary systems is maintained. In the event of a fault occuring, the train of selectors and certain of the auxiliary circuits are prevented from releasing, but an alarm is displayed. The calling line will be released. The hold-over feature may be disconnected by a key provided per register.

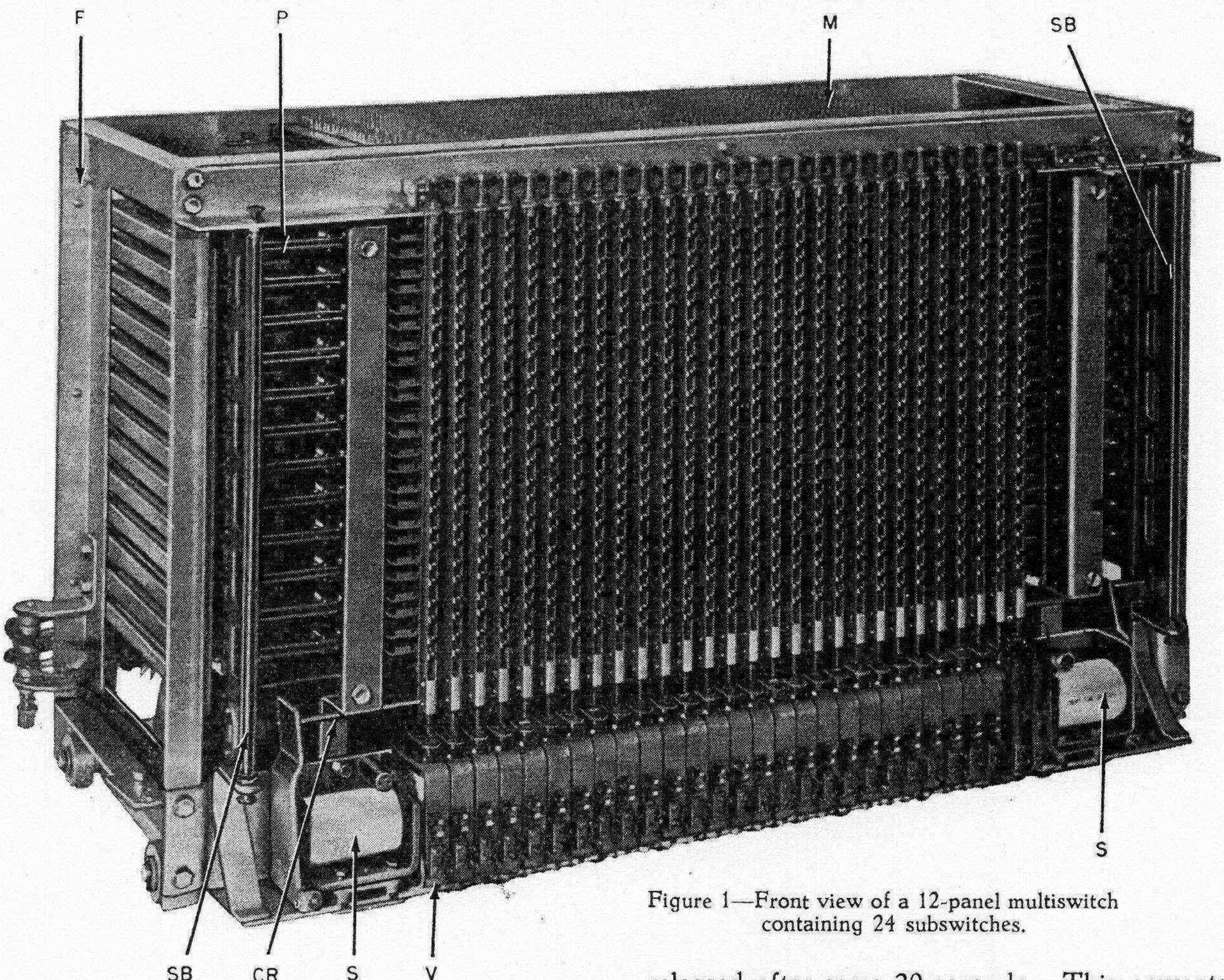



Figure 1—Front view of a 12-panel multiswitch containing 24 subswitches.

**R.** Nonexisting numbers dialled and calls to vacant directions are handled in the usual manner. Calls to dead lines are rerouted to an operator's position or a service tone is applied to the calling line. A line is also in the dead-line condition when its individual plug forming part of the line circuit has been removed for any reason.

## 3. *Multiswitch*

### 3.1. General

The multiswitch provides a capacity for mounting 3, 12, or 18 panels. Two subswitches, each of which can reach any one of a group of 100 outlets, are mounted on a panel. A multiswitch equipped with 36 subswitches is equivalent to a bay of that number of 100-point rotary finders interconnected by ribbon cable. It is 76 centimeters wide, 55 centimeters high, and 29 centimeters deep (30 by 21.7 by 11.4 inches). Figures 1 and 2 show a front and rear view of a complete 12-panel multiswitch that contains 24 subswitches.

Through switching for 5 wires is provided, but with a minor change the switch can be arranged to provide 10-wire through switching. The number of outlets that can be reached then is reduced from 100 to 50.

To minimize microphonic-contact noise, the multiple contacts are of the precious-metal pressure type. Gold is used as the contact material; in the future it may be replaced by rhodium. These contacts do not close or open while the circuits are energized.

by eliminated wtih their attendant possibilities of high-resistance noisy joints. High insulation resistance is guaranteed and is of special importance in tropical and subtropical countries.

For the operation of the subswitches, 26+2 vertical selection bars and associated electromagnets *V* are required. They are placed on the frame *F* into which the contact panels *P* slide. One panel mounts 2 subswitches. Two servo-magnets *S* are located at the bottom corners of the frame to control the horizontal bars.

All wires leaving a multiswitch and the conductors that form the multiple are connected through jack-in contacts so that a complete switch can be removed from the bay on which it is mounted. Every detail or subassembly of the multiple switch has been designed so that all parts can easily be dismounted, inspected, and repaired, should the necessity arise.

The life of a multiswitch is very long as the amount of wear caused by the small mechanical

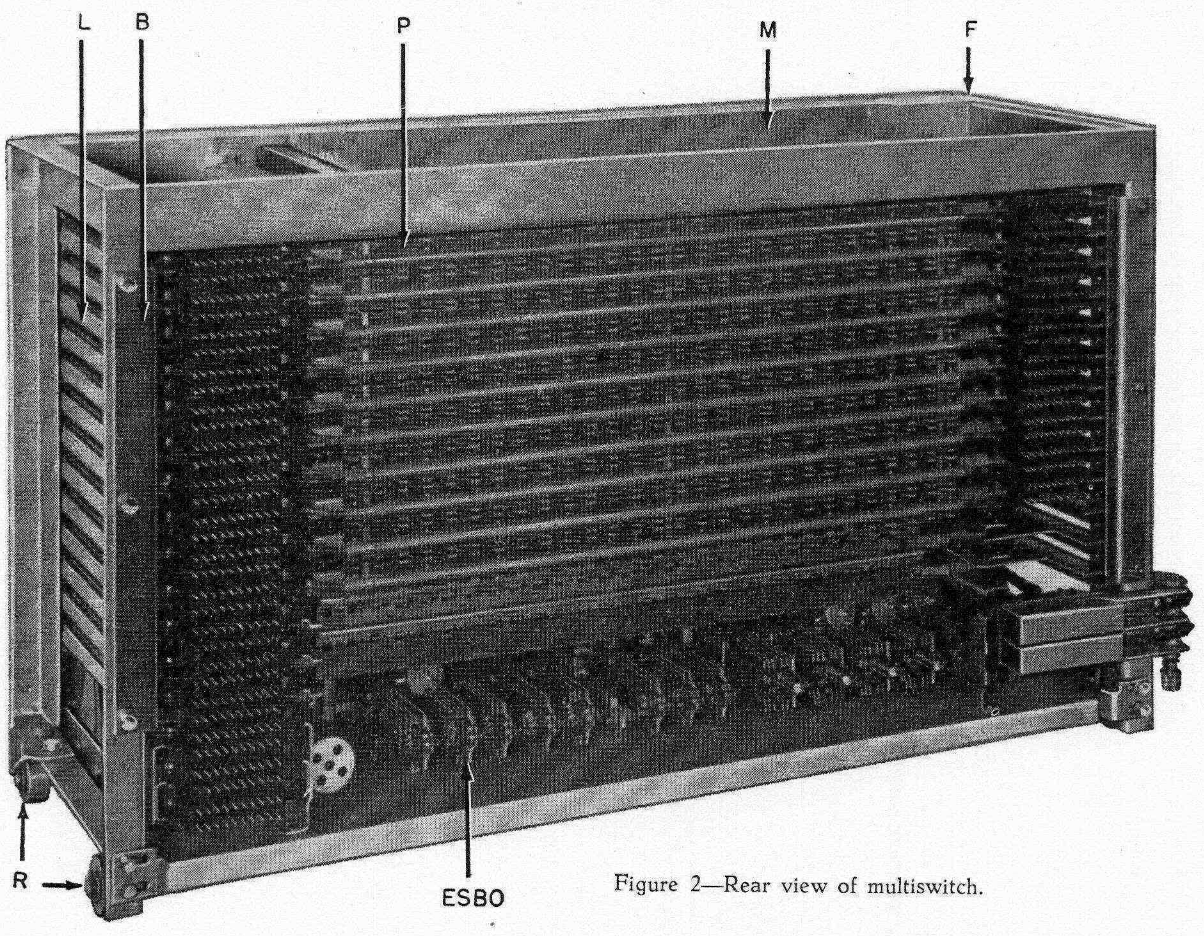



Figure 2—Rear view of multiswitch.

The multiple *M* is composed of bare wires running perpendicularly through the horizontally mounted subswitch panels *P*. Wire multipling ribbon cable and its soldering are there-

movements is negligibly low. Its operation and release take no appreciable time.

Because of its compact and novel design, the space required for a multiswitch is reduced to a minimum. It is highly suitable for mass production as the variety of piece parts of which it is composed is restricted. It is also convenient to manufacture small quantities in factories of reduced capacity for the design permits wide manufacturing limits and operating margins. These features obviously reflect favorably on the maintenance of the exchanges.

The multiswitch can be used in unmodified form for many other switching purposes, such as private automatic branch exchanges, toll switching offices, telegraph exchanges, and signalling equipment.

The choice of the 100-line switching capacity has mainly been governed by principles of systems design. Too small a switching capacity (10 or 20 outlets) introduces the necessity of multistage or multilink selection, which in turn leads to complication of the circuits controlling the selection and to the introduction of so-called common marker circuits. Single-stage selection, on the other hand, permits the use of conventional switching methods and simplified systems design.

A multiswitch has the following :

**A.** Switch frame.
**B.** Contact panels.
**C.** Horizontal-bar servomechanism.
**D.** Selection mechanism.
**E.** Vertical multiple.
**F.** Esbo panel (electronic selection and bar-operation circuit).

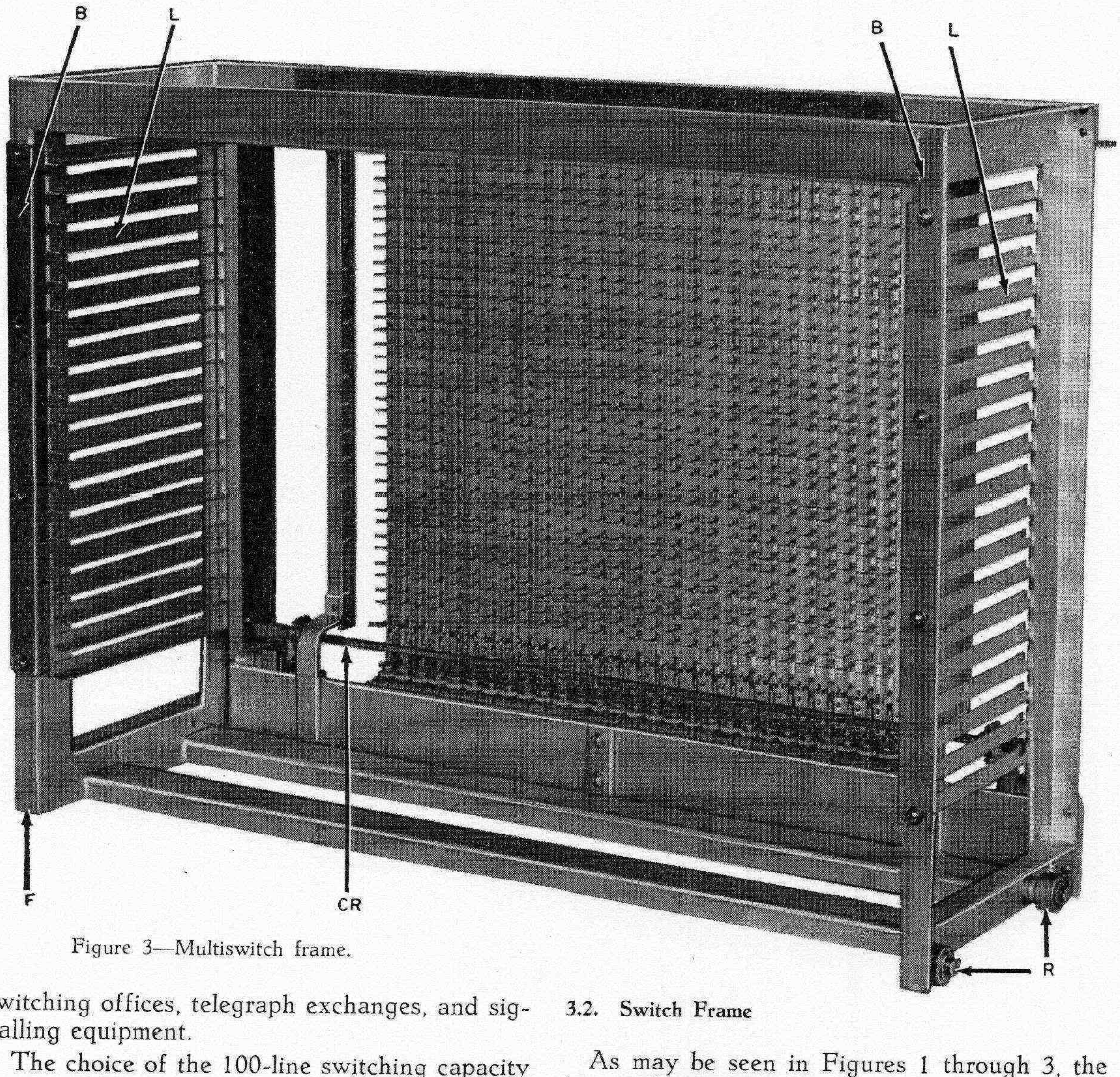


Figure 3—Multiswitch frame.

**3.2. Switch Frame**

As may be seen in Figures 1 through 3, the frame *F* of the switch is composed of folded steel sheets, 3 millimeters (0.118 inch) thick, welded together to form a solid unit. It is designed for minimum weight and high structural strength. At the top and bottom of the front of the frame are two angle irons serving to support the vertical-bar assemblies and the servomechanism operating the horizontal bars.

Space is provided at the top of the frame for the jacks of the multiple wires.

On both side flanges of the frame, a lattice work *L* provides supports into which the contact panels can be slid, one above the other. After placement, they are locked in by two bars *B*.

At the bottom of the frame, there is some space at the height of the electromagnets of the vertical bars, which space is used for the location of a panel mounting the equipment for the electronic selection and bar-operation circuit.

wires are inserted after all the panels have been placed in the frame. The contact springs in their neutral positions do not touch the multiple wires. The contact springs are split and carry welded gold-plated double contacts on both sides. The contact springs are joined and operated as a group by a sliding contact finger *CF*; one contact finger operates one row of 10 contacts and a total of 28 fingers are mounted on each side of the contact panel.

A contact finger consists of a metallic part supported at both ends *FS* by the frame and

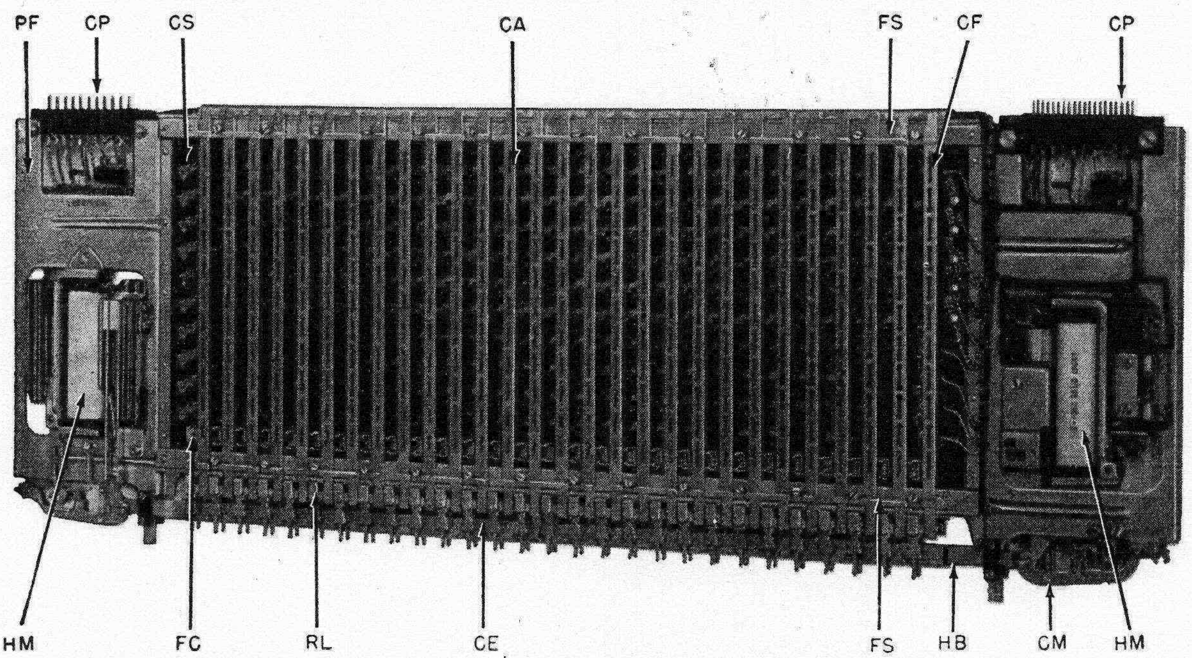


Figure 4—Top view of contact panel on which the subswitches are mounted.

The back of the frame is open. Rollers *R* mounted on the base of the frame permit easy removal of the complete unit.

**3.3. Contact Panel.**

The subswitch panels *P* are double sided and accommodate 2 of these switches. A subswitch has access to 104 outlets, and each outlet comprises 5 conductors.

Figure 4 shows a top view of a complete contact panel. It consists of a flat frame *PF* with the contact-spring assembly *CA* located in the middle, 2 electromagnets *HM* on the outer side, and 2 horizontal bars *HB* at the front side.

Running along the top and bottom surfaces of the panel are 10 phosphor-bronze contact strips *CS* fixed to a common phenol-fiber sheet. Each strip carries 27 contact springs to form the movable contacting elements of a subswitch.

Holes in each phenol-fiber sheet allow the free passage of the vertical multiple wires. These of an insulating part provided with slots that grip the contact springs. Each finger can be moved longitudinally in two directions and is held in a normal position by a small centering device *FC*. In this manner, each contact spring is kept in a neutral position between 2 vertical multiple wires.

When one of the contact fingers, numbered 1 to 26, is moved in one direction, 10 contact springs are slightly displaced in the same direction and then make contact with the 10 vertical wires placed at that side of the springs. Ample "follow" is provided. When a contact finger is displaced in the opposite direction, the same 10 springs make contact with the 10 multiple wires placed at the other side of the springs.

Each of the 2 groups of 10 contacts operated by one finger belongs to 2 outlets having 5 conductors apiece, so that one contact finger serves for 4 outlets.

The 27th and 28th contact fingers act on only 5 springs as may be seen in Figure 5, and one of these 2 is always operated simultaneously with any of the other 26 contact fingers. They serve to connect the 5 inleads *IL* of a subswitch to one or the other group of 5 strips of contact springs. Where the metallic part of a finger protrudes at the front of the panel frame, it is coupled to a rectangularly bent lever *RL* carrying a small coupling element *CE* that is normally pushed upwards by a small spring. Figure 6 shows an enlarged view.

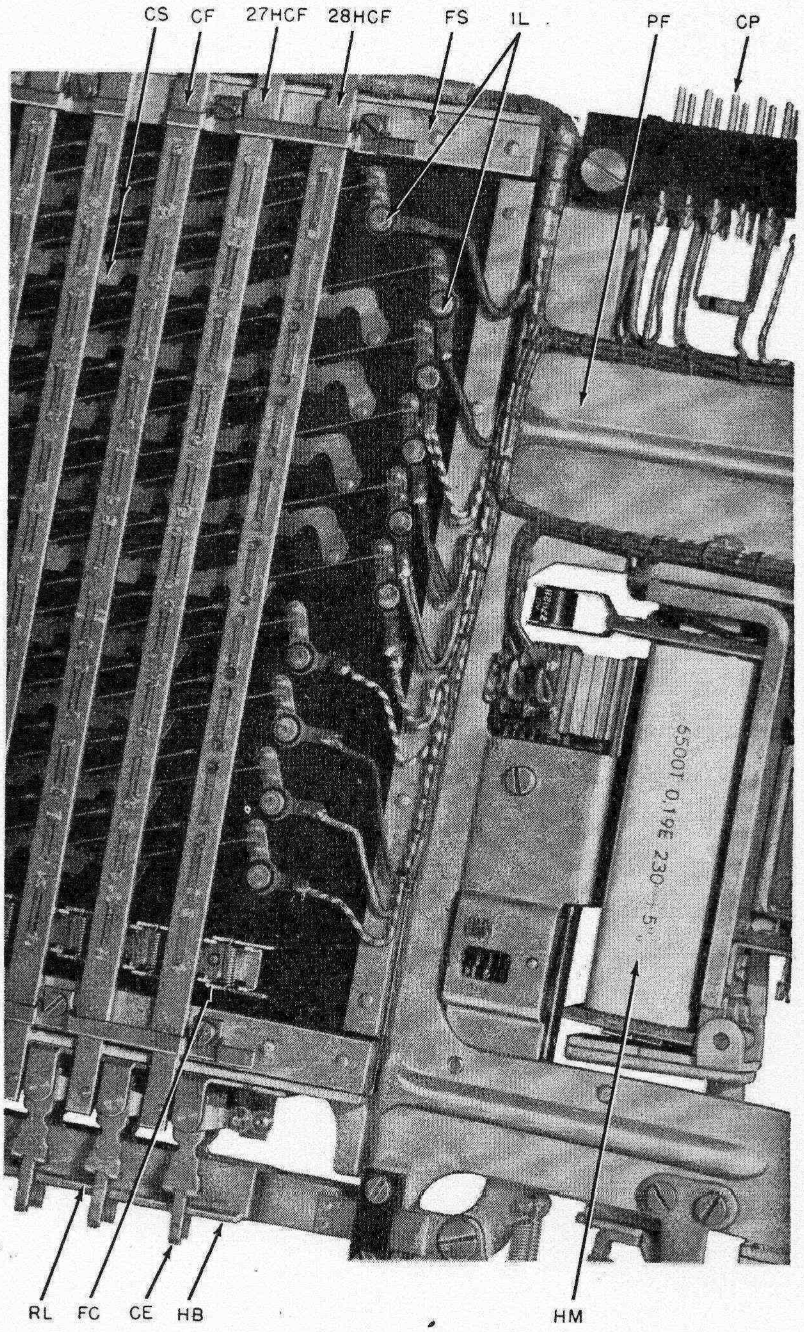



Figure 5—Close up of the 27th and 28th contact fingers.

At the front of each contact panel, 2 horizontal bars *HB* are located, one above the other. The upper bar serves for operating the contact fingers of the upper subswitch of the panel and the other for operating those of the bottom subswitch. Each bar is provided with 28 recesses *CR* into which the small coupling elements *CE* may drop. A horizontal bar moving to the left or to the right moves the finger to which it is coupled either forward or backward.

Electromagnets *HM*, one for each subswitch, are mounted at the outer ends of the panel. When the armature of *HM* is attracted, it moves 2 coupling members *CM* outward. These 2 levers are pivoted at the extremity of the horizontal bar. In this position, the coupling members engage with the front edge of a flat steel bar, *SB* in Figure 1, extending from the top to the bottom of the multiswitch frame and pivoted at its extremities.

The horizontal magnet *HM* is provided with a number of contact springs as is the horizontal bar.

At the back of the panel in Figure 6 may be seen a group of jack-in contact pins *CP* to which all the conductors leaving the panel are connected.

### 3.4. Servomechanism for Horizontal Bars.

At the bottom of the frame as shown in Figures 1 and 2 are 2 servomagnets *S*, which actuate the 2 flat steel bars *SB* already mentioned. These bars are coupled together by means of a rod *CR* (see Figure 3) and are kept in a neutral position by a centering device. Both flat bars move to the left when one magnet is energized and to the right when the other magnet is operated.

To operate the horizontal bar of a subswitch, first the horizontal magnet *HM* must be energized and move the coupling members *CM* outward so that they may be engaged by the vertically mounted flat steel bar *SB*. Then one of the servomagnets *S* is operated, depending on whether the horizontal bar is to be moved to the left or the right and whether a contact finger has to establish contact with the multiple wires located in front or behind the contact springs.

It is, therefore, by a choice between the left or right servomagnets and by that between the 27th or the 28th contact fingers *HCF* (see Figure 5), that one of the 4 contact groups controlled by each of the 26 other fingers is selected.

The manner in which the coupling members *CM*, forming part of a horizontal-bar assembly operate, is shown in Figure 7.

At *A*, the mechanism is at rest. The armature *HA* of the horizontal magnet is not attracted and the two coupling membres *CM* are held back by small springs.

*B* shows the situation after the armature has been attracted. A cam *HC* actuated by the armature has moved the two coupling members *CM* outward so that they may now be engaged by the flat steel bar *SB* actuated by the servomagnet *S*.

*C* and *D* show the conditions after one or the other servomagnet has been operated. In *C*, the horizontal bar has been pulled to the left and in *D* to the right. During this operation, pressure or pull is exercised on only one of the coupling members and the free one drops behind the cam *HC* placed on the armature.

When the servomagnet releases, it removes the pressure between the flat steel bar and the coupling member, which then also drops back. During conversation, the horizontal magnet remains energized with the horizontal bar hooked to the cam in one of the two operated positions, as is shown in *E* and *F*.

When the horizontal magnet releases, the horizontal bar, its coupling elements, and the contact fingers restore to normal.

### 3.5. Selecting Mechanism

The selecting mechanism is mounted at the front of the frame of a multiswitch and consists of 28 independent vertical-bar assemblies, each actuated by a plunger-type electromagnet.

Each of 26 vertical bars serves for the selection of one of the 26 groups of 4 outlets, whereas the 27th and the 28th bars serve for selection of one of 2 groups of 5 strips of contact springs.

Each vertical bar, *VB* of Figure 8, extends over the entire height of a multiswitch and is supported at the top by a small bearing. There is also mounted at this point, a spring that tends to move the bar upward. At the bottom, the bar is provided with a soft-steel plunger *VP* that operates into the inner shell of the electromagnet *VM* as a guide.

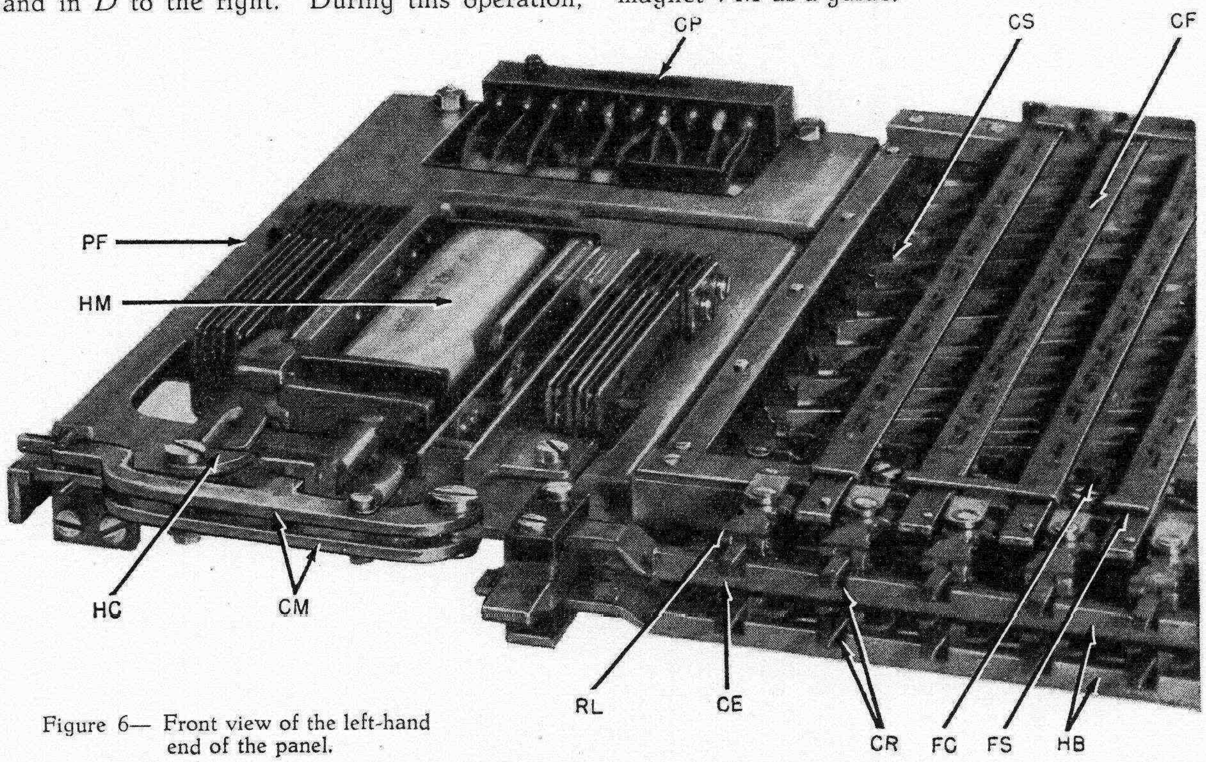



Figure 6— Front view of the left-hand end of the panel.

Each vertical bar carries a number of small clamped equally spaced phosphor springs *PS* and the assembly is so placed that these springs just rest on the small coupling elements *CE* (Figure 6) associated with the levers *RL* of the fingers. These elements, as already stated, are pushed upward by a small spring. When their small coupling element with it and, consequently, operates the contact finger. The vertical bar may then restore.

The coupling element stays in the recess of the horizontal bar owing to the friction between the side of the recess and the tip of the small coupling element.

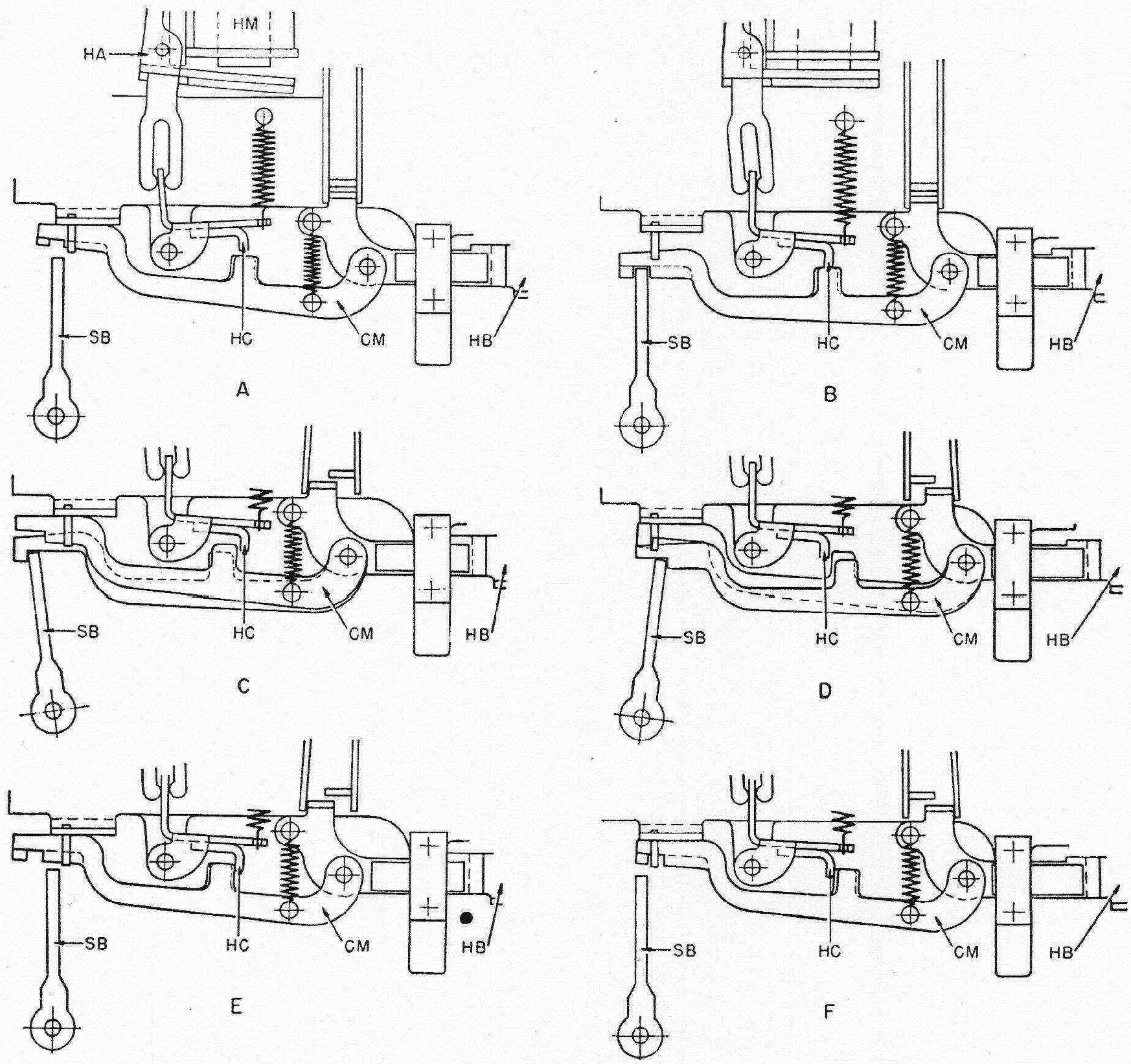



Figure 7—Horizontal-bar assembly.

tips are moved left or right, the levers and, consequently, the contact fingers must follow.

By operation of a vertical bar, all associated coupling elements of the contact fingers located on different contact panels but in one vertical row, one above the other, are lightly pushed into the recesses *CR* provided on the horizontal bars.

When one of the horizontal bars is then moved to the left or to the right, it takes the

### 3.6. Multiple

The multiple is composed of 26 identical assemblies. An assembly consists of 20 rods, each of 1.75-millimeter (0.069-inch) tickness and plated with a light coat of gold. The rods project slightly at the top and thus from jacks for the female parts of the jack-in assemblies.

The latter assemblies are mounted next to each other on a horizontal rod fixed to the multiswitch-bay framework in such a manner that they can be moved upward and away from the multiple assemblies, which are inserted through the holes of the contact panels.

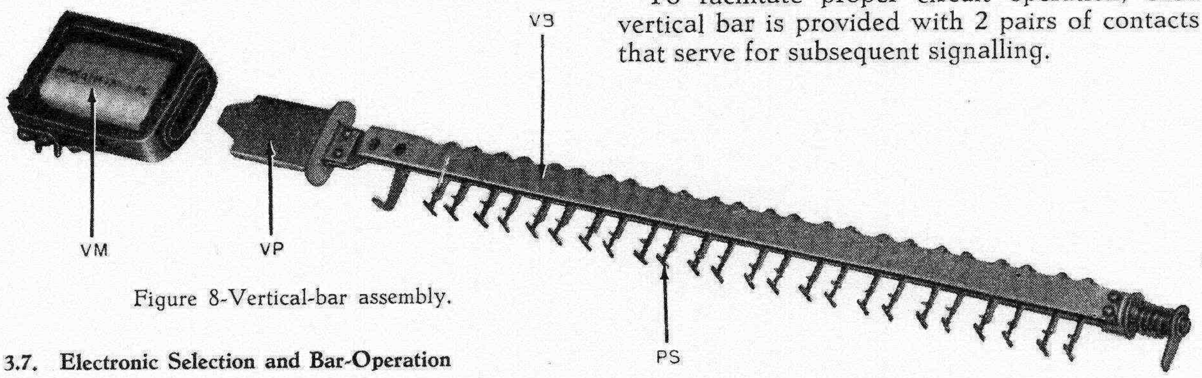



Figure 8-Vertical-bar assembly.

**3.7. Electronic Selection and Bar-Operation (Esbo[1]) Panel**

The jack-in-type esbo panel is located at the bottom of a multiswitch and is provided with steel bars suitable for mounting the various kinds of apparatus required for the esbo circuit serving the multiswitch. A typical panel is illustrated in Figure 9.

**3.8. Operation**

The sequence of operation necessary for the establishment of a connection on one of the subswitches is as follows.

The esbo circuit operates one of the 26 vertical bars plus the 27th or the 28th bar as the case may be. At the same time, the horizontal magnet of the subswitch on which the call is waiting for completion is operated.

By a second operation, the proper servomagnet is temporarily energized whereupon the call is switched through. The vertical bar is then restored. The horizontal-bar magnet remains energized.

**3.9. Vertical-Bar Contact Panel**

To facilitate proper circuit operation, each vertical bar is provided with 2 pairs of contacts that serve for subsequent signalling.

These contacts act on 4 of the 20 multiple wires and are mounted on a special contact panel, which is slid into the frame in the same manner as a normal contact panel. As may be seen in Figure 10, it carries no horizontal bars.

**3.10 Absent-Subscriber-Service Panels**

In the panels for absent-subscriber service shown in Figure 11, one contact finger is provided per line so that 2 panels are required for each 100-line subscribers' group. These fingers have only 2 positions, operated and non-operated, as compared with the 3 positions of the fingers of the contact panels. The fingers are temporarily coupled to the horizontal bar in the manner already described but whether the finger is moved from the nonoperated to the operated position or vice versa depends on whether the left- or the right-hand horizontal servomagnet is operated in combination with the proper horizontal magnet. A finger moved to the operated position may stay there for an indefinite

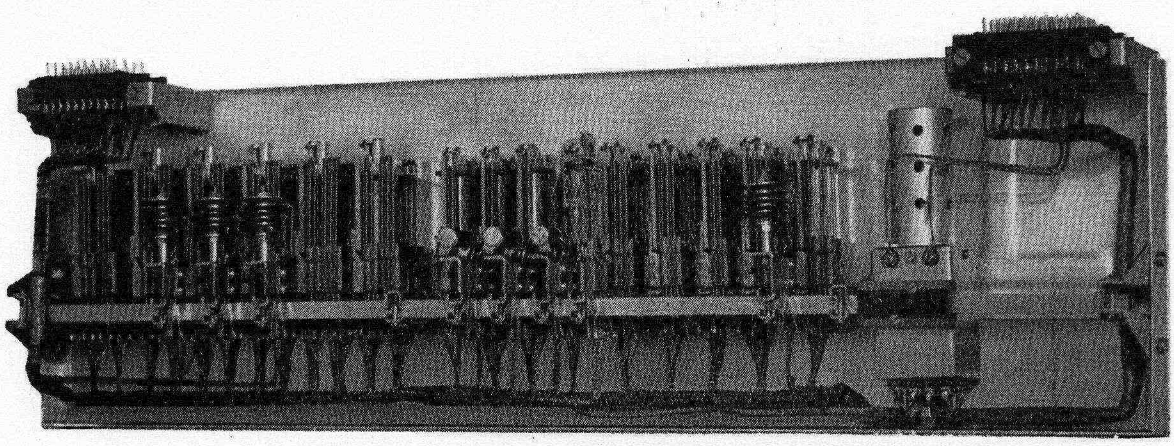


Figure 9—Esbo panel.

[1] The electronic selection and bar-operation circuit is called an esbo and will be referred to as such in the balance of this paper.

time as it is locked by a small pawl even though the horizontal magnet is released.

For restoring the finger to normal, the proper *HM* magnet is operated again together with the proper *VB* bar while the other servomagnet is energized.

An operated finger of an absent-subscriber-service panel connects impulse source $Nd_9$ to the *d* wire of the line circuit as explained in the last paragraph of section 4.5.

## 4. Principles of Electronic Control

### 4.1. Impulse Sources

An electronically operated impulse generator is provided for each exchange. It supplies a variety of positive impulses recurring at regular intervals but differing in basic voltage level, amplitude, recurrence period, and impulse duration. The manner in which this generator functions, its fundamental concepts, characteristics, and facilities will be described in a later article.

The duration of the main impulses is either 0.2 or 1 millisecond. The impulse of 0.2 millisecond corresponds to 5000 impulse periods per second, which frequency has been chosen with regard to the firing time of the cold-cathode tubes widely used in the system.

The various impulse sources that are provided by the generator may be grouped according to their basic potential, amplitude, recurrence frequency, and time position; certain conventions have been adopted for identification of the various sources according to these characteristics.

A capital letter is used to distinguish the types of impulse sources according to their basic potential and amplitude, a small letter indicates their recurrence frequency, and a number marks the time position. In this manner, every impulse source receives a distinct code that serves as a reference and contains all data necessary for quick understanding. The various characteristics are defined in Table 1.

All sources are capable of absorbing current during the periods between impulses and of supplying a potential during the impulses. The sources for series *Nd* and *Pd* (marked by an asterisk) are designed to supply current during the impulses.

The various basic voltage levels have been chosen for circuit reasons. The *N* sources, for instance, which are used in the subscriber's line explorer exclusively, must operate in conjunction with the −48-volt supply of the line and for this reason the 3 potentials of the *N* sources are negative with respect to ground.

The *R* sources are used in the recorders, where they serve to fire cold-cathode tubes and thus require an amplitude of 60 volts.

As will be seen in Table 2, group *a* includes 5 impulse sources, which are distinguished by subscript suffixes 1 to 5, the impulses of which are shifted by 0.2 millisecond. Those of group *b* are shifted by 1 millisecond.

The reason why the *b*-group impulses are of 1 millisecond, compared with 0.2-millisecond impulses for all other main sources, lies in the fact that the same recurrence period is employed for both groups *a* and *b*. The reason for this follows.

The connecting of +24 volts to the input terminal of the so-called gate circuit shown in Figure 12A and of impulse source $Pd_1$ to the

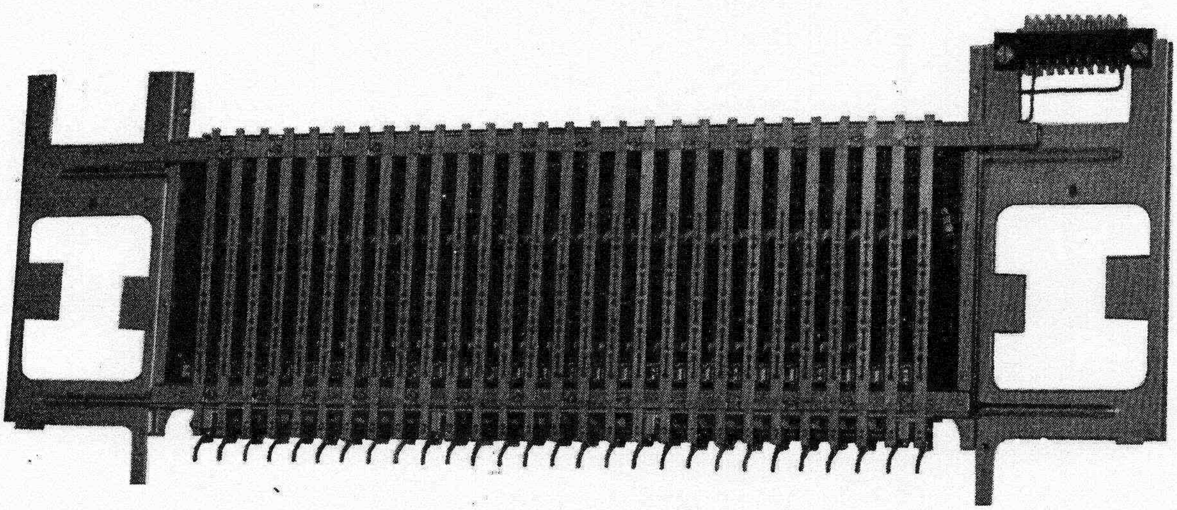


Figure 10—Vertical-bar contact panel.

control terminal provides a +24-volt impulse at the output terminal once every 11 impulses. Connecting sources $Pc_1$ and $Pd_1$, to the two control terminals of the gate circuit shown in Figure 12B and +24 volts to its input terminal provides an impulse at the output terminal every $4 \times 11$ impulses. The two sources combined, therefore, supply an impulse to the output terminal of the gate circuit only at their moment of coincidence; that is, in time position *1* of a cycle of 44 impulses. Similarly, sources $Pc_1$ and $Pd_2$ combined provide an impulse in time position *13* of the 44-impulse cycle.

From the use of the coincidence principle, as explained here, it becomes self-evident that the recurrence periods of the sources may not have a common factor. As the recurrence periods of the *a* and *b* groups are the same, and as they are used in combination, impulses of different lengths have to be introduced.

Besides these main impulse sources, the system utilizes 2 auxiliary series having impulses of a duration of 0.025 millisecond occurring 5000 times per second. They are used for timing purposes in impulse-regeneration circuits. The basic voltage of the one is +3 volts with an impulse potential of − 21 volts (negative going) and of the other − 53 volts and − 13 volts (positive going).

### 4.2. Call Detection

The subscriber's line circuit is of the fully electronic type and employs no mechanically operated apparatus such as relays.

It is shown in Figure 14 and consists of only 3 radio-type resistors and 2 small rectifiers. Each line further occupies one position in the 100-line multiple of a multiselector that accommodates both the line finders and the final selectors.

TABLE 1

CHARACTERISTICS OF PULSE SERIES

| Type | Groups | Basic Voltage | Amplitude in Volts | Crest Voltage |
|---|---|---|---|---|
| *N* | *a,b,c,e* | —40 | 16 | —24 |
| *N* | *d* | —40 | 24 | —16* |
| *P* | *a,b,c,e* | 0 | 16 | +16 |
| *P* | *d* | 0 | 24 | +24* |
| *R* | *a,b,c,d,e* | —110 | 60 | —50 |

TABLE 2

CHARACTERISTICS OF GROUPS

| Groups | Number of Sources and Recurrence Period (Expressed in Number of Impulses) | Impulse Duration in Milliseconds |
|---|---|---|
| *a* | 5 | 0.2 |
| *b* | 5 | 1.0 |
| *c* | 4 | 0.2 |
| *d* | 11 | 0.2 |
| *e* | 3 | 0.2 |

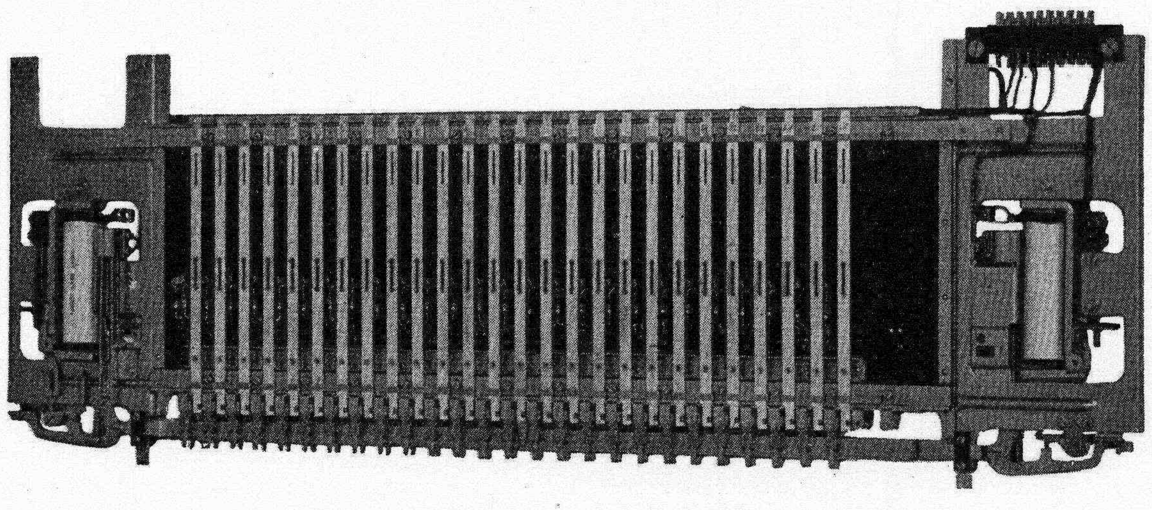


Figure 11—Absent-subscriber-service panel.

A variety of gate circuits is used for the several purposes described in the following paragraphs.

Figure 13 shows the voltage waveforms of impulse sources $Na_1$ to $Na_5$, $Nb_1$ *to* $Nb_5$, and $Nc_1$ *to* $Nc_4$ in their respective time positions.

When the handset rests on the cradle, the *a* wire of the subscriber's line is connected to ground via a 15,000-ohm resistance and the *b* wire to —48 volts through a 30,000-ohm resistance.

When a call is originated, the potential of the $b$ wire is changed to approximateliy —16 volts by the current flowing through the 15,000- and 30,000-ohm resistances, the subscriber's loop, and the station equipment.

This change in potential of the $b$ wire is utilized to signal to a later circuit over a single wire per group of 100 lines the calling condition of the line and its identity within the group.

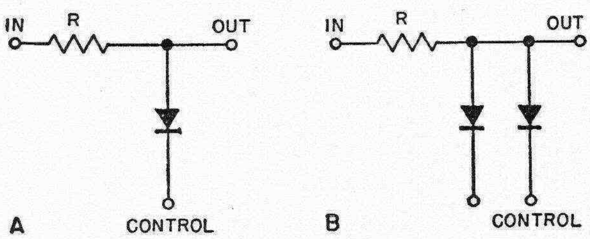


Figure 12—Typical gate circuits.

This objective is realized in an electronic manner by using a combination of gates called explorers and a number of impulse sources connected as shown.

A high ohmic resistance shown at the bottom of the figure tends to keep the potential of the common wire at – 40 volts. From this common wire 4 branches spread out ,each of which is provided with a decoupling rectifier and a second rectifier to connect them to 4 different impulse sources $Nc_1$ to $Nc_4$. Each of these 4 branches divides into 5 branches, each of which is again provided with a decoupling rectifier and connected via a second rectifier to one of 5 different sources called $Nb_1$ to $Nb_5$. In a similar manner, each of these $4 \times 5$ branches again splits in 5 branches provided with the proper rectifiers and connected to 5 different sources $Na_1$ to $Na_5$.

The 100 final branches are connected to the $c$ wires of the group of 100 line circuits. A $c$ wire is connected to its $b$ wire via a 30,000-ohm resistance.

Figure 13 shows the waveforms and potentials of the 14 impulse sources employed. The potentials vary between – 24 and – 40 volts. The impulses of sources $Na_1$ to $Na_5$ and $Nc_1$ to $Nc_4$ have the same length, 0.2 millisecond, but those of sources $Nb_1$ to $Nb_5$ are 5 times as

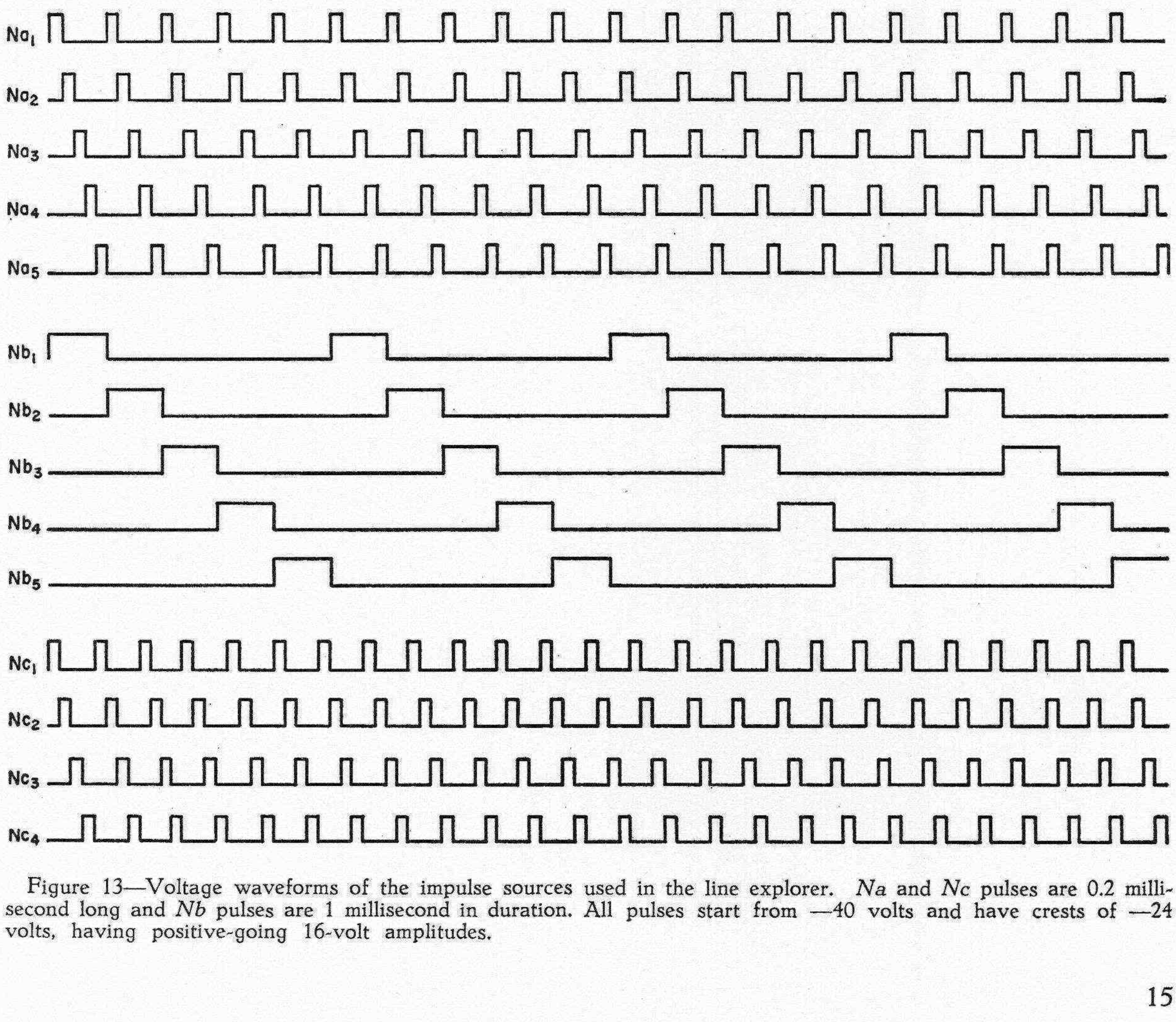


Figure 13—Voltage waveforms of the impulse sources used in the line explorer. $Na$ and $Nc$ pulses are 0.2 millisecond long and $Nb$ pulses are 1 millisecond in duration. All pulses start from —40 volts and have crests of —24 volts, having positive-going 16-volt amplitudes.

long, 1 millisecond. One will readily recognise that coincidence between the impulses of an *Na*, an *Nb*, and an *Nc* source occurs once every 20 milleseconds, so that a line signals its calling condition 50 times per second.

When a subscriber's line is at rest, the *b* wire is at – 48 volts and the common wire connected to the grid of the triode is at any moment at a more-positive potential, supplied either from one of the 3 impulse sources or from the – 40-volt voltage divider. In this condition, therefore, no current passes from the *b* wire through the 3 series rectifiers to the common wire. Also the 3 branch rectifiers involved in the path running from each line to the common wire are permanently in the nonconductive condition because the potential applied to them from the impulse sources is either equal to or positive with respect to the – 40 volts prevailing on the common wire. Consequently, when none of the lines of the group is in the calling condition, the potential of the common wire is maintained at – 40 volts.

When a subscriber's line originates a call, the potential of the *b* wire is raised to approximately – 16 volts and a current passes through the 3 rectifiers in series, which raises the voltage of the common point from – 40 to – 24 volts during the time the 3 impulse sources involved in the path running from the *c* wire to the common wire simultaneously provide a potential of – 24 volts. The duration of this time corresponds with the length of an *Na* or *Nc* impulse and it happens only at the time position allotted to that particular line by the specific choice of a combination of the 3 sources mentioned.

During each interval between two successive impulses, current will flow from the *b* wire, which is at – 16 volts, through the 30,000-ohm resistance connected between the *b* and *c* wires to the – 40 volts provided by one or more of the 3 impulse sources. However, the difference in potential is absorbed by the 30,000-ohm resistance, so that the – 40 volt potential of the common wire is virtually not affected.

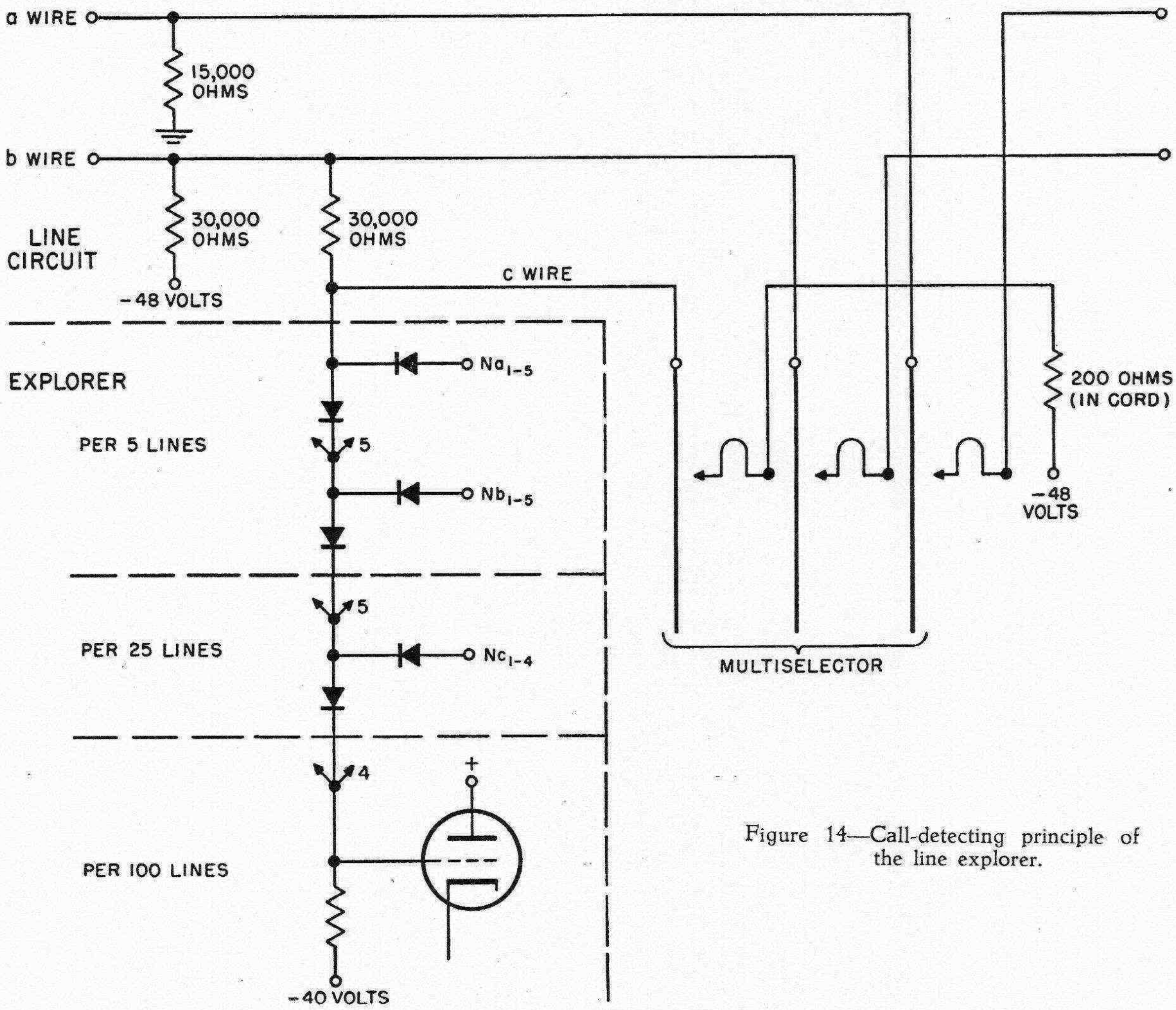



Figure 14—Call-detecting principle of the line explorer.

The gate circuits of the line explorer, therefore, serve the purpose of time selection, i.e., a direct-current signal applied to one of the input terminals of a gate network is transmitted to the output terminal at a selected time, while a small number of sources is employed.

By applying —48 volts through a low ohmic resistance to the *c* wire, the calling condition is cancelled during conversation.

When two or more lines of a 100-line group call simultaneously, each of these lines will produce an impulse in its own time position.

Section 4.4 describes the manner in which the time position of these impulses are recorded. The reader will note that interference between successive impulses is excluded and no special measures need be taken to prevent other subscribers' calls from becoming effective while a first call in a 100-line group is being handled.

#### 4.3. Group Selection and Hunting

For the purpose of selection and hunting, an explorer or tree of gates of the type shown in Figure 15 is provided per multiselector. In most respects, the arrangement is identical to that used for call detection. The gate wires of 100 outlets taper down via 20 and 4 branches to a common wire connected to a cathode-follower.

There are 14 different sources; $Pa_1$ to $Pa_5$, $Pb_1$ to $Pb_5$, and $Pc_1$ to $Pc_4$; that supply the same impulses as the $N$ sources mentioned in the preceding paragraph with the exception that the basic voltage lies at 0 volts and the impulse potential is +16 volts.

One combination of 3 sources identifies the position of an outlet in the multiple of the selector to which it is connected. In case an outlet also appears in the multiple of another multiselector, it is provided with another gate circuit associated with the explorer of that selector, the combination of impulses indicating its location in the other selector's multiple.

In addition to these 14 sources, a 4th group of 11 sources, designated $Pd_1$ to $Pd_{11}$, is provided for grouping the outlets into levels. They are cross-connected in any wanted manner to each outlet via a gate per outlet. The outlets of level *1* may be connected to source $Pd_1$; those of level *2* to $Pd_2$, etc. The recurrence period of a $Pd$ source corresponds to 11 impulses and the length of the impulse is 0.2 millisecond.

The scanning period of a group of 100 outlets is equivalent to 11 × 100 impulses of 0.2-millisecond duration over which period the 100 impulses identifying the 100 outlets are scattered. This is equivalent to a selector running at a speed of 455 steps per second.

An outlet provides an impulse only when it is free, that is, when +24 volts is connected to its gate wire.

At the governor circuit, which controls the selection and hunting, the signalling wire that conveys the impulses is connected to a comparator and impulse-regenerator circuit and from there to a recorder, which is described in the following section.

The governor connects the $Rd$ impulse source that corresponds to the wanted level to the control terminal of the comparator so that all impulses except those of the wanted group of outlets are absorbed.

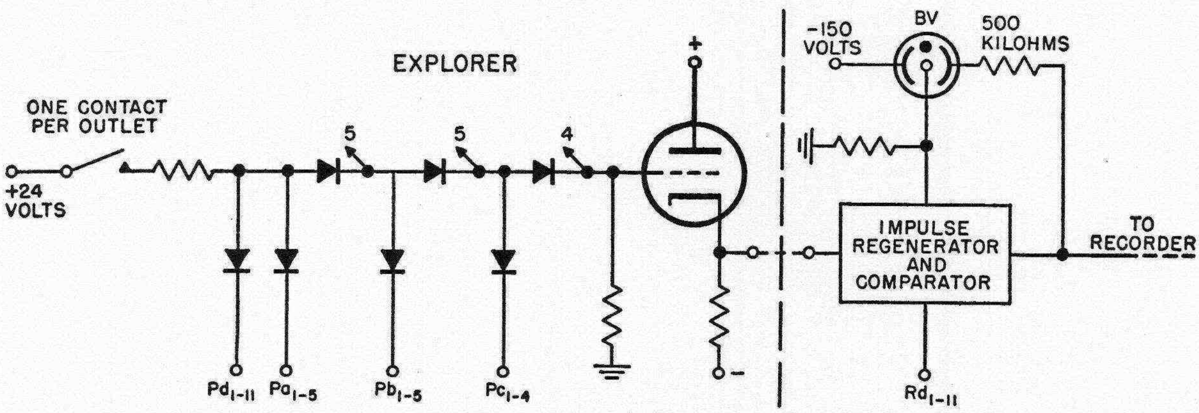



Figure 15—Group-selection principle.

The impulse regenerator brings the impulses received to the proper basic and impulse voltages required for the correct operations of the recorder and reshapes the impulses. For the latter purpose, each impulse that arrives is delayed by one time unit.

Figure 15 also shows an impulse-blocking tube *BV*, the purpose of which is described later.

### 4.4. Recorder

A recording circuit, the principle of which is shown in Figure 16, is used for the determination and registration of the time position of an impulse arriving on a signalling wire, such as the common wire mentioned in the preceding section.

The circuit is mainly composed of cold-cathode trigger tubes, each of which is associated with a relay and a gate. The cathodes are connected − 150 volts via a 30,000 ohm resistance. The gates are connected between the trigger cathodes and the signalling wire. When idle, this wire is at − 110 volts. The relays are connected to the anodes and via some auxiliary relay contact to ground. Impulse sources $Ra_1$ to $Ra_5$, $Rb_1$ to $Rb_5$, and $Rc_1$ to $Rc_4$, which are in synchronism with and similar to those used in the call-detector circuit, are connected to the control terminals of the gates. Their voltage basis, however, is − 110 volts and that of the impulses − 50 volts.

When the circuit is in the nonoperated condition, the voltage across the anode-cathode space (main gap) is therefore 150 volts, which is insufficient to provoke breakdown. To fire the tube, the potential of the trigger cathode must

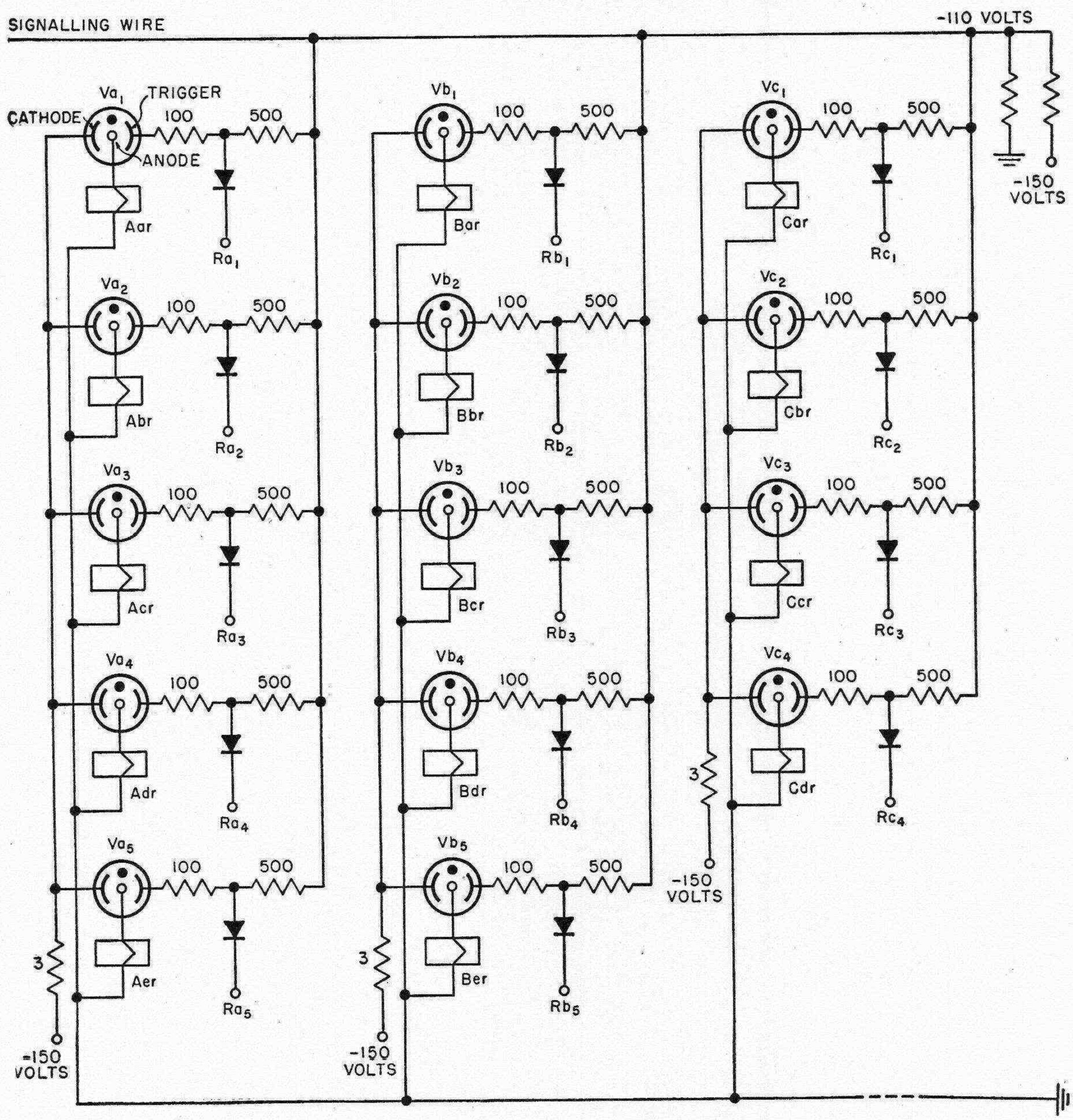



Figure 16—Recording principle. Resistance values are in kilohms. Relay windings *Aar, Bar, Car,* etc., are 1650 ohms each.

be changed from — 110 volts to approximately — 70 volts. The — 50-volt impulses supplied at the control terminals of the gates are unable to trigger the tube as the rectifier forming part of the gate is connected so that no current can pass from the impulse source to the trigger anode.

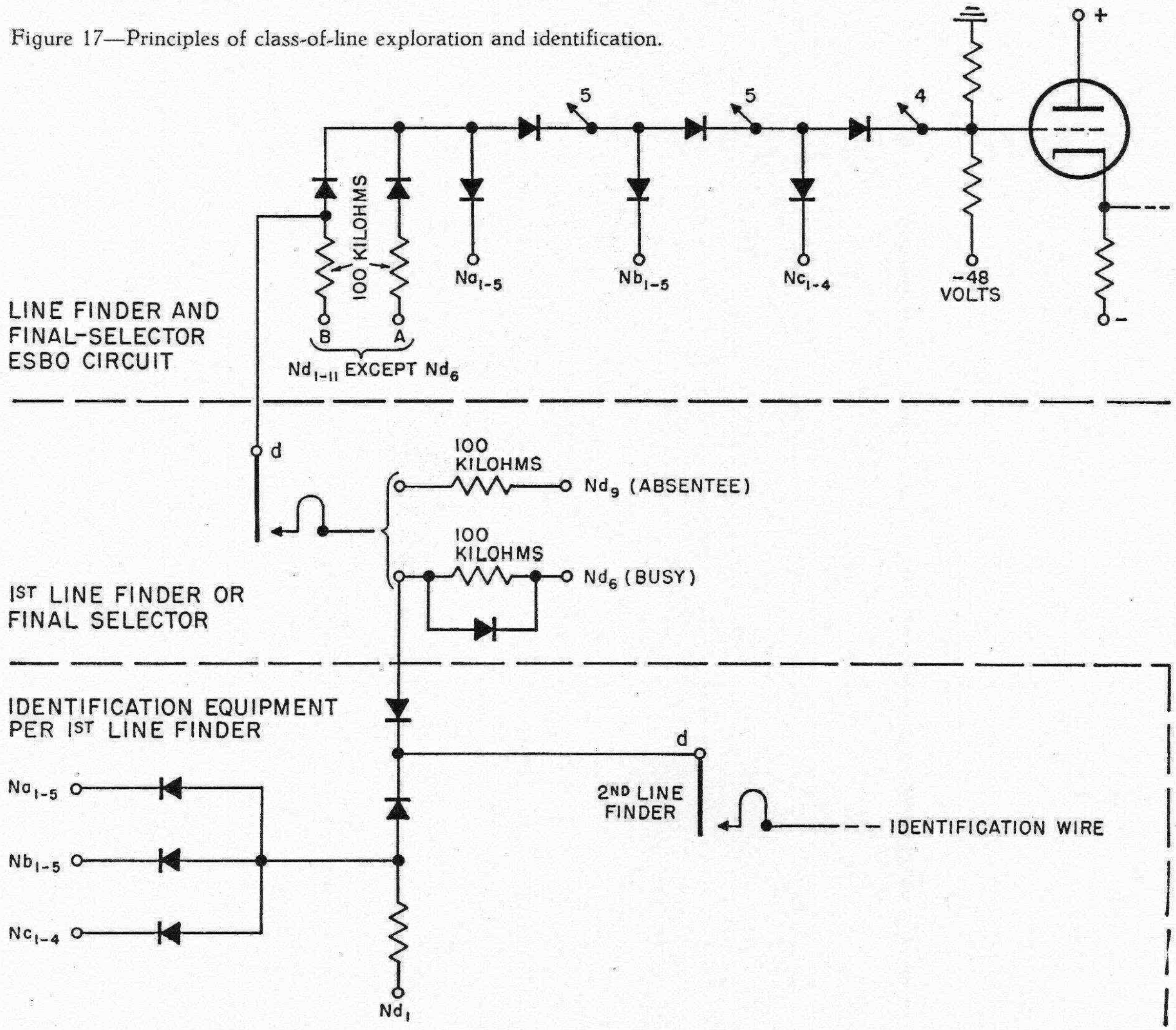
An impulse from a free outlet characterized by sources $Pa_1$, $Pb_1$, $Pc_1$, and $Pd_1$ will arrive in time position *1* on the inlet wire of the impulse comparator and regenerator shown in Figure 15. If source $Rd_1$ is connected by the governor to the comparator, the impulse regenerator will create an impulse in time position *2*. This impulse arrives on the signalling wire of Figure 16, where it will find — 50 volts on the control terminals of the gates associated with the tubes $Va_2$, $Vb_1$, and $Vc_2$, and — 110 volts on all other tubes *V*, as sources $Ra_2$, $Rb_1$, and $Rc_2$ at that particular moment must be the only 3 sources providing an impulse (see Figure 13). As a result, the tubes $Va_2$, $Vb_1$, and $Vc_2$ will fire and relays *Abr*, *Bar*, and *Cbr* will operate.

The current flowing through the 500-kilohm gate resistance of all other tubes are absorbed by the various impulse sources.

It should be observed that the impulse passed by the comparator (see Figure 15) and regenerated with a delay of one time unit by the regenerator fires the blocking tube *BV*, which acts on the comparator-regenerator circuit in such a manner that it immediately prevents any following impulses from passing through. This forestalls the breakdown of any other *V* tubes of Figure 16 by an impulse that may possibly arrive in the next time position.

By the operation of a combination of 3 relays, one in each group, the time position of the arriving impulse and thus the identity of the group selector outlet is determined. It remains registered until the common ground is removed.

Figure 17—Principles of class-of-line exploration and identification.



The recorder circuit described in connection with group selection is used for many other purposes, they form part of the *A* governors to record the identity of a call detector, subscriber's line, et cetera.

#### 4.5. Final Selection and Class-of-Line Indication

In the esbo circuit associated with a 100-line group, no explorer is needed for selection purposes as the register on receipt of the last two digits of an ordinary subscriber's number is sufficiently informed to determine which vertical bars of the multiselector have to be operated to carry out the selection of the line concerned.

However, whether the wanted line is free or busy has to be investigated, and hunting for a free line in a group has to take place in case the number dialled indicates a private-branch-exchange group, the first line of which is engaged. This requires the provision of an explorer for every 100-line group and advantage has been taken of this necessity to incorporate in the system a number of interesting features.

The explorer used is of the type already described and consists of the gate circuits and *Na*, *Nb*, and *Nc* sources shown in Figure 17. The individual wires of the 100 lines, however, are not connected to or disconnected from a direct-current potential to indicate the free or the busy condition as in the case of the group-selector explorer ; but they are connected to a variety of combinations of impulse sources *Nd*.

All sources used for the explorers described in the preceding paragraphs are capable of absorbing current during the periods between the impulses and of supplying a potential only during the impulses. The *Nd* sources, however, are capable of absorbing current during the periods between the impulses and of supplying current for the impulses. For this reason, the *Nd* sources supply $-16$ volts instead of $-24$ volts to cater for the loss caused by the gate network.

The combination of 25 sources mentioned establishes a scanning period of $4 \times 5 \times 5 \times 11$ of 1100 time positions.

In case of an ordinary line, source $Nd_7$ is permanently connected to the control terminal *A* and $Nd_{11}$ to terminal *B*. The impulse sources *Na*, *Nb*, and *Nc* in combination determine the number of the line within the 100-line group and its position in the multiple of the multiswitch.

As a result of this arrangement, a free ordinary line will provide 2 impulses on the common signalling wire within one complete cycle.

At the other end of this wire, the governor circuit selects the line by the connection of the proper 3 sources to 3 gate-controlled terminals in a manner similar to that already described for group selection.

The recorder comprises 11 tubes and gates controlled by *Rd* sources, and if the line is free the 7th and 11th tubes will fire. Thereupon the call is completed.

When the line is engaged, the final selector connects the $Nd_6$ source in parallel to the $Nd_{11}$ source on the *B* terminal via a resistance shunted by a rectifier. The effect is that the $Nd_{11}$ impulse is absorbed via the rectifier by the $Nd_6$ source and an $Nd_6$ impulse is supplied instead.

Subsequently, any governor selecting the same line will find impulses in time positions that will fire the 7th and 6th tubes and will then recognize that the line is busy.

Table 3 explains in detail the manner in which the various combinations of impulse sources are used to distinguish a variety of classes of lines.

In case the first line of a nonconsecutively numbered private-branch-exchange group is called, the first of the 5 groups in the table, the governor will select this line and receive either sources *1* and *7* or *1* and *6*. In the first case, the call will simply be completed to the line corresponding to the private-branch-exchange number. In the latter case, hunting has to take place in the first-hundreds' impulse cycle. The governor removes the 3 numerical sources previously connected to the gate-controlled terminals mentioned and connects $Pd_1$. A 3-digit recorder, as already described, will respond to the first impulse received and thereby register the location of a free line of the wanted group in the multiple of the final selector. The call is then completed in the normal manner.

From this it is apparent that the number of any of the associated private-branch-exchange lines can be used as a first number and further that their numbering need not be consecutive. This has the advantage that any available line in a 100-line group may serve for extending any of these 5 private-branch-exchange groups.

It will be noted from the table that the line that is used for the directory number has the characterizing *Nd* source connected to the gate-control terminal *A* whereas for all associated private-branch-exchange lines, this source is connected to the *B* terminal. As on busy lines, the sources on the *B* terminal are replaced by $Nd_6$, their impulses do not appear in the hundreds cycle allotted to this group. Consequently, busy lines of a private-branch-exchange group do not react on an explorer searching for a free line in that group with the exception of the line characterizing the group whose impulse remains while the line is busy. If all lines of a private-branch-exchange group are busy, the explorer

# TABLE 3

## IMPULSES THAT DISTINGUISH CLASSES OF LINES

| Class of Line | Description of Line Class | Nd Impulse Sources Connected to | | Impulses Supplied in 100-Second Cycles — When Line is | | |
|---|---|---|---|---|---|---|
| | | A Terminal | B Terminal | Free | Busy | Absentee (If free) |
| 1 | 1st Line of 1st Nonconsecutive Private-Branch-Exchange Group (Unrestricted) | 1 | 7 | 1+7 | 1+6 | 1+7+9 |
| 2 | 1st Line of 2nd Nonconsecutive Private-Branch-Exchange Group (Unrestricted) | 2 | 7 | 2+7 | 2+6 | 2+7+9 |
| 3 | 1st Line of 3rd Nonconsecutive Private-Branch-Exchange Group (Unrestricted) | 3 | 7 | 3+7 | 3+6 | 3+7+9 |
| 4 | 1st Line of 4th Nonconsecutive Private-Branch-Exchange Group (Unrestricted) | 4 | 7 | 4+7 | 4+6 | 4+7+9 |
| 5 | 1st Line of 5th Nonconsecutive Private-Branch-Exchange Group (Unrestricted) | 5 | 7 | 5+7 | 5+6 | 5+7+9 |
| 6 | 1st Line of 1st Nonconsecutive Private-Branche-Exchange Group (Restricted) | 1 | 8 | 1+8 | 1+6 | 1+8+9 |
| 7 | 1st Line of 2nd Nonconsecutive Private-Branche-Exchange Group (Restricted) | 2 | 8 | 2+8 | 2+6 | 2+8+9 |
| 8 | 1st Line of 3rd Nonconsecutive Private-Branche-Exchange Group (Restricted) | 3 | 8 | 3+8 | 3+6 | 3+8+9 |
| 9 | 1st Line of 4th Nonconsecutive Private-Branche-Exchange Group (Restricted) | 4 | 8 | 4+8 | 4+6 | 4+8+9 |
| 10 | 1st Line of 5th Nonconsecutive Private-Branch-Exchange Group (Restricted) | 5 | 8 | 5+8 | 5+6 | 5+8+9 |
| 11 | Other Lines of 1st Nonconsecutive Private-Branch-Exchange Group (Unrestricted) | 7 | 1 | 7+1 | 7+6 | 7+1+9 |
| 12 | Other Lines of 2nd Nonconsecutive Private-Branch-Exchange Group (Unrestricted) | 7 | 2 | 7+2 | 7+6 | 7+2+9 |
| 13 | Other Lines of 3rd Nonconsecutive Private-Branch-Exchange Group (Unrestricted) | 7 | 3 | 7+3 | 7+6 | 7+3+9 |
| 14 | Other Lines of 4th Nonconsecutive Private-Branch-Exchange Group (Unrestricted) | 7 | 4 | 7+4 | 7+6 | 7+4+9 |
| 15 | Other Lines of 5th Nonconsecutive Private-Branch-Exchange Group (Unrestricted) | 7 | 5 | 7+5 | 7+6 | 7+5+9 |
| 16 | Other Lines of 1st Nonconsecutive Private-Branch-Exchange Group (Restricted) | 8 | 1 | 8+1 | 8+6 | 8+1+9 |
| 17 | Other Lines of 2nd Nonconsecutive Private-Branch-Exchange Group (Restricted) | 8 | 2 | 8+2 | 8+6 | 8+2+9 |
| 18 | Other Lines of 3rd Nonconsecutive Private-Branch-Exchange Group (Restricted) | 8 | 3 | 8+3 | 8+6 | 8+3+9 |
| 19 | Other Lines of 4th Nonconsecutive Private-Branche-Exchange Group (Restricted) | 8 | 4 | 8+4 | 8+6 | 8+4+9 |
| 20 | Other Lines of 5th Nonconsecutive Private-Branch-Exchange Group (Restricted) | 8 | 5 | 8+5 | 8+6 | 8+5+9 |
| 21 | Single Line (Unrestricted) | 7 | 11 | 7+11 | 7+6 | 7+11+9 |
| 22 | Singe Line (Restricted) | 8 | 11 | 8+11 | 8+6 | 8+11+9 |
| 23 | Directory Number of Nonnumerical Private-Branch-Exchange Group | 9 | 10 | 9+10 | — | — |
| 24 | All Lines but Last of Unrestricted Private-Branch-Exchange Group with Consecutive Numbering | 11 | 7 | 11+7 | 11+6 | 11+7+9 |
| 25 | All Lines but Last of Restricted Private-Branch-Exchange Group with Consecutive Numbering | 11 | 8 | 11+8 | 11+6 | 11+8+9 |
| 26 | Last Line of Unrestricted Private-Branch-Exchange Group with Consecutive Numbering | 7 | 11 | 7+11 | 7+6 | 7+11+9 |
| 27 | Last Line of Restricted Private-Branch-Exchange Group with Consecutive Numbering | 8 | 11 | 8+11 | 8+6 | 8+11+9 |
| 28 | 2- of 4-Party Line (Number Per Line with Suffix) | 7 | 8 | 7+8 | 7+6 | — |
| 29 | Multislot Coin Box | 7 | 10 | 7+10 | 7+6 | — |
| 30 | Single-Slot Coin Box | 8 | 10 | 8+10 | 8+6 | — |
| 31 | Changed Number | 10 | 11 | 10+11 | — | — |
| 32 | Dead Line | 10 | 6 | 10+6 | — | — |

will complete its search through the whole hundreds cycle of the group without meeting any impulse characterized by that particular *Nd* source. Finally, it will again test the first line on which the *Nd* source remains present. This fact provides a signal to the governor that all lines of the private-branch-exchange group have been tested and found busy.

Any private-branch-exchange line may be called by its individual number during night-time, when the city lines may have been connected through to only certain stations of the private branch exchange. Calling such a line when busy by dialling its number does not cause private-branch-exchange hunting.

The same esbo and the associated class-of-line explorer is also utilized for originating calls as explained in section 7.1, and it will be noted from Table 3 that source $Nd_7$ serves, in general to indicate "no restriction" and source $Nd_8$ designates "restriction". The system, therefore, provides the possibility of excluding restricted lines from calling certain facilities. How far this restriction may be imposed depends on the requirements of a specific customer. Certain lines may thus be barred from toll service.

Should the first private-branch-exchange line group mentioned above be permitted to establish calls on a restricted basis only, source $Nd_8$ is substituted for sources $Nd_7$ on control terminal *B* of the first line of the group and on control terminal *A* of all other lines. (See line classes *1* and *6*, also *11* and *16*, of Table 3.)

If the lines of a private-branch-exchange group can be consecutively numbered, their lines are marked by sources $Nd_{11}$ (terminal *A*) and $Nd_7$ or $Nd_8$ depending on whether they are permitted unrestricted or restricted service, with the exception of the last line for which the order of connection to terminals *A* and *B* is reversed. (See line classes *24* and *25*, also *26* and *27*, of Table 3.) When such a group is called and the first line is found busy, the governor will try to select the next line and will continue to do so until a free line is found or until the code 7+6 or 8+6 (last line busy) is returned by the scanner, wehereupon a busy tone is applied to the caller's line.

The system further provides for a third type of private-branch-exchange grouping for which the gates associated with the calling number of the group (directory number) are connected to sources $Nd_9$ and $Nd_{10}$. (Class *23* in Table 3.) On receipt of these 2 types of impulses, the governor operates the vertical bar of the multi-switch via the esbo. A contact is thereby closed and by means of a multiple gate circuit an impulse in a characteristic time position is returned whereby the private-branch-exchange group is identified and recorded at the register circuit. The connection already established is then released and the information received is used for the establishment of a new connection, possibly via a completely different train of switches. A free line is then selected in the manner already described for group selection and via a special group of selectors giving access to these large private-branch-exchange groups. This arrangement provides for a number of large private-branch-exchange groups to which any exchange line may be assigned and which has only one calling number. The traffic originated by the lines of such a group pass via the first line finders, to which the lines remain connected. This feature, therefore, permits the distributing of incoming traffic from large private-branch-exchange groups over a number of first-line-finder groups.

In case the called line appears to be a 2- or 4-party line, the governor is informed by the receipt of codes *7* and *8*. The register is ordered to wait for a further figure (suffix) to be dialled by the subscriber ,on receipt of which the proper type of ringing is initiatied.

The codes *7-10* and *8-10* are used for coin boxes and the indication thereof is used to effect in certain cases a special routing of the call to conform to the prescribed method of handling coin-box calls.

Changed numbers and dead lines are marked by codes *10-11* and *10-6*, which permit the application of special tones to the calling lines.

Source $Nd_9$ is exclusively used for so-called absentee service. If required, the system may provide this service in which case 4 special switches (one per 25 lines) are supplied per 100-line group. In this manner, one special finger is provided per line as described in section 3.10 and when operated connects an $Nd_9$ source in addition to the $Nd_7$ and $Nd_{11}$ sources (single line). On receipt of the *9* code in the recorder, the automatic selecting equipment releases the established connection and chooses a route to the absentee-service operator instead.

#### 4.6. Identification

Identification of the calling subscriber's number is a feature required in conjunction with long-distance dialling by subscribers. It also simplifies false-call tracing, identification of malicious callers, and serves a number of other interesting purposes.

The solution offered by the electronic circuits is of striking simplicity, when compared with the highly complicated, cumbersome, and slow methods used in other, even modern, automatic systems.

The identification scheme employed is shown in the lower left corner of Figure 17. It makes use of the class-of-line explorer already available per final-selector esbo and of the fact that a group of first line finders serves a block of 100 numbers; there is no jumpering between the subscribers' lines and the first-line-finder multiple.

It will readily be understood that the potential of the *d* wire of a subscriber's line circuit, when busy, stays near —40 volts during the complete 1100-impulse cycle but that in one time position the potential rises to some — 24 volts, that is, when there is coincidence between source $Nd_6$ and the particular combination of *Na*, *Nb*, and *Nc* sources that identifies the number of the line.

When, therefore, the comparator (a gate circuit similar to Figure 12A) of the identification circuit is connected to $Rd_6$, its associated recorder will receive a code that corresponds to the last 2 digits of the caller's number.

In the first-line-finder circuit, another gate circuit is connetced via a decoupling rectifier to the identification wire that provides during the 100-mpulse cycle of $Nd_1$ an impulse that corresponds to the thousands and hundreds figures of the line number.

The comparator of the identification circuit then connects source $Rd_1$, whereupon its associated recorder will register a code in concordance with the thousands and hundreds figures.

#### 4.7. Explorers Operating in Parallel

For the arrangements described in the foregoing paragraphs, single explorers are used. They may be compared to a finder continuously hunting over a group of terminals and are sometimes called electronic finders.

In some instances, a number of circuits are provided with explorers that operate in parallel and explore the same group of circuits.

If a number of identical explorers were used, confusion could result when a circuit of one group would signal its free condition at the same time to several circuits of a former group. Such an arrangement would lead to considerable complications in the electronic circuits. To avoid these, the sources are connected by means of a staggered arrangement, which may best be explained by referring to Table 4. This table supposes 6 primary circuits and 12 secondary circuits. The circuit diagram is given in Figure 18.

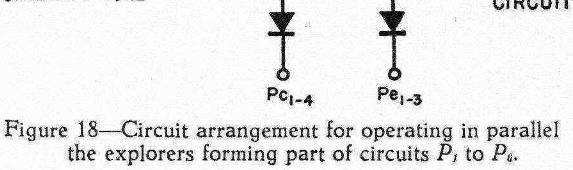



Figure 18—Circuit arrangement for operating in parallel the explorers forming part of circuits $P_1$ to $P_6$.

In time position *1* (coincidence between sources $Pc_1$ and $Pe_1$) the impulse paths between $P_1$ and $S_1$, $P_2$ and $S_{11}$, $P_3$ and $S_9$, $P_4$ and $S_7$, $P_5$ and $S_5$, and $P_6$ and $S_3$ are opened. In time position *2* (coincidence between sources $Pc_2$ and $Pe_2$) the paths $P_1$-$S_2$, $P_2$-$S_{12}$, $P_3$-$S_{10}$, etc., are opened.

By this arrangement, simultaneous testing of a secondary circuit by more than one primary circuit is excluded. The arrangement is comparable to a group of 6 mechanical 12-point switches rotating continuously in synchronism and staggered so that when switch *1* stands on terminal *1*, switch *2* stands on terminal *3*, *3* on *5*, et cetera.

Table 5 indicates which secondary circuits are explored by the various primary circuits in the 12 different time positions.

#### 4.8. Explorers Serving for Return Signalling

When a secondary circuit is tested by an explorer of a primary circuit, that is if an impulse indicating the free condition of a particular secondary circuit is registered at the primary circuit, the received impulse instantaneously disables the recorder of that primary circuit. This circuit, therefore, will stop any further exploration. Its diagram is given in Figure 19.

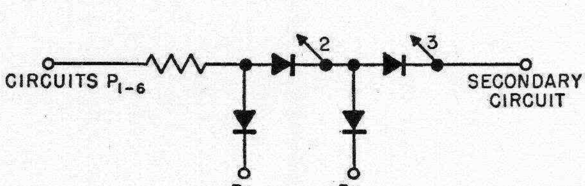



Figure 19—Circuit arrangement for operating in parallel the explorers forming part of circuits $S_1$ to $S_{12}$.

On the other hand, the secondary circuit must be rendered busy and be prevented from signalling the free condition to other primary circuits. This is performed by sending a seizure impulse from the primary circuit to that particular secondary circuit. This seizure impulse is, for reasons of practical circuit design, transmitted in the time position following that in which the first-mentioned impulse was received.

TABLE 4

SOURCE CONNECTIONS FOR EXPLORERS FOR CIRCUITS $P_1$ TO $P_6$

| To → | Primary Circuits | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $P_1$ | | $P_2$ | | $P_3$ | | $P_4$ | | $P_5$ | | $P_6$ | |
| Secondary Circuits | Source | | Source | | Source | | Source | | Source | | Source | |
| | Pc | Pe | Pc | Pe | Pc | Pe | Pc | Pe | Pc | Pe | Pc | Pe |
| $S_1$ | 1 | 1 | 3 | 3 | 1 | 2 | 3 | 1 | 1 | 3 | 3 | 2 |
| $S_2$ | 2 | 2 | 4 | 1 | 2 | 3 | 4 | 2 | 2 | 1 | 4 | 3 |
| $S_3$ | 3 | 3 | 1 | 2 | 3 | 1 | 1 | 3 | 3 | 2 | 1 | 1 |
| $S_4$ | 4 | 1 | 2 | 3 | 4 | 2 | 2 | 1 | 4 | 3 | 2 | 2 |
| $S_5$ | 1 | 2 | 3 | 1 | 1 | 3 | 3 | 2 | 1 | 1 | 3 | 3 |
| $S_6$ | 2 | 3 | 4 | 2 | 2 | 1 | 4 | 3 | 2 | 2 | 4 | 1 |
| $S_7$ | 3 | 1 | 1 | 3 | 3 | 2 | 1 | 1 | 3 | 3 | 1 | 2 |
| $S_8$ | 4 | 2 | 2 | 1 | 4 | 3 | 2 | 2 | 4 | 1 | 2 | 3 |
| $S_9$ | 1 | 3 | 3 | 2 | 1 | 1 | 3 | 3 | 1 | 2 | 3 | 1 |
| $S_{10}$ | 2 | 1 | 4 | 3 | 2 | 2 | 4 | 1 | 2 | 3 | 4 | 2 |
| $S_{11}$ | 3 | 2 | 1 | 1 | 3 | 3 | 1 | 2 | 3 | 1 | 1 | 3 |
| $S_{12}$ | 4 | 3 | 2 | 2 | 4 | 1 | 2 | 3 | 4 | 2 | 2 | 1 |

TABLE 5

TIME POSITIONS FOR EXPLORERS FOR CIRCUITS $P_1$ TO $P_6$

| Secondary Circuit Explored in Time Unit | Explorers Associated with Primary Circuit | | | | | |
|---|---|---|---|---|---|---|
| | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ | $P_6$ |
| 1 | $S_1$ | $S_{11}$ | $S_9$ | $S_7$ | $S_5$ | $S_3$ |
| 2 | $S_2$ | $S_{12}$ | $S_{10}$ | $S_8$ | $S_6$ | $S_4$ |
| 3 | $S_3$ | $S_1$ | $S_{11}$ | $S_9$ | $S_7$ | $S_5$ |
| 4 | $S_4$ | $S_2$ | $S_{12}$ | $S_{10}$ | $S_8$ | $S_6$ |
| 5 | $S_5$ | $S_3$ | $S_1$ | $S_{11}$ | $S_9$ | $S_7$ |
| 6 | $S_6$ | $S_4$ | $S_2$ | $S_{12}$ | $S_{10}$ | $S_8$ |
| 7 | $S_7$ | $S_5$ | $S_3$ | $S_1$ | $S_{11}$ | $S_9$ |
| 8 | $S_8$ | $S_6$ | $S_4$ | $S_2$ | $S_{12}$ | $S_{10}$ |
| 9 | $S_9$ | $S_7$ | $S_5$ | $S_3$ | $S_1$ | $S_{11}$ |
| 10 | $S_{10}$ | $S_8$ | $S_6$ | $S_4$ | $S_2$ | $S_{12}$ |
| 11 | $S_{11}$ | $S_9$ | $S_7$ | $S_5$ | $S_3$ | $S_1$ |
| 12 | $S_{12}$ | $S_{10}$ | $S_8$ | $S_6$ | $S_4$ | $S_2$ |

To transmit this impulse to the proper secondary circuit only, every secondary circuit is provided with an explorer operating in the opposite direction and having one branch per primary circuit.

It is obvious that these 2 groups of explorers operate in synchronism. Perfect synchronism would be obtained if the 2 paths between a primary and a secondary circuit, the one for the forward direction and the second for the backward direction, were controlled by exactly the same sources.

In order that the seizure impulse from a primary circuit be transmitted to a secondary circuit in the time position following that in which the test impulse was received at the primary circuit, the sources controlling the second path are so chosen that there is always a delay of one time position between a forward and an associated backward impulse.

Table 6 indicates the combinations of sources connected to the 12 explorers that form part of the 12 secondary circuits $S_1$ to $S_{12}$ and which may serve to send back impulses to the 6 primary circuits $P_1$ to $P_6$.

The sources are so chosen that the explorers may be used for return signalling required in connection with the 6 explorers to which Tables 4 and 5 refer.

It will be noted that when the explorer associated with circuit $P_4$ accepts an impulse from circuit $S_{12}$, in time position *6* (sources $Pc_2$ and $Pe_3$) the path from $P_4$ to $S_{12}$ is opened in the next time position.

Table 7 indicates which primary circuits are explored by the various secondary circuits in the 12 different time positions. Comparison with Table 5 shows at a glance the shifting of one time unit.

#### 4.9. Double-Stage Selection

Normally, a selection consists of choosing a free outlet via one selector but in certain instances the electronic principles described can be applied advantageously to provide an arrangement in which an outlet that is reached via 2 consecutive selection stages is chosen by a single selection process.

A case in point is the selection of an outgoing junction via a first group selector (acting as *A* selector) and a junction selector (acting as *B*

TABLE 6

SOURCE CONNECTIONS FOR EXPLORERS FOR CIRCUITS $S_1$ TO $S_{12}$

| To → Primary Circuits | $P_1$ | | $P_2$ | | $P_3$ | | $P_4$ | | $P_5$ | | $P_6$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Secondary Circuits | Source | | Source | | Source | | Source | | Source | | Source | |
| | Pc | Pe | Pc | Pe | Pc | Pe | Pc | Pe | Pc | Pe | Pc | Pe |
| $S_1$ | 2 | 2 | 4 | 1 | 2 | 3 | 4 | 2 | 2 | 1 | 4 | 3 |
| $S_2$ | 3 | 3 | 1 | 2 | 3 | 1 | 1 | 3 | 3 | 2 | 1 | 1 |
| $S_3$ | 4 | 1 | 2 | 3 | 4 | 2 | 2 | 1 | 4 | 3 | 2 | 2 |
| $S_4$ | 1 | 2 | 3 | 1 | 1 | 3 | 3 | 2 | 1 | 1 | 3 | 3 |
| $S_5$ | 2 | 3 | 4 | 2 | 2 | 1 | 4 | 3 | 2 | 2 | 4 | 1 |
| $S_6$ | 3 | 1 | 1 | 3 | 3 | 2 | 1 | 1 | 3 | 3 | 1 | 2 |
| $S_7$ | 4 | 2 | 2 | 1 | 4 | 3 | 2 | 2 | 4 | 1 | 2 | 3 |
| $S_8$ | 1 | 3 | 3 | 2 | 1 | 1 | 3 | 3 | 1 | 2 | 3 | 1 |
| $S_9$ | 2 | 1 | 4 | 3 | 2 | 2 | 4 | 1 | 2 | 3 | 4 | 2 |
| $S_{10}$ | 3 | 2 | 1 | 1 | 3 | 3 | 1 | 2 | 3 | 1 | 1 | 3 |
| $S_{11}$ | 4 | 3 | 2 | 2 | 4 | 1 | 2 | 3 | 4 | 2 | 2 | 1 |
| $S_{12}$ | 1 | 1 | 3 | 3 | 1 | 2 | 3 | 1 | 1 | 3 | 3 | 2 |

selector). The circuit complication introduced by such an arrangement is largely offset by the increased efficiency of the junctions, which now operate in so-called ideal groups.

In a similar manner, selection of a register by an *A* governor is controlled not only by the fact that the register chosen must be free but also whether it can provide access to the calling subscriber's line via a proper cord circuit and first line finder.

Figure 20 shows the electronic circuit principles on which double-stage selection is based. Every *A* selector is provided with an explorer identical to the one described in section 4.4. The final branches to which the *e* wires of the *A* selector outlets are connected have the 2 usual control terminals. One terminal is used for the connection of *Pa* sources; the second terminal is not connected directly to a *Pd* source but jumpered instead to a wire of the *B*-selector esbo circuit serving the multiswitch on which that particular *B* selector is located.

Each *e* wire of a *B*-selector outlet is provided with a gate circuit controlled by sources $Pd_1$ to $Pd_{11}$, which provide the level or group indication.

If there are free outlets on the first *B*-selector level, one or more *e* wires apply +24 volts to gate circuits connected to $Pd_1$. These impulses will, therefore, appear on the common esbo wire. This wire will thus carry all *Pd* impulses except those indicating a direction that is engaged.

The comparator by simply applying an *Rd* source that corresponds with the wanted level on the *B* selector will permit only such impulses to react on the recorder that indicate a *B* selector that is free and that provides access to a free junction in the wanted group.

TABLE 7

TIME POSITIONS FOR EXPLORERS FOR CIRCUITS $S_1$ TO $S_{12}$

| Explorers Associated with Secondary Circuit Providing Impulse Path in Time Position | Primary Circuit Explored | | | | | |
|---|---|---|---|---|---|---|
| | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ | $P_6$ |
| 2 | $S_1$ | $S_{11}$ | $S_9$ | $S_7$ | $S_5$ | $S_3$ |
| 3 | $S_2$ | $S_{12}$ | $S_{10}$ | $S_8$ | $S_6$ | $S_4$ |
| 4 | $S_3$ | $S_1$ | $S_{11}$ | $S_9$ | $S_7$ | $S_5$ |
| 5 | $S_4$ | $S_2$ | $S_{12}$ | $S_{10}$ | $S_8$ | $S_6$ |
| 6 | $S_5$ | $S_3$ | $S_1$ | $S_{11}$ | $S_9$ | $S_7$ |
| 7 | $S_6$ | $S_4$ | $S_2$ | $S_{12}$ | $S_{10}$ | $S_8$ |
| 8 | $S_7$ | $S_5$ | $S_3$ | $S_1$ | $S_{11}$ | $S_9$ |
| 9 | $S_8$ | $S_6$ | $S_4$ | $S_2$ | $S_{12}$ | $S_{10}$ |
| 10 | $S_9$ | $S_7$ | $S_5$ | $S_3$ | $S_1$ | $S_{11}$ |
| 11 | $S_{10}$ | $S_8$ | $S_6$ | $S_4$ | $S_2$ | $S_{12}$ |
| 12 | $S_{11}$ | $S_9$ | $S_7$ | $S_5$ | $S_3$ | $S_1$ |
| 1 | $S_{12}$ | $S_{10}$ | $S_8$ | $S_6$ | $S_4$ | $S_2$ |

The code registered by the recorder indicates the location of the selected outlet of the *A* selector so that selection may proceed.

The blocking impulse passes via an explorer arranged for return signalling and arises in the proper *B*-selector esbo, where it operates a monostable multivibrator acting on the lead carrying the *Pd* pulses. The purpose of this circuit is to absorb temporarily all *Pd* impulses on the impulse wire and thus render the *B* esbo circuit briefly inaccessible to other calls. The time lag after which the monostable multivibrator is restored to normal is sufficient for the governor to connect itself to the *B* esbo and to busy an outlet in the wanted group.

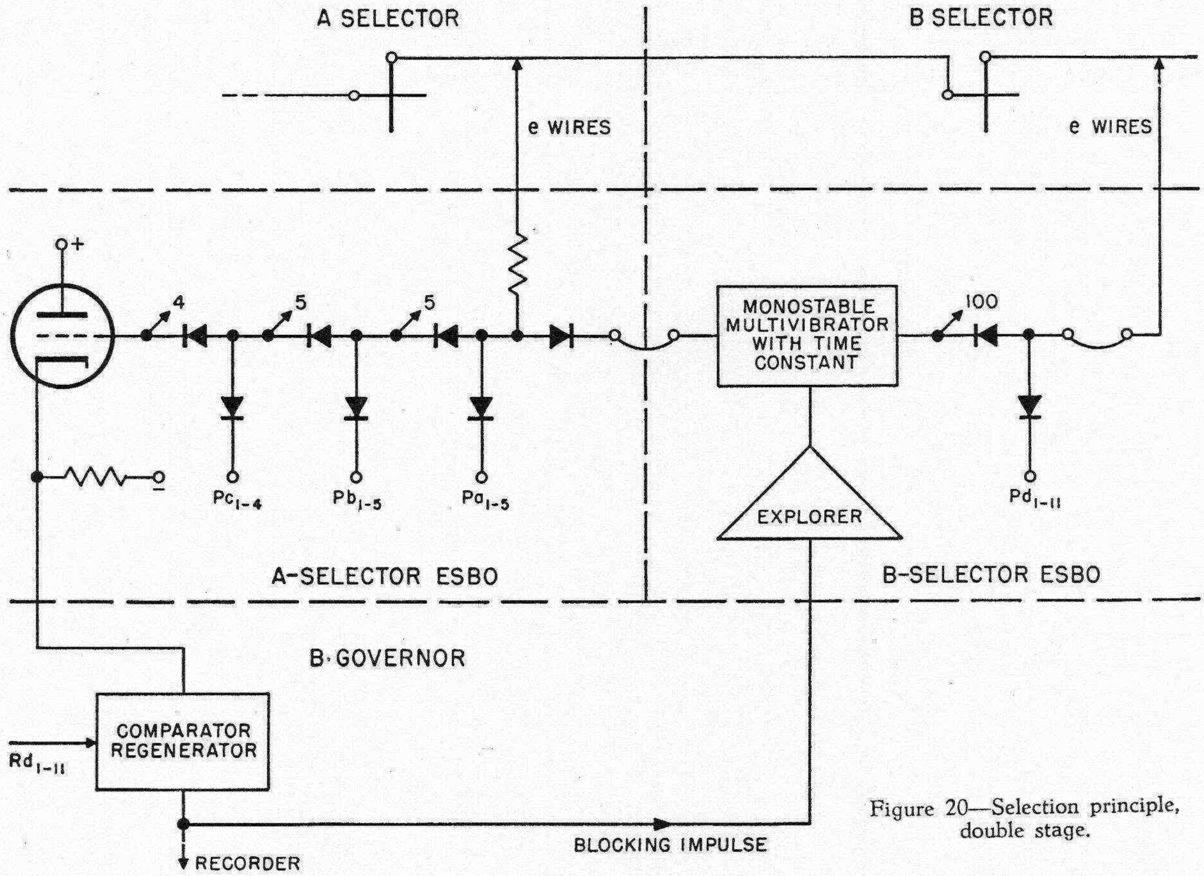



Figure 20—Selection principle, double stage.

### 4.10. Sequence Test

Before engaging the esbo circuit, a governor tests whether the circuit is free or busy. In the former case, it renders the esbo instantaneously busy.

Advantage is drawn from the availability of impulse sources to differentiate the moments at which the various governors test. For this reason the test is called a sequence test and may be compared to the double test used in the rotary systems.

The test wire of the esbo circuit in the free condition shown in Figure 21 is connected through a 5100-ohm resistance to +24 volts when busy to ground. At the moment the governor tests, it connects the test wire to the grid of a cathode-follower and places two gate circuits in parallel. The control terminals of these gate circuits are connected to a combination of *R* sources characteristic for the governor.

At the moment of coincidence of the connected sources, +42 volts is extended to the grid of the triode, the plate circuit of which acts on the trigger electrode of a cold-cathode tube. The latter tube fires and the test relay *Tr* operates. At the same time, the test wire is reduced to ground potential because the anode of the cold-cathode tube connected to the esbo test wire assumes a more-negative potential as a result of its becoming conductive.

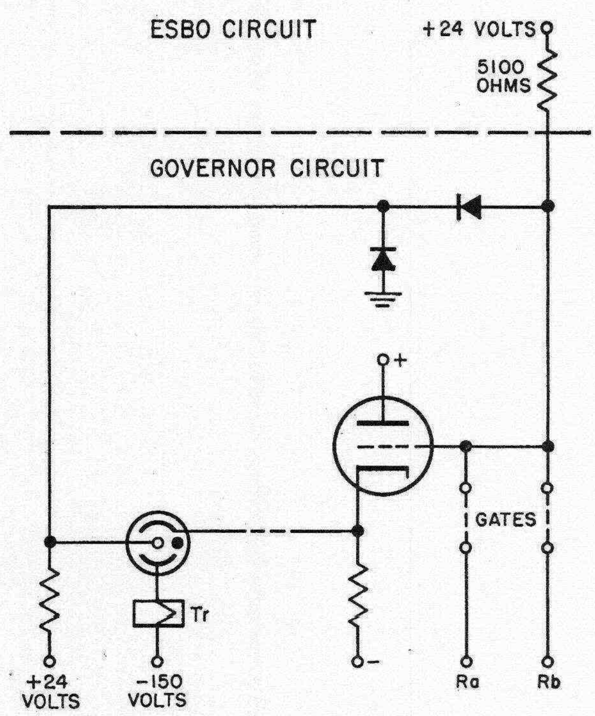



Figure 21—Principle of the sequence test.

### 5. *Basic Principles of Circuit Design*

To increase the certainty and speed of operation and to facilitate maintenance, all circuits have been designed to perform in the so-called "chain" manner, that is by a compelled sequence of functions whereby timing relations are avoided.

A special effort has been made to reduce the variety of relays employed, the number of types of coil windings for the relays, and to avoid the use of relays having more than one winding. This facilitates the manufacture of the system.

The moment the subscriber's loop is closed for the purpose of originating a call, the line will instantly test busy to final selectors. This is a useful feature in connection with private automatic branch exchanges providing automatic connection to the city exchange. It avoids the possibility of an extension of the private branch exchange seizing a city line some moments before this same city line may have been taken by a final selector, in which case two persons who do not desire to speak to each other are connected.

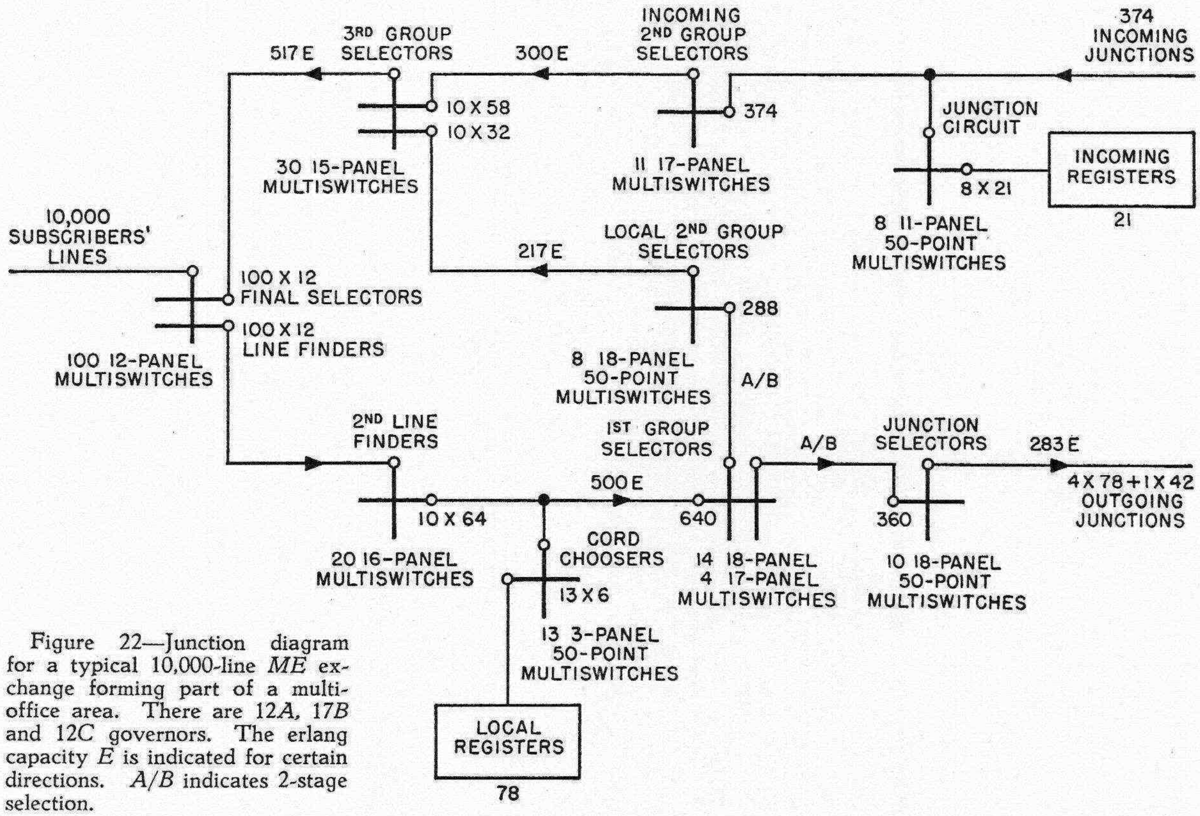



Figure 22—Junction diagram for a typical 10,000-line *ME* exchange forming part of a multi-office area. There are 12*A*, 17*B* and 12*C* governors. The erlang capacity *E* is indicated for certain directions. *A/B* indicates 2-stage selection.

All circuits have been standardized. It is anticipated that *ME* exchanges may be built to interwork with any other system without adaptation of any circuits but the registers and the junction circuits.

The complete train of local-switching equipment is common for local and toll traffic.

All circuits have been so designed that they become inaccessible and cannot tie up other circuits whenever battery is missing as would be the case if a fuse were blown or removed.

On successive calls, a subscriber is always connected to different cords and registers, so that in case of a failure of one of these circuits, no permanent inability to establish calls results during slack hours.

The electronic control of the selectors or finders is so arranged that operation is as for nonhoming switches, that is hunting starts anywhere in the multiple. This arrangement offers the advantage that traffic is on the average equally distributed over all outlets resulting in even wear of the apparatus. Further, successive calls will never seize the same switch twice in succession.

The system is arranged to give any desired type of toll switching facilities. Means may be provided so that if offering is required on busy lines, this will not be repeated on the same line of a private-branch-exchange group if several consecutive toll switchting calls would find the group busy.

## 6. *Typical Junction Diagram*

A typical junction diagram and associated floor plan have been prepared to give a complete picture of the manner in which the *ME* system can be applied to a 10,000-line exchange in a multioffice area.

The diagram of such an exchange is shown in Figure 22 and is based on an originating busy-hour calling rate of 0.05 erlang per line and an average call duration of 120 seconds. Such traffic figures may be considered as medium-heavy. Some 60 percent of the traffic is outgoing and incoming. Four groups of outgoing junctions lead to distant exchanges and a 5th group handles special-service traffic. The various special services are considered to be centralized in a distant office. Among the incoming junctions, there is a group that handles the switching of toll traffic.

A call is extended to a register via 100-point first and second line finders and 50-point cord choosers. Outgoing calls are routed via 100-point first group selectors and 50-point junction selectors, which operate in two-stage selection as indicated by *A/B*. The junction selectors have 50 points only as a junction need not appear more than once in the multiples. As a rule, every local circuit appears in 2 multiple splits in a manner designated as "homogeneous grading".

Local calls are routed via local and third group selectors and final selectors. All these switches are of the 100-point type except the local group selectors, which need only 50 points as they operate also as *B* selectors in conjunction with the first group selectors.

On a local call, therefore, 6 subswitches in all remain engaged during conversation and the number of relays engaged amounts to 12, which all form part of the cord circuit. Neither the selectors nor the line circuits include any relays.

On an outgoing call, 4 subswitches remain engaged during conversation and a total of 14 relays, each outgoing junction circuit consisting of 2 relays. On incoming calls, 3 successive subswitches complete a connection with relays located at the incoming end only.

The various quantities of circuits required are indicated on the diagram together with the number of multiswitches and of double-sided contact panels that must be provided.

All circuit requirements are based on the traffic quantities indicated and a loss probability of $P = 0.01$, except the auxiliary circuits, which are based on $P = 0.001$. However, as the cost of a contact panel is rather low compared with that of the multiswitch and its associated esbo circuit, especially as no relay circuits are associated, the cost of the exchange is hardly affected by a somewhat more liberal calculation. In the case of the line finders, 12 circuits per group are shown although 11 circuits would be sufficient to carry the traffic. As the contact panels are double sided, the 12th subswitch is automatically provided.

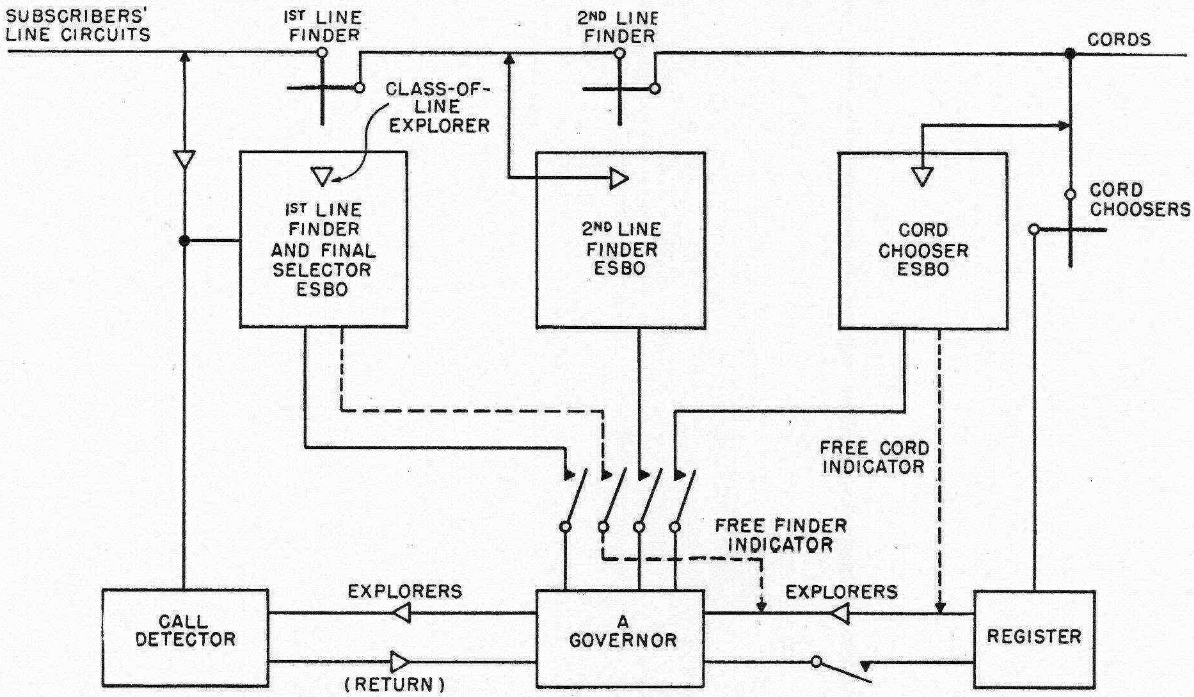


Figure 23—Principle of extending a calling line to a free register.

## 7. *Method of Operation*

### 7.1. Extending Calling Line to a Free Register

The *ME* system belongs to the group of indirect automatic switching systems, that is, the digits sent by the subscriber's dial are received in register circuits.

As in the rotary systems, first and second line finders are employed. Whereas, however, in these systems the line finders hunt in a group and in a manner backward to the direction of the call, in the *ME* system the identity of the calling line is signalled to an *A* governor that chooses a free register and through this selects the calling line via second and first line finders.

The general principle underlying the connection of a calling line to a register is shown in Figure 23. The lines have, via first and second line finders located on multiswitches, access to cord circuits. The cord circuits have access to registers via cord choosers. While the line finders are of the 100-point 5-contact type, the cord choosers are of the 50-point 10-contact type.

A group of 100 subscribers is served by one multiswitch, which mounts both first line finders and final selectors and which is served by an esbo circuit. The equipment common for 100 lines further comprises an electronic explorer and a call detector.

The multiswitches that mount the second line finders and cord choosers are each also provided with an esbo.

The complete operation of extending a line to a register is controlled by an *A* governor, which can connect itself by means of relays to any of the 3 types of esbo circuits mentioned and also to any register.

Before an esbo is engaged, a sequence test is performed by the governor as was described in section 4.10.

One group of *A* governors is provided per exchange and their quantity is determined by the traffic they handle. Owing to the short holding time, only a small number is required.

The calling condition of a line is signalled via a line explorer to a call detector that in turn engages a free *A* governor.

The call detector and *A* governor for this purpose act as the primary and secondary circuits, respectively, as referred to in sections 4.7 and 4.8.

The time position of the return impulse identifies the call detector and thus the 100-line group in which the calling line is located. This information is stored by the *A* governor and used to operate a connecting relay that establishes a metallic connection between the line esbo and the governor. Via a contact of this relay, the pulse wire of the line explorer is connected to the governor and the time position of the calling impulse is recorded and signifies the last 2 digits of the caller's number and serves to locate the multiple wires of the calling line on the multiswitch. The proper combination of vertical bars and servomagnets is operated by the governor via the esbo circuit.

An explorer is provided for each combined line finder and final-selector esbo and serves to indicate the class of the calling line. Its impulse wire is also brought to the governor, which, later transmits the information to the register.

Concurrently with the operations described above, the governor hunts for a free register.

As the cord chooser has a capacity of 50 cords, one register may reach only that number. This rather-limited accessibility is improved by permitting the *A* governor to select through an explorer a register that has access to an appropriate free cord circuit that in turn has access to a free finder in the calling group. In this instance, one group of cords serves 1000 lines. This exploration is accomplished in a manner similar to the double-stage selection described in section 4.9.

The governor now operates two relays that connect it metallically to the chosen register and to the cord-chooser esbo associated with the multiswitch on which the register subswitch is located. This esbo circuit includes an explorer through which the governor selects a cord in the correct group. By knowledge of the time position of the impulse recorded, the governor operates the proper vertical bars via the esbo; at the same time the proper horizontal magnet is operated via the register. By the operation of the proper servomagnet, the connection between the register and the cord is made. The cord-chooser esbo is then released.

The identity of the second-line-finder esbo associated with the cord chooser is derived from the identities of the cord group and the register subgroup. The governor operating the corresponding relay attaches itself to the proper esbo and obtains from the impulse wire of the explorer the time position of a free first line finder in the proper group.

The vertical bars of the second-line-finder multiswitch are again operated via the esbo and the horizontal magnet of the second line finder via the register and the cord chooser. Operation of the proper servomagnet completes the through connection, whereupon the esbo is released. The horizontal-bar magnet is held from the register.

The governor now operates the horizontal-bar magnet of the first-line-finder circuit engaged by the register via the cord chooser and second line finder, the vertical bars already having been operated via the first-line-finder esbo. By a subsequent operation of the proper servomagnet, the connection between the calling line and a register is completed.

The first-line-finder esbo is released and the *A* governor transfers the class-of-line indication to the register, whereupon it releases and restores to normal.

#### 7.2. Group Selection

When a register is connected, matters proceed in a well-known manner in that a dial tone is applied to the line and the digits dialled by the subscriber are stored in the register.

a register is tested by different *B* governors is sufficient to operate a connecting relay and remove the calling condition in the register.

A connecting relay that corresponds to the code received by the recorder forming part of the *B* governor is operated.

The first-group-selector esbo then signals its identity by electronic means to the governor, whereupon a relay is operated closing the leads between the 2 circuits.

In the meantime, the register transmits the wanted-level indication to the governor, which connects itself to the impulse wire of the explorer forming part of the first-group-selector esbo and records the first free impulse that arrives in the wanted cycle (section 4.4). After a sequence test (section 4.10), the esbo circuit is engaged by the governor, which then oper-

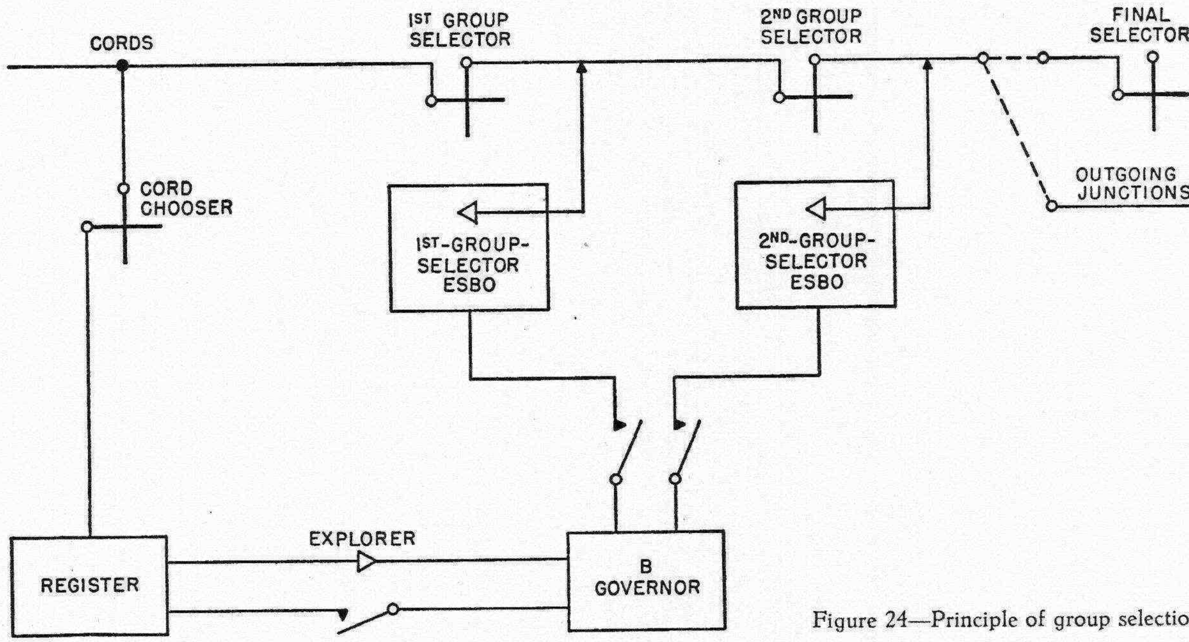



Figure 24—Principle of group selection.

As soon as the number of digits received is sufficient to complete all local group selection, that is, up to a final selector, an outgoing junction, or a special-service circuit, the register calls for a free *B* governor. See Figure 24.

These governors serve the purpose of group selection exclusively and are provided in sufficient number to handle the traffic.

When calling for a *B* governor, the register applies a potential to its gate circuits forming part of the explorers associated with these governors. In the manner explained in section 4.7, the *B* governor tests all registers in sequence and the time interval between the moment

ates the corresponding vertical bars of the first-group-selector multiswitch. The horizontal-bar magnet is operated at the same time via the register and cord circuits.

Before operating a servomagnet to complete connection through the first group selector, the condition on the test wire of the selected outlet is investigated, this wire being connected to the governor via a contact operated by the vertical bar. The latter carries out a sequence test on this wire to determine if the outlet is free or busy and to render it engaged for other calls.

When this sequence test proves succesful, the horizontal servomagnet is energized, thus completing the connection.

Each first-group-selector esbo includes an additional explorer that signals to the *B* governor the identity of the multiswitch on which the required group selector is located and consequently that of its associated esbo. After receipt of this information, the *B* governor releases the first-group-selector esbo and connects itself to the new esbo.

The *B* governor then receives from the register the group signal for the next selection and for this and all further group selections it proceeds in the same manner as described for the first group selector.

When the *B* governor completes the selection of an outgoing junction, it is informed of this fact by the identity explorer of the last esbo, whereupon it is released. The register then transfers the necessary digits to the distant exchange by means of 4-element codes composed of 2 different frequencies as first applied in the *7E* machine switching system.

When the *B* governor completes the selection of a special-service line, the cord circuit is advanced to the talking condition and the register is released.

### 7.3. Line Selection

The esbo circuit of a penultimate multiswitch differs from other group-selector esbos in that it does not include an identity explorer. This stems from the fact that the identity of the final esbo is known from the thousands and hundreds figures. Selection within the local block of 10,000 numbers is in broad terms performed on a decimal basis.

Line selection is controlled by a group of *C* governors sufficient in number to carry the traffic. See Figure 25. The moment the subscriber starts to send the units figure, the register connects itself metallically to a *C* governor in a manner identical to that described for the *B* governors.

The register transfers the thousands and hundreds figures to the *C* governor so as to permit this circuit to operate the connecting relay of the proper final-selector esbo circuit. It also transfers the last 2 digits of the wanted line ; these are first utilized by the governor to obtain from the impulse wire of the class-of-line explorer the condition and the class of the line (section 4.5).

If the desired line is free, a sequence test is made on the esbo and it is engaged. The proper combination of vertical bars is operated by the governor via the esbo and the proper horizontal bar magnet via the register and the train of group selectors already engaged. The condition of the *c* wire of the wanted line is again checked via the vertical-bar contacts by means of an electronic direct-current comparator circuit to make sure that no call was originated on this line during the short time that elapsed since the line condition was explored. The proper horizontal servomagnet is then temporarily energized and the call is switched through. The cord is switched through to the ringing condition and the register, *C* governor, and esbo are released.

If the called number belongs to a single line that is busy, the cord circuit is switched through to the busy condition immediately after the class-of-line explorer has signalled this condition, whereupon all auxiliary circuits are released. Also the various group selectors already engaged are released so that during the time the calling subscriber receives the busy tone, only a line finder and a cord circuit remain engaged.

If the called number belongs to the first line of a private-branch-exchange group having non-consecutive numbering and this line happens to be busy, the *C* governor hunts by means of the class-of-line explorer for a free line belonging to that private-branch-exchange group.

When such a line is found, the *C* governor proceeds in the manner described for a free single line. If no line of the wanted private-branch-exchange is found free after the exploration of the 100-line group, busy tone is passed to the caller. The system provides for 5 groups of private branch exchanges with nonconsecutive numbering in each 100-line group.

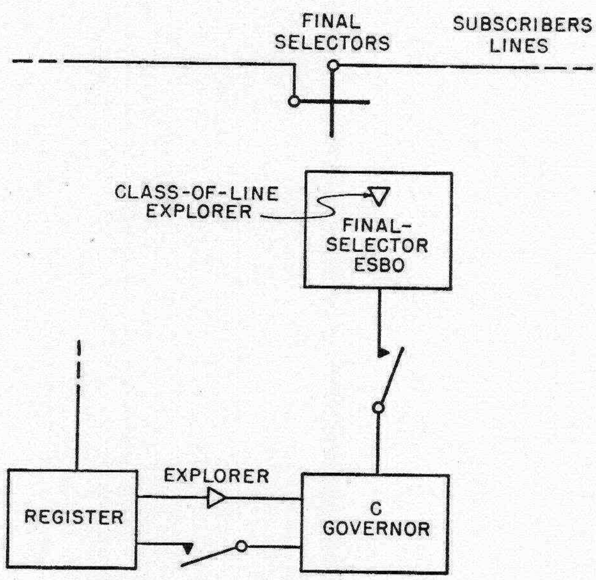
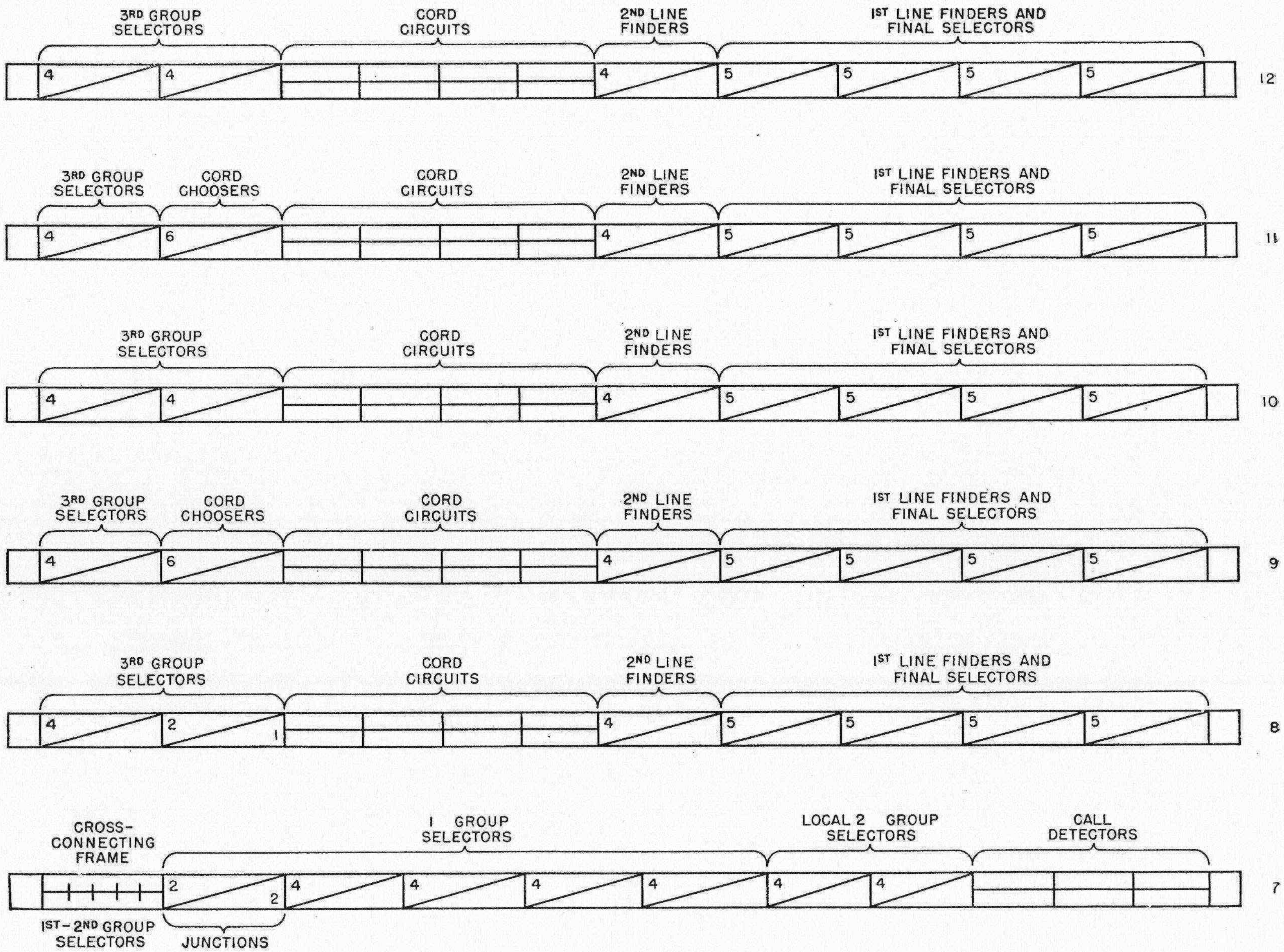



Figure 25—Principle of final selection.

If the called line forms part of a private-branch-exchange group with consecutive numbering, if it is not the last line of this group,


3RD GROUP SELECTORS
CORD CIRCUITS
2ND LINE FINDERS
1ST LINE FINDERS AND FINAL SELECTORS
4 4 4 5 5 5 5
12
3RD GROUP SELECTORS
CORD CHOOSERS
CORD CIRCUITS
2ND LINE FINDERS
1ST LINE FINDERS AND FINAL SELECTORS
4 6 4 5 5 5 5
11
3RD GROUP SELECTORS
CORD CIRCUITS
2ND LINE FINDERS
1ST LINE FINDERS AND FINAL SELECTORS
4 4 4 5 5 5 5
10
3RD GROUP SELECTORS
CORD CHOOSERS
CORD CIRCUITS
2ND LINE FINDERS
1ST LINE FINDERS AND FINAL SELECTORS
4 6 4 5 5 5 5
9
3RD GROUP SELECTORS
CORD CIRCUITS
2ND LINE FINDERS
1ST LINE FINDERS AND FINAL SELECTORS
4 2 1 4 5 5 5 5
8
CROSS-CONNECTING FRAME
I GROUP SELECTORS
LOCAL 2 GROUP SELECTORS
CALL DETECTORS
2 2 4 4 4 4 4 4
7
1ST-2ND GROUP SELECTORS
JUNCTIONS

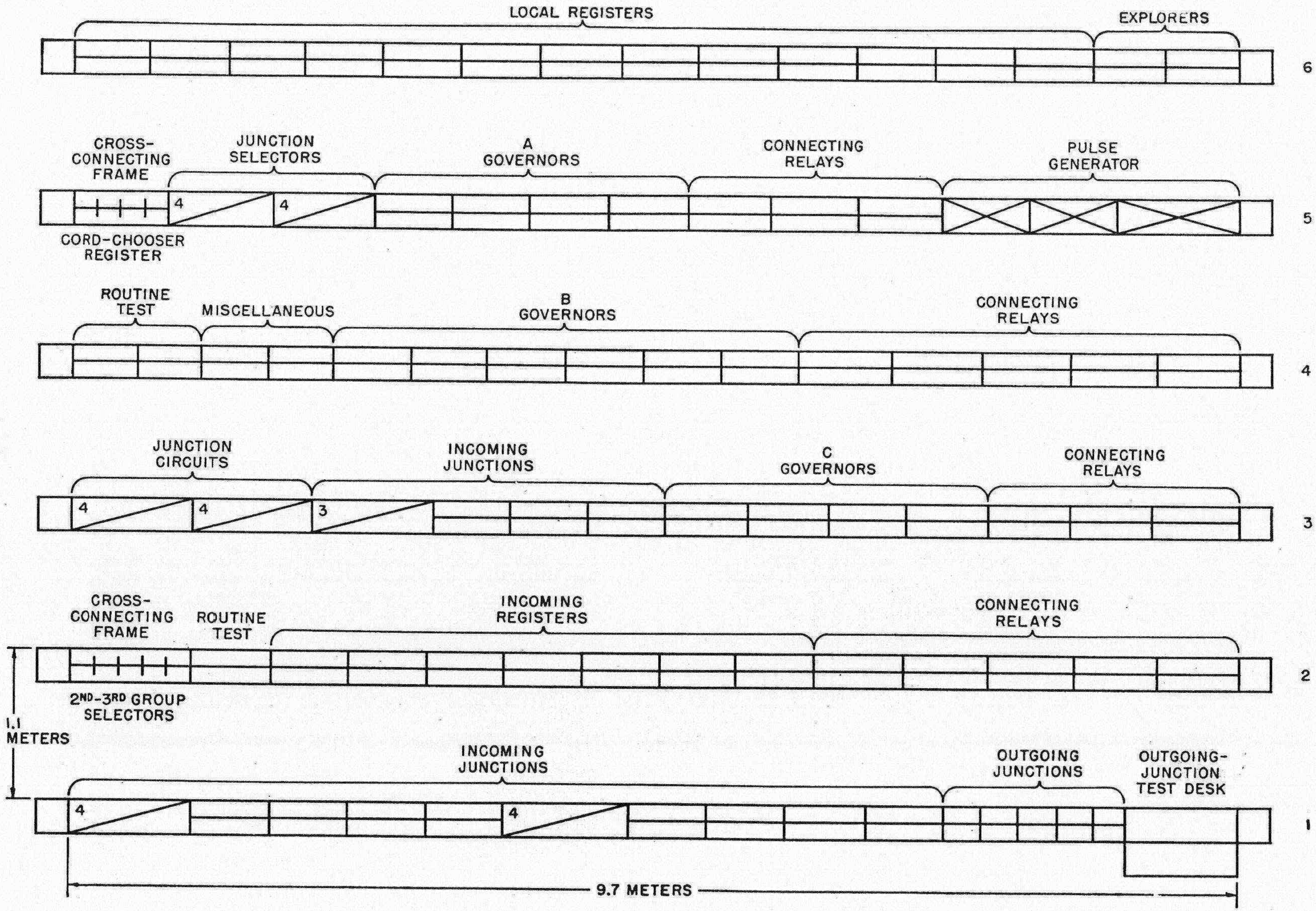



Figure 26—Typical switch-rack layout for a 10,000-line exchange.

and if it is found busy ($Nd_6$ in Table 3) the busy signal is combined with the select-next-line indication $Nd_{11}$. When receiving this combination of signals, the $C$ governor changes the source combination connected to its comparator to instruct it to explore the next line. This process is repeated until a free line is reached or until the last line is found busy. When busy, the last line is marked by the same indication as a busy single line, by sources $Nd_6$ and either $Nd_7$ or $Nd_8$. It should be mentioned that all lines of a consecutively numbered private-branch-exchange group should have the same tens figure. In each 100-line group, any number of private-branch-exchange groups with consecutive numbers may be connected within the capacity available.

If the called line is characterized by a rerouting signal, for example, by an indication marking a nonnumerical private-branch-exchange group, a changed-number line, a dead line, or a line in the absentee condition (sources $Nd_9$ or $Nd_{10}$), a corresponding signal is sent to the register, which releases the complete connection and auxiliary circuits and reroutes the call to the wanted destination.

## 8. *Floor Plan*

A typical floor-plan layout for a 10,000-line exchange is shown in Figure 26.

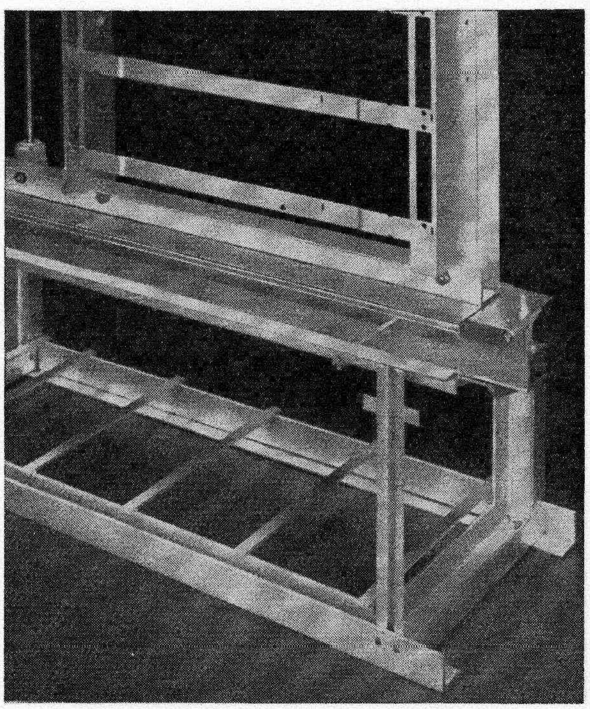


Figure 27—Construction of lower part of switch rack.

The corresponding junction diagram shown in Figure 22 indicates the various amounts of equipment that have been located on this plan.

In total, some 120 meters (394 feet) of single-row switch racks are required for this medium-heavy-traffic exchange providing for some 55 percent of trunked traffic. Part of the rack space is occupied by cross-connecting frames and an outgoing-junction test desk. A standard bay height of 3 meters (9.8 feet) has been adopted. A switch bay of this height can mount six 3-panel, five 12-panel, or four 18-panel multiswitches.

Five nearly identical single-row switch racks each mount the equipment for a 2000-line block. A first-line-finder-and-final-selector switch bay mounts the complete equipment for five 100-subscriber-line groups, that is, 500 line circuits, 5 line and class-of-line explorers, 5 × 12 first line finders, 5×12 final selectors, and 5 esbos. The call detectors are placed in row 7.

The 4 second-line-finder multiswitches mount on one bay. Cord circuits are mounted two-per-relay-unit, and each bay provides for 18 units.

The first group selectors, local second group selectors, and junction selectors are situated near their associated cross-connecting frame. Rows *3, 4, 5,* and *6* accommodate the local registers, explorers, governors, connecting relays, and pulse generator.

The incoming junction circuits, together with their junction choosers, incoming registers, and register-connecting relays are located on rows *1* to *3*.

The outgoing junction circuits are located near the outgoing junction test desk.

The plan further provides sufficient bay space for routine test equipment and miscellaneous equipment, such as alarm circuits, identification equipment, et cetera.

From this floor plan, it can be concluded that the floor space occupancy of the system is quite modest.

The switch racks employed are of the kind developed for the *7E* machine switching system, the latest type of which is shown in Figure 27. With this type of rack, the switchboard cabling runs from the bays downward instead of upward, as has been the general practice. This new method of cabling offers several advantages, such as better protection against fire, neater appearance of the exchange, and easier installation.

The transverse cable runs may either be placed on top of the switch-rack ends, on the floor in one of the aisles, or against the ceiling of the floor below. The latter is the most eco-

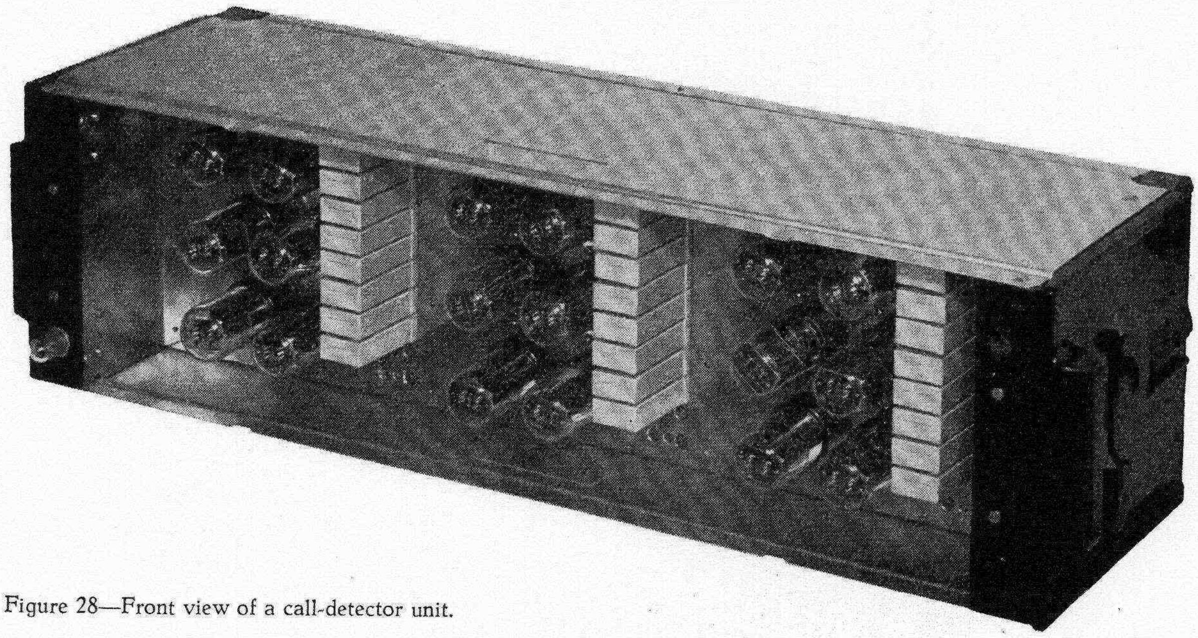


Figure 28—Front view of a call-detector unit.

nomical and neatest solution although the second can be applied to advantage in small exchanges.

## 9. *Apparatus Units and Bays*

Figures 28 and 29 show front and rear views of a call-detector unit, mounting 3 circuits.

The unit is of the jack-in type developed for the *7E* system and consists of 2 bakelite flanges mounting the fuses, jacks, and lamps. The terminals located at the back of the unit jack into the associated female contacts mounted on the bay. Levers located on the sides of a pair of flanges lock the unit in the bay.

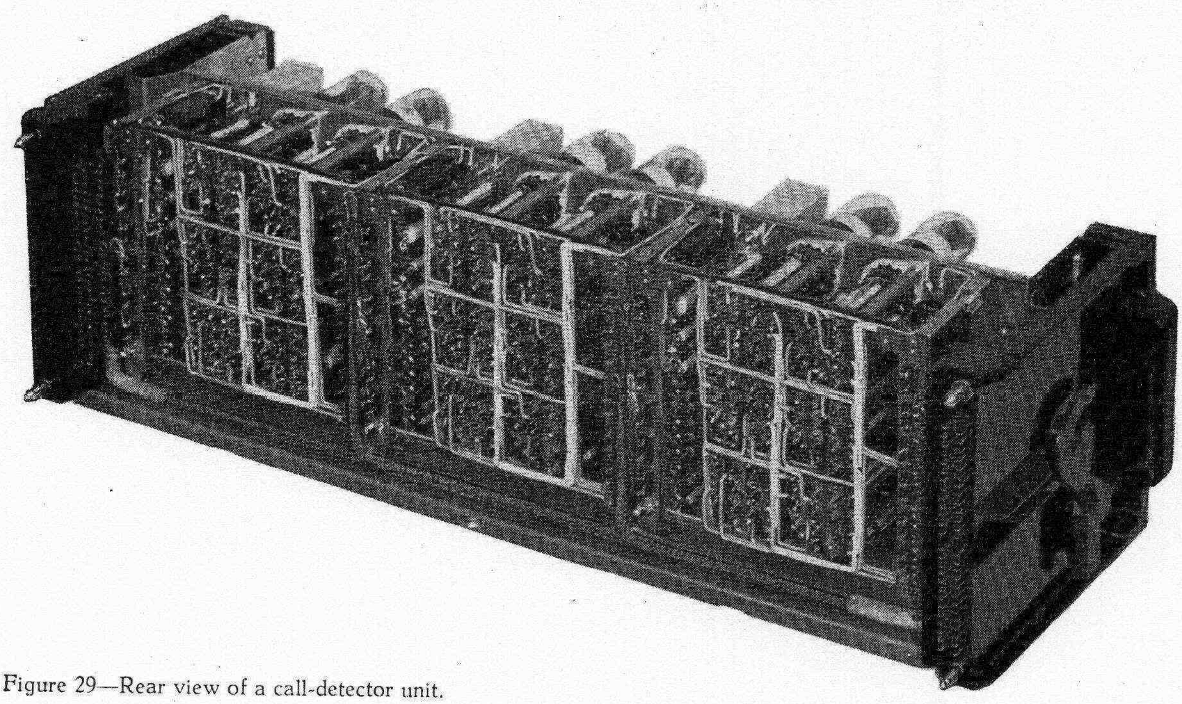


Figure 29—Rear view of a call-detector unit.

Figure 30 shows a rear view of a cord-circuit relay unit mounting 2 circuits. The relays and other circuit equipment are mounted on 3 bars fastened to the inside of the bakelite flanges. This arrangement has the advantage that no mounting plates are used, thereby eliminating a piece part of which a great variety are often used.

The jack-in units carry front and rear covers that can readily be removed ; the units are completely dustproof.

The line unit shown in Figure 31 comprises 4 terminal strips having T-shaped terminals, on the front end of which small plugs containing the line resistors are inserted. The line explorer and the class-of-call explorer are mounted on 2 assemblies next to the terminal strips. These assemblies are pivoted at their ends so as to permit easy changing of the class-of-line jumpers, which are clearly visible in the photograph.

The unit also includes the jack-in assemblies for connecting the subscribers' lines and associated equipment to the switch multiple.

Figures 35, 36, and 37 are front views of the three types of governors employed.

A completely equipped first-line-finder-and-final-selector bay is shown in Figures 38 and 39.

### *10. Cabling and Cross-Connection*

As the system operates with stage-by-stage selection, the general cabling layout corresponds in all major respects to that of systems using 100-point switches such as the *7D* or *7E* rotary systems.

The explorers hunt for a free outlet in a manner comparable with that of a nonhoming switch and for this reason homogeneous gradings are used, that is, gradings in which all outlets are connected to the same number of splits. The traffic offered is on the average evenly distributed over the outlets, and this arrangement provides a better efficiency than if, for example, part of the outlets were connected to 2 multiple splits and another part to 3 splits.

Figure 40 shows a typical homogeneous grading for 6 splits numbered from I to VI. Cyclic slipping is shown and the number placed

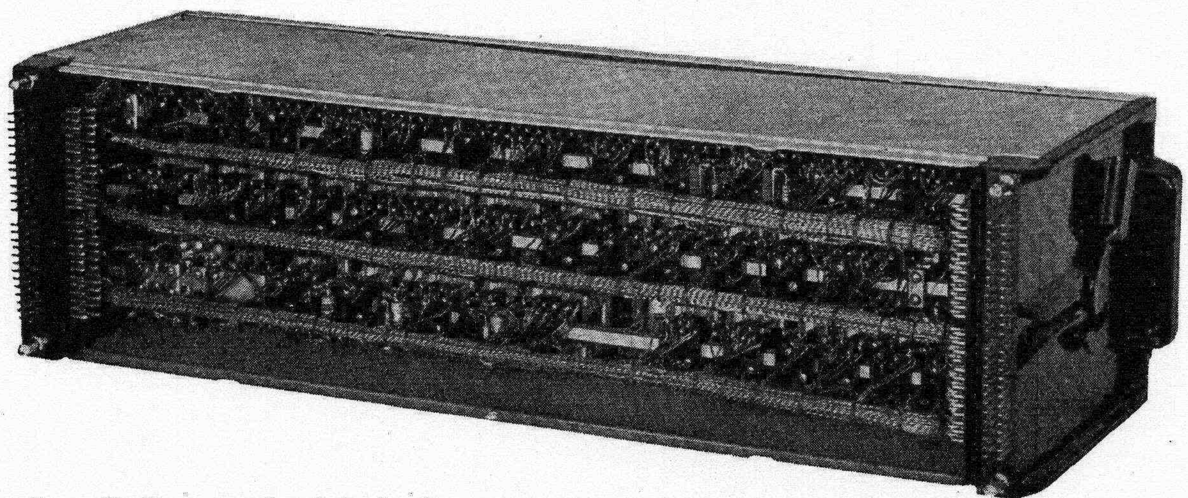


Figure 30—Rear view of cord-circuit unit.

in small circles indicate the number of the outlets connected. With 6 splits, 1 block of 6 sets of each 10 time positions permits obtaining 2 complete cycles so that the complete 6 sets of 100 time positions provide 20 complete cycles. When assigning the outlets to the various levels, care must be taken so that the outlets belonging to one level are evenly scattered over the 100

The units shown in Figures 32 and 33 contain explorers such as are provided between registers and governors.

Figure 34 shows a front view of a 4-digit register circuit. It contains only a restricted amount of apparatus, mostly relays, as the electronic selection control equipment forms part of the governors.

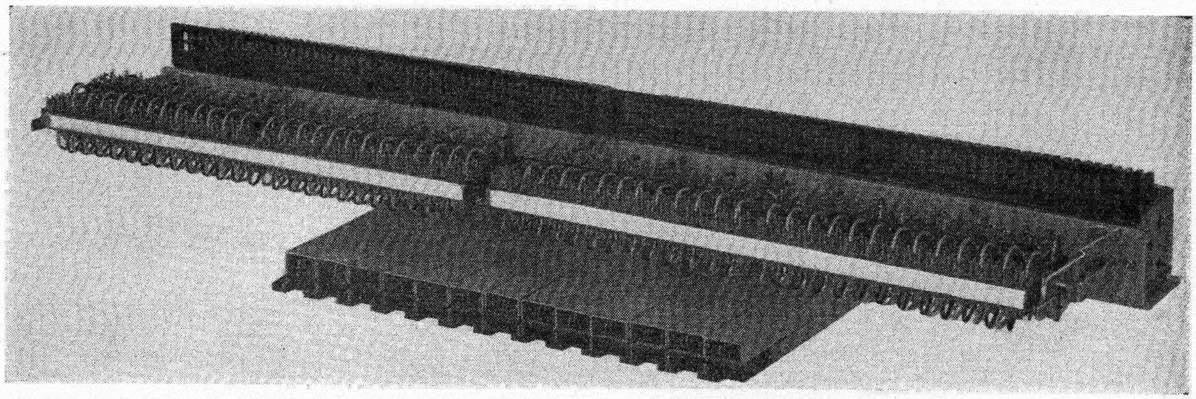


Figure 31—Line-circuit, line-explorer, and jack-in assemblies.

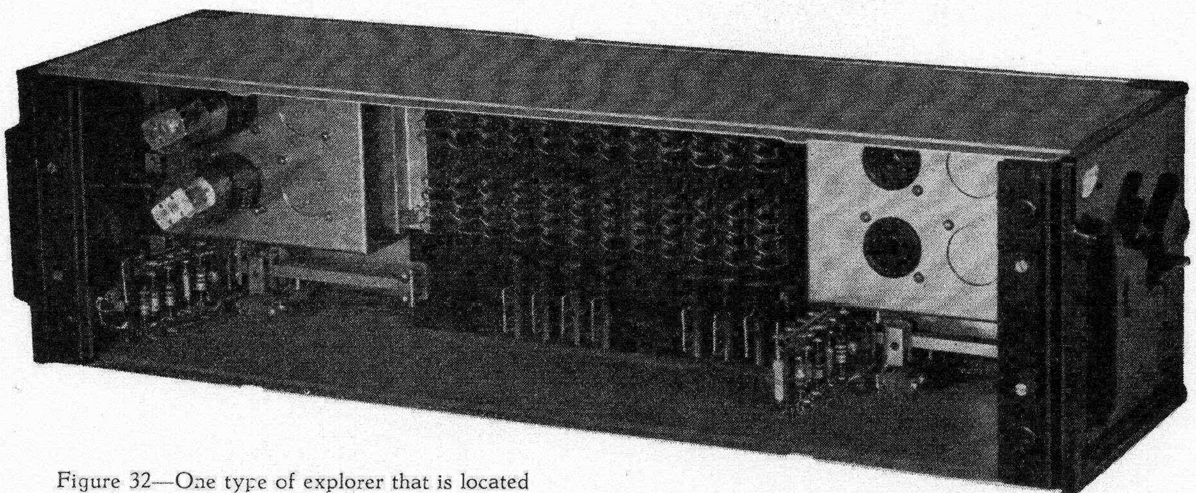


Figure 32—One type of explorer that is located between the registers and governors.

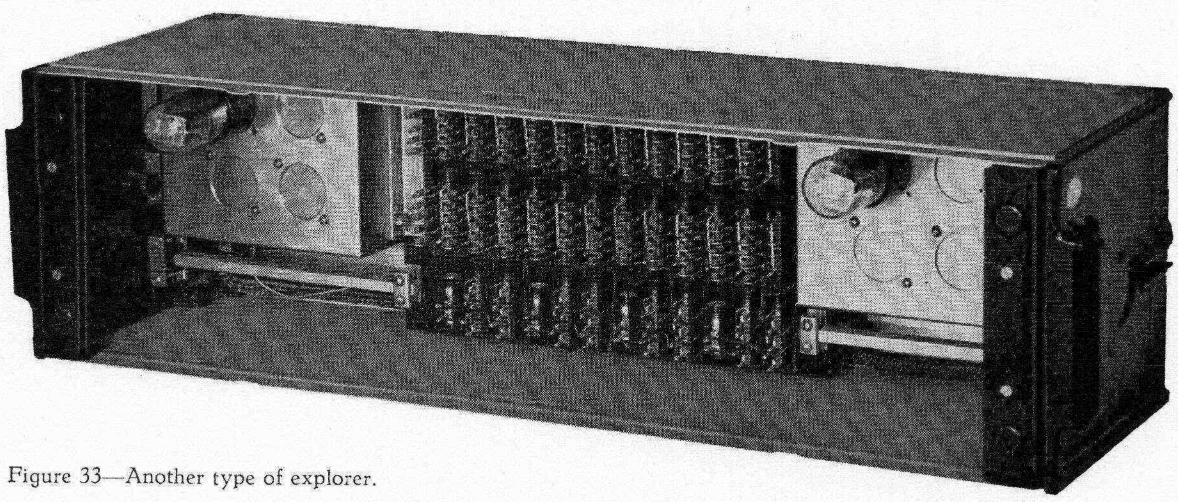


Figure 33—Another type of explorer.

time positions and that the nearest approach is made to complete cycles. For example, for a level of 20 outlets, time positions *1, 6, 11, 16,* etc., which provide a spacing of 5 units and 4 full cycles, should be chosen.

The switchboard cable is composed of cotton-covered black-enamelled wires with standard code coloring but with an acetate coating. This reduces fire hazard compared with the use of waxed cable ends.

Further, efficient routine test methods may be provided by which incipient faults are detected before they develop into machine or circuit troubles. The equipment under routine test remains in its proper location on the racks and no interference with the exchange traffic can occur.

Maintenance is further reduced by the elimination of the usual two relays in the subscriber's line equipment. A call detector operating

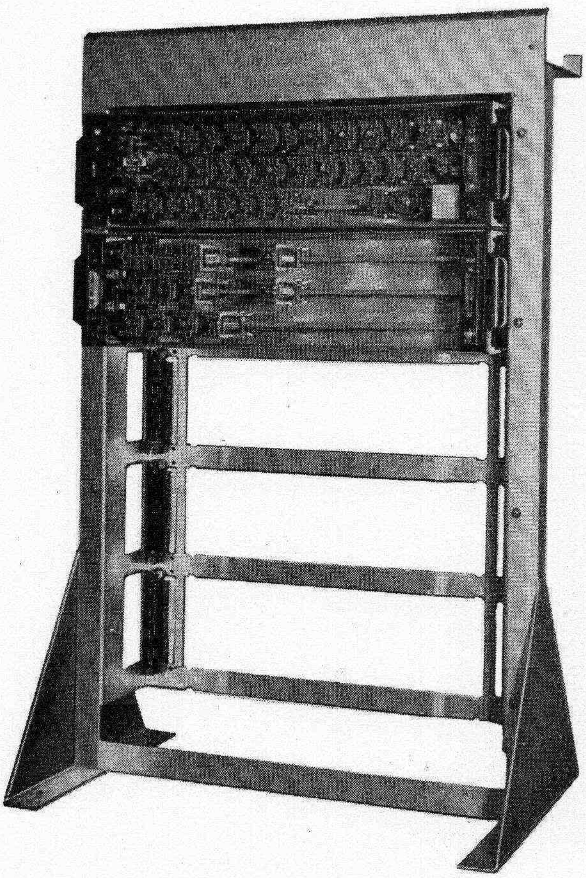


Figure 34—Four-digit register.

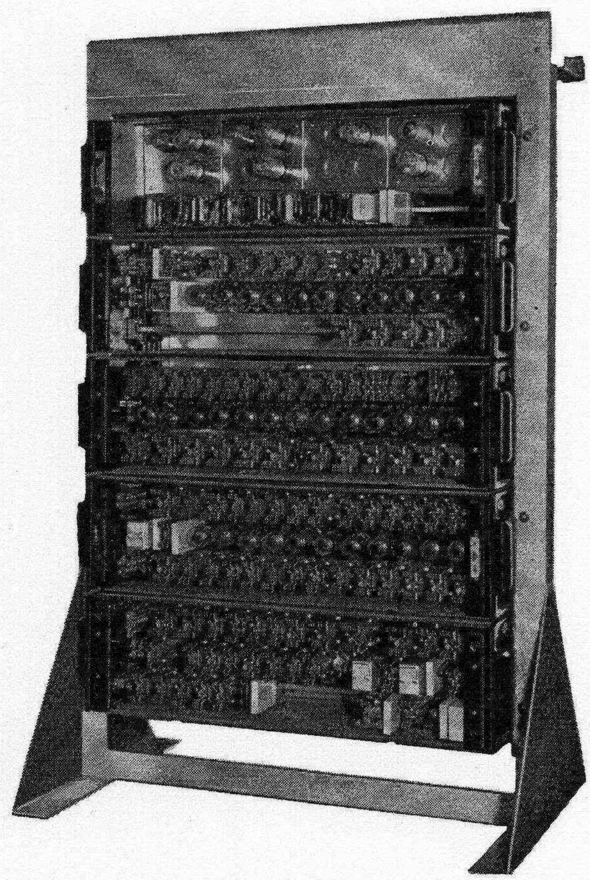


Figure 35—A governor.

on an electronic basis is associated with every group of 100 subscribers' lines. These call detectors are tested in rotation once every 100 seconds.

## *11. Maintenance Facilities*

Great care has been taken to produce reliable service while restricting maintenance to a minimum and facilitating the tracing of faults. The latter is of special importance as the various selecting operations happen at high speed and no mechanical and visible hunting takes place.

One of the main features that constitue an aid to locating faults is the holdover facility mentioned in a previous section.

The multiple switch has already proved its reliability under actual traffic conditions. As it can easily be disassembled, all parts are accessible both for inspection and repair.

All circuits and switches are of the jack-in type so that a faulty circuit or switching element can readilly be replaced and repaired on the bench.

Maintenance is also facilitated by the absence of close adjustment limits and by the wide operating margins of the multiswitch.

The relays are of modern design and of robust construction. They provide heavy contact pressure and stable adjustment. Where necessary, the relay contacts are protected by spark quenchers.

which avoids timing relations. Operation is certain and fast, the locating of troubles is facilitated.

Counting of impulses is restricted to the input stepping equipment of the registers.

All relay units and multiswitches are completely enclosed, thus providing excellent protection against dust or damage.

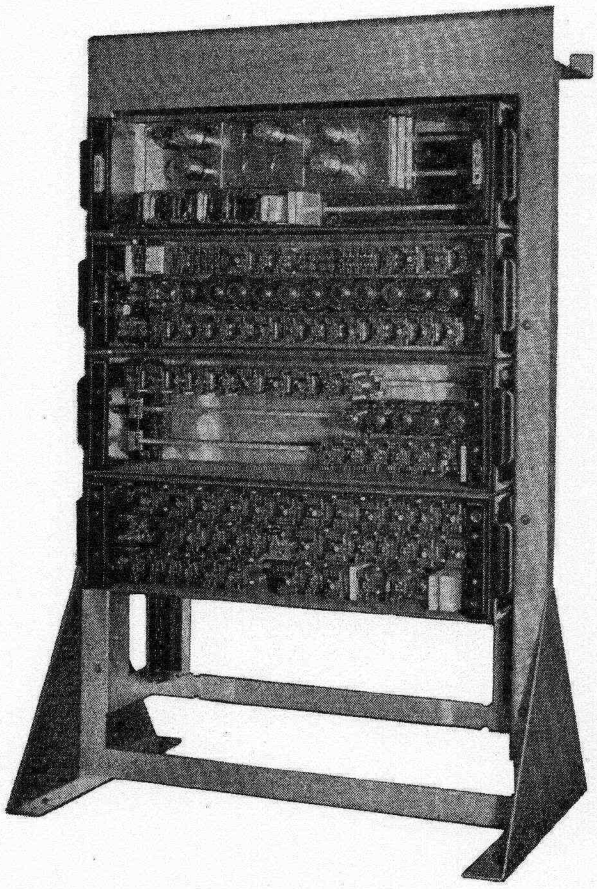


Figure 36—*B* governor.

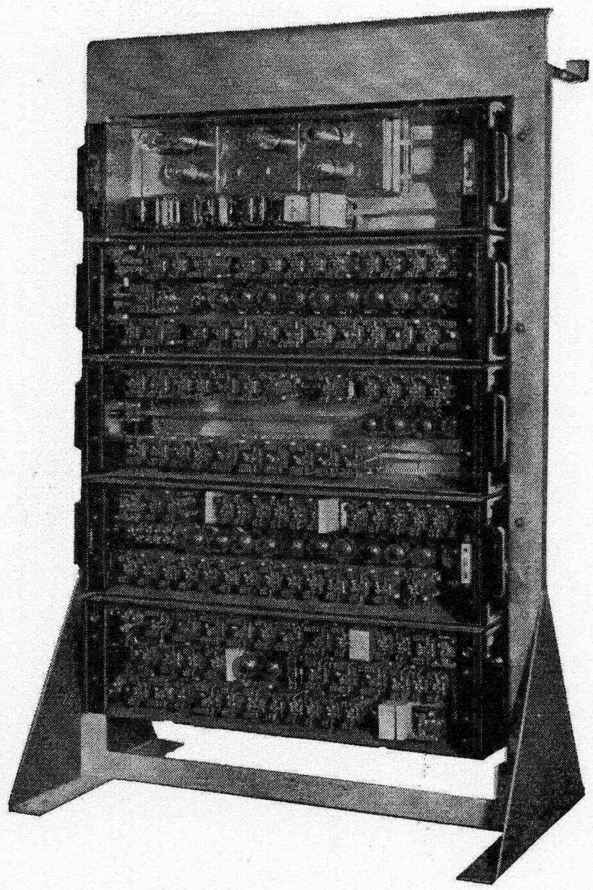


Figure 37—*C* governor.

All but a few of the relays are designed with such wide limits that only mechanical readjustment of spring and armature tensions is needed, thus avoiding the necessity of checking current limits. They have demonstrated highly satisfactory service coupled with long life.

All circuits operate in the so-called "chain" manner, by a compelled sequence of operation,

The local cable forms are enclosed inside dustproof coverings and are thus effectively protected against the disintegrating effect of light.

The busy jack of engaged circuits may be plugged in without disturbing existing connections.

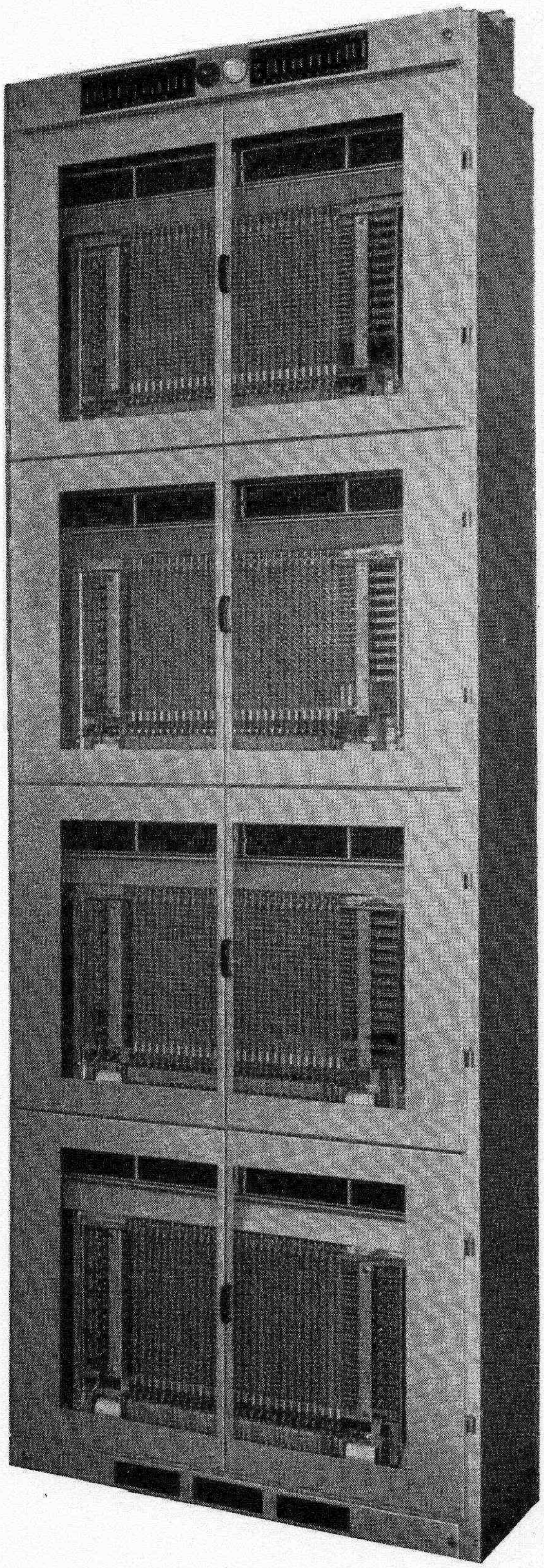


Figure 38—Front view of multiswitch bay.

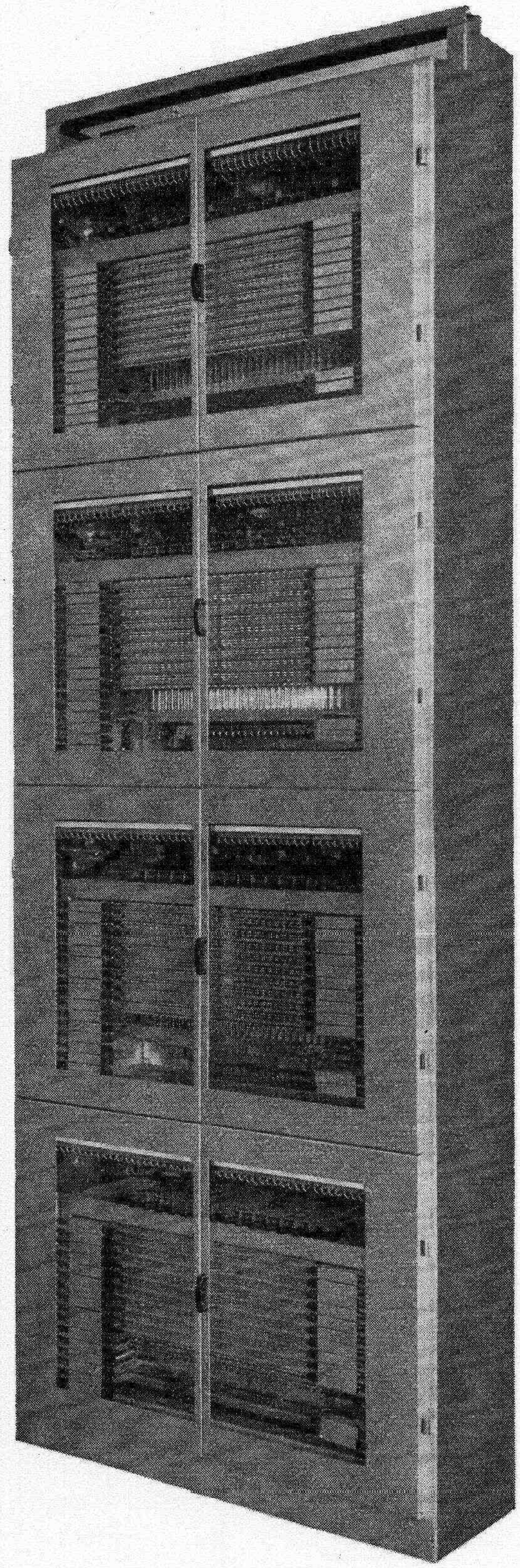


Figure 39—Rear view of multiswitch bay.

All common leads may be individually isolated by cutout jacks in each to facilitate the tracing of trouble.

The junctions between offices are of the 2-wire type and are generally operated in only one direction. They may be taken out of service at either end and are automatically isolated in case of trouble.

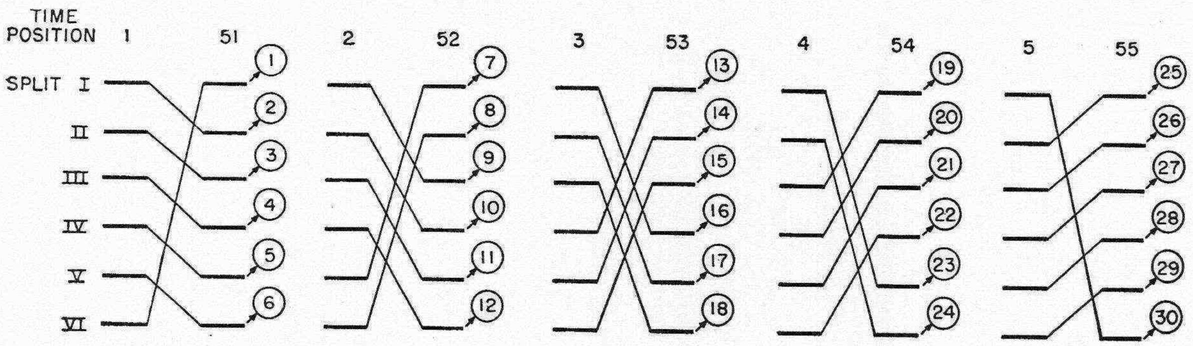



Figure 40—Typical homogeneous grading. Outlet numbers are in circles. The same arrangement repeats itself for blocks of time positions *6* to *10* and *56* to *60*, *11* to *15* and *61* to *65*, *etc.*

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