



ELECTRICAL COMMUNICATION

*Technical Journal of the
International Telephone and Telegraph Corporation
and Associate Companies*

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TRADA PENTACONTA PRIVATE AUTOMATIC BRANCH EXCHANGES

CROSSBAR CITOMAT PRIVATE AUTOMATIC BRANCH EXCHANGES

AUTOMATIC 7E ROTARY TELEPRINTER SWITCHING SYSTEM

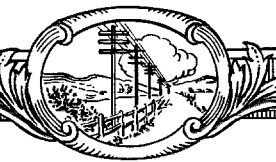
CIRCUITS OF 7E ROTARY TELEPHONE SWITCHING SYSTEM



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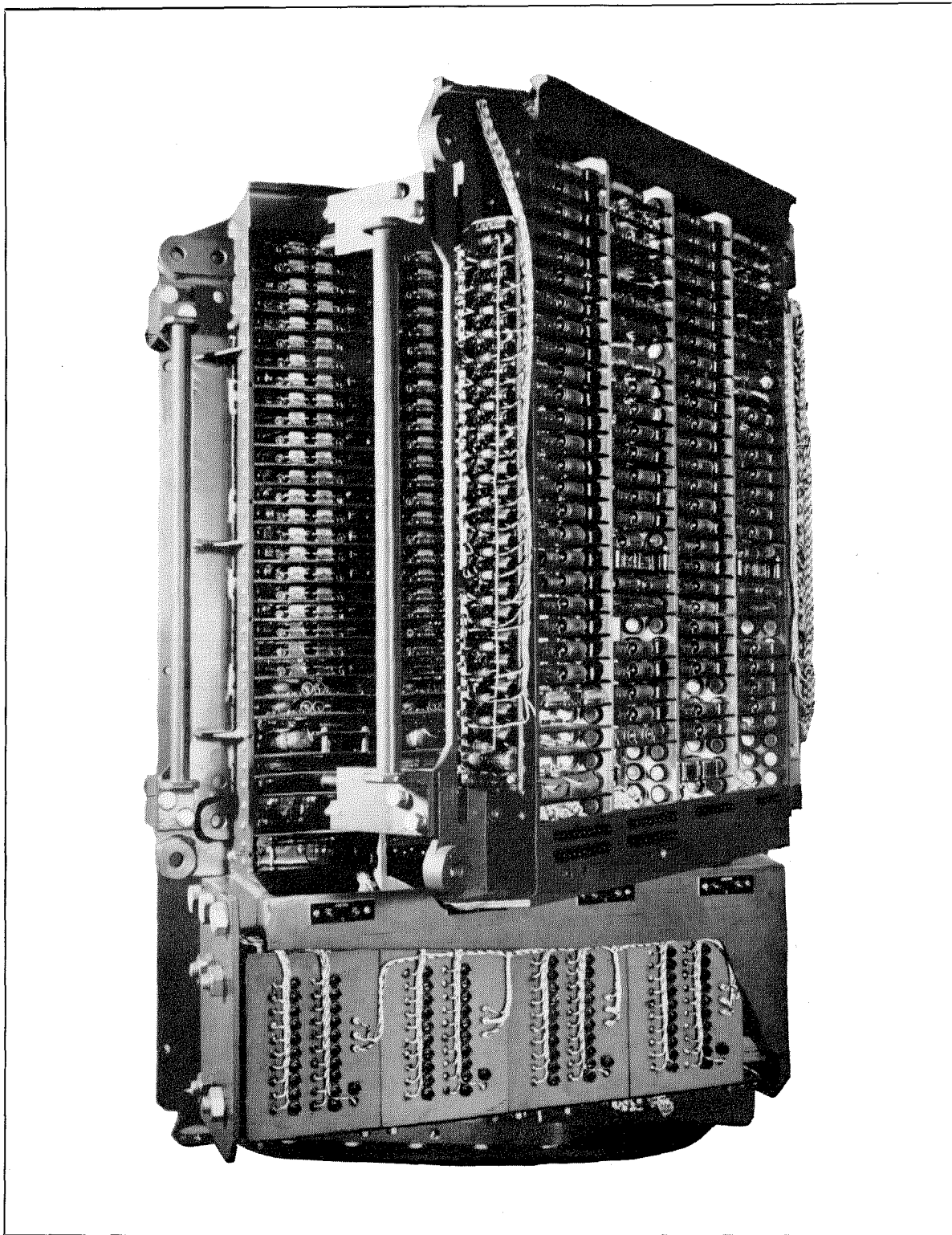
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A prototype all-electronic telephone exchange has been developed for the French Navy by Laboratoire Central de Télécommunications; Paris, France. The unit switches 20 lines, but is only slightly over 2 feet (60 centimeters) high. No mechanical movement is involved in its operation; all signaling and switching being done electronically. Relay and switch contacts are replaced by small bistable magnetic cores that either allow or impede the flow of current in miniature silicon diodes: switching is instantaneous. It was developed to withstand the humidity, shock, and vibration of naval service, which previously demanded manual operation for these reasons and to provide high reliability. Work is under way on a civilian design

Trada Pentaconta Private Automatic Branch Exchanges

By MARC VERNE

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CRITICAL observations of telephone system operation in recent years has shown that certain improvements are desirable. Better transmission quality through the elimination of all spurious noise, particularly that caused by contacts inserted in the speech circuits, would be welcome as would higher speed in the completion of calls with automatic equipment.

A step toward the first objective can be made by the exclusive use of precious-metal contacts in the speech circuits; the second requires switching elements capable of the rapid operation obtainable when contact motion is small. The Pentaconta system¹ was designed with these two problems in view and experience with it in central offices both in France and other countries has shown that it gives complete satisfaction on these two points.

It would be worthwhile to obtain these same improvements in private automatic branch exchanges by utilizing the Pentaconta principles, which also offer other interesting advantages in small- and medium-capacity private installations. An important feature of the system is that the switching elements require no critical adjustment after assembly and, the contact motion being small, readjustment is not needed to compensate for wear. Another is that proper operation is obtained over the wide range from 44 to 56 volts.

These two properties mean that a minimum of maintenance work is required; no adjustment of relays or selectors has ever been necessary in any Pentaconta exchange. With the wide voltage tolerance available, the exchange battery can often be eliminated and the operating power can be supplied by the power mains. These are particularly important points in private branch installations because a skilled maintenance staff is usually not available for the switching equipment and storage batteries, so that expensive

and time-consuming recourse must be made to the service staff of the equipment manufacturer.

1. Elements of System

As the Pentaconta system has already been described¹ in detail, only a brief review of the simple and sturdy relays and selector shown in Figure 1 will be given here.

1.1 RELAY

The relay was specially designed for the system and is used in a number of functions; it has precious-metal contacts and is stable in adjustment, requiring practically no maintenance.

Two types of coils are used, one having a thickness of a single spring pile-up and the other is as thick as two pile-ups. The yokes usually used accommodate either 2 or 3 pile-ups and can mount 2 or 3 small coils or one large one.

1.2 MULTISWITCH

The multiswitch is an assembly of selectors, as may be seen in Figure 2, having common operating means. They use precious-metal twin pressure-type contacts, contact motion being about that of a relay.

The capacity of the selector is generally 52 outlets; this, together with their rapidity of operation makes it possible to reduce the number required. Usually, 17 selectors are mounted in one multiswitch frame, but for small exchanges, selectors are available with 14 and 24 outlets.

2. General Features

Using the above-described switching elements, there has been developed a range of private automatic branch exchanges enabling direct seizure of trunk lines by the local extensions. These have been given the name Trada Pentaconta; Trada is an abbreviation derived from French words meaning call and ring, transfer, and callback: the circuit capacities are listed in Table 1.

¹F. Gohorel, "Pentaconta Dial Telephone Switching System," *Electrical Communication*, volume 31, pages 75-106; June, 1954.

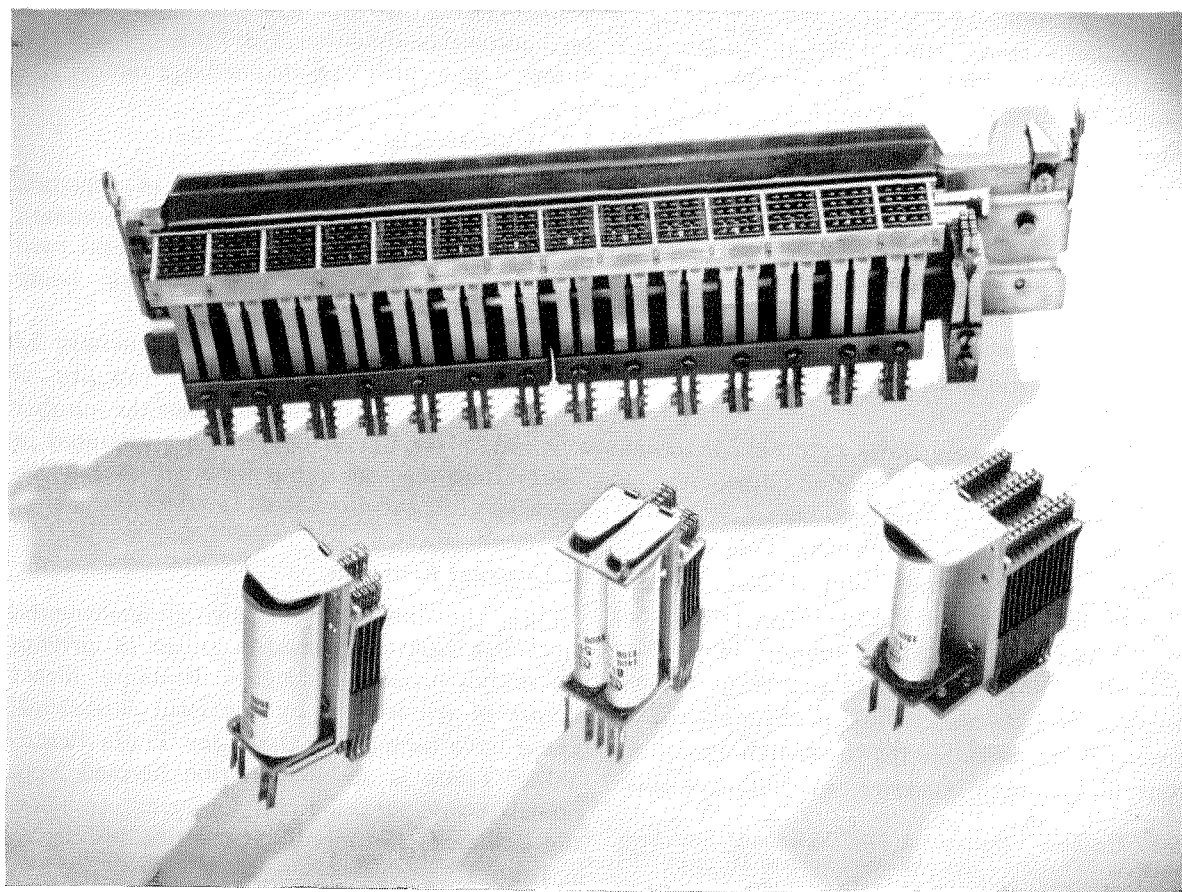
Each exchange is self-contained in a single cabinet except the Trada 16, which has additional cabinets depending on how many of the 600 possible extensions and how many trunks are equipped.

2.1 EXTENSION SUBSCRIBERS' SETS

The subscribers' sets are of the 2-wire dial type without key or button. Until recently, button-type sets were used to allow trunk-line connection and for call transfer, but buttonless sets can provide the same services and have several distinct advantages.

- A. They are simpler and about 5-percent less expensive.
- B. The button requires a connection to ground. With lead-covered cables, this is a simple matter,

Figure 1—Pentaconta selector and three types of relays.



but with the plastic-covered cables generally coming into use, a third wire would be necessary. Also, in some places, local ordinances prohibit

TABLE 1
CIRCUIT CAPACITIES OF TRADA PENTACONTA

Trada	Central-Office Trunks	Local Link Circuits	Local Extension Lines
1	1	1	6
3	3	2	12
4	4	3	22
5	5	6	50
16*	16	16	100

* Installations of the Trada-16 type can be expanded to 600 extensions and an unlimited number of trunk lines.

grounding at the subscriber's premises to eliminate a possible hazard to him through faults on nearby power-distribution systems.

C. A completely dial-operated subscriber's set provides the subscriber with a consistency of

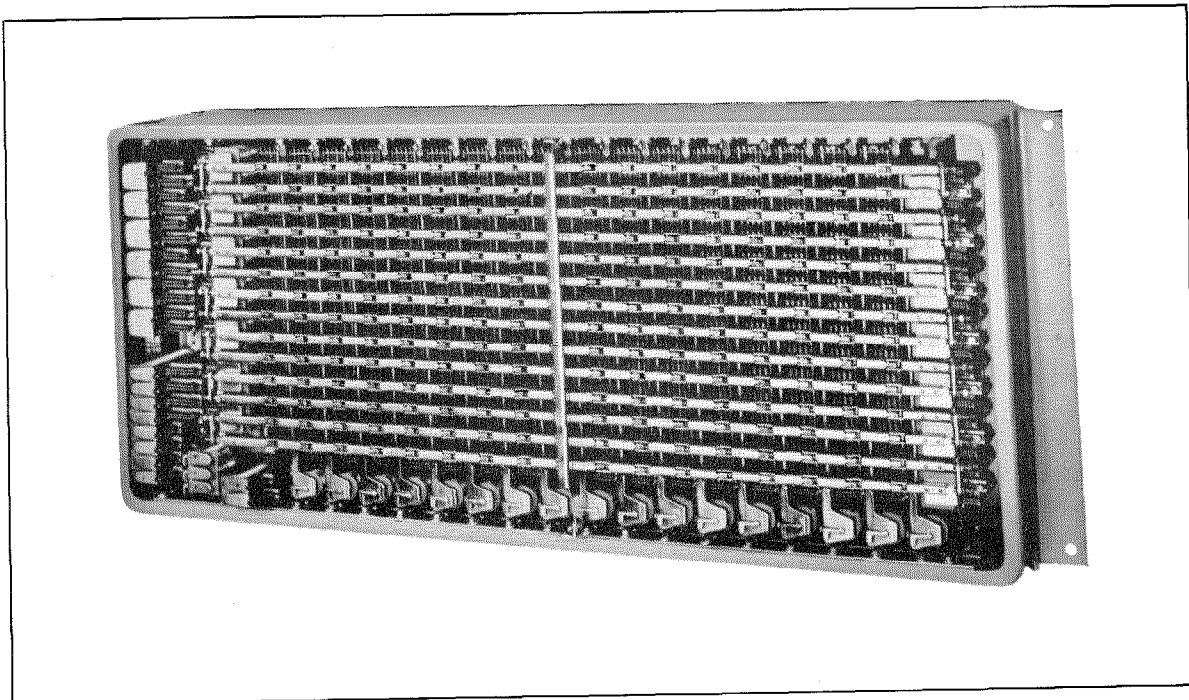


Figure 2—The multiswitch is built up of a number of Pentaconta selectors in a common frame.

operation in which trunk lines as well as other extensions can be dialed by number. Experience has shown this system to be very acceptable to the user.

For these reasons, a buttonless subscriber's set was adopted. Provided the loop resistance does not exceed 1000 ohms, they are directly connected to the switching apparatus; otherwise, a matching equipment is necessary.

2.2 EXTENSION SERVICE RESTRICTIONS

Extensions can be assigned to any of the following services by strap-type connections in the switching cabinet.

- A. Fully restricted service limited only to local calls.
- B. Partially restricted service in which trunk calls can be made only through an operator, but transferred trunk calls can be received.
- C. Unrestricted service that can seize a trunk line by dialing a code number.

2.3 PARTY-LINE EXTENSIONS

Except for the Trada 1, the number of extensions can be increased by using 2-branch party lines. For nonprivacy party lines, the subscribers' sets are connected in parallel, with the ringers connected between ground and opposite sides of the line, a particularly economical and practical arrangement when both subscribers are in the same room. Additional equipment in the subscriber's set will permit party-line-service-privacy.

Using party lines, the Trada 3 will accommodate 10 lines (20 sets); Trada 4, 13 lines (26 sets); Trada 5, 18 lines (36 sets); and Trada 16, 100 lines (200 sets).

2.4 HANDLING OF CALLS

2.4.1 Subscriber Operations, Call Transfer

All subscriber operations have been simplified as far as possible. Internal calls are completed by dialing the desired extension. External calls are made by dialing a code to seize a trunk line; when dial tone from the public exchange is heard, the desired number is dialed. Trunk calls can also be made through the private-exchange operator.

During a trunk call, the private-exchange subscriber can hold the call and speak to another internal subscriber by dialing, say, digit 2 followed by the desired extension number. After this, he may release the local connection and resume the trunk-call conversation by dialing, say, the digit 1; or, by simply replacing the handset on the cradle, the trunk call is transferred to the other local extension. Any wrong operation during transfer is automatically signaled to the operator's position. The trunk line is released when the last local subscriber hangs up.

2.4.2 Calls to Operator, Interruption of Calls

During a trunk call, the subscriber may also call the private-exchange operator into the connection by dialing, say, 0. He may also call the central-office operator, if the connection is through a manual exchange, by dialing, say, 1.

Incoming calls from the public network are received by the private-exchange operator, who then rings the desired extension by dialing its code. Ringing current is applied and the operator withdraws from the connection when the extension answers. If the extension is busy with another extension or a local call and the new call is a toll or long-distance call, the operator can interrupt the call in process to announce the new call. The new call can be accepted by the extension simply by returning the handset to the cradle, immediately after which the bell will ring and the new conversation may be commenced.

If the subscriber does not wish to accept the new call immediately, the operator can withdraw to handle other calls and the new call will automatically ring the private-exchange extension when that handset is replaced.

When several trunk calls are waiting for the same busy extension, they are automatically put through in turn each on completion of the previous one.

2.4.3 Unattended Operation

When the operator leaves her desk, she places the equipment in the call-transfer condition and two call-handling sequences can be arranged.

2.4.3.1 Reduced Service

Outside calls are signaled by ringers specially mounted for that purpose. Any extension entitled

to receive an outside call can answer by dialing a preassigned code. The call can be transferred as in paragraph 2.4.1.

2.4.3.2 Night Transfer

All outside calls ring a single designated extension and are transferred to the desired extension as in paragraph 2.4.1. Simultaneous outside calls are stacked as received and each is handled in its turn from the single extension.

3. Trada Series

3.1 TRADA 1

The Trada 1 is an all-relay exchange having a capacity of 6 extensions and 1 trunk line. The

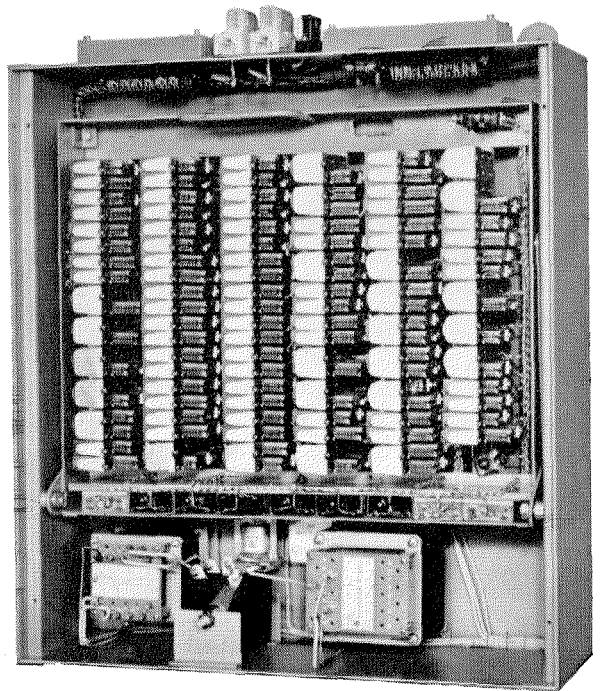


Figure 3—The Trada 1, with a capacity of 6 local lines and 1 trunk, is an all-relay branch exchange.

switching mechanism and power supply, which operates from the mains, are completely contained in the wall-mounting metallic cabinet shown in Figure 3.

The extensions have single-digit code (2 through 7), extension 2 having transfer keys and a magnetic visual indicator showing when the trunk is busy. The circuit is arranged to allow

connection to the trunk even when the local link is busy.

extension's horizontal selector bar and the trunk connector to connect the trunk to the extension, after which the local link is released.

For call transfer, the connected extension can seize a local link while holding the trunk by means of two special callback circuits.

This, in general, describes the operation of the Trada circuits; a more complete explanation will be given later.

3.3 TRADA 4

The Trada 4 is completely contained in a metallic cabinet, as shown in Figure 5. Because its capacity is greater than the Trada 3, a larger multiswitch having 11 selectors and 24 outlets is used.

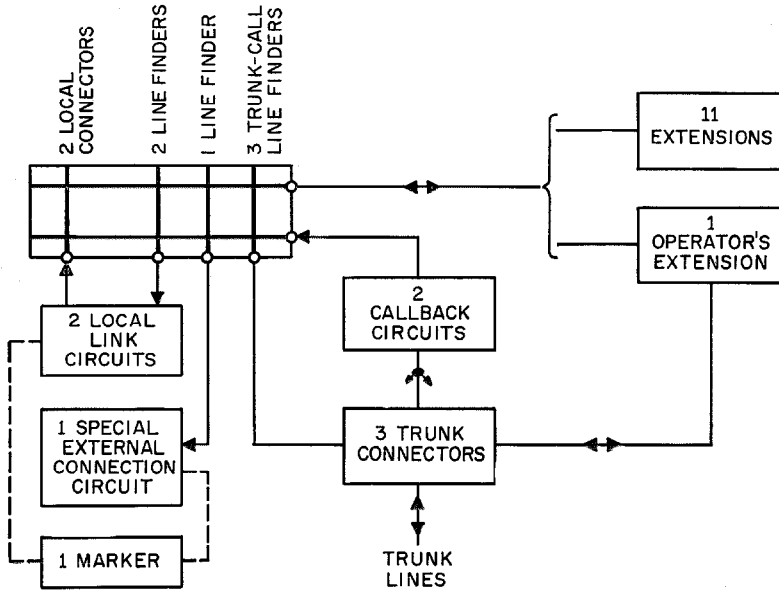


Figure 4—Connection diagram of Trada-3 exchange with 12 extensions, 3 trunks, and 2 local link circuits.

A special supervisory extension for monitoring outside calls is also available.

3.2 TRADA 3

The Trada 3 also mounts in a wall cabinet; its features are similar to the Trada 1, except that its larger capacity requires a multiswitch having 14 outlets and 8 selectors. Figure 4 shows the wiring diagram.

A call initiated from an extension is connected to a local link circuit by the line finder. The dialed pulses are received in the cord circuit. After the last dial pulse, a common marker connects to the cord circuit, indicates the level of the called extension, connects the latter to the cord circuit through the connector, and releases itself for other calls.

If the two local links are busy, the calling extension connects to the special external connection circuit giving access to the trunk lines, but will send busy tone if the code dialed does not correspond to the code for the trunks.

When a trunk code is dialed, the marker indicates a free trunk and energizes the exten-

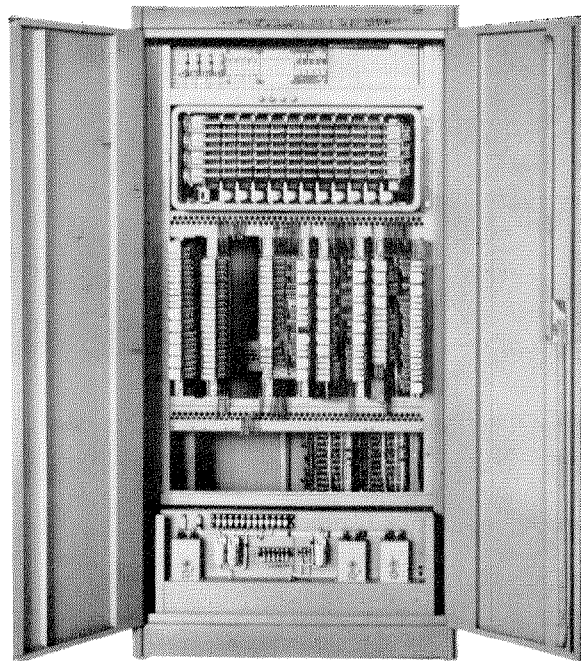


Figure 5—Trada-4 branch exchange. Capacity is 22 extensions, 3 links, and 4 trunks. From top down are connecting panel and fuses, multiswitch, relay and control circuits, and power supply.

The circuits and their operation are the same as those of Figure 4, with the exception that the dial pulses are first stored in a circuit called the receiver that then connects to the marker for completion of the connection. The receiver simplifies the current-supply circuits of the subscribers' sets and also contains relays for blocking trunk calls from restricted-service extensions.

3.4 TRADA 5

The Trada 5, shown in Figure 6, is similar to the Trada 4 except for the larger capacity of 50

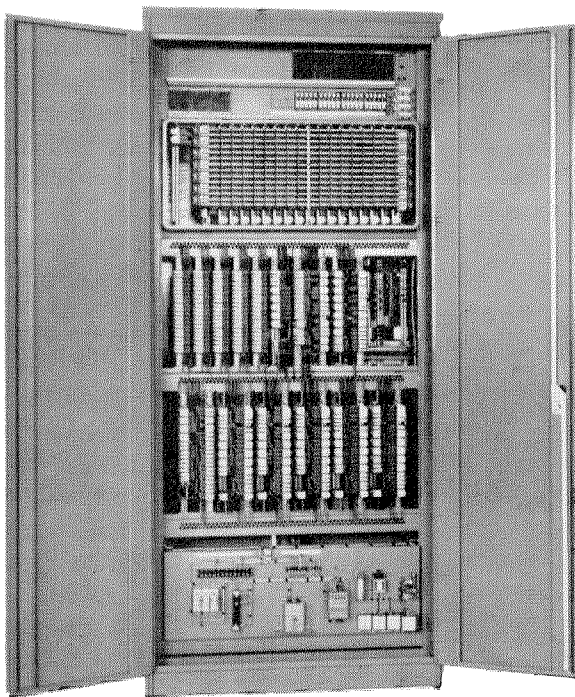


Figure 6—Trada-5 exchange. Capacity is 50 extensions, 6 local links, and 5 trunks.

extensions, 6 link circuits, and 5 trunks. Also, no special external-trunk-connection circuit is used for seizing trunks when all local links are in use since experience has shown this to be unnecessary when 6 links serve 50 extensions.

3.5 TRADA 16

Although the Trada 16 circuits are fundamentally the same as those described above, this

exchange is different in that the number of extensions and trunks can be expanded. The installation consists of two distinct parts.

A. The local switching system, which is a private automatic exchange complete within itself, requiring either a manual switchboard or further automatic equipment to enable connection to trunk lines.

B. The automatic trunk-line connecting equipment.

A complete installation will consist of 1 cabinet of local-link equipment per 100 lines (to which is added 1 cabinet of secondary selector equipment if the installation exceeds 300 outlets) plus 1 cabinet of trunk-line equipment per 100 lines per 16 trunks.

The power supply is in another cabinet.

3.5.1 Circuit Operation

The above-described division of functions is further illustrated by Figure 7.

The particular arrangement shown is for 98 extensions, split in two groups, and the operator's set. The local switching system contains a 50's selector to connect the cord circuit with any of the extensions. The circuit chain when setting up a call is as follows.

- A.** Calling extension
- B.** Line finder
- C.** Cord circuit
- D.** 50's selector
- E.** Connector
- F.** Called extension.

As explained above, the dial pulses are registered in the receiver, which transmits the information to the marker: both release when the connection is completed. For safety reasons, this exchange is provided with two markers; one would be sufficient for the traffic. The markers do not operate simultaneously.

Trunk connections are obtained by means of a chain parallel to the above in the trunk-line-connector unit. It operates when the extension dials a trunk-line code, the local-unit receiver

3.5.2 Numbering

The extensions have 3-digit codes. The operator, the trunk lines, and any tie lines have

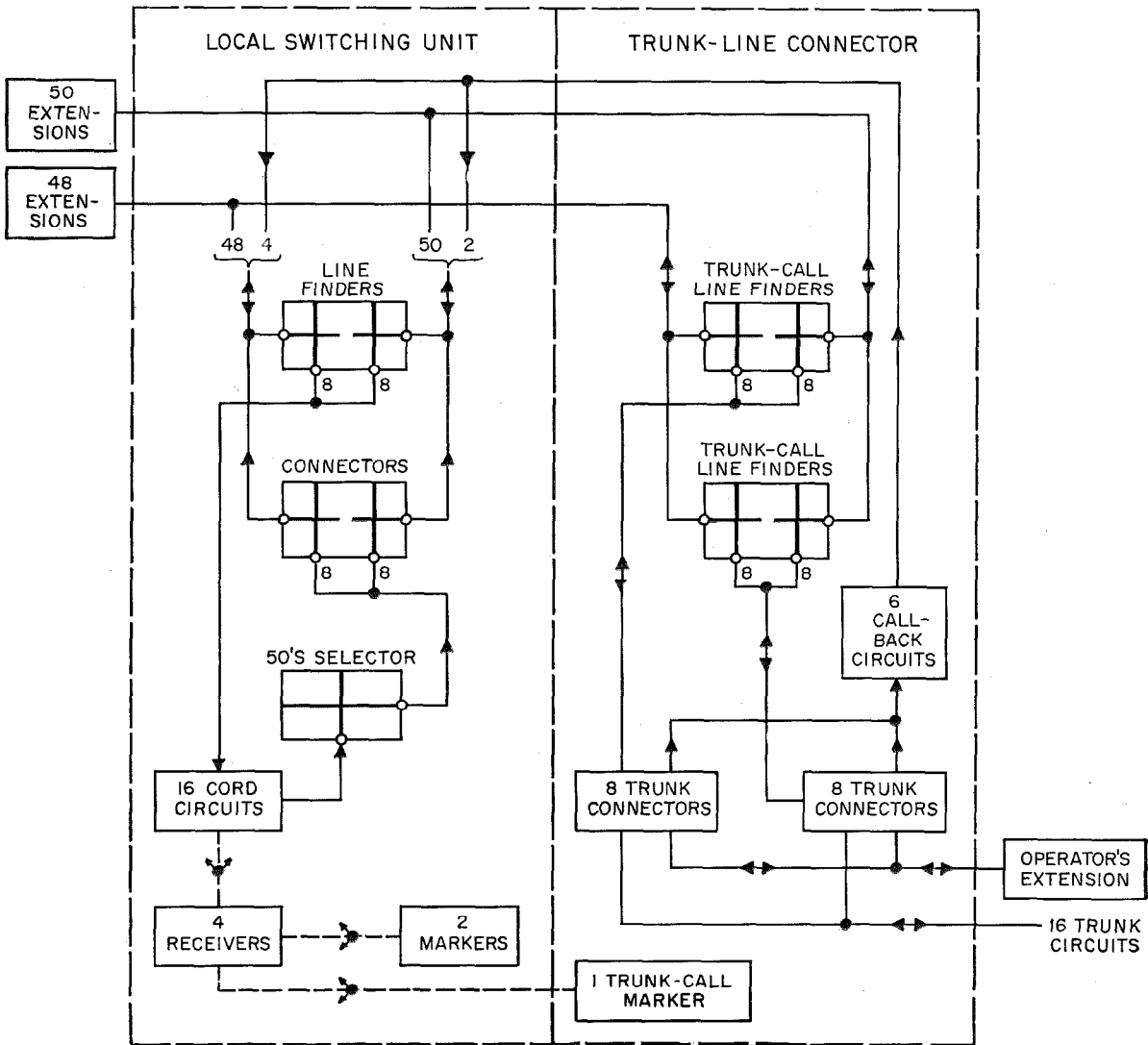


Figure 7—Trada-16 circuits for 100 subscribers, 16 trunks, and 16 links.

connecting with a so-called trunk-call marker that controls the trunk-call line finders and connects the extension to a free trunk through the trunk connectors. The local chain and markers then release.

The double-call circuit enables the extension to seize a local link circuit while holding a trunk circuit.

single-digit codes. When party lines are used, the two extensions on a given line differ in the hundreds digit, as, 237 and 637.

3.5.3 Equipment Packaging

Figure 8 shows a 100-line local-switching cabinet. At the top are the line relays and below,

three multiswitches. The receivers, cord circuits, and other equipment are mounted behind the multiswitch frame, which can be swung out. At the bottom is space for an emergency ringing

mounting the operator's handset and the signaling and control elements for the trunks and operator's lines. For the Trada 16, several such positions can be equipped.

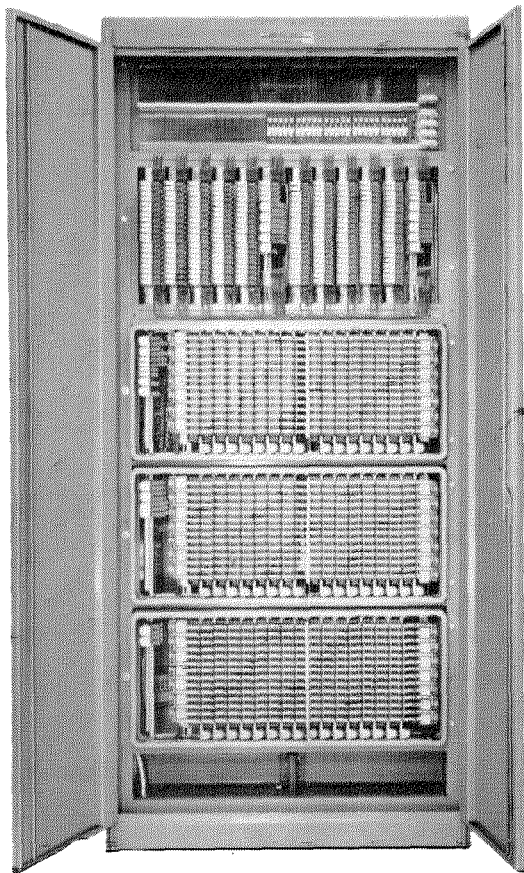


Figure 8—Trada-16 local switching cabinet equipped for 100 lines.

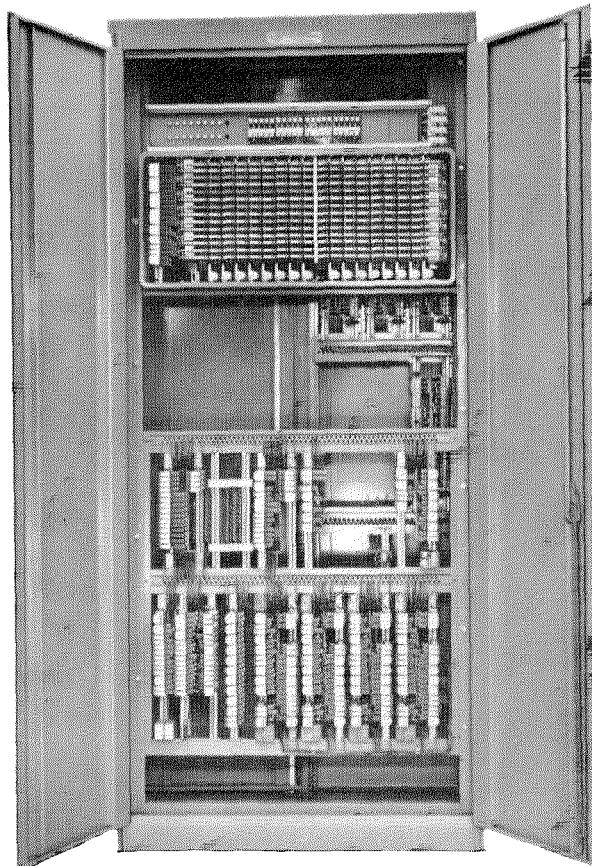


Figure 9—Trada-16 trunk-line-connector cabinet equipped for 8 trunks.

machine. Only the first 100's cabinet of an installation is equipped with markers, timers, and ringing machine.

Figure 9 shows a trunk-line-connector cabinet equipped for 8 trunks: only one multiswitch of trunk line finders is necessary. At the top is the multiswitch and below are the trunk-call marker, operator's circuit equipment, and 4 trunk connectors. Other equipment is mounted behind the swinging frame. Space is available in the cabinet to expand the trunk-connecting equipment to 16 trunks and two operator's circuits.

3.5.4 Operator's Position

Trada exchanges are supervised from an operator's position at which is an equipment

For smaller exchanges, up to 8 trunks, there is available a small operator's set as shown in Figure 10; it may be placed on a desk, leaving the operator free for other duties.

For the larger exchanges, where full-time operation is required, the operator's position shown in Figure 11 is used. It will accommodate 16 trunks and 2 operator's lines and can be equipped with a sending keyset, if desired.

4. Circuit Operation

4.1 GENERAL

Figure 12, a wiring diagram of the Trada 16, will serve to illustrate the operation of a typical

exchange. As mentioned in conjunction with Figure 7, the circuit sequence is, calling extension, line finder, cord circuit, 50's selector, connector and called extension. Some details of these circuits follow.

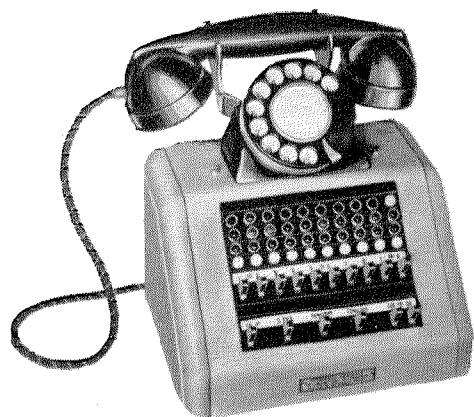


Figure 10—Operator's set for exchanges of up to 8 trunks.

Each extension is connected to a line circuit consisting of line relay *B* and cutoff relay *A*, which can assume one of the following combinations.

- B* open, *A* open—Extension handset on cradle.
- B* closed, *A* open—Extension handset off cradle, call being made.
- B* closed, *A* closed—Connection made, call in process.
- B* open, *A* closed—Called extension busy. Busy tone is sent through pilot relay *F*, which is common to a 50-line group.

When the calling party lifts the handset from the cradle, relay *B* closes the circuit of pilot

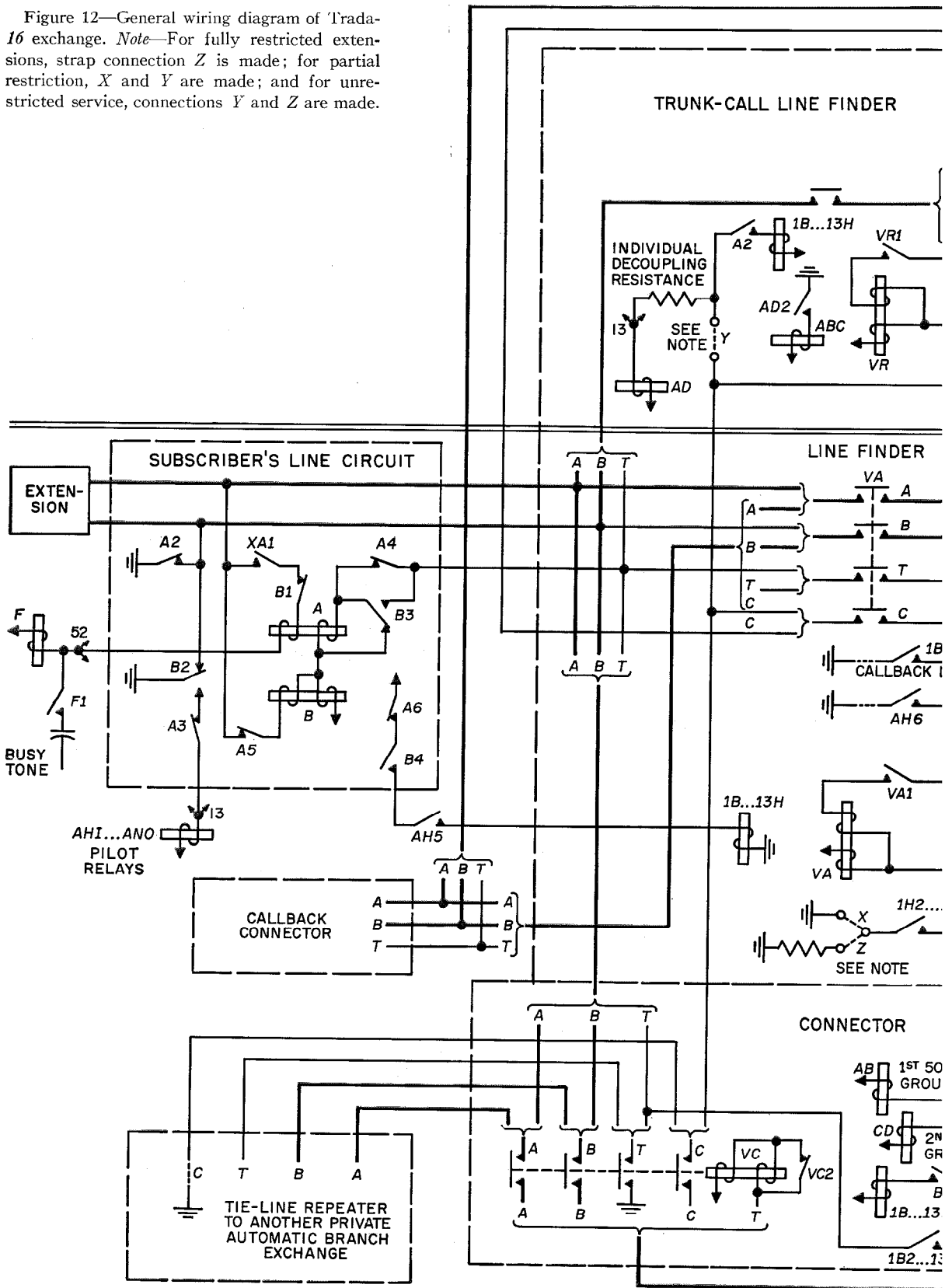
relays *AHI*, which are so arranged that only one is energized per call, thus avoiding double connections when subscribers lift their handsets simultaneously. These pilot relays control the line finder, operating horizontal selector bar *1B . . . 13H* and the switching bar *14B* or *14H* corresponding to the level of the calling extension.

The pilot relays also select the cord circuit and receiver for the call. Figure 13 shows that all receivers having at least one cord circuit free for use are characterized by a closed *BVI* contact, so that starting relay *ADE* is closed in the first available receiver in the chain. The high-resistance winding of *BVW* is now short-circuited and a relay *BDEF* will connect the cord circuit. Relays *BDEF*



Figure 11—Operator's position handling up to 16 trunks and 2 operator's lines.

Figure 12—General wiring diagram of Trada-16 exchange. *Note*—For fully restricted extensions, strap connection Z is made; for partial restriction, X and Y are made; and for unrestricted service, connections Y and Z are made.



are wired in sequence so that only a single cord circuit is connected.

Vertical electromagnet *VA* of the line finder (Figure 12) now operates, connecting the extension to the cord circuit. The cutoff relay closes, releasing the pilot relays and selecting bars of the line finder, which become available for the next call. Only electromagnet *VA* remains energized until the connection is released. The receiver cannot be seized again until all other receivers in the cabinet are engaged in turn; it's relay *AG* remains energized until the end-of-chain relays *IJ* and *KL* operate (Figure 13). This method distributes the calls over the circuits.

The *ADE* relay of the cord circuit supplies

current to the subscriber's set and retransmits the dial pulses to relay *BG* of the receiver circuit. These pulses are counted by a set of 6 relays *AJ . . . AO*. At the end of the first digit, these counting relays operate a set of relays recording the 100's digit, the contacts of the latter set being connected in a pyramid circuit making it possible to choose a marking wire for the digit.

The following digit is counted in the same manner and a marking wire is selected by the 10's pyramid. The last digit is recorded in the counting relays themselves, which then lock. The *AQ1* contact closes and the receiver is connected to a marker through the *ARST* relay.

The *ARST* relays are in chain circuits that assure that several receivers cannot seize one

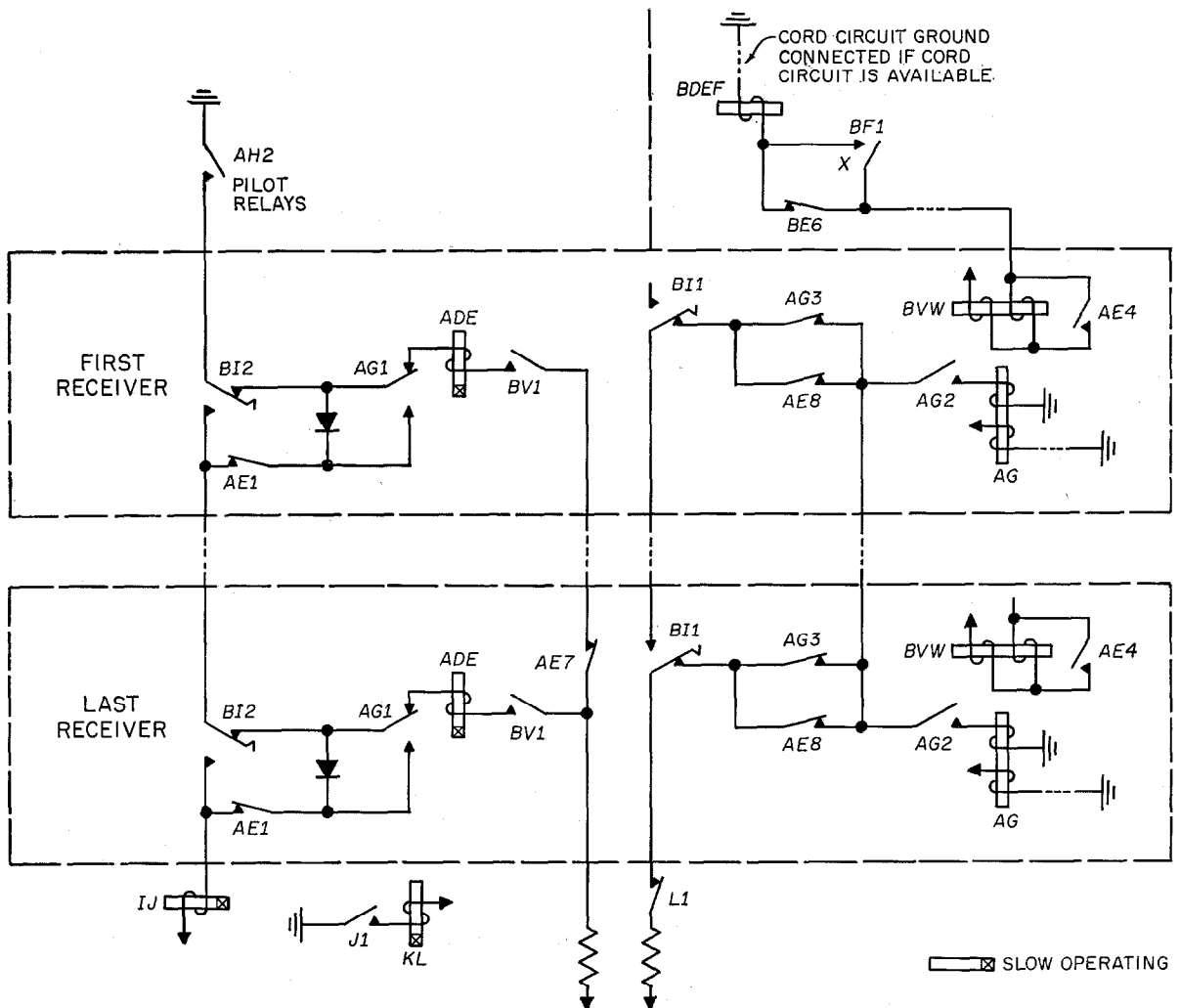


Figure 13—Circuits for starting and distributing calls among the receivers.

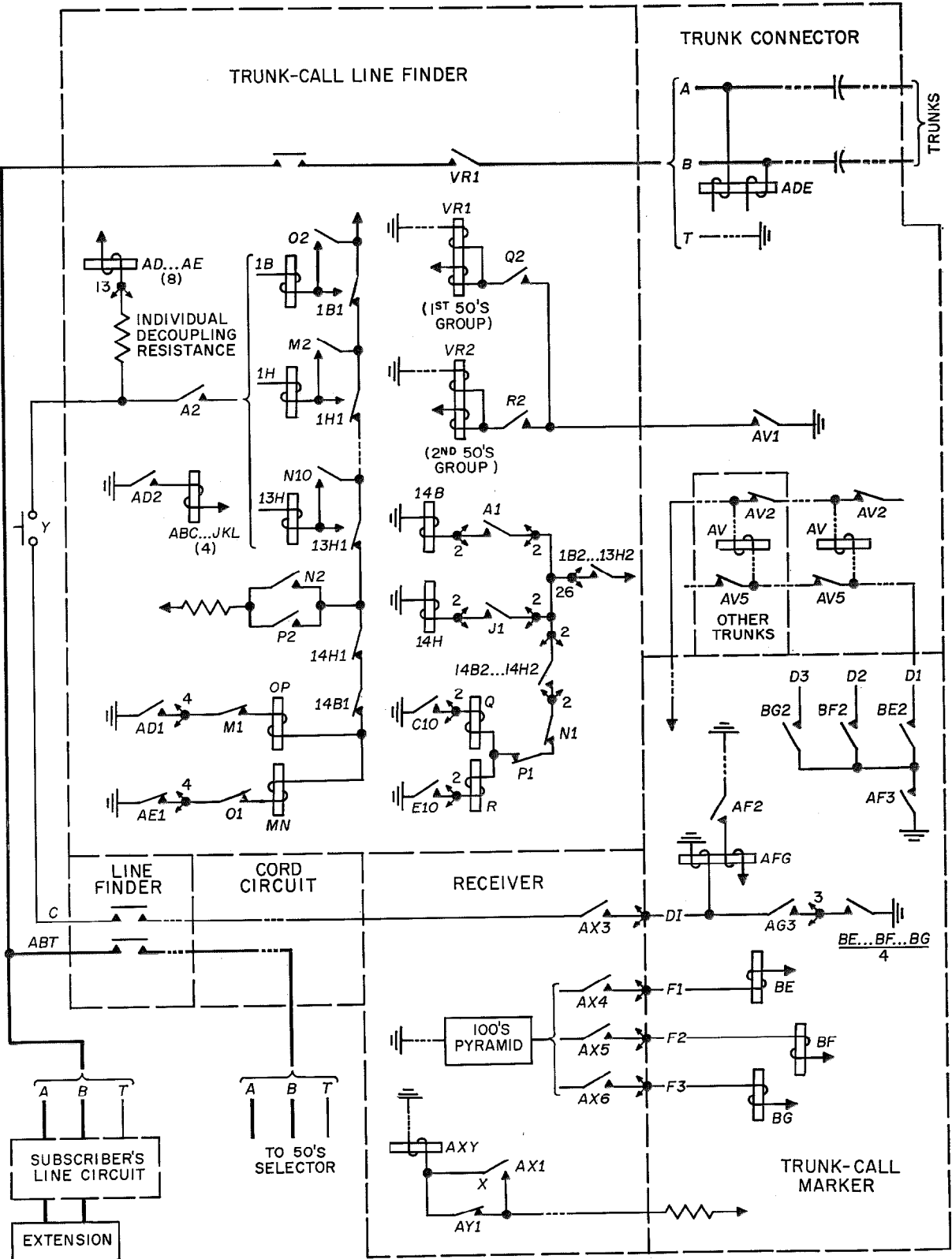


Figure 14—Circuits for direct trunk-line seizure.

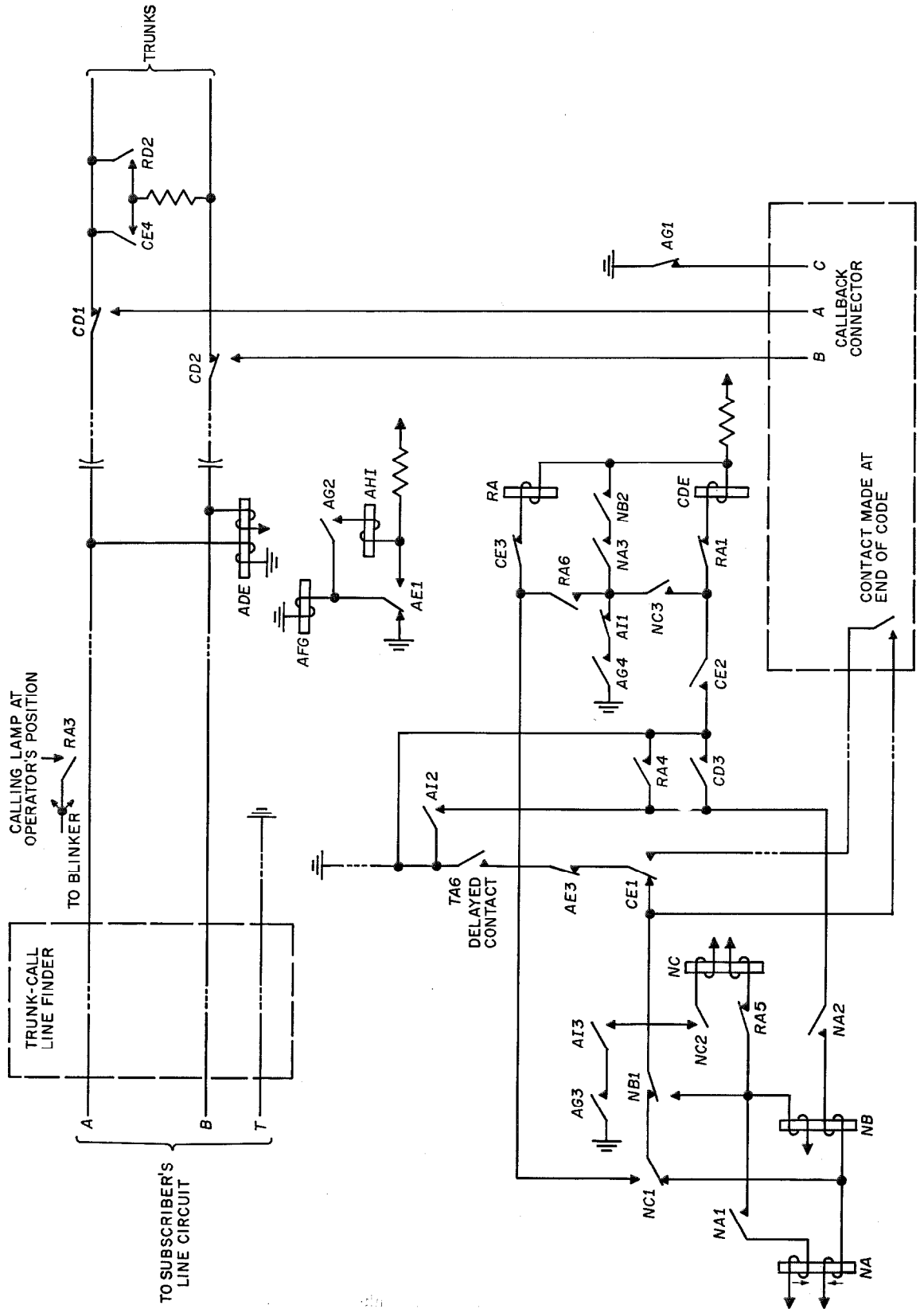


Figure 15—Circuits for callback and resumption of trunk-line connection.

marker and also that a receiver cannot seize several markers.

The stored digits are retransmitted to the connector marking pyramid, which then contains the following information.

- A. The connector selector magnet for the called extension.
- B. The selector-bar level of the called extension.
- C. The 50's group of the called extension.

The selector bars of the connector are operated through the 50's relays *AB* or *CD* and the marker, now connected to the called line, tests the line by relay *AI*. At the same time, the called line is connected with the cord circuit by means of the 50's selector.

The two multiswitches now being set up for the connection and the test being positive, the vertical electromagnet of the 50's selector is operated and allows operation of the vertical electromagnet of the connector.

The connection being complete, the receiver and marker are released by a circuit not shown in Figure 12. The selector bars of both 50's selector and connector are released and become available for the next call.

If the called extension is busy, test relay *AI* does not operate and a slow-acting relay breaks the connection, the calling extension receiving busy tone through the subscriber's line circuit.

4.2 SEIZURE OF TRUNKS

The extension having dialed a trunk-line code, the receiver connects itself with the trunk-call marker by means of relays *BDE* and *AXY*.

Figure 14 shows the connection of an extension with a trunk line. The service restrictions of the extension determine the action of relay *AFG*; if the extension is unrestricted, *AFG* receives battery through wire *DI*, wire *C*, strap connection *Y*, the decoupling resistance, and pilot relay *AD*. Relay *AFG* places ground on wire *DI*, causing the pilot relay to operate. The latter positions the trunk-call line finder selector bars *IB . . . 13H* through common relays *ABC . . . JKL* after testing for their availability by means of relays *MN* and *OP* and then ensures the operation of electromagnets *14B* or *14H*.

The end-of-selection relay *Q* or *R* controls the operation of trunk-call line-finder vertical electromagnets *VR1* or *VR2*; the trunk was chosen by relay *BE*, which energized one of the starting relays *AV*. These relays are connected in chain circuits to avoid double connections.

The calling extension has now been connected to the trunk, which grounds wire *T* to release the local circuit: relay *BF* of the receiver is short-circuited by this ground and, through a circuit not shown, disconnects the cord circuit and, in sequence, the receiver and trunk-call marker. The selector bars of the trunk-call line finder are released and all of these circuits are available for the next call.

If the extension is fully restricted, strap connection *Y* is open and relay *AFG* of the trunk-call marker will not close; a slow relay breaks the connection, sending busy tone to the caller.

If the extension is partially restricted and entitled to trunk calls through the operator only, relay *AF* of the receiver always operates when the receiver is connected to the calling line. If a trunk-line code is dialed, the call will automatically go to the operator through contact *AF2* of the receiver (Figure 12).

4.3 CALLBACK CIRCUIT

Some time after the dialing on the trunk line of the last digit of the number of the desired subscriber, a delay device closes contact *TA6* of the callback circuit shown in Figure 15. From thence on, dial pulses are received on counting relays *NA* and *NB* and are interpreted as callbacks.

If, in the midst of a trunk call, the extension dials digit 2, relays *NA* and *NB* are closed at the first pulse, and *NC* at the second. When relay *AHI* opens, relay *CDE* closes and transfers the extension line wires to one of the callback link circuits that are connected to the line finder. The trunk call is held by contact *CE4*.

The internal circuit now operates in the normal manner; a free cord circuit and receiver are seized, then a marker when dialing is complete, and finally the internal connection is made. This closes an end-of-dialing contact and the operation path of relays *NA* and *NB* is restored.

4.4 CALLING IN THE OPERATOR

If a subscriber connected to a trunk line dials a digit larger than 2 (say, 0), at the third pulse,

relay *RA* is closed and holds until the end of the digit. This breaks the circuit of relay *CDE* and signals the operator by lighting the trunk-line call lamp. In case there is no answer, the subscriber can resume the trunk-line connection by dialing the digit 1, which will close relays *NA* and *NB* and short-circuit *RA*.

4.5 RECONNECTION WITH TRUNK; CALL TRANSFER

If, during a callback, the subscriber wishes to resume his trunk-line connection, he dials digit 1; relays *NA* and *NB* operate, short-circuiting *CDE*, and thus releasing the rest of the chain.

During a callback, if the subscriber wishes to connect his called party with the trunk call, he simply replaces his handset on its cradle. The *AHI* relay of the callback line is then placed in the *C*-wire circuit (Figure 12) and receives battery through contact *AF4* of the cord circuit, through the 50's selector, and *Y* strap connection, the decoupling resistance, and pilot relay of the called party.

Relay *AHI* operates, grounding the *C* wire, thus marking the called party on the line-finder

selector bar. The connection is established as described in section 4.1 and the called party is connected with the trunk call.

When the subscriber replaced his handset to effect the call transfer, relay *ADE* of the trunk-line connector (Figure 15) released, closing relay *NA*. After the transfer is made, *ADE* closes again, *NB* closes, and relay *CDE* is short-circuited, releasing the rest of the chain of relays.

4.6 INCOMING TRUNK CALLS

Incoming calls are received by the operator and directed to the desired extension by dialing. The operator's dial pulses are received in a recorder that actuates the relays of a marking pyramid. The pyramid contacts control the pilot relays of the local line finder through the usual decoupling resistances and allow connection of the trunk with the extension as explained in section 4.1.

5. Additional Circuit Possibilities

5.1 GROUPED LINES

Grouped lines provide a facility whereby an incoming call to a certain code will test in sequence through a designated group of exten-

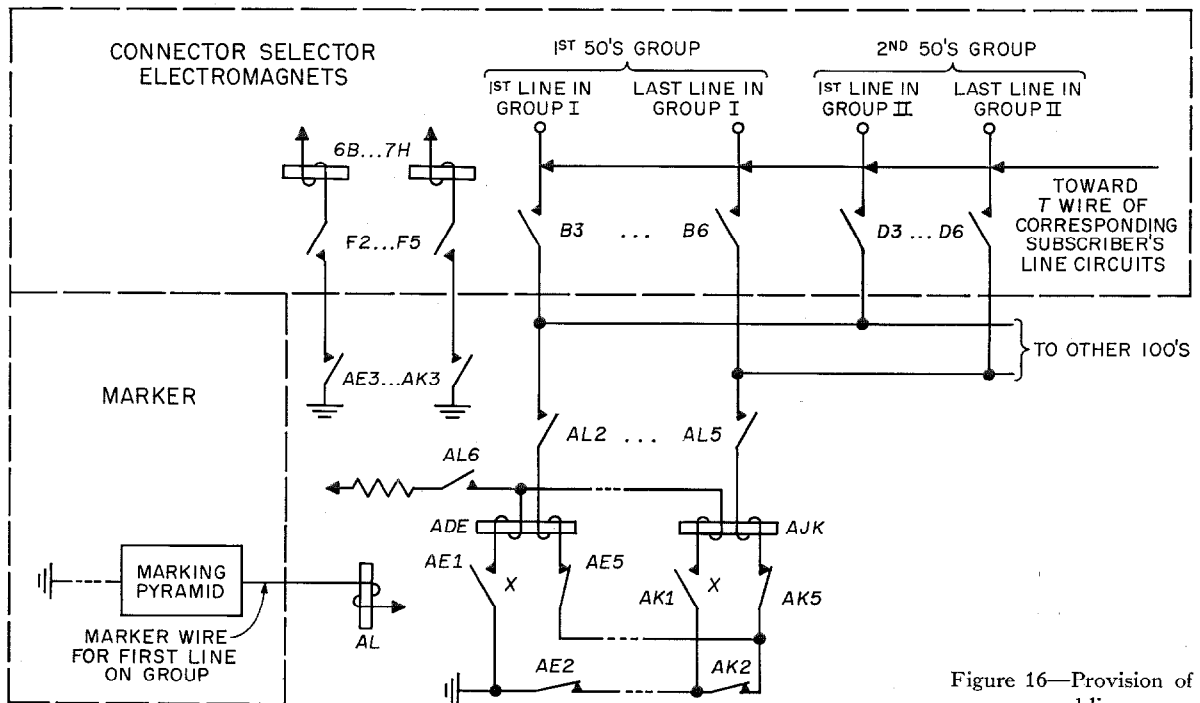


Figure 16—Provision of grouped lines.

sions until a free extension is found, which it will then ring.

In the Trada 16, the wires of the marking pyramid being multiplied on all selector bars of the connectors, the provision of grouped lines in each 50 can be made simply and inexpensively. It is only necessary to connect the marking wire of the first line of the group to the special test equipment represented in Figure 16.

The equipment comprises a test relay for each line that operates if the corresponding line is free and permits the selector bar of the connector to be marked. If all lines of the group are busy, a slow-acting relay releases the connection and the calling line receives busy tone. Normal provision is for 4 grouped lines per 50, but a greater number can be had by special arrangements.

5.2 TIE LINES

In the Trada 16, it is possible to bypass the transmission bridge in the cord circuits by means of a relay *BGH* (Figure 12), making it possible to avoid retransmission of dial pulses. The installation can then be used as a transit center.

Bypassing of the transmission bridge is done by the marker when the receiver recognizes a tie-line code. The extension receives current from the tie-line repeater and the latter holds the cord circuit by grounding the *C* wire.

5.3 TRUNK-ACCESS TIE LINES

Special tie lines are employed to connect the Trada exchange to another private exchange also having access to external trunks. They are for use in transferring external trunks between the two exchanges.

5.4 PAGING SERVICE

Paging is provided by an arrangement whereby a special code dialed from any extension connects that extension with the paging circuit. Dialing the code of the extension normally used by the desired person results in a special signal being broadcast by chimes, horns, Morse code, flashing lights, et cetera. On recognition of the summons, the paged person may dial the paging service code from any extension and will be connected with the caller. The number of extensions that can be paged is unlimited.

5.5 PRIORITY SUBSCRIBERS

Priority extensions are provided with a special means of contacting the operator, either through a separate line to the operator's position, or through a third wire and a button on the extension. In the last case, the operator, upon recognition of the lamp signal, will dial the extension's code via a service line.

5.6 SPECIAL NIGHT TRANSFER

Usually, the night transfer is made to one selected extension only. With extra equipment, it is possible to provide a choice of several extensions by means of keys. It is also possible to transfer individual trunk calls to selected subscribers' sets.

5.7 SUBSCRIBER'S BUSY LAMPS

For the Trada 16, it is possible to equip the operator's position with busy lamps for the extensions by supplying an additional subscriber's line relay with an extra contact.

5.8 TRUNK-LINE CHAIN CONVERSATIONS

With this feature, the operator's position is fitted with a special holding key for each trunk, which will prevent release of the trunk when a connected extension hangs up. Instead of release, the operator is signaled and can direct the trunk call to another extension until all calls are made; the trunk is then released by means of the key.

5.9 REVERTIVE RINGING

For more flexible use of party lines on the Trada 16, it is possible to set up a circuit whereby one member of a party line can ring the other. This is done by dialing a code and replacing the handset. Both extensions of the party line will then ring and will be connected when the handsets are lifted.

5.10 MANUAL TRUNK CONNECTION

The Trada 16 can, of course, be used strictly as an internal automatic exchange without connection to trunk lines. Provision can then be made for access to the trunk network by a special manual keyboard.

Dialing of a trunk code will then cause the

50's selector to light a calling lamp on the keyboard through the *C* wire of the line finder. If the lamp is defective, the call will come through on the service links. Operation of a key on the keyboard will connect the calling extension with a trunk.

5.11 OTHER POSSIBILITIES

The following facilities can also be provided on the branch exchanges by special arrangements.

- A. Conference circuits.
- B. Supervisory subscribers' sets allowing secret monitoring and cutting off of trunk calls.
- C. Operator dialing by sending keyset.
- D. Operator dialing of predetermined codes by automatic sender.
- E. Metering of external calls.

Recent Telecommunication Development

Etching of Lord Rayleigh

JOHN WILLIAM STRUTT, LORD RAYLEIGH (1842–1919), is depicted in the latest etching of the series published by the International Telecommunications Union.

Born and educated in England, physicist Rayleigh is perhaps best known for his work in sound. His book, "A Treatise on Sound," is even today a standard work. He also carried out experiments in optics and studied the properties of gases.

Lord Rayleigh was the recipient of many honors, including the Nobel prize and the presidency of the Royal Society. He was among the original members of the Order of Merit, established at the time of the coronation of King Edward VII.



The etching of Rayleigh is the 22nd in the series that was started in 1935. On a good grade of paper measuring 9 by 6 $\frac{3}{8}$ inches (23 by 17 centimeters) including margins, these etchings are available at 3 Swiss francs each from Secrétariat général de l'Union internationale des Télécommunications, Palais Wilson, 52, rue des Pâquis, Genève, Suisse. The entire series is comprised of etchings of Ampère, Armstrong, Baudot, Bell, Erlang, Faraday, Ferrié, Fresnel, Gauss and Weber, Heaviside, Hertz, Hughes, Kelvin, Lorentz, Marconi, Maxwell, Morse, Popov, Pupin, Rayleigh, Siemens, and Tesla.

Crossbar Citomat, a Development in Medium-Sized Private Automatic Branch Exchanges*

By ARTHUR MEHLIS and KURT KLINKHAMMER

Mix & Genest; Stuttgart, Germany

THE QUESTION as to whether wiping-contact or pressure-contact switches should be used as connecting elements in automatic telephony is not a new one. Economic factors must guide the engineer in considering the replacement of wiping-contact switches by pressure-contact switches, of which relays are the simplest type. The pressure-contact switch with precious-metal contacts, while more expensive, has certain advantages over the wiping-contact type with base-metal contacts.

Relays have always been used in the smaller

private branch exchanges when cost was not a major consideration; operation and maintenance experts prefer relay-type switches to those of the wiping-contact type provided the difference in cost is negligible.

Relays have the following advantages: simplicity, reliability, low maintenance, low noise level due to precious-metal contacts, a well-regulated power supply due to absence of large peak-current drains, long life, no time loss between series of dial pulses, and good adaptability to the problems of subscriber toll dialing.

These advantages recommend the utilization of relay-type switches to private branch exchanges that are not constantly attended; however, the relay is not the best solution with respect to cost. For this reason, Mix & Genest

* Reprinted from *Fernmeldetechnische Zeitschrift*, volume 7, pages 178-179, 184-186; April, 1954; also, *SEG-Nachrichten*, volume 2, pages 5-14; number 1, 1954. Figures 1 and 2 were not included in the original publication of the paper.

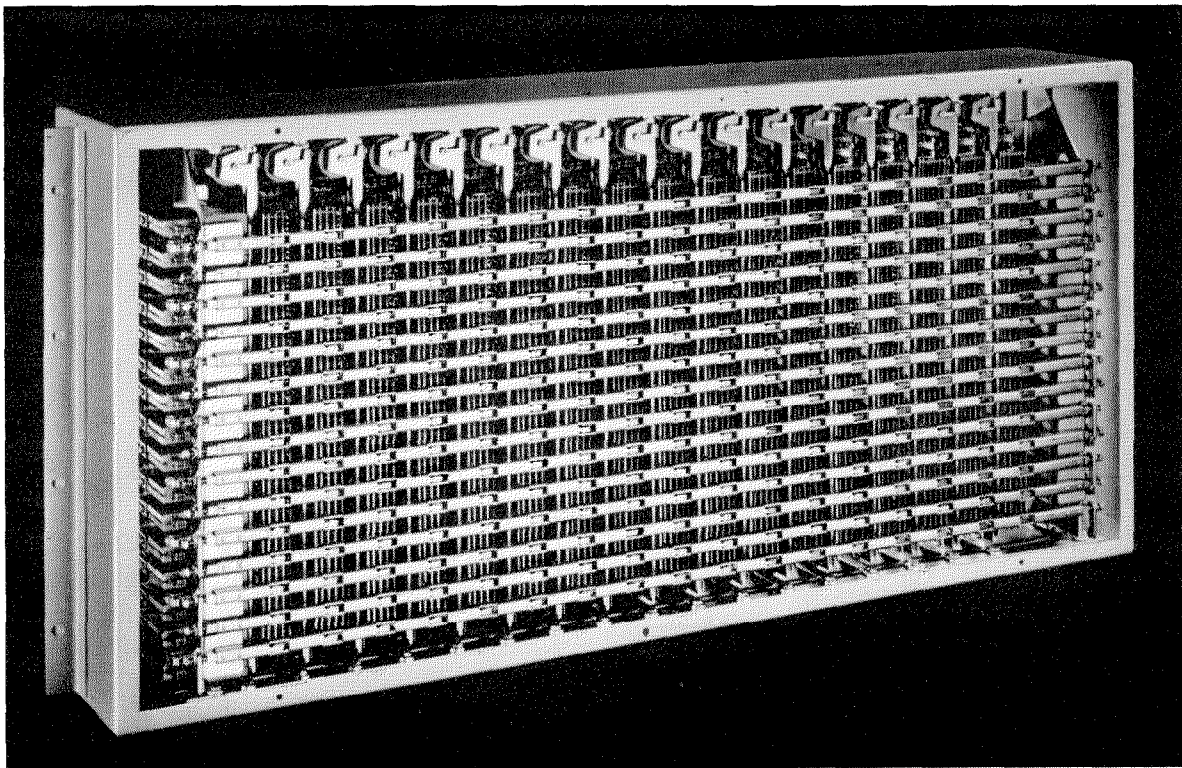


Figure 1—Type KS53 crossbar switch.

have introduced crossbar switches with precious-metal contacts to these branch exchanges.

1. General

The specific requirements in the development of the new medium-sized private automatic branch exchanges were: better transmission through the use of precious-metal contacts, higher switching speed, lower noise level, reduced wear, and insensitivity to power-supply voltage variations. There were, in addition, the service requirements for adapting the new exchanges to subscriber toll dialing, for simplified and more-rapid maintenance, and for accommodating the complete switching equipment including the main distribution frame and the power supply in a cabinet-like enclosure.

The system requirements excluded solution of the problem with conventional step-by-step switches and thus led to the development of the type *KS53* crossbar switch (Figure 1) and type *ZM53* magnetic counter (Figure 2), and to

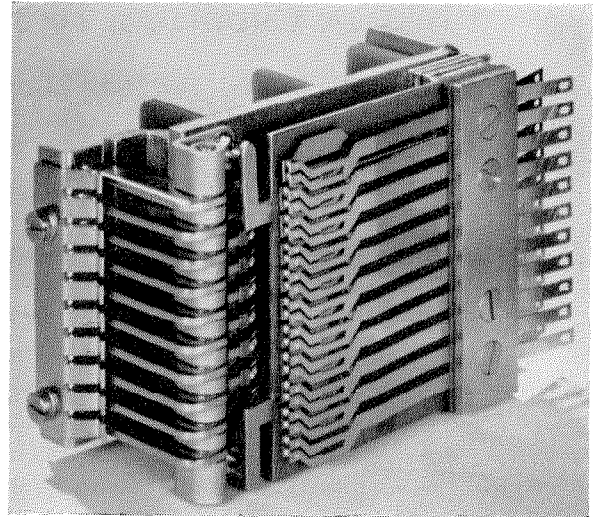


Figure 2—Type *ZM53* magnetic counter.

their application to private automatic branch exchanges. Due to its simple relay-like structure and its precious-metal contacts, the crossbar switch is particularly well adapted for meeting the above-mentioned requirements. The combination of the magnetic counter and the crossbar switch permits the well-known and proven principles of direct dialing to be applied to the crossbar switch, a switching medium that otherwise would only be suitable for indirect switching systems.

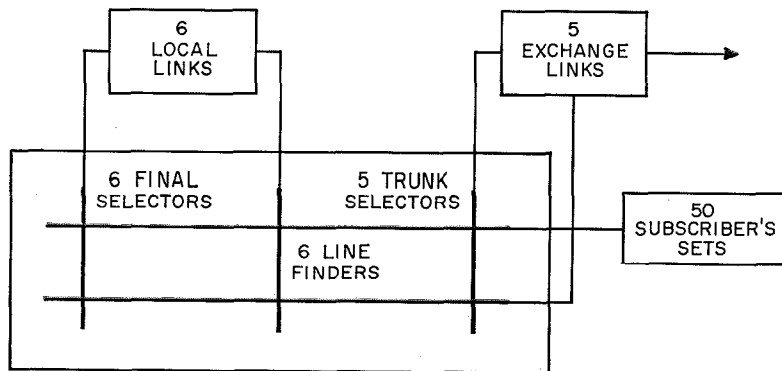
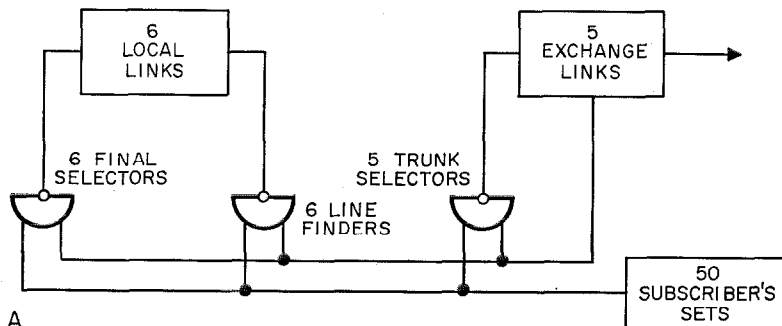


Figure 3—Trunking scheme of private automatic branch exchange with 5 trunks, 50 lines, and 6 local links. *A* = Step-by-step selector system. *B* = crossbar switch system.

2. Grouping

2.1 TRUNKING METHOD

Figure 3 shows the trunking scheme of a private automatic branch exchange with 5 trunks, 50 lines, and 6 local links using a crossbar switch as compared with that of a conventional system using step-by-step switches. In either system, all 50 subscribers obtain access to all line finders, final selectors, and trunk selectors. The single- or two-motion selector

of the older system corresponds to a vertical unit (a bridge) of the *KS53* crossbar switch.

While in the conventional systems, the pulses from the subscriber's dial act directly on the magnet of the final selector, moving its wipers to the desired position, the dial pulses in the crossbar system are first registered by magnetic counters that in turn control the final selector bridge when dialing is completed. Calls to the public exchange are in either case initiated by the subscriber pressing his ground button, which causes the associated subscriber line circuits to transmit a starting signal to the trunk selector or the trunk-selector bridge. The callback circuits are switched in the same manner as the subscriber's lines and provide similar service facilities. The comparison shows that with respect to trunking method and service facilities, the crossbar private automatic branch exchange differs in no way from the well-known step-by-step systems.

2.2 WIRING OF CROSSBAR SWITCH

The wiring of the crossbar bridges and the associated horizontal selecting rods is shown

schematically in Figure 4. The *KS53* crossbar switch is equipped with 17 vertical units that, in the example given, are used to perform the functions of 6 line finders, 6 final selectors, and 5 trunk selectors. Each of these selector units has access to 56 outlets. The inlet to a bridge (in the diagram only one wire, yet actually three or four wires) is extended via two transfer points to two vertical multiples (contact wires), of which the left one is assigned to subscribers with odd numbers and the right one to subscribers with even numbers. Selection of these multiples is performed by the uppermost selecting rod under control of either select magnet *SU* (odd subscriber numbers) or select magnet *SG* (even subscriber numbers).

To extend the incoming circuit to a subscriber's line, another selecting rod has to be actuated by energizing, for instance, select magnet *S13/14*, which results in the marking fingers of this rod being placed beside the contact sets of subscribers 13 and 14.

When the bridge magnet is energized, each of the two previously controlled marking fingers operates a contact set and the bridge inlet is

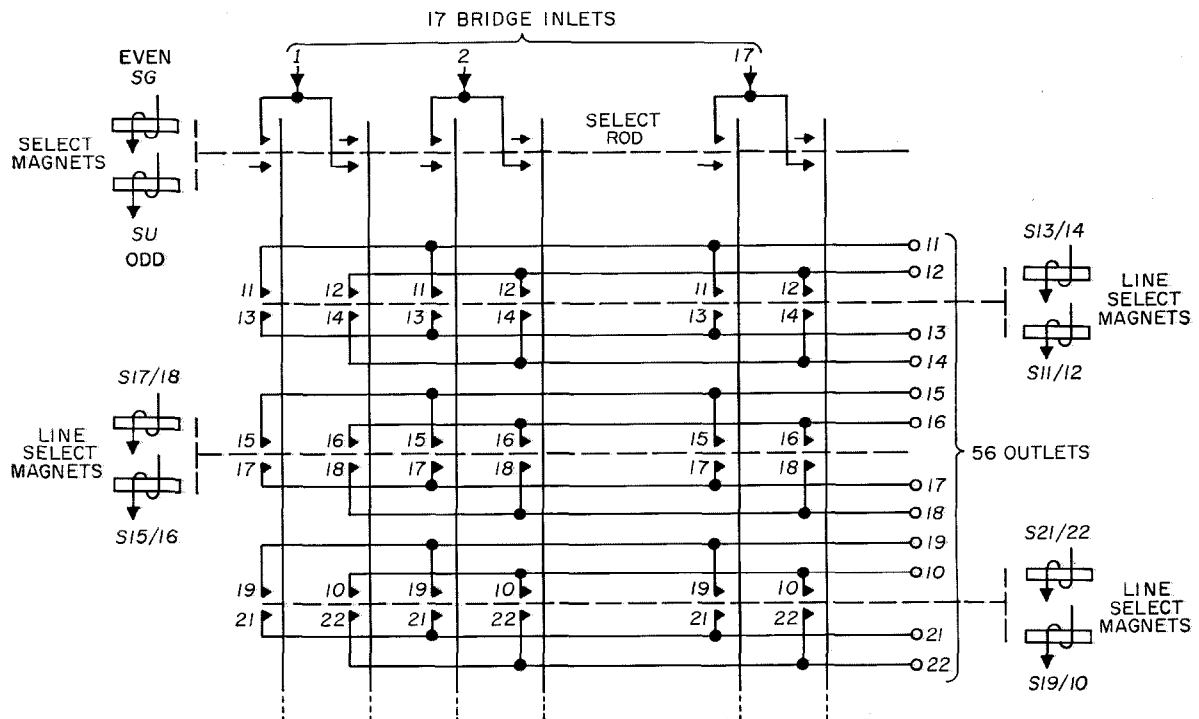


Figure 4—Wiring of crossbar switch.

connected through to the desired subscriber. It follows that the connection of an incoming circuit to any outgoing line requires the operation of one magnet of the uppermost selecting rod (changeover rod) followed by the operation of another select magnet and then the bridge magnet. Thereafter the select magnet may again be de-energized or used for any other connection. The contact sets, once closed by a bridge magnet, remain operated until this magnet is de-energized.

The selecting rods with their marking fingers constitute a common selecting device for the crossbar switch and all its bridges. Hence, only one bridge can be operated at a time and all switching operations have to be carried out in successive order.

3. Handling of Calls

3.1 STARTING OPERATIONS AND INTERNAL CALLS

Figure 5 shows the basic circuit layout of a crossbar private automatic branch exchange. The subscriber line circuit (bottom right) is designed to send a starting signal to the local connecting link (*R*-relay operated) when the handset is lifted, and a starting signal to the exchange connecting link (*T*-relay operated) when the pushbutton (grounding button) on the subscriber's set is pressed.

This information is evaluated by the starting circuits, which are shown schematically in Figure 5 (bottom left).

The starting circuits comprise four vertical contact chains. Of these chain circuits, two start trunk calls and two start internal calls. The exchange and local starting chains are further subdivided and assigned to odd and even subscriber groups, respectively. When now, say, subscriber 15 originates an internal call, group relay *1HU* (subscriber group 1, internal call, odd calling number) enters into action. By forming further subscriber groups with corresponding group relays *2HU*, *2AU* . . . and *3HU*, *3AU* . . . (not represented in Figure 5), it is possible to keep the chains of line-relay contacts short.

Operating group relay *1HU* first keeps select magnet *S15/16* in the same circuit in unoperated condition and applies ground potential to locking relay *HU* to determine whether the starting operations can proceed.

Locking relay *HU* is connected in a common lockout circuit with corresponding locking relays *AU*, *HG*, and *AG* as well as with local-link locking relays *S*, locking relays *UM* of the exchange connecting links and locking relay *ZU* of the operator's circuit, the arrangement being such that only one of them can operate at a time while all the others are locked out. Since each connecting unit can operate the select magnets only if the associated locking relay is operated, double connections are positively avoided.

When operating, locking relay *HU* shunts a high-resistance winding of group relay *1HU*, which enables the hitherto nonoperative select magnet *S15/16* to operate. At the same time, another *HU* contact closes the circuit for the changeover-rod *SU* magnet, thus completing the subscriber marking operation. Immediately after this, one *SU*-magnet contact brings impulse-limiting relay *JB* into action, whose contact puts ground on the line-finder circuit; in the described case, this causes the bridge magnet of line finder *AS1* to operate and connect the calling line to the inlet of the local link. Line relay *R* and cutoff relay *T* in the subscriber line circuit now both operate through the *C*-wire circuit.

Impulse-limiting relay *JB* also provides for the slow release of relay *HU* by short-circuiting and thus terminates the starting operations. The releasing *HU* relay enables the hitherto shorted *A* relay in the local link to pull in and, in consequence, the line-finder circuit to be extended to the finder of the following link over a contact of busy relay *C* (not represented). Thereafter, the connected subscriber may begin dialing the calling number of the wanted subscriber and with the two impulse trains control the associated magnetic impulse counters *Z* and *E* (tens and units selection). The contacts of these relay-like magnetic counters are wired in a way similar to a single-motion selector and therefore are schematically represented by two contact arcs and wipers *Z* and *E*.

Following the selection of the desired number, ground is applied to locking relay *S* of the local link, which will operate unless the common lockout circuit is already engaged. As relay *S* operates, the contact banks of the two magnetic counters are grounded and the information

corresponding to the dialed digits is transmitted to the multiplied tens and units lines.

According to the unit digit dialed, one of 5 number relays ($N1$ to $N5$) is energized over the unit line and, depending on the digit being even or odd, in addition relay U or G operates (Figure 5, top left). The select magnet corresponding to the dialed calling number can now operate via the decade point ($D1$ to $D10$) determined by the position of the tens magnetic counter, the U or G relay controlling at the same time the change-over rod (Figure 5, bottom left). Now, following operation of relay S , the final-selector bridge will operate and connect the dialed line to the outgoing end of the engaged local link. All other operations, as testing, first ring, et cetera, are accomplished in the conventional manner.

3.2 OUTGOING TRUNK CALLS

It is assumed that subscriber 15 has set up an internal connection after removal of his handset and now presses his button to initiate a trunk call. This causes the engaged local link to release due to operation of a differential relay X (not represented) and the subscriber line circuit to send the information, " T relay operated, R relay nonoperated." The same effect is obtained if all local links are busy: operation of the ground button becomes directly effective in the subscriber line circuit.

In the starting circuits, group relay IAU (first subscriber group, trunk call, odd calling number) is energized. This relay determines from the associated locking relay AU whether the starting signal can be extended or not. The whole process is quite analogous to the seizure of a local link except that now the starting signal is conveyed to the circuits of the exchange link and that it is the next free trunk selector bridge that connects the calling subscriber. Following this connecting process, busy relay VI of the engaged exchange link is energized.

3.3 TRUNKING FACILITIES FOR SUBSCRIBERS

The placing of automatic outgoing trunk calls involves transmission of a starting impulse over the starting circuit assigned to the calling subscriber. This starting impulse is made impossible for partly restricted subscriber 16 and fully

restricted subscriber 17 represented in Figure 5 (by wiring changes on the associated subscriber line relays).

There is, in addition, the necessity for ascertaining the type of subscriber (fully, partly, or nonrestricted) in the case of incoming trunk calls. With subscriber toll dialing, it must further be ensured that only those subscribers can originate automatic outgoing toll calls who are entitled to do so. This is accomplished in the following way: Whenever a selecting rod is controlled, a special group of select-magnet contacts operates and puts ground on certain strapping points assigned to each subscriber. Thence, this potential can be extended to either relay BA (permission to receive incoming trunk calls) or relay BF (permission to place automatic toll calls).

In the example (Figure 5), the subscribers are switched in the following way:

Subscriber 15 is entitled to place automatic outgoing trunk calls and to receive incoming trunk calls (nonrestricted).

Subscriber 16 is entitled to place outgoing trunk calls through the operator and to receive incoming trunk calls (partly restricted).

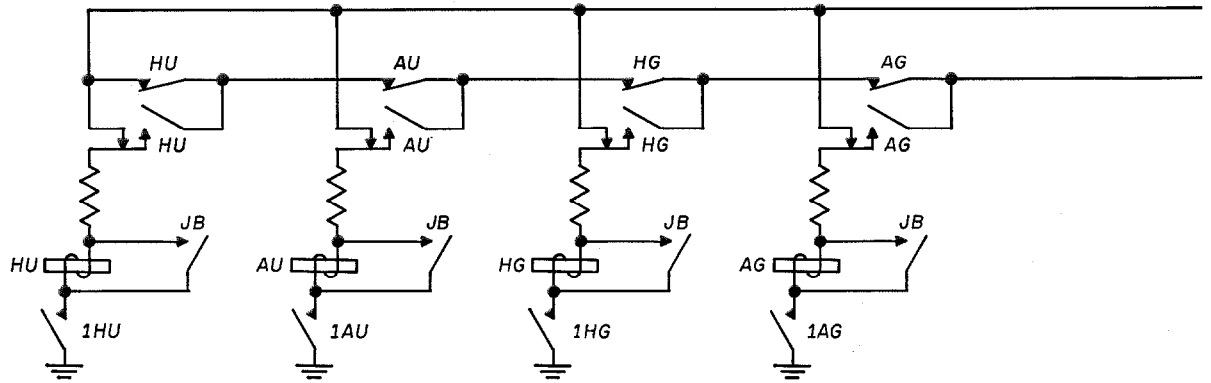
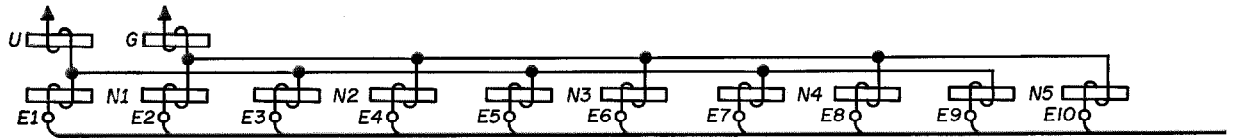
Subscriber 17 has no access at all to the public exchange (fully restricted).

Subscriber 18 is entitled to place automatic toll calls (nonrestricted, with full toll dialing facilities).

Permission to place automatic toll calls includes all other facilities and is made known to the exchange link during its seizure in a specific way not described here.

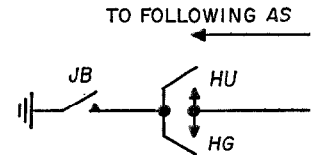
3.4 INCOMING TRUNK CALLS

Any incoming trunk call is announced visually on the attendant's cabinet and is answered by the operator pressing the associated answering button AB (magnetic-type pushbutton), which connects her answering set to the engaged trunk line through the exchange-link answering relay. To extend the trunk call to any subscriber, the

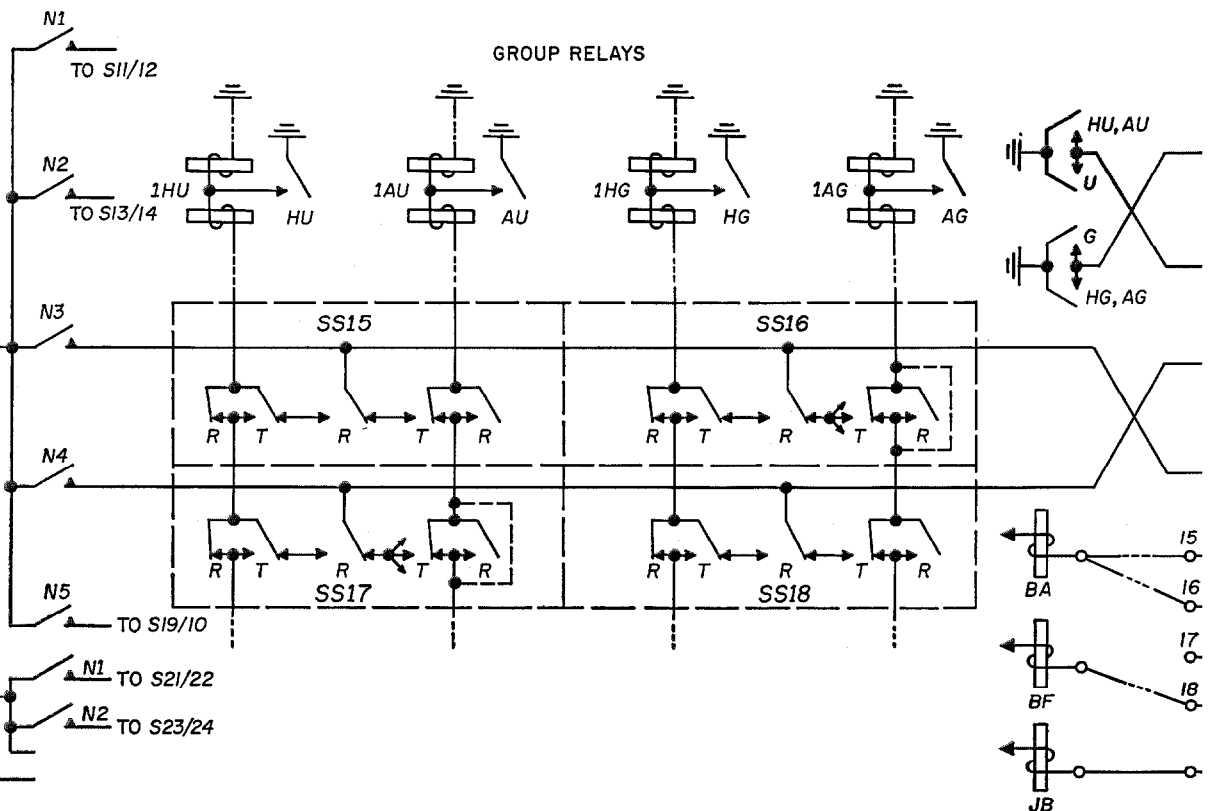


LOCKING RELAYS

STARTING AND GROUPING CIRCUITS

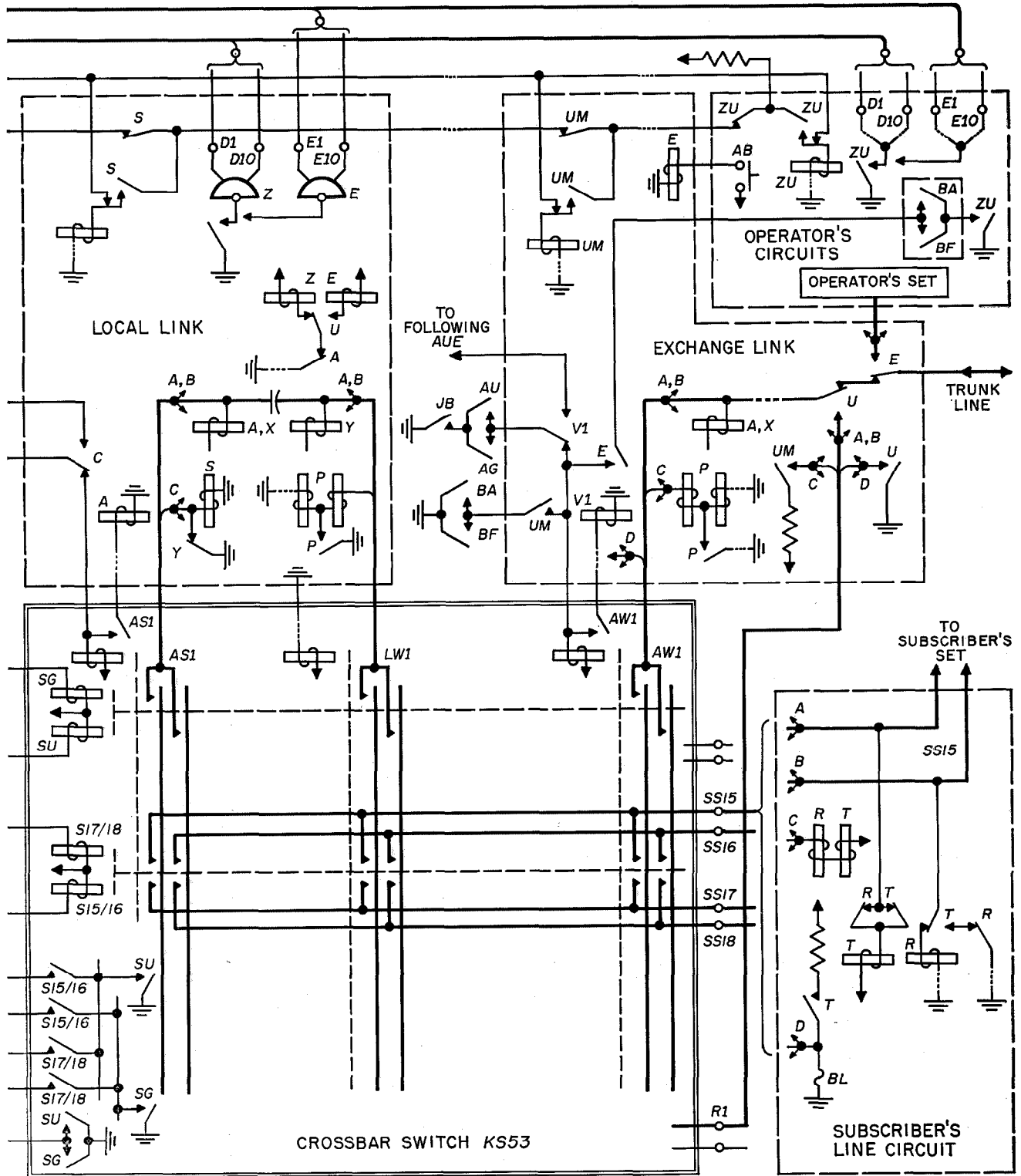


TO FOLLOWING AS



GROUP RELAYS

Figure 5—Simplified diagram of crossbar Citomat circuits.



operator keys the calling number of the desired party on a single-row key-type sending strip (not represented in Figure 5), thus storing the two digits in a relay combination. This is an arrangement of contacts that in quite the same manner as the tens and units magnetic counters of the local links prepares the application of a potential to the selected tens and units circuits (indicated by dotted lines in Figure 5, top right). Immediately after the digit keying, ground potential is offered to locking relay *ZU*, thereby asking if the call-allotting operation can proceed. If so, the *ZU* relay pulls up and causes the relay combination to become effective (in a similar way to the case of a local call). As a result, two select magnets of the selecting rods associated with the desired subscriber are energized and prepare the closing of the respective contact sets by means of the trunk-selector bridge.

The trunk call cannot, however, be connected through until one of two relays *BA* or *BF* (permission to receive outside calls) has come into action, which takes place during selecting-rod operation. Trunk-selector-bridge magnet *AW1* therefore operates under the control of contact *BA* or *BF* and one contact each of answering relay *E* and locking relay *ZU* (Figure 5, top right). If neither contact *BA* nor *BF* is closed, the trunk selector bridge cannot operate and the operator receives a wrong-connection signal. It is particularly noteworthy that the described operations only require the operating and releasing time of but a few relays so that not more than 200 milliseconds elapse from selection of the second digit until the moment the called subscriber receives the first ring or the operator the wrong-connection or busy signal. Thus, the call-allotting process no longer depends on the lengthy operating time of dial switches, impulse keysenders, and step-by-step switches.

3.5 CALLBACK AND TRANSFER OF TRUNK CALLS

During a trunk call, the internal subscriber may originate a callback in the well-known manner by pressing his grounding button; in so doing, he actuates a switch (*U* in the exchange link) and connects his line to a special callback circuit that causes the connection of an idle local link. It is assumed that in this way the *A*

subscriber has established a callback connection to the *B* subscriber and now wants the trunk call to be transferred to the latter.

To accomplish this, it is necessary to reproduce the selecting-rod combination of the *B* subscriber, that is, to control the appropriate selecting rods in the previous manner and to reoperate the trunk selector bridge with this selecting-rod position. After the *A* subscriber has replaced his handset, the trunk selector bridge is therefore caused to restore to normal and the exchange-link *UM* relay is connected to the common lockout circuit to find out whether the intended transfer can be performed. Unless the lockout circuit is engaged otherwise, a *UM* contact of operating *UM* relay applies negative potential to the callback-circuit *C* wire and causes an increased current to flow through the local-link *C* wire and energize the second winding of locking relay *S*.

As the previous position of the tens and units magnetic counters is still unchanged, it would now be possible for the *S* relay to effect the necessary selecting-rod position for the trunk-selector bridge. Such a procedure is, however, objectionable since in case of collective numbers, there would be no clear relation between dialed calling number and the actually reached line. For this reason, the *B*-subscriber marking is accomplished by utilizing the final-selector position itself rather than by using the magnetic-counter positions.

The adopted procedure may be gathered from Figure 6, which shows the final-selector wiring. It consists essentially of restoring the magnetic counters at the beginning of the transfer operation and sending a signal over the specially switched (split) final-selector *D* wire immediately relay *S* has been energized via the incoming *C* wire. Contrary to other wires, the *D* wires are switched in such a way that the vertical multiples are directly connected (hence, not by means of the changeover rod). The left-hand multiple *D2* is used for transmitting a direct control signal to the desired-subscriber's select magnet, whereas the right-hand multiple *D1* serves to actuate the changeover-rod select magnet. In this way, it is ensured that desired-subscriber marking is always clear and exactly corresponds to the previous final-selector position.

Following select-magnet operation, relay *BA*

or *BF* is energized (unless the desired subscriber is fully restricted) and the circuit of the trunk-selector bridge magnet completed over a contact of previously energized locking relay *UM* and closing contact *BA* or *BF* (see Figure 5). If

relay (and not the *U* relay) is energized, and the ground potential offered can only be conveyed to select magnet *S13/14* if the intermediate cutoff relay contact *T14* of line 14 is at normal.

In the event of line 14 being busy, said cutoff-relay contact passes the offered potential to select magnet *S19/10* so that line 10 will be connected. If number 10 is also busy, the connection will be extended to line 26. In this way, it is possible to form a line group out of any even or odd calling numbers.

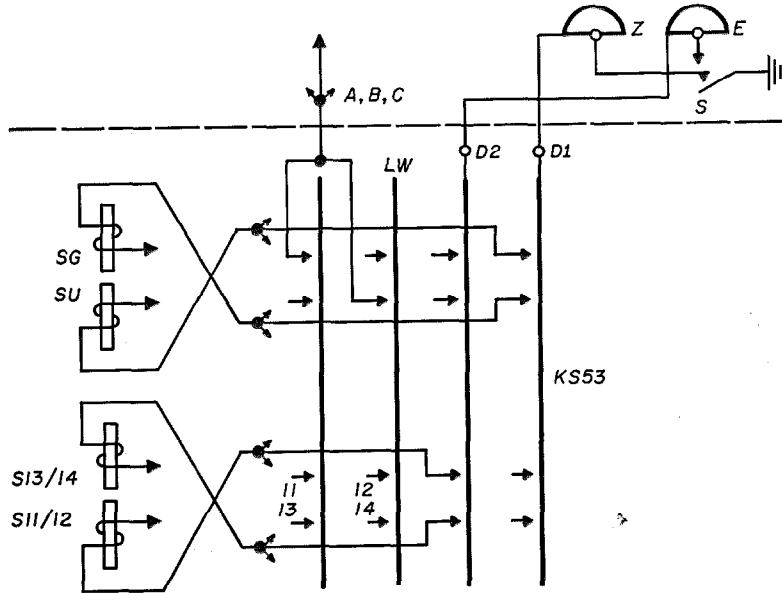


Figure 6—Wiring of final selector.

relay *BA* or *BF* fails to operate (because the subscriber is fully restricted or because no subscriber has been called via the callback circuit), the trunk selector bridge is not operated again, and the trunk call is automatically extended to the operator, who receives a recall signal.

3.6 COLLECTIVE NUMBERS

When, on dialing a collective number, the associated line is found busy, the control signal is passed to the next free line of the same group. Let us consider the circuits of a subscriber with several lines (14, 10, and 26), all three obtainable by the collective number 14 (see Figure 7).

When selecting calling number 13 or 14, a ground potential is furnished via decade terminal *D1* and number-relay contact *N2*, this potential being directed via additionally inserted contacts *U* and *G* to subscriber 13 or 14, as the case may be. If subscriber 13 is dialed, the connection is set up according to the aforementioned procedure. If, however, number 14 is dialed, the *G*

handling of calls through the attendant's cabinet is exclusively accomplished by means of pushbuttons. All switching operations are greatly simplified by use of magnetic-type pushbuttons (Figure 8).

3.7 ATTENDANT'S CABINET

This will be obvious when considering the process of allotting an incoming trunk call to any subscriber. In this case, the operator has to perform but two different manipulations:

A. In response to the trunk calling signal, the operator presses the associated magnetic-type answering button and is immediately connected with the caller.

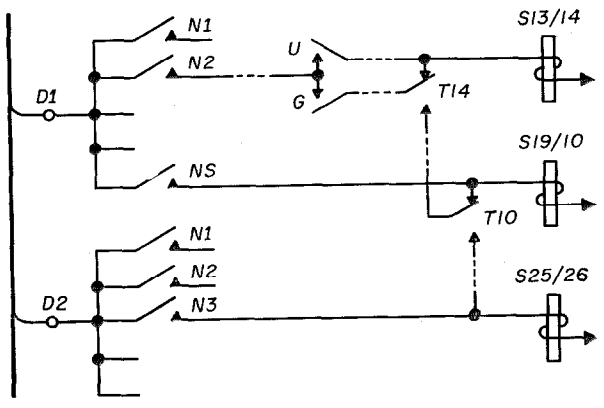


Figure 7—Wiring example for collective numbers (line groups).

B. To complete the desired connection, the operator keys the number of the wanted internal subscriber on the single-row key strip.

Immediately after this, the connection is established and the magnetic-type answering button restores to normal, unless the called party is found engaged.



Figure 8—Attendant's cabinet for the crossbar Citomat having 5 trunks, 50 lines, and 6 local links.

In case the called subscriber is busy, the answering button remains operated; now the operator may cut in on the busy connection or inform the public subscriber and then withdraw from the connection.

In general, shifting from one trunk line to another is most simply effected by pressing the answering button of the new trunk line (or service line, respectively), which automatically resets the previously operated answering button.

The attendant's cabinet provides space for mounting a busy-lamp panel that displays the subscriber's busy state and thus facilitates traffic handling for the operator. Such a busy-lamp panel may at the same time be used for identifying subscribers in the case of toll-rate indication.

4. Additional Facilities

4.1 STORING KEYSENDER AND DESTINATION KEYS

To facilitate public-exchange calls or internal calls over the service line, the operator's dial may be replaced by a storing keysender. The storing keysender is an arrangement of relays and capacitors that is controlled by the same digit-key strip used for extending outside calls to internal subscribers; it is designed to store at least 10 digits and to translate them into corresponding trains of impulses. This is a valuable aid to the operator, all the more so as it is possible to handle other calls while the storing keysender is in action.

If desired, the storing keysender can be supplemented by so-called destination keys (rapid call). Such destination keys enable up to 10-digit calling numbers that have to be selected frequently (as the code numbers of often-wanted local exchanges in the toll dialing area or other calling numbers) to be selected by pressing but a single pushbutton. If, for example, the destination key serves to select a local-exchange code number of the nationwide dialing system, the operator may key the local subscriber number immediately after pressing the destination key and the storing keysender will emit the registered impulse trains in correct sequence. On the attendant's cabinet (Figure 8), the destination keys take the place of the dial, which can be dispensed with if the storing keysender is mounted.

4.2 TOLL RATE INDICATION

Facilities for toll rate indication can be furnished as an addition to the exchange links and

serve the purpose of assessing automatic-toll-call fees. They provide at the same time for prevention of automatic toll calls attempted by subscribers who are denied toll-area access.

When a subscriber with full toll dialing facilities originates an automatic toll call, relay *BF* is energized, as already shown, and in turn operates relay *F* in the engaged exchange link. See Figure 9. In a similar way, relay *F* may be energized by the operator, after allotting a trunk line, to enable a nonrestricted subscriber to set up automatic toll calls.

With automatic toll calls, the first metering pulse is received at the beginning of the con-

versation, the current pulses received during conversation control meter *ZA* and relay *AZ* operates. Relay *AZ* completes the circuit of the toll supervisory lamp *FU* that lights and warns the operator that a toll call is in progress. At the end of the call, relay *M* operates—disconnecting any other *M* relay—and connects the toll supervisory lamp and the busy lamp of the speaking subscriber to the flicker line.

Now the operator can read the meter indication marked by the flashing lamp *FU* and determine the subscriber's number by means of the flickering busy lamp, both lamps being afterwards cancelled by button *FT*.

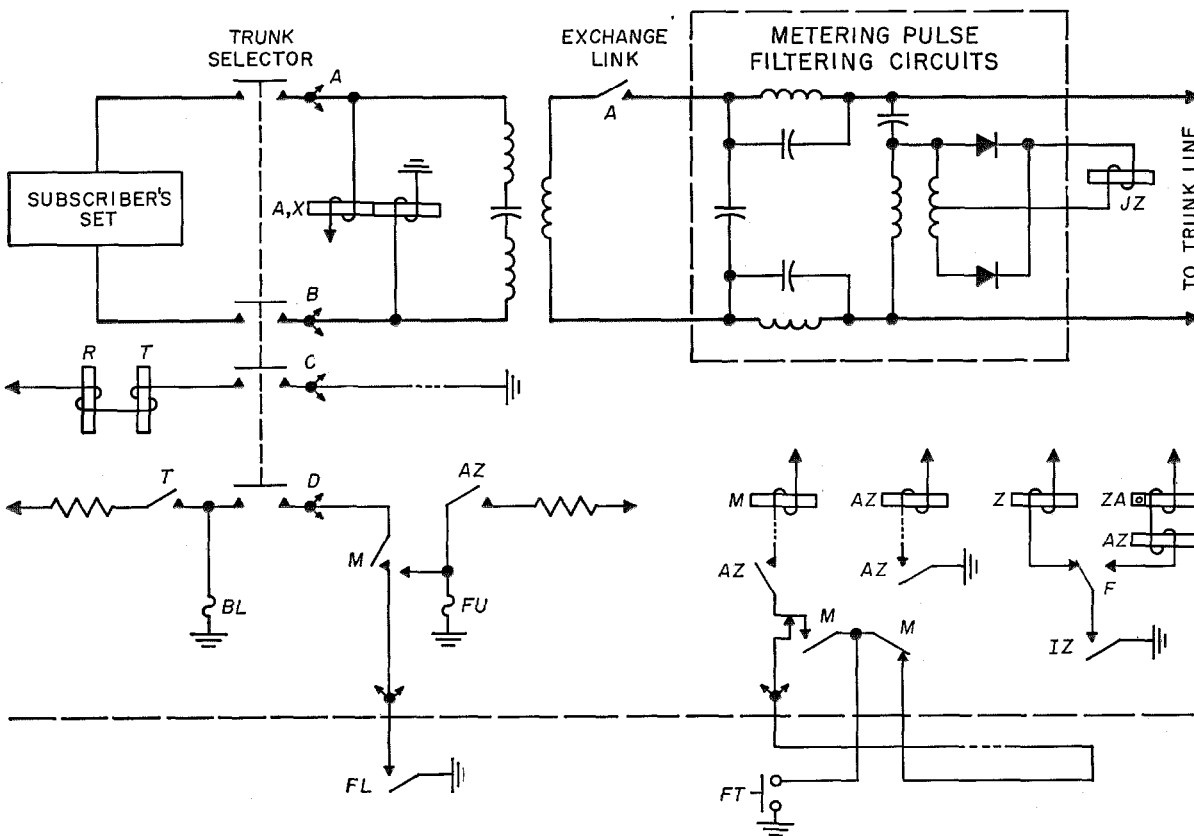


Figure 9—Toll-rate-indication circuits (addition to exchange link).

versation and conveyed to the exchange link in the form of a 16-kilocycle-per-second current pulse. This pulse operates the highly sensitive *JZ* relay. In the event of a metering pulse received with an originating toll call attempted by a subscriber who is not entitled to it (*F* relay not operated), disconnect relay *Z* is energized and the connection cleared down. Otherwise, if

4.3 CALLED-NUMBER-BARRING FACILITY (RESTRICTED OUTGOING SERVICE)

In some cases, it may be desirable to have suitable facilities whereby particular public-network numbers can be automatically barred to outgoing calls. Such facilities may be provided instead of, or in addition to, the above-

described toll-rate indicating device that also prevents setting up of automatic toll calls by unauthorized subscribers.

Since normally such called-number-barring facilities involve a considerable amount of equipment, it is necessary to utilize them as economically as possible, which was obtained by providing a restricted number of such devices and allotting them as necessary, rather than giving each exchange link a barring device of its own. This method is acceptable, as temporary connection of the devices to the exchange links is accomplished by relays, that is, practically without delay and since the called-number-barring devices are no longer equipped with rotary switches, but with magnetic counters that are less subject to wear.

The connecting method is schematically shown in Figure 10. Associated with the 5 exchange links of the crossbar 5-trunk, 50-line, 6-link exchange are two called-number-barring devices that are sufficient to supervise the entire outgoing traffic.

Immediately after an exchange link has been taken into use, the called-number-barring circuit is connected to this exchange link, unless the calling subscriber is entitled to toll calls, which is marked by relay *F* operating. When the barring facility is connected, the speech circuit is extended through to the public exchange whence the caller receives dial tone. The dial pulses following are picked up and checked by the barring circuit. If a barred number is dialed, the

barring circuit causes the engaged exchange link *SP* relay to operate and break the trunk loop. After this, the barring facility is again free to serve another trunk call.

If a subscriber starts dialing when all barring facilities are busy, he automatically energizes a locking relay. Should he seize a barring device without subsequent dialing, the connection will be released after some time through *SP*-relay operation.

4.4 TIE-LINE CALLS

In addition to the well-known possibilities afforded by tie lines, facilities were created for the revertive release of incoming interswitch-board connections, which is generally not possible

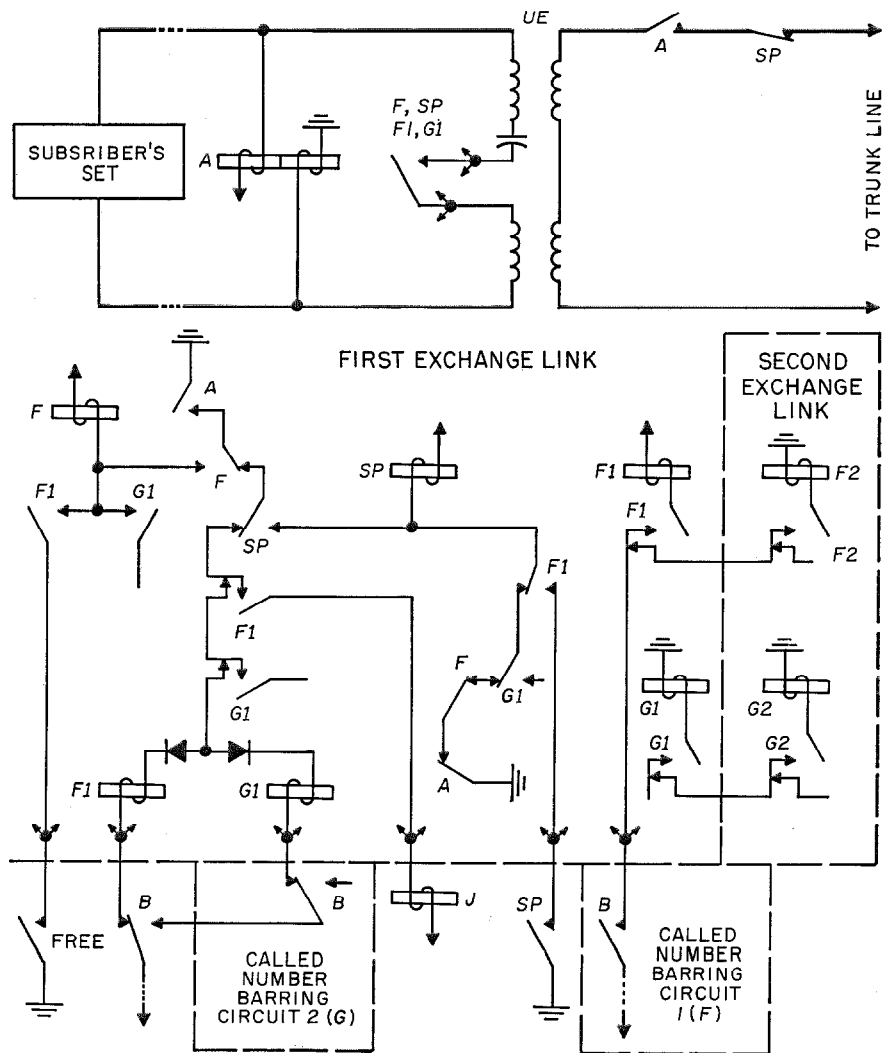


Figure 10—Connection circuit for called-number-barring facility.

in private branch systems providing exchange-link starting from the subscriber line circuits. This feature has been introduced to prevent tie lines from remaining engaged an unduly long time.

The problem consists of effecting reverteive release of the tie line if the called subscriber is found busy or if he finishes the call. Revertive

way telephone set and a signal lamp on the attendant's cabinet.

By pressing a nonlocking button associated with the particular priority line, the operator is enabled to answer such calls at any time and during any other switching manipulation. After release of this button, she may proceed with the interrupted manipulation.

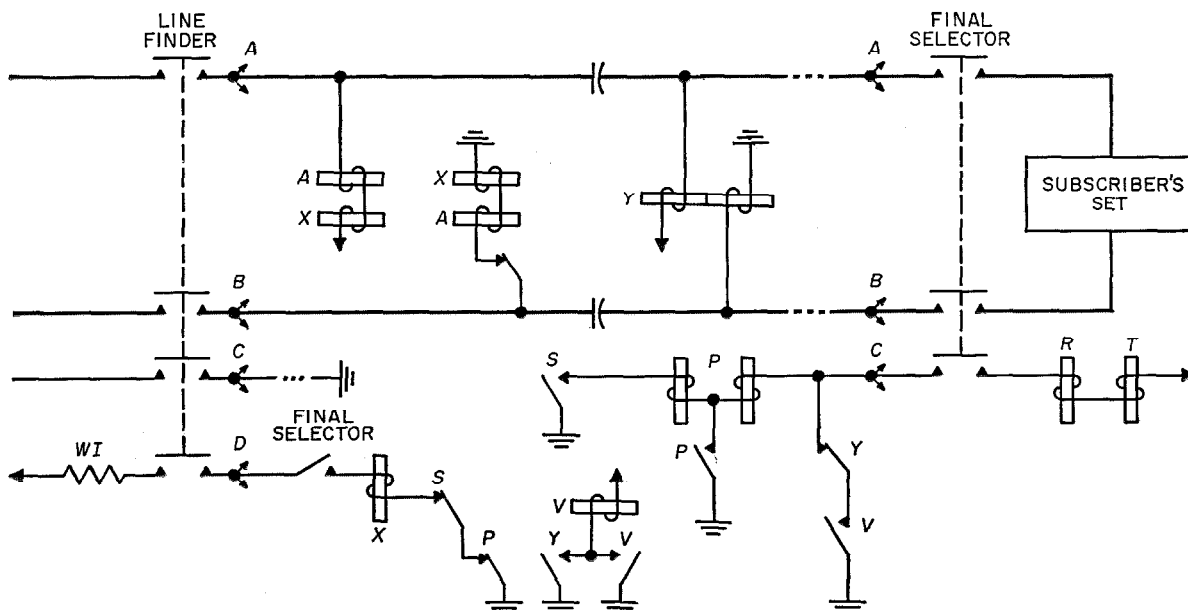


Figure 11—Revertive release of local connecting link via *D* wire of line finder.

release is, however, only possible if the local link has been engaged by an incoming tie-line call.

Figure 11 shows the required switching operations in simplified form. From the tie-line repeater, a negative potential is sent via the *D* wire of the line finder to the local link. As a result, differential relay *X* is energized if, after operation of the final selector, test relay *P* fails to operate or if the latter is de-energized by the called subscriber replacing his handset. The *X* relay breaks the loop, thus causing release of the local link and, in turn, the incoming tie-line repeater as well as the repeater of the distant switchboard. The calling subscriber receives busy signal from his own switchboard.

4.5 PRIORITY SERVICE

A limited number of subscribers can be equipped for direct key calling to the operator. For this purpose they are given a special two-

4.6 CUTTING IN ON BUSY LINES

Cutting in on busy lines requires an additional pushbutton on the subscriber's set. By pressing this button, any busy subscriber's line may be entered, which condition is communicated to the busy parties by a superimposed ticking tone. The cutting-in feature is most important when during a toll connection the branch-exchange subscriber wants to place an internal call (callback) and finds the called local line busy. In this case, it is possible for the calling subscriber to enter the dialed line via the exchange and the local connecting link used for the callback.

If the subscriber whose line has thus been entered restores his handset, he immediately receives a new calling signal and is, on removing the handset again, connected with the cutting-in subscriber.

4.7 CODE NUMBERS AND SINGLE-DIGIT DIALING

Code numbers are quite generally used for starting an exchange link in case of a callback to another public subscriber. The code number performs in this case the function of the grounding button that cannot be used on an engaged exchange link for technical reasons. It should, however, be noted that in both cases the obtained effect is quite the same.

Code numbers are further employed for originating outgoing trunk calls if it is essential to seize a particular trunk line, the number of which has to be communicated to the toll operator at night. In this case, a specific switching signal is sent via the local link to the starting circuits that ensure that the calling subscriber will be connected to the desired trunk line. In the same manner, it is possible to select particular trunk lines connecting with main exchanges in different places.

Usually, such code numbers comprise two digits but by the provision of suitable additions in the local links, it is possible to use single-digit code numbers. The same applies to calls over tie-line, service-line, paging (staff-locating) facilities, et cetera, the use of single-digit numbers being conditional on the availability of a sufficient number of first digits within the numbering scheme.

5. Admissible Voltage Variation

In the crossbar system, the switching components are less affected by operating-voltage variations than they are in mechanically driven step-by-step systems.

In step-by-step systems, there is a definite lower limit to voltage variation since with very-rapid succession of dial impulses, the rather

considerable mass of the selector gears must be moved quickly enough to follow these impulses. The upper operating-voltage limit is set by the necessity of arc suppression, which in view of the rather high currents appears to be very difficult.

In practical service, especially of private branch exchanges, there is always the danger of inadmissible voltage variation resulting from either wide mains-voltage fluctuations or from faulty manipulations of the incorporated trickle charger, both giving rise to functional troubles.

The wider voltage tolerances in crossbar systems therefore mean increased reliability in service.

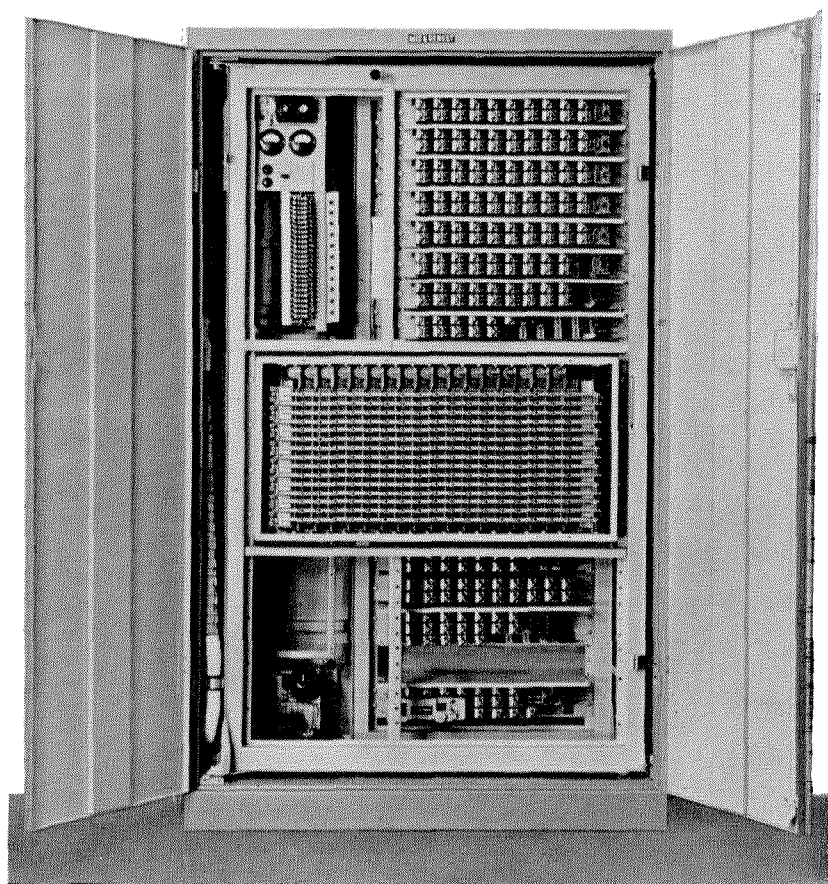


Figure 12—Crossbar Citomat with 5 trunks, 50 lines, and 6 local links in wall-mounting floor-type cabinet.

6. Accommodation

The crossbar Citomat is accommodated in a floor-type metal cabinet intended for wall mounting (Figure 12). The crossbar switch and the

relay strips are mounted on two hinged frames that can easily be swung open to facilitate inspection and maintenance. Within the cabinet, at the rear, are mounted the main and cross-connecting distribution frame, the main and secondary fuses, the locking keys, as well as the trickle charger including switch panel.

Concentration of all components in a common cabinet permits space-saving installation of the Citomat exchange even in business rooms and offices. As the operating noises are minimized due to the type of switching components used, there will be no annoyance to persons working in the same room.

7. Crossbar Private Exchanges of Higher Capacity

7.1 CROSSBAR CITOMAT, 10 TRUNKS, 100 LINES, 12 LINKS

Although the operating principles outlined in the foregoing primarily refer to the smaller

Citomat, they may—with slight modifications—also be applied to similar Citomats of higher capacity. The essential difference lies merely in the method of interior trunking and grouping of the elements.

The Citomat having 10 trunk lines, 100 subscriber's lines, and 12 internal links provides capacity for twice as many subscribers and local connecting links as the Citomat described earlier, requiring four times as many crossbar switches.

The required grouping method is shown schematically in Figure 13. To obtain 100-outlet (112-outlet) selectors, two 50-outlet (56-outlet) crossbar bridges each are connected in parallel. The switching elements are accommodated in two cabinets; an *A* and a *B* cabinet. The *A* switchboard practically equals that of the type shown in Figure 12 except that for the type 10-100-12, an additional crossbar switch *A'* is mounted. The *B* switchboard largely resembles

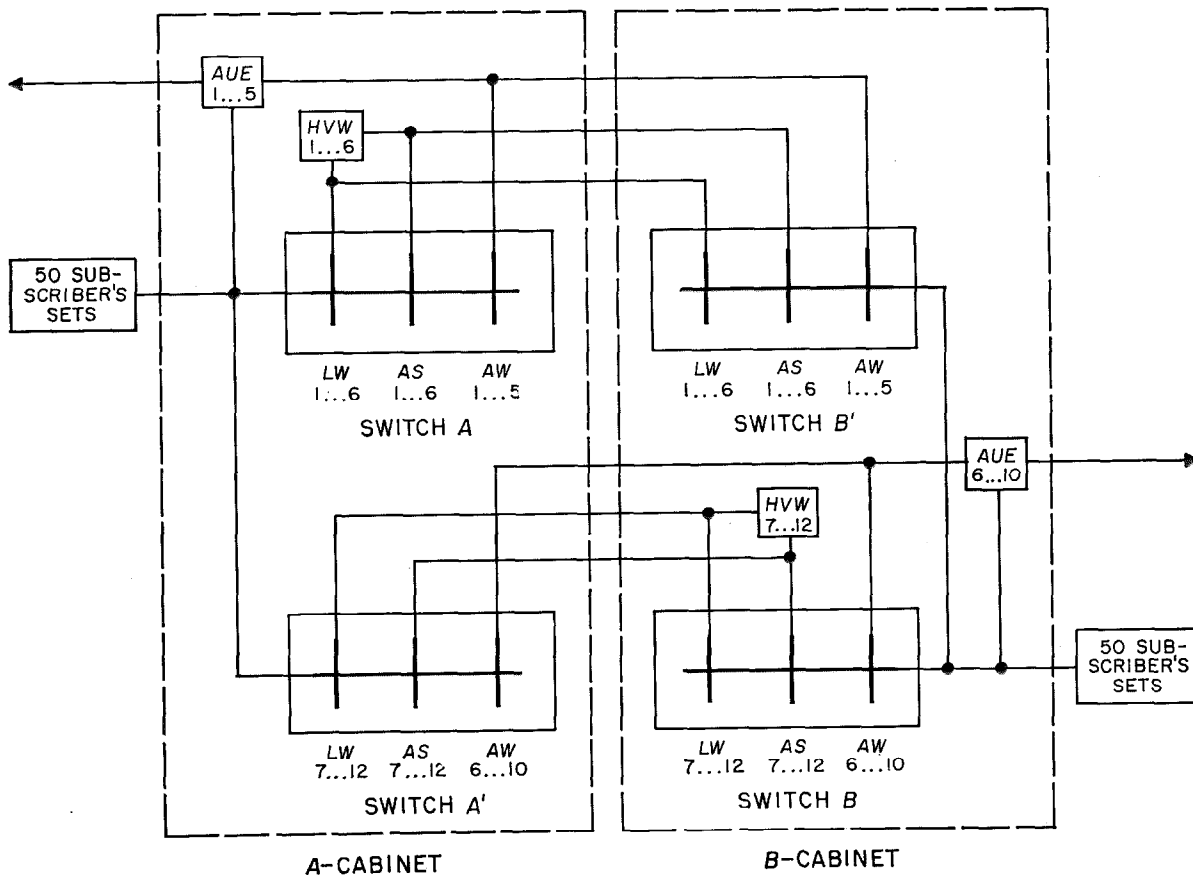


Figure 13—Basic layout of crossbar Citomat with 10 trunks, 100 lines, and 12 local links.

the *A* switchboard except that common facilities, such as signal circuits, et cetera, are not duplicated.

It should be noted that each of the cabinets caters for only 50 subscribers. The selectors, however, are "split up" and have one "arm" in either cabinet.

7.2 CROSSBAR CITOMAT, 7 TRUNKS, 60 LINES, 6 LINKS

Because of its greater capacity, this Citomat is accommodated in a somewhat higher cabinet than that of the 5-50-6 Citomat, but the construction is essentially the same.

The method of grouping may be gathered from Figure 14. It will be seen that only two crossbar switches are needed if an immaterial group splitting on the line-finder side is accepted. The majority of the subscribers (groups 2 and 3 with a total of 44 lines) is not affected since these are given full access to all line finders and local links. However, group 1 with 4 subscribers and the callback lines can only reach line finders 1, 2, 3, and 4 and the group 4 with 12 subscribers has access only to the line finders 5, 6, 3, and 4. To mitigate the effect of this group splitting, an arrangement has been introduced that causes originating calls always to seize those line finders that are accessible to individual groups only (*AS* 1, 2 and 5, 6, respectively), while line finders 3 and 4 (common to all groups) are only used when all others are busy.

On the final-selector and trunk-selector side there is, of course, full access for all subscriber groups.

7.3 CROSSBAR CITOMAT, 8 TRUNKS, 50 LINES, 6 LINKS

This Citomat uses the same cabinet as the 7-60-6 Citomat and also requires two crossbar switches the wiring arrangement of which is shown in Figure 15.

Switch *A* is exactly equal to switch *A* of the 5-50-6 Citomat. The remaining three trunk selectors that cannot be accommodated on this switch are on switch *A'*.

There is, however, a new problem in that the 8 exchange links also require 8 callback lines, while the 56-outlet crossbar switch can only afford 6 callback circuits, maximum.

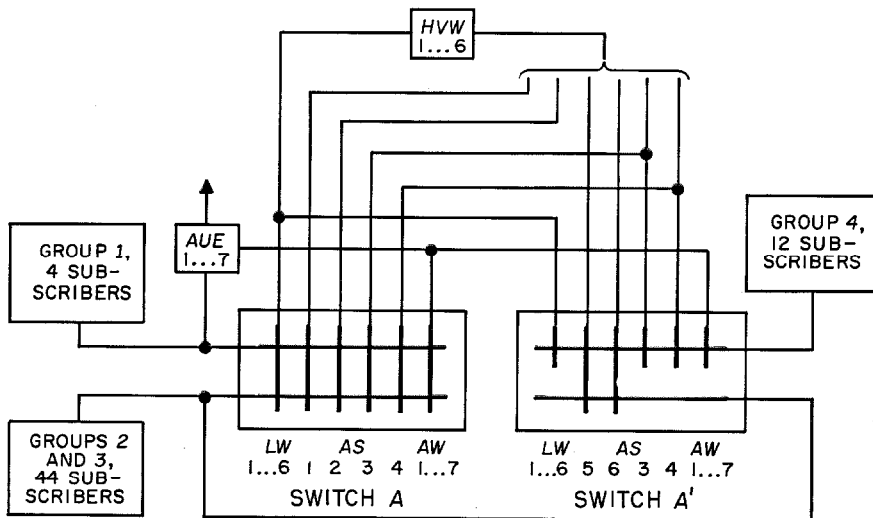


Figure 14—Basic layout of crossbar Citomat with 7 trunks, 60 lines, and 6 local links.

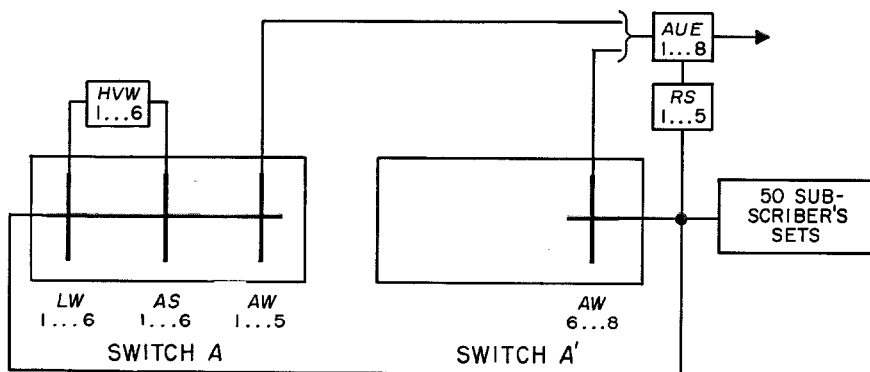


Figure 15—Basic layout of crossbar Citomat with 8 trunks, 50 lines, and 6 local links.

To overcome this difficulty, a novel switching element, the so-called callback line finder *RS* was introduced. This is an arrangement of relays designed to choose and connect a free callback circuit, if need arises, and thereby enables the necessary 8 callback circuits to be reduced to only 5 circuits.

8. Equipment Functional Symbols

AB = Answering button
AG = Locking relay, external call, even number
AS = Line finder
ASI = Magnet of line-finder bridge
AU = Locking relay, external call, odd number
AUE = Exchange connecting link
AW = Trunk selector
AWI = Magnet of trunk-selector bridge
BA = Incoming trunk-call control relay
BF = Outgoing trunk-call control relay
E = Units magnetic counter
G = Even-number select-magnet relay
HG = Locking relay, internal call, even number

HU = Locking relay, internal call, odd number
HVV = Local connecting link
JB = Impulse-limiting relay
KS53 = Crossbar switch
LW = Final selector
LW1 = Magnet of final-selector bridge
N = Number relay
P = Test relay
R = Line relay
RS = Callback line finder
S = Local-link locking relay
SG = Select magnet, even number
SU = Select magnet, odd number
S13/14 = Line select magnet, numbers 13 and 14
T = Cutoff relay
TLN = Private-branch-exchange subscriber
U = Select-magnet relay, odd number
UE = Trunk-line repeating coil
X = Differential relay
Z = Tens magnetic counter
1AG = Group relay, external call, even number
1AU = Group relay, external call, odd number
1HG = Group relay, internal call, even number
1HU = Group relay, internal call, odd number.

Automatic 7E Rotary Teleprinter Switching System

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A DISTINCTION can be made in telegraph switching between two classes of service, that is, the public telegraph service and the telex service. The public telegraph service involves the collection and delivery to and from the general public of messages in record form, there being no direct communication between the transmitting and receiving parties. The telex service provides a direct communication between the clients similar to that given by the telephone.

The telephone service and the public telegraph service each have their particular advantages but the telex service combines the most-important features of both.

Due to the number of persons who handle a message, the exchange of information between two parties via the public telegraph takes much longer than it does by telephone. The telephone service, however, provides no record of the message received and the called station must be attended if the message is to be received.

The telex service, in addition to direct communication on a no-delay basis even in the international field, permits exchange of messages in both directions, gives a printed record of the transmitted information to both the calling and called parties, and the caller's message will be received at the called station even when it is unattended.

There is another very important point that arises in favor of the telex system. Because a narrow bandwidth of only 120 cycles per second is required for this kind of telegraphy, the channels may be considerably cheaper than those used for telephony and consequently lower tariffs are applied, especially for international traffic. In Europe, the international telex rates are half the telephone rates. These cheaper rates and the provision of "on demand" service are the main reasons for the exceptional growth of the European telex traffic.

The narrow frequency band, however, imposes certain limitations on signaling and supervisory methods. The majority of automatic teleprinter switching systems now in operation employs for switching and signaling both the apparatus and the techniques used in automatic telephone switching, with certain modifications rendered necessary by the differences between telephone and telegraph circuit requirements.

Tone signals of the type used in telephony for dialing, ringing, and busy signals can obviously not be used for telegraphy, but no suitable signaling system specially adapted to the characteristics of the teleprinter and the requirements of an eventual global network have been substituted.

Furthermore, insufficient consideration has been given to the conditions imposed by the use of telegraph regenerative repeaters and modern radio links.

In close cooperation, the engineering staffs of the Dutch Posts, Telegraphs, and Telephones Administration¹ and the Bell Telephone Manufacturing Company, have developed a practical and economical method of introducing the teleprinter into an automatic switching system in which the teleprinter keyboard is used for controlling the selection. The caller receives a supervisory report on the progress of a call in the form of a typewritten record.

The 7E rotary automatic teleprinter switching system has been designed with the following objectives in mind.

- A. Utilizing the capabilities of teleprinter to the fullest extent.
- B. Providing improved methods of selection and supervision.

¹An important part of the research work was done in the laboratories of the Dutch Administration under the supervision of Professor Doctor R. M. M. Oberman.

C. Satisfying the present as well as the future requirements of the international telegraph network.

D. Minimizing "lost traffic" in establishing trunk and international calls.

E. Combining both public telegraph and telex services as well as those for government and private users in one system of lines and exchanges to obtain maximum efficiency of lines and switching equipment.

F. Providing a switching system with a low maintenance cost.

The first exchange of this system was installed in Amsterdam and officially inaugurated by the Netherlands Posts, Telegraphs, and Telephones Administration on 15 February 1954. This exchange was the first of an automatic telegraph network in the Netherlands that now consists of 3 main exchanges in Amsterdam, Rotterdam, and The Hague, with a present capacity of 1400, 800, and 600 subscriber-station lines, respectively.

A maximum of 16 subexchanges has been foreseen within the network, each of which will have a capacity of 100 or more subscriber-station lines. A subexchange of this type will be installed to serve a limited area as the traffic in such an area exceeds a certain limit. This arrangement is more economical than to connect all the subscriber stations of this area directly to one of the main exchanges.

Fully automatic switching equipment is provided for incoming international traffic. Actually the control of this traffic is directed by operators in the originating countries, but in a number of countries arrangements will be made to handle the incoming international service on a fully automatic basis not requiring such operators.

Part of the outgoing international traffic is handled on a semiautomatic basis in which the telex subscriber reaches a manual switchboard by calling a 2-digit number. The operator

of this switchboard selects directly the telex subscriber in the foreign country if that country is equipped with an automatic switching system.

The rapid growth of the telex traffic and the fact that approximately 70 percent of the traffic originated in the Netherlands was international placed before the administration the choice of increasing considerably the number of operating positions and staff handling this outgoing traffic or of providing connections for the greater part of this traffic on a fully automatic basis by means of which the telex subscriber could select directly by keyboard operation the desired subscriber station in the foreign country. It was considered to be more economical to handle this traffic as far as possible by fully automatic switching. The telegraph exchanges were therefore provided with automatic switching equipment that enables the telex subscribers in the Netherlands to select directly telex subscribers in Austria, Belgium, Denmark, West Germany, Sweden, and Switzerland. The growth of the telex traffic in Europe from 1934 to 1954 is shown in Figure 1. This curve shows the number of call minutes per year in millions.

When automatic switching systems for the telex service are installed in France and Great Britain, about 95 percent of the international telex traffic of the Netherlands will be handled on a fully automatic basis. The importance of the automatization of this telex service is indicated in Figure 2, which shows amounts of international telex traffic expressed in thousands

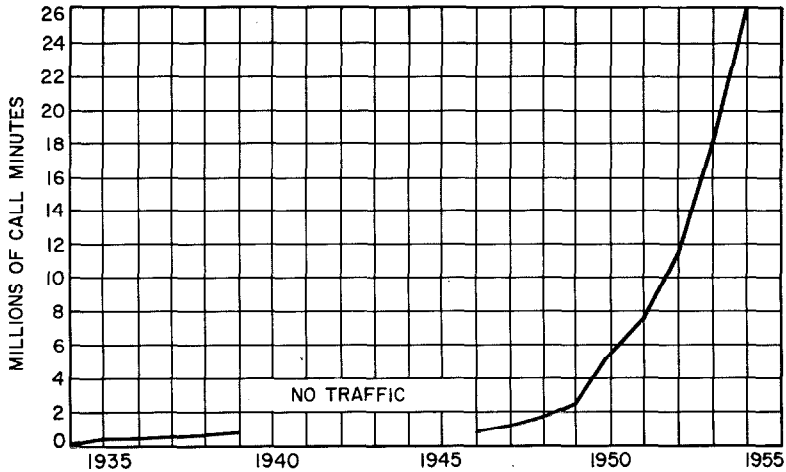


Figure 1—Growth of telex traffic in Europe in millions of call minutes per year.

of call minutes for some different countries during January 1955; the Netherlands being second after Western Germany. Figure 3 shows how

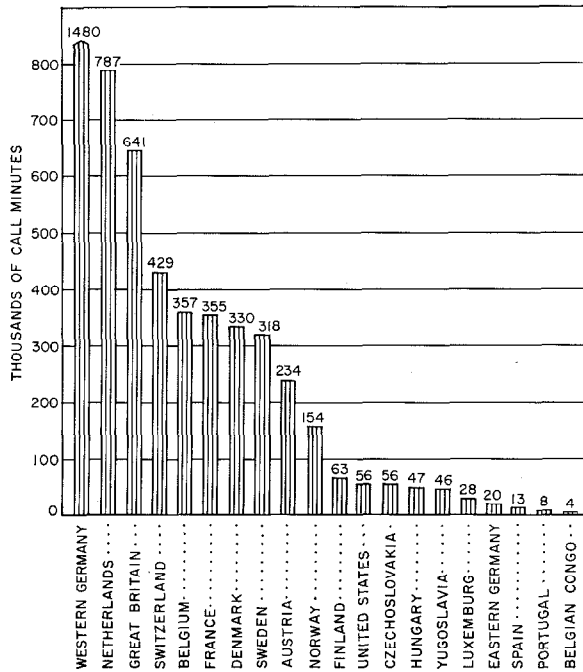


Figure 2—International telex traffic in thousands of call minutes during January 1955 for various countries.

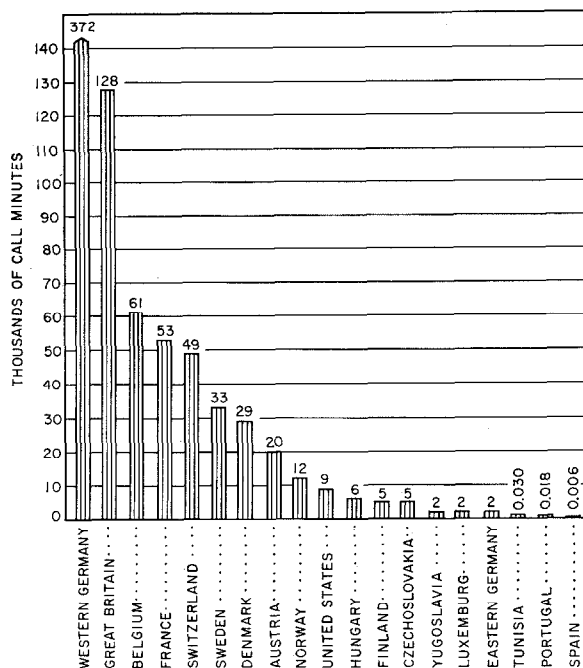


Figure 3—International telex traffic with the Netherlands during January 1955.

during the same period the international telex traffic in the Netherlands was divided among different countries. Figure 4 gives a comparison between the international telex traffic and the international telephone traffic of the Netherlands. It will be seen that during February 1955 the telex traffic with 7 out of 17 countries exceeded the telephone traffic. Since then, the telex traffic to Sweden also surpassed the telephone traffic.

On 9 September 1953, the first intercontinental automatic telegraph connection was set up via a radio link by an operator in New York. This operator selected by teleprinter keyboard a subscriber's station connected to the Amsterdam telegraph exchange. Since February 1956, automatic transit calls have been made by operators in New York, over switching equipment in the telegraph exchange in Amsterdam, to telex subscribers in other countries of Europe.

1. Fundamental Plan

With the exchanges in Amsterdam, Rotterdam, and The Hague in service, the fundamental

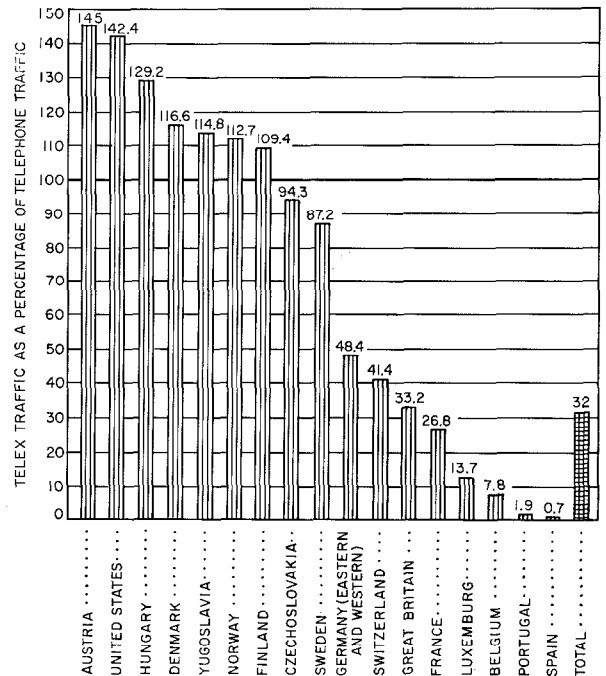


Figure 4—International telex traffic in the Netherlands during February 1955 expressed as a percentage of the international telephone traffic.

plan of the telegraph network of the Netherlands is as shown in Figure 5. All subscribers in the various districts are at present connected directly to one of the main exchanges in Amsterdam, Rotterdam, or The Hague. These exchanges are directly interconnected so that not more than one interexchange junction is required to complete any inland call using the regularly assigned route.

The country is divided into 19 districts for establishing tariffs for local and interlocal calls. Later, when subexchanges are installed, these exchanges will be connected to both Amsterdam and Rotterdam for reasons of economy and assured service.

2. Junction Diagram

Figure 6 shows a simplified junction diagram of the Amsterdam telegraph exchange. A subscriber connected to this exchange can establish a connection to any subscriber station in the country by typing a 5-digit number. A line finder connects the calling party to a connecting circuit provided with a telegraph repeater; a local register after being connected to this connecting circuit controls the selection. In the case of a local call, a connection is established over a 1st, 3rd, and final selector.

For an outgoing call to another exchange in the Netherlands, a connection is established over 1st and 2nd group selectors to an interexchange junction.

The local exchange sends the number of the called subscriber's station in the form of teleprinter signals to the incoming register connected to the distant end of the junction. This register controls the selection in the distant exchange.

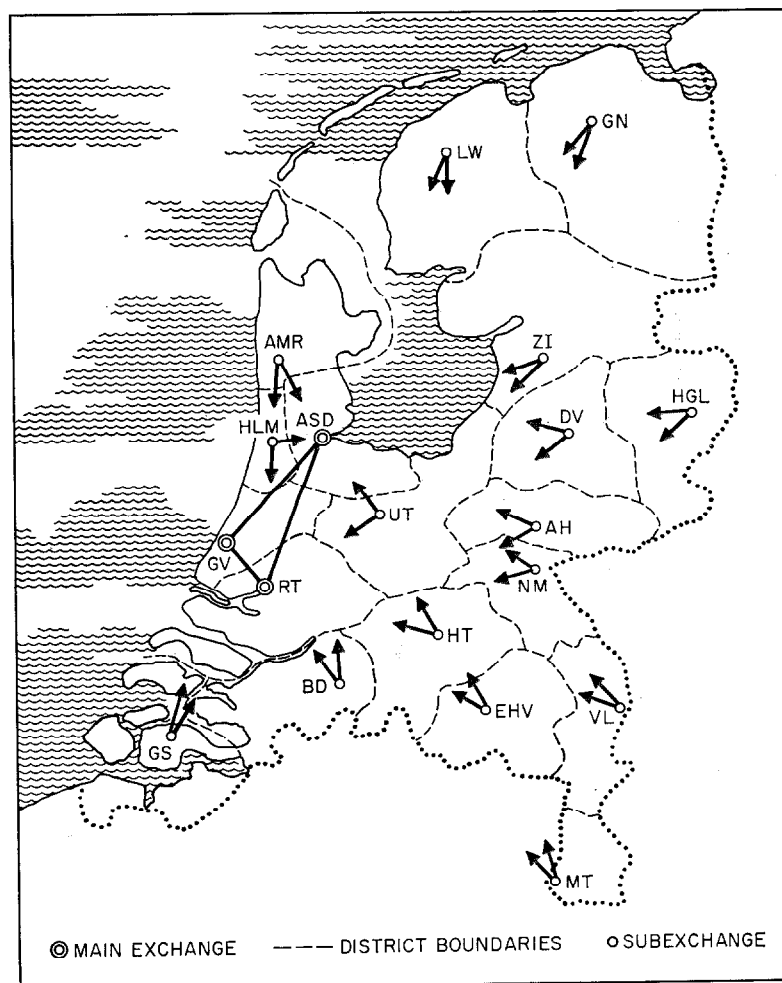


Figure 5—Fundamental plan for the telegraph switching network of the Netherlands showing three major exchanges, 16 subexchanges, and boundaries of switching districts.

For international calls or calls to special services, the subscriber types a 2-digit number. Three levels of the 1st group selectors are reserved for fully automatic switching to subscribers in other countries, each level giving access to 10 countries. A subscriber after typing the 2-digit number assigned to the country to which the call is being made, will be connected to a 2nd group selector for outgoing international traffic. This circuit is provided with the necessary apparatus for indicating the charges for international calls and will give access to different types of international registers. Such an international register adapts itself entirely to the switching and supervisory requirements of the foreign switching system.

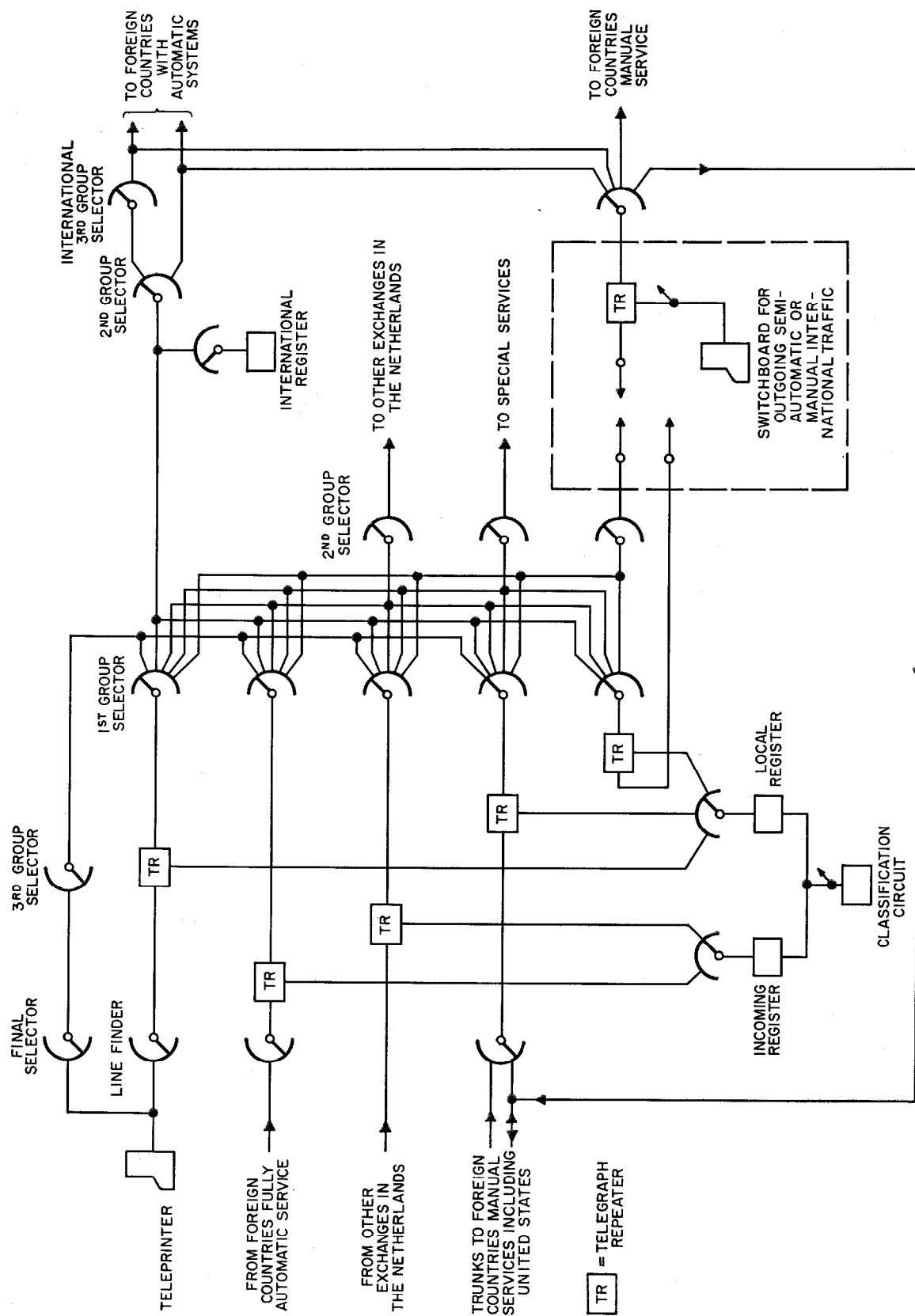


Figure 6—Simplified junction diagram of the Amsterdam telegraph exchange.

Actually, only one type of international register is provided as all the countries to which fully automatic service is now given or will be given in the near future have dial-operated systems that respond to the same type of register. It is anticipated, however, that in the future fully automatic service will be given to countries using switching systems having entirely different methods of signaling and supervising. For instance, in France, Italy, and Norway, the selection will be controlled by teleprinter signals instead of dialed impulses. For the service to such countries, other international registers will be required. The 2nd-group-selector circuit is arranged to connect the calling party automatically to a suitable register and to indicate at the same time the tariff that is to be charged.

The calling subscriber receives a printed indication when an international register is connected to his line, whereupon he may send the number of the required subscriber as given in the directory of the foreign country. Hunting for a free international junction is only started after the complete subscriber's number is received by the register. If there are a number of junction groups toward the same country, a selection among them is made by a 3rd group selector under the control of the international register; in that case, the required direction is indicated by the subscriber's number.

The international register now in use receives the selecting information from the calling subscriber in the form of telegraph signals but controls the switches in the foreign countries by sending dialed impulses.

For the traffic to West Germany, there are separate groups of junctions to Hamburg, Frankfurt, and Düsseldorf. The junctions to Hamburg form the main group and, if all junctions are occupied to Frankfurt or Düsseldorf, calls will be routed automatically over the junctions to Hamburg.

For indicating the charges for calls, impulses are sent from the 2nd group selector circuit to the service meter associated with the line circuit of the calling subscriber. These impulses are

sent at the same time to a meter forming part of the international junction circuit, registering the paid occupation time of the traffic passing over that junction.

One level of the 1st group selectors is reserved for calls to the manual international switchboard. A subscriber can reach a position on that switchboard by typing a 2-digit number. For calls to countries provided with an automatic switching system, the operator of such a position selects directly the called subscriber's station and writes a ticket for the charges of the call.

3. Classification of Lines

The system has been developed to function as a private-line system and at the same time as a public message system. Service may be given to a variety of classes of subscribers' stations, including public telegraph offices, private telex subscribers, governmental services, and a number of private networks. The system is designed so that subscriber stations of a particular class, whether they be connected to the same exchange or to different exchanges in the country, can intercommunicate with each other but cannot become through-connected to subscriber stations of other classes. Subscriber stations belonging to one class may form an entirely isolated group of lines, notwithstanding the fact that the same switching equipment and interoffice junctions are used for all classes of lines. Nevertheless, it is also possible to permit subscriber stations belonging in one group to reach stations in one or more other groups.

Restrictions in switching facilities can be applied to any class of lines. Thus, the lines over which public telegraph offices receive their interoffice traffic may not be called by private telex subscribers, and, conversely, precautions are taken to ensure that public telegraph interoffice traffic cannot be diverted to private subscribers. Lines to public telegraph offices and to private telex subscribers are therefore put in different classes and, before communication can proceed, the class of both the calling and the called teleprinter station is identified to determine whether

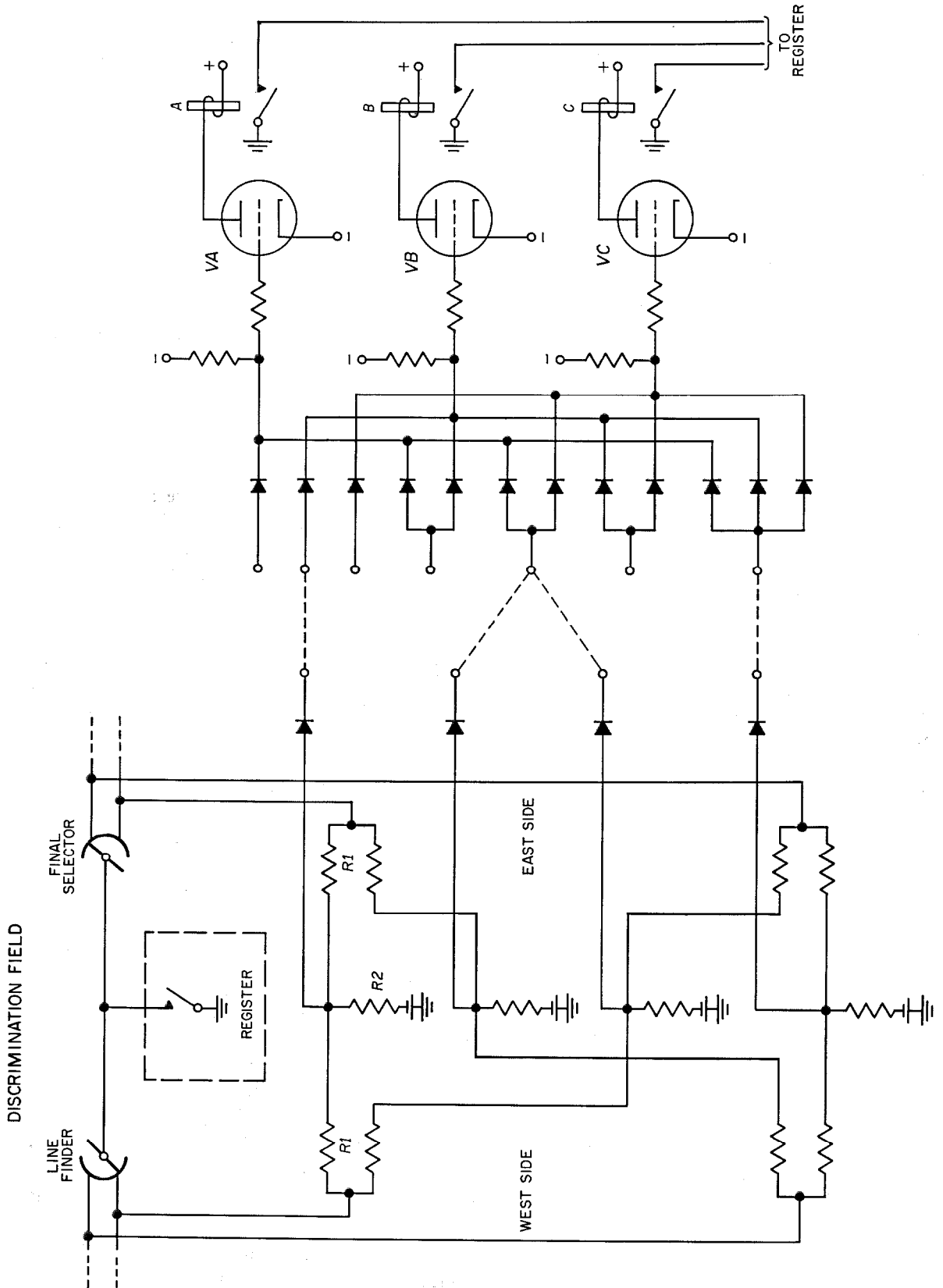


Figure 7—Discrimination circuit

or not interconnection is permitted. Figure 7 shows a block diagram of the classification circuit, which is common per exchange. After the selection has been completed under the control of the register, but before the connection is established, the register is connected to this classification circuit.

The line finders and selectors are provided with a level of arc contacts, which are multiplied at the side of both the line finders and final selectors, for all lines belonging to the same class. There are therefore two separate multiples for each class, one of the line-finder contacts and another of the final-selector contacts, which are connected, respectively, to the west and the east sides of the discrimination field, if both subscriber stations are connected to the same exchanges. The line-finder multiple of each class is connected via a resistance RI with all the class multiples at the final side.

Following the connection of the classification circuit to the register, a ground potential is extended over the line finder and final selector, respectively, to the west and the east side of the discrimination field. The midpoint of the resistances RI characterizing each class combination is connected to the grid circuit of one or more vacuum tubes. The midpoint of the two resistances establishing the class of the call under control will have a higher positive potential than all other corresponding midpoints of resistances because ground potential is received over two resistances in parallel. The vacuum tube or tubes connected to this midpoint become conductive, thereby operating a combination of the relays A , B , and C . The energization of each of these relays imposes certain limitations on the operation of the register, for instance, to break down connections that are not permissible.

The classification circuit has only a controlling function and, if it is out of service, calls will proceed in the normal way except that the limitations imposed on certain classes of lines will not be effective.

If the calling and called subscriber stations are not connected to the same exchange, the circuit will operate differently. After the calling station is connected to the register and a junction to another exchange is selected, the selecting information is sent in the form of teleprinter

signals to the incoming register in the distant exchange. The classification circuit of the local exchange determines the class of the calling station and this information is sent in the form of a single teleprinter signal to the incoming register. After the selection in the distant exchange has been completed, a classification circuit is connected to this incoming register.

The west side of the discrimination field receives ground potential from this register according to the class of the calling station; the east side receives its potential from the final-selector multiple. The circuit operates thereafter as for a local call.

4. Line Circuits

The following different types of lines may be connected to the system.

A. Lines connecting local subscriber stations. These are 2-wire loop circuits arranged for single-current operation.

B. Lines connecting long-distance subscriber stations via voice-frequency multichannel telegraph systems. These are lines that are not operated over 2-wire loop circuits because of the distance involved or for economical considerations, such as the availability of voice-frequency channels. Such telegraph channels use double-current operation with the cord repeater in the exchange and require a converter at the distant end to connect to the single-current telegraph apparatus.

C. Junctions for interexchange traffic for which voice-frequency multichannel telegraph systems are always used. They employ double-current operation with the exchange circuits.

In the exchange, neither the subscriber-station line circuits nor the interexchange junction circuits are provided with telegraph repeaters. The repeaters are incorporated into the connecting circuits.

The subscriber-station line circuits are universal circuits that can be arranged to serve either for local or long-distance subscriber-station lines, each circuit being provided with adjustable resistances for controlling line and bias currents.

5. Universal Cord Repeater

The system permits the interconnection of all lines or junctions between which communication may be required without the necessity of adjustment and with practically no signal distortion in the switching circuits.

In previous switching methods, the above is achieved by providing all lines and junctions with telegraph repeaters. In the 7E system, this problem has been solved simply and economically by employing universal repeaters in the connecting circuits, there being fewer connecting circuits than lines and junctions.

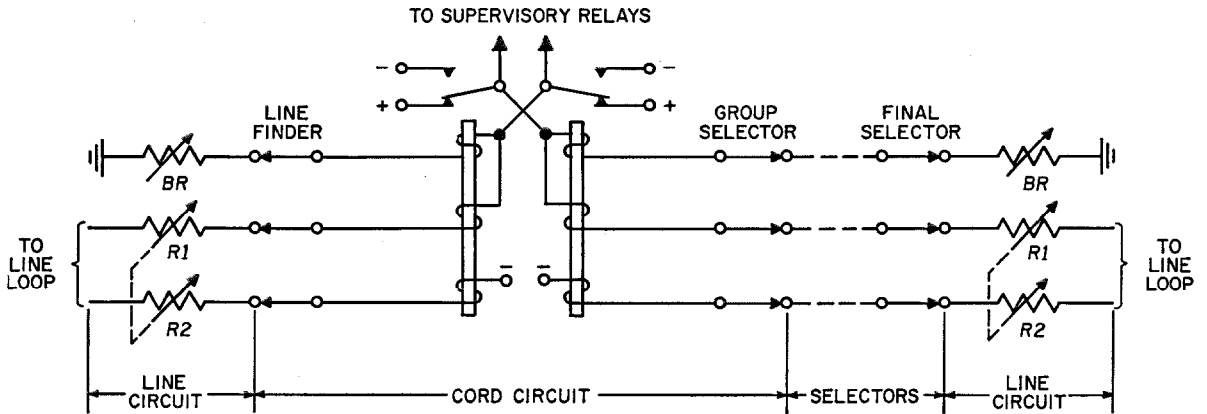


Figure 8—Universal cord repeater for single-current operation between two-wire loop circuits.

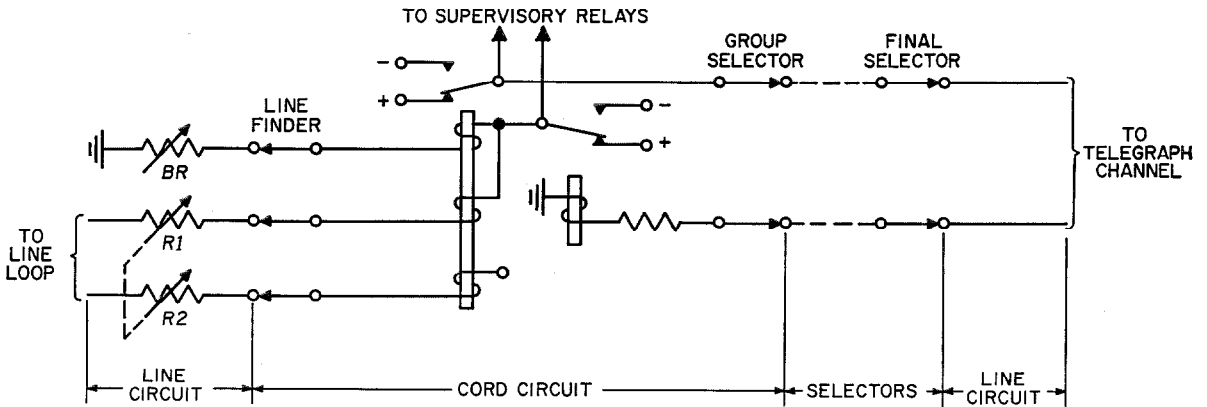


Figure 9—Universal cord repeater for two-wire single-current to double-current operation.

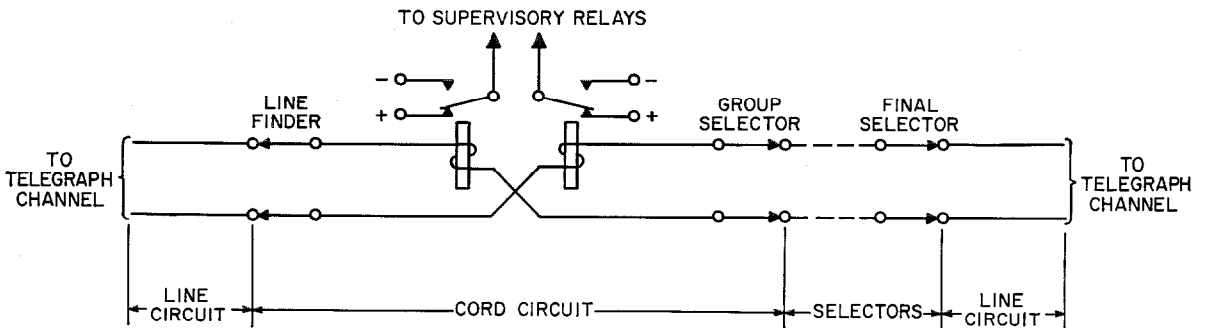


Figure 10—Universal cord repeater for double-current to double-current operation.

The repeater in the connecting circuit automatically adapts to both the calling and called lines, so that the following types of through-connection may be established.

- A. Local line to local line.
- B. Local line to long-distance line or to inter-exchange junction.
- C. Long-distance line or interexchange junction to local line.
- D. Long-distance line or interexchange junction to long-distance line or interexchange junction.

The following advantages are obtained by placing the repeaters in the connecting circuits.

- A. Economy in the use of telegraph relays and in the concomitant maintenance of them. In the Amsterdam exchange a group of 100 lines is served by 24 cord repeaters. This is on the basis of a traffic of 4.2 equated busy-hour calls per line with a loss-call probability factor of $P = 0.005$.
- B. The considerable reduction in the number of telegraph repeaters justifies the introduction of a number of improvements in this apparatus. Low-pass transmission filters have been added to prevent interference in telephone circuits. Repeaters and line circuits are balanced to prevent mutual interference between telegraph circuits. The use of these repeaters permits service over local subscriber lines to distances of the order of 60 kilometers (37 miles).
- C. The subscriber-station line circuits are not affected by faults in the cord repeaters.

Figures 8 to 10 show how the universal cord repeater is adapted to different types of lines.

Figure 8 shows a connection between 2-wire loop circuits both of which are arranged for single-current operation. The resistances R_1 , R_2 , and BR form part of the line circuit. The resistances R_1 and R_2 serve to adjust the

current in the line loop. The resistance BR serves to adapt the repeater by means of the bias circuit to the characteristics of the line.

Figure 9 shows a 2-wire single-current loop circuit connected for double-current operation to a telegraph channel for a long-distance subscriber-station line or an interoffice junction.

Figure 10 shows a connection between two telegraph channels with double-current operation between these channels. In this case, there is no repetition of signals in the cord repeater, the telegraph relays serve only for supervisory purposes.

6. *Permutation-Code Signaling*

Selection signals are sent by means of the keyboard of the teleprinter instead of a dial as in telephony. Keyboard sending has the following advantages over the use of a dial.

- A. No dial is required.
- B. The selection information is recorded on the teleprinter as transmitted before the selection is started. This enables the operator to check the transmission of the correct number. It also facilitates staff supervision in the public service and the investigation of claims made by subscribers.
- C. The selecting signals are identical to those used for the normal transmission of messages and they can, therefore, be sent through any type of regenerative repeater or be recorded on perforated tape when storage is required as for example in the case of teleprinter operation with error correction over radio links.
- D. Keyboard sending reduces the holding time of junctions and apparatus as the selecting signals are sent at teleprinter transmitting speed. In telegraph switching, speed in making a connection is even of more importance than in telephony. The average traffic per subscriber station is approximately 4 times as high as in telephony. This fact increases considerably the probability of finding a called station occupied, with the result being that there is a high percentage of

ineffective calls. Quicker selection reduces this unproductive loading of the network and apparatus.

E. An important international factor is that standards for the transmission of teleprinter signals are fixed by international conventions. Whereas the characteristics of dial sending differ from country to country.

7. Selection

Selection is based on the use of single-motion selectors of the rotary type, the operation of which is controlled by applying the principle of multipotential comparison. This is accomplished by discrimination among 24 different sources of 450-cycle alternating current divided into 2 equal groups; the first being of 12 volts and the second of 20 volts. The sources of each group differ in their phase angles by 30 degrees or multiples thereof and each of these sources is used to characterize a different group of outlets in the group-selector arcs. In the final-selector arcs, the individual outlets and the first of a decimal group are also characterized by the connection of a different alternating-current source. Selection speed is increased by using selectors having no home position and by the elimination of control circuits.

8. Supervision

Facilities are incorporated whereby letter code groups may be transmitted from the exchange to the teleprinter of the calling party to indicate certain conditions that may be met while a call is being set up. The codes that have been selected conform to those adopted by the Comité Consultatif International Télégraphique for international use. They are produced by a code sender in the register in the exchange.

To enable a subscriber to establish and release a connection, a control box is provided in addition to the teleprinter. This control box is fitted with a start and release button and a pilot lamp.

A call is originated by depressing the start button. This starts the teleprinter motor, a

register in the exchange is connected, and its serial number is transmitted to the subscriber's teleprinter. This information facilitates the tracing of trouble in cases of faulty operation.

A teleprinter may transmit 31 different signal combinations but only the 13 required for setting up a connection are accepted by the register.

Following the receipt of the serial number, the subscriber sends the selecting signals by depressing the **FIGURE SHIFT** key followed by the desired subscriber's number. The actual selection is then started by depressing either the key with the + or the - sign.

Any deviation from this procedure will cause the register to release the call, thus preventing an erroneous selection by the transmission of text after the faulty release of an established connection.

For a normal call, the selection process is started by depressing the + key. If, however, a particular subscriber has the privilege of obtaining a through connection to any occupied subscriber's station, breaking down an existing connection if necessary, the - key is depressed after sending the called number. If the - key is depressed by a nonprivileged subscriber, the connection is immediately released.

When the selection has been completed, the answer-back device of the called teleprinter is put in operation by an appropriate signal from the controlling register. It prints the called subscriber's name code on both teleprinters, preceded by the time of the day at which the call is made, which is sent by the controlling register.

The calling subscriber now has a printed record of the serial number of the register, the selection information transmitted, the time, and the name code of the called subscriber. The printing of the latter information ensures the caller that the selection has been correct.

Calling a subscriber's station connected to a distant exchange will require the services of not only the local register but one or more incoming registers in other exchanges. The serial numbers of these additional incoming registers will be reported to the calling subscriber. This informa-

tion will indicate whether the call has been established over the regularly assigned route or some alternative route.

A subscriber making a fully automatic international call will receive the same register serial numbers as for a local or interdistrict call in reaching the international register. On being connected, that register will send the signals for CARRIAGE RETURN and LINE FEED followed by its serial number and a question mark. The fact that this information is printed on a new line and followed by a question mark indicates that the subscriber is connected to an international register and that the called subscriber's number may be sent.

If the called line cannot be connected, the reason will be indicated by the reception at the calling station of one of the code groups given in Table 1.

TABLE 1
CODE TO IDENTIFY CALLED-LINE CONDITIONS

Code	Condition
<i>OCC</i>	Occupied
<i>DER</i>	Out of order or mains failure
<i>NP</i>	Nonexisting line
<i>NA</i>	Line of a class not permitted to be connected
<i>NC</i>	No free selector or junction available for connection

9. Code Receiver

The code receiver, which forms part of the register circuit, serves to receive and record the teleprinter signals that control the selection. It has to test each of the 5 code units of such a signal for positive or negative potential. Distortion introduced by different circuit elements may shift the start and end of these code units in relation to their theoretical centers in an undistorted signal. To permit the reception of highly distorted signals, it is necessary that this test be made exactly at the middle of each code unit in relation to the start unit and for the shortest possible time. This time is known as the striking time. It is not possible to receive a signal correctly if such a displacement approaches

50 percent of the normal length of a code unit. The code receiver consists of 3 parts, a time base, distributor, and recorder as shown in Figure 11.

The time base is a flip-flop square-wave impulse generator using two pentodes. On receipt of the start unit of a signal, the time base is started. Two polarized relays *KA* and *KB* connected in the anode circuits follow the oscillations.

The contacts of one of these relays control the moments of striking, while the contacts of the other control the operation of the distributing and recording relays.

The middle of the first striking interval occurs approximately 30 milliseconds after the beginning of the start impulse and is followed by 4 other striking actions exactly 20 milliseconds apart.

In the rest position, *V1* is conducting, *V2* is nonconducting, and the distributing relay *KD* is operated so that contacts *KD1*, *KD2*, and *KD3* are opened. Following the starting of the time-base by the receive relay *KC*, this relay is short-circuited by contacts *KD1* of the distributing relay. Each striking time, this short-circuit is momentarily removed, during the changeover of the contact of relay *KA*. It is during this time that the receiving relay can change contact, should there be a reversal of polarity in the line. Following each striking time, another distributing relay is operated, connecting another recording relay to the mark contact of the receiving relay *KC*, which is operated when the latter relay is on its mark contact. A complete signal is recorded with the final connection of the 5th recording relay. The distributing relay *KD* is then operated to cut off the time base, whereupon the circuit is prepared for further signal reception.

10. Alternative Routing

The system is arranged to enable the equipment to select alternative routes automatically, when no circuits are available in the first-choice route. Besides providing protection against complete interruption of service when all circuits on certain routes are out of service,

alternative routing contributes greatly to the economy of the line plant. Peaks of traffic are sporadic and usually do not affect all junction groups at the same time. The phase-comparison system lends itself remarkably well to a simple method of alternative routing. As an example, if a group of junctions is marked by phase 2 and no free outlet is found, the test limit of the phase comparator, which was 30 degrees, is enlarged to 60 degrees, whereupon the selector will test on junctions characterized by the presence of any of phases 1, 2, or 3.

11. Multiline Hunting Over Nonconsecutive Lines

A plurality of lines connected to the same subscriber or office may be connected within a hundreds group to the arcs of the final selectors in an arbitrary way and need not necessarily be connected to consecutive terminals as is the usual practice. This feature makes it possible to extend such a group by any number of free line terminals available in the same 100-line group, without requiring the reservation of a corresponding number of spare contacts after the last terminal of the group, with the consequent uneconomic utilization of the final selector.

In addition to the normal phase marking for the selection of individual lines, each multiline connected to a particular final group will be characterized on a separate row of terminals, by its own group phase. A maximum of 24 multilines may be accommodated per final group. All lines, with the exception of the first, will have the group phase disconnected when occupied.

Following the selection of the first line of a group in the normal manner, the phase comparator in the register is next connected to the final-selector brush providing access to the special group-marking terminals. The register identifies the reference phase characterizing this line group. This reference phase remains connected to the phase comparator and the final selector hunts for a free line having this phase as it characterizes all the lines in the particular group desired. If all lines in the group are busy, the selector will return to the first terminal, where the group phase is always connected, and will stop on this line. If the first line is still busy, the register will

inform the calling line by connecting the busy signal to it.

12. Recording Calls for Billing

The recording of all fully automatic calls for billing purposes is done by means of multi-metering; that is, impulses are sent from a common device at regular intervals to a service meter forming part of the line equipment of each calling subscriber. The frequency with which these impulses are sent depends on the established tariff. For a local call, which has the lowest tariff, one impulse is sent every 3 minutes. For the same period of time, 15 impulses are transmitted for an interdistrict call, 36 for a call to Germany, and 102 for a call to Sweden.

The Dutch telegraph network is divided into 19 districts; there is a local tariff for calls between subscribers in the same district and an interdistrict tariff for calls between subscribers in different districts.

The fact that a connection is made to a subscriber in another district than the one in which the exchange is located gives no assurance that this is an interdistrict call, because all districts do not have their own switching centers. Both parties may be located in the same district and be connected to an exchange in a neighboring district.

To determine whether the calling and the called parties are located in the same district, the phase comparator in the register is used. All lines to subscribers in a certain district have the same phase connected to the line circuit. Before a connection is completed, the phase comparator in the register compares the phases connected to the line circuits of the calling and called parties. The local tariff is charged only if both line circuits have the same phase marking.

13. Improved Supervisory Control

The release signal in telegraph switching systems is generally given by an impulse of sufficiently long duration to be distinguished from the impulses normally transmitted by the teleprinter. The longest negative impulse received in teleprinter code may be 127 milliseconds produced by a negative signal of 120 milliseconds + 7 milliseconds of distortion. By making the release signal not less than 500

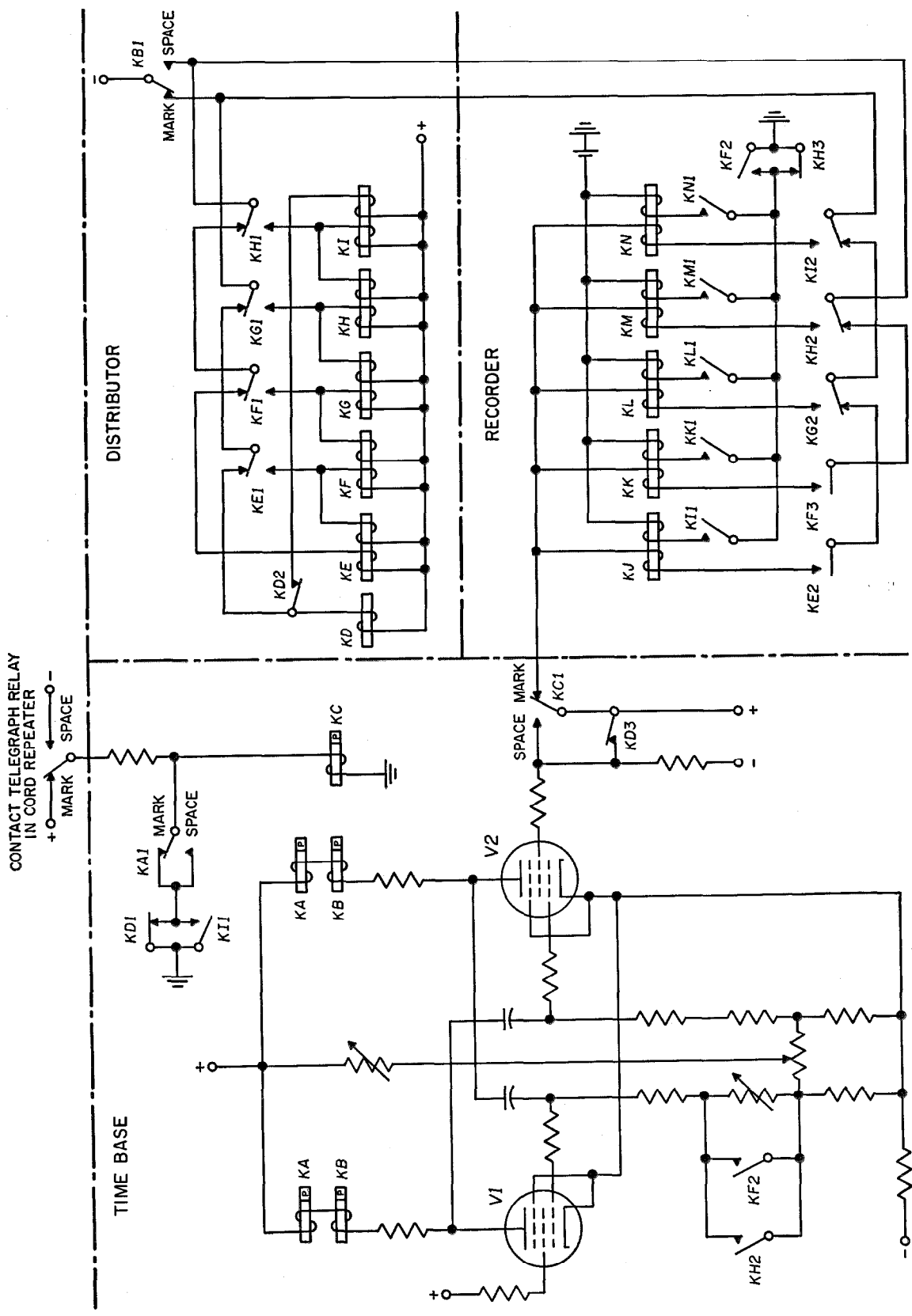
CONTACT TELEGRAPH RELAY
IN CORD REPEATER

TIME BASE

DISTRIBUTOR

RECORDER

Figure 11—Teleprinter code receiver.



milliseconds, this signal may be utilized by a delayed-release relay.

This method, however, has a disadvantage in that such a release signal not only operates the supervisory control circuit but passes on to the teleprinter of the other party, which is thereby held in the spacing condition resulting in pumping.

Invariably, a superfluous character is printed at the end of the signal. This undesirable behavior may be overcome by arranging the connecting circuit to limit the time during which this release signal is transmitted to the distant teleprinter.

A further requirement is met in the case of an outgoing call. In this instance, the register of the local exchange disconnects after the selection information has been sent to the distant register. On completion of selection, the distant register transmits a signal to the local connecting circuit indicating that metering is to start. This metering signal also must be distinguished from all others in the connecting circuit and a negative impulse of 150 milliseconds has been chosen. The requirements of the supervisory control in the connecting circuit are therefore as follows.

- A. Nonoperation by impulses not exceeding 127 milliseconds.
- B. Splitting of the connecting circuit to the other party, to block a signal that continues longer than 135 milliseconds.
- C. Initiation of metering by an impulse of 150 milliseconds.
- D. Release of the connection by an impulse of at least 500 milliseconds.

An electronic circuit has been developed to provide these close time limits, which cannot be obtained with relays. The armatures of the transmission relays in the cord repeater are connected via resistance-capacitance circuits to the control grids of vacuum tubes. Relays connected in the anode circuits of these tubes control the metering of the calls and the splitting and release of the connection.

Impulses of less than 130 milliseconds have no effect on these relays. After an impulse has

continued for 135 milliseconds, the connecting circuit will be split to prevent the signal from reaching the other party. An impulse lasting more than 140 milliseconds will start the metering of the call. An impulse longer than 500 milliseconds will release the connection.

14. Overload Provision

Automatic switching systems designed to handle public telegraph service must be capable of dealing with peak traffic loads. In the Netherlands, there are a number of small telegraph offices in which the postal and telegraph services are combined. In such offices, it must be possible to dispatch telegrams without delay, but it is not necessary that direct connection be provided to the actual office of destination. When a called station is busy, the calling lines are automatically switched to reperforators at switching centers. The transmitted message is thus stored in perforated tape and can be sent forward automatically as soon as the called station becomes free.

15. Equipment

The equipment layout and the apparatus for the 7E telegraph switching system are to a large extent similar to those used in the 7E telephone switching system.^{2,3}

The switches used are of the well-known power-driven rotary single-motion type. Models having 7 double brushes and 100 sets of outlets are employed both as line finders and selectors. A two-relay circuit is associated with each group selector or final selector. Neither selectors nor finders are provided with a home position but remain on the terminals to which the previous operation took them. This reduces hunting and holding time on each call and lessens the wear on the switches.

The system makes use of the U- and Y-type relays developed by Bell Telephone Laboratories (United States) and other flat-type relays of similar construction. Small sensitive polarized telegraph relays are employed. For the registra-

² M. den Hertog and J. Kruithof, "Principles of 7E Rotary Telephone Switching System," *Electrical Communication*, volume 33, pages 195-219; September, 1956.

³ M. den Hertog and J. Kruithof, "Equipment Practices in the 7E Rotary Telephone Switching System," *Electrical Communication*, volume 33, pages 278-307; December, 1956.

tion of selection information, a multicode relay has been developed. All relays are mounted in completely enclosed dustproof units. With the exception of those associated with the line circuits, these relay units are jack-in, which

which provide means for jumpering and strapping for the following purposes.

A. To classify a line by connecting it to a particular group of the classification circuit.

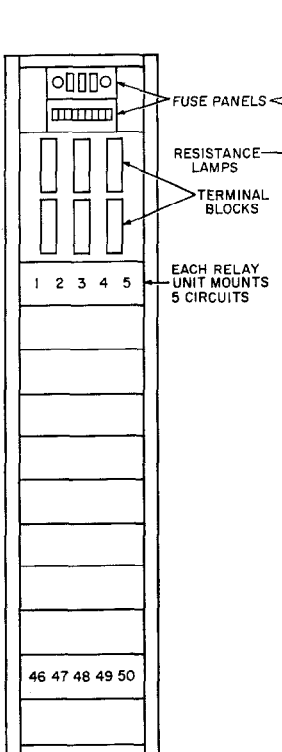


Figure 12—Equipment unit for 50 line circuits.

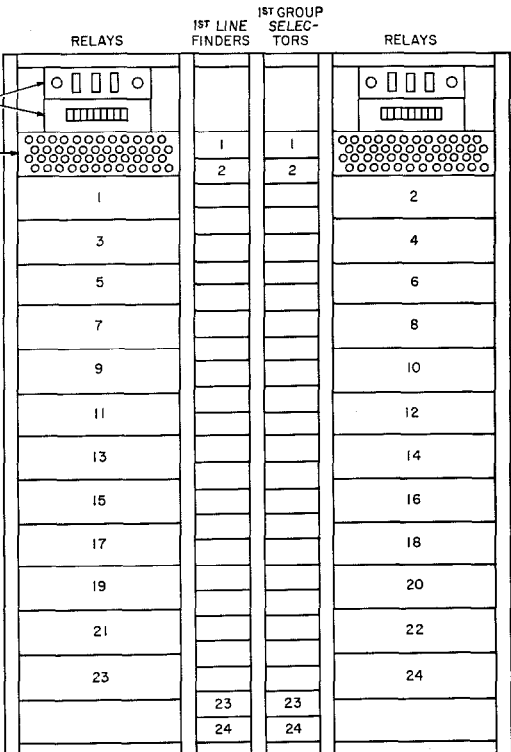


Figure 13—Equipment unit for 24 connecting circuits.

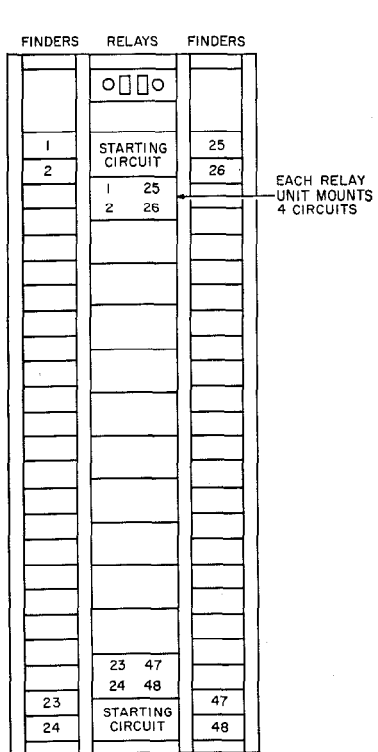


Figure 14—Equipment units for two groups of 24 final selectors.

permits mounting, wiring, and testing to be done on the workbench.

The components for 5 subscribers' line circuits are mounted together in one apparatus unit, each line circuit including 3 flat-type relays and 2 adjustable resistors. The adjustable resistors control the line and bias currents of the telegraph repeater that forms part of the connecting circuit. Before a line is put in service, these resistors must be adjusted to compensate for the line characteristics. These units are mounted permanently as the removal of such a unit would take 5 lines out of service. Ten such apparatus units are mounted on one bay.

Figure 12 shows the equipment layout of a bay with a capacity of 50 line circuits. On the top part of the bay are mounted 6 terminal strips,

B. To indicate in which district a subscriber's station is located by connecting the line circuit to a source of alternating current having a particular phase angle.

C. To indicate a line belonging to a private-branch-exchange group by connecting it to a phase marking that particular group.

D. To identify any or all of the following 3 privileges that may be given to a line individually and independently of its class.

- a. Making a call to a subscriber station not belonging to its own line class.
- b. Making international connections.

c. Reaching an occupied subscriber station after breaking down an existing connection.

One or more of these privileges can be given to a line by making cross-connections at the top of the line bay.

Figure 13 shows the equipment layout of a group of connecting circuits consisting of one bay with 24 line finders, one bay with 24 first group selectors, and 2 bays each with 12 apparatus units. Each apparatus unit is equipped for one connecting circuit, including a telegraph repeater.

Figure 14 shows the equipment layout of 2 groups of final selectors, each with 24 circuits. This equipment consists of 2 bays mounting 24 selectors each and one bay accommodating 14 apparatus units. There are 4 selector circuits in each of 12 of the apparatus units and the remaining 2 units each contain one starting circuit.

The line, connecting, and final selector circuits for 200 subscriber-station lines are mounted

together on one switch rack. This equipment includes 200 line circuits, 2 groups of connecting circuits including the telegraph repeaters and starting circuits, and 2 groups of final selectors. The interconnecting cables for the 200-line unit are located in the base of the switch rack. The cabling interconnecting the different rows of switch racks runs in an enclosed cable rack on the floor of the switch room and interconnecting the bases of the switch racks at their extremities. Figure 15 shows the major part of such a switch rack. Starting from the left are 3 bays of line circuits. The 3 bays that follow are equipped with 2 groups each of 24 final-selector circuits. A group of 24 connecting circuits is mounted on the next 4 bays. All equipment, including the line finders and selectors, is completely covered, both front and rear, to exclude dust.

Figure 16 shows 6 registers mounted on 3 bays. To indicate the arrangement of equipment, the covers have been removed from the apparatus comprising one register. All apparatus units are plug-in. Each register consists of 3 units, the 2 smaller of which are mounted in the upper part

Figure 15—Part of switch rack mounting circuits for 200 subscribers' lines.



of the bay. One of these is the code sender and receiver and the other is the electronic selection control. A larger unit mounted on the lower part of the bay contains the recording and switching relays.

The test apparatus for checking the operation of the code senders and receivers of both registers mounted on each bay are on the center panels just above the 2 large units.

Figure 17 gives a general view of the Amsterdam telegraph exchange. The switch rack in front is equipped with register circuits.

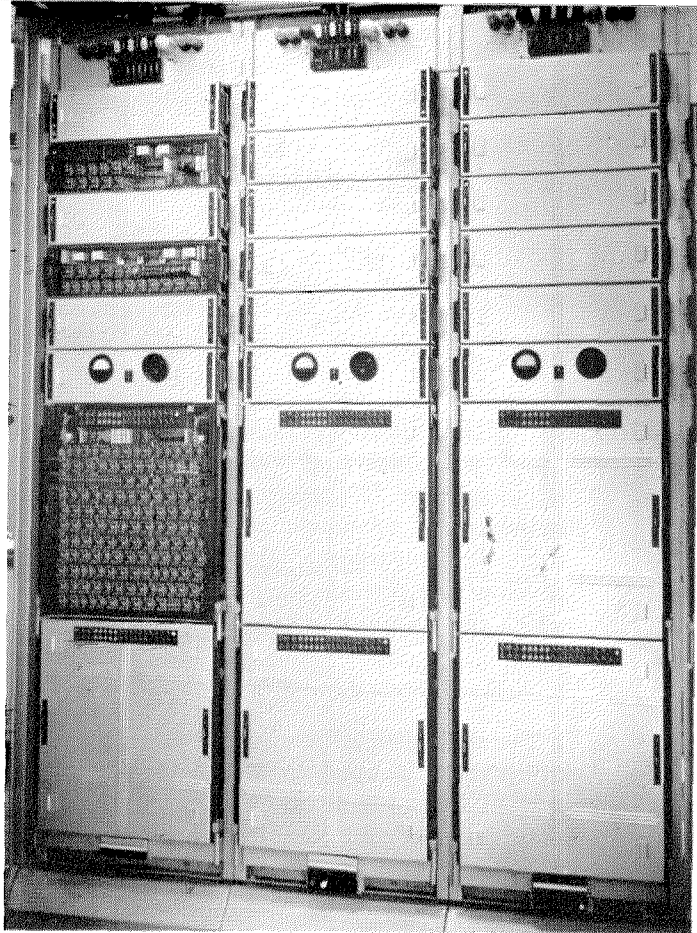
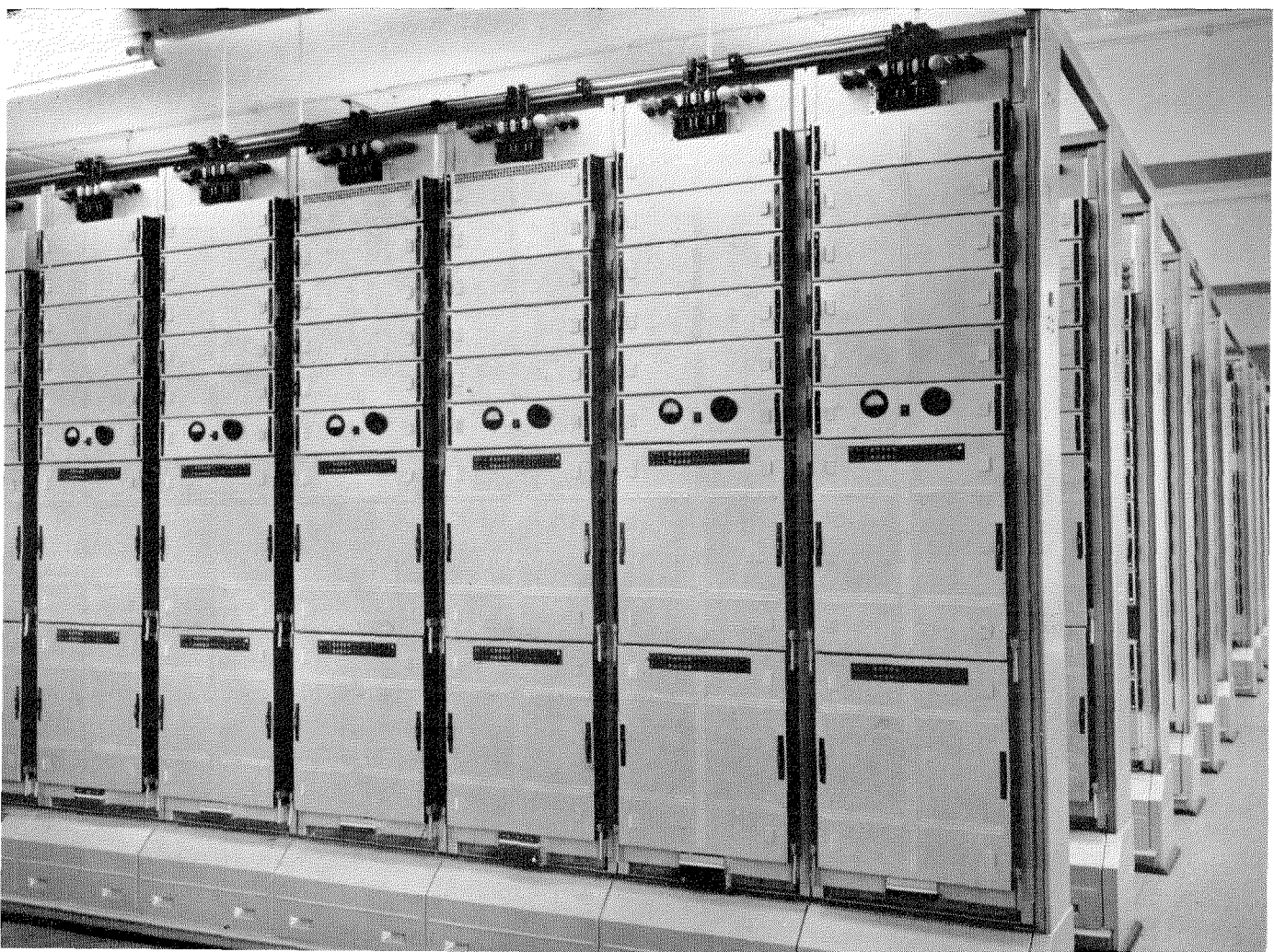


Figure 16—At right, three bays mounting 6 registers. The covers have been removed from one register.

Figure 17—Below is a general view of the Amsterdam telegraph exchange.



Fundamental Circuits of 7E Rotary Telephone Switching System

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PREVIOUS ARTICLES have outlined the principles¹ and the equipment practices² of the 7E rotary system for machine switching of telephone calls. This article will treat the fundamental circuits that have been developed to provide the switching functions on which the system is based.

1. Subscriber's Line Circuit

The subscriber's line circuit utilizes only static equipment, the operating principles of which are evident from Figure 1. On lifting the handset, the subscriber's line circuit between wires *A* and *B* is closed causing a current to flow from ground through *R1*, the line loop, *R2*, *R3*, battery of 48 volts, and ground return. *R3* being equal to *R1* and *R2* in series and the resistance of the subscriber's loop being negligible, conductor *C* assumes a value of -24 volts.

This change of potential on conductor *C* from -48 to -24 volts is transmitted through the miniature metallic rectifier *CR2* to a point that is common to 50 subscribers' lines and to which a call detector is connected. The rectifier prevents the -24 volts at the common point from being impressed on all *C* conductors of the 50 lines in the group, all lines not in calling condition being held at -48 volts by the battery connected to *R3*.

When a 1st line finder starts to hunt for a calling line, its *C* brush is connected via the *B* brush of a 2nd line finder, through the cord circuit, via brush *A* of the cord chooser, to a static circuit at the register, the operation of which is similar to that of the call detector. This circuit is arranged to respond to -24 volts,

¹ M. den Hertog and J. Kruithof, "Principles of 7E Rotary Telephone Switching System," *Electrical Communication*, volume 33, pages 195-219; September, 1956.

² M. den Hertog and J. Kruithof, "Equipment Practices in the 7E Rotary Telephone Switching System," *Electrical Communication*, volume 33, pages 278-307; December, 1956.

which causes relay *FTR* to operate. When hunting starts, contacts *FT1* complete a circuit from ground via brush *B* of the cord chooser, brush *C* of the 2nd line finder, the clutch magnet of the 1st line finder, battery, and ground return. Operation of the clutch magnet causes the brushes of the 1st line finder to wipe over the line terminals until the *C* brush is connected to the *C* conductor of the calling line. The -24 volts on the *C* conductor connected through the register circuit causes relay *FTR* to operate, opening contacts *FT1* that release the clutch magnet to stop the sweep of the brushes of the 1st line finder on the calling-line terminals.

When the calling line is found, a relay not shown in Figure 1 operates and the *C* contact of the 1st line finder is connected to -48 volts through a low resistance and the relay contacts that are shown in the figure. The reapplication of -48 volts to the *C* conductor cancels the calling condition of the subscriber's line and the call detector ceases to function for this call.

Simultaneously, -48 volts is connected through 5700 ohms from the cord circuit via the *D* brushes of both 1st and 2nd line finders to the particular resistance termination that identifies the class of line and that also has the effect of marking the circuit as being busy.

Although *R1* and *R2* remain connected to the subscriber's line, their presence may be neglected for all practical purposes. *R1* is connected to ground and *R2* is connected through 240 ohms to -48 volts. They are in parallel with the windings of the battery-supply and supervisory relays in the cord circuit. They have no effect on the balance and insert a loss of only 0.1 decibel in the speech circuit.

If the line is called, the final selector applies the same potentials to the *C* and *D* conductors as does the 1st line finder when the line originates a call. The line will be marked as busy when the final selector engages it and the closing of the subscriber's line circuit on lifting of the handset

will not affect the call detector because the *C* conductor will be at substantially -48 volts.

The closing of the subscriber's line loop on initiating a call immediately marks the line as busy to all terminating calls. A terminating call will not be connected unless a called line tests free and the line loop is open. This prevents the occurrence of certain difficulties encountered in private branch exchanges provided with automatic out-dialing facilities.

2. Call Detector

A call detector is normally provided for each 50 subscribers' lines. Its function is to initiate the actions whereby a free cord circuit and register are connected to each line as it is placed in the calling condition.

As will be seen in Figure 1, when none of the 50 lines are in the calling condition, the -48 volts at the junction of *R2* and *R3* holds in the nonconducting condition rectifiers *CR2*, *CR3*, and *CR4*, preventing the 450-cycle input to transformer *T1* from reaching *T2*. On the initiation of a call, the voltage at *R2-R3* drops to -24 volts, which is more positive than the -35 volts at the center of the secondary winding of *T1*. The 3 rectifiers become conducting and the 450-cycle output of *T2* ignites the gas-filled cold-cathode trigger tube *V1* and actuates relay *AR*, which starts the line finders hunting for the calling line. When the calling line is found, its *C* conductor is connected to -48 volts through a low resistance and rectifiers *CR3* and *CR4* stop conducting, the 450-cycle voltage is removed from *V1*, which is extinguished when the 50-cycle voltage in its striking circuit goes through zero. This releases relay *AR* and the call detector is ready for the next call.

This arrangement requires no power in the standby condition. The cold-cathode tube operates only while the line finders are searching for the calling line so its life is long; it will be in operating condition for only about 15 minutes in each 24-hour period.

3. Phase Comparator

A simplified form of the phase comparator is shown in Figure 2. The register circuit shown in part at the left acts to control the position of the selector switch.

The clutch magnet of the selector switch is actuated through contacts *WP1* in the register. The contacts over which brush *E* of the selector wipes are connected to 10 phases of a 450-cycle 6-volt source as indicated in the phasor diagram. These connections are not made direct to the selector test terminals but are made through the individual selectors or junctions in the next selection stage to which access is provided and will not be completed unless that stage is free. Similar arrangements have been used with direct-current test voltages in previous systems.

The 10 phases appearing on the selector contacts are also impressed from the same source on 10 contacts in the register, one of which is selected by the dialed digit and is connected to terminal 3 of the autotransformer *T1*. Assuming the digit to be 3, the corresponding phase angle will be 60 degrees as will be evident from the phasor diagram. The application of this phase to terminal 3 with the midpoint, terminal 2, being grounded, produces at terminal 1 of *T1* a 6-volt alternating-current potential having a phase angle of 240 degrees. There will be 12 volts between terminals 1 and 3. This 12 volts is impressed across *R1* and winding 4-5 of transformer *T2*. As *R1* and winding 4-5 are equal in impedance, the junction between them *S* is at ground potential.

Conductor *E* from the selector will be at ground potential when it is on a busy terminal or between two adjacent terminals.

Transformer *T2* has a step-up ratio of approximately 30 and the 6 volts across 4-5 produce about 180 volts across 6-8. The midpoint of the secondary, terminal 7, is connected to -150 volts. If the potential between terminals 6 and 8 exceeds its breakdown value of approximately 70 volts, *V1* will ionize. The ionization current is limited by *R2* and *R3* to produce a sustaining potential across the two cathodes of about 60 volts. Under these conditions, one of the cathodes will be at $-150 - (60/2) = -180$ volts and the other will be at $-150 + (60/2) = -120$ volts with respect to the anode. Regardless of the voltage between terminals 6 and 8, the tube conductance will adjust to stabilize the voltage from cathode to cathode to 60 volts. Half of the surplus voltage

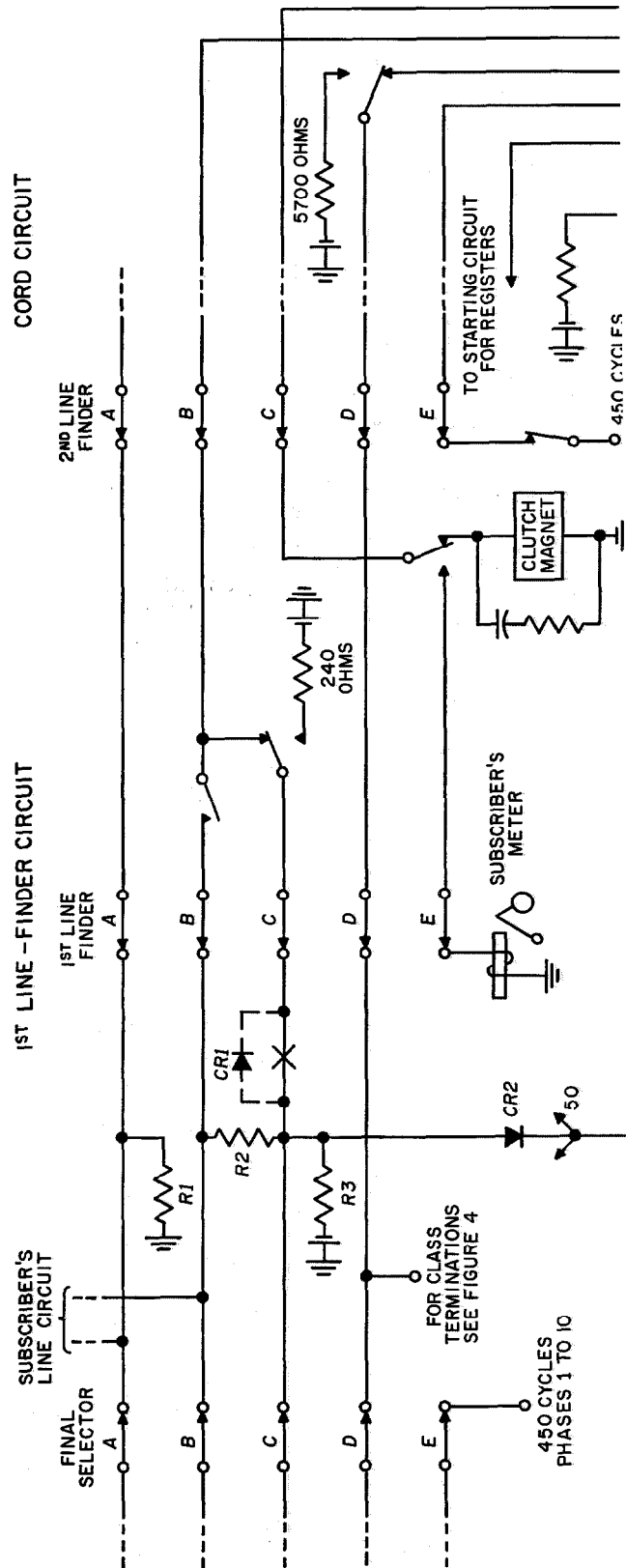
is absorbed in $R2$ and half in $R3$. As the polarity of the voltage across θ and δ changes, the two cathodes alternate between -180 and -120 volts.

When $V1$ is ionized, a current flows from the -180 -volt cathode via the cathode-anode gap and $R4$ to ground. As the sustaining voltage across the cathode-anode gap is approximately 75 volts, the anode will be maintained at $-180 + 75 = -105$ volts. $C1$, which is shunted across $R4$, will be charged to this voltage while the tube is ionized and will discharge only slightly during periods between frings as $R4$ is 6 megohms.

It is evident that $V1$ acts as a full-wave rectifier and as a voltage stabilizer. It maintains a direct voltage of -105 volts at its anode as long as sufficient 450-cycle voltage is applied to its cathodes to cause ionization. The -105 volts across $C1$ is applied to the trigger electrode of $V2$, the cathode of which is connected to -130 volts. The 25 volts across the control gap of $V2$ will not ignite the tube and relay WPR is not actuated, its contacts $WP1$ remain closed and the selector clutch is energized to drive the selector. Thus the selector brush E wipes over the terminals and sequentially connects the potentials found on each terminal to the comparator at S .

If the brush touches terminal 1 of the selector and it is free, an alternating voltage of 6 volts and zero phase angle will be impressed on point S of the comparator via an impedance that is low compared to that of $R1$ or winding 4-5. There is now impressed across winding 4-5 of $T2$ alternating voltages having phase angles of 0 and 60 degrees. The resulting voltage is shown by the broken lines of the phasor diagram and has a value of 6 volts. From this it may be concluded that only the phase angle changes in $T2$; all other conditions remain unchanged as compared with the condition when brush E is open. The comparator does not respond and the selector brush continues to rotate.

If the brush now passes to a free outlet of group 2, the winding 4-5 of $T2$ will be connected to 30- and 60-degree phase angles. The resulting potential is indicated in the phasor diagram by the broken line between the 30- and 60-degree phase angles. This produces a root-mean-square voltage across winding 4-5 of slightly over half



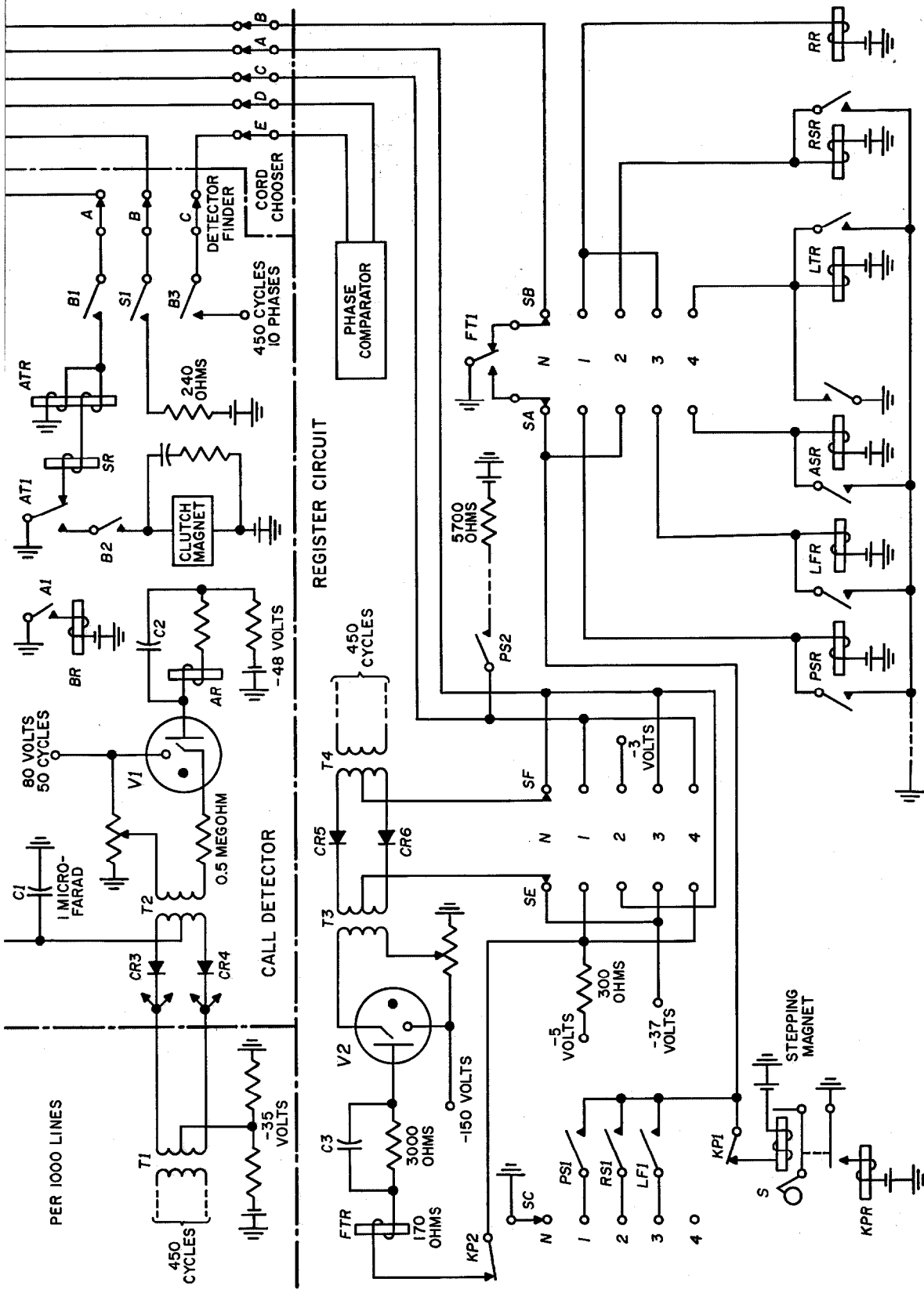


Figure 1—Subscriber's line circuit including call detector to demonstrate method of testing a calling line.

the source voltage, or approximately 3 volts. This is still adequate to maintain *V1* ionized and the selector continues to rotate.

When the selector brush encounters a free outlet of group 3 to which the 60-degree phase is connected, equal potentials will be connected to terminals 4 and 5 of *T2* and no current will flow in the winding. This removes the alternating voltage from the cathodes of *V1*, which then assume the -150 volts connected to terminal 7 of *T2*. As the anode is maintained at -105 volts by the charge on *C1*, the anode-cathode voltage is only 45 volts and the ionization is extinguished. *C1* discharges through *R4*, bringing the trigger of *V2* to ground potential. *V2* then ionizes, producing a current in its cathode-anode gap to actuate relay *WPR* and open contacts *WP1* and stop the selector.

The circuit components have been chosen to permit the brush of the selector to continue moving for 7 milliseconds after the *E* brush touches the desired terminal. At a rate of 60 steps per second, the additional movement brings the brush to the approximate center of the terminal, ensuring a safe and reliable contact.

As the phase comparator responds only when the reference and test potentials have identical characteristics (within certain limits), the characteristic sources may differ in phase, amplitude, or frequency, or a combination of these three properties. Potential sources differing in two such properties, such as phase and amplitude, have been used in the *7E* system. Some sources have equal amplitude and varying phases as in the case described and others may have equal phases and varying amplitudes.

3.1 OPERATING LIMITS

From the data given in section 3, the operating limits of the phase comparator may be determined.

3.1.1 Undesired Voltage-Phase Characteristic

The comparator will not respond if the voltage across winding 6-8 of *T2* is sufficient to ionize *V1* across the two cathodes. This requires approximately 70 volts. A root-mean-square value of 49.5 volts produces a peak value of 70 volts. The minimum sustaining peak value of 60 volts is

produced by a root-mean-square value of 42.5 volts. Ionization at the peaks of such a voltage will keep *C1* charged and prevent *V2* from igniting.

With a voltage step-up of 30 in *T2*, a root-mean-square voltage of $49.5/30 = 1.65$ will ignite *V1*. The comparator will not respond unless the difference between the reference and test voltages is less than 1.65 root-mean-square volts. The minimum voltage difference produced under nonoperating conditions occurs when the reference and test voltages differ by 30 degrees and is equal to 3.12 volts. Thus, the limit of operation is reached when this minimum nonoperating voltage drops to 53 percent of its normal value. The limits may be specified in several ways as follows.

A. The phase angle of 30 degrees separating the adjacent places producing the minimum nonoperating current value must be reduced to about 16 degrees before that minimum will cause operation.

B. The normal 6-volt root-mean-square voltage must drop to 3.25 volts before a false operation occurs when the test and reference voltages are within 30 degrees of each other.

C. The resistance of the lead from the comparator to the selector can be increased to about 800 ohms, or slightly less than the impedance of the comparator, before failure occurs. The presence of contact resistance of this magnitude will not be damaging.

The actual voltage of the multiphase 450-cycle source is maintained within 10 percent of 6 volts so that the maximum margin is provided for the other two characteristics of the system, phase and resistance.

3.1.2 Desired Voltage-Phase Characteristic

The maximum difference between the reference and test voltages that will still cause the comparator to respond are root-mean-square values of 49.5 volts across terminals 6 and 8 and 1.65 volts between 4 and 5. So long as the difference between reference and test voltages applied to *T2* is less than 1.65 volts, the comparator will

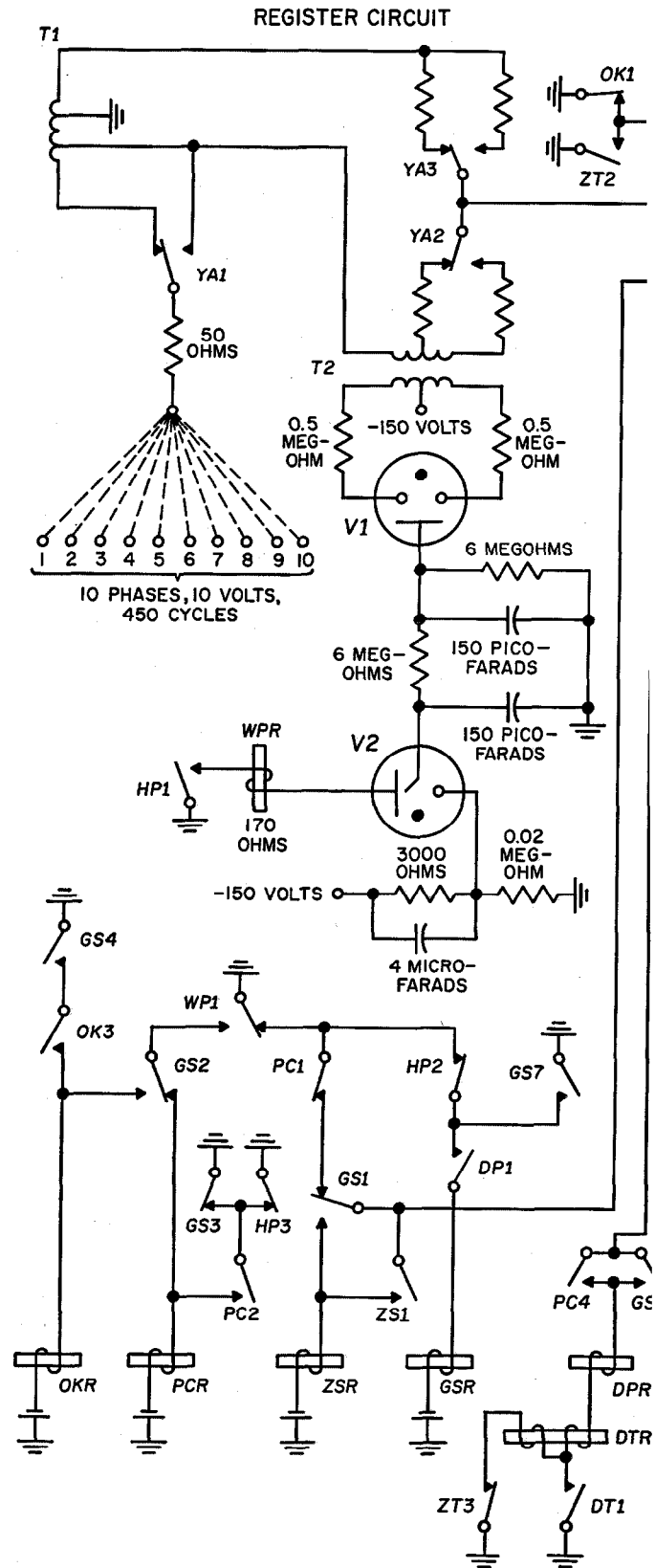
over the outlets of the next selector on its right, connecting the voltage-phase conditions found over *A4*, *B2*, and conductor *B*, to *YA2* in the register.

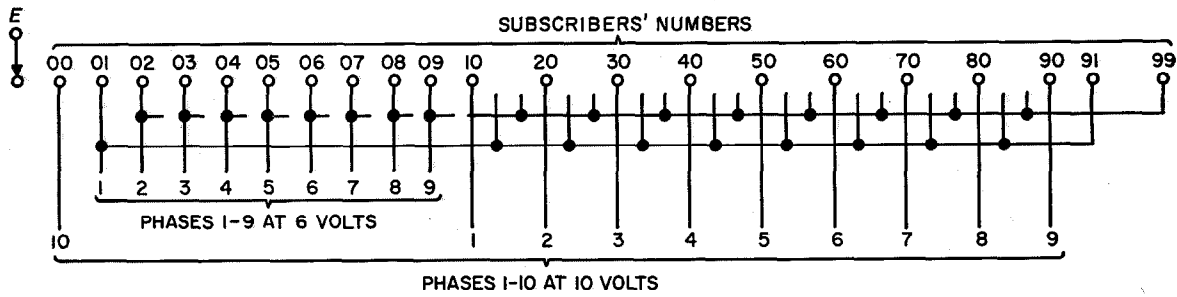
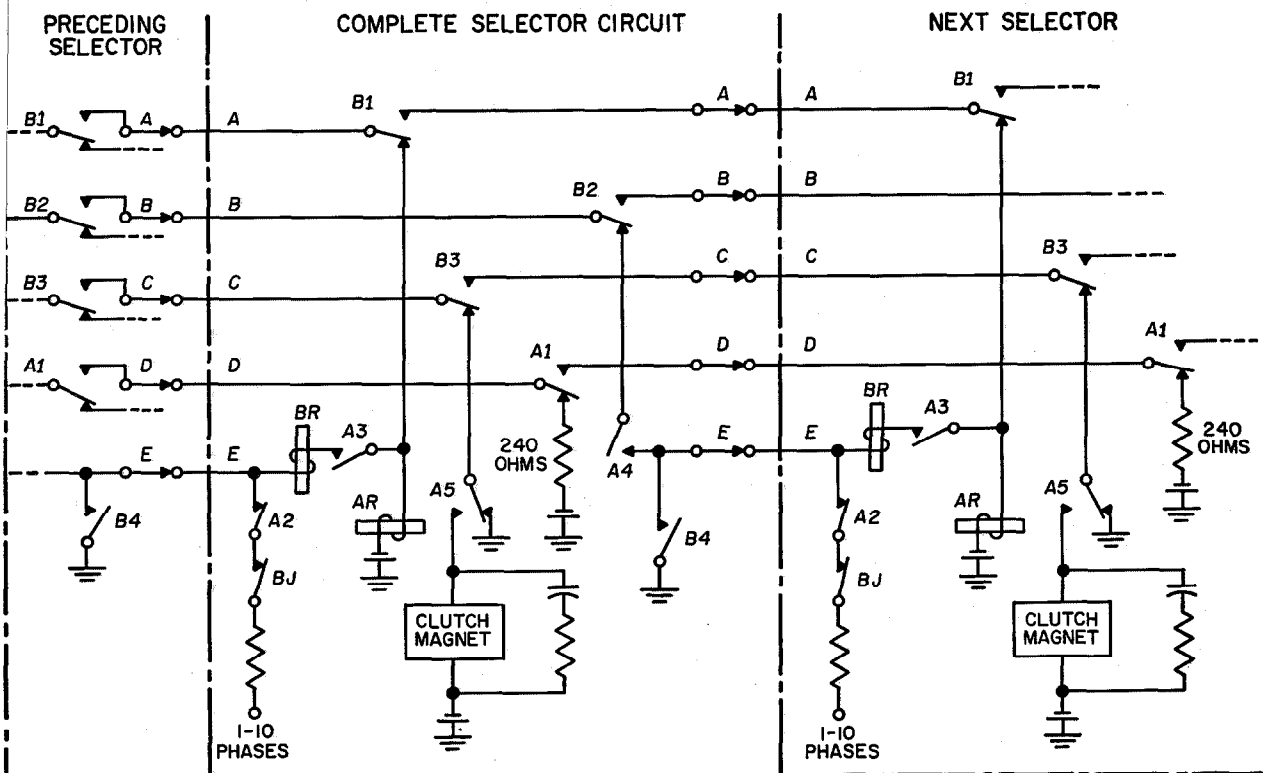
When a free selector having the required voltage-phase characteristic has been found, *V2* in the comparator ignites and operates *WPR* to stop the rotation of the selector by opening *WP1*. The transfer of *WP1* contacts operates relay *PCR*, which locks in this condition by means of *PC2* and *GS3*. This operation also opens *PC1* to prevent the clutch magnet from being energized later through *WP1*. The opening of contacts *PC3* releases relay *HPR*, which was previously actuated when the digit controlling the selection was received in the register. Its closing of *HP1* completed the circuit of *WPR* to ground. The release of *HPR* opens *HP1*, which extinguishes *V2*, and this releases *WPR*. *PC1* having opened, the release of *WPR* does not start selector rotation again.

Contact *PC4* closes, connecting the double-test relays *DTR* and *DPR* over conductor *D*, contacts *A1* in the next selector, 240 ohms, to battery. Relay *DTR* will operate only if the next selector being tested offers the "free" battery voltage and in a well-known manner prevents simultaneous seizure of a free selector by two hunting selectors.

Closing of *DT1* introduces the low resistance into the test circuit, definitely engaging the selector chosen and operating relay *DPR*. The closing of *DP1* operates *GSR* via *HP2* and *WP1*. The comparator will now check for the second time to insure that the wanted voltage-phase characteristic has been found. *GS6* closes to operate *HPR* and the closing of *HP1* grounds the anode of *V2* through *WPR*, permitting *V2* to ionize again. If the reference and test voltage-phase characteristics are still the same, the comparator functions again.

Make contact *WP1* has been switched over by *GS2* to relay *OKR*, which operates if this second comparison test is successful. Relay *OKR* locks to ground via the front contacts of *OK3* and *GS4*. The actuated *OK2* releases relay *HPR*, which in turn causes release of *WPR*. Conductor *A* is disconnected from ground by the opening of *OK1*, permitting relay *BR* in the group selector under consideration to operate in series with *AR*





CONNECTIONS OF ALTERNATING VOLTAGES IN FINAL-SELECTOR TEST MULTIPLE

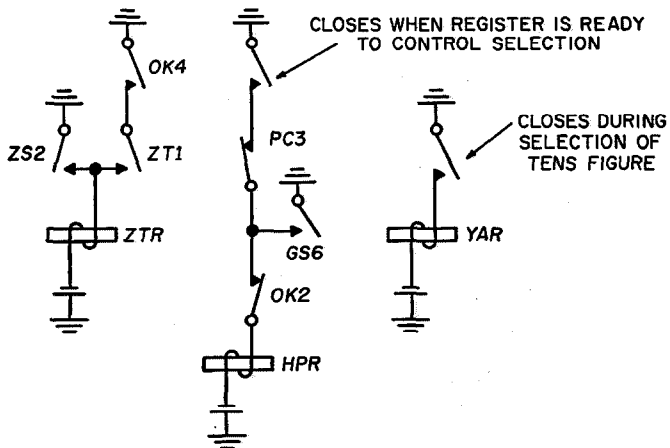


Figure 3—Selector circuit and selection control.

through a ground on the *E* brush in the preceding selector. The operation of *B3* in the selector under consideration, places ground on conductor *C* via *B3* and *A5* of the next selector. The ground on conductor *C* via *GS1* in the register operates *ZSR*. This informs the register that *BR* has been energized. Contacts *ZS2* now operate *ZTR* and *ZT2* replaces ground on conductor *A*. *ZTR* locks closed via *ZT1* and *OK4*.

The grounding of conductor *A* operates relay *AR* in the next selector, which signals to the register by opening contacts *A1* to remove battery through 240 ohms from the *D* conductor and thus release *DTR* and *DPR*. The breaking of contacts *A5* removes ground from the *C* conductor to release *ZSR*. Opening of *A2* disconnects the characteristic voltage-phase source from the *E* conductor.

The release of *DTR*, *DPR*, and *ZSR* in turn through their contacts release *GSR* through *DP1*, *OKR* through *GS4*, *ZTR* through *OK4*. *PCR* was released during the second comparison when its holding circuit was opened by breaking of *HP3* and *GS3*.

The register circuit now assumes the original condition at the beginning of the operation just described, being connected via four metallic conductors to the selector just engaged. Ground, via conductor *A*, permits *AR* in the selector under consideration to be energized. By opening *ZT2* after *OK1* makes, ground is maintained uninterruptedly on conductor *A*.

5. Final Selector

The circuit of the final selector is nearly identical to that of the group selector and its operation will be described with reference to Figure 3. The 100-point final selector performs two consecutive selections controlled by the dialed tens and units digits. The voltage-phase sources controlling the selection are connected to the *E* terminal of each outlet as indicated in the center of Figure 3.

Every tenth *E* terminal of the 100-outlet switch is connected to a 10-volt source having phase angles corresponding to the 10 digits with phase 10 for 0. The intervening 9 terminals are connected to 6-volt characteristic phases.

The dialed tens selection is made first by causing the final selector to hunt for the desired first terminal of the decimal group. Having

found the required tens position based on the 10-volt source, the search continues over the next 9 terminals for the desired units outlet under control of the 6-volt source. If the units figure is zero, that selection is suppressed and the brush stays on the tens terminal that corresponds to the zero units position.

For simplicity, only a 10-volt source is employed in the register. Relay *YAR* in the register controls the operating voltage. Contacts *YA1* select the end of the winding of autotransformer *T1* for the 10-volt input against ground to produce 6 volts across the output windings or the tap position to develop 10 volts each side of ground. The resistors selected by *YA2* and *YA3* adjust the voltage across the primary of *T2* so that under both 6- and 10-volt operation, the secondary voltages are the same for the control of *VI*.

When a tens selection is to be made, *YAR* is operated by the register and sets the comparator for 10-volt operation and the phase corresponding to the dialed digit is connected to *T1*. The selector rotates and ignores all 6-volt outlets regardless of phase. It stops at the terminal that has a 10-volt phase that matches that connected to *T1*. In this case, the register conditions differ from those for group-selector operation in that the operating ground for *AR* in the final-selector stage is maintained closed over conductor *A* and prevents *BR* from being energized.

The units selection is then made by releasing *YAR* to produce the 6-volt condition in the comparator and connecting the proper phase to *T1*. The comparator will now respond only to a 6-volt test source of the required phase, which will be found in the next 9 terminals unless the digit is zero. In the latter case, the units selection is suppressed as the brush has stopped on the zero units terminal which is also the tens terminal.

6. Discussion of Selector Circuits

The following points are significant with regard to the operation of the selector circuits described in sections 4 and 5.

A. Each selector utilizes only two relays and neither of these requires special adjustments or must meet any critical current or timing limits.

B. The switching operations are extremely simple, one relay, *AR*, being energized by ground being applied to the *A* conductor and the second relay, *BR*, being actuated by opening this ground connection and causing both relays to lock in series with each other. The selector circuit is released by interrupting this locked ground and the circuit is free to handle the next call.

The selector switch does not return to a normal or home position but stays at the terminals at which it was last used. This reduces holding time of the selector on each call and saves appreciably on wear and tear. The switches average only 15 terminals of motion per call.

C. The selectors are controlled on a compulsory-sequence-operation basis. No new operation can occur until the preceding function has been completed and checked.

As an example, selection will not be started by the register until it has determined that the *AR* relay of the selector to be controlled has operated on ground connected via conductor *A*. Actuation of *AR* removes ground from conductor *C* and battery from *D*, which conditions are checked by the register. When the ground is removed from conductor *A* by the register to cause *BR* to operate, the reappearance of ground on the *C* conductor from the next selector is checked. Only then will ground be reconnected to conductor *A* to operate *AR* in the next selector just engaged. This ensures that ground is removed from the *A* wire just long enough for *BR* to operate, assuring safety of operation in minimum time.

Compulsory-sequence operation is utilized throughout the switching system to provide a high degree of reliability and complete freedom from timing relations. Faults caused by selector circuits practically never occur.

All local group selectors, final selectors, and first line finders operate in a similar manner and each contains these two relays. Their relays are mounted in jack-in units that may be used with any of the circuits. As these circuits constitute the majority of the exchange equipment, the use of simple, uniform, interchangeable units leads to great simplification in manufacture, installation, and maintenance.

7. Test of Calling Line

As was described in a previous paper,¹ the originating register controls the hunting of the first line finder to locate the calling line. After the line finder has stopped on the calling line, the register tests to determine the class of line and other conditions.

Figure 1 shows the essential circuits required to connect a calling line to a free cord and register. As soon as a free first line finder in the wanted group has been selected, the register takes control of the hunting operation. In this initial condition, a small step-by-step marking switch *S* stands in the normal position *N*.

There are five brushes on the step-by-step marking switch. Brushes *SE* and *SF* are connected to a static switching circuit that operates if the voltages and their polarities connected to *SE* and *SF* cause the metallic rectifiers *CR5* and *CR6* to conduct. The terminals contacted by these brushes go to the various circuits that are to be tested. Conduction of the switch operates relay *FTR* that is connected to brushes *SA* and *SB* to perform the switching functions dictated by the results of the tests. The fifth brush *SC* is concerned with the stepping of the marking switch from one position to the next position.

In the normal position, brush *SB* of switch *S* connects ground through *FT1* via conductor *B* of the cord circuit, brush *C* of the second line finder to the clutch magnet of the first line finder, starting its rotation.

The test wiper *C* of the first line finder consecutively connects the *C* conductors of the subscribers' lines via brush *B* of the second line finder, brush *A* of the cord circuit, brush *SF* of the step-by-step switch to the midpoint of the secondary winding of *T4*. Subscribers' lines that are in the free condition are at -48 volts through *R3*. As the center tap of *T3* is at -37 volts, rectifiers *CR4* and *CR5* prevent any current flow through this circuit.

The calling line, by bridging conductors *A* and *B*, has reduced the voltage on the *C* wire to -24 volts, which is more positive than the -37 volts on *T3* and rectifiers *CR5* and *CR6* conduct. The 450-cycle voltage across the primary of *T4* now appears across the secondary of *T3* and causes *V2* to ionize, actuating *FTR*. This opens contacts *FT1* and stops the finder switch on the

calling line. The make contact of *FT1* energizes the stepping magnet of *S* bringing it from position *N* to *1*. In this operation, the stepping magnet pulses *KPR*, which extinguishes *V2* by opening *KP2*.

In position *1* of switch *S*, a check is made that ground is on the *D* conductor of the calling line. This is necessary to ensure that the first line finder is properly centered on the calling line's terminals as the *D* brush of the line finder is narrower than the others. The ground is necessary later to detect lines that are in the absentee condition. It also is used to prevent two finders from seizing the calling line simultaneously.

Assuming the subscriber's *D* wire to be grounded, this condition will be transmitted via brushes *D* of the first and second line finders, brush *C* of the cord circuit, brush *SF* of switch *S* in position *1*, the secondary of *T4*, rectifiers *CR5* and *CR6*, the primary of *T3*, brush *SE* of switch *S*, a resistance of 300 ohms to -5 volts. This current operates the static switch to ionize *V2* and actuate *FTR*.

This happens so rapidly that the circuit putting ground on relay *RR* through brush *SB* in position *1* and *FT1* is opened before *RR* can operate; *FT1* then actuates locking relay *PSR* through brush *SA* in position *1*.

The current through *FTR* also passes through the 300 ohms between *SE* brush in position *1* and -5 volts, increasing the voltage at *SE* to about -10 volts, which is impressed on the subscriber's *D* conductor. If another first line finder should arrive at this line at the same moment, the static switch in the register of the newly arrived finder would be prevented from operating because the *D* conductor will be more negative than the -5 -volt reference voltage in the register before *V2* ionizes.

If two finders should arrive at a calling line at exactly the same instant, there would be a slight difference in the operating times of the two static switches; one would lead the other and prevent it from seizing the line. The difference in operating times of the static switches is enhanced by connecting them to the 12 different phases of the 450-cycle source used for controlling selection.

The operation of *PSR* causes it to lock and applies -48 volts to the *D* conductor of the subscriber's line, making it busy to all other

calls. This circuit is from -48 volts, 5700 ohms, contacts *PS2*, brush *C* of the cord circuit, and brushes *D* of the second and first line finders to the subscriber's line conductor *D*. This busy condition is independent of the initial busying caused by the firing of *V2* in position *1* of switch *S*. In addition, the closing of contacts *PS1* steps the switch *S* to position *2*, extinguishing *V2* through the momentary operation of *KPR*.

In position *2* of switch *S*, a test is made to determine if rectifier *CR1* is in the *C* conductor of the subscriber's line, which indicates it to be of the restricted-service class.

If *CR1* is not present, the -24 volts at the junction of *R2* and *R3* is applied to the static switch through brush *SE* of the stepping switch *S* to operate against -3 volts on brush *SF*. The reference voltage of -3 being more positive than the -24 volts on the *C* wire, the rectifiers *CR5* and *CR6* conduct, *V2* ionizes, *FTR* operates to step switch *S* to position *3*, extinguishing *V2* via *KPR*.

If *CR1* is present, it is connected in opposing polarity to *CR5* and *CR6* so the static switch will not operate. Instead, *RSR* will operate through *FT1* and brush *SB* in position *2*. This relay locks. Contacts *RS1* actuate the stepping switch to position *3* while locked *RSR* records the restricted class of the connected subscriber's line.

Position *3* of switch *S* connects the static switch through brushes *SE* and *SF* as in position *N*. The switch operates immediately confirming that the first line finder actually is connected to a line in the calling condition. Switch *S* then advances to position *4*.

The absentee condition of the line is determined in position *4*. The *D* wire of a subscriber's line in the absentee condition is grounded. If it is not in the absentee condition, there will be a resistance between the *D* conductor and ground, the value of resistance being set by the class of line as indicated in Figure 4.

Contacts *PS2* (*PSR* was locked in position *1*) apply -48 volts through 5700 ohms to conductor *D*. If wire *D* is grounded for the absentee condition, the battery produces no voltage on brush *SF* in position *4* and the static switch operates on the -5 volts applied to brush *SE* in position *4*. This ignites *V2* and operates *FTR*.

Locking relay *ASR* operates through brush *SA* in position 4 and *FT1*.

If not in the absentee condition, the *D* conductor of the subscriber's line will have 1000 ohms or more, depending on its class, in series with the ground. The battery and 5700 ohms are in series with this resistance and for the 1000-ohm inserted resistance, produce a negative voltage of about -7 volts on conductor *D* of the line finders. This -7 volts on brush *SF* in position 4 is more negative than the reference -5 volts on brush *SE* and the static switch does not operate. Relay *LTR* then operates and locks through brush *SB* in position 4 and *FT1*. The operation of *LTR* concludes the test of the calling line. In the absentee condition, a make contact on *ASR* will also operate *LTR* to conclude the test.

The operation of *LTR* does a number of things not shown in Figure 1. Relays in the cord circuit and first line finder place -48 volts through a low resistance on the *C* conductor of the subscriber's line to release the call detector, -48 volts is applied through 5700 ohms to the *D* conductor in the cord circuit to render the line busy independently of the register, and the subscriber's message register is connected via brush *E* of the first line finder, brush *C* of the second line finder, and brush *B* of the cord chooser to the register. Through equipment not shown in Figure 1, the register tests the continuity of this circuit and at the same time tests the operation of the relay at the first line finder.

Switch *S* remains in position 4 until the called line has been selected.

8. Test of Called Line

Figure 4 shows the arrangements for determining the class of a called line and the operation involved in hunting over lines for private branch exchanges. Much of the equipment has already been described in part in Figure 3.

The step-by-step switch *S* is in position 4, where it was on completing the testing of the calling line. It is further assumed that the drawing represents conditions at the moment after the final selector under the control of the register has stopped on the subscriber's line corresponding to the dialed number. The register and the final selector are metallically connected

over conductors *A*, *B*, *C*, and *D*, passing through all intermediary switches, which are not shown in the figure.

8.1 CALLED LINE FREE

On completion of the selection of the called line, the static switch is connected via brushes *SE* and *SF* in position 4, respectively, to a reference voltage of -5 and to the *D* conductor of the called subscriber's line. The line being free, its *D* wire is grounded and the static switch operates to actuate *FTR*. Contacts *FT1* through brush *SA* operate locking relay *PHR*.

As when testing the calling line, the anode current of *V2* passing through the 300 ohms in series with the -5 -volt reference source renders the line busy to other calls and precludes its seizure by another selector.

Closing of *PH3* contacts places -48 volts in series with 5700 ohms on the *D* conductor to continue it busy regardless of further operation of switch *S*. *PH2* actuates the step-by-step magnet advancing switch *S* to position 5 and extinguishing *V2* through the pulsing of *KPR*.

In position 5, the *D* conductor is tested again, but it now has -48 volts through 5700 ohms on it. The conditions are similar to those of position 4 when testing the calling line and the static switch will operate only if the *D* wire of the subscriber's line is directly grounded, which is the absentee condition.

If the line is not in the absentee condition, *FT1* through actuated contacts *PH1* will operate *ODR*, which locks, and also operates *DMR* through *OD1*. *OD3* and *OD4* connect conductors *A* and *B* to ground via 2000 ohms and to -48 volts through 500 ohms, respectively. *DM4* connects conductor *B* to the static switch, which is also connected to a reference voltage of -43 volts through *DM5*. If now the *B* conductor is negative with respect to -43 volts, the static switch will conduct. This condition requires that the subscriber's loop be open and this condition exists if the subscriber is not making a call.

If the subscriber was not making a call when or shortly before his line was seized by the final selector, the static switch will conduct, *V2* will ignite, and *FTR* will operate. *FT1* through *DM1* will actuate *SFR*. This indicates that the

called line is free and ringing current is applied to conductors *A* and *B* through contacts *SF1* and *SF2*. Although not shown in Figure 4, *SFR* also causes the cord circuit after a short delay to apply interrupted ringing current to the subscriber's line. This delay serves to maintain the pulse of immediate ringing current for a suitable time.

Nonoperation of the static switch indicates that the selected subscriber's line is busy. *FT1* through *DM2* causes *SBR* to operate and lock. This relay causes the cord circuit to apply busy tone to the calling line.

8.2 CALLED LINE BUSY

8.2.1 Single or Intermediate Private-Branch-Exchange Line

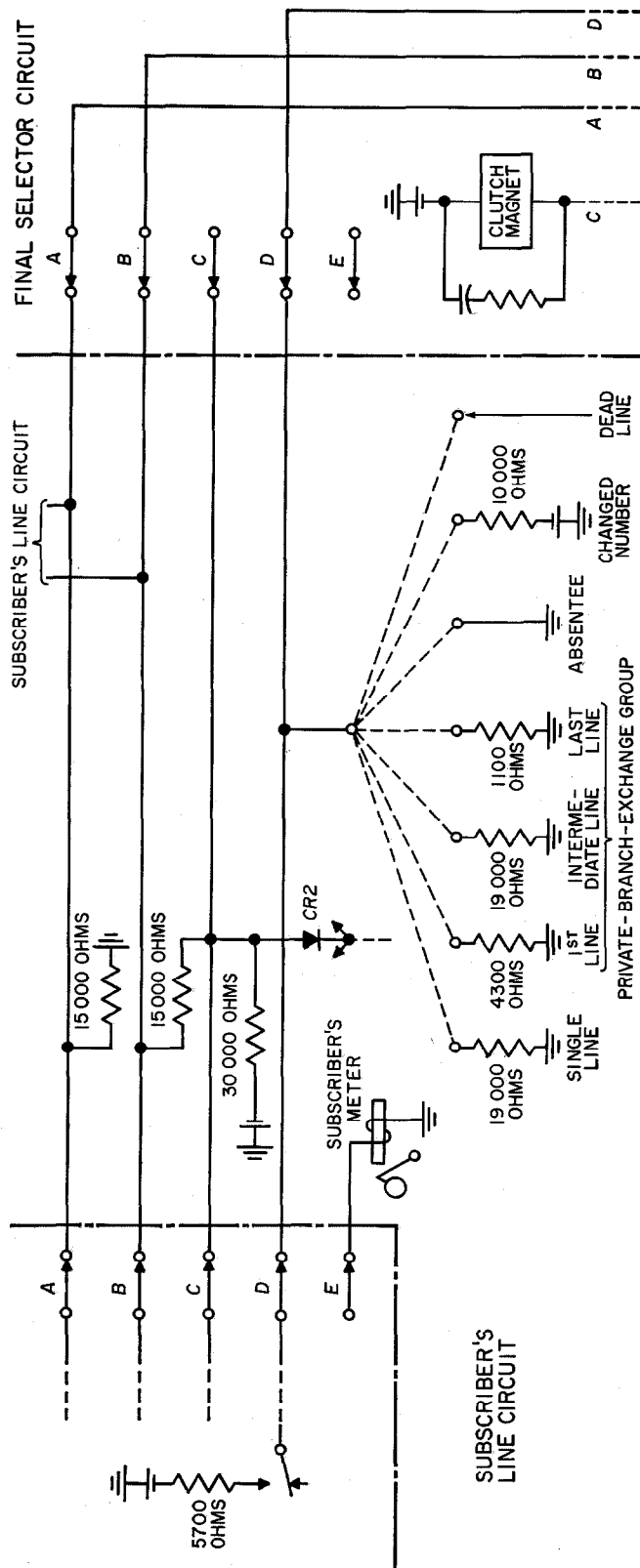
Assuming the called line to be busy, the failure of the static switch to operate in position 4 of switch *S* results in the operation of the stepping magnet for *S* through *FT1* and brush *SB* in position 4.

The circuit conditions in position 5 are identical with those of position 4 provided *PHR* has not operated. Consequently, switch *S* steps immediately to position 6.

In position 6, conductor *D* is tested to determine if it is a busy single or private-branch-exchange line. As will be seen in the subscriber's line circuit of Figure 4, a single line and an intermediate private-branch-exchange line are identified by having their *D* wires connected to ground through 19 000 ohms. As the busy condition has placed - 48 volts through 5700 ohms on the *D* conductor, the resulting voltage on the *D* wire is - 37 volts.

In position 6, the static switch is connected to the *D* conductor and a reference voltage of - 17.4 and will operate only if the *D* wire is positive with respect to the reference voltage. For the conditions assumed, the static switch will not operate. Instead, switch *S* is stepped to position 7 through *FT1* and brush *SB*.

Identical conditions exist in position 7 as in position 6, except that the reference voltage is - 34.2. Once more the static switch fails to function and switch *S* goes to position 8 and a reference voltage of - 46.1. This reference voltage is more negative than the - 37 volts on the *D* conductor and the static switch



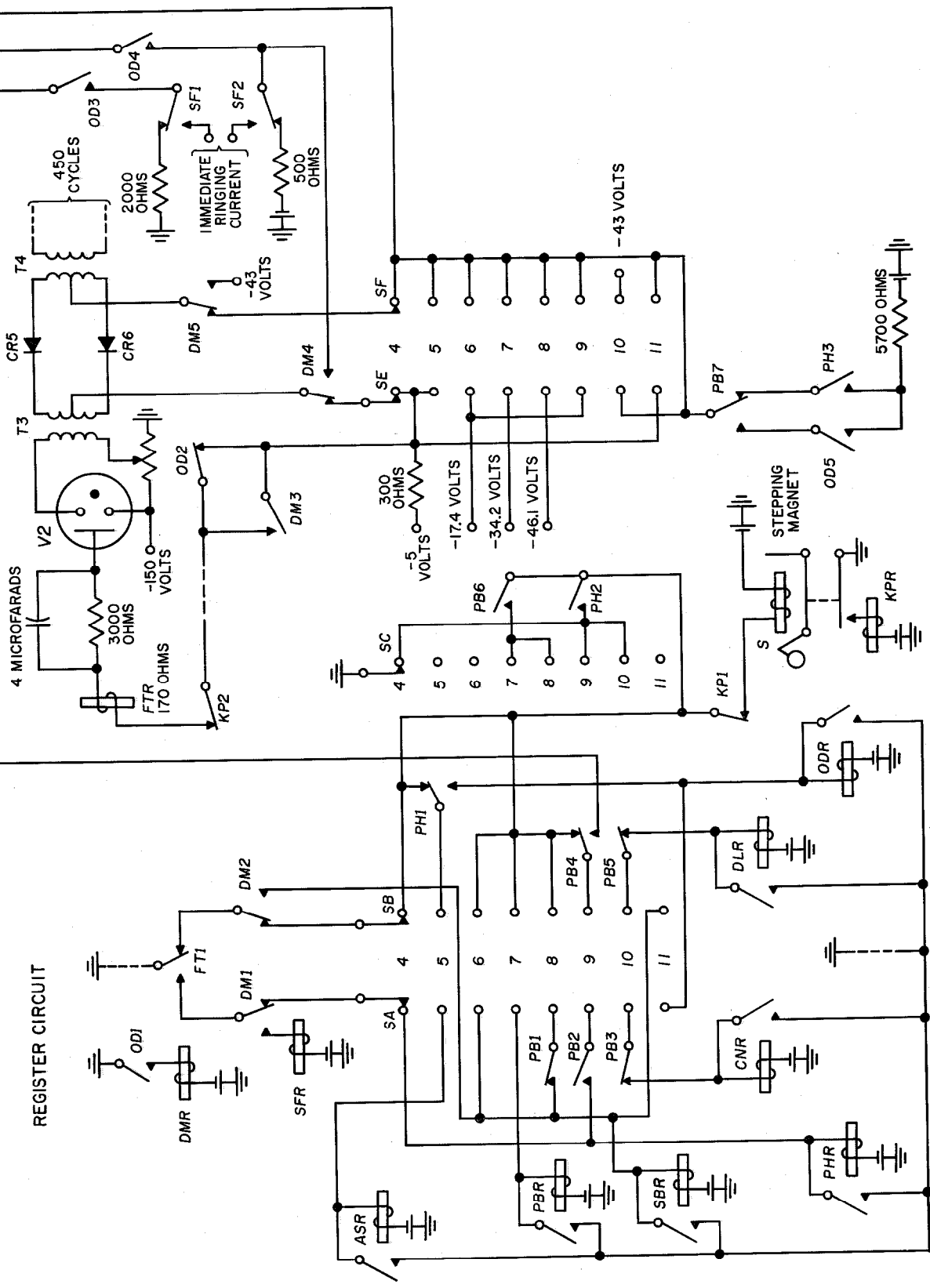


Figure 4—Determination of class of called line and hunting operations for private branch exchanges.

conducts, operating *FTR*. *FT1* through brush *SA* in position 8 operates and locks *SBR*.

Operation of *SBR* indicates that the line is busy and does not require private-branch-exchange hunting (it is not the first private-branch-exchange line). Through circuits not shown in Figure 4, *SBR* causes the cord circuit to supply busy tone to the calling line and all selectors employed in switching the connection to the called line are set free.

8.2.2 First Private-Branch-Exchange Line

The first or directory number of a private branch exchange is characterized by having its *D* conductor grounded through 4300 ohms. When busied from -48 volts through 5700 ohms, the resulting voltage is about -21 volts.

The static switch will not operate until the *D*-conductor negative voltage is lower than the negative reference voltage. This occurs at position 7 of switch *S* and *FT1* through brush *SA* in position 7 actuates *PBR*, which locks. *PB6* applies ground from brush *SC* in position 7 to the stepping magnet, advancing switch *S* to position 8 and then to position 9. The operation of the static switch in position 8 has no effect because *PBR* has operated. In stepping to position 9, *V2* is extinguished by *KP2*.

In position 9, the reference voltage is again -17.4 and the static switch does not conduct. The ground on *FT1* is applied via brush *SB* in position 9 and actuates *PB4* to conductor *C* and the clutch magnet of the final selector to initiate hunting for a free line.

8.2.3 Hunting for Free Private-Branch-Exchange Line

As previously noted, free lines have their *D* conductors grounded and the final selector switch will wipe over the terminals of all lines constituting the private-branch-exchange group until it finds a free line or arrives at the last line in the group. When a free line is met, the static switch conducts, *FTR* operates, and the clutch magnet circuit is interrupted to stop the selector on the free outlet. The static switch will not operate on the busy lines as their *D* wires are at -37 volts. It will stop on any free intermediate or last line of a private-branch-exchange group as, being grounded, they are positive with

respect to the -17.4 -volt reference value in position 9.

When *FT1* operates through brush *SA* in position 9, *PHR* is actuated and locks. This advances switch *S* to position 10 through brush *SC* in position 9. The position-10 contacts for brushes *SA* and *SB* are now open through the operation of *PBR* and its contacts *PB3* and *PB5*, so operation of the static switch has no effect. Switch *S* is stepped to position 11 by brush *SC* on contact 10 and closed *PH2*.

In position 11, the static switch is referred to -5 volts through 300 ohms. When testing the free grounded *D* wire on which the selector has stopped, the static switch operates and the anode current of *V2* flowing through the 300 ohms guards the line against seizure by any other selector. *FT1* through brush *SA* in position 11 actuates *ODR*, which locks, and this actuates *DMR*. Contacts *DM4* and *DM5* connect the static switch to the subscriber's *A* and *B* conductors and a -43 -volt reference voltage. If the loop is closed by the initiation of a call by the subscriber at this moment, about -10 volts appears at *DM4* and the static switch does not operate. If the subscriber's loop is open and the line is therefore free, the full -48 volts through 500 ohms through *SF2* appears at *DM4* and the static switch conducts. Operation of *FT1* energizes *SFR* and immediate ringing is applied to the subscriber's line.

8.2.4 All Private-Branch-Exchange Lines Busy

When the final selector is caused to hunt for a free line in a private-branch-exchange group in position 9 of switch *S*, the static switch will respond to any negative voltage on the *D* conductor that is positive with respect to -17.4 volts. When busy, the voltages on the first and intermediate lines of a private-branch-exchange group are -21 and -37 , respectively. The last line of the group, being grounded through only 1000 ohms, is maintained at -7.2 volts when busy and will actuate the switch. Operations proceed from position 9 as in the previous case where it was assumed that the last line was free. Switch *S* steps to positions 10 and 11. In position 11, the static switch tests the *D* wire against -5 volts and will not operate as the test voltage is -7.2 . Accordingly, *FT1* through

brush *SB* in position *11* will actuate *SBR*, which will cause busy tone to be sent to the calling line.

8.3 CALLED LINE ABSENTEE

As explained in section 8.1, if a ground exists on the *D* conductor of the called line in position *4* of switch *S*, the test is repeated in position *5* to determine if it is a direct ground indicating the absentee class. As the static switch will then operate only if it is a direct ground, its conduction causes *FT1* through brush *SA* in position *5* to operate *ASR*. In a manner not shown in Figure 4, *ASR* causes the register to break down the connection to the called line and reroutes the call to the absentee operator.

8.4 CALLED LINE NUMBER CHANGED

When a number is changed, the line corresponding to the discarded number is connected to -48 volts through $10\,000$ ohms. If such a line is selected, the static switch cannot act in positions *4* through *9* of switch *S* and it will advance to position *10*.

A -43 -volt reference and the -48 -volt test value are applied to the static switch in position *10* and it conducts. *FT1* through brush *SA* in position *10* operates *CNR*, which locks. Although not shown in Figure 4, *CNR* causes the register to break down the connections to the called line and reroutes the call to the changed-numbers operator.

8.5 DEAD LINE

A dead line has neither ground nor battery on the *D* conductor. When such a line is selected, the static switch cannot act on any position until switch *S* reaches position *10*. Failure to act on position *10* permits *FT1* through brush *SB* in position *10* to operate *DLR*.

As in the previous cases, the details are not shown in the figure, but *DLR* causes the register to break down the connections to the called line and supply dead-line tone to the calling line.

9. Design Features

Certain design criteria were established to insure maximum reliability of operation. Pre-

cautions were taken to prevent abnormal adverse conditions from interfering with the performance of the system. Some of these design principles are listed below.

A. Relays are designed to have wide operating limits. With the exception of a few in the register circuit, they may be maintained with only mechanical adjustments; the electrical features need not be considered. As a rule, all relays will receive at least 50-percent more than the minimum operating current under the most adverse conditions to which they will be subjected.

B. No relays are required to operate under marginal conditions.

C. Slow-operating relays have been avoided and in only a few cases, such as the relays controlling the interdigital times at the register, are slow-releasing relays used. In general, the correct performance of the system does not depend on the operating or releasing times of relays or other apparatus. This stems from the application of the principle of compelled-sequence operation.

D. Twin hemispherical silver contacts are employed for relays with the exception of those carrying speech for which twin palladium contacts are provided.

E. The blowing of a fuse takes the circuit out of service even if it is only one of several fuses in that circuit.

F. The jacking-out of a relay or group of relays, even if they are only part of the circuit and other relays are elsewhere, will put the circuit out of service.

G. No part of a circuit that is being broken down, such as a selector, register, or junction, can be taken for a new connection until it has been completely returned to its normal unoperated condition.

H. Successive calls from a subscriber's line will engage different line-finder, cord, and register circuits so that a faulty unit will not prevent the subscriber from obtaining service.

I. The use of nonhoming switches and homogeneous grading results in equal distribution of traffic over all switch outlets and produces uniform wear of the equipment. Consecutive calls will not seize the same switch twice in succession; which during times of light traffic avoids the possibility of noncompletion of a call because the first circuit tested is faulty.

Wear on the switches is reduced as they need run over an average of only 15 terminals per call, reducing maintenance and noise.

J. All relays are protected by dust-proof covers. The cable forms are not exposed to light, which can fade the colors and cause deterioration of the insulating properties.

United States Patents Issued to International Telephone and Telegraph System; August - October 1956

UNITED STATES patents numbering 58 were issued between August 1 and October 31, 1956 in behalf of the International System. The names of the inventors, subjects of the patents, and Patent Office serial numbers are given below.

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He entered the service of the Bell Telephone Manufacturing Company at Antwerp as a student engineer in 1921. After working in equipment engineering and in the manual and automatic circuit design departments, he was placed in charge of the design and development of telegraph switching systems in 1936. He is now the chief of the telegraph department and reports in this issue on the new 7E rotary automatic teleprinter switching system.

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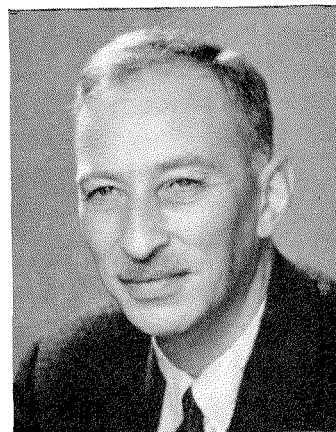
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ARTHUR MEHLIS

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