ELECTRICAL COMMUNICATION

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

MANUFACTURE OF COMMUNICATION CABLES IN AUSTRALIA

MINIATURIZED TUNING-INDICATOR TUBE EM-85

EQUIPMENT OF THE 7E ROTARY TELEPHONE SWITCHING SYSTEM

PROBABILITY APPLIED TO TELECOMMUNICATION SYSTEMS WITH STORAGE

Volume 33 DECEMBER, 1956 Number 4

ELECTRICAL COMMUNICATION

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International Telephone and Telegraph Corporation
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H. P. WESTMAN, Editor
J. E. SCHLAIKJER, Assistant Editor

Published Quarterly by the
INTERNATIONAL TELEPHONE AND TELEGRAPH CORPORATION
67 BROAD STREET, NEW YORK 4, NEW YORK, U.S.A.
Edmond H. Leavey, President
Geoffrey A. Ogilvie, Vice President and Secretary

Subscription, $2.00 per year; single copies, 50 cents

Volume 33 DECEMBER, 1956 Number 4

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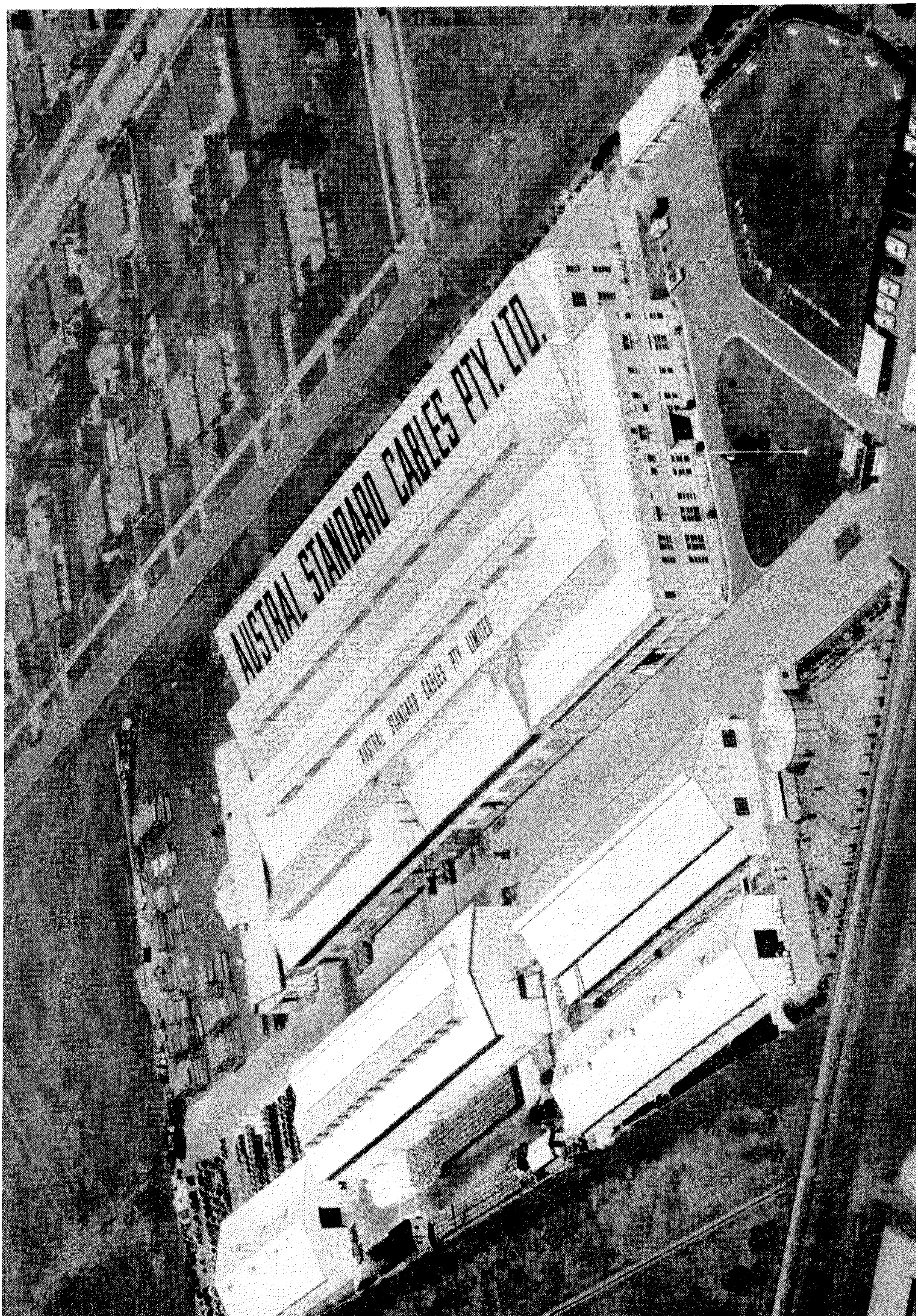
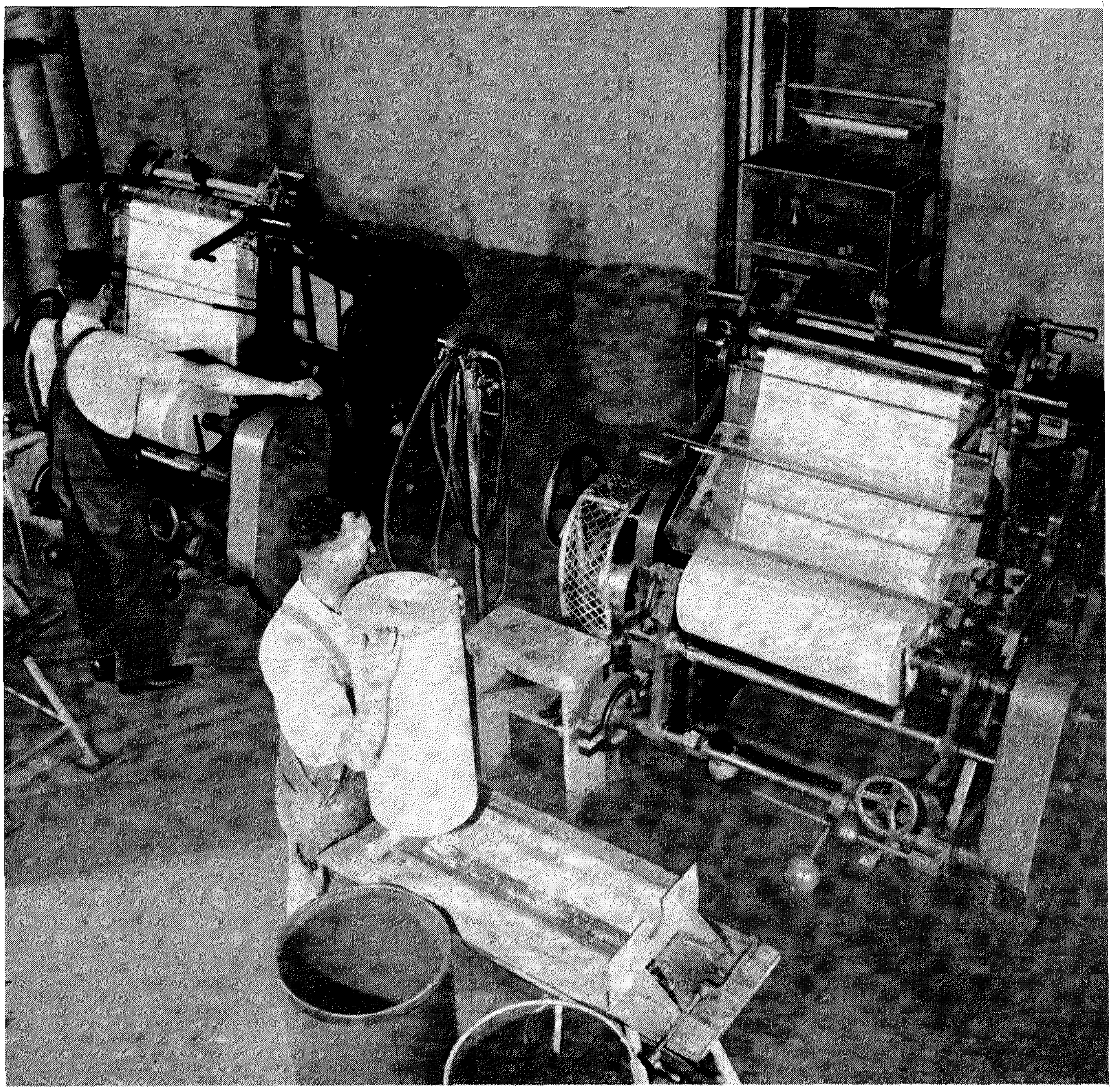
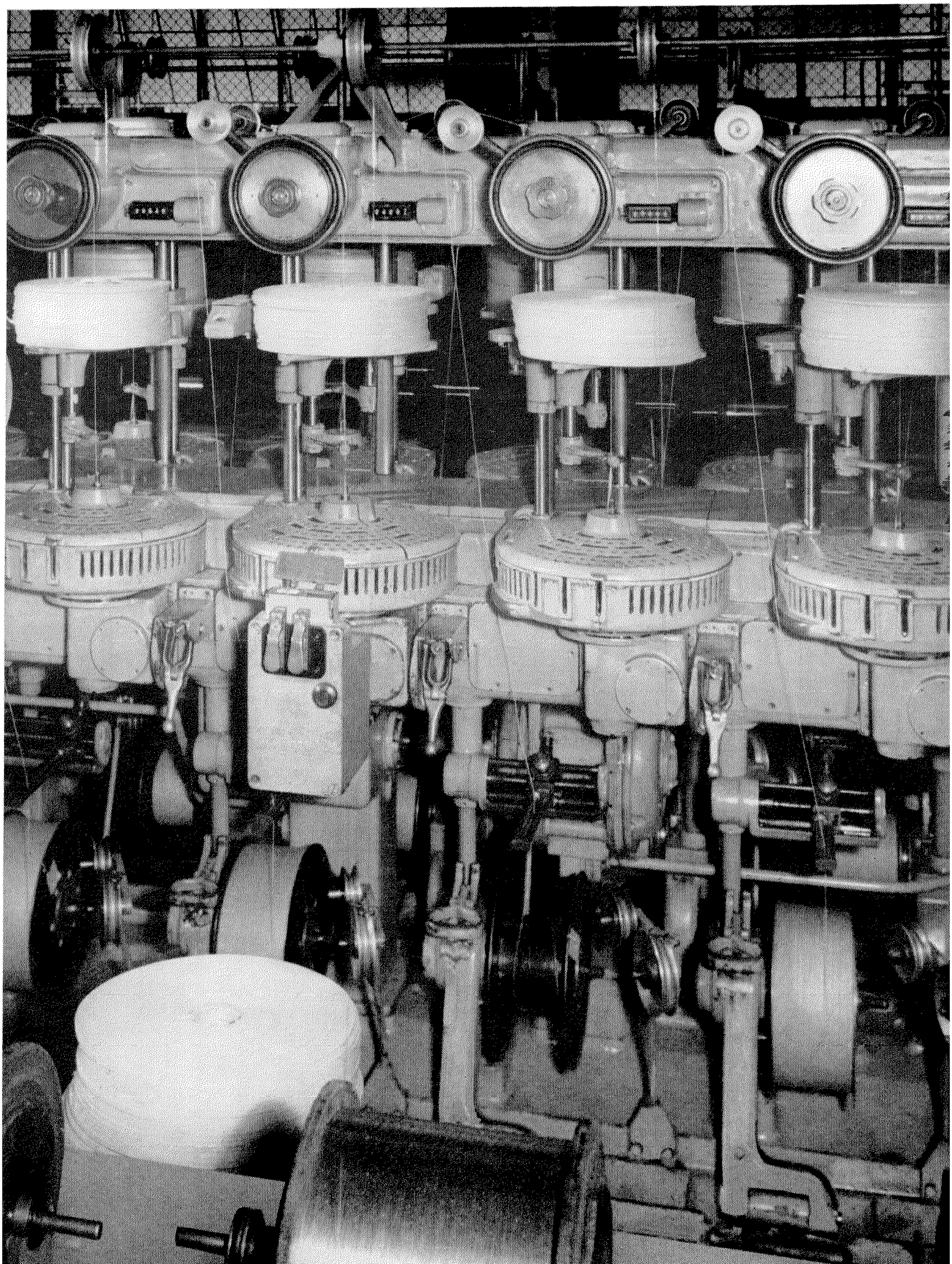

AUSTRAL STANDARD CABLES PTY. LTD.
AUSTRAL STANDARD CABLES PTY LIMITED

Manufacture of Communication Cables in Australia

On the opposite page is an aerial view of the main plant of Austral Standard Cables Pty. Limited, an associate of International Telephone and Telegraph Corporation in Melbourne, Australia. The plant was specifically designed to supply cables and insulated wire for use in the ever-expanding communication network of Australia. Some views of the operations in the plant are shown on the following pages.

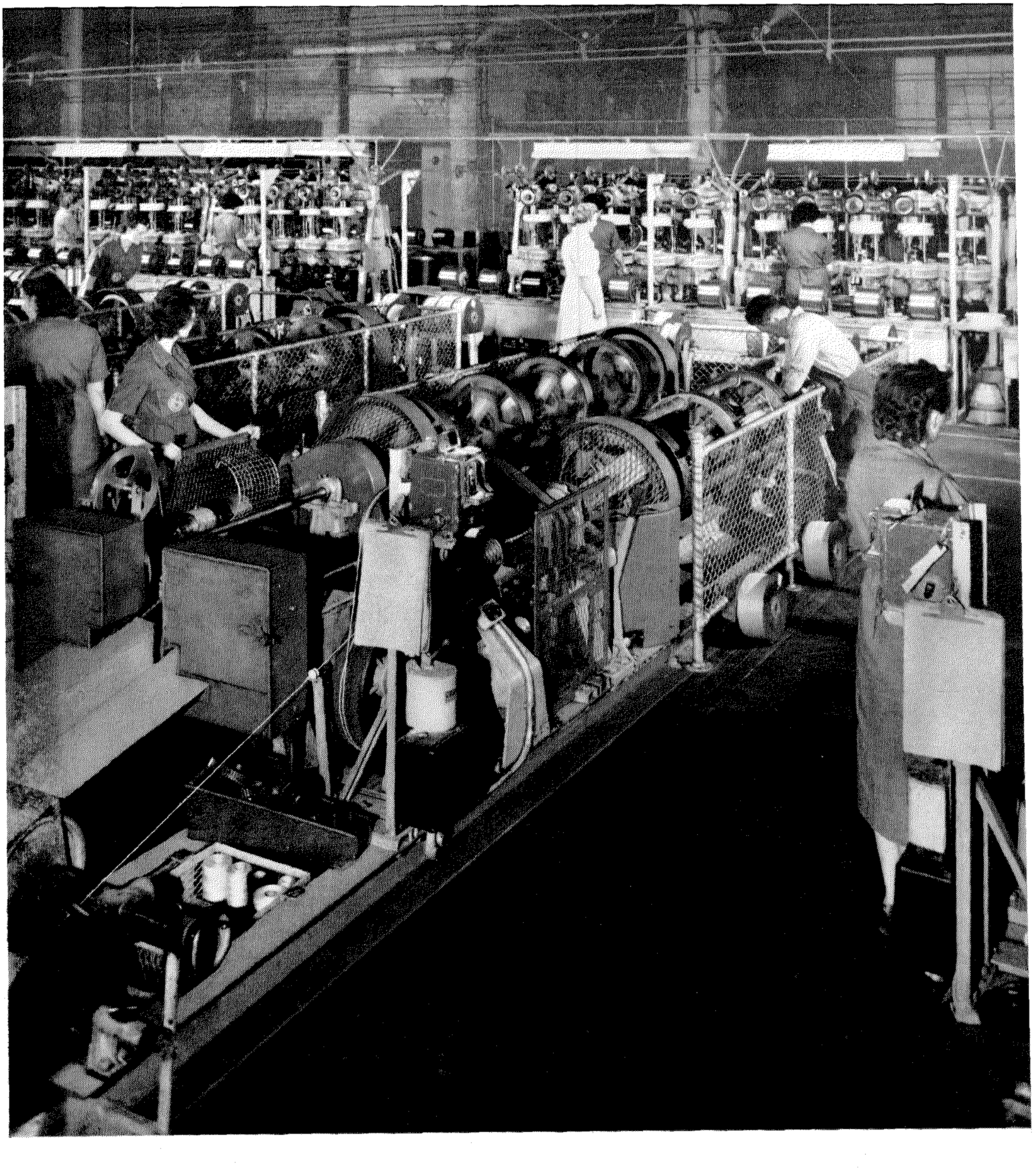
1. Telephone voice-frequency cables are usually insulated with a wrapping of paper around the bare wire for low capacitance and hence low losses. Below is shown two paper marking and slitting machines that place ink marks on the paper (for wire identification after the cable is made up) and then slit the paper into strips about 0·25-inch (6-millimetres) wide.



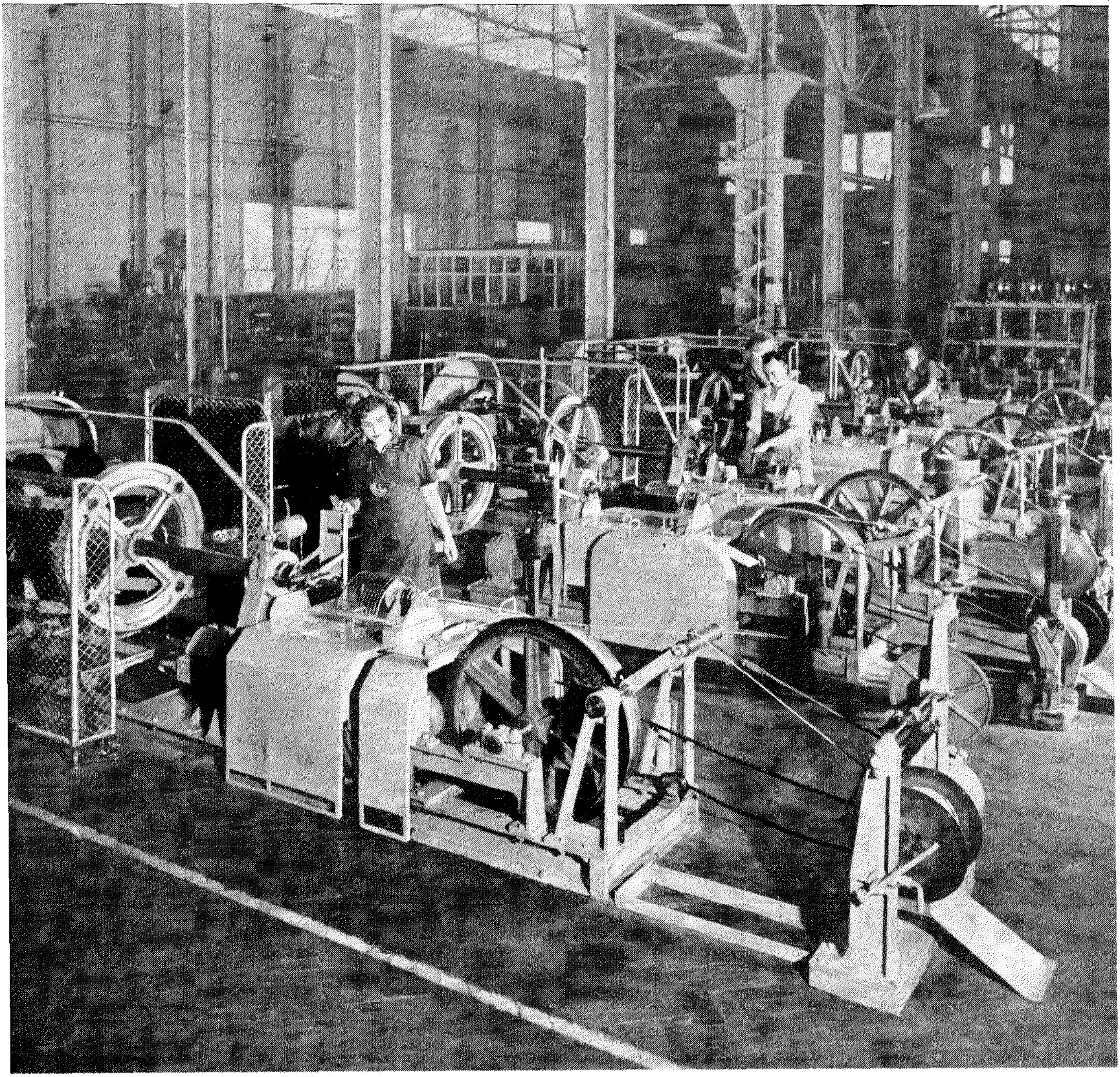


2. On the opposite page is part of a 10-head insulating machine for loop-cable wire. Bare copper wire is pulled from the large spools in the foreground through the tape head in the cylindrical guard, where the paper tape is wrapped spirally around the wire, and the insulated wire is then wound on the spools at the base of the machine.

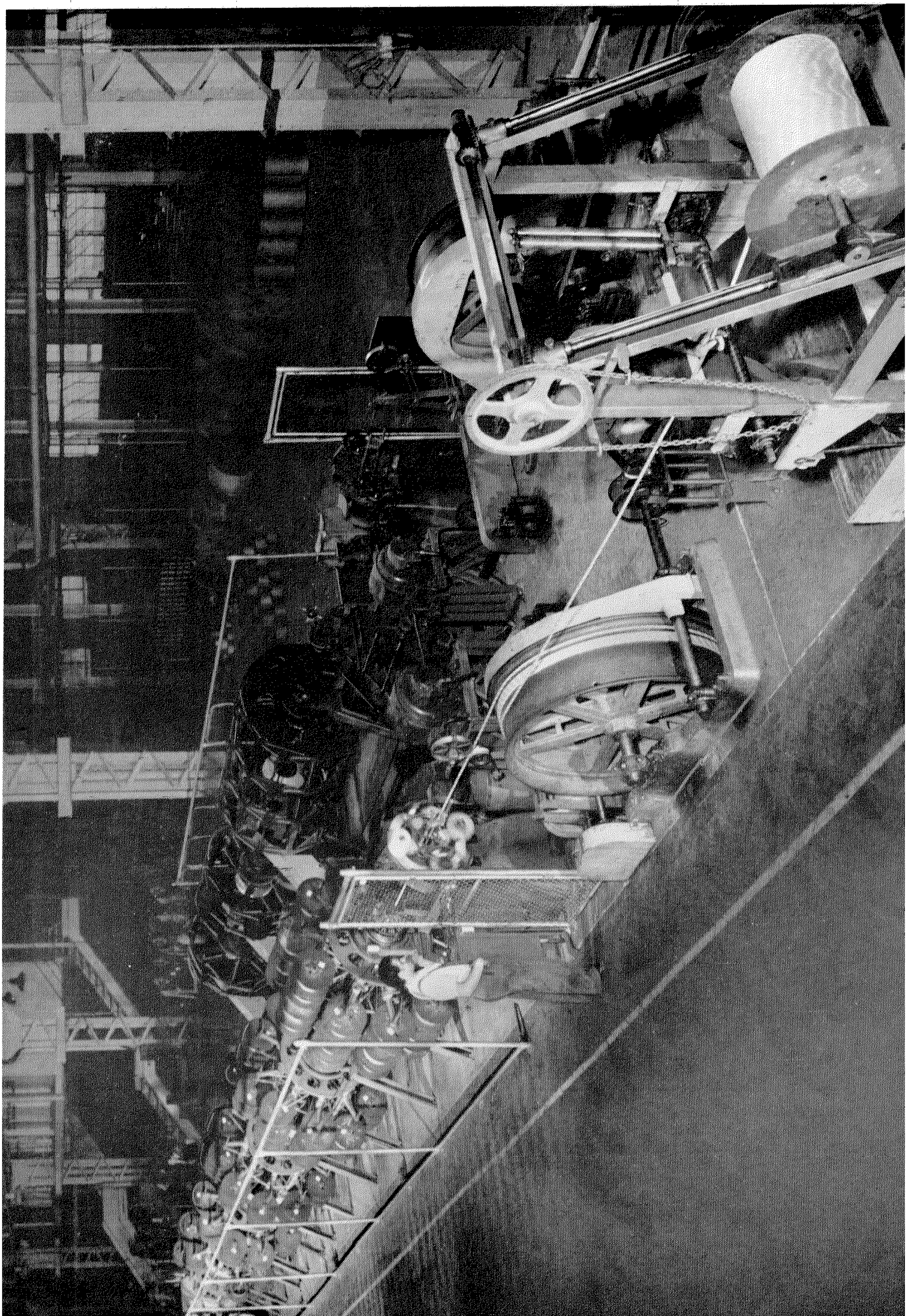
3. Below is a general view of the room, showing the insulating machines in the background and horizontal tubular quadding machines in the foreground. The quadding machines produce units consisting of four wires twisted and bound together spirally, called a star quad. A majority of telephone-type cables are built up from star-quad units.



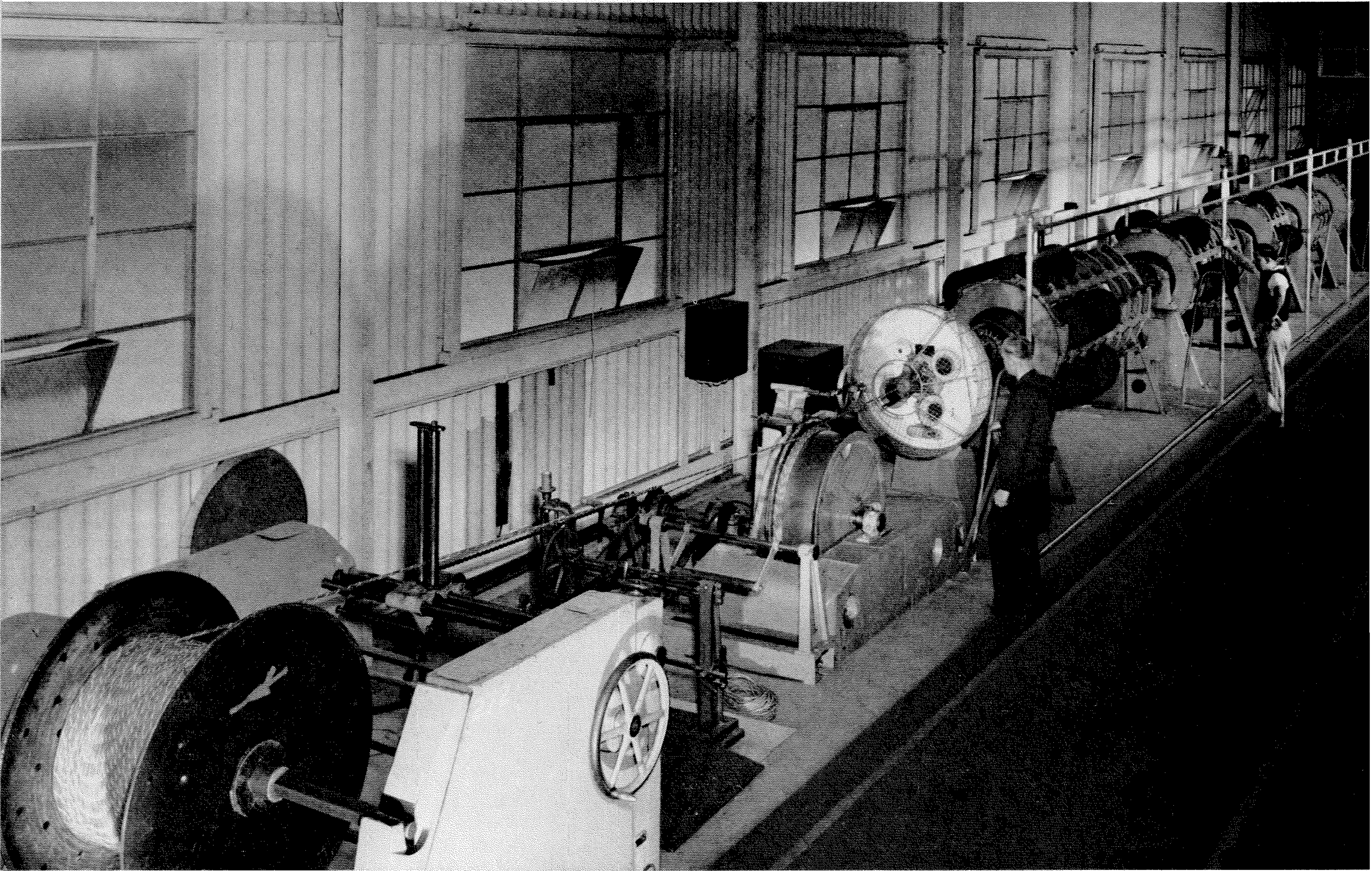
4. On the opposite page is a view of a 4-head string-and-paper wrapping machine to cover wire for major trunk and carrier-frequency cables that require extra-high-quality insulation. Wire is supplied to the machine from a spool or coil on the tapered cylindrical stand at the floor. An open spiral of paper string is wrapped around it after which it goes through the paper-tape-wrapping head behind the guard. The insulated wire passes around the capstan at the top to a take-up spool behind the machine.

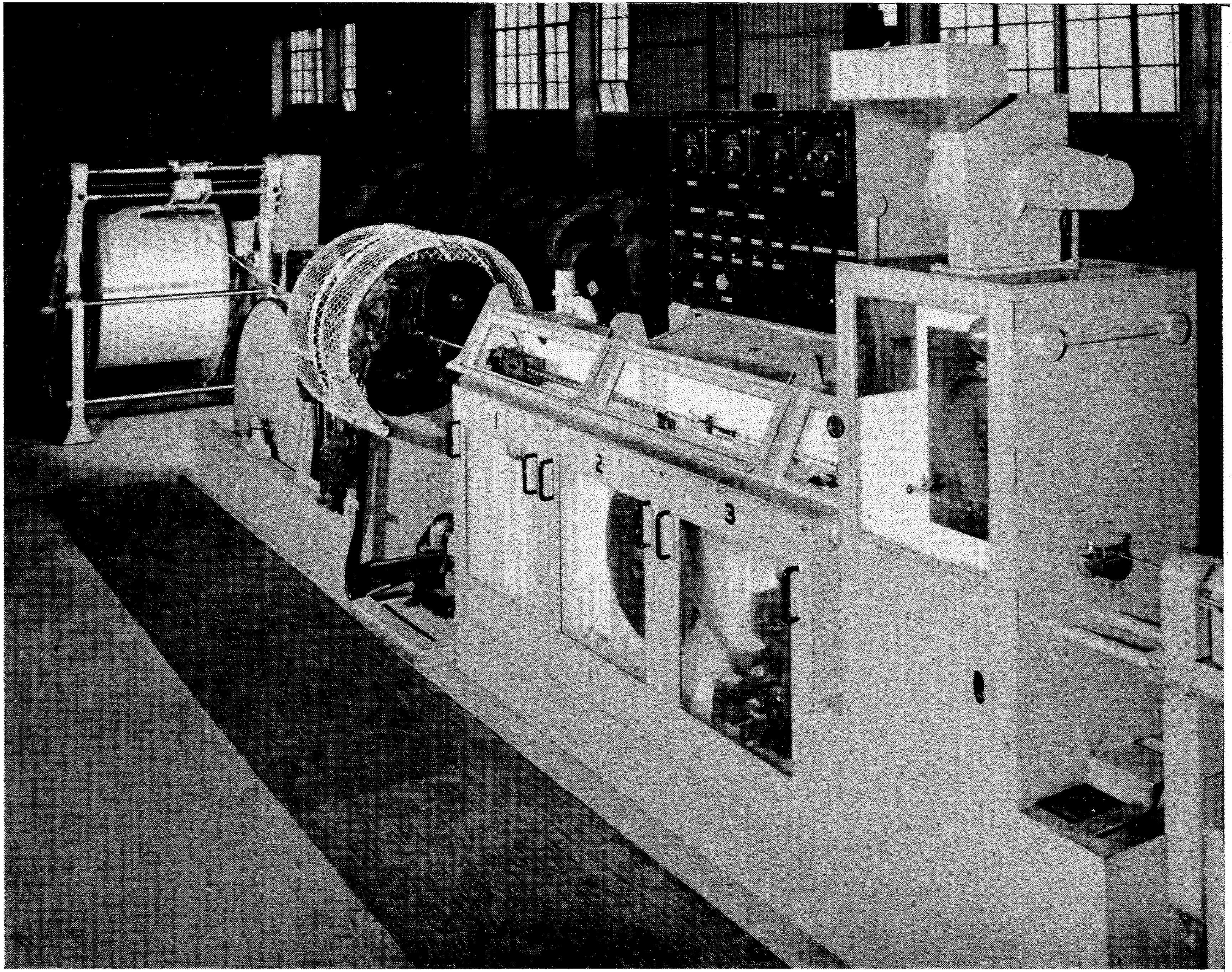


5. Above is a bank of machines making quads of string-and-paper-insulated wire. The carriage at the left rotates four spools of insulated wire, the wires being pulled by the capstan through the machine to the take-up spool at the right. As in the quadding machine shown in 3, a paper string is centred among the wires and a textile whipping is wrapped around the quad to hold the wires in place.

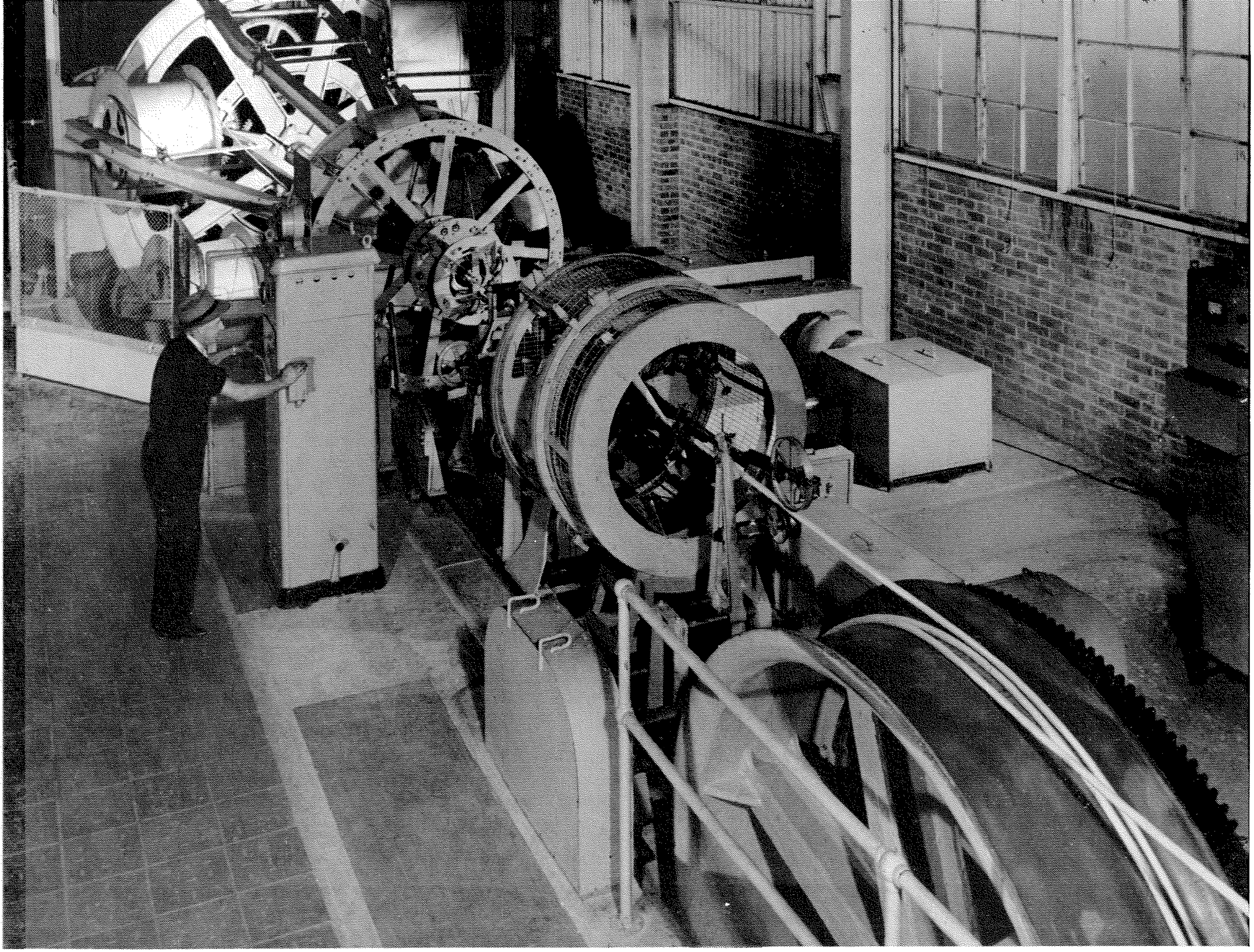


6–7. Above and below are two views of the cable-core stranding area. Above is a standard type of loop-cable stranding machine, and below is a machine for stranding major trunk and/or carrier-frequency cable. Both machines have individually driven carriages, rotatable in either direction, that hold spools of quad. The lay of each layer of quads is adjustable by gear changes in the carriages and capstan. Textile or paper binders are applied over each layer by lapping heads and the last lapping head before the capstan can apply four paper tapes in one operation.

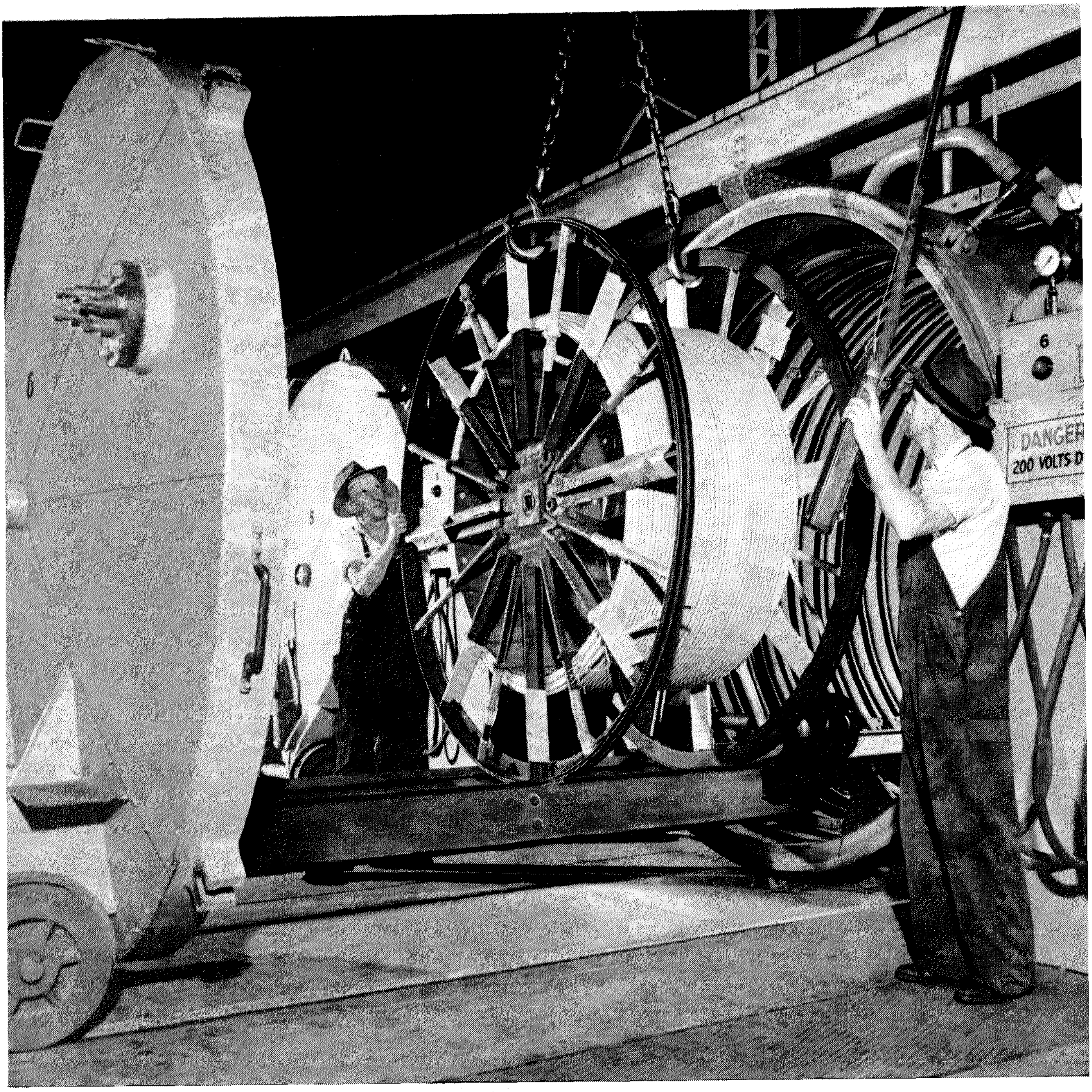




8. Core-forming machine for 0·375-inch- (95-millimetre-) diameter coaxial cable. Bare copper wire is supplied to the machine from the right. The wheel in the first cabinet places slit polythene washers on the wire. In the next three cabinets, copper strip passes through rollers that corrugate its edges and carry it to a position just below the washers on the wire. At the end of the third cabinet, a tool forms the strip into a tube fitting snugly around the washers. The carriage applies two steel tapes; capstan and take-up reel are in the background.

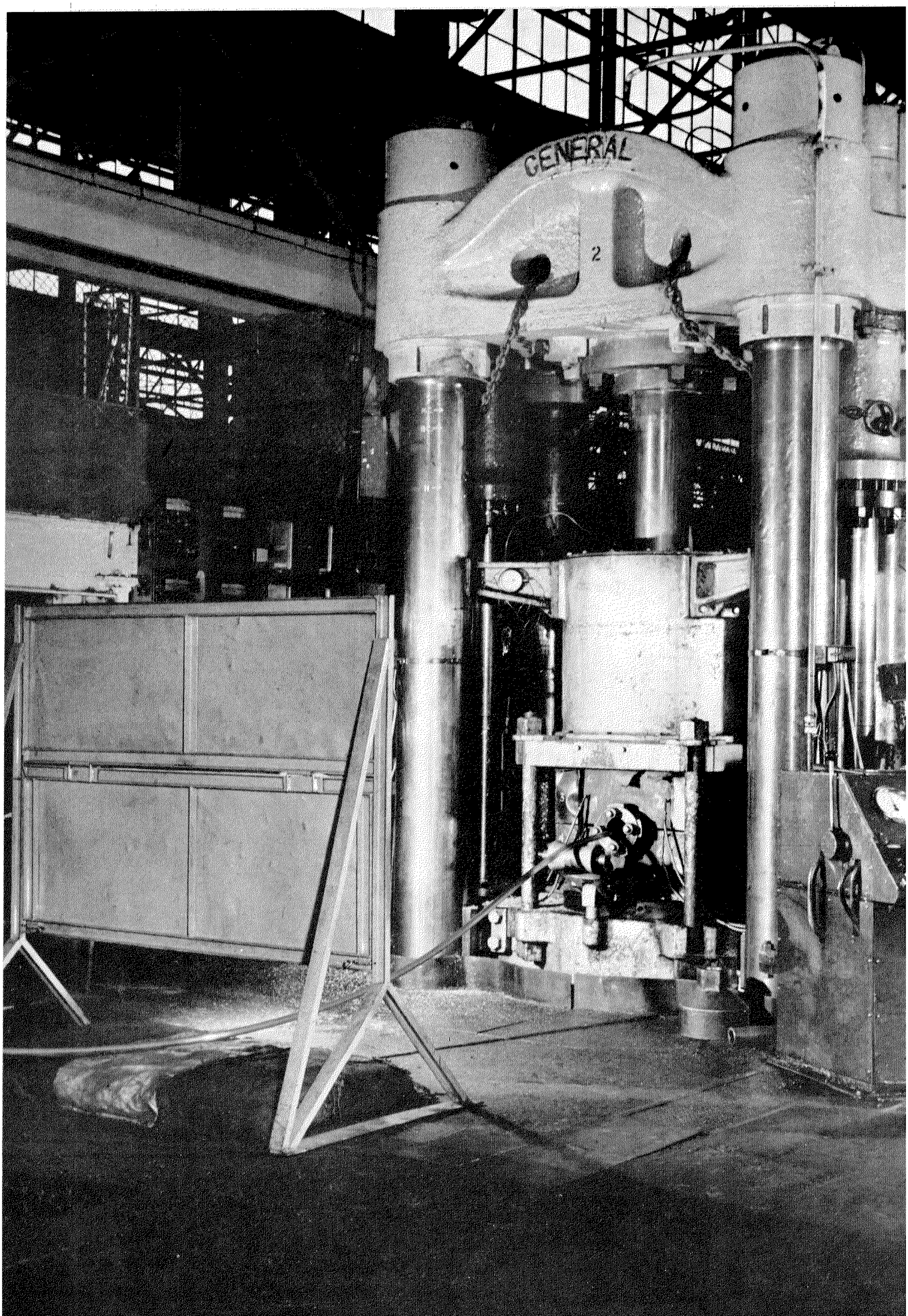


9. Machine for laying together two to six coaxial tubes with interstitial pairs or quads. The carriage in the left background rotates in either direction and is arranged so as not to twist or distort the coaxial tubes on the spools. The next carriage holds the pairs or quads and the cylindrical guard contains a 4-head paper-lapping machine. The variable-speed capstan is in the foreground.



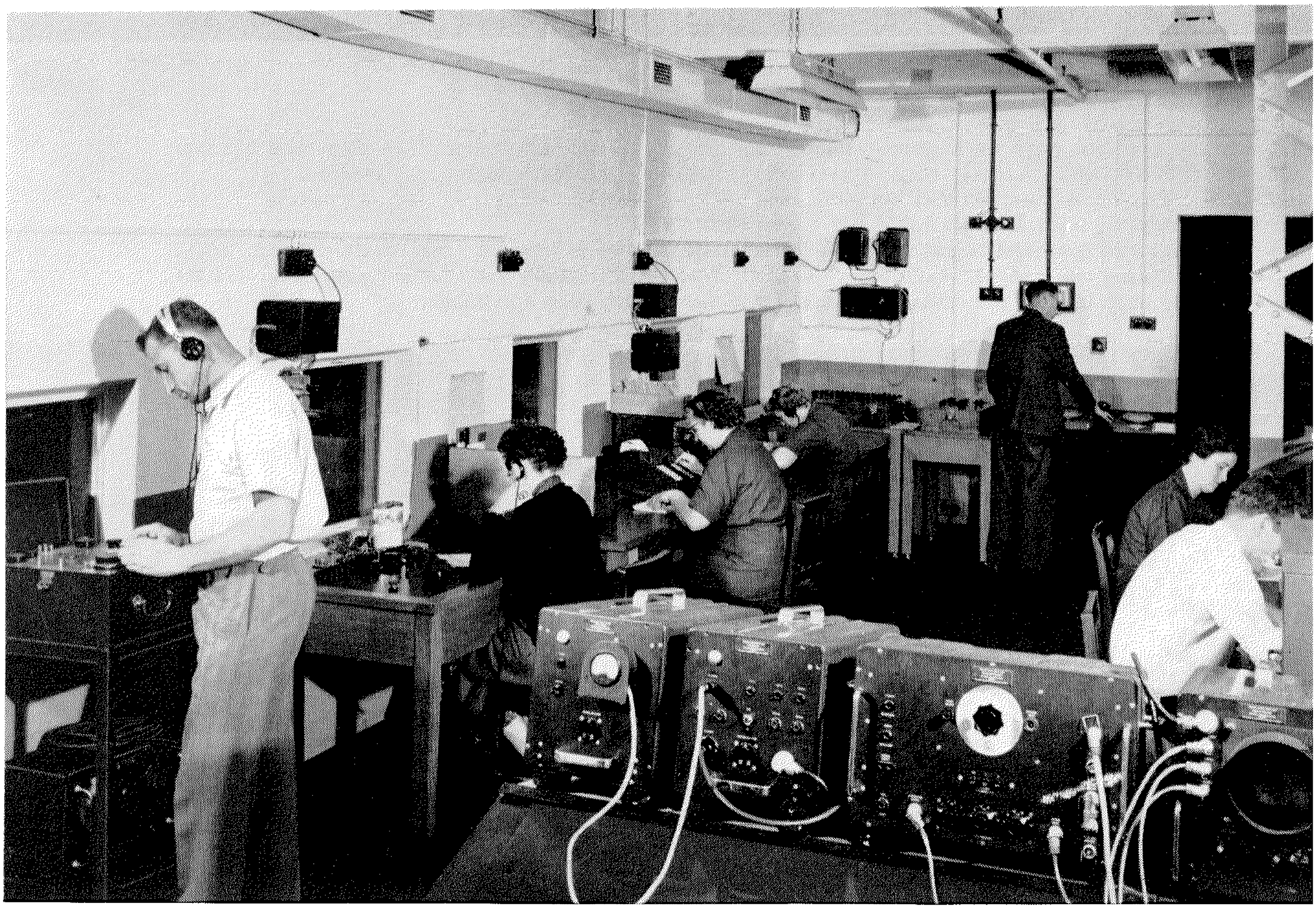
10. The completed cores, after coming off the stranding machines, must be thoroughly dried before sheathing. A vacuum drying oven is shown above. Heat is supplied by the steam coil visible on the inside surface of the oven. The power panel at the right controls direct current that is passed through the conductors. The resulting extra heat inside the core itself speeds up the drying operation.

11. On the facing page is a view of the direct-current converters that supply the current for the vacuum drying ovens. The control panel is behind the operator at his desk.

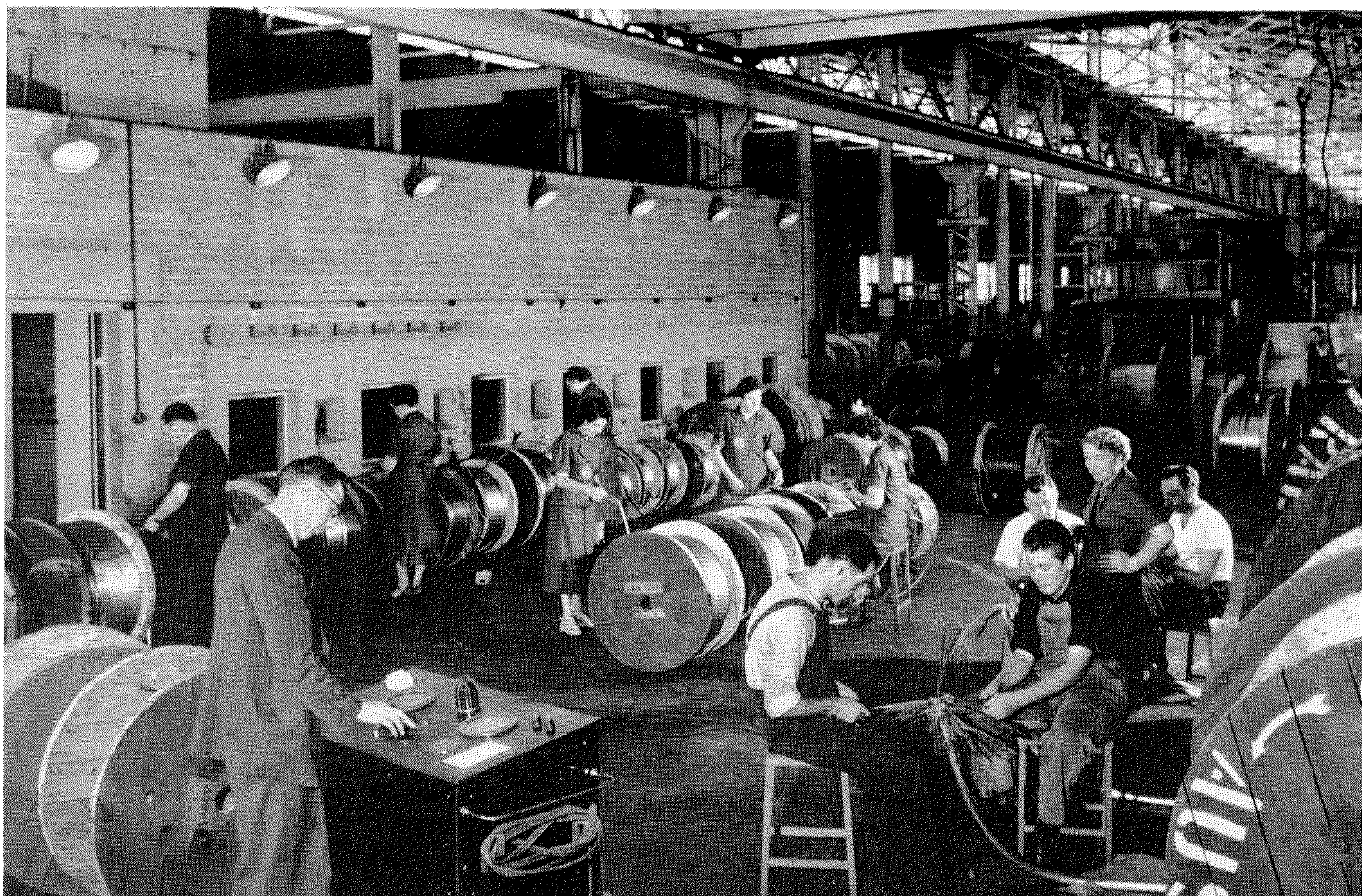

GENERAL
2

12. On the opposite page is a photograph of a 3000-ton (2 700 000-kilogramme) vertical hydraulic lead press. The cable core covered with the lead sheath is extruded from an adjustable die block; the cylindrical lead container is just above. A 5-ton (4500-kilogramme) oil-heated lead-supply kettle and a holding oven to keep the cable warm and dry are in the left background. The plant also has two 1000-ton (900 000-kilogramme) presses.

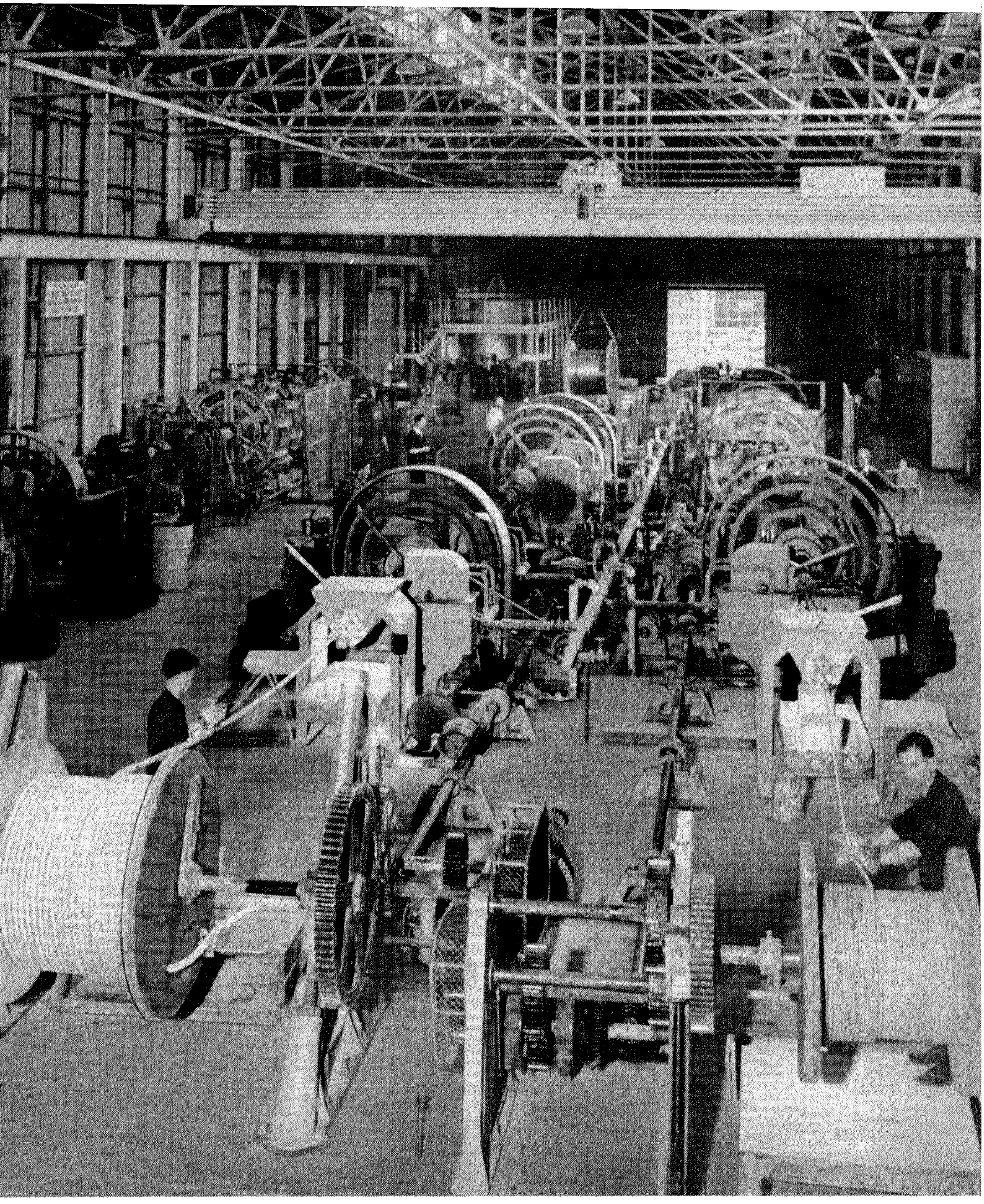
13. Below is shown the drum-making shop. Wooden drums are used for shipping cable and for some of the shop operations.

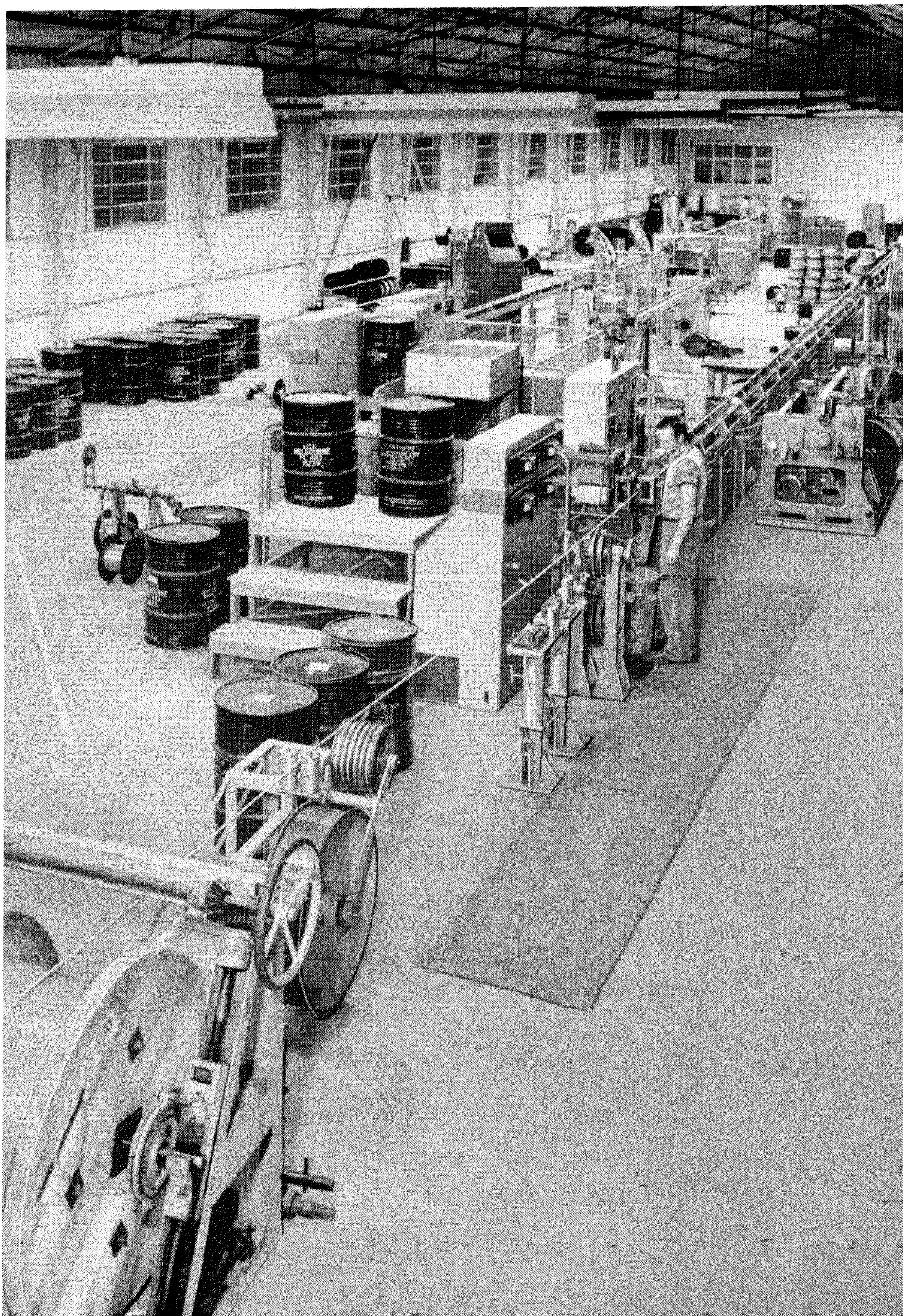


14. On this page are shown the testing of completed cables. Below, test leads are connected to the cable ends and above is the alternating-current test room where cable frequency characteristics are checked.



15. Some cables are covered with steel wire or tape armouring over the lead sheath.





16. On the opposite page is a view of the plastic extrusion shop showing four extruders. In some cases, the cores of communication cables are covered with a plastic sheath for protection.

17. The shipping department is shown below, where the drums of cables are enclosed and stencilled prior to shipment of the product. In addition to manufacture of the large communication cables shown in this picture series, Austral Standard Cables Pty. Limited also produces plastic- and textile-covered wire for telephone-switchboard connections and other purposes.

Miniaturized Tuning-Indicator Tube EM85*

By FRIEDRICH MALSCH

C. Lorenz, A. G.; Stuttgart, Germany

DEVELOPMENTS in radio tubes are resulting in smaller and smaller dimensions; the miniature and rimlock tubes have diameters of about 17 to 22 millimeters (0.67 to 0.87 inch). This improvement has not so far been made in the case of indicator tubes, the trend being to retain the target area to maintain the tuning sensitivity. In the tube types so far used, the bulb diameter (about 29 millimeters or 1.14 inches) determines the size of the target area because the circular target, filling the bulb section completely at its top, is located perpendicularly to the bulb axis. The Magic Fan *EM71*[1,2] permitted shortening the tube bulb by utilization of a loctal tube base. For small receivers, however, even this tube is too large, so that only the bigger receivers of the middle and higher price classes could be equipped with tuning-indicator tubes. A suitable indicator tube with moderate space requirements was still needed for small receivers. This demand is fulfilled by the Magic Fan *EM85*, a 9-pin miniature tube complying with the new noval tube technique.

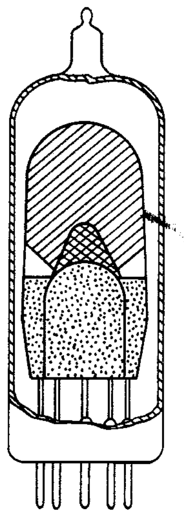


Figure 1—Actual-sized drawing of tube.

1. Principle and Circuit

The tube operates according to the well-known principle of cutting a variable shadow sector out of as large a target area as possible with greatest sharpness of the shadow edges. As usual, it contains a triode amplifier and an indicator system with a large target of green fluorescence. The change of the shadow sector is accomplished by a deflector rod. This deflector is not connected to the triode plate within the tube, but can be connected externally. The variable-mu triode operates as a direct-current amplifier, the deflector voltage being developed across the triode plate resistance.

Since the deflector and the plate are not connected internally, it is possible to use the triode separately from the indicator system. The cathodes of the triode and indicator system and the grid of the indicator system are interconnected.

2. Construction

In the loctal *EM71* tube, the sensitivity had been attained by extension of the sharp shadow edge and by enlarging the angular deflection.[2] This was possible by arranging the cathode system in the vicinity of the bulb periphery. When the shadow angle is largest, the shadow sector fills the largest portion of the bulb cross section. Using the older principle of construction, if bulb diameter and, hence, the electrode system were reduced to the size of a miniature tube, that is, from 29 to 22 millimeters (1.14 to 0.87 inch), then the shadow length would be decreased by about 30 percent and the luminous area by about 50 percent. Both the over-all visual impression and the tuning sensitivity would greatly suffer. Moreover, the new small-diameter tubes have the exhaust tip on the top, which would impede observation of the tube through the top.

For these reasons, a new arrangement had to be found that permitted a large target to be mounted in a narrow bulb. This was accomplished by a system having the indicator cathode axis perpendicular to the bulb axis and with a target of the shape of an elongated shell filling almost the whole bulb length and width. The

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* Reprinted from *Radio Mentor*, volume 18, pages 356, 358, and 360; August, 1952.

1 "Der Magische Faecher (*EM71*), Eine Neue Abstimmanzeigeroehre," *Radio Mentor*, volume 16, page 533; October, 1950.

2 F. Malsch, "Die Entwicklung der Abstimmanzeigeroehren fur Rundfunkgerate," *Radio Mentor*, volume 17, pages 124–129; March, 1951.

target is observed through the cylindrical portion of the bulb.

The shape of the target is unconventional for indicating or measuring instruments. The electron-beam pointer of the *EM85* has a variable

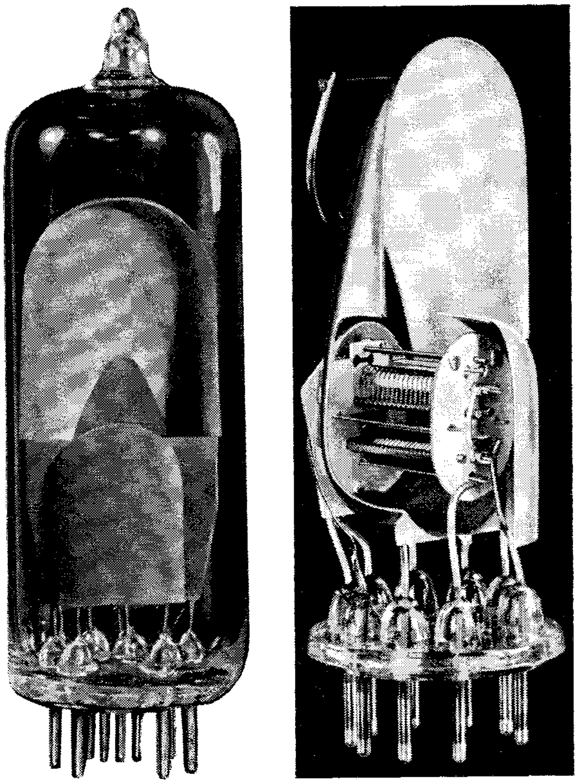


Figure 2—Complete tube at left. At right, a cut-away view of electrode systems.

length and reaches the target edge in all its positions, the elongated target thus adding greatly to indicating sensitivity. The length of the shadow edges changes from about 11 to 22 millimeters (0.43 to 0.87 inch). In the loctal tube, the pointer length varies between 13 and 16 millimeters (0.51 and 0.63 inch), in other well-known indicator tubes the target radius is a fixed 8 millimeters (0.3 inch). The largest shadow angle is 100 degrees, and the shadow arc length, measured along the edge of the target, is 41 millimeters (1.62 inches). The maximum shadow angle is reduced to 100 degrees (compared with the 120 degrees of the loctal type), so that the luminous sectors are not too small when the shadow angle is greatest. In this manner, the initial sensitivity is also increased.

Figure 1 shows the dimensions of the *EM85*. The volume of the tube is about 50 percent smaller than that of the loctal tube; the target area is the same in both tubes, however. The electrode arrangements are shown in Figure 2; the socket connection diagram in Figure 3. The indicator system is mounted above the triode system. This construction permits the target to occupy the largest portion of the available space. Indicator and triode systems are mounted between two mica spacers and thus form a mechanical unit. The systems are separated by a shield connected to the cathode. The indicator system contains a cathode, a space-charge grid, and the deflecting electrode with two angularly shaped counterelectrodes producing the shadow angle.

The triode has a variable-mu grid. Usually, the triode is operated as a resistance-coupled amplifier by connecting the plate and the deflecting electrode through an external resistance of 0.5 megohm. At a plate voltage of 250 volts, the highest possible initial sensitivity is obtained, when with a grid voltage of about − 18 volts, the shadow angle approaches 0 degrees without overlapping of the two luminous edges. In Figure 2 the triode plate is partly cut away to show the grid and the cathode of the triode. The triode and the electron-beam-forming system of the indicator are covered by a cap.

The arc-like cut-away portion at the bottom of the target gives contrast to the luminous area

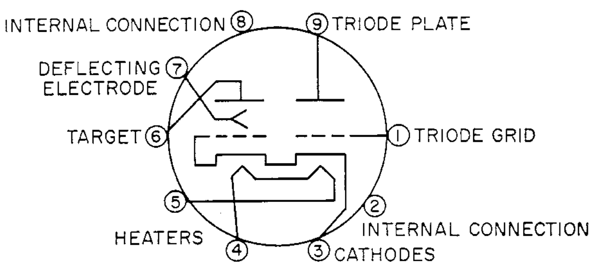


Figure 3—Socket connection diagram.

and draws the attention of the observer to the periphery of the target where the movement of the luminous edges and, hence, the tuning sensitivity, are greatest.

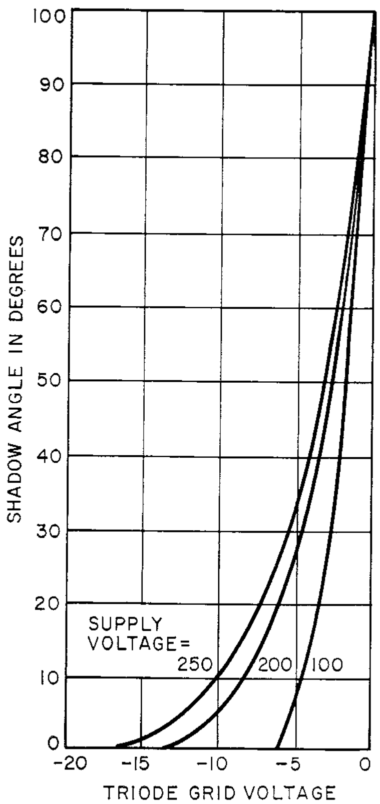


Figure 4—Shadow angle as a function of triode grid voltage. Plate load resistor = 470 kilohms.

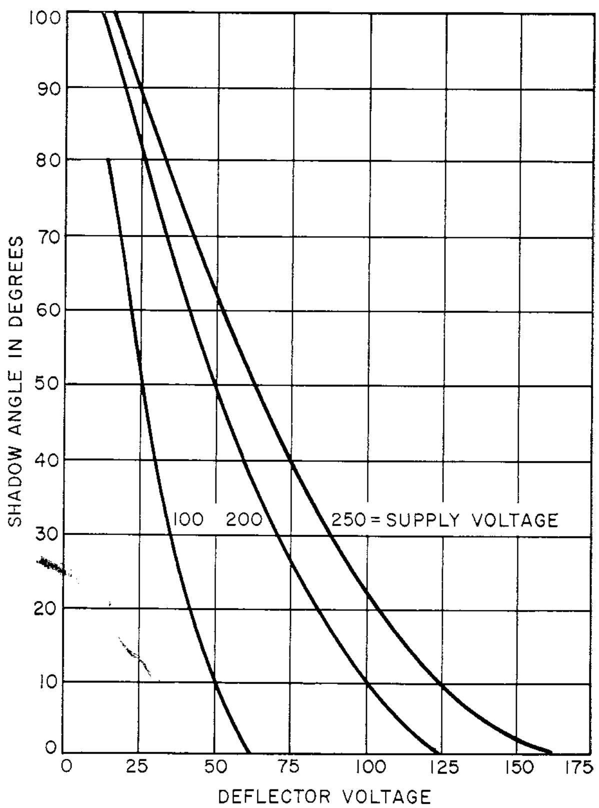


Figure 5—Shadow angle as a function of deflector rod voltage.

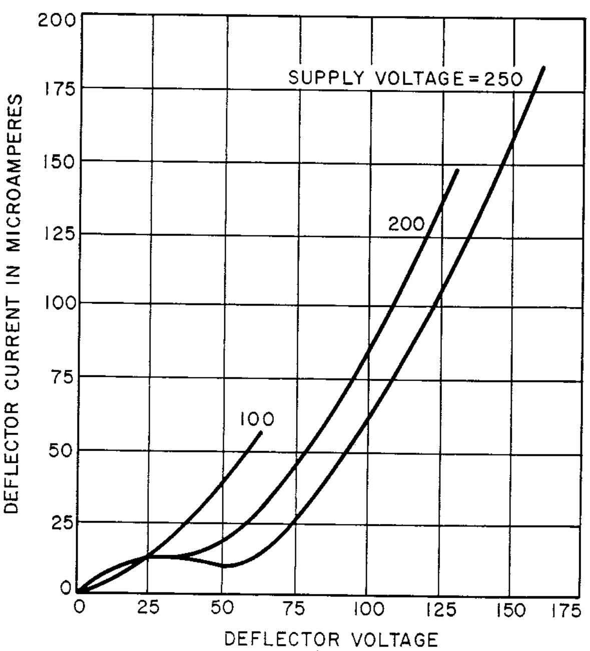


Figure 6—Deflector current–voltage characteristics.

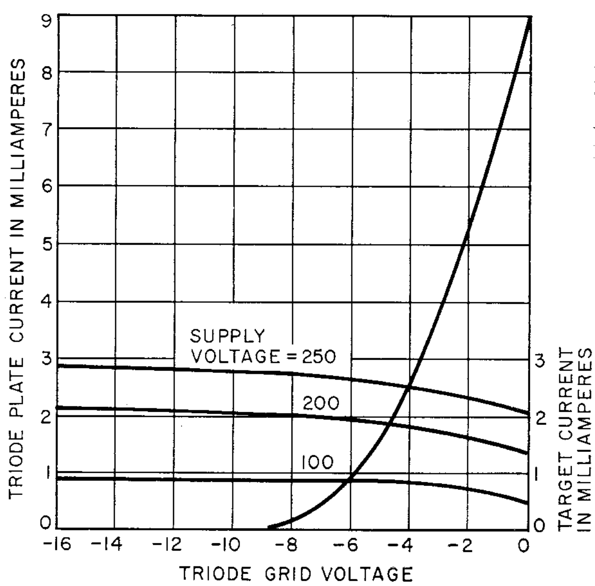


Figure 7—Target current and triode plate current versus triode grid voltage for an initial triode plate voltage of 100.

The mounting of the electrode systems on the tube base is very rigid so that no special supports are necessary in the bulb. The target is welded to three of the pins and forms the support for the whole system. The electric connections between the individual electrodes and the pins are led up along both sides similar to the case of metal-type tubes with horizontally arranged electrode systems. The getter yoke is attached to the back of the target so that the back wall of the bulb can be coated.

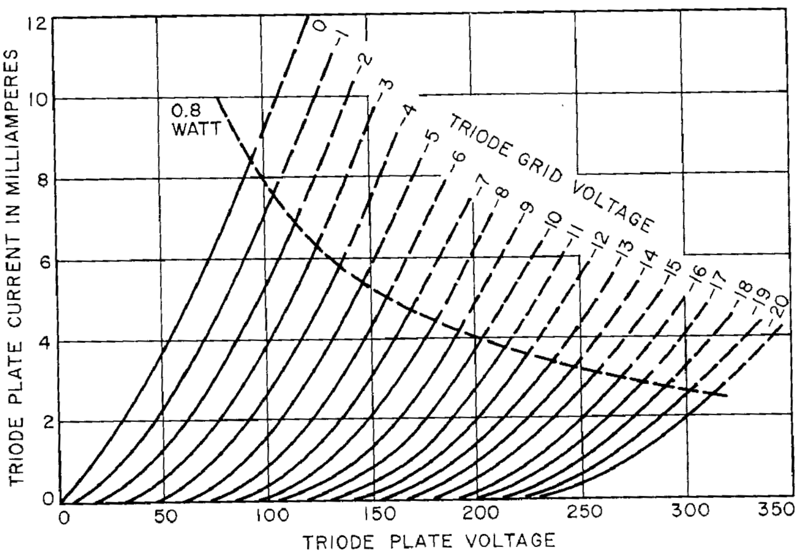


Figure 8—Plate current-voltage curves of triode. The maximum power capability is 0.8 watt.

3. *Tuning Sensitivity*

Various electrical characteristics of the tube are given in Figures 4–10. Figure 4 shows the shadow angle versus the grid voltage and Figure 5 the shadow angle as a function of the deflector voltage. These characteristics are not entirely suitable for judging the tuning sensitivity. The change of the shadow arc s along the target periphery versus the grid voltage is a better measure of sensitivity. In this new tube with a long narrow target, the shadow arc length is greater than in older tubes. The dependence of the arc length on control voltage is plotted in Figure 9. Retaining the earlier[2] definition of the tuning sensitivity,

$$A = \frac{\Delta s}{E_g/10},$$

where

A = tuning sensitivity in millimeters per volt
Δs = change in arc length in millimeters
E_g = triode grid voltage

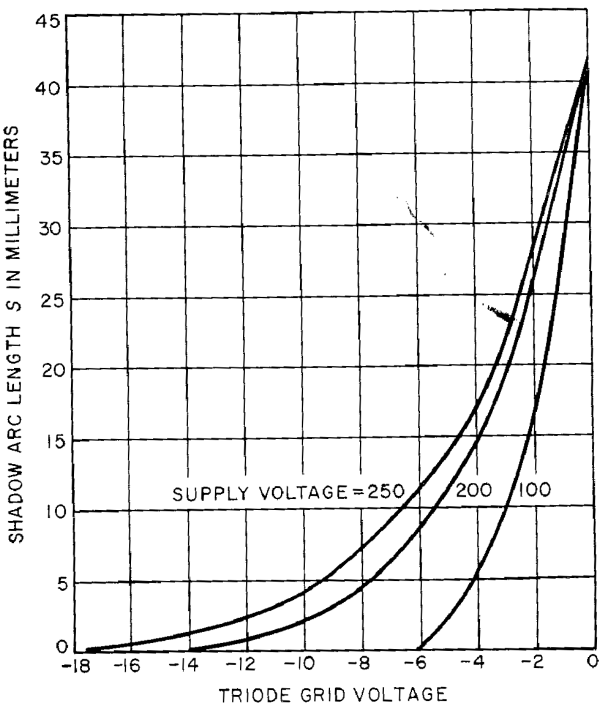


Figure 9—Shadow arc length s versus triode grid voltage.

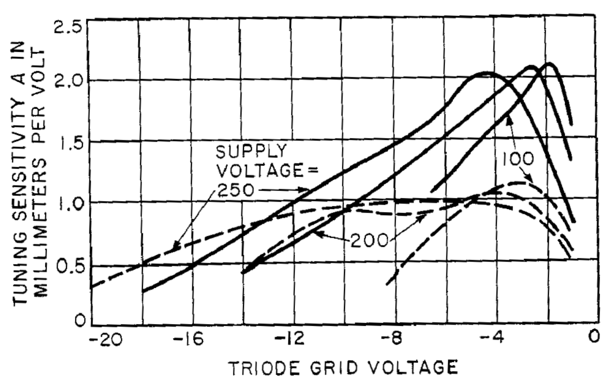


Figure 10—Tuning sensitivity versus triode grid voltage. Solid curves = *EM85*, dashed curves = *EM71*.

(meaning that the tuning sensitivity equals the change of the shadow arc length at a grid-voltage variation of 10 percent), the values of Figure 10 are obtained. It will be seen that, particularly when tuning to stations with a low field strength, the tuning sensitivity is nearly twice as great as in the older tubes. For local stations it is equal to that of the older tubes.

4. *Ratings*

4.1 Basic Ratings

Heater Voltage	6.3	volts
Heater Current	0.3	ampere
Maximum Supply Voltage	300	volts
Maximum Triode Anode Dissipation	0.8	watt
Maximum Target Voltage	300	volts
Minimum Target Voltage	100	volts
Maximum Cathode Current	6	milliamperes
Maximum Triode Grid Resistor	3	megohms
Maximum Heater-to-Cathode Voltage	100	volts

4.2 Tuning-Indicator Operating Characteristics

4.2.1 Control Electrode Connected to Anode of Triode

Anode Supply Voltage	250	200	100	volts
Target Voltage	250	200	100	volts
Anode Current	0.5 to 0.12	0.4 to 0.1	0.2 to 0.07	milliampere
Triode Anode Resistor	470	470	470	kilohms
Triode Grid Voltage	0 to − 18	0 to − 14	0 to − 6	volts
Target Current	2.1	1.4	0.5	milliamperes
Shadow Angle	100 to 0	100 to 0	100 to 0	degrees
Triode Grid Resistor	3	3	3	megohms

4.2.2 No Connection Between Control Electrode and Triode Anode

Anode Supply Voltage	250	200	100	volts
Target Voltage	250	200	100	volts
Target Current	2.1	1.4	0.5	milliamperes
Deflector Voltage	5 to 160	5 to 125	5 to 60	volts
Deflector Current	5 to 180	5 to 130	3 to 50	microamperes
Shadow Angle	100 to 0	110 to 0	110 to 0	degrees

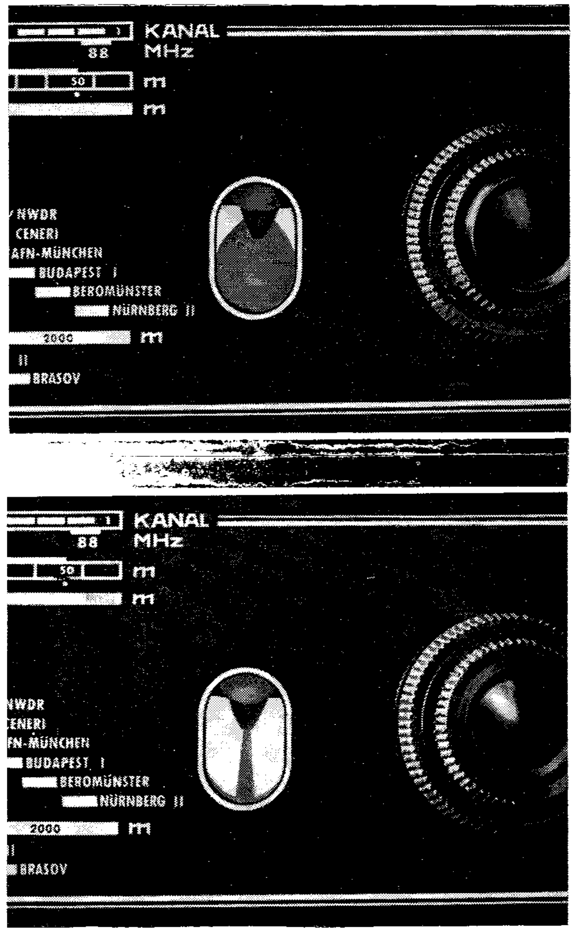


Figure 11—Tube mounted behind the panel of a receiver. At top, no input to receiver; below, strong signal input.

4.3 Triode Characteristics

Anode Voltage	100	volts
Control-Grid Voltage	− 5.8	volts
Anode Current	1.0	milliampere
Mutual Conductance	600	micromhos
Anode Resistance	22 200	ohms
Interlectrode Capacitances (No External Shield)		
Input	4.5	micromicrofarads
Output	3.5	micromicrofarads

5. *Mounting*

While the previous tubes are viewed from the top and are therefore mounted with the tube axis perpendicular to the receiver front panel, the new tubes are viewed at a right angle to the bulb axis and are therefore mounted parallel to the panel. This is of particular advantage where the tube is mounted behind the tuning dial. The tube has a diameter of only 21 millimeters (0.83 inch) and is easily accommodated even in small sets. Due to the large area of the target, however, it does not appear smaller than the previous tubes. Figure 11 shows the dial of a receiver using the tube. The set has been photographed during operation at low and high grid voltages. The pictures show the high tuning sensitivity and the excellent sharpness of the shadow edges. In the example shown, the tube is inverted and suspended immediately behind the dial; however, it is also possible to mount the tube upright, depending on the construction of the receiver and the slope of the dial.

When the tube is mounted behind the dial, the target top edge should be parallel to the dial. To avoid correction work in the assembly, the tube pins and the target are so arranged that all tubes are viewed from the direction of the missing base pin.

Recent Telecommunication Development

Etching of A. J. Fresnel

August Jean Fresnel (1788–1827) is the subject of the latest of the series of etchings published by the International Telecommunications Union. Born and educated in France, Fresnel served as an engineer for the government.

His work in optics appears to have begun about 1814; later work did a great deal toward establishing the wave theory of light. Fresnel's studies on interference of light waves is applied today in calculations regarding interference to radio-relay-system beams by reflecting objects. The Fresnel, or stepped lens has long been applied to the focusing of light beams and has found late use in the focusing of radio beams in relay systems.

The etching of Fresnel is the 21st in the series that was started in 1935. On a good grade of paper measuring 9 by 6⅝ 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 Ampere, Armstrong, Baudot, Bell, Erland, Faraday, Ferrié, Fresnel, Gauss and Weber, Heaviside, Hertz, Hughes, Kelvin, Lorentz, Marconi, Maxwell, Morse, Popov, Pupin, Siemens, and Tesla.

Equipment Practices in the 7E Rotary Telephone Switching System

By MARTINUS DEN HERTOG
Bell Telephone Manufacturing Company; Antwerp, Belgium
and
JAKOB KRUITHOF
International Standard Electric Corporation; Antwerp, Belgium

PRINCIPLES of operation of the *7E* rotary telephone switching system were outlined in a previous paper.[1] This present paper will describe the equipment itself, its arrangement, homogeneous grading, and junction diagrams.

1. *Main Distributing Frame*

1.1 General Design

One design principle of the *7E* system is that all subscribers' line changes be made on the main distributing frame. They must not require alterations in wiring of relay bays or on cross-connecting frames in the switch room. In particular, it avoids the replacing of regular line and cutoff relays by special relays when a line is to be modified for party-line working, for connection as a pay station, or for use in radio-diffusion service. Wiring changes that are usually made in line circuits or other parts of the automatic equipment to provide for certain types of private-branch-exchange operation or for restricting service facilities are similarly unnecessary.

As a result, all work that need be done on the subscribers' line circuits can be constantly supervised by the wire chief, who can be responsible for all changes in these circuits, both in the terminal room and in the outside plant.

1.2 Line Jack Strip

A new design of line jack strip is mounted on the horizontal or exchange side of the main distributing frame. The cables from the combined line-finder and final-selector multiples terminate at soldering tags at the bottom and the jumpers to the terminal strip on the vertical side of the frame go to terminals on the top of the jack strips. At the front of the jack strip is a vertical row of terminals for each line over which the subscriber's line plug is slipped. Figure 1 is a view of two assembled jack strips with their top protective covers in the opened and closed positions. A disassembled unit is in Figure 2. The connections to the various elements of the circuit are shown in Figure 3.

Break contacts are not provided as is usual in the *A* and *B* conductors to permit the outside line to be isolated from the exchange circuits for testing. This is accomplished by replacing the line plug with a patching cord that terminates in a suitable connector and extends the line to the wire-chief's desk. Only the multiple to the line finders and final selectors remain connected to the outside line and they will not interfere with its being tested. The elimination of the usual break contacts increases the reliability of operation and reduces maintenance.

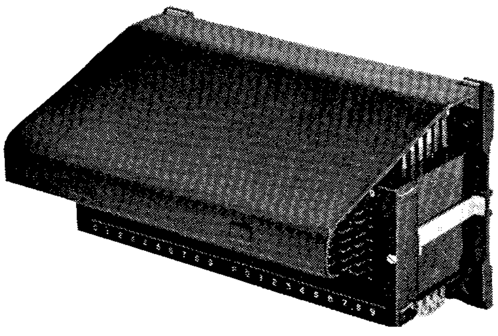
A jack strip provides for 20 lines and is mounted in a bakelite base to which a protective cover is hinged. Each T-shaped terminal piece is punched from a single sheet of metal and is folded as necessary to clear the adjacent terminals. There are 6 of these T-shaped terminals in a set and 21 sets are assembled and held in place by three perforated phenol-fiber sheets. The ends of their terminal pieces extend through slots in the fiber sheets and no other fastening is needed.

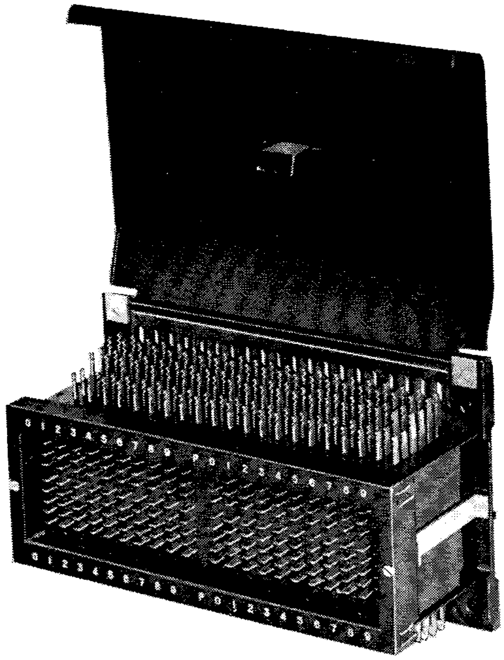
The complete terminal assembly fits into grooves in the bakelite base and is held in place by a rectangular bakelite frame that is fastened to the base with screws and two metallic brackets.

The switchboard cables pass through fanning holes at the bottom of the base and the jumpers

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

Figure 1—Line jack strips with protective covers open and closed.





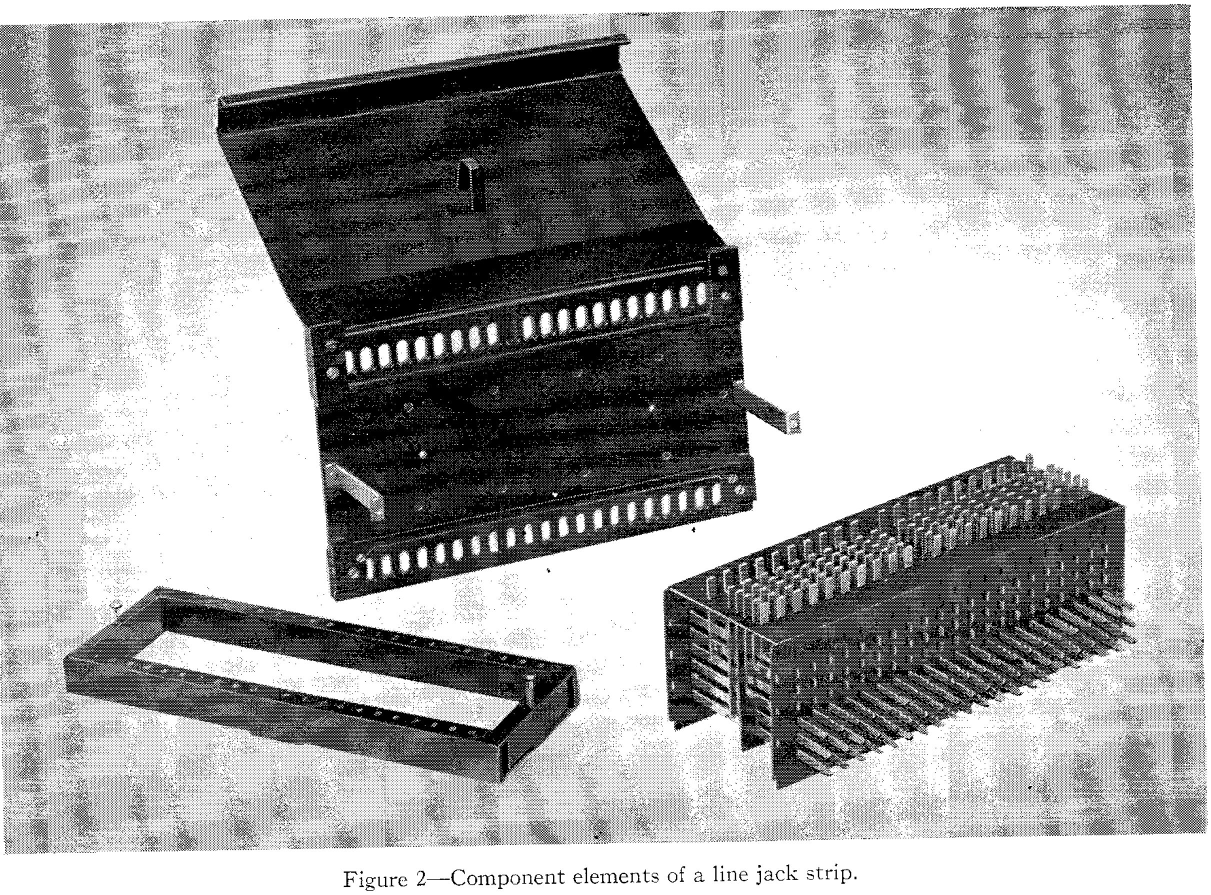


Figure 2—Component elements of a line jack strip.

go through similar holes at the top. The hinged cover normally rests over the top terminals and the upper ends of the line plugs to protect them against mechanical damage and dust. The plug, with which it is interchangeable. Two such cords are required for a patch.

The first cord connects the desired subscriber's line to the *P* terminals on the jack strip or on an

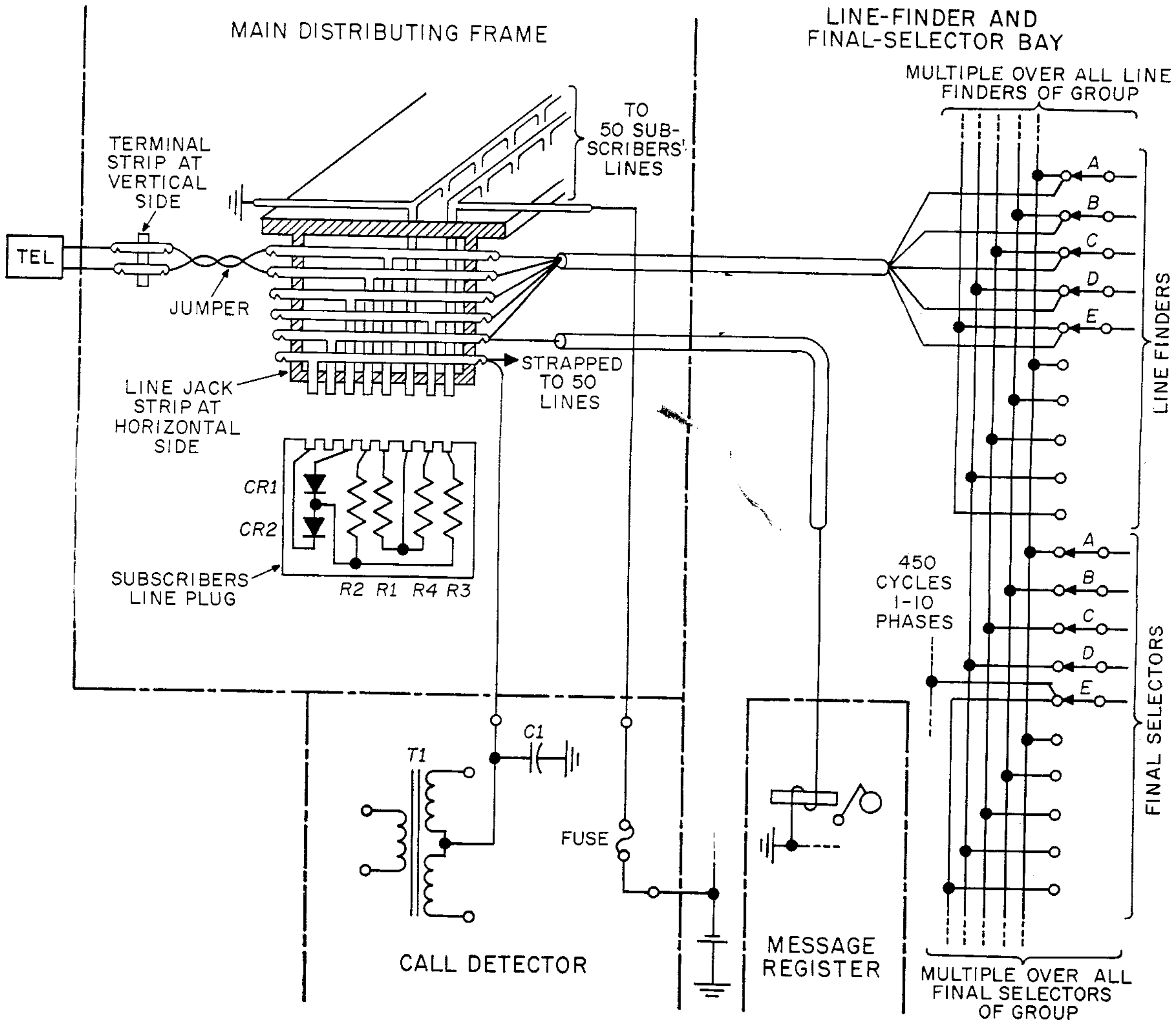


Figure 3—Schematic diagram of main-distributing-frame connections.

bakelite frame identifies each subscriber's line number by suitable engraving.

The set of terminals in the middle of the strip are called *P* terminals and are in addition to the 20 sets for lines. They may be connected to the wire-chief's desk so that only a short patching cord is needed to connect a subscribers line for testing.

1.3 Patching Cords

Each end of a patching cord terminates in a plug of the shape and size of a subscriber's line adjacent strip if more than one subscriber's line in a group of 20 is being patched. All of the *P* terminals on the various jack strips are concentrated on additional jack strips, also mounted on the horizontal side of the main distributing frame. The second patching cord connects the *P* terminals on the concentration strips to another strip on which junctions to the wire chief's desk, service-observation circuits, and similar functions terminate.

1.4 Cross-Connections for Special Facilities

It is, of course, still possible to solder jumper connections between subscriber's line circuits on the main distributing frame and terminations for special facilities. This would be done for the insertion of adapter circuits for pay stations, malicious-call circuits, and similar auxiliary facilities. These jumpers are soldered to the top terminals of the line jack strips.

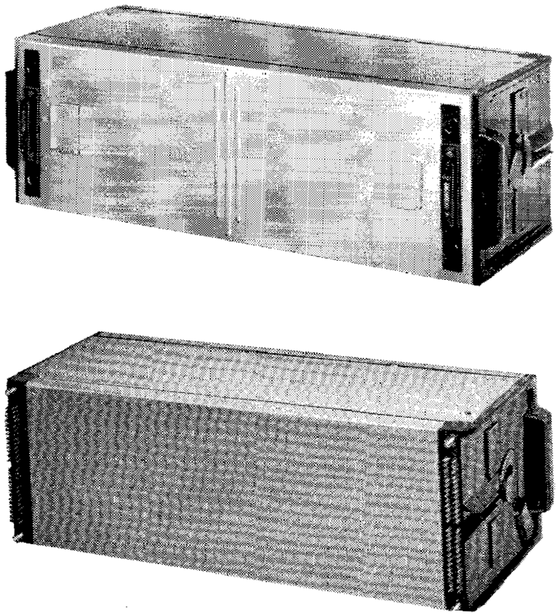


Figure 4—Front and rear views of a jack-in-relay mounting unit with dust covers in place.

2. *Bay Design and Equipment*

The apparatus is mounted on vertical bay frames that are arranged in rows. Bays may be distinguished according to the type of equipment mounted on them, such as finder bays, relay bays, register bays, et cetera. Two or three bays may be bolted together as an equipment unit to permit the complete wiring and testing in the factory of a circuit distributed over the bays.

2.1 Finder and Selector Bays

A single type of switch is used for the finder and selector circuits and the standard bay is based on the vertical mounting requirements of these switches. The bays are 280 millimeters (11 inches) wide by 3115 millimeters (122.7 inches) high. The vertical mounting space of 2880 millimeters (113.5 inches) accommodates 36 switches spaced 80 millimeters (3.2 inches) apart center to center.

The over-all height of the switch racks that accommodate the bays is 3665 millimeters (144.4 inches). Assuming that no cabling is run over the tops of the switch racks, a minimum ceiling height of 3750 millimeters (147.8 inches) is required to provide a clear space of 85 millimeters (3.4 inches) between the racks and the ceiling.

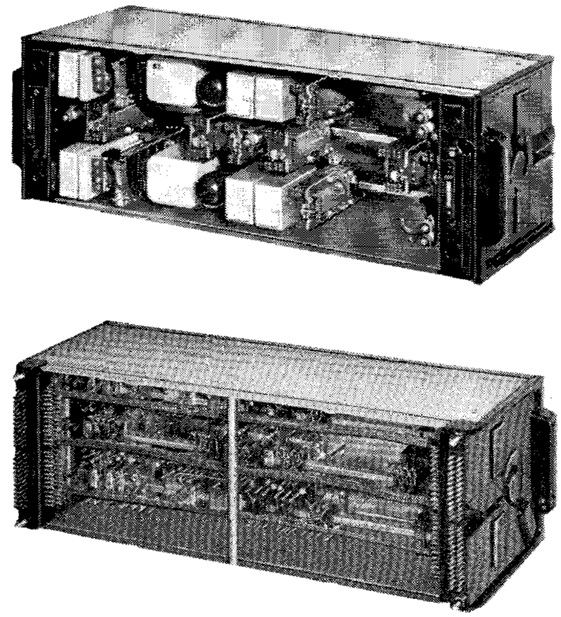


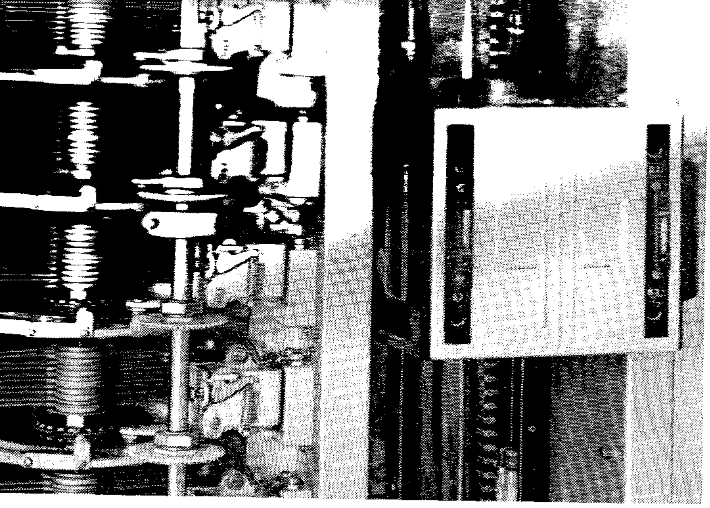
Figure 5—Front and rear views of uncovered relay mounting unit.

Shorter bays mounting fewer than 36 switches can be provided if the ceiling height of the switch room will not accommodate the standard switch rack.

2.2 Relay Bays

In the standard height of the bays, there is space for 18 relay mounting units, each of which is equivalent to two switches. Each mounting unit provides space for the circuit apparatus associated with either two adjacent finders on the next bay or with four finders on the two adjacent bays. These associated finders and relays are connected through a short cable form.

Front and rear views of the jack-in relay mounting units are shown in Figure 4 with dust



covers in place and in Figure 5 without the covers.

Five different widths of relay mounting units and bays have been designed to accommodate the varying amounts of equipment required for different circuits. Maximum interchangeability

Figure 6—View of a jack-in relay mounting unit in position on bay. The relay mounting unit is associated with the two finder switches at its left and with two others to its right that are not shown.

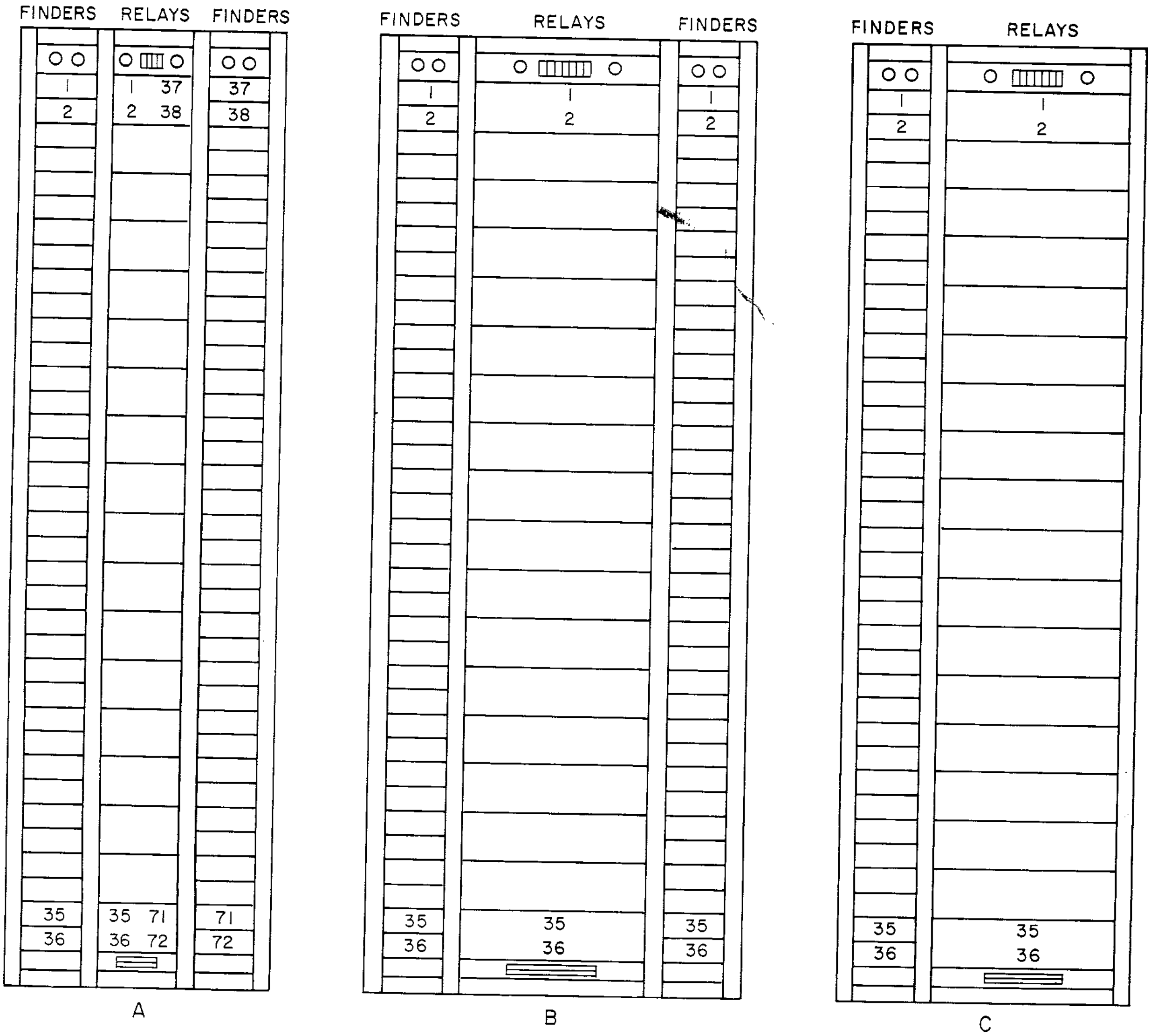


Figure 7—Equipment arrangements. At *A*, 72 first line finders, group selectors, or final selectors and their associated relay units are mounted as shown. Each relay unit includes the apparatus required by the four immediately adjacent switches. At *B*, 36 cord circuits are mounted on three bays, each circuit including a second line finder at the left, a group selector at the right, and 12 relays between them. Each relay mounting unit contains 24 relays to care for two circuits. At *C*, are 36 incoming group selectors, each requiring a finder switch and 11 relays. A relay unit serves two circuits and carries 22 relays.

of parts among the different widths of bays and mountings has been provided. For example, the bakelite ends of all the mounting units are identical and include the 52 male connectors for each end, the handle and lever for activating and locking the jack-in mechanism, fuse mounting, jack and lamp space, and the fastening plates for the three rectangular bars on which the relays and other circuit parts are clamped. Also to these ends are fastened the top and bottom shielding plates as well as the front and rear covers. The various sizes of mounting units differ only in the lengths of the mounting bars and enclosing panels.

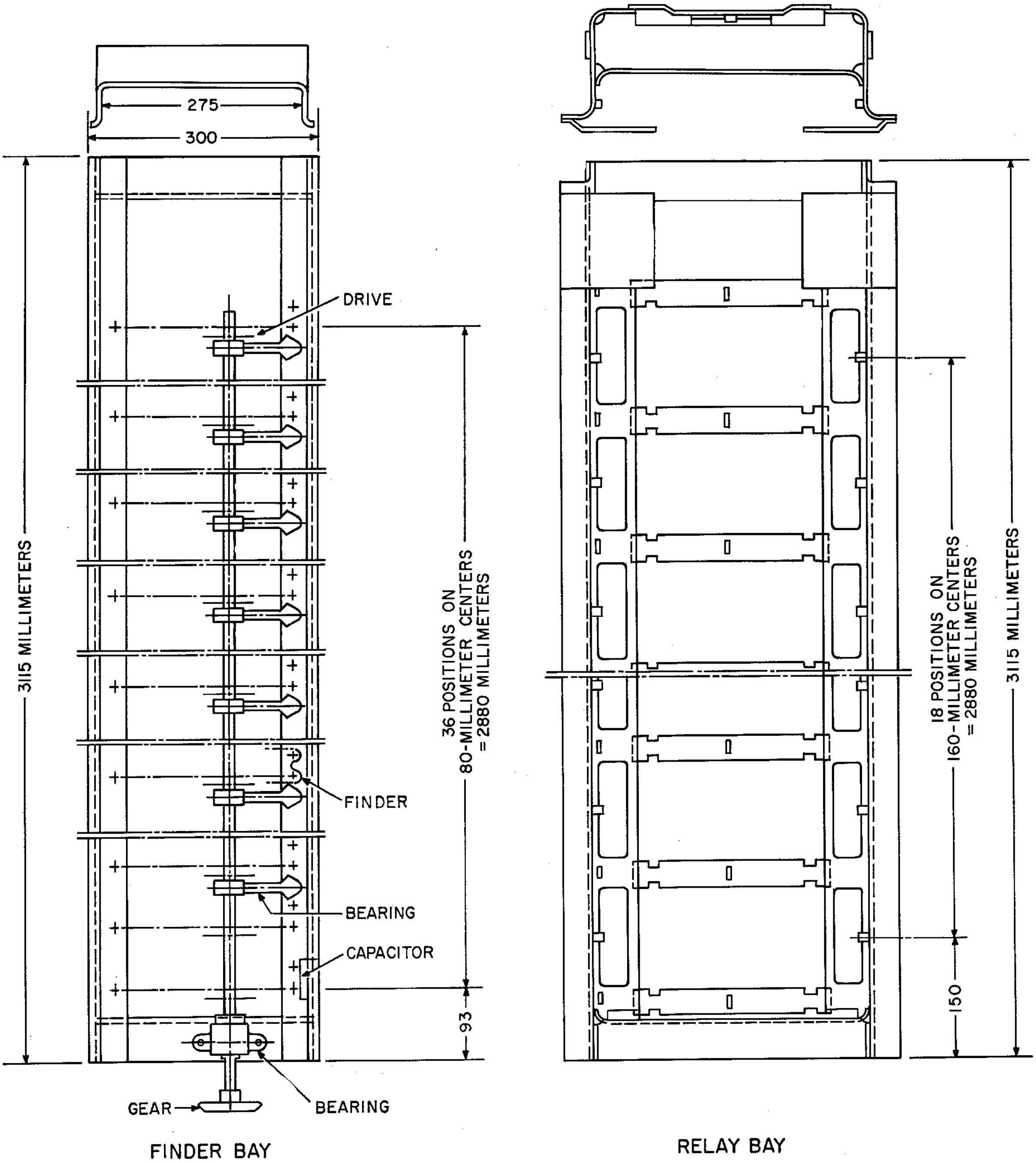


Figure 8—Arrangement of finder and relay bays.

Figure 6 is a view of parts of adjacent relay and finder bays. The single jack-in relay mounting unit shown accommodates four sets of two relays each that are connected to the two finder switches immediately to the left of the unit and to two others at the right that are not visible in the figure. The female connectors for the relay units may be seen above and below the unit that is in place. In this case, the amount of equipment per circuit is small and 72 line-finder, group-selector, or final-selector equipments would be accommodated in an equipment unit as shown in Figure 7A.

The arrangement in Figure 7B is for 36 cord circuits, each of which consists of a second line finder, a first group selector, and 12 relays. In this case, the relay mounting unit must be longer than in the previous design to accommodate the 24 relays required for two cord circuits.

Each of the 36 incoming-group-selector circuits indicated in Figure 7C requires a selector switch and 11 relays. Again the relay mounting unit serves two circuits and contains 22 relays.

This design provides extreme flexibility in the layout of equipment. Figure 8 shows the constructional features of two typical bays, a finder bay and a relay bay. As in the case of the relay mounting units, the relay bays use many identical elements, the variations in width being provided for by different lengths of cross members. The base for a switch rack is shown in Figure 9.

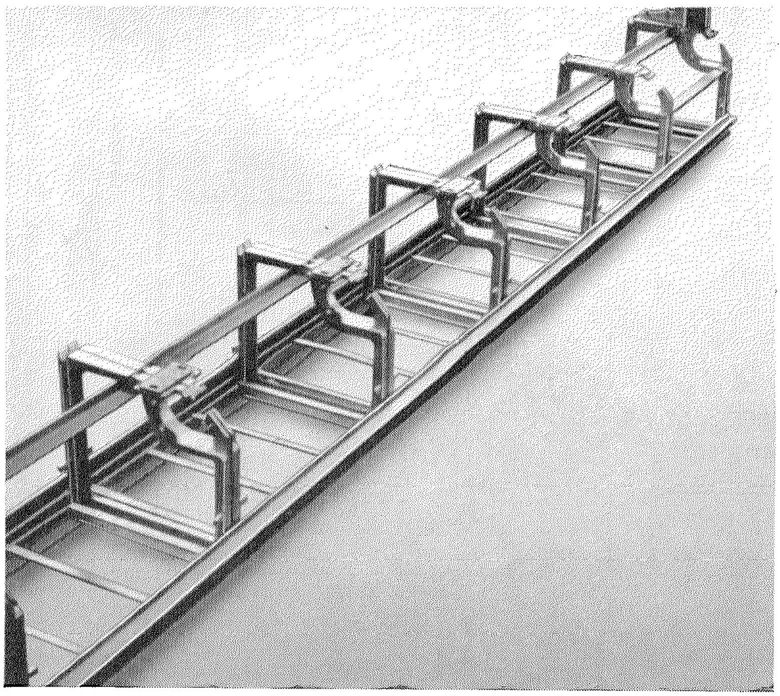


Figure 9—Base for a switch rack.

2.3 Equipment Units

The equipment units indicated in Figure 7 may be used in a large variety of ways, both as regards the types of circuits served and the number of circuits provided. In Figure 7A for instance, all 72 circuits could be group selectors and the arcs of all 36 switches in each bay will usually be interconnected by a straight multiple. The two selector bays associated with an equipment unit may belong to the same selector stage and their multiples may be connected in the same grading or, alternatively, they may be associated with different selector stages such as second and third group selectors.

Some other arrangements in which 72 circuits may be used for line finders, final selectors, and sometimes as penultimate selectors to suit various traffic densities are shown in Figure 10.

In Figure 10A, the 72 circuits are used for first line finders and final selectors for two groups of 100 subscribers. This provides a total of 36 line finders and final selectors for each 100 subscribers, which may be divided into 18 line finders and 18 final selectors for each 100-subscriber group. Such an arrangement is needed for subscriber groups having an extremely high traffic rate and will handle originating and terminating traffic of 10 erlangs each per 100 lines.

As shown in Figure 10B, the 72 circuits may be divided into three groups each serving 100 subscribers. Each subscriber group would have 12 line finders and 12 final selectors which could handle 5.8 erlangs of originating and of terminating traffic.

In Figure 10C, there are four groups of switches serving 100 subscribers each. Each group of

18 switches would provide 9 line finders and 9 final selectors and provide for 3.6 erlangs of originating traffic and the same amount of terminating traffic.

When divided among five groups of 100 subscribers each as in Figure 10D, there will be 7 line finders and 7 final selectors for each group to provide for 2.5 erlangs of traffic. Only 70 circuits will be thus employed, and the remaining two circuits may be added to one or two of the subscriber groups.

In some cases, it may be economical to distribute the fourth group or penultimate selectors for a group of 1000 subscribers over the equipment units on which first line finders and final selectors for the 10 groups of 100 subscribers'

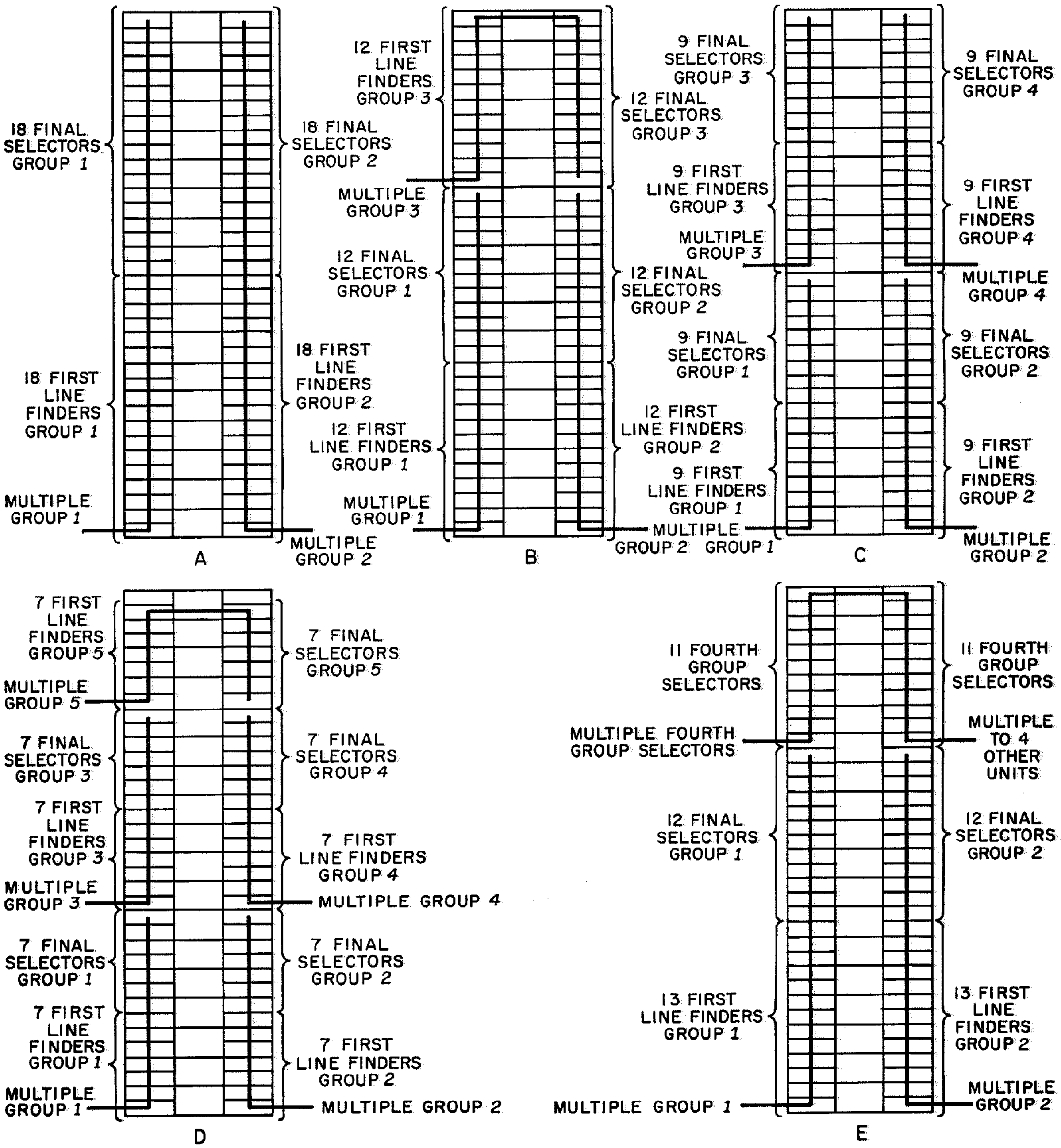


Figure 10—Some of the possibilities provided by the equipment of Figure 7A.

lines are accommodated. If the traffic requires 13 first line finders and 12 final selectors per 100 lines, the arrangement of Figure 10B does not provide the space for 25 switches per 100 lines and 10A requires 5 units to accommodate the 10 groups of line finders and final selectors plus two more equipment units for the required 110 penultimate selectors. In Figure 10E, only 5 equipment units will be needed as each unit mounts two groups of 25 switches and has space for 22 penultimate selectors to distrlbute the 110 over the 5 units.

This flexibility originates from the fact that all line-finder, final-selector, and group-selector circuits employ the same apparatus and the four circuits in each relay mounting unit may be used indiscriminately as line finders, group selectors, or final selectors. It may be noted in Figure 10E that the 7th relay unit from the bottom is used with both line finders and final selectors and that the 6th relay unit from the top serves both final selectors and penultimate selectors.

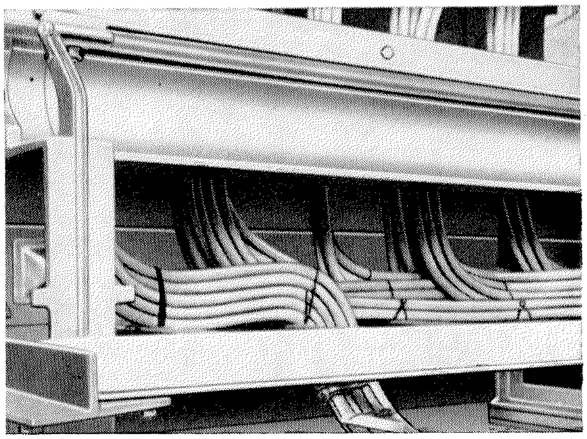


Figure 12—Cable run in switch rack base.

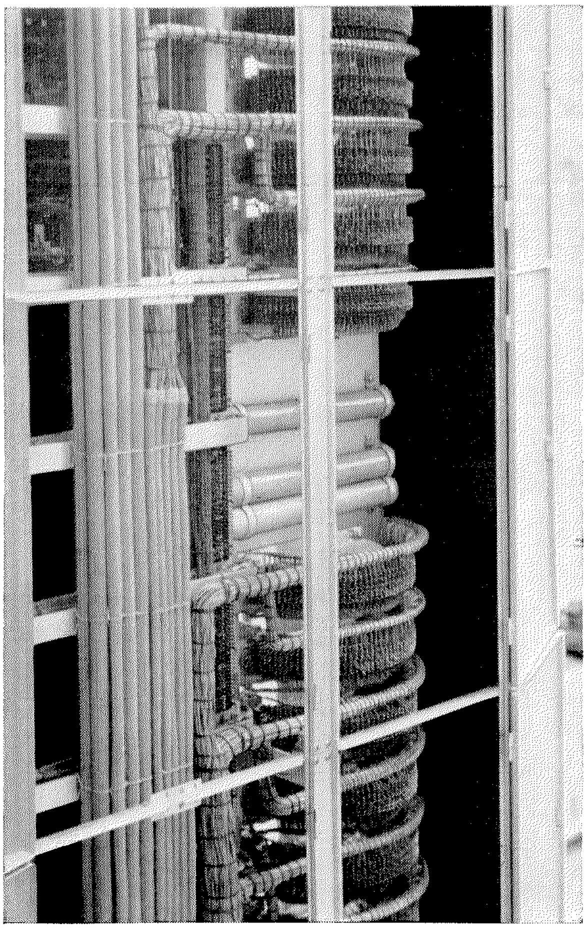


Figure 11—Rear view of bays showing cabling.

Another important factor in obtaining flexibility is that the subscribers' line circuits are mounted on the main distributing frame and not on the line-finder bays as in previously developed rotary systems. If the varying amounts of subscribers' line equipment were mounted with the line finders in the switch room, the equipment units of Figure 10 would have required various types of relay bays instead of a uniform type that may be employed for all traffic densities.

There are, of course, many other arrangements not shown in Figure 10. For example, some 100-line groups in a 1000-line block may require higher traffic-handling ability than others to care for private branch exchanges. The flexibility of the system permits best possible use to be made of the equipment space available to provide minimum space occupancy and maximum economy.

3. Equipment Line-Up

3.1 Floor Plan and Cabling

It is customary for exchange equipment to be grouped in blocks to serve 1000 subscribers and to mount each such block in a single row of switch racks.

In some cases having low traffic density or where the switch room is of suitable size, 2000 lines can be served by a row of switch rack. It may then be economical to connect the first line finders of 20 groups of 100 subscribers' lines in the multiple of one group of second line finders to provide one group of cord circuits per 2000 lines. In each case, attention must be given to the switching plan and equipment layout to economize on space and interconnecting cable.

By placing the apparatus forming part of each 1000- or 2000-line block in a single switch-rack row, much of the interconnecting cable is also restricted to that row. In Figure 11, showing the rear side of a switch-rack row with the shielding doors open, the interconnecting cables from the apparatus go down inside the shielded switch rack. In Figure 12, the cable is shown entering the base of the switch rack. There are several advantages to accommodating the cable in the base of the switch rack.

A. Protection is provided against dust and fire by the complete shielding of the base.

B. Cables are readily accessible for inspection and additions. Work is carried out at floor level without the use of ladders or scaffolds.

C. The upper part of the switch rack is simplified as no cable racks or intermediate uprights are needed.

D. Improved appearance and better lighting are obtained. Fluorescent fixtures may be installed at the top of and between switch racks to produce a clear diffuse illumination that discloses details of equipment and colors of wires without the use of portable lamps.

The cabling interconnecting the various rows of switch racks may be laid in a number of alternative ways. In new buildings, it is preferable to provide a cable hole through the floor

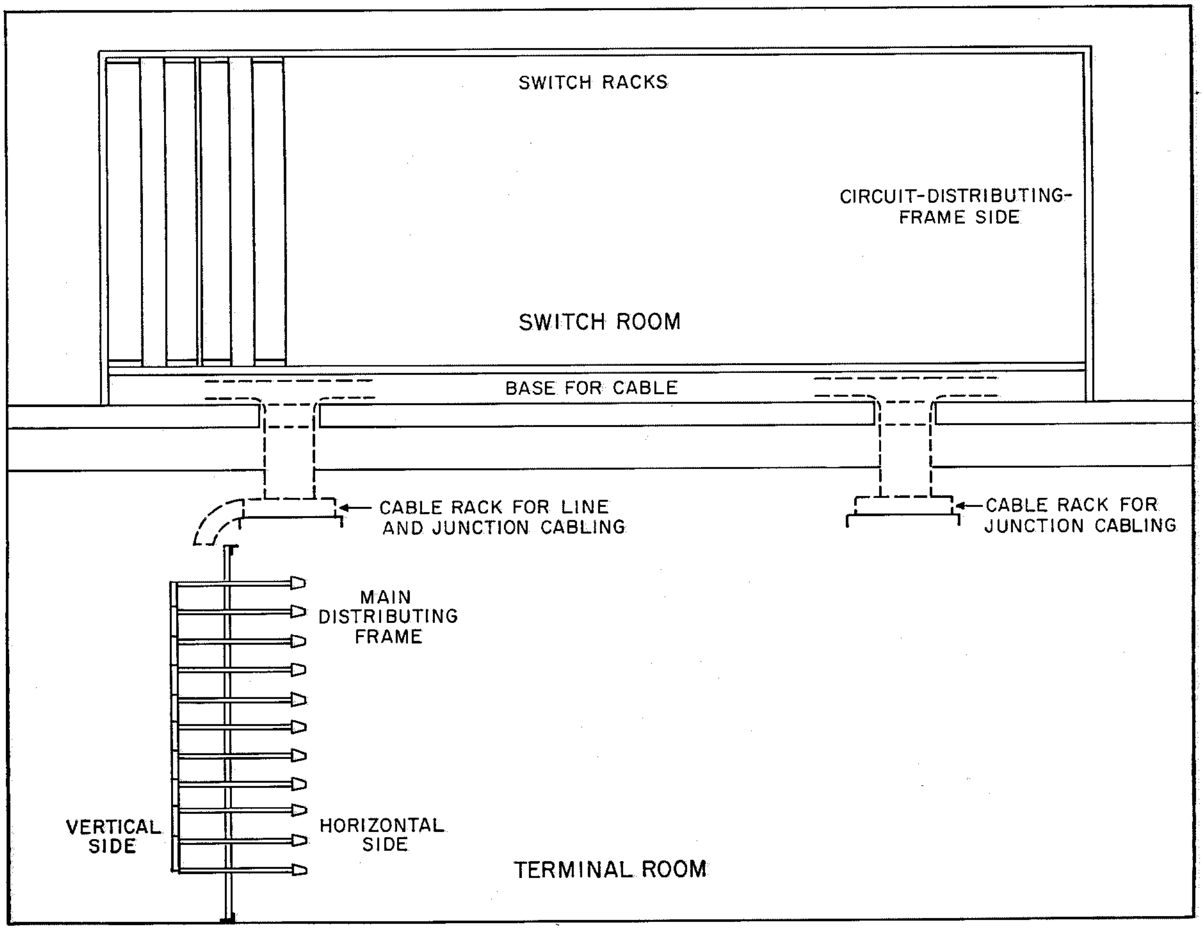


Figure 13—Typical method of running cables on racks attached to the ceiling of the room beneath the switch room.

Figure 14—Cable run on switch-room floor at end of switch-rack rows.

underneath each switch-rack base. The cabling may be supported on a rack fastened to the ceiling of the room below. Often this will be the terminal room of the exchange in which the main distributing frame is mounted and cable holes between the two rooms will be required for the cables from the main distributing frame to the switching equipment. This method is illustrated in Figure 13; it uses the minimum amount of cable and none of it is visible in the switch room.

An alternative method is to construct on the switch-room floor an enclosed cable rack connecting to all of the bases of the rows of switch racks through which the cabling normally runs. Cable between rows will then pass through this rack. This method is shown in Figure 14.

A third method is to bring the interrow cabling from the base of the switch rack at the end of the row inside a shielded cable shaft to a rack above the corridor alongside of the racks as shown in Figure 15.

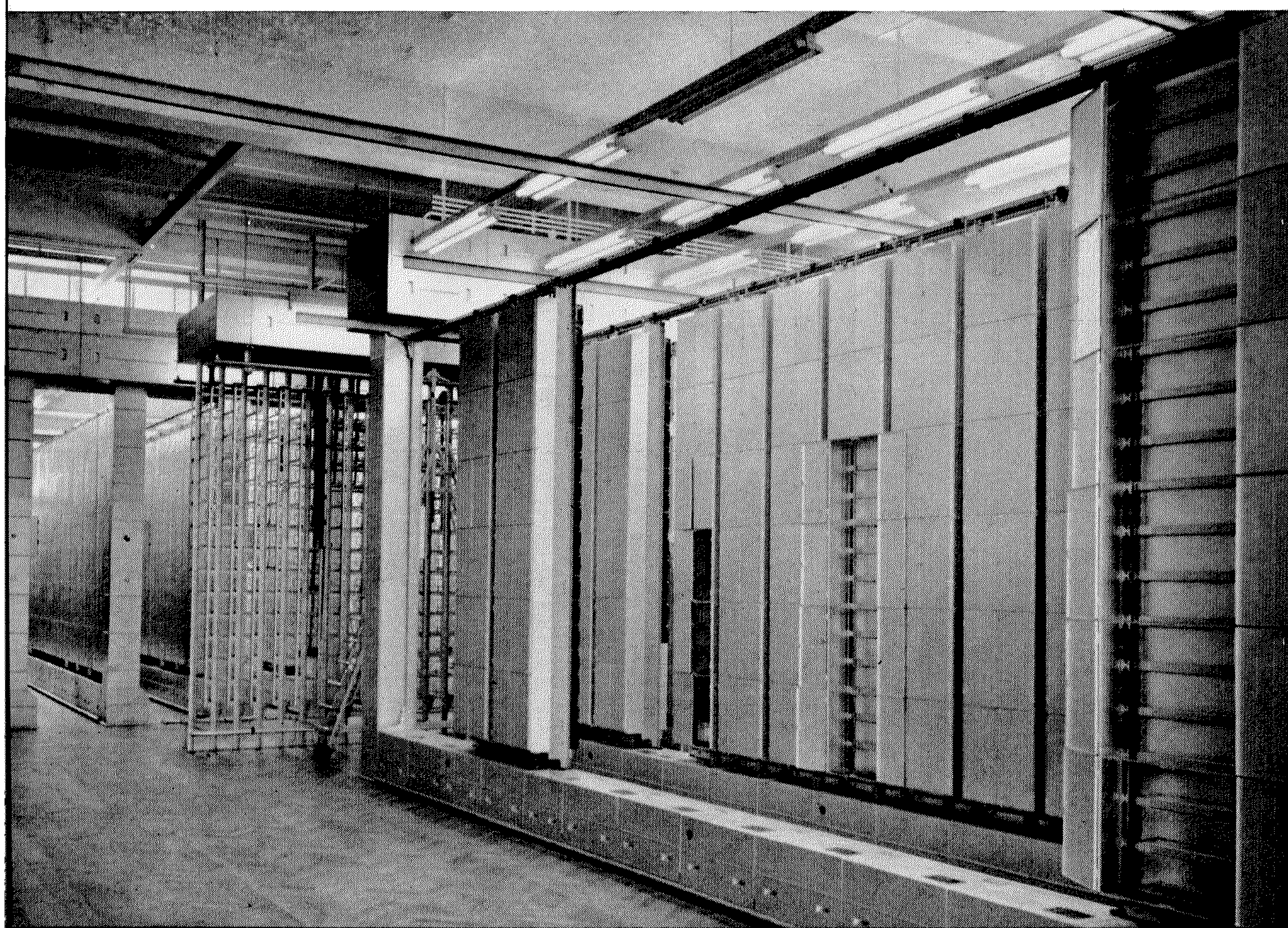
Figure 15—Cable run placed above the switch racks along the ends of the rows.

Cables from equipment going to the base of the switch rack run behind the relay bays, which provide the necessary supports. This is permissible because the relay mounting units may be detached from the bay. It is unnecessary to provide access to the rear of the relay units when they are plugged into the bay. Inspection and repair work is done in a workshop by removing the entire relay mounting unit. Moreover, with the unit in operating position, all relay contacts and winding terminals may be reached from the front of the unit by removing the front cover.

3.2 Motor Drive

As will be seen in Figure 16, the driving motor for the rotary switches operates a horizontal shaft that runs through a separate compartment in the base of the switch rack. The vertical shafts of the finder and selector bays of one row are geared to this horizontal shaft. Removable covers protect maintenance staff against injury but permit ready access to the bearings and gears for inspection and lubrication.

The motor is mounted vertically on one of the



relay bays, usually the call-detector bay. It is coupled to the horizontal shaft through a built-in worm gear. A flexible coupling between the gear and the shaft cares for any misalignment. The motor is held in a vertical operating position by a strong leaf spring. To remove the motor, the spring is lifted and the motor is swivelled forward around the axis of the horizontal shaft as shown in Figure 17, the flexible coupling is then disengaged and the motor removed. No tools are needed and a motor can be replaced in a few seconds.

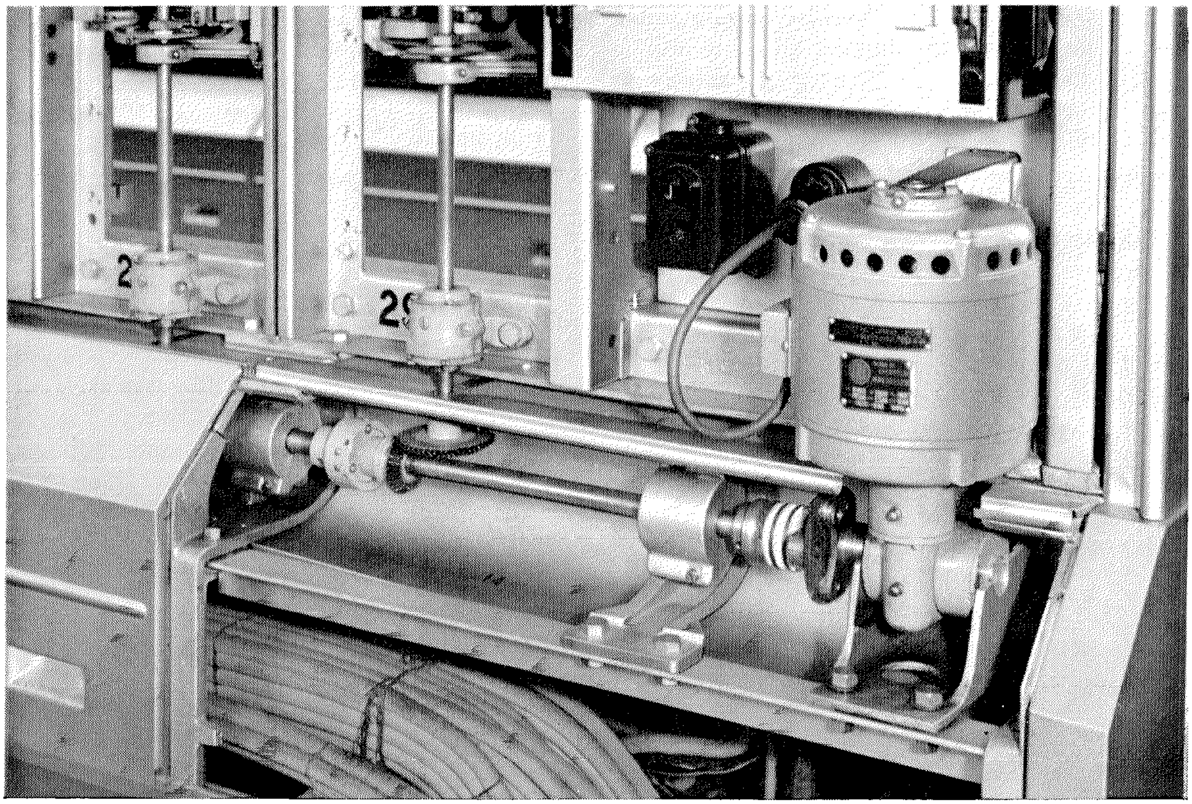


Figure 16—Motor drive arrangement showing horizontal shaft and gearing takeoff for vertical shafts on each switch bay. The shafting runs in a separate compartment above the cable run in the base of the switch rack.

4. *Homogeneous Grading*

The general principles underlying the theory of grading will not be treated here. Consideration will be given only to those special conditions met in the *7E* system, principal among which is that neither the selector nor finder switches are provided with home positions.

If the number of circuits in a group is greater than the number of contacts in the level to which they are to be connected, the multiple must be split by dividing the group into subgroups. This reduces the efficiency and grading methods are used to regain some of the lost efficiency. For switches with homing positions, advantage may

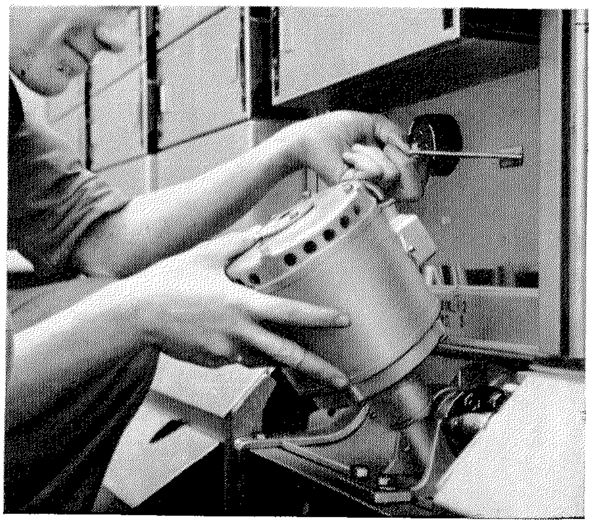


Figure 17—Method of removing switch-rack motor.

be taken of the fact that the circuits in a group will be tested in a definite order. The circuits at the beginning of the banks carry more traffic than those that will be tested later or are of higher rank. The efficiency of these higher-rank circuits is increased by connecting them to more than one split.

From a traffic viewpoint, there are three main objections to applying this principle to the *7E* system. First, with nonhoming switches, the same average traffic is offered to all contacts and no improvement in efficiency is provided by connecting some circuits to more splits than others.

Second, if grading schemes using individuals and commons of different orders were applied to nonhoming switches, a large percentage of the calls might test commons of higher order before those of lower order or individuals and this would adversely affect the efficiency of the graded group.

Third, it has been demonstrated by extensive tests with the rotary traffic machine[2] that gradings using individuals and commons of different order do not provide the optimum efficiency for the connected group. Optimum efficiency is obtained preferably by using commons of only one order and by applying the principle of "perfect combination" whereby connections among splits are arranged so that all combinations between any two splits preferably occur an equal number of times.

Such gradings do not suffer from the first two objections noted above and, furthermore, they offer improved efficiency. They have been termed "homogeneous gradings." Homogeneous grading gives a choice among gradings consisting exclusively of twos, threes, fours, et cetera, in which all circuits of the next switching stage are connected to bank contacts of two, three, or more splits. Gradings with threes require a larger number of smaller multiple splits than those with twos and will, therefore, show slightly higher efficiency. On the other hand, a limit is placed by the capacity of the standard switch bay. A 36-switch unit is rather large for threes and to avoid cutting the bay multiple cabling, twos are preferred.

[2] J. Kruithof, "Rotary Traffic Machine," *Electrical Communication,* volume 23, pages 192–211; June, 1946: page 205.

4.1 Bank Subdivision and Number of Splits

For a graded group of outlets using only twos and having an accessibility of a terminals, the relation $aS = 2n$ should be satisfied, where n is the number of outlets and S is the number of splits.

In the *7E* system, the number of contacts a that may be assigned to a group of outlets may be varied. The total number of contacts assigned to an assembly of groups may not exceed the contact capacity of the bank, which for the rotary switch is 100.

The number of circuits in a graded group depends on the traffic to be carried, the number of contacts assigned to the group (accessibility), and the grading used. A convenient method of calculating graded groups[3] was developed by the British Post Office. It is based on the efficiency of imperfect groups built in accordance with a "smooth progression" grading scheme. The *7E* system uses the perfect-combination principle, which provides higher efficiency. The use of the British Post Office procedure for calculating graded homogeneous groups inherently provides a margin of safety that has been confirmed by tests with the traffic machine.

To facilitate the subdivision of the contact bank and the calculation of the number of outlets per group, the families of curves shown in Figures 18–21 have been prepared. They are based on the British Post Office method for graded groups and indicate the relations between traffic volume, accessibility, and number of outlets. The arrangement of the curves is such that the different split regions are separated by equidistant horizontal lines.

As an example, assume that a number of group selectors mounted on six bays are to provide access to seven groups of outlets; the first group carrying a negligible amount of traffic; the second and third groups carrying 20 erlangs each; the fourth, fifth, and sixth handling 30 erlangs each; while the last group carries 50 erlangs.

Reference to Figure 18 shows that for 20 erlangs and for 6 splits, an accessibility of 12 contacts is required. For 5 and 7 splits, 14 and 11

[3] G. S. Berkeley, "Traffic and Trunking Principles in Automatic Telephony," Second revised edition, E. Benn Limited; London, England: 1949.

bank contacts are needed. Similar data for all the groups are displayed in Table 1.

It is evident that a satisfactory subdivision of the bank can be obtained with 6 splits. It provides 4 terminals for the first group. The number of outlets required amounts to 96 × 6 ÷ 2 = 288 circuits, plus a few circuits for group 1.

TABLE 1
GROUP ACCESSIBILITIES FOR VARIOUS SPLITS FOR HOMOGENEOUS GRADING

Outlet Groups	Traffic in Erlangs	Accessibility in Number of Contacts		
		5 Splits	6 Splits	7 Splits
1	—	—	—	—
2	20	14	12	11
3	20	14	12	11
4	30	19	16	15
5	30	19	16	15
6	30	19	16	15
7	50	28	24	21
Total Contacts		113	96	88

Had the number of bays been 5 instead of 6, the use of 5 splits would not be possible as the total number of bank contacts would amount to 113, which exceeds the capacity of the selector switch. There are two suitable solutions.

The first solution is to provide 6 only partially equipped bays. The other arrangement would be to reduce the number of groups of outlets connected to the selector banks. An additional selecting stage would be provided for a few directions of minor importance. The first solution is the more economical.

If, however, the number of bays had been 7, the total number of bank contacts would be only 88 and 12 contacts would be unused. The number of outlets required would be 88 × 7 ÷ 2 = 308

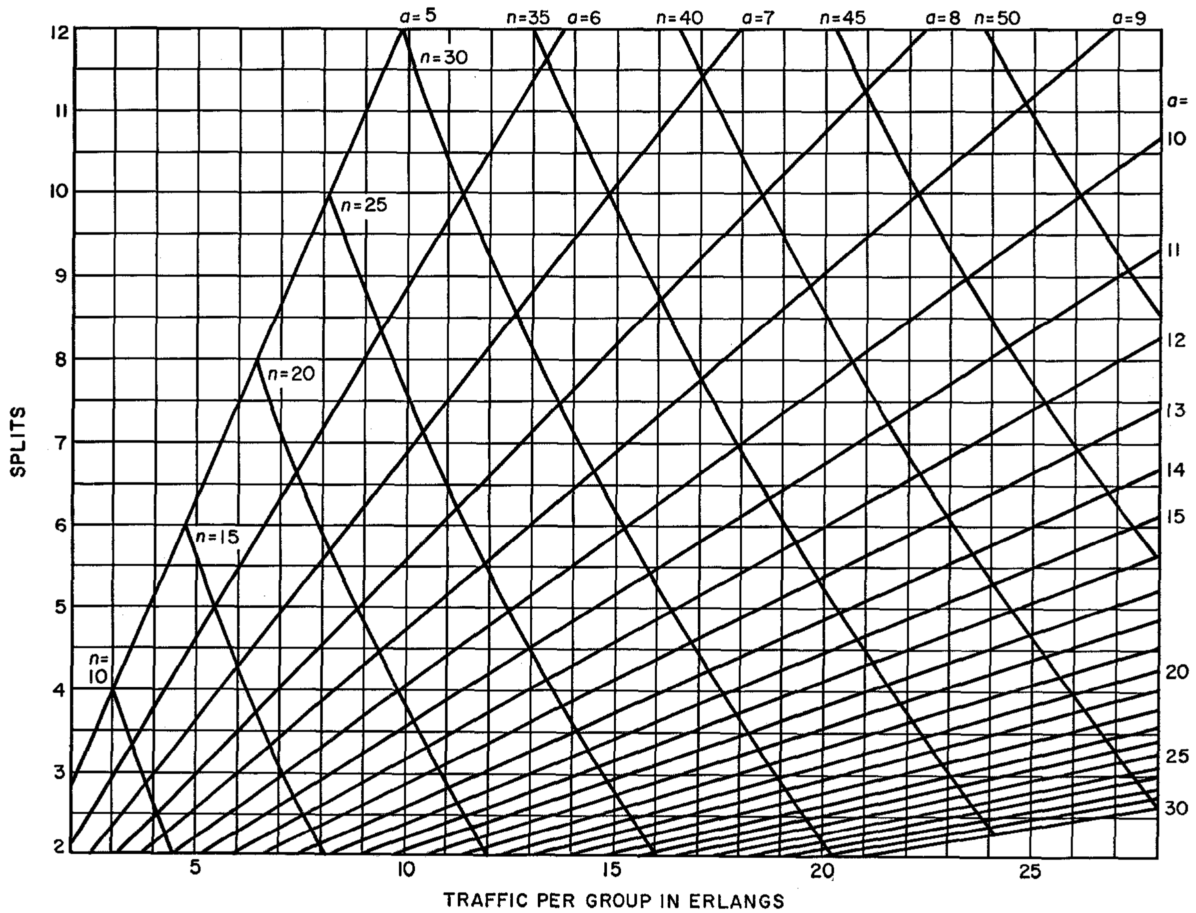


Figure 18—Accessibility a and number of outlets required n plotted against number of splits for traffic values between 2 and 28 erlangs per group and for probability of loss $P = 0.01$.

circuits plus a few for the first group compared with 288 for the 6-split arrangement. This larger number of circuits results from only partial utilization of the bank.

Two remedies are available. Six splits may be used and the excess bay connected in multiple with one of the others. This gives splits of unequal size and traffic loads but is permissible in exceptional cases. The traffic machine shows that the grade of service is at least as good as that for which the grading was calculated by the British Post Office method.

The other and recommended arrangement is to make the number of splits equal the number of bays, 7 in this instance, and use the full bank capacity by adopting the 6-split contact subdivision. This arrangement provides the minimum number of outlets and offers greater flexibility for future traffic fluctuation than the first method. As a consequence, a number of fours have to be introduced or full availability for one or two minor groups may be adopted. The fours must be spread proportionally over the outlet groups and are obtained by interconnecting two twos. These temporary connections may be broken later if the number of circuits to be connected is increased.

The average traffic load on contacts connected in fours can be equalized somewhat by proper allocation of the bank contacts to the outlets of the various groups. With homogeneous grading, the contacts connected to the outlets of a particular group are spaced approximately equally in the selector arc to reduce hunting time and load the outlets evenly. By reducing the spacing between these contacts, the traffic load of the second contact is somewhat reduced.

If the number of contacts, calculated for a number of splits equal to the number of bays, is considerably smaller than 100, say 75 or 50, the

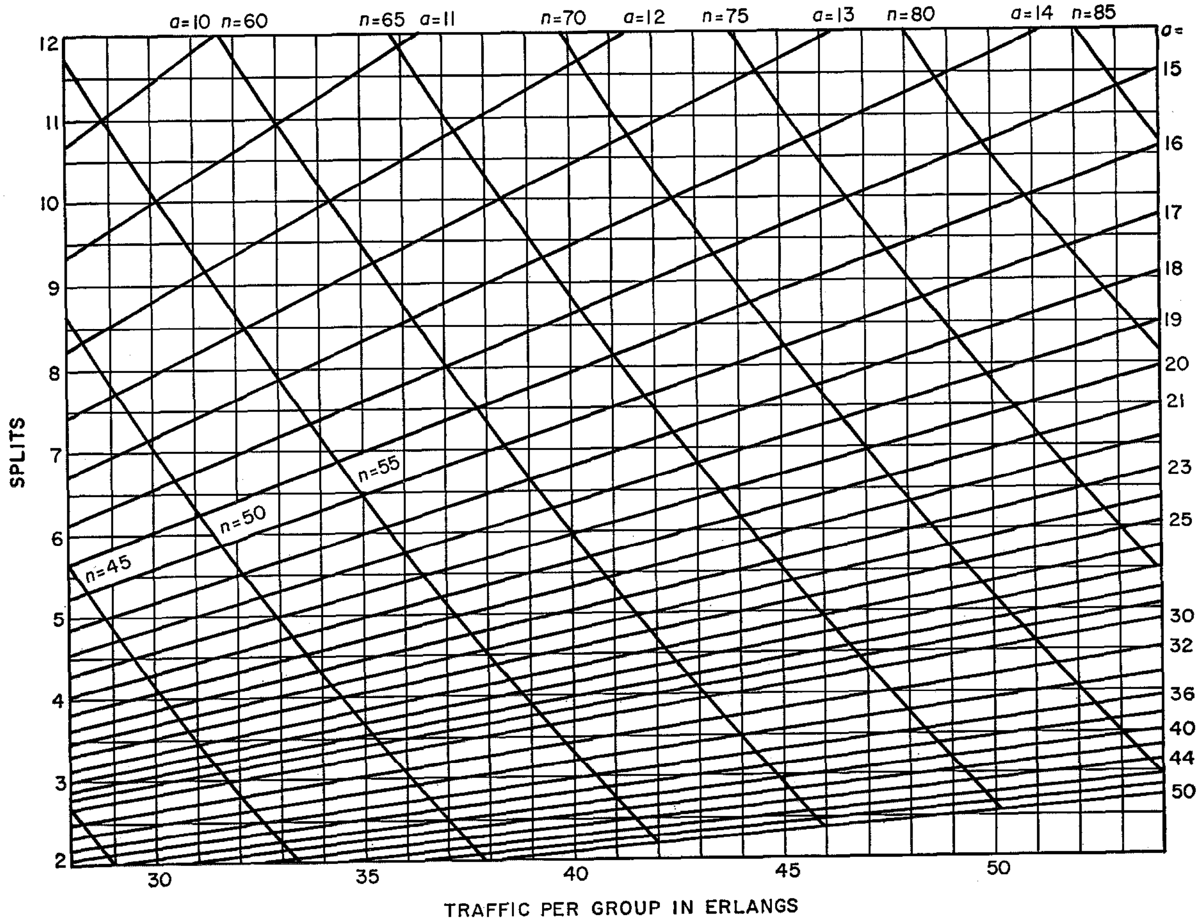


Figure 19—Continuation of Figure 18 for traffic values between 28 and 55 erlangs.

splits should include $1\frac{1}{2}$ or 2 bays. This may occur with multiples using low type of bays or which give access to a rather small number of outlet groups. This arrangement reduces the exchange cabling and cross-connecting equipment.

In designing a homogeneous grading, the main objective is to use to a maximum the available capacity of 100 contacts.

Very large multiples are usually divided into subgradings, which for convenience are limited to 11 or 12 splits. Preference should obviously be given to the largest number of splits, as this provides an increased efficiency for the outlets and a consequent reduction in their number with the usual requirement that full utilization be made of bank capacity.

4.2 Formation of Homogeneous Grading

When the number of splits and the number of bank contacts allocated to the various levels have been established, a suitable grading scheme must be chosen. As already stated, a perfect combination of splits should be employed with homogeneous grading; that is, the grading arrangement with twos should be chosen so that for each level, each combination of two splits appears approximately the same number of times.

It will be apparent that the grading schemes for each of the different groups of outlets connected to a group of selectors will similarly have the same number of splits and be only of twos. This permits a permanent homogeneous grading for the multiple of the entire bank to be built in advance of the allocation of contacts to the different levels.

Such a prearranged cabling and grading scheme must satisfy a number of conditions. It should provide sufficient flexibility to allow for rearrangement of bank multiples, which are subject to frequent changes during the life of an

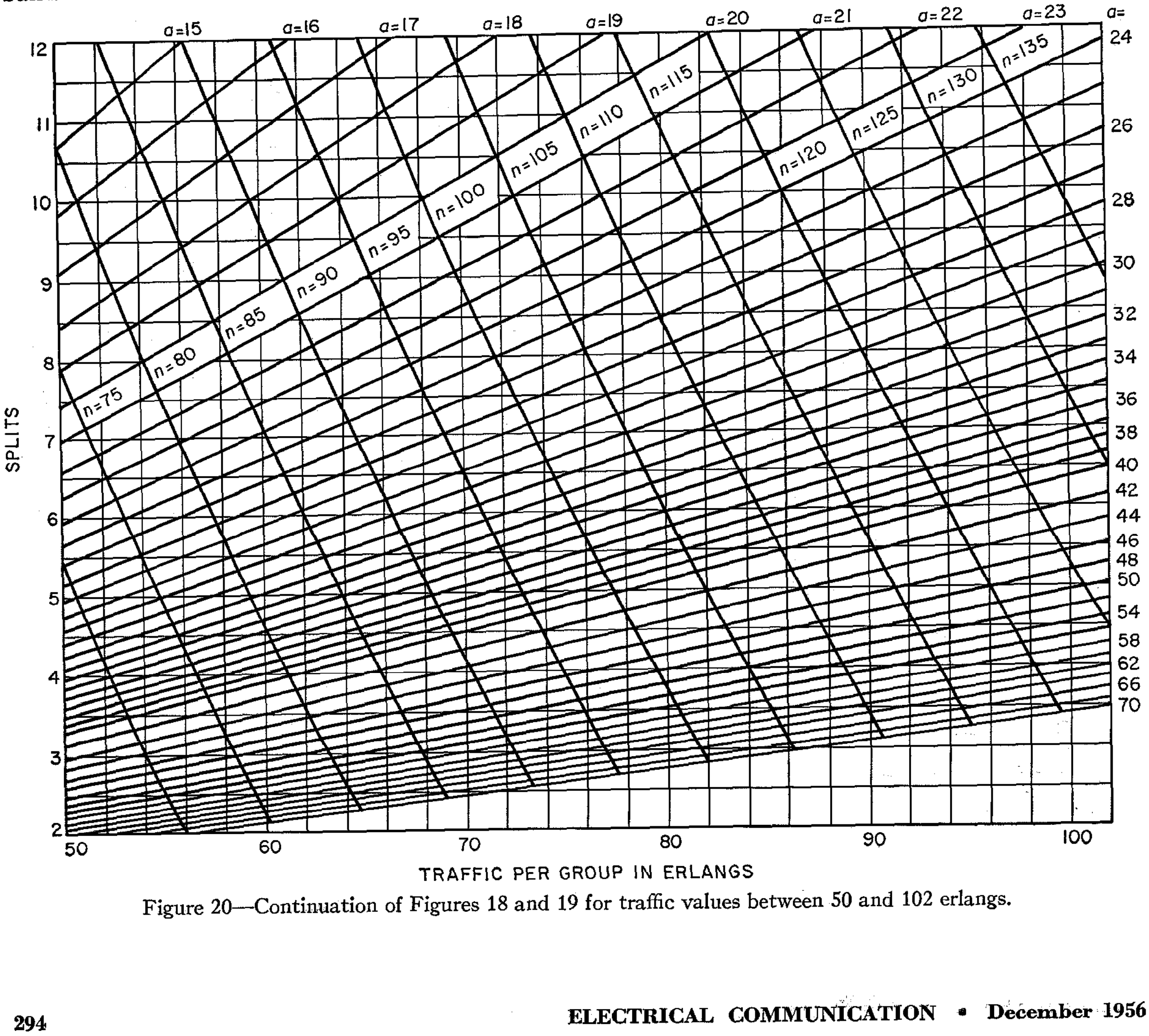


Figure 20—Continuation of Figures 18 and 19 for traffic values between 50 and 102 erlangs.

exchange. These modifications may be caused by changes in traffic, routing of traffic, and the number of outgoing directions, as well as the introduction of extensions, et cetera. The most difficult condition is the latter in which a grading of four splits, for instance, may have to be extended to six or more splits.

In the *7E* system, the complete banks of the various splits are usually cabled to terminal strips on one side of a floor-type circuit distributing frame. The other side of the frame accommodates the terminal strips to which the circuits of the next switching stage are connected. Other cabling arrangements are feasible, such as the introduction of mixing panels or the use of several rack-type frames for one multiple. A method based on the direct interconnection of the splits by short crossover multiple cables avoids the use of circuit distributing frames but may be applied to advantage only to multiples or parts of multiples that will not require modification at a later time.

As all outlets appear in two splits, the switch bank is divided into two parts, one consisting of contacts 1 to 50 and the other 51 to 100. They are designated as *CS* and *CS'*, respectively.

From each *CS* set of terminals, one set of 5-wire jumpers goes to the *CS'* terminals of a different split (grading jumpers) and another set of connectors goes to a set of terminals on the opposite side of the distributing frame (connecting jumpers).

Experience with homogeneous grading has produced three typical methods that are distinguished by the arrangement of the terminal strips on the circuit distributing frame.

In the first arrangement, the 100 bank contacts of a split are soldered in numerical sequence to the terminals of adjacent strips.

In the second, the *CS* and *CS'* groups of contacts are soldered to different groups of

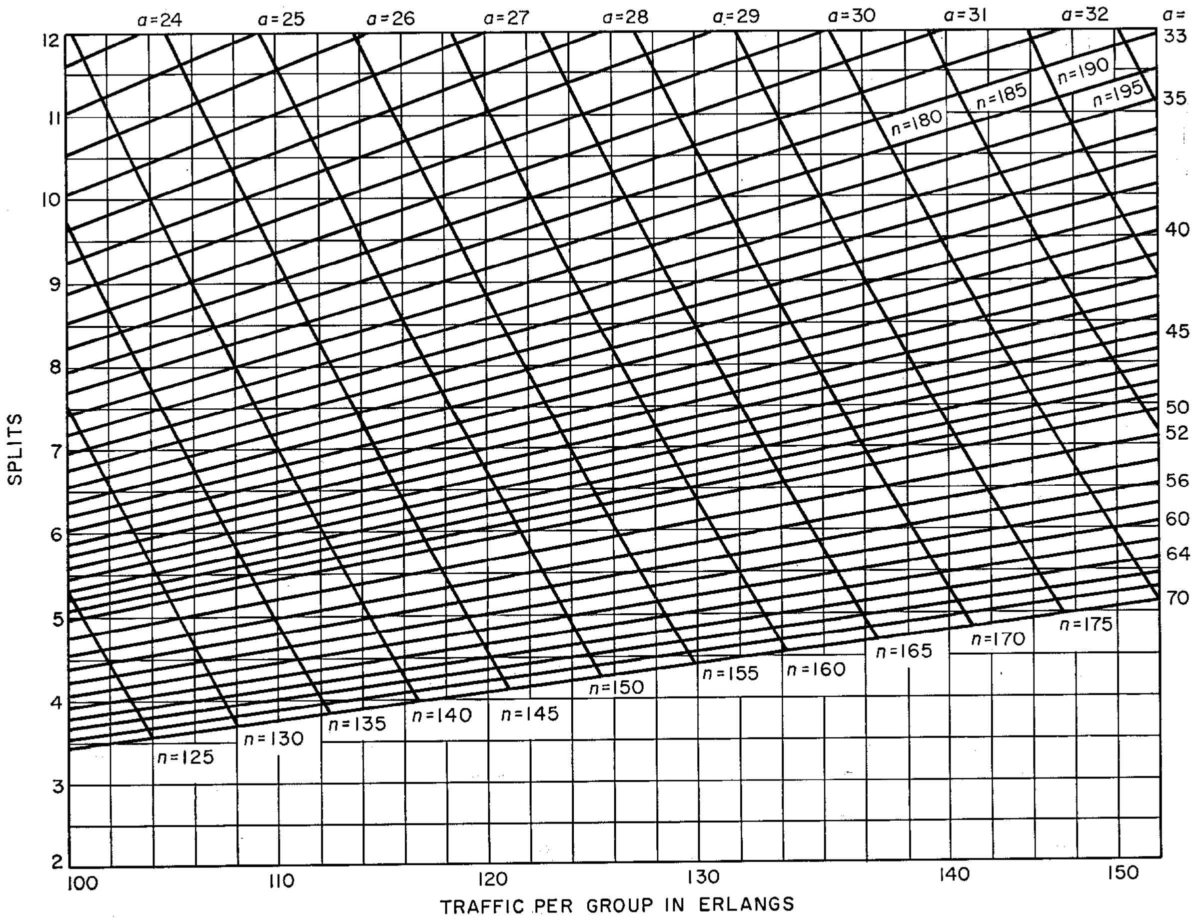


Figure 21—Continuation of Figures 18–20 for traffic values between 100 and 152 erlangs.

terminal strips that need not be adjacent to each other.

In the third arrangement, the 50 contacts of the *CS* part of the switch are soldered to the odd-numbered terminals and the *CS′* contacts to the even-numbered terminals of adjacent strips.

Figure 22 shows an elaboration of the first arrangement. The grading jumpers are shown for three different multiples having 4, 5, and 6 splits. They are shown as if directly interconnecting the bank contacts, although actually they run between circuit-distributing-frame terminals. The 100 contacts of a split are divided into sets of 10 each and the contacts within each set are treated in an identical manner from a grading point of view. The first contact in the figure, therefore, represents actual bank contacts 1 through 10, the second 51 through 60, and so on.

If a four-split grading must later be converted to a five-split grading, the changes in grading jumpers will be the same for every 10 consecutive contacts.

The 10-contact grouping facilitates installation work and possible rejumpering. The drawback to this division is that a completely cyclic arrangement of split combinations can be realized with only 6 and 11 split gradings. However, practice has shown that, with the allocation of contacts to the groups of outlets to be connected, complete cycles within a group are rarely obtained.

The choice of 10 contacts in a group is based on the fact that the maximum number of levels to which switches give access does not normally exceed 10.

The first arrangement places no restrictions on the types of cables, but requires full jumpering of all cross-connections.

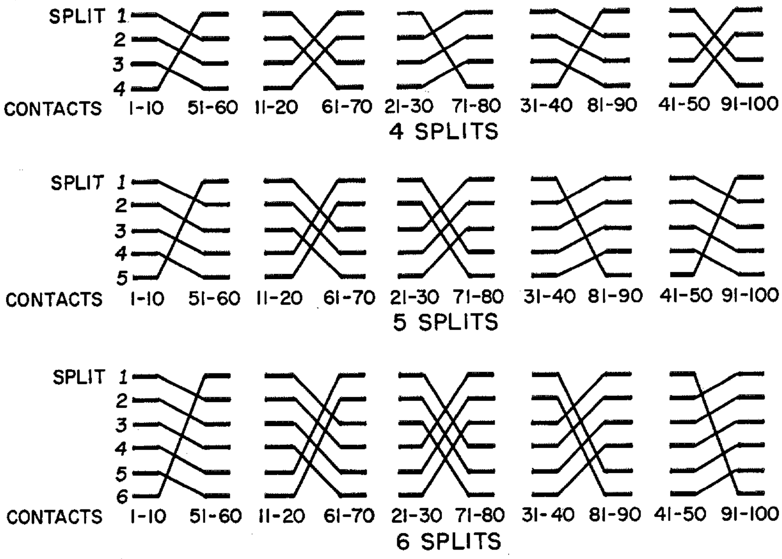


Figure 22—Homogeneous grading arrangement in which grading jumpers for banks are divided into 10-contact groups.

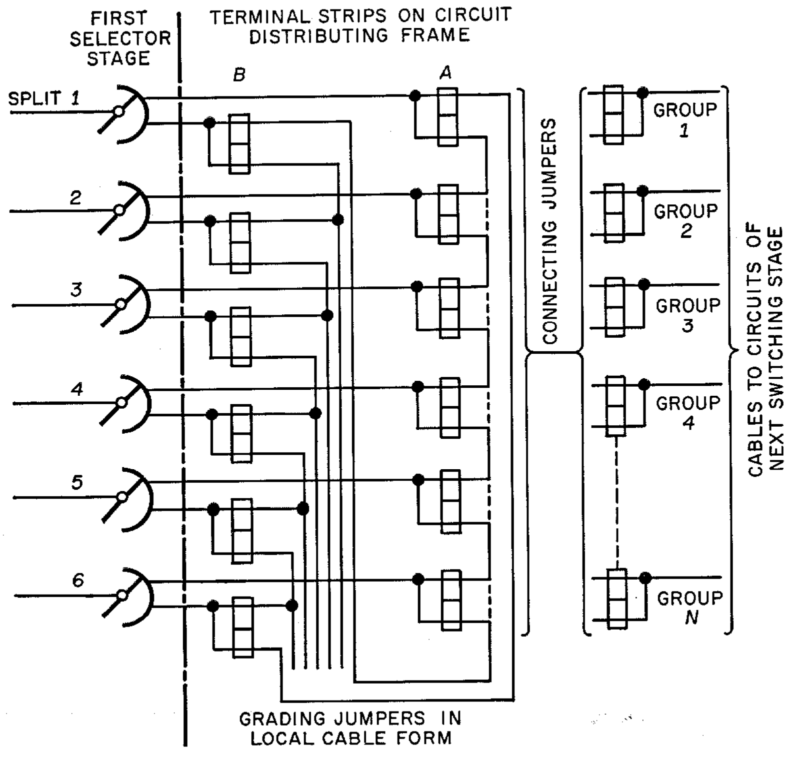


Figure 23—Cabling between selector stages and jumpering on the circuit distributing frame for 6 splits of homogeneous grading.

Figure 23 is an example of the second arrangement. A grading of 6 splits is shown providing access to 300 circuits belonging to the next switching stage. The *CS* part of the bank is cabled to terminal strips *A* and the *CS'* part to terminal strips *B*.

The grading jumpers between splits are handmade cable forms and interconnect the *A* and *B* terminals according to the ultimate planned grading scheme. One such cable form is provided for connecting 50 *B* terminals to the wanted *A* terminals of all other splits. The cable forms can be soldered once and for all, as this scheme is not affected by later modifications in the group allocation (connecting jumpers).

To avoid modification of the grading scheme incorporated in the permanent cable forms (grading jumpers) due to later extensions of the multiple, the *A* strips are originally equipped for the planned ultimate number of splits whereas the *B* strips are provided for only the existing splits.

With this arrangement, the *A* terminals of existing splits connect either a *CS* and *CS'* contact or only a *CS* contact. The *A* terminal strips of nonexisting splits connect either *CS'* contacts or no contacts at all. A homogeneous grading arrangement can readily be obtained for the initial stage by interconnecting the terminals of the *A* strips. In case of extension to a larger number of splits, the major modification is the removal of the last-mentioned jumpers.

Table 2 is an example of the numbering of the circuit-distributing-frame terminal strips according to the third arrangement. It assumes a grading of 11 splits. The cabling for the first part of the selector bank fans out over the strips of one horizontal shelf, while those from the second part of the arc are distributed over 5 different shelves. As discussed previously, the contacts within each set of 10 contacts are treated as identical from a grading point of view.

Advantages of this scheme are that the grading as a whole is conveniently arranged and that the jumpers become mere straps between adjacent terminals. A disadvantage is that for gradings above 6 splits, rather small size cable must be used.

With any of the examples described, full flexibility is obtained as the complete banks of all splits are brought to the circuit distributing frame.

4.3 Contact Allocation

In the example under consideration, a 6-split grading connects 294 outlets on 7 groups of circuits of 6, 36, 36, 48, 48, 48, and 72 circuits each. As the grading arrangement for 6 splits is cyclical, when dividing the bank into 10 subgroups of 10 contacts each, the outlet allocation of only about one sixth of the outlets over the first 50 contacts of any split need be considered in designing the connecting jumpers. All the

TABLE 2

Circuit-Distributing-Frame Terminal-Strip for 11-Split Homogeneous Grading

Terminal Strip	1		2		3		4		5	
Terminal Numbers	Odd	Even	Odd	Even	Odd	Even	Odd	Even	Odd	Even
Connect to Contacts	1–10	51–60	11–20	61–70	21–30	71–80	31–40	81–90	41–50	91–100
Shelves	of Splits									
1	1	2	1	3	1	4	1	5	1	6
2	2	3	2	4	2	5	2	6	2	7
3	3	4	3	5	3	6	3	7	3	8
4	4	5	4	6	4	7	4	8	4	9
5	5	6	5	7	5	8	5	9	5	10
6	6	7	6	8	6	9	6	10	6	11
7	7	8	7	9	7	10	7	11	7	1
8	8	9	8	10	8	11	8	1	8	2
9	9	10	9	11	9	1	9	2	9	3
10	10	11	10	1	10	2	10	3	10	4
11	11	1	11	2	11	3	11	4	11	5

Example: To the even terminals of strip 3 of shelf 6, contacts 71–80 of split 9 are connected.

numbers of circuits are divisible by 6 and consideration of one split is sufficient.

This simplification does not affect the operating procedure. It signifies only that the same pattern is applicable to all splits; 1 group of 1 circuit, 2 of 6 circuits, 3 of 8, and 1 of 12 are distributed evenly over the first 50 contacts. The total number of circuits is 49 and there are 50 contacts, so one "four" is needed. The enumerated groups will be numbered 1 through 7 for convenience.

The allocation shown in Figure 24 was commenced by allotting the terminals required for

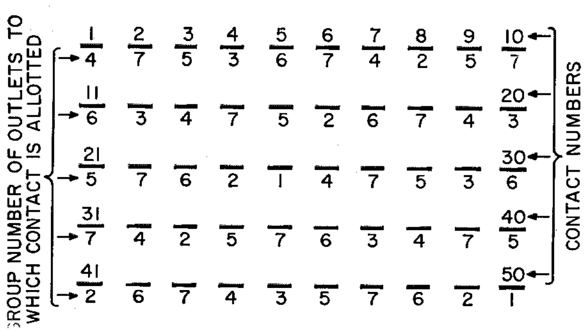


Figure 24—Allocation of 50 bank contacts *CS* of split 1 to various outgoing groups of outlets in homogeneous grading.

groups of 4, 5, and 6 so that the 3 groups each of 8 contacts are equally divided over the total of 50 terminals. Next, the 12 terminals for group 2 were allotted to some of the contacts left free, using an equal distribution, and finally, the remaining terminals were allotted to groups 3, 2, and 1.

As terminals 25 and 50 were to be connected to a single outlet, fours are introduced by a jumper between 25 of split 1 and 50 of split 6, et cetera, in a cyclic manner.

It is necessary to determine whether for every outgoing direction the various splits help each other suitably by checking the various circuit combinations for all other splits. A traffic peak in one split will then be equally shared by all splits.

It may be necessary to use splits of unequal sizes. Tests with the rotary traffic machine have shown that with homing switches, gradings of a homogeneous type can cope with traffic unbalances of 50 percent or more without the overall efficiency being impaired below the value calculated by the British Post Office equation. Although the tests were made with homing switches, they should not differ substantially for nonhoming switches.

4.4 Conclusion

It may be concluded that homogeneous grading is highly efficient and may be applied to homing or nonhoming switches. A permanent grading arrangement may be applied to the entire capacity of the bank without considering the distribution of contacts over the different groups. On the average, all circuits are equally loaded and by spreading the contacts of a group over the bank, minimum hunting time is achieved. Methods may be devised to reduce to a minimum possible future modification of the jumpering on the circuit distributing frames.

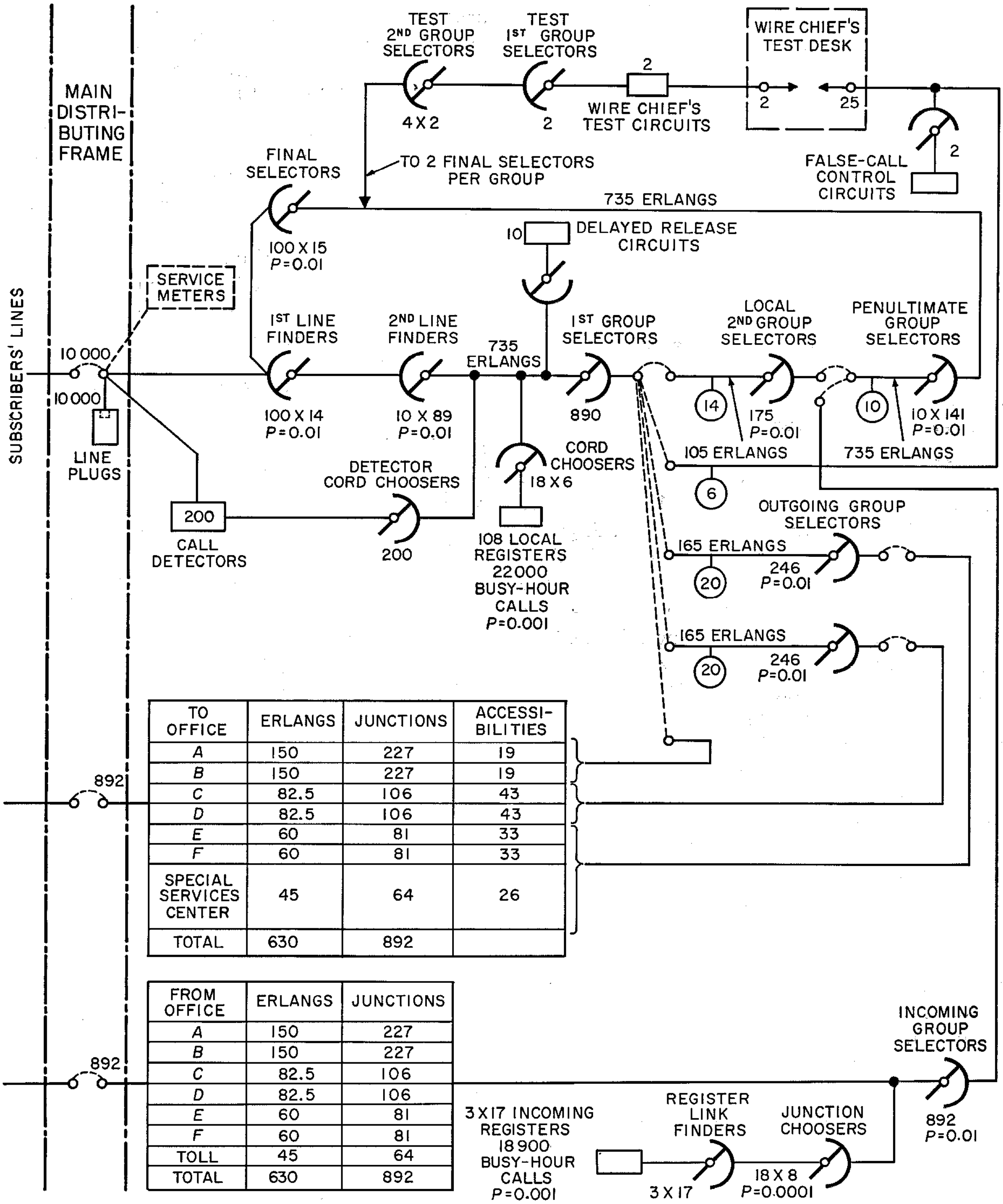
5. *Junction Diagrams and Floor Plans*

To demonstrate the adaptability of the *7E* system, three typical exchanges will be considered. The first is a 10 000-line exchange in a large multioffice area having heavy traffic and a large percentage of trunked traffic. The second is a fair-sized rural center exchange of 6000 lines with medium traffic that serves a number of smaller rural end exchanges. The third is a typical rural end exchange of 900 lines and low traffic.

The junction diagrams show the various switching stages for each example. The numbers of switches, circuits, and junctions have been computed with the Erlang equation for lost traffic in the case of ideal circuit groups and with the British Post Office equation for haphazard traffic for graded circuit groups. The probability figures adopted are shown for each case on the diagrams. As stated in section 4, experience has shown that this last method of calculation results in a slightly larger number of circuits than are actually required since homogeneous grading ensures better efficiency than is assumed in the equation.

A further increase in traffic capacity results from the assumption that there will be lost calls although rotary, with its continuous hunting, only delays calls and does not lose them.

Unlimited time is not allowed in finding free switch outlets; the registers are set to a predetermined value that is usually between 20 and



TO OFFICE	ERLANGS	JUNCTIONS	ACCESSI-BILITIES
A	150	227	19
B	150	227	19
C	82.5	106	43
D	82.5	106	43
E	60	81	33
F	60	81	33
SPECIAL SERVICES CENTER	45	64	26
TOTAL	630	892	

FROM OFFICE	ERLANGS	JUNCTIONS
A	150	227
B	150	227
C	82.5	106
D	82.5	106
E	60	81
F	60	81
TOLL	45	64
TOTAL	630	892

Figure 25—Typical junction diagram for a 10 000-line exchange in multioffice area. The figures in circles indicate accessibilities. The originating and terminating traffic rates are each 0.0735 eglang. The originating calling rate is 2.2 busy-hour calls. Traffic to or from distant exchanges equals 80 percent of originating traffic. Traffic to centralized special services is 6 percent of originating traffic as is the incoming toll traffic.

30 seconds. So long as the traffic load does not exceed the computed equipment capacity, a free outlet will be found in almost every case during the first revolution of the switch.

5.1 High-Traffic Multioffice 10 000-Line Exchange

The junction diagram for the 10 000-line office is shown in Figure 25. The average traffic originated per subscriber line is 0.0735 erlang or 2.2 equated busy-hour calls, the average holding time being 2 minutes. This originating traffic is 14-percent local, 80-percent outgoing to 6 distant exchanges and 6 percent to special services that are centralized in one of the exchanges in the area. The total traffic incoming from the distant exchanges is equal to that outgoing to those exchanges. The toll switching traffic amounts to 6 percent of the originating traffic.

Figure 25 shows that the first line-finder group serving 100 subscribers requires 14 line finders with a loss probability P of 1 percent. A group of cord circuits is provided for each 1000 lines and the total of 140 first line finders serving the 1000-line group are connected to the 100-point second line finders using a grading scheme. The traffic via the first group selectors divides into three parts; that toward subscribers in the same exchange, traffic to distant exchanges, and traffic to the centralized special services. As the number of levels on the group selectors as well as the number of outlets per direction may be chosen at will, the switching arrangements from this point must be studied for each case to obtain the most-economical solution. The outgoing junctions should be given good efficiency to reduce the cost of the junction cable network. The accessibility to the groups of outgoing trunks should, therefore, not be too low. It may be obtained in some cases by introducing an additional selecting stage for some or all of these groups.

On the other hand, with the homogeneous grading scheme used for interconnecting the successive selecting stages, an economical arrangement results when the different groups of outlets are distributed over the various selector groups so that every selector group gives access to groups of outlets of approximately equal load. As shown in Figure 25, the local traffic is directed via the 1st group selectors to one group of 175 local 2nd group selectors, the accessibility to this group being 14 outlets. There are 7 outgoing directions including those to centralized special services. The two most-heavily loaded directions are connected to the 1st group selector banks and have an accessibility of 19 outlets for each group. The other 5 directions have been distrlbuted over two groups of outgoing group selectors each carrying approximately the same traffic and each being accessible via 20 outlets of the 1st group selectors.

One of the groups of outgoing selectors gives access to two distant exchanges with an accessibility of 43 for each exchange, whereas the second gives access to the two remaining exchanges and to the centralized special services with accessibilities of 33 for each of the former and 26 for the latter. In this manner, the total number of outgoing junctions amounts to 892, whereas 2×246 additional outgoing group selectors are required.

The incoming traffic enters the exchange on 892 incoming group selectors, this number having been assumed to be equal to the number of outgoing junctions to distant exchanges. The incoming group selectors are multipled to the local 2nd group selectors and give access to 10 groups of penultimate group selectors, each consisting of 141 switches. Each group of final selectors requires 15 switches.

The local registers form, for all practical purposes, an ideal group and are subdivided into 18 subgroups of 6 registers each. A register subgroup has access to 5 cord circuits in each of the cord groups serving 1000 lines.

To connect the incoming registers to incoming junctions, 18 groups of 8 register connecting links are required. The incoming registers are in 3 groups of 17 circuits each.

The floor plan is shown in Figure 26. It requires 17 switch racks, each about 9.7 meters (31.8 feet) long and one approximately 6 meters (19.7 feet) long. As explained in section 3.1, the equipment is grouped in units of 1000 lines to reduce interrack and multiple cabling. The equipment for each 1000 lines consists of call detectors, 1st line finders, final selectors, and penultimate group selectors. The racks numbered 1 through 10 mount the whole of this equipment. On each rack are mounted 6 equipment units accommodating 1st line finders, final selectors,

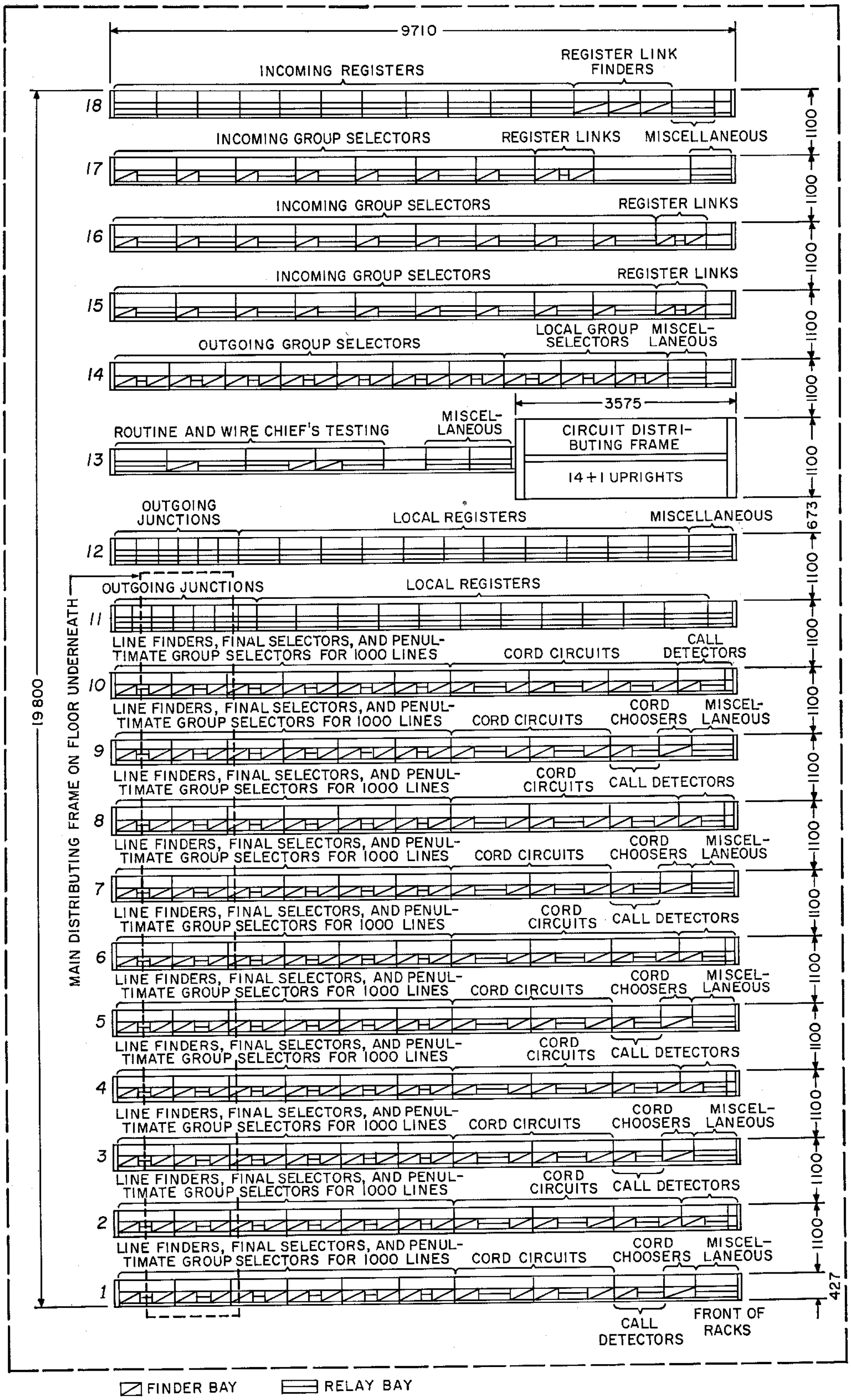


Figure 26—Typical switch-room floor plan for a 10 000-line exchange having a traffic rate of 0.0735 erlang with a holding time of 2 minutes. The switch-rack height of 3.665 meters (12 feet) requires a clear ceiling height of 4 meters (13.1 feet). The total switch-rack length is 171.3 meters (562 feet). The occupied floor space is 193 square meters (2077 square feet) and the occupied volume is 709 cubic meters (25-077 cubic feet). The switch-rack occupancy is 97 percent. The switch racks, including cabling and shielding, weigh 560 kilograms per running meter (376 pounds per running foot). Dimensions shown in the drawing are in millimeters.

and penultimate group selectors of the type shown in Figure 7A. Five of these units each mount 2 × 14 first line finders, 2 × 15 final selectors, and 2 × 7 penultimate group selectors. The 71 remaining penultimate selectors are mounted on a sixth unit. As the equipment units in Figure 7B have a capacity of 36 cord circuits and each cord group contains 89 circuits, five equipment units are required for two 1000-line groups. Two cord-circuit equipment units appear in each odd-numbered and three in each even-numbered row of switch racks.

The call-detector unit, composed of one finder bay and one relay bay, mounts the 20 call-detector circuits for the 1000 lines as well as a delayed-release circuit. The switch-rack motor mounts in the lower part of this bay, together with its control equipment. The five cord-choser bays required for the exchange are placed near the cord circuits to reduce cabling. Each cord-choser bay mounts 4 groups of 6 finders each.

The local register circuits and the outgoing junction circuits mount on racks 11 and 12. There are 22 bays, each providing space for 5 register circuits. Each of the 13 outgoing-junction bays mounts 72 circuits.

Rack 14 carries two groups of 246 outgoing group selectors and 175 local group selectors. They are accommodated on 10 equipment units capable of holding 72 group selectors each.

Racks 15, 16, and 17 accommodate the 25 incoming group selector units comprising 892 circuits. Each unit consists of a finder bay and a relay bay and has a capacity of 36 circuits as shown in Figure 7C. Three equipment units for register connecting links mount also on these racks. Each has two finder and one relay bays with a capacity of 6 groups of 18 register connecting links.

Rack 18 takes 11 bays mounting a total of 55 incoming register circuits and three link finder bays with 24 finders each, placed near the incoming registers.

Routine test equipment, the wire chief's test bay, and some miscellaneous bays are on rack 13.

A cross-connecting frame having 14 verticals plus one end vertical is located in the middle of the room. The cross-connections between the different selecting stages shown on the junction diagram are effected on this frame.

Figure 26 shows in dotted lines the location of the main distributing frame in the terminal room just below the switch room. The cabling from the main distributing frame to the line finders and final selectors passes through holes beneath each corresponding switch rack. Two such cable racks will be suspended from the ceiling of the terminal room near the ends of the switch-rack rows and the interrack cabling will pass through holes inside the switch-rack feet to these cable racks.

Service meters, if required, will be placed in the terminal room, where the wire chief's test desk is also located.

5.2 Medium-Traffic Rural-Center 6000-Line Exchange

A rural area is usually divided into sectors having end exchanges connected to a center exchange, which in turn is connected to a rural main exchange that is the trunking center for connections between the different sectors and to other areas. The end exchanges may or may not be equipped with registers.

Figure 27 shows the switching arrangement for a 6000-line rural center exchange to which 4 register-equipped end exchanges are connected. The traffic rate is assumed to be 0.042 erlang or 1.26 equated busy-hour calls and the holding time of the calls is 2 minutes.

The originating traffic is 50 percent local, 22 percent to the rural main exchange, and 28 percent equally divided among the four end exchanges. The incoming traffic is assumed to be the same as the outgoing traffic.

The originating traffic is carried by 60 groups of 10 line finders each. At 1 per 1000 lines, 6 cord groups, each of 54 circuits, are required. The 1st line finders of 10 groups are connected in straight multiple to all 2nd line finders of a group. The 1st group selectors give access to 6 groups of penultimate group selectors, to one group of outgoing group selectors providing access to the end exchanges, and one group of outgoing junctions to the rural main exchange.

The 108 incoming group selectors for the end exchanges are multipled to the arcs of the local 1st group selectors. The 96 incoming group selectors from the rural main exchange are also multipled to the 1st group selectors, except for the outlets to the rural main exchange that are not multipled to their arcs. The number of penultimate group selectors per group is 79. There are 120 outgoing group selectors that handle the traffic from the rural center to the end exchanges as well as the traffic between the

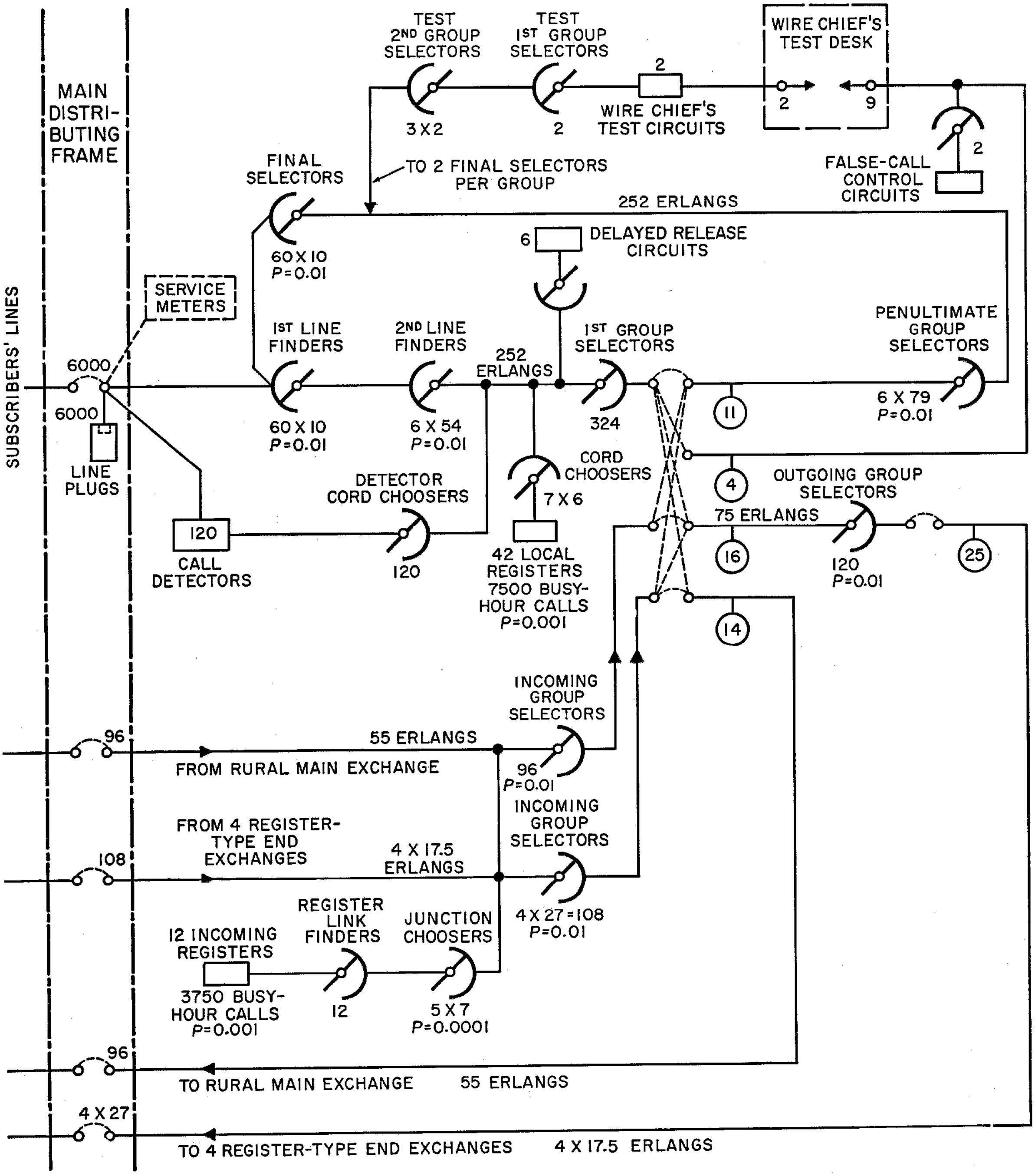


Figure 27—Typical junction diagram for a 6000-line rural center exchange. The figures in circles indicate accessibilities. The originating and terminating traffic rates are each 0.042 erlang. The originating calling rate is 1.25 busy-hour calls. Traffic to or from the rural main exchange is 22 percent and for the four end exchanges, 28 percent of the originating traffic.

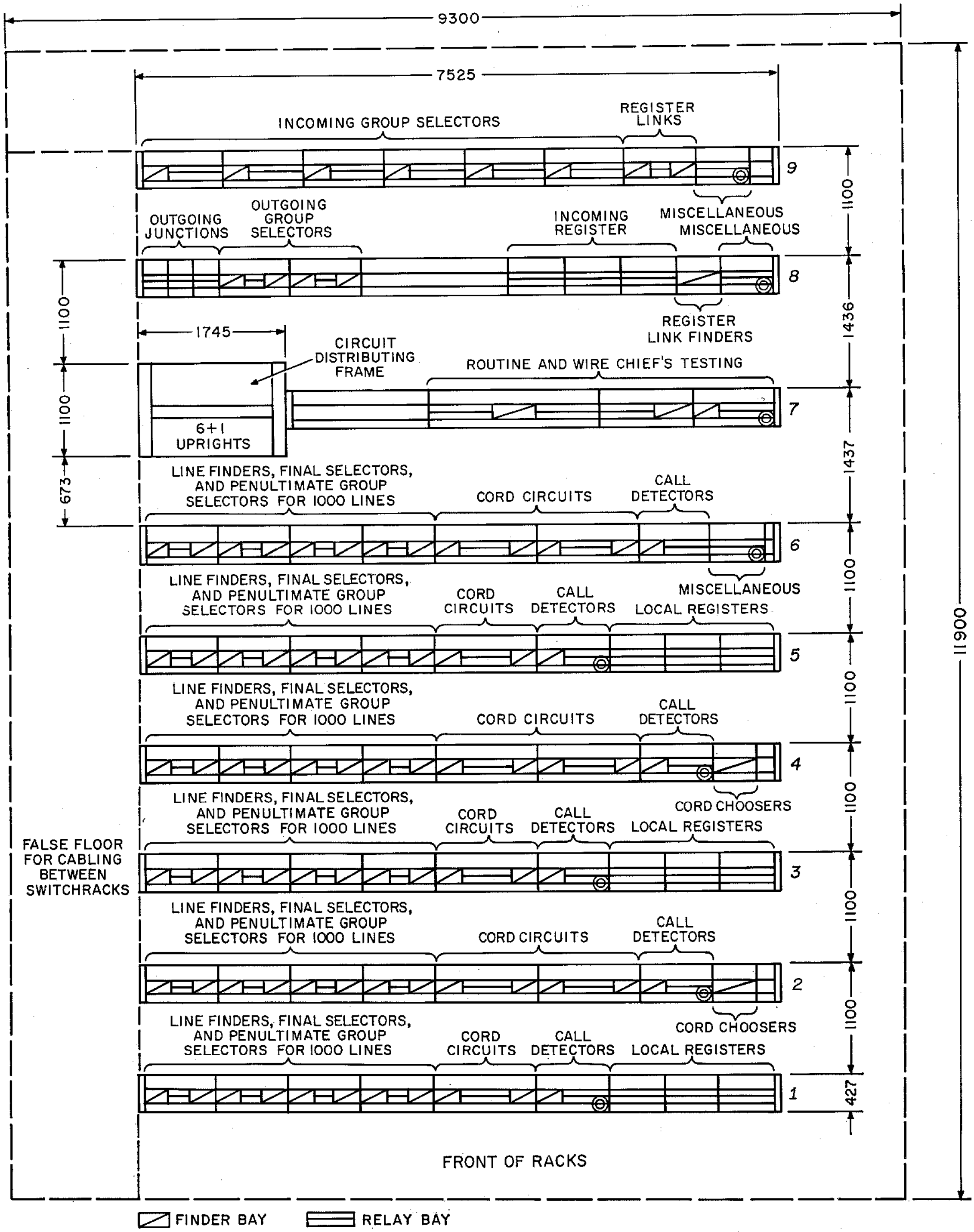


Figure 28—Typical switch-room floor plan for 6000-line rural center exchange having a traffic rate of 0.042 erlang with a holding time of 2 minutes. The ceiling height, switch-rack height, and switch-rack weight are as in Figure 26. The total length of switch racks is 66 meters (217 feet). The occupied floor space is 74.5 square meters (805 square feet) and the occupied volume is 298 cubic meters (10 550 cubic feet). The switch racks are 93 percent occupied by equipment. Dimensions shown in the drawing are in millimeters.

end centers, which is tandemed via the center exchange. The 96 outgoing junctions to the rural main exchange handle the traffic from the center exchange and the tandem traffic from the end exchanges that has to be routed via the main exchange.

There are 42 local registers in 7 groups of 6 each. A group of 12 incoming registers controls the selections for the incoming traffic and 5 × 7 register links connect them to the incoming circuits.

The floor plan is shown in Figure 28. The equipment is accommodated in 9 racks. The first 6 racks each mount the equipment for 1000 lines, which comprises 3 units each with 3 × 10 line finders, 3 × 10 final selectors, and 2 × 6 penultimate group selectors, 1 unit with 10 line finders, 10 final selectors, and 48 penultimate group selectors, and further, 1 or 2 units of cord circuits and 1 call-detector unit. The 2 cord-choser bays and 9 register bays are also on these racks.

Automatic routine test equipment and the wire chief's test circuits are on the 7th rack, which is not so long as the others. Racks 8 and 9 mount outgoing junction circuits, outgoing group selectors, incoming group selectors, register connecting links, and link finders.

A circuit distributing frame is placed at the center of the room. A total of 66 meters (217 feet) of switch rack is used and the occupied floor space is 74.5 square meters (805 square feet).

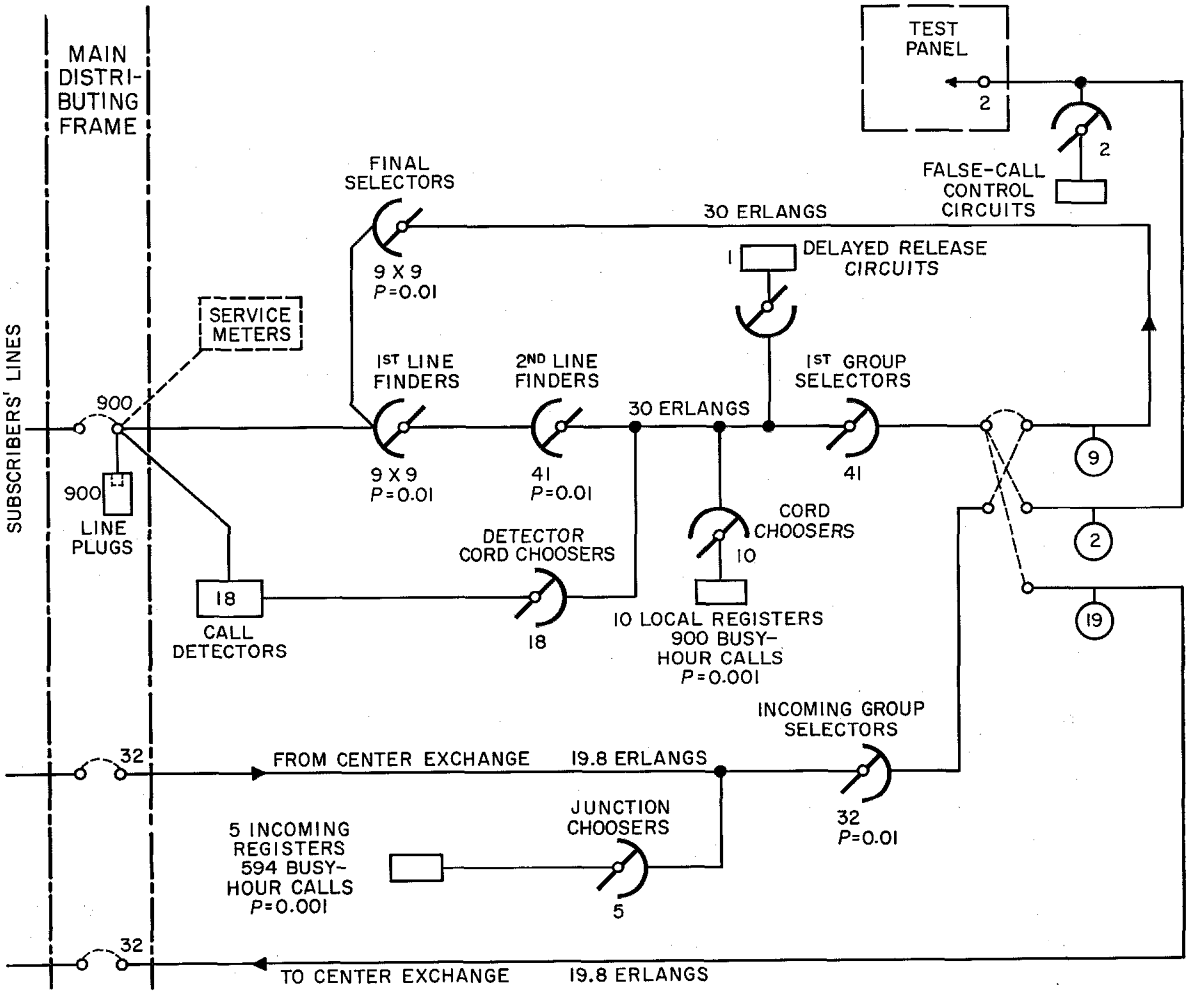


Figure 29—Typical junction diagram for a 900-line rural end exchange. The figures in circles indicate accessibilities. The originating and terminating traffic rates are each 0.033 erlang. The originating calling rate is 1 busy-hour call. Traffic to or from the center exchange is 66 percent of the originating traffic.

It is assumed that the main distributing frame is located, together with the wire chief's test position and the service-meter rack, in a separate room on the same floor as the switch room.

is concentrated on one group of 41 cord circuits. The 1st group selectors give access to 9 groups of 9 final selectors and to one group of outgoing junctions to the center exchange. Full accessi-

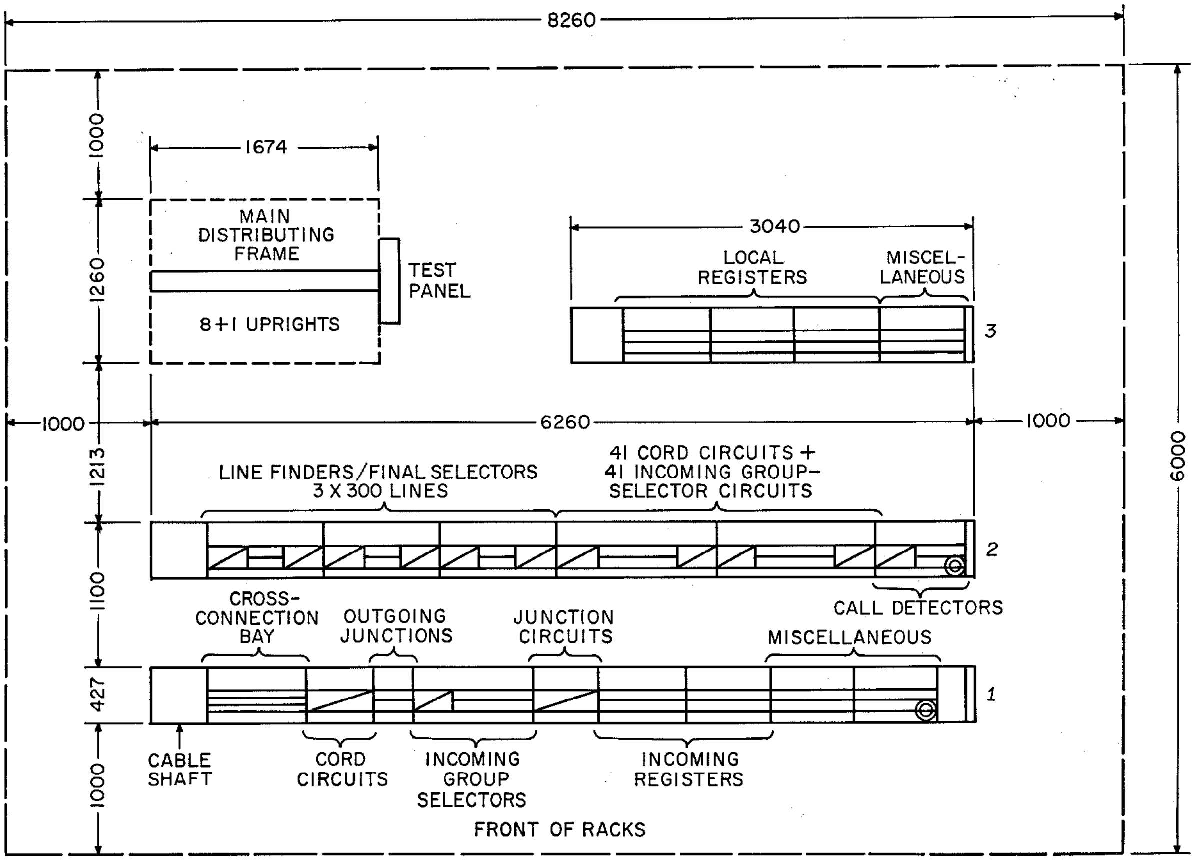


Figure 30—Typical switch-room floor plan for a 900-line rural end exchange having a traffic rate of 0.033 erlang with a holding time of 2 minutes. The switch-rack height of 3.185 meters (10.4 feet) requires a clear ceiling height of 3.9 meters (12.8 feet). The total length of switch racks including cable boxes is 15.6 meters (51.2 feet). The occupied floor space is 25 square meters (270 square feet) and the occupied volume is 97.7 cubic meters (3459 cubic feet) The switch racks are 100 percent filled with equipment. Including cabling and shielding, the switch racks weigh 440 kilograms per running meter (295 pounds per running foot). Dimensions shown in the drawing are in millimeters.

The cabling from the main distributing frame to the line finders and the interswitch-rack cabling is laid underneath a false floor that runs along one side of the switch room as shown in Figure 14.

5.3 Rural 900-Line End Exchange

Figure 29 shows the switching arrangement of a 900-line rural end exchange. The originating traffic of 0.033 erlang or 1 equated busy-hour call per line with a holding time of 2 minutes is handled by 9 groups of 9 each 1st line finders and

bility is provided for the final selector groups, whereas 19 outlets in the group selector multiple are reserved for the outgoing direction. The traffic to the center exchange amounts to 66 percent of the originating traffic and requires 32 junctions. The 32 incoming junctions terminate on incoming group selectors that give access to the final selector groups. A group of 10 local registers and 5 incoming registers ensures the control of the selectors for originating and incoming calls.

The floor plan is shown in Figure 30. As lower switch racks have been used, the finder bays accommodate only 28 instead of 36 line finders.

The three switch racks have a total length of 15.6 meters (51.2 feet). The line finders and final selectors serving 3 groups of 100 lines each are mounted together on one equipment unit consisting of two finder bays and one relay bay. Three such units are shown on the second rack, which also mounts the call-detector unit and two cord units. The first cord unit is fully equipped with 28 cord circuits, the second has 13 cord circuits, and 4 incoming group selector circuits are mounted in the remaining space. The other groups of circuits are on racks 1 and 3.

The main distributing frame is located in the switch room.

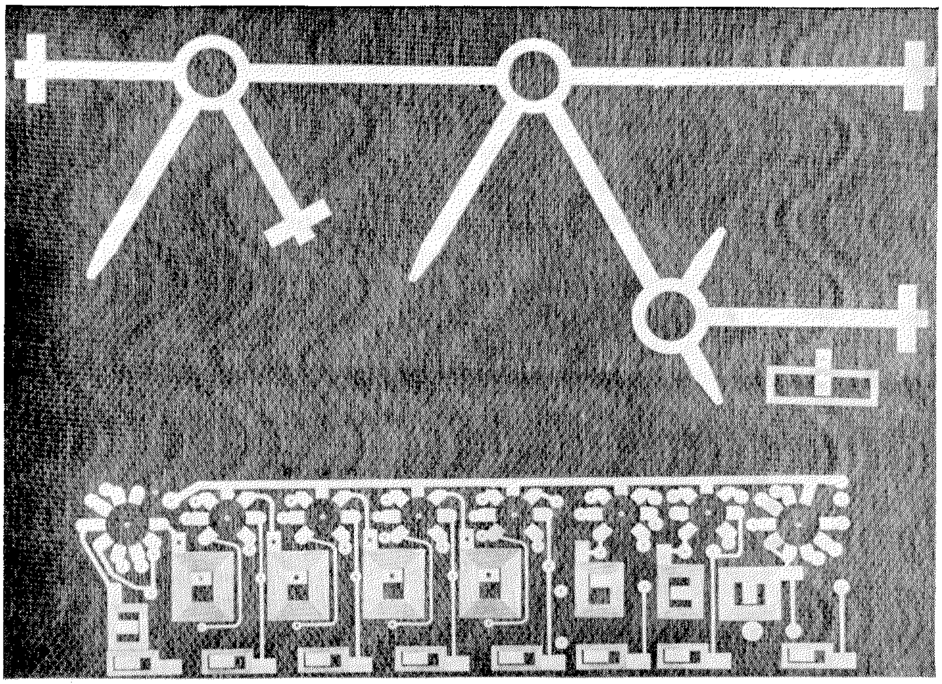
The total occupied floor space is 25 square meters (270 square feet). The interrack cabling will go upward through cable shafts at one end of each switch rack to the cable racks above the equipment as illustrated in Figure 15.

Recent Telecommunication Development

Combination Microstrip and Intermediate-Frequency Printed Circuit*

THE SAME ETCHING or engraving process can be used to produce simultaneously both a microwave printed circuit and the more-familiar form of radio-frequency printed circuit. The photograph below shows a particular example of a microwave receiver with automatic-frequency-control circuit and intermediate-frequency amplifier. Here, both types of circuits have been printed on the same board in one operation. This technique features great accuracy, adaptability to mass production, and large economy in cost, space, and weight.

* Illustration reprinted from *IRE Transactions on Microwave Theory and Techniques*, volume MTT-3, page 39; March, 1955. Copyright © 1955 by The Institute of Radio Engineers, Incorporated.



Probability Studies Applied to Telecommunication Systems With Storage*

By E. P. G. WRIGHT and JOSEPH RICE

Standard Telecommunication Laboratories, Limited; London, England

DELAYS to telegraph messages for varying traffic and numbers of addresses have been obtained by throwdown methods for a message-length distribution usually found for such messages. Results of these throwdown processes have been utilised to provide empirical formulae. Additional work includes a theoretical approach to obtaining the delays incurred by multi-address messages, a comparison being made of all three methods. A further section considers the effect of message precedence on delay.

• • •

1. *Introduction*

It seems likely that for some years to come the present high activity on the research and development of data processing systems will continue and that, in consequence, new methods and new components will become available for telecommunication engineers.

A step forward in electronic switching may well commence with those systems in which a continuous speech path between two subscribers does not need to be maintained because, in such circumstances, the switching problem tends to resemble the normal data processing systems.

One such application is that of a telegraph exchange system to meet the needs of military services or industry for which a duplex path is not essential. It is well known that the use of expensive long-distance lines can be appreciably reduced by introducing a measure of storage. The consequential increase in line efficiency is spontaneous, but the relation between line occupancy and delay must be known, both in normal and abnormal busy-hour conditions.

To meet normal requirements it may be necessary to guarantee that in, say, 95 per cent of the busy hours not more than, say, 3 per cent of the messages will be delayed by more than t seconds. Existing delay formulae provide a means of solving the general problem, but there are some interesting new problems that necessitate special handling.

Briefly, these special considerations concern the fact that the introduction of priorities can permit line occupancies to be raised because for different classes of urgency a range of times, t_1, t_2, t_3, et cetera, can be accepted for the traffic delay. Furthermore, many messages may carry several addresses, and the traffic for certain common equipment will depend on the overall delay until retransmission is made to the line suffering from the greatest delay at the time in question; this traffic has to be determined. Throughout the calculations it must be remembered that the message-holding time is not constant nor yet distributed on an exponential basis but tends to be characterised by a fixed minimum that represents a substantial percentage of the whole. It is interesting to speculate whether a similar condition does not arise in connection with the traffic to register and similar circuits in telephone exchanges, as it is to be expected that the holding time would not be exponentially distributed and that the maximum delay tolerable might represent a substantial percentage of the average holding time.

Reference will be made to theoretical and empirical solutions that have been checked by throwdown methods. It is well known that an inaccurate solution can result from the problem being inaccurately stated. By examining the matter from several aspects it is certainly less likely that an inaccuracy will escape detection. To quote one example, it is evident that when plotting traffic offered to a line against delay there will be a non-linear increase leading to an

* The information given was produced for a paper delivered at the First International Congress on the Application of the Theory of Probability in Telephone Engineering and Administration held in Copenhagen, Denmark, on June 20–23, 1955.

infinite delay when the occupancy passes 100 per cent. However, in actual practice, as may be illustrated by a throwdown for a series of consecutive hours, each with an occupancy exceeding 100 per cent, it does not necessarily lead up to an excessive delay, and if there is a midday or evening drop in the traffic the highest delay may not be serious. Furthermore, in such conditions the greatest delay may not coincide with the busy hour during which the occupancy is highest; for example, if the circuit occupancy over a series of consecutive hours is 105, 110, 115, 110, 102 and 95 per cent, it is likely that the maximum delay will be experienced in one or other of the last two hours. This situation becomes obvious when it is appreciated that the traffic for each hour is not only that which occurs during the hour but also that which is carried forward from the previous hour.

The later sections explain how the throwdown to determine message delays has been organised, and Table 1 shows the tabulated results, which can be compared with theoretical figures on the basis that the holding-time distribution is substantially of the type to be described.

It is also interesting to consider the delays not only as forecast by a curve derived from a formula but also as experienced in a throwdown in which the volume and average holding time of the messages have varied from hour to hour. It is immediately apparent that there is no precise delay period that corresponds to any particular traffic occupancy. Assuming that the traffic data is based on the average of a few of the busiest hours over a period of months, it is to be expected that:—

A. Very few busy hours indeed will have such characteristics. When such hours occur, the delays are not necessarily those given by the formula. However, the average of the delays for this traffic will approximate to the formula value.

B. There will be no certainty that the traffic will not be considerably greater for some busy hours.

C. The busy-hour traffic may be appreciably augmented by traffic carried forward from the previous hour.

D. Certain busy hours with less traffic than the average may experience a longer delay than the average.

These results can be seen by reference to Table 2.

The authors are not aware of any published literature dealing with the calculation of delays for multi-address messages or the advantages to be obtained by the use of message precedence. The findings of such studies are presented in later sections. It would seem that the use of precedence would have some application also to manual and semi-automatic telephone systems.

TABLE 1

THROWDOWN SUMMARIES FOR A SINGLE LINE

Average Traffic Occupancy in Erlangs	Hours Studied	Total Number of Messages	Number of Messages Delayed	Total Delay in Minutes	Average Delay per Delayed Message in Minutes	Percentage of Messages Delayed	Average Delay for All Messages in Minutes
0·067	384	960	60	64·4	1·07	6·25	0·067
0·083	384	1200	95	110·7	1·16	7·92	0·092
0·133	192	960	118	139·7	1·18	12·29	0·146
0·167	192	1200	199	269·6	1·35	16·58	0·225
0·267	96	960	255	372·5	1·46	26·6	0·388
0·333	96	1200	397	661·9	1·66	33·1	0·552
0·4	64	960	389	675·8	1·74	40·5	0·704
0·533	96	1920	1037	2365·1	2·28	54·0	1·232
0·627	48	1125	709	1977·2	2·76	63·0	1·758
0·667	48	1200	799	2466·5	3·07	66·6	2·055
0·8	32	960	778	3713·1	4·52	81·0	3·868

2. *Message-Length Distribution*

The throwdown studies to be described were intended to determine the percentage of messages delayed, the average delay per message delayed, and the average delay per message for different volumes of traffic offered to a single line. It may be thought that these results could be obtained from normal delay formulae. However, these

TABLE 2

HOURLY RESULTS FOR 0·667*E* THROWDOWN

Hour Number	Percentage Occupancy	Total Delay in Minutes	Total Number of Messages	Number of Messages Delayed	Delay for All Messages in Minutes
1	75·1	35·9	30	18	1.2
2	87·1	123·4	29	26	4·3
3	47·8	10·3	20	8	0·5
4	58·5	35·8	23	15	1·5
5	41·0	11·0	20	10	0·5
6	51·6	14·4	21	12	0·7
7	75·3	50·7	27	20	1·8
8	84·6	57·6	28	18	2·1
9	54·0	16·5	21	11	0·8
10	32·8	2·0	10	1	0·2
11	78·0	138·2	29	20	4·8
12	57·0	53·7	23	17	2·3
13	74·5	31·9	26	15	1·2
14	63·0	38·6	22	14	1·8
15	80·5	58·3	32	24	1·8
16	52·0	17·3	23	14	0·8
17	48·8	10·0	19	7	0·5
18	90·5	120·8	29	23	4·2
19	59·0	16·6	21	11	0·8
20	59·6	39·6	24	13	1·7
21	68·1	40·1	31	19	1·3
22	58·5	16·2	25	12	0·6
23	41·6	10·8	18	6	0·6
24	91·6	94·3	30	27	3·1
25	68·6	75·0	26	18	2·9
26	59·5	51·0	24	16	2·1
27	63·0	47·2	21	18	2·2
28	69·0	55·4	28	18	2·0
29	44·0	20·4	20	10	1·0
30	71·3	40·4	22	16	1·8
31	52·8	13·0	19	9	0·7
32	63·1	31·7	29	17	1·1
33	39·3	1·9	16	4	0·1
34	61·0	48·5	26	18	1·9
35	96·0	120·7	34	31	3·6
36	65·8	30·7	24	13	1·3
37	68·6	39·9	26	15	1·5
38	66·5	24·5	28	16	0·9
39	95·3	56·2	30	23	1·9
40	55·0	72·0	16	13	4·5
41	84·6	89·0	32	27	2·8
42	88·3	80·9	31	26	2·6
43	98·1	182·7	34	32	5·4
44	79·5	101·6	26	24	3·9
45	65·7	19·2	25	14	0·8
46	65·8	34·3	26	17	1·3
47	56·0	49·4	22	15	2·2
48	90·3	136·9	34	28	4·0
Totals	66·7 (Average)	2466·5	1200	799	2·055 (Average)

formulae are based on either a constant message length or an exponential distribution, and for the telegraph traffic to be considered neither of these applied. One requirement was to determine if the formulae could be adjusted to apply to the message-length distribution for the telegraph traffic under consideration. The actual message-length distribution was obtained from a check made of the traffic dealt with at an operational signal centre. The distribution obtained showed that there was a constant length of message coupled with an exponential portion. The explanation of this is that each message contained routing instructions and other necessary data. For the traffic examined and used in the studies, the average message length was 1·6 minutes; the constant part was 0·555 minute, and the average for the exponential portion of the message lengths was 1·045 minutes. An approximation for the exponential part of the distribution curve is given by:—

Proportion of messages with length $> t$ $= \exp\ [-\ (t - 0{\cdot}555)/1{\cdot}045]$ with $t > 0{\cdot}555$ minute.

3. *Investigation of Message Delays*

3.1 Throwdown

3.1.1 Production of Data

Throwdown studies were carried out to obtain results for a single line carrying traffic varying from approximately 0·06 to 0·8 erlang. It was considered adequate that each study should deal with traffic of the order of 1000 messages, which for the range considered meant 32 hours of study for the maximum traffic and proportionately more hours for smaller traffic. Of course it would have been simpler to carry out the studies with an equal number of hours for each value of traffic but, with the smaller values of delay encountered for the low traffic densities, the results would have been less reliable. Furthermore, since a study had to be organised for the number of messages required for the highest occupancy, it was possible to rearrange these data for all other occupancies. The preparation of each study was similar to the method used for telephone traffic. Random numbers were obtained from the last two digits of subscribers' numbers in a telephone directory, omitting all numbers that could not be considered of a chance nature. These numbers were used to determine how many messages should originate in each hour, and other numbers were then used to determine at what times the messages should originate in these hours. The next stage was to stipulate the lengths of the messages. The original message-length check gave the lengths of messages between certain ranges and, from these, eight lengths and the proportions of these different lengths were determined. Again using random numbers, the order of appearance of these messages was obtained, and the message lengths so found were coupled with the random times already mentioned. Having marshalled the artificial traffic thus, the throwdown studies were carried out to obtain the required information.

3.1.2 Summary of Results

Table 1 shows a summary of the results obtained for different values of average traffic applied to a single line. Considering the column "Percentage of Messages Delayed," the values obtained are approximately equal to the percentage occupancy in each case. This is in accordance with what one would expect for if a line is carrying a traffic of A erlangs the probability that it will be engaged is A and, therefore, the probability that a message will encounter delay, that is $P\ (> 0)$, is also A. The other results obtained, that is, the average delay per message, will be considered shortly.

3.1.3 Review of Statistics

Table 2 shows in more detail the progressive results obtained for the throwdown in which $0{\cdot}667E$ was the average hourly traffic offered to a single line for a period of 48 hours. The column "Percentage Occupancy" shows large variations in the individual hourly traffic, which is typical of both telephone and telegraph systems. It is interesting to note that the average delay for *all* messages was 2·055 minutes whereas the average delay on *delayed* messages was 3·087 minutes. During hour 11 the average delay per delayed message was 6·91 minutes; this value is higher than that for any other hour. The occupancy for hour 11 was 78 per cent, and no overflow traffic was brought in from the previous hour. The highest average delay for all messages was 5·4 minutes in hour 43 which had the highest occupancy, namely 98·1 per cent, but a corresponding figure of 4·5 minutes was found in hour 40 when the occupancy was as low as 55 per cent. Considering individual message delays, which are not shown in the table, the longest delays occurred in hour 11 (13·3, 12·8 and 11·6 minutes), hour 40 (11·8 and 11·7 minutes) and hour 2 (11·1 minutes). These maximum message delay figures represent approximately twice the average delay for delayed messages in the hours concerned. The formula for delay is:—

$$P(>t) = P(>0) \exp[-(t/D)]$$

where

$P(>t)$ = probability of delay greater than t
$P(>0)$ = probability of delay greater than 0
D = average delay *per message delayed.*

The throwdown gave results that are a good fit for delays up to three times the average delay per message delayed, taken over 48 hours. Above this value the results are not in line with the formula; this can be attributed to the fact that samples of long delay were few in number and to the fact that messages with a holding time exceeding 5 minutes were excluded from the study, this being a usual practical requirement during the busy hour. This study is summarised at the end of Table 2, and the summarised results for other traffic occupancies are given in Table 1. Similar conclusions apply to the throwdown in which 0·533E was the average hourly traffic taken over 96 hours.

3.1.4 Analysis of Hourly Results

Figure 1 is a diagrammatic method of illustrating some of the results obtained from the throwdown studies for 0·333, 0·533 and 0·667 erlang. Using the individual hourly results of the average delay per message, the percentage of hours having a delay greater than a stipulated amount was obtained. The three curves show, for the traffics considered, the percentage of hours in which the average delay per message exceeds a certain amount plotted against time. One point of interest arises from these curves. For the lower values of delay for the 0·533- and 0·667-erlang curves there is a tendency towards a plateau formation. It should be noted that the points shown in this region are represented by the majority of samples taken, whereas points for the longer delays are necessarily less accurate

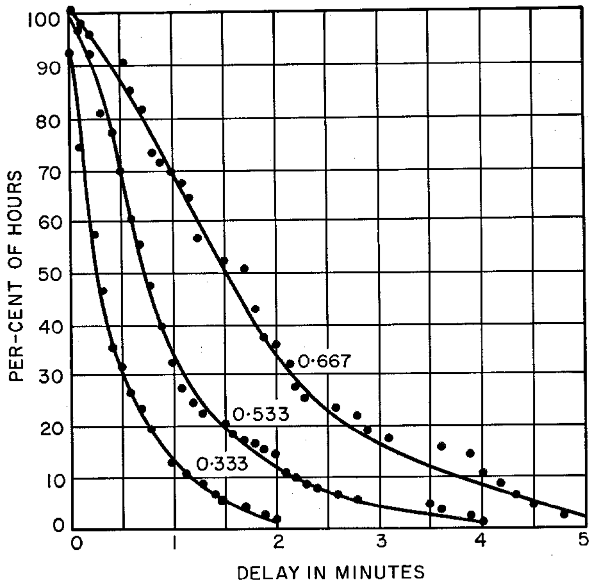


Figure 1—Probability that the message delay in any hour will exceed a specified value for single-line groups for the indicated traffic densities in erlangs.

since these are given by fewer samples. Corresponding curves could be drawn for the delay per delayed message; these are probably the more important for design purposes, but the relation between these delays and the average message delay during an hour is reasonably stable.

3.2 Possibility of Using Theoretical Formulae

As already stated, the message-length distribution considered included a constant and an exponential portion. Since it is likely that other traffic samples would show the same form, but might have a different length of constant portion, it is reasonable to consider the delay not simply as a time but rather as a multiple of the average of the variable portion of the message holding time. Thus, in Figure 2, the mean curve has been drawn for the points obtained in the traffic studies to show the relation between the ratio of the delay for all messages to the variable portion of the holding time against the percentage occupancy of the line. The mean curve is in agreement with the law

$$y = A/(1 - A).$$

For the message delay with an exponential distribution of holding time, probability theory gives the following:—

$$D = h/(N - A)$$

where

h = average holding time per message
N = number of lines in the group.

The average delay *for all messages* = $P(> 0) \times D$, where $P(> 0)$ = probability of messages being delayed (more than 0 seconds). Thus, for a single line, the average delay per message is:—

$$P(> 0) \times h/(1 - A) = A \times h/(1 - A)$$

(see section 3.1.2) but this expression, $A \times h/(1 - A)$, is also equal to the average delay for all messages plotted in Figure 2 for the case where the holding time has a constant and a variable portion in which only the variable portion is used in the formula. This suggests that the delay formulae normally used for exponential distributions may be applied to telegraph-traffic-type distributions, bearing in mind the new value that must be used for the average holding time.

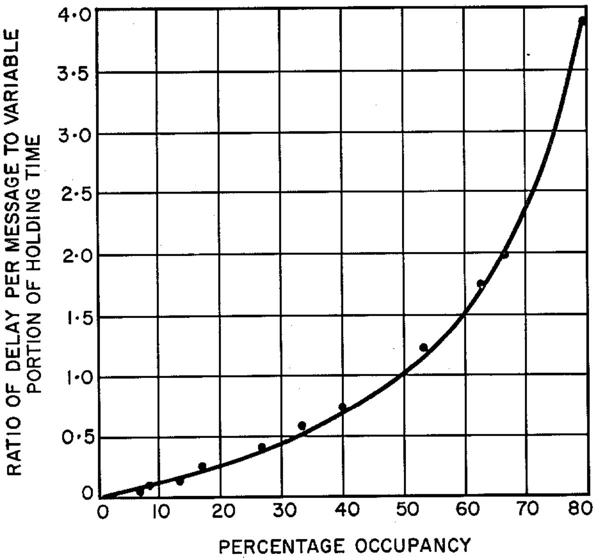


Figure 2—Average delay per message as a multiple of the average holding time in respect to occupancy for a single-line group.

Figure 3 compares the delays caused by different line occupancies according to whether the message holding time is constant, exponential or partly constant and partly exponential. It can be checked that the results quoted in the last column of Table 1 agree most closely with the intermediate curve.

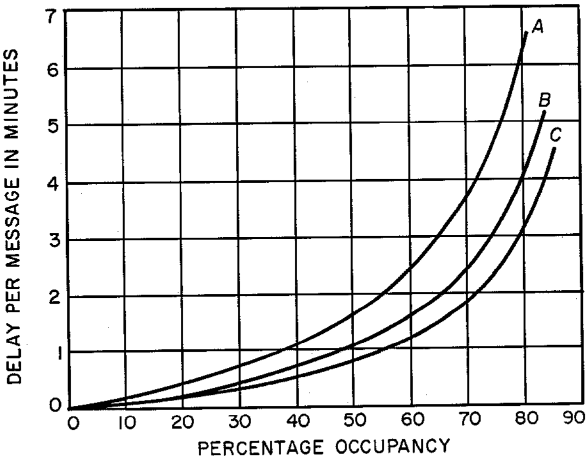


Figure 3—Average delay per message compared for different holding-time distributions in relation to line occupancy. A is for an exponential holding-time distribution with an average of 1·6 minutes. B is for a constant holding-time distribution of 0·555 minute plus an exponential portion of 1·005 minutes. C is for a constant holding-time distribution of 1·6 minutes.

4. *Groups of Lines*

From the conclusion reached in section 3.2 it is possible to obtain all the required information for groups of lines from theoretical delay formulae, again making the average holding time in these formulae equal to the average holding time of the exponential portion of the message length.

Figure 4 shows the average holding time per message related to line occupancy for groups of from 1 to 4 lines calculated on the exponentially distributed portion of the holding time.

5. *Determination of Average Message Delays during Overload Hours*

Table 2 gives a distribution of traffic over 48 hours, providing an average of 0·667E in each hour. The average message delay has been shown to be in accordance with theory for this traffic intensity. In many circumstances it may be more important to know the delay on the busiest days rather than the average value. If the 6 busiest days are taken, the average occupancy is greater than $0{\cdot}9E$, and theory gives a delay of approximately 20 minutes, which is far greater than any figure shown in Table 2. This is presumably due to the fact that the 6 busiest hours have a very small deviation from the average, whereas a random distribution may be expected to show a deviation of perhaps 50 per cent above and below the average.

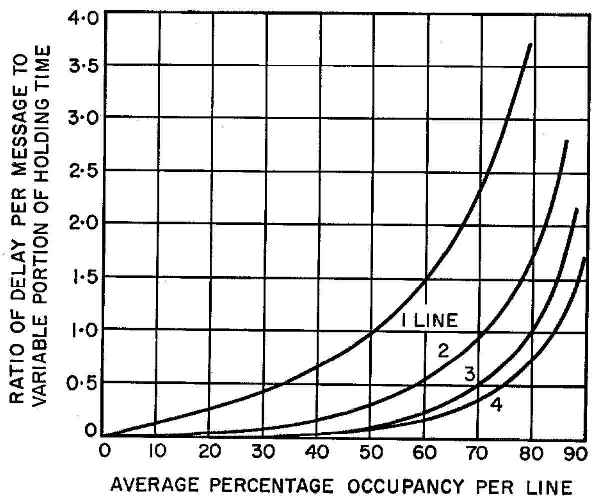


Figure 4—Average delay per message as a multiple of average holding time in respect to occupancy for different line groups.

The figures in Table 2 suggest that a better procedure to ascertain the overload condition would be to take the 24 days with the busiest hours. Such an average would be $0{\cdot}8E$, indicating according to theory a delay of 4·25 minutes, which can be seen from Table 2 to be much more realistic than the 20-minute figure.

If it should be desired to forecast the delay in the busiest hour, then an approximation can be made by taking one third of the days with the busiest traffic; this gives an average of $0{\cdot}84E$ indicating a delay of 5·4 minutes.

While it is to be expected that a single example is insufficient for a satisfactory process to be developed, it is difficult in practice to obtain statistics for a large number of hours that are not influenced by seasonal changes or a gradual traffic volume change. The single example quoted seems sufficient to be sure that "delay" cannot be considered on the same basis as "loss" when dealing with overloads.

6. *Multi-Address Messages*

6.1 General Considerations

In telegraph systems, particularly those used by the military services, one requisite is a means of dealing with multi-address messages, that is messages to be transmitted to more than one destination. No matter in what way such messages are stored for eventual disposal, the average delay incurred by these messages is a factor in determining the amount of storage equipment required. Simple consideration shows that the delay incurred by a multi-address message will not be the same as that incurred by a single-address message. As will be shown later, it is possible to formulate a theory for the determination of these delays but, before dealing with this, a method of finding it by means of throwdown methods will be described.

It would be possible to devise a throwdown in which certain messages were originated for transmission on two or more lines, as would occur in a practical system. However, this would be exceedingly complex both in preparing and then carrying out the operation. The method used was quite simple and is adaptable to any number of addresses; in fact, in carrying out these studies, the numbers of addresses used were 2, 3, 4, 6, 8, and 12. Owing to the number of hours being somewhat restricted, the values obtained for the larger numbers of addresses tended to be more inaccurate than the others, but they provide a useful guide.

6.2 Complications Associated with Multi-Address Messages

The following are illustrations of the points to be considered in a multi-address message throwdown:—

A. The number of lines in a group to a particular destination is dependent upon the traffic for that destination.

B. The average busy-hour traffic to a destination may be known, but the individual busy-hour traffic will vary about this mean.

C. The average busy-hour traffic to the different destinations will be different.

D. The busy hours for the different destinations may occur at different times.

E. The average message-length distribution over a long period may be known, but in any one hour it will vary about this mean.

To avoid over-complicating the issue, a detailed elaboration of all these variables has not been attempted, but they are dealt with briefly in the following paragraphs.

The number of lines to each destination is limited to one. If a certain traffic is applied to one line, the average delay per message that will result will be greater than if there is the same average traffic per line applied to a group of lines. This is analogous to the case of lost calls in a telephone system, when the loss for a certain traffic applied to, say, two lines is less than if half the traffic is applied to one line. Thus, if single lines only are considered, the values of average delay so determined may be taken as maximum values; groups of lines would have lower delays for the same traffic per line.

For purposes of the throwdown, the busy-hour traffic is considered to be constant for each destination. If the delay were to be linearly related to traffic density, this assumption would not result in an error since in practice traffic is equally distributed above and below the average. However, the relation has been shown by the studies and may also be shown theoretically to be non-linear, but the resultant error will not be great for with practical traffic the variations above and below the mean are not sufficient to have much effect.

Regarding the difference between the volumes of traffic to the different destinations, if the value of traffic in each study represents the traffic to the destination that has the heaviest traffic, then the results obtained will represent a maximum value for the average delay.

In practice, it would appear that the busy hours for the different destinations do not occur at the same time, similar to the case with tandem exchanges in telephone systems; but for simplicity the individual busy hours were considered to be simultaneous. Again this produces a maximum value for the average delay.

The message-length distribution is considered to be the same for each hour as for the distribution over a long period. The effect of this should be negligible, particularly when one relates it to the fact that the individual hourly traffic is considered to be constant, the effect of which has already been considered.

6.3 Throwdown

6.3.1 Basis of Arrangement

The message-length distribution considered was the same as that used for the throwdown studies already described. With this distribution as a basis, new traffic studies were devised, using random numbers as before for different hourly traffic applied to one line. However, for each study the traffic in each hour was made the same, the number of hours taken being 48. Three values of traffic were considered, namely $0{\cdot}4E$, $0{\cdot}533E$ and $0{\cdot}667E$. Since the message distribution was the same for each hour, the number of messages per hour in each of these three studies remained constant, the actual number of messages per hour being 15, 20, and 25 respectively. Using this information, it is possible to obtain the average delay per message for equal hourly traffic.

The times of initiation of the different messages were obtained from random numbers, and, if one considers, say, two separate hours for a particular traffic, it is unlikely that a message will be initiated in both hours at the same time. Of course, it would be possible to arrange that this did occur but, as already stated, this would prove very complex in producing a throwdown. However, since the delays so obtained may be taken as representative of a single-address case, if one considers a call in a particular hour and the equivalent call in a second hour, then the greater of the delays for these two calls should be representative of a delay for a two-address message. Taking two calls at a time, this process may be carried out for the whole of the single-address data. The average of the delays for a particular traffic obtained by this method may be taken as the average delay for a two-address message.

As stated, one throwdown involved a traffic of $0{\cdot}533E$, the number of calls per hour being 20, the average length of message being 1·6 minutes and the number of hours being 48. Thus, 960 calls were used for this throwdown. With the calls taken in pairs as suggested, the equivalent number of two-address messages was 480. Pairs were considered in other combinations, that is the first message in one hour, the second message in another; the second message in the first hour, the third message in the second hour; et cetera. Thus, many other combinations were obtained to give a more reliable value for the average delay.

This same process was carried out combining the hours in threes, fours, et cetera, to give the average delays for messages with three or more addresses for the three sets of traffic data available.

6.3.2 *Throwdown Results*

The studies were based on equal hourly traffic and, as explained in section 6.2, it is likely that the results so obtained are lower than if the practical case of traffic variation, to give the same average traffic, had been taken. Comparison of results for a single-address message has shown this to be the case; this is due to the fact that traffic above the average adds more to the total delay than the corresponding traffic below the average subtracts from the total delay. For this reason the tabulated results of the multi-address throwdown studies show the average delays for *all* messages as a multiple of D, where D is the average delay for all single-address messages *that are delayed*. It should be understood that the value of D will vary for the individual traffic densities considered. The results of the throwdown are shown in Table 3.

TABLE 3
VALUES OF DELAY BASED ON D

Number of Addresses	Traffic per Line		
	0·4E	0·533E	0·667E
1	0·40	0·53	0·67
2	0·59	0·90	1·08
3	0·90	1·19	1·37
4	1·07	1·41	1·59
6	—	1·79	1·95
8	—	1·99	2·15
12	—	2·36	2·52

The results obtained for multi-address messages are also included in Figure 3; these curves give a near approximation to the average delays encountered by messages having different numbers of addresses for the traffic considered. Although only three values of traffic are shown, the curves may be used to forecast delays for other values of traffic if close accuracy is not essential. It was decided to deduce empirical formulae to assist in calculating other results. The method of obtaining these formulae will now be described.

6.4 Empirical Traffic Study

6.4.1 *Basis of Arrangement*

The 0·667E throwdown for multi-address messages, already described, was used to provide data required for the production of empirical formulae. By detailed analysis of this throwdown it was possible to find the percentages of messages for different configurations of the delay incurred on the separate channels. Although the formulae so derived for various numbers of addresses are based on one traffic only, it was hoped that they could also be applied to other traffic densities. The validity of this assumption can be gathered by the comparison between the throwdown results and the empirical formulae results that will be given later.

6.4.2 *Two-Address Messages*

In the case of a two-address message, the following situations may arise:—

A. No delay on either line to which the message is to be transmitted.

B. Delay on line 1, no delay on line 2.

C. No delay on line 1, delay on line 2.

D. Delay on both lines.

Assume that the routes to the two destinations consist of single lines and that both lines are dealing with the same traffic A. Since the calls initiated for the two lines, except for the call under consideration, may be regarded as independent, the respective probabilities for the occurrence of the conditions **A** to **D** are $(1 - A)^2$, $A(1 - A)$, $(1 - A)A$, and A^2. Furthermore, if the average delay for a single-address message that is delayed is D for both lines, the average delays for cases **A**, **B**, and **C** will be 0, D, and D respectively. For case **D** the situation is more complicated, and the average delay for this condition is analysed in the following paragraph.

Although the average delay for delayed messages D is the same for both lines, the actual delays will be above and below this value D. If the delay for the message under consideration is less than D on one line and greater than D on the other, then the overall delay for this two-address message will be equal to the greater of these two delays. There are two further configurations for delay on both addresses, namely both delays less than D and both delays greater than D. If the proportion of messages and the average delays for these three distributions are known, it is possible to calculate the contributions of these to the overall delay.

From the multi-address throwdown based on $0{\cdot}667E$ to each line, that is 25 messages per hour and an average holding time of 1·6 minutes, of the two-address messages for which delay was encountered on both lines 41 per cent had both delays less than D, 46 per cent had one delay greater than and the other less than D, and 13 per cent had both delays greater than D. The respective average delays for these conditions were found to be $0{\cdot}61D$, $2{\cdot}02D$, and $2{\cdot}35D$. Although these proportions and delays are derived for a particular traffic, there is every justification to believe that they are applicable to any traffic; having postulated that the messages are being delayed on both lines, the actual traffic on the lines has no bearing on the values being considered. Using the above figures, the average delay for the conditions when delay is encountered on both lines is:—

$$0{\cdot}41 \times 0{\cdot}61D + 0{\cdot}46 \times 2{\cdot}02D + 0{\cdot}13 \times 2{\cdot}35D = 1{\cdot}49D.$$

Considering all the conditions given above, the average delay incurred by two-address messages is given by:—

$$A(1 - A)D + (1 - A)AD + A^2 \times 1{\cdot}49D = AD(2 - 0{\cdot}51A). \quad (1)$$

6.4.3 Three-Address Messages

With a three-address message the following delay situations may be encountered:—

A. The message is not delayed on any of the three lines.

B. Delay occurs on one but not on the other two lines.

C. Delay occurs on two but not on the third line.

D. Delay occurs on all three lines.

The respective probabilities for these occurrences are $(1 - A)^3$, $3A(1 - A)^2$, $3A^2(1 - A)$, and A^3; the respective delays for cases **A**, **B**, and **C** are 0, D and $1{\cdot}49D$ (obtained from the two-address both-delayed condition), but the delay for the fourth case has to be derived.

For case **D** there will be various combinations of delay above and below the delay D. From the three-address throwdown it was found that of the calls for which delay was encountered on all lines 25 per cent had all delays less than D, 44 per cent had two delays less than D and one delay greater than D, 26 per cent had one delay less than D and two delays greater than D, and 5 per cent had all three delays greater than D. The respective average delays for these situations were $0{\cdot}70D$, $2{\cdot}02D$, $2{\cdot}35D$, and $2{\cdot}63D$. Thus, the average delay for the condition when the three addresses are all delayed is:—

$$0{\cdot}25 \times 0{\cdot}70D + 0{\cdot}44 \times 2{\cdot}02D + 0{\cdot}26 \times 2{\cdot}35D + 0{\cdot}05 \times 2{\cdot}63D = 1{\cdot}81D.$$

Considering all the above conditions, the average delay incurred by three-address messages is given by:—

$$3A(1 - A)^2D + 3A^2(1 - A) \times 1{\cdot}49D + A^3 \times 1{\cdot}81D = AD(3 - 1{\cdot}53A + 0{\cdot}34A^2). \quad (2)$$

6.4.4 Four-Address Messages

From the four-address throwdown it was found that, of the cases when all four addresses encountered delay, 16 per cent had the four delays less than D, 37 per cent had three delays less than and one delay greater than D, 32 per cent had two delays less than and two delays greater than D, 13 per cent had one delay less than and three greater than D, and 2 per cent had the four delays greater than D. The respective delays were $0{\cdot}75D$, $2{\cdot}02D$, $2{\cdot}35D$, $2{\cdot}63D$, and $2{\cdot}82D$. The average delay for the condition of delay for all four addresses is:—

$$0{\cdot}16 \times 0{\cdot}75D + 0{\cdot}37 \times 2{\cdot}02D + 0{\cdot}32 \times 2{\cdot}35D + 0{\cdot}13 \times 2{\cdot}63D + 0{\cdot}02 \times 2{\cdot}82D = 2{\cdot}02D.$$

The probabilities of the different combinations of delay are easily obtained, and the average delay for each of these is obtainable from the foregoing. Hence the average delay incurred by four-address messages is given by:—

$$4A(1-A)^3 \times D + 6A^2(1-A)^2 \times 1{\cdot}49D + 4A^3(1-A) \times 1{\cdot}81D + A^4 \times 2{\cdot}02D = AD(4 - 3{\cdot}06A + 1{\cdot}36A^2 - 0{\cdot}28A^3). \quad (3)$$

6.4.5 Forecasting Delay for Further Addresses

Using the values already obtained for two, three, and four addresses all delayed, namely $1{\cdot}49D$, $1{\cdot}81D$, and $2{\cdot}02D$, and using the further condition that one address will have D as the delay, it is possible to draw a curve whereby the corresponding values for five and six addresses all delayed may be forecast. The curve may be further extended, but it is considered that the values obtained might not be dependable; even the points already known are the result of throwdown studies and, furthermore, it is extremely difficult to extrapolate a curve of this nature for further points to be obtained with a reasonable degree of certainty.

For five and six addresses all delayed the respective values obtained from the curve are $2{\cdot}28D$ and $2{\cdot}45D$. Using these values and the probabilities of the different conditions of delay, the following formulae give the average delays for five- and six-address messages respectively:—

$$AD(5 - 5A + 3{\cdot}3A^2 - 1{\cdot}2A^3 + 0{\cdot}18A^4) \quad (4)$$

$$\bar{A}D(6 - 7{\cdot}5A + 6{\cdot}6A^2 - 3{\cdot}6A^3 + 1{\cdot}08A^4 - 0{\cdot}13A^5). \quad (5)$$

6.4.6 Empirical Study Results

When using the formulae given for messages of two or more addresses, it should be remembered that the value of D is that for the average delay on a single-address message delayed for the particular traffic being considered. To test the validity of the formulae that are based on the $0{\cdot}667E$ throwdown, the values for the other traffics used in the multi-address throwdown studies have been calculated. These are summarised in Table 4.

TABLE 4

VALUES OF DELAY BASED ON D

Number of Addresses	Traffic per Line		
	$0{\cdot}4E$	$0{\cdot}533E$	$0{\cdot}667E$
1	0·40	0·53	0·67
2	0·72	0·94	1·11
3	0·98	1.21	1·42
4	1·19	1·44	1·65
5	1·37	1·64	1·80
6	1·52	1·78	1·97

Comparison of these results with those for the equivalent conditions obtained in the throwdown studies shows close agreement for $0{\cdot}533E$ and $0{\cdot}667E$ and rough agreement for $0{\cdot}4E$. Regarding the latter, this is not surprising as the original throwdown covered only 48 hours.

Using the formulae obtained, it is possible to forecast the average delays for one to six addresses for any value of traffic, bearing in mind that these formulae are based on lines loaded to substantially the same occupancy. These could be used with discretion to give an idea of the delay in other conditions.

6.5 THEORETICAL METHOD OF OBTAINING MULTI-ADDRESS MESSAGE DELAYS

It has been shown in section 3.2 that the theoretical delay formulae for an exponential distribution may be used by making the necessary correction for the average holding time. Based on this fact, theoretical formulae have been produced for obtaining the average delays incurred by multi-address messages for the more general cases when line groups and traffic carried per group are not equal.

The following formula is the generalised result for the average delay for the cases considered in the throwdown and empirical approaches:—

$$AD \left\{ n - \frac{C_2^n}{2} A + \ldots + (-1)^{r-1} \frac{C_r^n}{r} A^{r-1} + \ldots + (-1)^{n-1} \frac{1}{n} A^{n-1} \right\}$$

where C_r^n = combination of n things taken r at a time.

From Figure 5 it can be seen that there is close agreement between the curves obtained by the three methods.

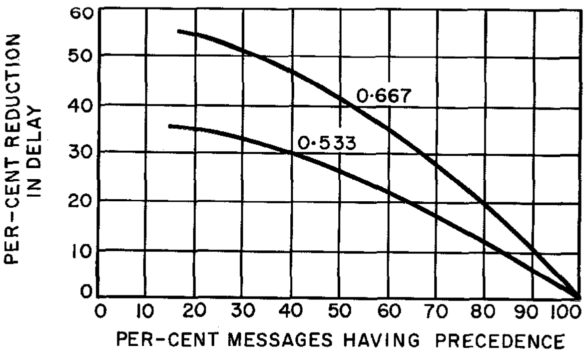


Figure 6—Effect of precedence on delay for indicated traffic density in erlangs.

7. *Priority Advantage Studies*

7.1 Conditions Studied

It is frequently found that a percentage of the traffic to be carried over a telegraph network is relatively non-urgent and can be treated on a deferred basis without any serious loss of value. It is a natural consequence that it should be arranged that this non-urgent traffic should give way to urgent traffic. In a no-delay system there is no opportunity to use precedence since it is very unlikely that two messages will arrive simultaneously when one channel only is available.

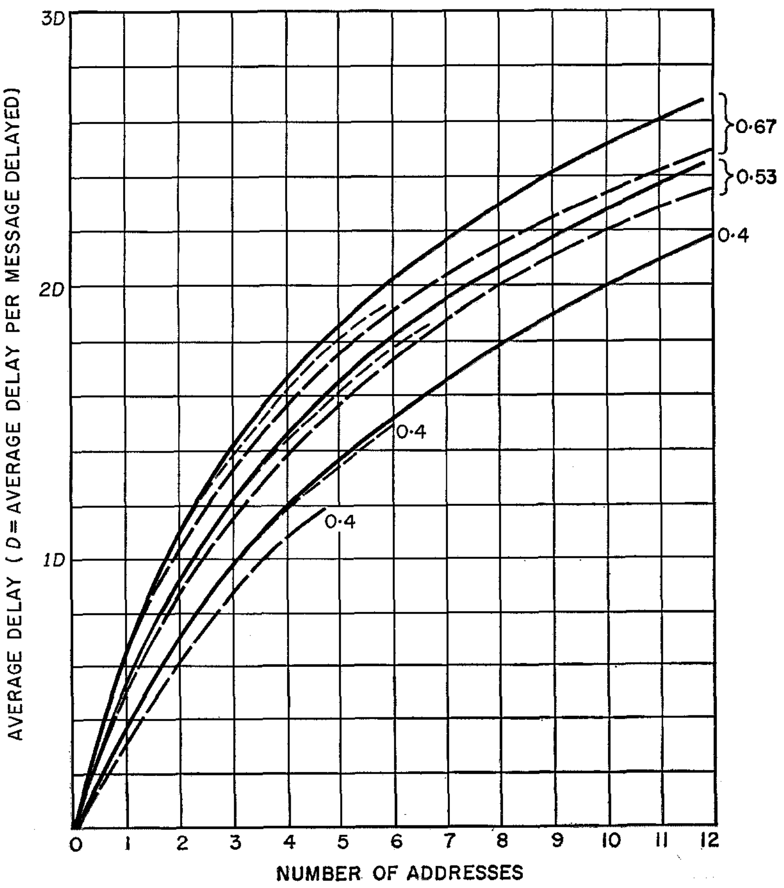


Figure 5—Comparison of throwdown (long-dashed curves), empirical (short-dashed curves), and theoretical (solid-line curves) for the indicated traffic densities in erlangs for multi-address messages for a single-line group.

The advantage to be gained by the use of preferential treatment depends evidently on the extent of delay experienced by the group in question, the more the delay the greater the advantage. The advantage is also dependent on the percentage of the total traffic that is marked priority. It is clear that this variation will be a function of $(M - m)/m$ where M is the total traffic and m is that marked priority.

7.2 Results of Studies

Figure 6 shows the results of throwdown studies, the reduction in delay being plotted against the percentage of messages having precedence. In the case of the 0·667E occupancy, if 16 per cent of the messages have precedence there is a saving of 55·1 per cent in the average delay for these messages; if the precedence is extended to 33 per cent the saving in delay falls to 50·4 per cent, whereas a further extension to

48 per cent results in the delay falling to 42·1 per cent. A second study was made comprising 20 messages per hour, also with an average holding time of 1·6 minutes, that is an occupancy of 0·533E. With this reduced traffic it will be seen that the reduction in delay is less than with the higher occupancy.

Figure 7 illustrates the condition when several classes of precedence are considered for an

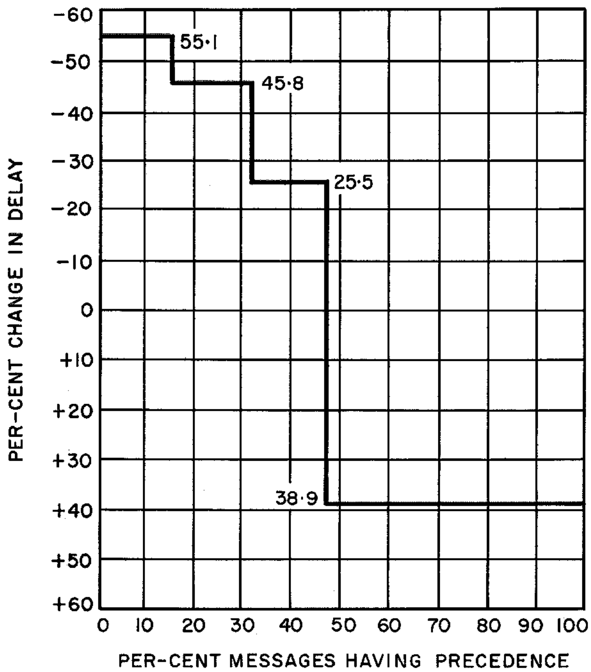


Figure 7—Relative effect on delay of using four precedence states for a traffic occupancy of 0·667 erlang.

occupancy of 0·667E. In the example shown there are four classes. The highest priority is marked on 16 per cent of the traffic, and as in the previous case there is a saving of 55·1 per cent in the average delay. The second priority is marked on a further 16 per cent of the traffic, which achieves a saving of 45·8 per cent. The third priority is marked on a further 16 per cent of the traffic, which achieves a saving of only 25·5 per cent. The remaining traffic is deferred and suffers an increase of 38·9 per cent.

It may be remarked that, if the percentage of messages in the third category is increased, the decrease in delay for this category will fall, but nevertheless there will be an increased delay for the deferred traffic. The traffic in the highest and second categories will not be changed. Similarly, if the percentage of traffic in the highest or second category is increased, the charged category and all lower categories will suffer. If, on the other hand, the percentage in the highest category is increased, and the percentage in the second category correspondingly reduced, while the remaining categories are unaltered, the highest priority will deteriorate. If the percentage of the highest priority is increased to 32 per cent, and the second priority is eliminated, then the advantage will have fallen to 50·4 per cent.

The above information was derived from a throwdown comprising 25 messages per hour with an average holding time of 1·6 minutes. The holding time distribution assumed that the shortest message was of approximately 0·5 minute. With this traffic an average of 16·125 messages per hour out of 25 were delayed; the average delay of delayed messages was 2·316 minutes, and the average delay of all messages was 1·494 minutes. If the number of messages varies in a random manner between hours but maintains an average of 25 messages per hour, it is clear that the delays will increase by a small amount. It is evident that the precedence advantage will alter in a corresponding way, but it seems unlikely that it will make any appreciable change to the percentage reduction in delay.

7.3 Application of Precedence Technique

A review of the precedence results indicates that the introduction of precedence effects an appreciable reduction in the delay that would otherwise be expected; a corresponding increase in delay must be applied to the deferred traffic. The arrangement can, therefore, be advantageous although ideally it would be valuable to be able to make a large saving, perhaps 90 per cent, in the case of the highest priority and it would be of little disadvantage if the deferred traffic suffered more severely. Nevertheless, it must be pointed out that for convenience the savings are shown as an alteration of *average* delays whereas, in fact, the priority advantage tends to subtract sizable periods from the long delays but has very little effect on the messages subjected to short delays. This fact will be appreciated when it is considered that an advantage occurs only when a priority message arrives and a deferred (or lower priority) message is already waiting. When this condition does arise, the delay will be cut down by the holding time of the deferred message. In the study for an occupancy of $0{\cdot}667E$ the average delay of delayed messages was 2·316 minutes; a saving of 50 per cent reduces this delay to 1·16 minutes, chiefly by deducting deferred-message holding times ranging from 1 to 5 minutes but averaging 1·6 minutes. There can be little doubt that the shape of the message-delay distribution curve would be basically changed in the sense that the proportion of long delays would be reduced. This is an important feature as the quality of service may be specified on the basis that not more than X percentage of the messages of highest priority should be delayed by more than 2 minutes rather than that the average delay of all such messages should not exceed 0·75 minute. Such a specification requirement may apply to priority messages as a whole or to each relay station.

It would appear that the use of precedence is valuable, and the next step to consider is how many stages of precedence should be accommodated. An answer that might satisfy many applications would be:—

A. Top priority category (very small percentage).

B. Ordinary priority category.

C. Deferred category.

With this combination the most urgent messages obtain the maximum advantage and at the same time the deferred traffic never obstructs any other traffic.

No mention has been made of the use of breakdown facilities because the breakdown of existing messages does not introduce a probability problem. Nevertheless, it is proper to point out that the circuit and operating problems associated with breakdown may be eliminated if the highest priority provides a sufficiently high quality of service.

Range of Multichannel Radio Links Between 30 and 10 000 Megacycles

By HELMUT CARL

Correction for Volume 33, Pages 165–173; June 1956

ATTENUATION is plotted against distance in Figure 7 and the legend should identify the lower curve as being only the beyond-the-horizon component while the four upper curves give the total attenuation made up of both the free-space and beyond-the-horizon components for the indicated frequencies.

We are indebted to Mr. P. H. Hellner, chief engineer of the Post and Telegraph Administration of Helsinki, Finland, for drawing our attention to this error.

United States Patents Issued to International Telephone and Telegraph System; May-July 1956

United States patents numbering 59 were issued between May 1 and July 31, 1956 to the indicated companies in the International System. The names of the inventors, subjects of the patents, and Patent Office serial numbers are given below.

J. P. Adams, International Telephone and Telegraph Corporation, Shield for Microstrip Circuits, 2 754 484.

P. R. Adams and S. B. Pickles, Federal Telecommunication Laboratories, Omnirange Beacon System, 2 753 554.

P. R. R. Aigrain, Laboratorie Central de Télécommunications (Paris), Potential Comparing Device, 2 752 489.

P. R. R. Aigrain, Laboratorie Central de Télécommunications (Paris), Impulse Coincidence Circuit, 2 752 530.

W. Bergholtz and H. Plitschka, Mix and Genest (Stuttgart), Circuit Arrangement for Pulse-Controlled Telephone System, 2 744 160.

W. A. Billings, W. W. Wright, and A. T. Watts, Standard Telephones and Cables (London), Indirectly Heated Cathodes, 2 749 470.

J. H. Bryant and A. G. Peifer, Federal Telecommunication Laboratories, Signal-Indicating Device, 2 753 484.

J. L. Culbertson, Kellogg Switchboard and Supply Company, Line-Clearing Apparatus for a Telephone System, Re. 24 171.

C. T. Daly and R. C. Jones, Standard Telephones and Cables (London), Fault-Alarm Arrangements for Electric Communication System, 2 744 170.

M. Den Hertog, Bell Telephone Manufacturing Company (Antwerp), Telephone Exchange Equipment, 2 744 163.

M. den Hertog and C. de Zeeuw, Bell Telephone Manufacturing Company (Antwerp), Selection System for Electrical Circuits or Equipment, 2 744 162.

F. H. de Roovere, Bell Telephone Manufacturing Company (Antwerp), Method of Mounting an Electric Capacitor or Other Electric Components in a Metallic Case, 2 751 665.

L. A. DeRosa, F. X. Bucher, and T. J. Golden, Federal Telecommunication Laboratories, Switching Devices, 2 749 524.

M. Dishal, Federal Telecommunication Laboratories, Band-Pass Filters, 2 749 523.

L. Diven and R. R. Waer, Federal Telecommunication Laboratories, Frequency Divider, 2 753 455.

S. H. M. Dodington, Federal Telecommunication Laboratories, Duty-Cycle Control for Radio Beacons, 2 753 553.

S. H. M. Dodington, Federal Telecommunication Laboratories, Motor Speed Control, 2 753 507.

S. H. M. Dodington and C. R. Wilson, Federal Telecommunication Laboratories, Pulsed Radio-Frequency Amplifier, 2 753 525.

C. E. Eadon-Clarke, Standard Telephones and Cables (London), Gas-Burner System Having Time Controlled Air and Fuel Supply, 2 743 771.

C. C. Eaglesfield, Standard Telephones and Cables (London), Electron Discharge Apparatus, 2 745 957.

H. F. Englemann, Federal Telecommunication Laboratories, Radio-Frequency Coupling Devices, 2 755 447.

H. F. Engelmann and J. A. Kostriza, Federal Telecommunication Laboratories, Microwave Coupling Arrangements, 2 749 521.

P. T. Farnsworth, Capehart–Farnsworth Company, Cathode-Ray Tube and System, 2 754 449.

C. H. Foulkes, P. A. Childs, and R. E. Smith, Standard Telephones and Cables (London), Electromagnetic Light-Current Contact-Making Relays, 2 752 450.

S. Gallee, C. Lorenz (Stuttgart), Method of Manufacturing Cylindrical Self-Induction Coils, 2 751 666.

L. Goldstein, D. J. LeVine, and W. Sichak, Federal Telecommunication Laboratories, Waveguide Gas Switching Device, 2 745 072.

M. C. Goodall, Standard Telephones and Cables, (London), Electron Discharge Apparatus, 2 752 523.

D. D. Grieg and H. F. Engelmann, Federal Telecommunication Laboratories, Radio-Frequency Filter, 2 751 558.

P. Gumbert, Schaub Apparatebau (Pforzheim), Device for Clamping a Foil Inserted into the Gap Formed by Both of the Pole Ends of a Sound Top for Magnetic Sound Implements, 2 749 391.

W. G. Hill, Standard Telephones and Cables (London), Joints for Coaxial Cable, 2 743 505.

A. Horvath, Federal Telecommunication Laboratories, High-Q Frequency Tuner, 2 753 530.

J. F. Houdek, Kellogg Switchboard and Supply Company, Automatic Intercommunication Telephone System, 2 749 388.

T. M. Jackson and I. H. Fraser, Standard Telephones and Cables (London), Electrical Circuits Using Multigap Cold-Cathode Gas-Filled Tubes, 2 749 479.

J. A. Kostriza, Federal Telecommunication Laboratories, Electromagnetic Horn, 2 749 545.

J. A. Kostriza and P. Terranova, Federal Telecommunication Laboratories, Directional Couplers for Microwave Transmission, 2 749 519.

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S. W. Lewinter, Federal Telecommunication Laboratories, Ringing Circuit for Telephone Line and Radio Order Wire, 2 749 390.

P. E. Lighty, Federal Telecommunication Laboratories, Selenium Rectifiers and Method of Manufacture, 2 745 047.

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C. I. Martinez, Federal Telecommunication Laboratories, Radiation-Responsive Device, 2 753 418.

S. E. Mayer, Standard Telephones and Cables (London), Light Cells or Rectifiers, 2 749 488.

S. E. Mayer and R. A. Hill, Standard Telecommunication Laboratories (London), Dry Contact Rectifiers, 2 749 489.

A. Mehlis, Mix and Genest (Stuttgart), Circuit Arrangement for All-Relay Selecting Equipment, 2 744 161.

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S. B. Pickles, Federal Telecommunication Laboratories, Omnirange Beacon System, 2 753 556.

W. Pouliart, Bell Telephone Manufacturing Company, (Antwerp), Impulse Register–Translator Arrangement, 2 749 540.

A. J. Radcliffe, Kellogg Switchboard and Supply Company, Compressor–Expander Volume-Range Control Device, 2 757 246.

D. C. Rogers, Standard Telephones and Cables (London), Electron Discharge Device, 2 749 476.

L. Rosenberg and R. B. Lewthwaite, Federal Telecommunication Laboratories, Radiant-Heat Detector, 2 753 420.

R. D. Salmon and L. A. G. Nash, Creed and Company (Croydon), Clutch Mechanism, 2 747 712.

K. O. Seiler, Süddeutsche Apparatefabrick (Nürnberg), Method of Cleaning and/or Etching Semiconducting Material, in particular Germanium and Silicon, 2 744 000.

J. B. Setchfield, Standard Telecommunication Laboratories (London), Arrangement for Measuring the Power Transmitted through an Electromagnetic Waveguide, 2 744 239.

A. Shadowitz, Federal Telecommunication Laboratories, Frequency-Modulated Oscillator System, 2 749 518.

D. E. Skelton, Standard Telephones and Cables (London), Electroacoustic Transducers, 2 748 882.

J. Stillman, Federal Telecommunication Laboratories, Automatic Tuner, 2 745 015.

W. J. Stray, Standard Telephones and Cables (London), Methods of Sealing Electrical Components in Metallic Casings, 2 751 674.

C. G. Treadwell, Standard Telephones and Cables (London), Electric Pulse-Code-Modulation Systems, 2 752 569.

E. P. G. Wright, Standard Telecommunication Laboratories (London), Telegraph Repeaters, 2 749 386.

E. P. G. Wright, G. C. Hartley, D. A. Weir, and J. Rice, Standard Telecommunication Laboratories (London), Multiplex Electric Signaling System, 2 744 159.

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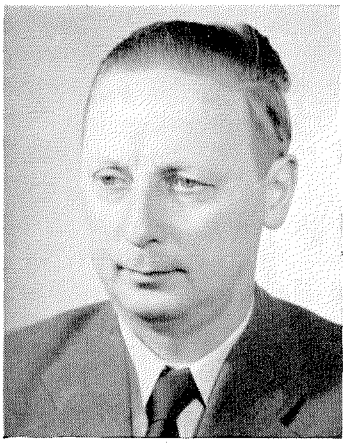

Friedrich Malsch

Martinus den Hertog. A photograph and biography of Mr. den Hertog, coauthor of the paper on the 7*E* rotary system will be found on page 250 of the September 1956 issue.

• • •

Jakob Kruithof. A photograph and biography of Dr. Kruithof, an author of the article on the 7*E* rotary switching system will be found on pages 250–251 of the September 1956 issue.

• • •

Friedrich Malsch was born in Jena, Germany, in 1904. After graduating from the technical college in Stuttgart, he worked as a designer for Brown, Boveri and Company in Mannheim. For five years, he served as an assistant at the technical college in Aachen from which he received a doctorate in engineering in 1934.

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• • •

Joseph Rice was born in Creswell, Derbyshire, England on April 14, 1916. He received a B. Eng. degree in 1938 and an M. Eng. degree in 1947 from the University of Liverpool.

He joined the staff of the Automatic Electric Company as a graduate apprentice in 1938. From 1939 to 1946, he served in the Royal Signals attaining the rank of major.

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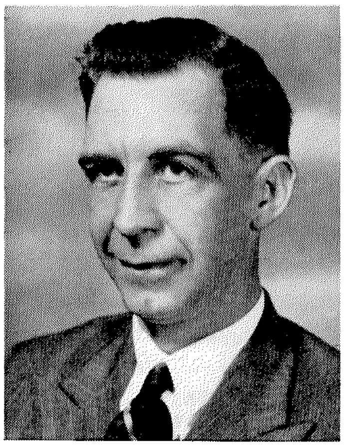
Mr. Rice is a member of the Most Excellent Order of the British Empire and was Mentioned in Despatches for service in the 8th Army. He is an Associate Member of the Institution of Electrical Engineers.



Joseph Rice

E. P. G. Wright

E. P. G. Wright joined the equipment engineering branch of the Western Electric Company in London in 1920, and in 1926 he took charge of project engineering when the company became associated with the International System. In 1928, Mr. Wright was transferred to the laboratories to work on switching problems.

He was in charge of switching system development for Standard Telephones and Cables Limited from 1932 until 1939. He was then appointed to the newly formed Standard Telecommunication Laboratories and has since been working on information-processing systems.

Mr. Wright is a Member of the Institution of Electrical Engineers and has three times been awarded the Fahie Premium by the Institution. He has been a delegate of the Comité Consultatif International Téléphonique for 18 years.

Mr. Wright is coauthor of a paper in this issue on probability studies relating to electronic telegraph switching systems.

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- Compañía Peruana de Teléfonos Limitada..........Lima

PUERTO RICO—
- Porto Rico Telephone Company...............San Juan
- Radio Corporation of Porto Rico...............San Juan

SPAIN—
- Compañía Radio Aérea Marítima Española........Madrid

UNITED KINGDOM—
- International Marine Radio Company Limited....Croydon