EB. 541

TYPE 5005 Crossbar System

PLESSEY Telecommunications

EB 541 · TECHNICAL INFORMATION RELATING TO

TYPE 5005 Crossbar System

PLESSEY
Telecommunications

The Plessey Company Limited, Telecommunications Group,
Edge Lane, Liverpool 7.
Telephone: Stoneycroft 4830. Telex: 62267

GATEWAY EXCHANGE, SYDNEY, AUSTRALIA.—This exchange is the 4-wire switching centre terminating the Commonwealth Pacific cable. It permits operators in all the main switching centres in Australia to dial direct to subscribers in North America and Great Britain, using high-speed v.f. signals. It also provides for operators in Great Britain and North America to dial direct to subscribers throughout Australia.

CONTENTS

CONTENTS

PART 1

TRUNKING

PART 2

OUTLINE OF OPERATION

PART 3 SECURITY

CONTENTS (Continued)

PART 6

MISCELLANEOUS FACILITIES

CONTENTS (Continued)

INTRODUCTION

The 5005A Crossbar System is a register-controlled system using crossbar switches arranged in a link trunking scheme, and is suitable for exchanges ranging from 500 to 100 000 lines in size.

Crossbar switches and relays, the main components of the 5005 System, are well known and well proven in operation, and no attempt is made in this bulletin to explain their mechanical operation.

The 5005A System differs from older crossbar systems in its trunking scheme, circuitry and equipment mounting practice, all of which embody new principles developed by the Company during ten years of experimental construction and field trial.

These new principles are based upon the idea of construction in small, self-contained units, with a minimum of common control equipment. This results in circuits which are simple, easy to understand, and easy to maintain.

This bulletin explains in detail how these new principles work, and also gives details of the facilities provided by the 5005A System.

Other systems in the 5005 series are:—

5005 D —rural automatic exchange (r.a.x.) (60-600 lines, or 100-1 000 lines).

5005 P —private automatic branch exchange (p.a.b.x.) (60-240 lines, and 240-4 800 lines).

5005 T —4-wire Trunk Transit Exchange (in units of 100 trunks).

The 5005A System is suitable for local exchanges, tandem exchanges, and local exchange with tandem facilities.

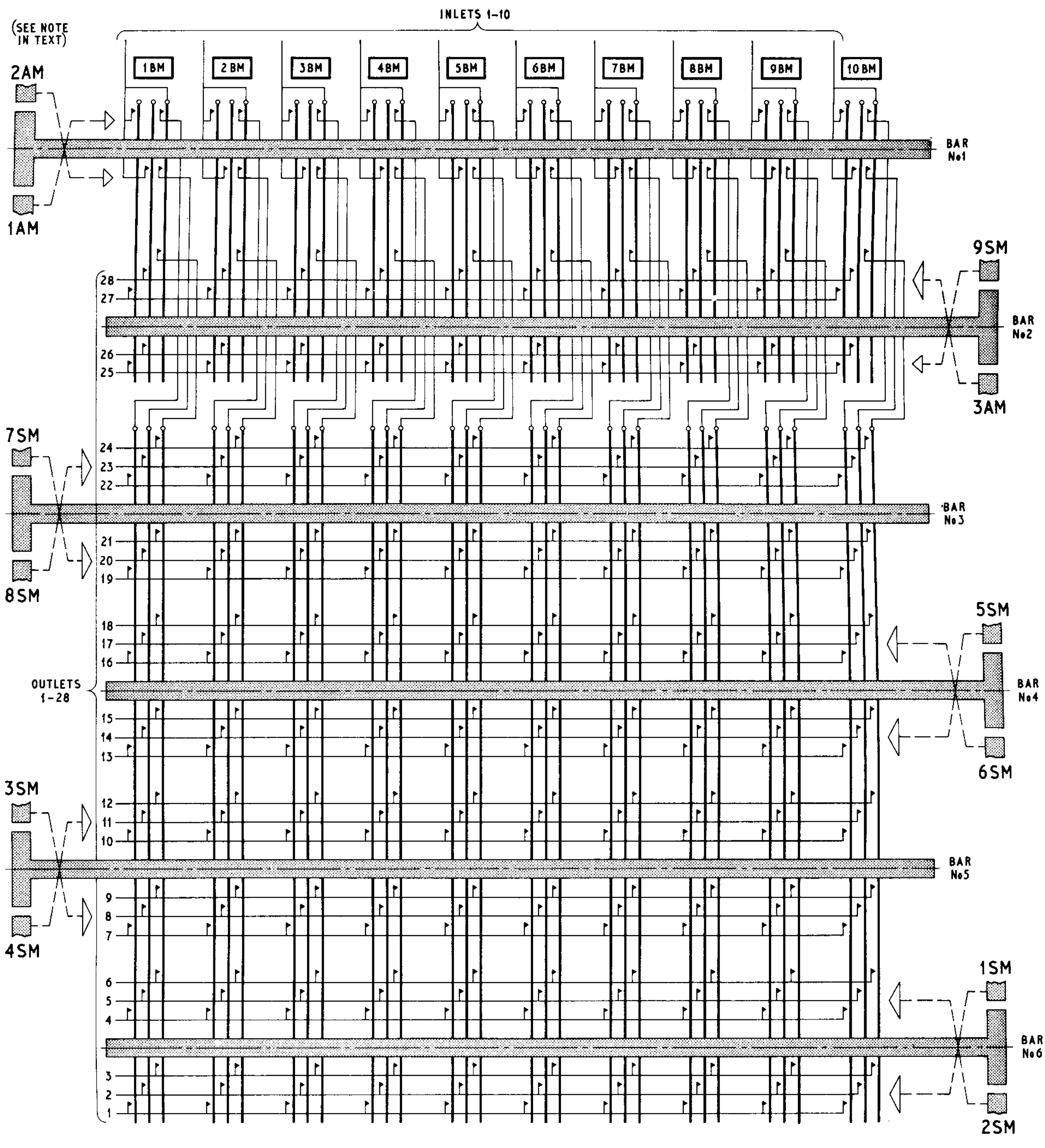


Figure 1 (*b*). CROSSBAR SWITCH TRUNKING, METHOD OF CONNECTING INLETS TO OUTLETS

THE CROSSBAR SWITCH

The crossbar switch has ten inlets (called "bridges"), each of which can be connected to any one of up to 28 outlets by the operation of the appropriate crosspoints. This is shown diagrammatically in Fig. 1 (*a*). Fig. 1 (*c*) shows the switch in its shelf-mounted position.

A switch outlet is selected by the operation of two magnets (select and auxiliary) controlling the appropriate pair of selecting bars, followed by the operation of a bridge magnet, as shown in Fig. 1 (*b*).

Table I lists the combinations of select and auxiliary magnets to be operated to prepare the switching circuit of any inlet for a particular outlet.

TABLE I

Outlet No.	Combination for Crosspoint preparation
1	1 SM and 1 AM
2	1 SM and 2 AM
3	1 SM and 3 AM
4	2 SM and 1 AM
5	2 SM and 2 AM
6	2 SM and 3 AM
7	3 SM and 1 AM
8	3 SM and 2 AM
9	3 SM and 3 AM
10	4 SM and 1 AM
11	4 SM and 2 AM
12	4 SM and 3 AM
13	5 SM and 1 AM
14	5 SM and 2 AM
15	5 SM and 3 AM
16	6 SM and 1 AM
17	6 SM and 2 AM
18	6 SM and 3 AM
19	7 SM and 1 AM
20	7 SM and 2 AM
21	7 SM and 3 AM
22	8 SM and 1 AM
23	8 SM and 2 AM
24	8 SM and 3 AM
25	9 SM and 1 AM
26	9 SM and 2 AM
27	3 AM and 1 AM
28	3 AM and 2 AM

Referring to the conventions in Fig. 1 (*b*), the select or auxiliary magnets (SM or AM) shown above and below the selecting bar prepare the crosspoints shown below and above the bar respectively. Thus 6 SM is associated with the crosspoints for outlets 16, 17 and 18.

The contacts of two crosspoints to select an outlet are closed by:

(*a*) the operation of the auxiliary magnet (AM) followed by:

(*b*) the operation of the select magnet (SM) followed by:

(*c*) the operation of the bridge magnet (BM).

The auxiliary magnet (AM) and the select magnet (SM) are now allowed to release, and can be used on other calls. The crosspoint contacts remain closed so long as the bridge magnet (BM) remains operated.

As bar No. 2 cannot be moved by 9 SM and 3 AM at the same time, 9 SM controls only two outlets (when associated with 1 AM or 2 AM).

For convenience of trunking, only 25 outlets are generally used, but 28 outlets are used where the greater availability is an advantage, as on outgoing junctions.

A crossbar switch can carry ten simultaneous calls, one from each inlet, but obviously each of the ten calls must go to a different outlet. These calls must also be set up one at a time, but as setting up takes only a fraction of a second, this limitation does not affect the service to a noticeable extent.

PRINCIPLES OF LINK TRUNKING

In a link trunking scheme, there are two ranks of crossbar switches, designated "A" and "B" respectively, and the switches in the "A" rank are connected to those in the "B" rank by links. This is illustrated in Fig. 2 (*a*) which shows three "A" switches (each with only three inlets and four outlets shown for simplicity), connected via 12 links

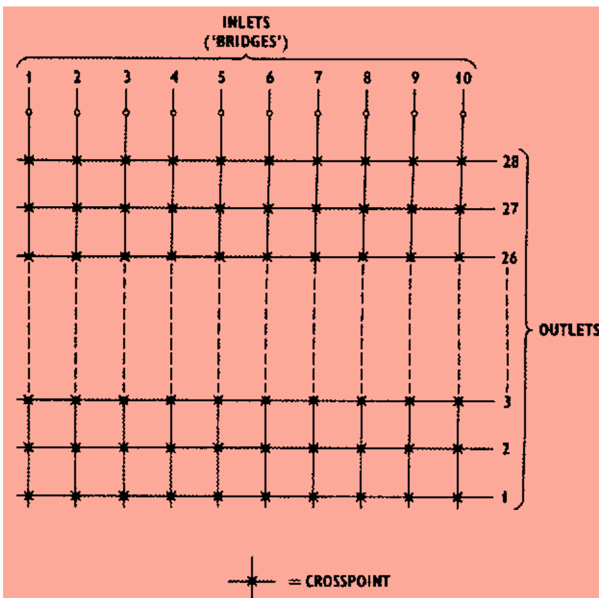


Figure 1 (a).
CROSSBAR SWITCH TRUNKING, BASIC PRINCIPLE

to four "B" switches which have a total of 16 outgoing trunks, arranged in four groups of four trunks each. Any incoming trunk can be connected to any link by the operation of the appropriate crosspoint in an "A" switch. Similarly, any link can be connected to any outgoing trunk by the operation of the appropriate crosspoint in a "B" switch.

The link trunking arrangement allows any inlet to be connected to a free outlet in the required group of outlets. A call cannot however be set up by dialling directly on to the "A" and "B" switches. The dialled digits have to be received on a register, which then controls the operation of the select magnets and bridge magnets to set up the call.

A call can be set up from a given inlet to a free outlet in a chosen group, or "level", of outlets. The call has a choice of as many different paths per level as there are outlets on the "A" switch of origin; but each busy outlet on the "A" switch of origin blocks access to a "B" switch, and therefore to one outlet in the required level even though that outlet may itself be free. This is called "internal blocking" or "link congestion". It is minimised by providing "expansion" at each rank of switches, that is, by arranging each switch so that it has more outlets than inlets. Suitable allowance for this blocking effect is made in switch quantity calculations so that the required over-all grade of service is provided.

If an attempt were made to set up a call from a given inlet to one particular outlet (instead of to any free outlet in a chosen level), using the arrangement of Fig. 2 (*a*), the effect of internal blocking would be intolerable, as one busy link could block access completely. This blocking can be avoided by using three ranks of switches instead of two, as shown in Fig. 2 (*b*). In this case, there is a path from a given inlet to a chosen outlet through every intermediate switch.

In the 5005 System, local calls are set up, after dialling is completed, through two stages, each stage having "A" and "B" switches, so that there are, in effect, two ranks of intermediate switches between the "A" switch of origin and the "B" switch serving the called subscriber. This reduces internal blocking to a value compatible with a normally acceptable grade of service.

LINK TRUNKING IN THE 5005 SYSTEM

A call is set up through the 5005 exchange in two steps:

1. The caller lifts his handset and is connected to a free "transmission relay group" (t.r.g.) which has access to a free register. The caller then dials the number he requires into the register.
2. The t.r.g. is connected to the called subscriber via two switching stages, each stage comprising an "A" and a "B" rank of switches. The register then releases.

It is convenient to consider step 2 first.

The two switching stages through which the t.r.g. is connected to the called subscriber are the "router stage" and the "distributor stage", and these are shown diagrammatically on Fig. 3.

Before dialling commences, a call enters a router on one

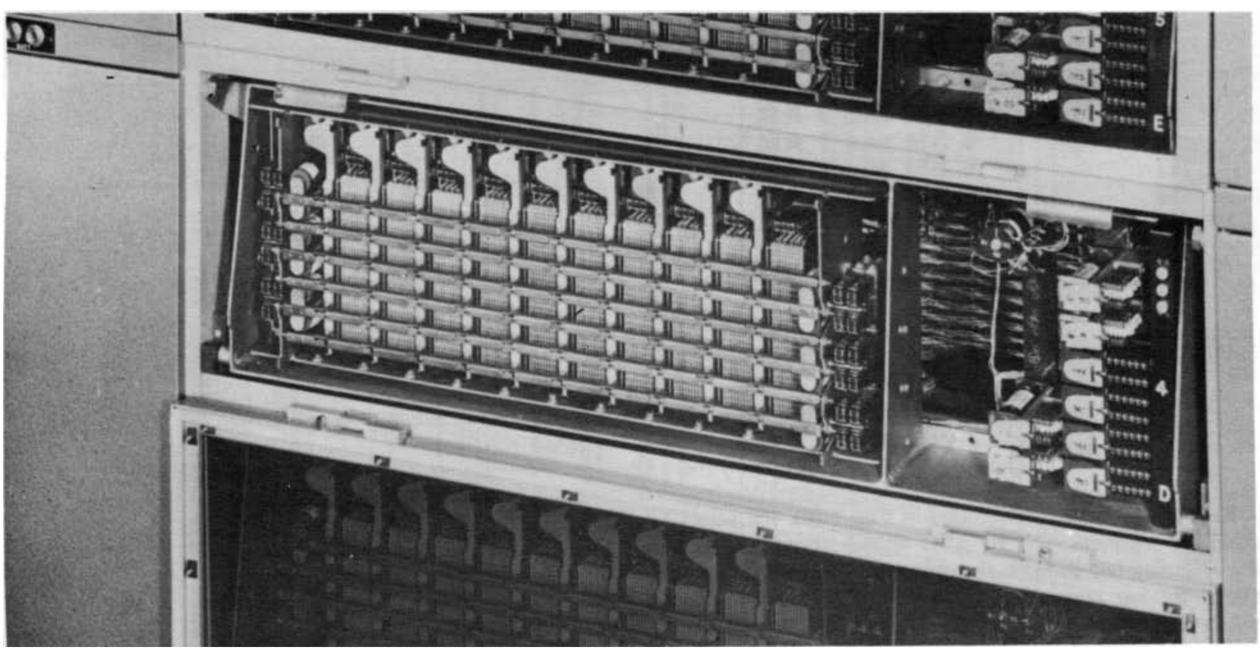


Figure 1 (*c*). SHELF-MOUNTED CROSSBAR SWITCH AND ASSOCIATED RELAYS, WITH COVER HINGED DOWN

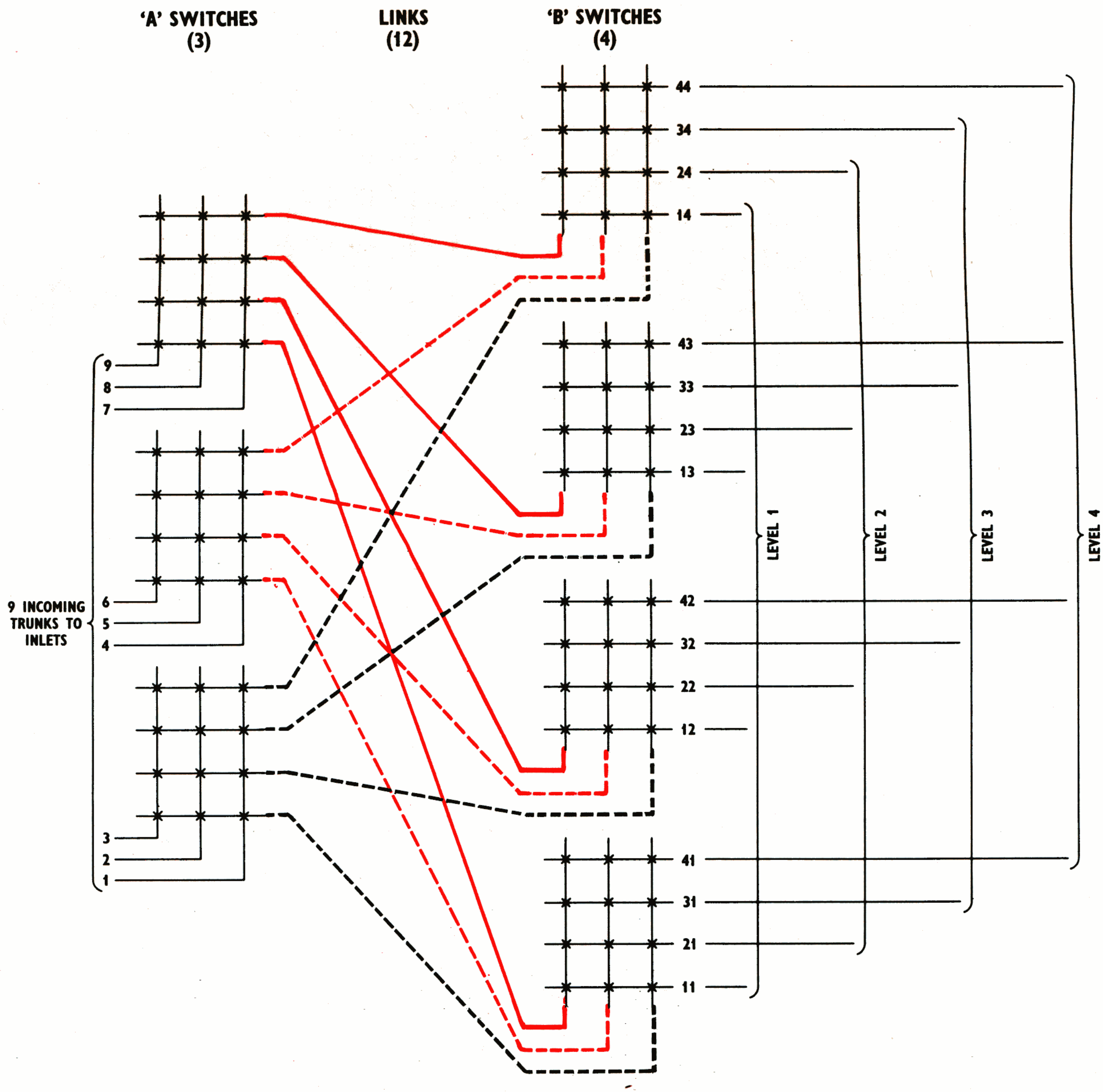


Figure 2 (*a*). LINK TRUNKING, GENERAL PRINCIPLE

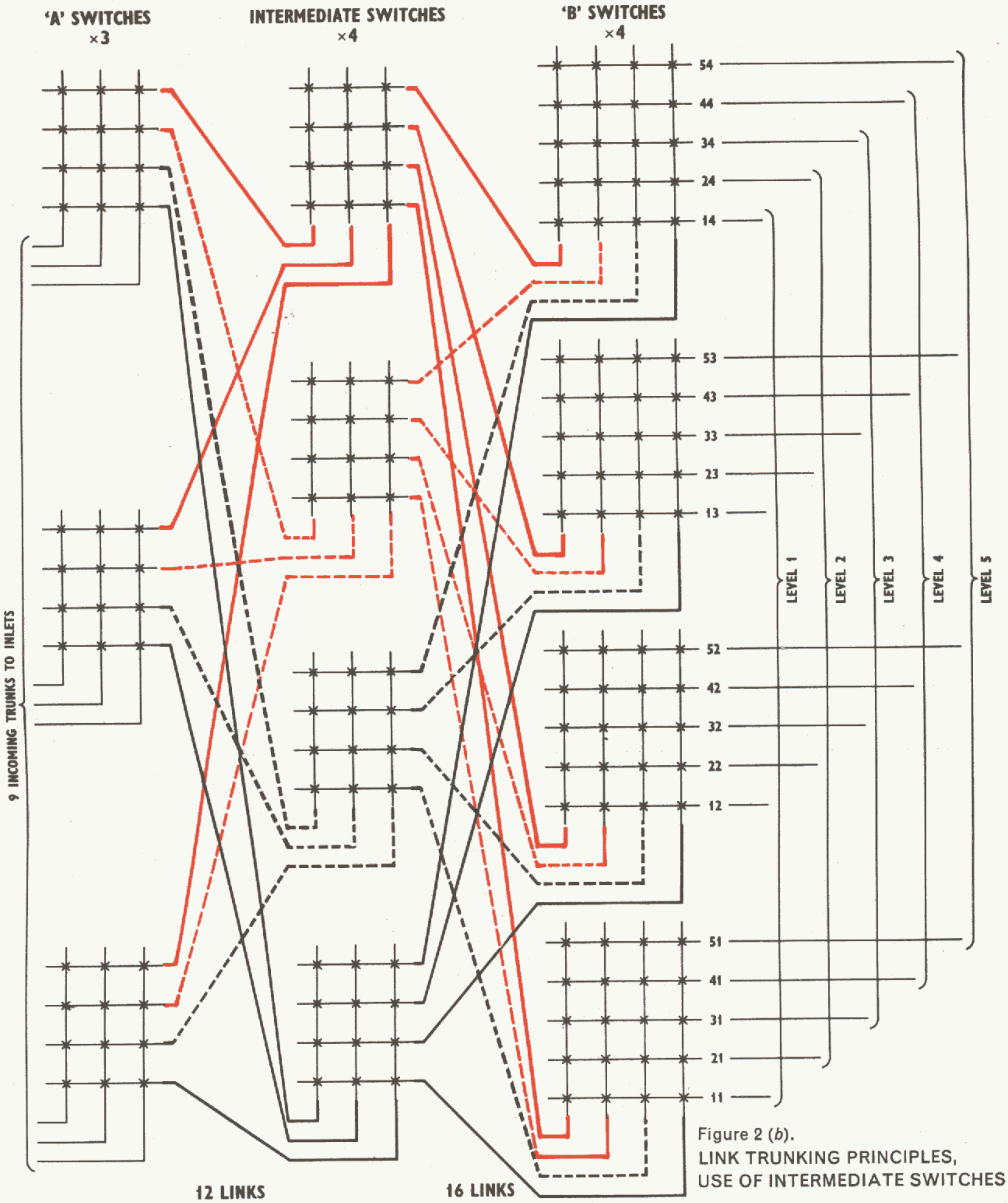


Figure 2 (*b*).
LINK TRUNKING PRINCIPLES,
USE OF INTERMEDIATE SWITCHES

of the 160 incoming trunks. After dialling, the call is connected to the required subscriber's line via the following path:—a crosspoint in route switch "A"; a link; a crosspoint in any route switch "B"; through the trunk connecting frame (t.c.f.); a crosspoint in any distributor switch "A"; a link; and a crosspoint in the terminating distributor switch "B".

Fig. 4 illustrates how an originating call from a subscriber's line is connected, before dialling, to one of the 160 incoming trunks of the router.

Two distributors, originating and terminating respectively, are shown in Fig. 4. These distributors are actually identical as each can handle both originating and terminating traffic, but one has been drawn reversed in order to show clearly the path of a call. The path is via the "B" and "A" switches of the distributor containing the caller's line, through the t.c.f. to the t.r.g. (step 1); then via route switches "A" and "B", the t.c.f., and the "A" and "B" switches of the distributor to which is connected the subscriber's line (step 2).

Of the ten bridges in each distributor switch "A", five are used for "terminating trunks" and the other five are used for "originating trunks". Thus each distributor with eight "A" switches provides 40 originating trunks for calls originated by its 500 subscribers, and 40 terminating trunks for calls terminating on its 500 subscribers. These quantities are suitable for low and medium calling rates. For high calling rates the number of distributor switches "A" can be increased to provide up to 80 originating and 80 terminating trunks.

It is useful at this point to establish a definition cf "inlet" and "outlet" on a crossbar switch. The convention adopted is that the bridges are the "inlets". Although distributor switches carry originating and terminating traffic, when the method of call path allocation is considered it is logical to designate the bridges as "inlets" in both cases.

A distributor switch "A" has the five bridges for "originating trunks" connected to t.r.g.s; the other five bridges for "terminating trunks" are connected to the outlets of route switches "B". For call path allocation the t.r.g. is the focal point. An originating call seizes a t.r.g., from which, via an "originating trunk" inlet, a path is set up to the calling number. When the called number is dialled, a path is set up from the t.r.g. via the route switches and a "terminating trunk" inlet on a distributor

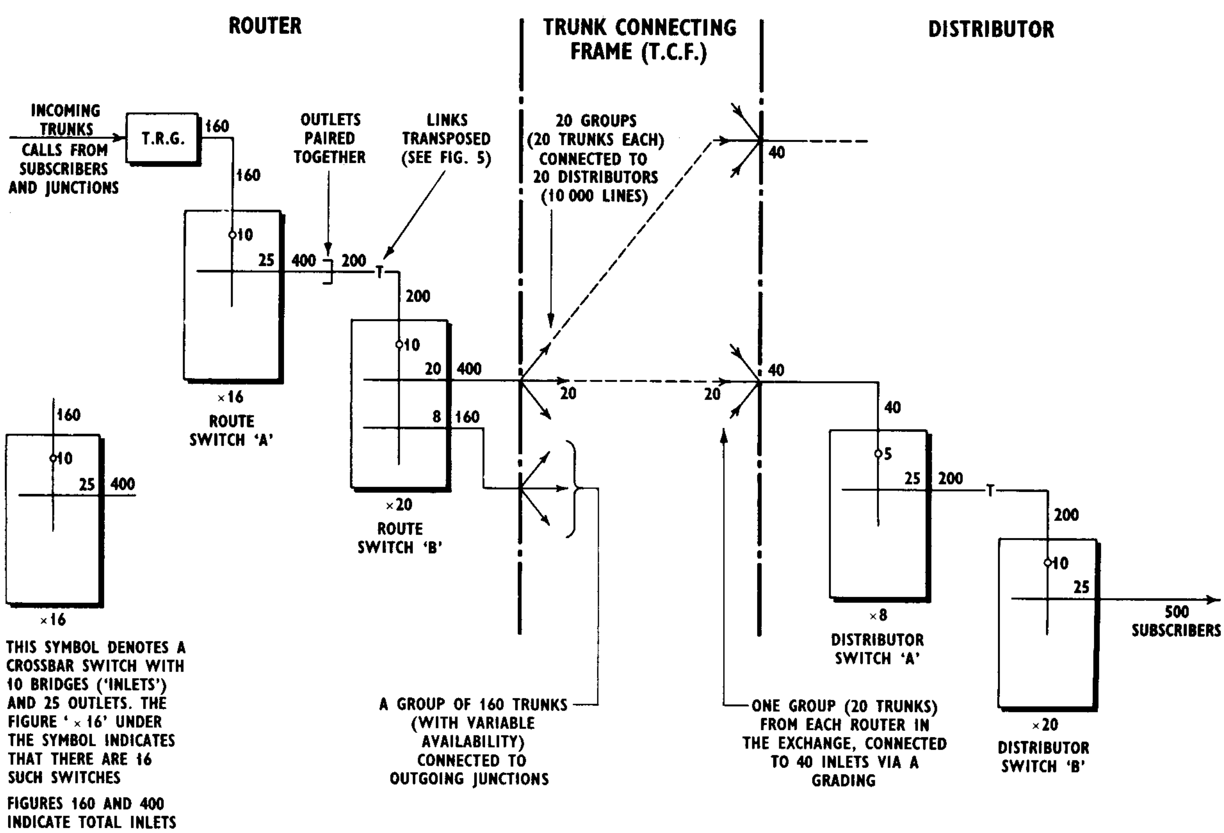


Figure 3. ROUTER/DISTRIBUTOR TRUNKING, AN OUTLINE

switch, to the marked called number. Thus the path is always through a crossbar switch in the same direction—"inlet" to "outlet".

The method of setting up a call by means of the "self-steering" principle is described on page 22.

ALLOCATION OF LINKS

LINKS IN DISTRIBUTOR

In a normal distributor there are eight distributor switches "A" with 25 outlets each, and 20 distributor switches "B" with 10 inlets each. Of the 25 outlets on each distributor switch "A", 15 go singly to different distributor switches "B", and the other 10 go in five pairs to the remaining five distributor switches "B".

At each distributor switch "B", six inlets come singly from six distributor switches "A" and the other four inlets come in two pairs from the remaining two distributor switches "A". Fig. 5 illustrates this system of allocating links singly and in pairs.

This "single and pair" system of link allocation provides an accessibility between the subscribers and the common equipment which approaches closely to the "full availability" condition for most calling rates met in practice (as illustrated in the switch computation curves Figs. 24-28).

The system also gives a more efficient "erlang per cross-point" utilisation than allocation wholly in singles or wholly in pairs.

LINKS IN ROUTER

The 16 "A" switches in a router, each with 25 outlets, provide access from 160 originating trunks to 400 links (Fig. 3). This rate of expansion is greater than necessary and so the outlets of each "A" switch are paired with the outlets of an adjacent switch, in effect giving the equivalent of a switch with 20 inlets and 25 outlets. Access is thus provided from the 160 originating trunks to 200 links, which are connected to the 200 inlets of the "B" switches (20 "B" switches with 10 inlets each) according to the same "single and pair" method used in the distributor.

MOUNTING AND CABLING OF "A" AND "B" SWITCHES

The link trunking scheme illustrated in Fig. 2 (*b*) allows each crossbar switch to be constructed as a unit with the outlet crosspoints of all ten bridges internally multipled together and wired out to a terminal block. The links between the "A" switches and the "B" switches are provided by external connections between the terminal

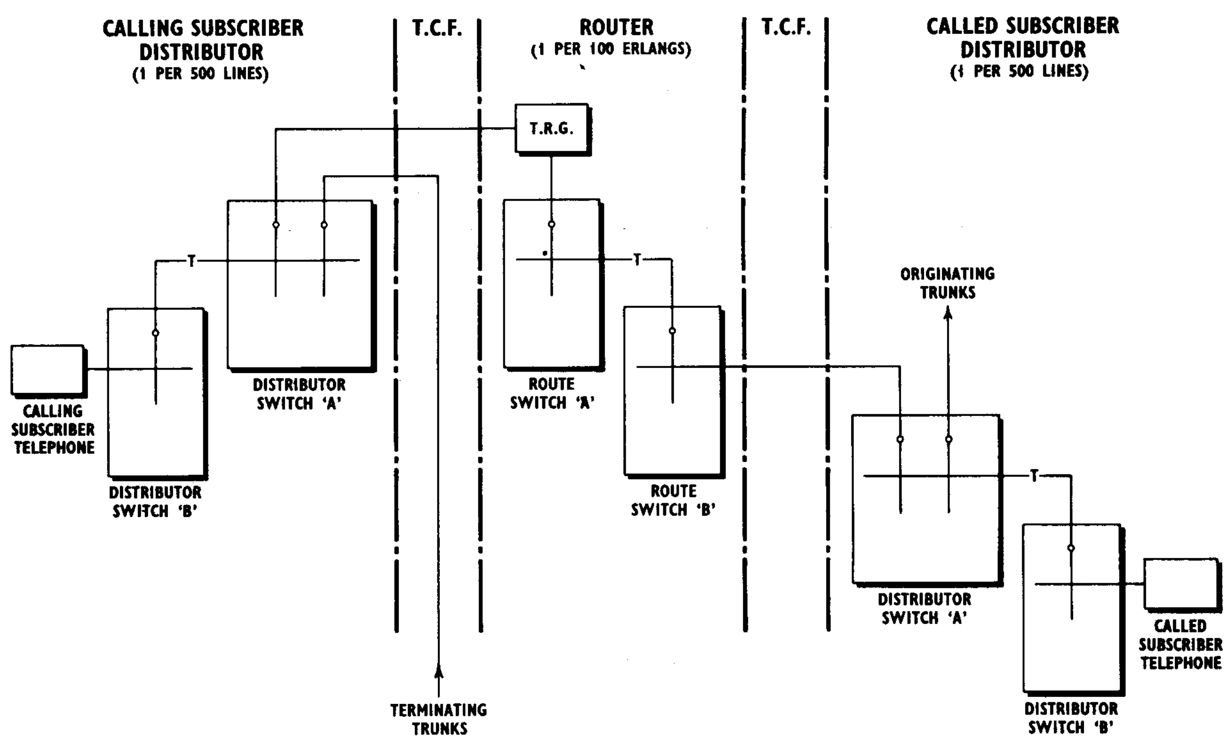


Figure 4. TRUNKING SCHEME FOR A 10 000-LINE EXCHANGE

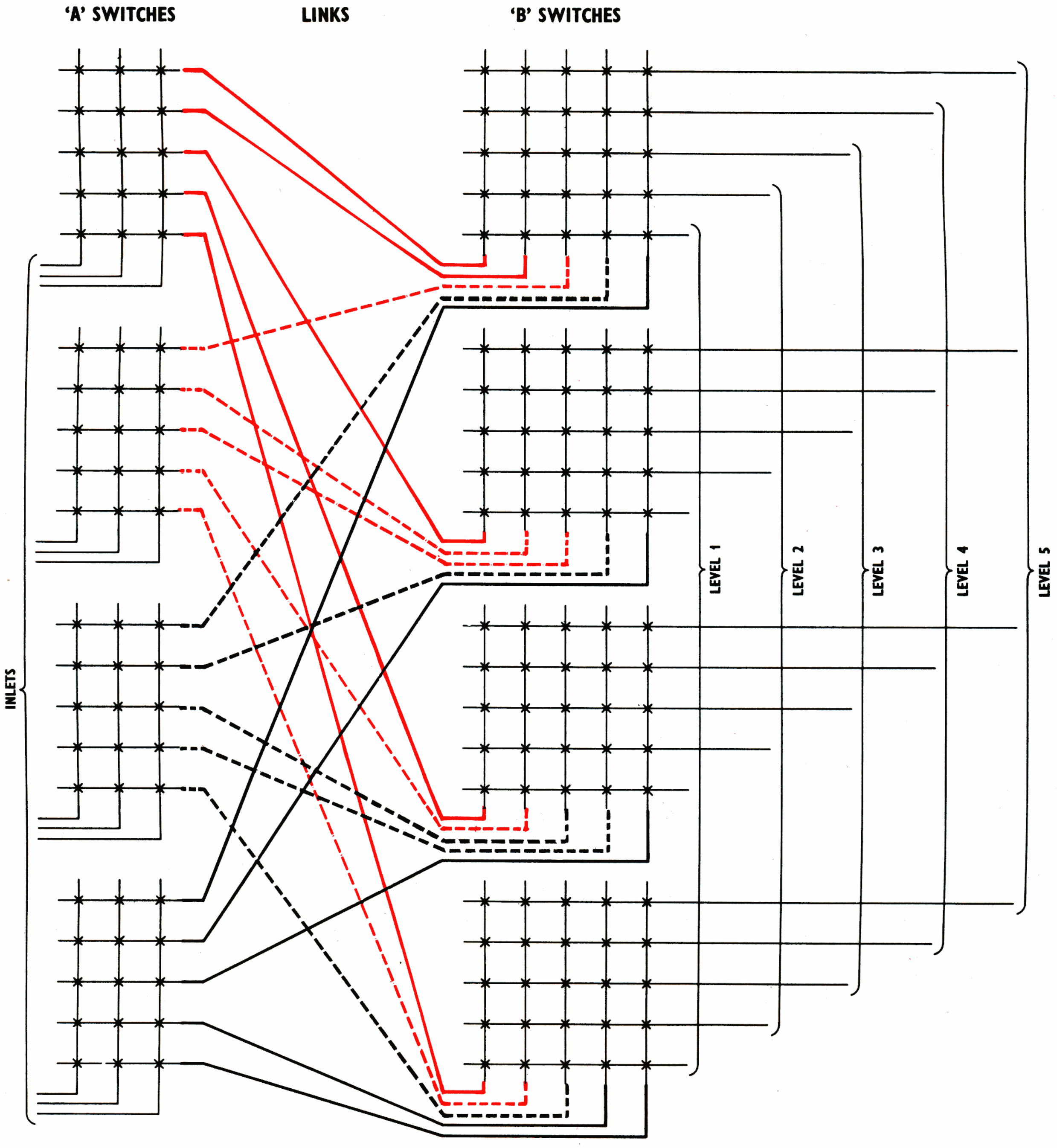


Figure 5. SWITCH "A" TO SWITCH "B" LINK ALLOCATION—IN SINGLES AND PAIRS

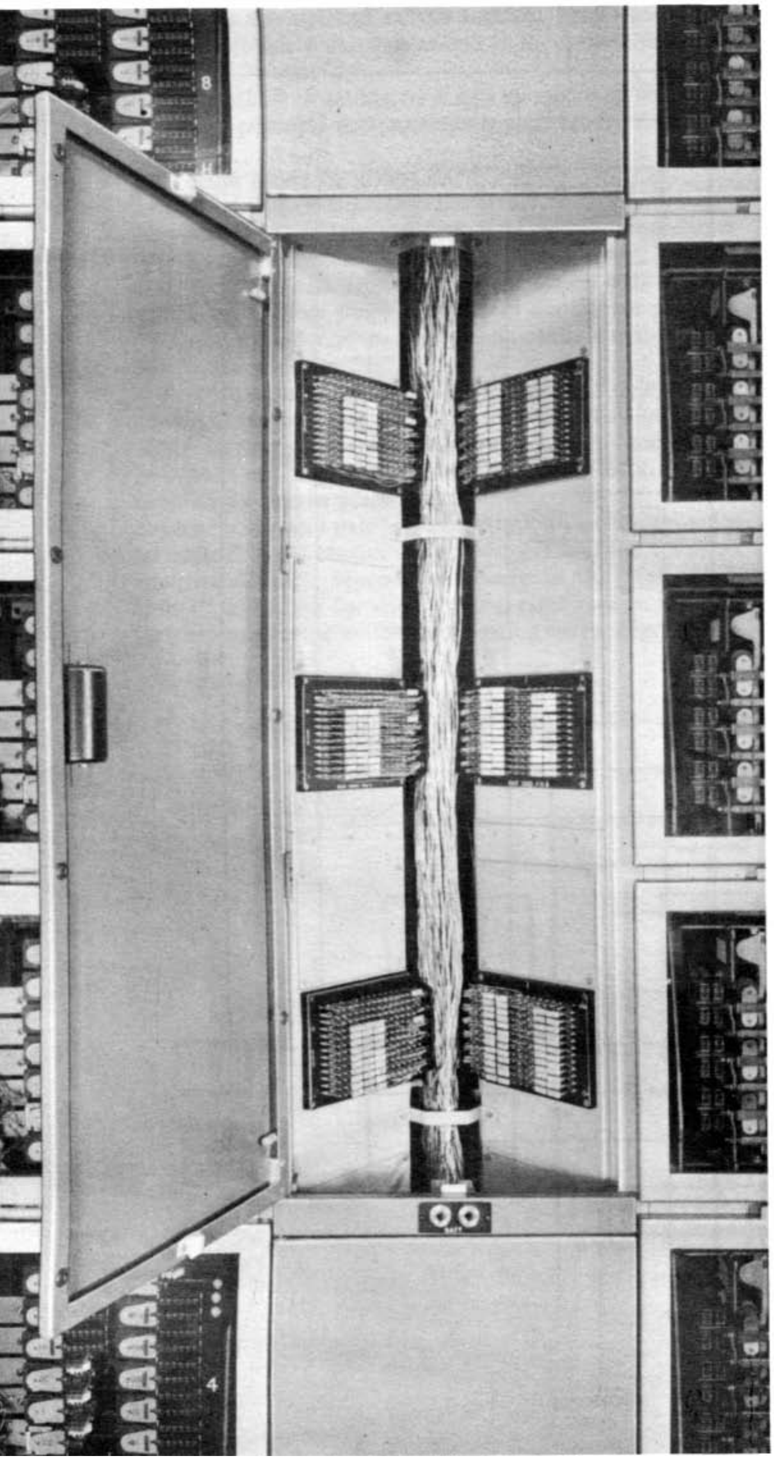


Figure 6 (*a*). VIEW OF INTER-RACK SPACE WITH DOOR OPEN

blocks of these switches, as follows:

The 16 "A" switches of a router are mounted back to back on the two faces of a rack (eight per face). Similarly, the 20 "B" switches are mounted back to back on the two faces of the next rack (ten per face).

The space between these two racks is called the "inter-rack space". It provides a place for joining, with one straight vertical cable, all the outlets of the 16 "A" switches on the first rack to the inlets of the 20 "B" switches on the second rack. This is illustrated diagrammatically in Fig. 6. Fig. 6 (*a*) is a view of an inter-rack space with the door to one section open to show the cabling and terminal blocks.

Similar arrangements are made for the links between distributor switches "A" and "B".

This description of mounting and cabling arrangements is given here to draw attention to the co-ordination between trunking and physical arrangement, by combining the most economical use of switches (by trunking efficiency) with the most economical arrangement of mounting, wiring and cabling.

THE DISTRIBUTOR START-SHIFT

When a subscriber makes a call, the selection of one originating trunk out of five within a distributor switch "A" is governed by a relay chain circuit within that switch. The eight distributor switches "A" are themselves connected in an endless-chain circuit, from an access point of view, with a movable starting point. An external relay chain, called the "start-shift", advances the starting point by five trunks after each call or after "time-out" on an unsuccessful attempt to call, thereby ensuring that a different "A" switch is allocated on successive calls.

The functions of the start-shift are to distribute the traffic evenly and to ensure that a caller searches for a different path on each successive call.

THE SELF-STEERING PRINCIPLE

Fig. 7 shows in outline the basic circuit arrangements as applied to a trunking stage comprising "A" and "B" ranks of switches. For simplicity a separate select magnet is shown for each outlet.

Assume that a call is to be set up from the relay group associated with inlet "X" in the "A" rank, to outlet "Y" in the "B" rank.

An earth is applied to terminal "M" of outlet "Y", by means to be described later. This operates 1 SM in the "B" switch, thereby operating relay M. Relay M connects earth to all free inlets, that is, to those inlets whose bridge magnets (BM) are not operated.

From all free inlets, earth passes via the links to one outlet in each "A" switch and there operates one select magnet. Assuming that inlet 2 in the "B" switch is free, then, in the "A" switch, 1 SM will operate and in turn will operate relay M. Relay M connects earth to the "M" wire of all free inlets of the "A" switch, including "X".

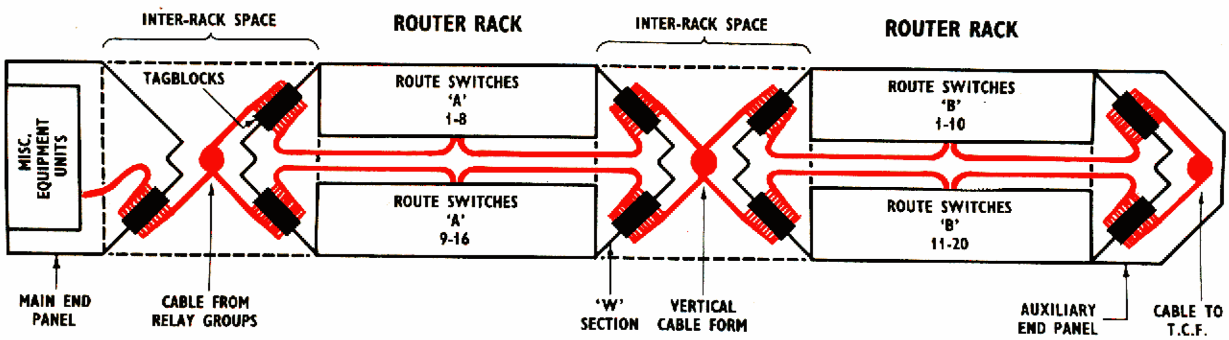


Figure 6. PLAN OF TYPICAL RACK SUITE, ILLUSTRATING INTER-RACK SPACES, END PANELS, ETC. (NOT TO SCALE)

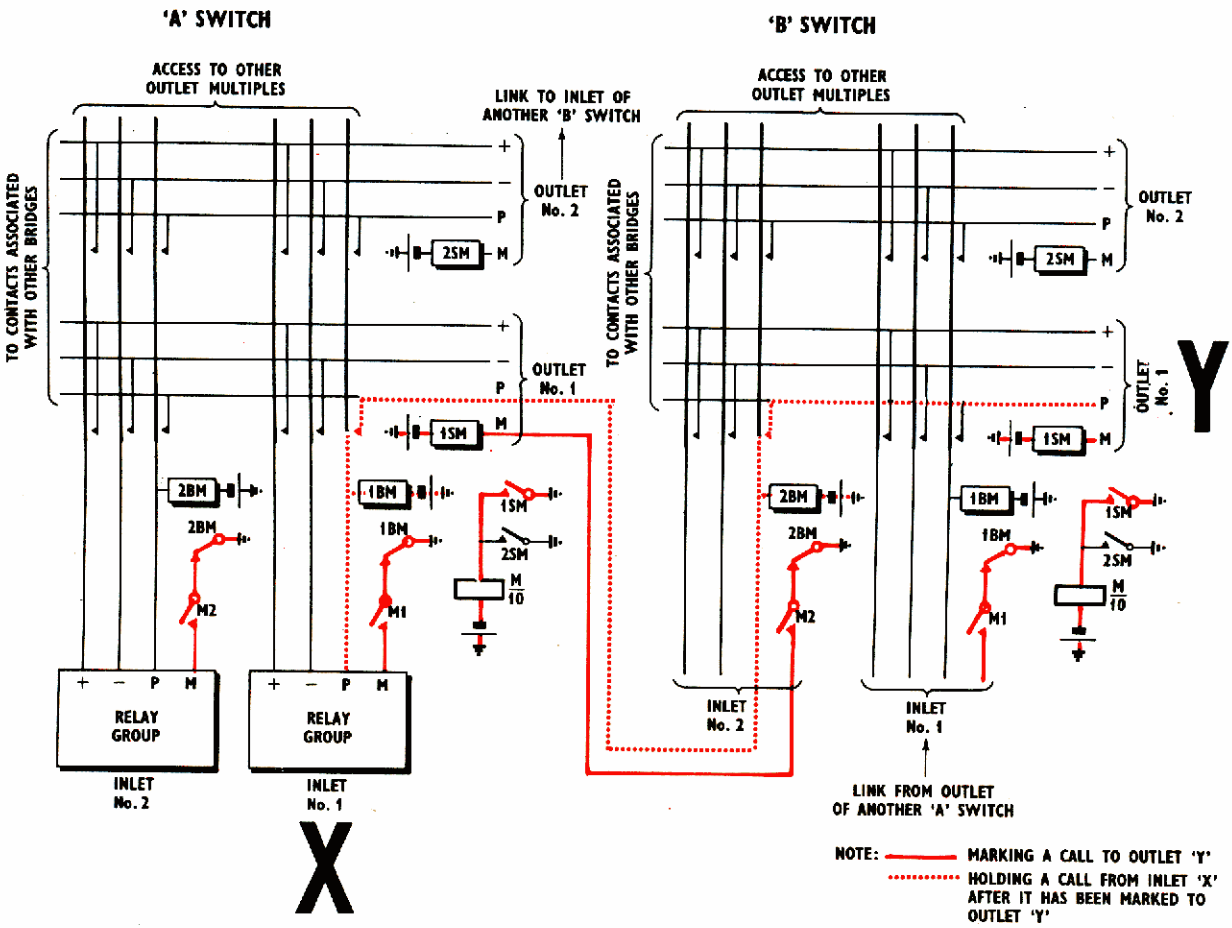


Figure 7. SELF-STEERING PRINCIPLE

The relay group for inlet "X" then applies earth to the "P" wire of inlet "X". This operates the bridge magnet (1 BM) in the "A" switch and closes the crosspoint to connect inlet "X" to outlet No. 1 of the "A" switch. (This crosspoint had already been prepared by the operation of 1 SM.)

The earth on the "P" wire is thus extended to operate 2 BM in the "B" switch and closes the crosspoint in the "B" switch to connect the link to outlet "Y".

The marking signal at outlet "Y" is now removed (by means not shown), so that the select magnets and M relays release successively in the "B" and "A" switches.

The above process, initiated by the placing of an earth on the "M" wire of one outlet, can continue through as many ranks of switches as necessary to connect one point with another. In Fig. 3 it enables a call to be set up from the inlet of route switch "A" to a subscriber's line on distributor switch "B". All available paths are tested but the call is set up over only one path because in each crossbar switch only one select magnet can be operated at a time, and thus the operation of the bridge magnet closes only one crosspoint. The one-at-a-time operation of select magnets is described later.

In the simplified system so far described it would obviously be necessary to ensure that only one call would be set up at a time, because otherwise different markings could conflict with one another. In practice, however, it is only necessary to provide for one-call-at-a-time operation along the route which a call must take, and other calls can be set up at the same time along other, non-conflicting, routes. This will be explained later. This restriction of marking to the route which the call must take, greatly reduces the number of unwanted select-magnet operations.

The manner in which one-at-a-time operation is ensured for a particular crossbar switch is illustrated in Fig. 8. This figure shows two of the nine select magnets, from the arrangement of Fig. 7, arranged so that although all the magnets can operate when earth is applied to their "M" wires, only one magnet can hold. Also, once a magnet operates and holds, the operation of MK prevents the operation of any other magnets.

TRANSMISSION RELAY GROUP, REGISTER CONNECTOR, AND REGISTER

TRANSMISSION RELAY GROUPS (T.R.G.)

Local t.r.g.

This is a group of relays in an originating trunk as shown in Fig. 4. It provides battery feed to the calling and called subscribers and controls ringing and metering. When used on an outgoing junction call it gives a loop forward, and accepts reverse-battery supervision. Provision is made for switching the "feeding bridge" out of circuit when required in order to provide a clean metallic loop through the exchange (for example, on a call to a test desk, or to a party-line ring-back circuit). The originating trunks from the distributor switches "A" are connected to the t.r.g.s through a grading on the trunk connecting frame (t.c.f.).

Incoming t.r.g.

This is similar to a local t.r.g. Each incoming junction is terminated on its own incoming t.r.g.

REGISTER CONNECTORS

Local Register Connector

Each local t.r.g. contains two connecting relays which provide access to two registers. A t.r.g. is not seized by a calling line unless it has access to a free register. When searching for a free t.r.g., the calling line always takes one that has access to a free first-choice register in preference to one that has access only to a free second-choice register. Normally, a first-choice register serves 10 t.r.g s and a second-choice register serves from 10 to 80 t.r.g.s (typically 40) according to the ratio of register holding time to t.r.g. holding time.

Originating trunks are connected to t.r.g.s, via jumpers at the t.c.f., in such a way that a calling line has access to a different first-choice register on each originating trunk—of which there are a minimum of 40 (and 80 if additional distributor switches "A" are used in an exchange with a high calling rate).

Incoming Register Connector

It is not always possible to arrange that the distant exchange will select an outgoing junction which has access to a free register; nor is it always desirable to do so, because this restriction of choice would cause artificial busying of junctions. The register connectors serving t.r.g's on which incoming junctions are terminated are therefore provided with access to ten incoming registers.

REGISTER

The register contains a group of relays which counts the impulses dialled by the caller, and further relay groups on which the digits are stored. There is a group of registers for each router, usually 16 first-choice (one per 10 t.r.g.s) and, say, four second-choice. But these quantities can be varied according to traffic requirements. Incoming registers are separately grouped.

OTHER FUNCTIONAL UNITS

In addition there are the following functional units which are described later in the "Outline of Operation" (Part 2).

Router control; coder; sender; 500-line marker; junction marker; route relays; second-stage route switches.

Other functional units for providing optional facilities are described in Part 6.

PART 2 OUTLINE OF OPERATION

OUTLINE OF OPERATION

LOCAL CALL

Calling subscriber connected to register

When a subscriber lifts his handset, relay LR in his line circuit operates and "marks" the outlet in the distributor switch "B" to which he is connected. This switch in turn repeats the marking over all free links to the "A" switches in this 500-line distributor, resulting in the seizure of a free t.r.g. and register. Dial tone is returned to the subscriber from the register.

As explained on page 24 and illustrated in Fig. 8, within any one switch only one call can be set up at a time. If two calls attempt to use the same switch simultaneously, one is delayed while the other is set up, but the delay is usually only a fraction of a second. If two calls are waiting, a waiting terminating call has preference over a waiting originating call.

CLASSIFICATION OF CALLER

When a register is seized, the classification of the calling subscriber is signalled to the register and stored in it. This information is compared later with the digits dialled, in order to determine whether special action is required.

The method by which the "originating call" classification of the subscriber is signalled to the register is shown in Fig. 9. When the crosspoints have been operated to connect the calling subscriber's line to the register, a circuit is established from the caller's classification tag to the register, via the negative speech wire, where a classification relay is operated according to the potential on the subscriber's classification tag. As soon as the classification relay in the register operates, it applies earth to the positive speech wire, thereby operating the caller's K relay. This relay locks to the "P" wire and extends the speech wires to the caller's line. Four different potentials are provided and a fifth signal is obtained by leaving the classification terminal disconnected.

There are also four possible classifications for terminating calls, which are obtained when the LR relay is not operated. The uses to which these classification signals are put are described later.

CLASSIFICATION OF INCOMING JUNCTIONS

When an incoming junction call arrives, the incoming t.r.g. seizes a register. "Incoming junction" classification signals are provided in case special facilities, such as trunk offering, are required for particular junctions.

DIALLING

The register counts and stores each digit as the subscriber dials. When it has received sufficient digits it sets up the call as detailed below.

SETTING UP A CALL TO A LOCAL SUBSCRIBER

ROUTER CONTROL

When the register has received all the digits, it applies to a router control for permission to "mark" a call. For simplicity it will be assumed that there is only one router control per router and that therefore only one register per router can mark at a time.

500-LINE MARKER

When the register has received permission to mark from its router control, it applies to the "500-line marker" in the required distributor for permission to "mark" a call there.

The marker is a relay group which will accept only one call at a time. It has five "hundreds" relays (each with ten contacts) and 50 "tens" relays. The register operates the appropriate "hundreds" relay, and then a "tens" relay to give access to ten subscribers' line circuits. The router

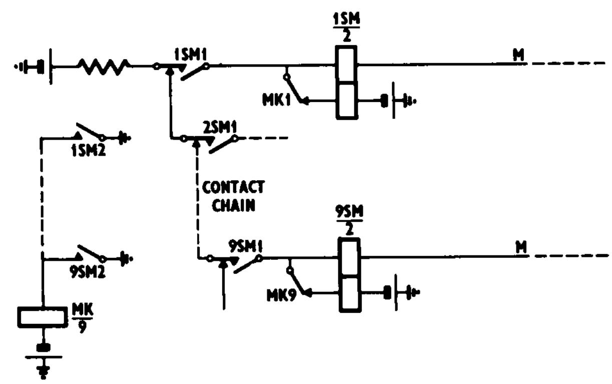


Figure 8. ONE-AT-A-TIME SELECT MAGNET OPERATION, BASIC CIRCUIT

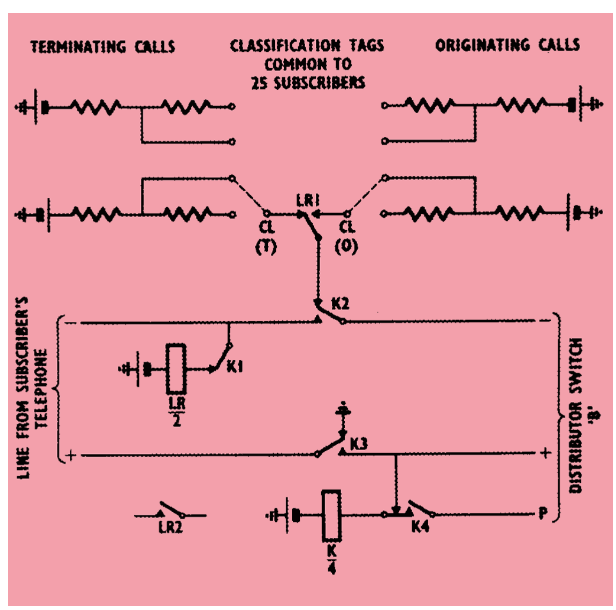


Figure 9. SUBSCRIBER CLASSIFICATION PRINCIPLE

control finally applies a marking signal to the required line within the selected "tens" group.

The marker has thus a simple relay "tree" circuit which enables a register to find and mark a particular subscriber's line in a 500-line group.

MARKING A SUBSCRIBER

When the register has obtained access to the called subscriber's marking wire via the marker, there are four possible conditions which it may encounter, namely:—

Marking wire connected to negative battery—*indicating subscriber free*.

Marking wire connected to earth—*indicating subscriber busy*.

Marking wire connected to positive battery—*indicating "dead" number*.

Marking wire disconnected—*indicating fault in marking system*.

Considering these four conditions in reverse order:—

Marking Wire Disconnected

The register records details of the disconnection fault on a meter or fault recorder, and then makes a second attempt via an alternative group of marking wires. If at the second attempt the fault condition is again encountered, busy or N.U. tone is returned to the caller, and the register releases.

Marking Wire Connected to Positive Battery

The register causes N.U. tone to be returned to the caller, and then releases.

Marking Wire Connected to Earth

The register causes busy tone to be returned to the caller, then releases.

Marking Wire Connected to Negative Battery

The earth applied by the router control to the subscriber's marking wire via the register and marker, marks the distributor switch "B" outlet serving the called subscriber. The marking is now passed backwards, as explained on page 22, from the "B" switch via all free links to the "A" switches in this 500-line distributor, and then via the route switches "B" to the route switch "A" serving the t.r.g. on which the call is waiting to be set up.

ROUTE RELAYS

It will be seen from Fig. 3, page 19, that the 40 terminating trunks of the distributor are accessible via a grading at the t.c.f. from route switch "B" outlets in all the routers. It is necessary for the marking to go back to the router containing the t.r.g. on which the call is waiting to be set up, and it is desirable to prevent the marking from going back to any other routers. Continuing on the assumption that only one call at a time can be marked in a router, this restriction of marking to the required router would be carried out by a "route relay" which has a contact in the "M" wire of each of the 20 terminating trunks leading from the router of origin to the distributor of destination. (In practice there are four route relays, each controlling five terminating trunks and therefore having five contacts per relay.)

The route relays are operated from the marker. The marker chooses the route relays which control the group of terminating trunks coming from the router in which the call is waiting to be set up. The choice of route relay depends upon the path of entry by which the marker was seized; that is, there is a separate entry relay in the marker for each router, as shown on Fig. 10 and explained on page 29.

MARKING ROUTE SWITCH "A"

The marking coming back from the route switches "B" is also restricted to entering only that route switch "A" serving the t.r.g. on which the call is waiting to be set up.

The arrival of the marking in route switch "A" causes a signal to be applied to the router control to indicate that a free path has been selected from the t.r.g. to the called subscriber.

The router control now applies earth via the register and the t.r.g. to operate the bridge magnet in route switch "A". This extends the call to one route switch "B" (determined by which select magnet in route switch "A" was operated), and so on through distributor switches "A" and "B" to the called subscriber's line.

CONTINUITY CHECK AND CALLED SUBSCRIBER'S CLASSIFICATION

When the call has been set up from the t.r.g. to the called subscriber's line circuit, the "terminating call" classification is received by the router control in the same manner as the "originating call" classification was received by the register, as described on page 27. There are four "terminating call" classification signals, comprising positive or negative potentials applied through high or low resistances to the negative speech wire. The receipt of the classification signal and its subsequent removal when relay K operates, proves the continuity of the circuit (Fig. 9).

When the router control receives this classification signal on the negative wire, it applies earth to the positive wire. This operates the K relay which locks to the "P" wire and removes the classification signal from the negative wire. The K relay also extends the negative and positive speech wires to the called subscriber's line. The router control now tests for the absence of the classification signal to prove the operation of relay K.

The router control also tests for the absence of a loop on the called subscriber's line. The reason for this test is to safeguard against two possibilities:

(*a*) If the line serves a p.a.b.x., it could have been seized from the p.a.b.x. while the call was in process of being set up, and connection to an unwanted extension might

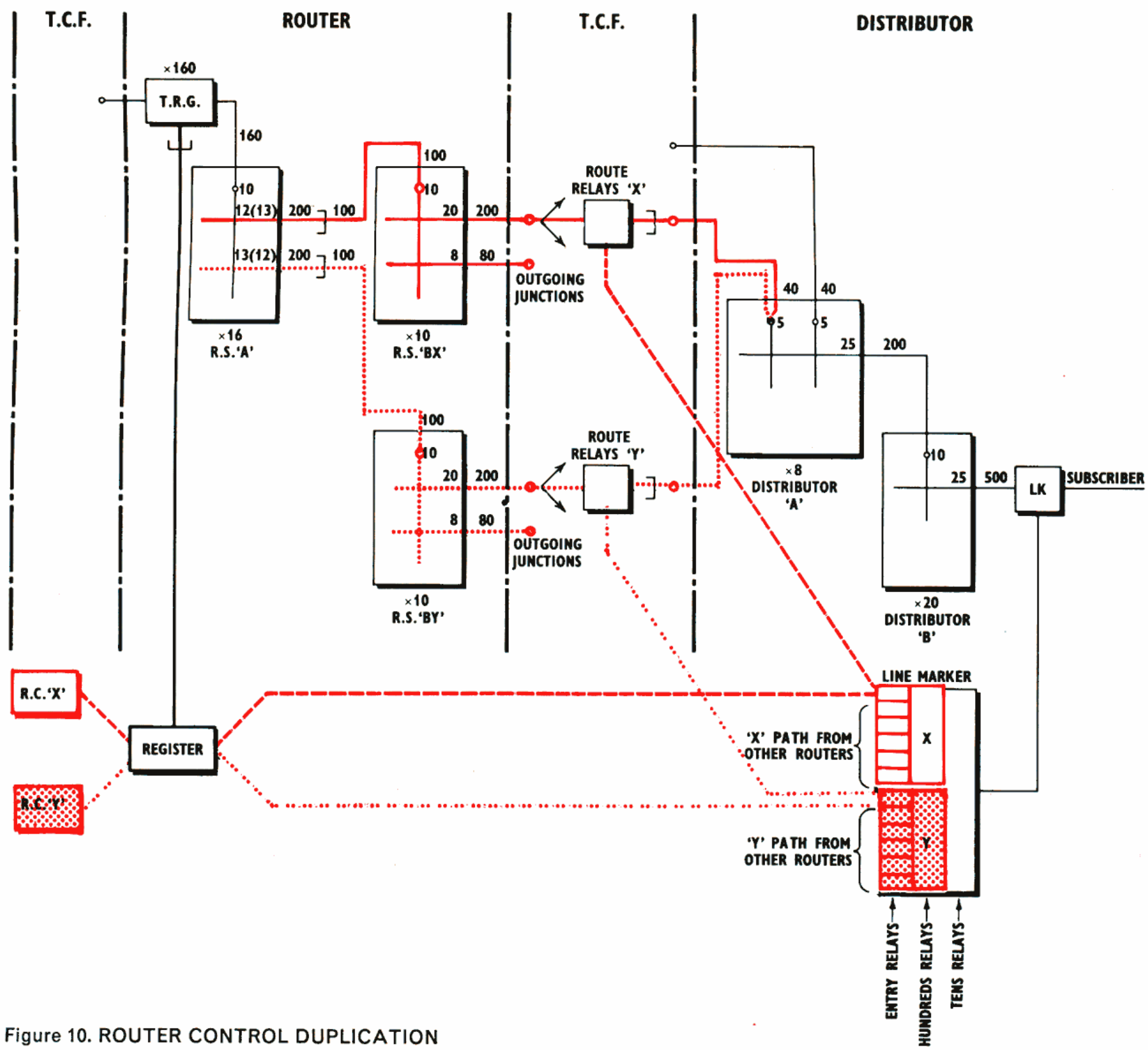


Figure 10. ROUTER CONTROL DUPLICATION

possibly be established and metered.

(*b*) If the line is used on a shared-service or party line system in which an earthing button has to be depressed in order to call the exchange, there is a possibility that a "handset-off" or short-circuit line fault could exist without busying the line circuit at the exchange. The caller might thus be connected to a faulty line, and metered for the call.

However, if the absence-of-loop test detects the existence of a loop on the called line the router control causes the t.r.g. to return busy tone to the caller, and the router control and register are released.

IMMEDIATE RING

On a successful call, before the register releases it causes the t.r.g. to apply a pulse of continuous ringing to the called line prior to the connection of interrupted ringing. This is to ensure busying a p.m.b.x. or p.a.b.x. line at its distant end as quickly as possible after seizure, to prevent seizure in the other direction.

DUPLICATION OF ROUTER CONTROLS

Under the description of router control earlier, it was assumed for simplicity that there was only one router control for each router. Actually two, designated "X" and

"Y" respectively, are provided in order to reduce the probability that a call would have to wait for their use. The holding time of a router control is about one second.

Each register in a router has access to both router controls and seizes either at random if both are free. The trunking is shown in Fig. 10.

The route switches "B" are divided into two groups of ten. In each group of "BX" or "BY" switches, the "M" wires of the outlets pass through contacts of route relays which operate on calls handled by router control "X" or "Y" respectively.

The outlets of each route switch "A" are also divided into two groups (12 and 13 in odd switches, 13 and 12 in even switches). These two groups of outlets lead to route switches "BX" and "BY" respectively.

When a call is "marked", the router control signals,via the register, to the route switch "A" serving the t.r.g. on which the call is waiting to be set up. This signal allows the route switch "A" to admit marking at its "X" outlets if the signal came from router control "X", or at its "Y" outlets if the signal came from router control "Y". It is thus possible to set up two calls simultaneously in the same router without conflicting marking, providing that they go to different 500-line distributors and that they do not originate in the same route switch "A". If they do go to the same 500-line distributor, or originate in the same route switch "A", one of the calls is delayed while the other is set up. This delay would not normally exceed one second and would usually be much less.

SECOND-ATTEMPT MARKING

Failure to set up a call can be due to any one of the following causes:

Subscriber busy or in "P.G." condition.
Dead number.
Marking failure.
All trunks busy.
Continuity failure.

If the call is not set up at the first attempt, due to one of the last three of the above causes, the router control instructs the register to make a second attempt; whereupon the register releases that router control and seizes the other one.

If the first attempt had used router control "X", router control "Y" is used on the second attempt. Entry to the 500-line marker is now by the "Y" path instead of the "X" path, and the "Y" group of "hundreds" relays is selected for line marking.

An attempt is now made to set up the call through a "Y" outlet on route switch "A", a route switch "BY", a "Y" inlet on distributor switch "A" and (very probably) a different link to distributor switch "B".

Failure to set up a call at the first and/or second attempt can be recorded on the traffic analysis meter (described on page 42) or on a fault recorder (Teleprinter or Teletype).

CALLED SUBSCRIBER ANSWERS

When the called subscriber answers, ringing is tripped and the conversation proceeds. The battery feed to the calling subscriber is reversed while the called subscriber is in the "off-hook" condition.

On a local call the caller's meter is operated once when the called subscriber answers. The meter operating circuit in the t.r.g. is arranged to prevent false operation of the calling subscriber's meter due to the called subscriber causing his switch-hook contacts to open and shut intermittently when lifting the handset from the rest.

An alternative circuit for the t.r.g. can be provided for timing of local calls, with repeated meter operation. This is described on page 67.

CLEARING

The call is released when the caller replaces his handset. If the called subscriber has not already cleared, his line is "parked" at his line circuit in the "P.G." condition.

If the called subscriber clears but the calling subscriber fails to do so, the call is forcibly released after a time-out period of 1 to 2 minutes, and the calling line is parked at its line circuit in the "P.G." condition.

Other systems of clearing can be provided optionally by modifications to the t.r.g.

OUTGOING JUNCTION CALL

DETERMINATION OF ROUTE

The digit store in the register is wired to tags on which straps can be placed to enable the register to discriminate, after receiving sufficient digits, between a local call, an outgoing junction, and a dead level.

When the register recognises that the call is for an outgoing junction, it applies to its router control for permission to mark, and also informs the router control that the call is for an outgoing junction. The router control now seizes a coder, of which there are usually two per exchange, one accessible from all the "X" router controls, and one from all the "Y" router controls.

Coder

The router control connects the digit store and the caller's classification store from the register to the coder.

A group of digit relays is provided in the coder for each digit that has to be examined. The first two groups provide for 100 2-digit codes, of which (typically) any ten would be connected to the third group to form 100 3-digit codes, and so on.

Any required number of codes up to 100 2-digit, 1 000 3-digit, etc. can be provided by equipping the appropriate relays, but it is unnecessary to equip relays for codes which will not be used.

The contacts of the digit relays are connected to a strapping field from which the following information is returned to the router control:

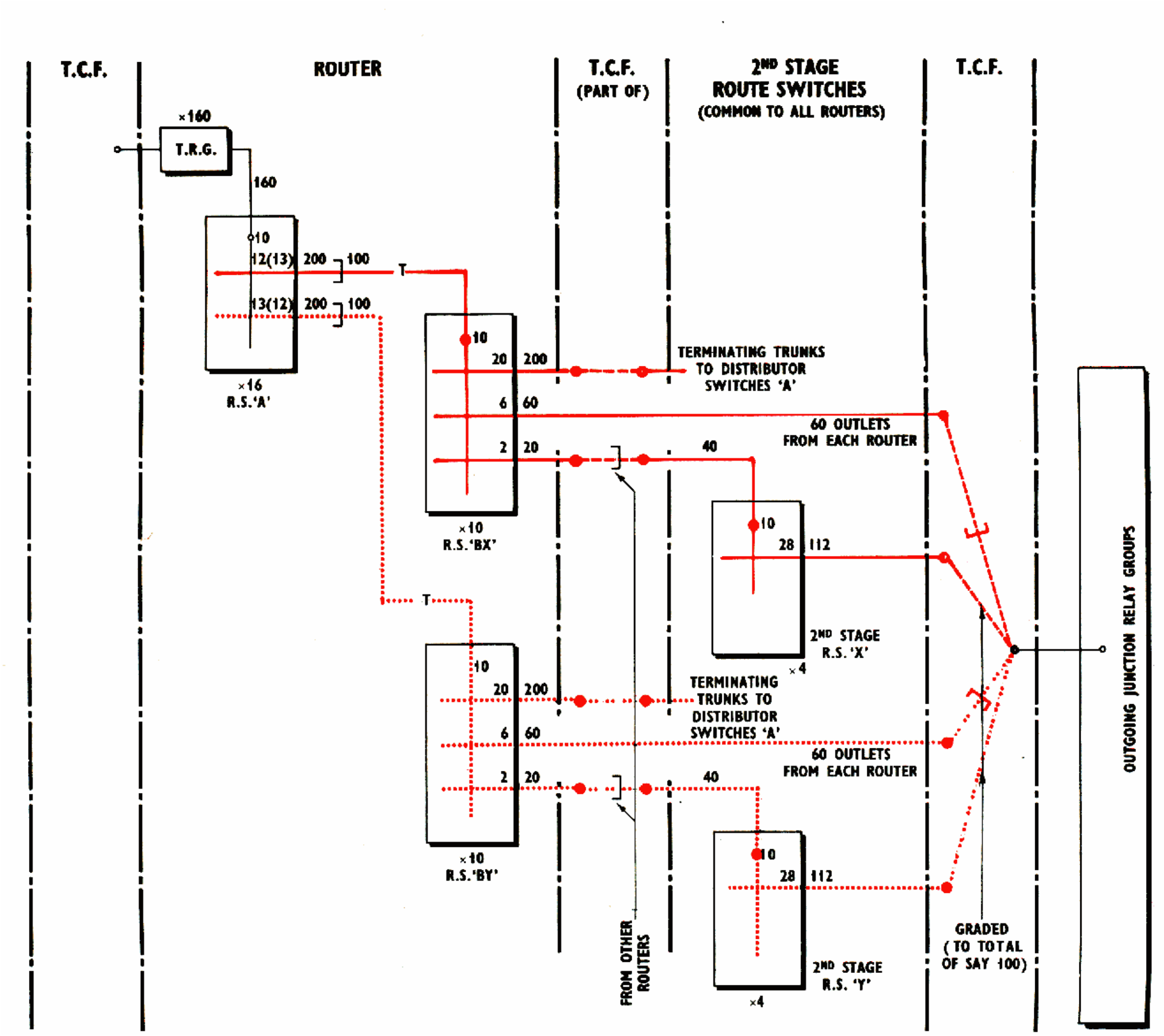


Figure 11. TYPICAL ARRANGEMENT WITH SECOND STAGE ROUTE SWITCHES (FOR INCREASING JUNCTION ACCESS)

(i) The required junction route.
(ii) The alternative junction route.
(iii) The tariff.
(iv) The total number of digits needed to complete the call (with an "ambiguity" signal if the call is going into an area whose exchanges have mixed numbers of digits).
(v) Special instructions if the caller has dialled a code which is barred by his classification.

In some cases, the number of digits presented to the coder may be insufficient for it to return instructions to the router control. In this case, the coder returns a "Come Again" signal via the router control to the register. The register then releases the router control, and re-seizes it after the caller has dialled another digit.

Having passed instructions to the router control, the coder releases. Its holding time is about 100 milliseconds per call.

MARKING A JUNCTION CALL

General

The router control now applies to the appropriate junction marker for permission to mark a group of junctions under its control. This procedure follows almost exactly the procedure of applying to a 500-line marker for permission to mark a subscriber's line under its control.

Mass Marking
A marking signal is placed by the junction marker on every free junction line circuit it controls in the required group of junctions. The marking is passed back from the route switch "BX" or "BY" outlets, through a route switch "A" to the router control. The router control applies earth via the register and the t.r.g. to operate the bridge magnets in route switches "A" and "B" in succession. Mass marking is used for single-way junction routes.

Individual Marking
A marking signal is placed by the junction marker on one free junction in the required group of junctions. The marking is passed back to the router control by the self-steering principle and the call is set up as described above. Individual marking is used for both-way junctions. It is usually used in association with second stage route switches to be described later.

The Order of Search of Outgoing Junctions
The "X" and "Y" Junction markers can be arranged to search into quite separate halves of each junction route (e.g. for very large junction routes) or they can both be arranged to search over the entire route using different orders of search, such as:

"X" 1, 3, 5, etc., then 2, 4, 6, etc.
"Y" 2, 4, 6, etc., then 1, 3, 5, etc.

ALTERNATIVE ROUTING
At first attempt marking; the router control tries to set up the call by the primary route, and if all outlets giving access to this route are busy, it tries to set up the call by the alternative route. If all outlets to both the primary and alternative routes are busy at the first attempt marking, the register seizes the other router control which repeats the process.

Full availability to junctions in the primary and alternative routes is given at both first and second attempt marking unless the number of junctions is so large that limited availability is more economical, in which case, access to different junctions within the same route can be provided at the second attempt marking.

SECOND STAGE ROUTER
A second stage router consists of an "X" and a "Y" junction marker and outgoing junction relays; a second stage router may, or may not, contain second-stage route switches, according to whether or not additional access to junctions is required.

In a 10 000 line exchange the 560 router outlets would normally serve 20 distributors via 20 terminating trunks each, leaving 160 outlets for access to outgoing junctions. In a smaller exchange, more outlets would be left available for outgoing junctions.

If the number of route switch "B" outlets is insufficient to serve all the outgoing junctions, second-stage route switches are provided. A second-stage route switch is physically and electrically identical with a route switch "B" and the trunking arrangement is shown in Fig. 11.

Outlets can be allocated to groups of junctions in any combinations of direct outlets and indirect outlets (via second-stage route switches). A call will always take a direct outlet in preference to an indirect one, because the marking takes a little longer to get through the second-stage route switch. There is no limit to the number of second-stage route switches and therefore access can be given to any number of outgoing junctions.

If junction groups are served by direct outlets from route switches "BX" and "BY", at least 10 outlets on "BX" and 10 on "BY" are usually allocated to each junction group, even though there may be fewer than 20 junctions in the group and some outlets have to be paralleled. This is done to ensure efficient occupancy of the links between route switches "A" and route switches "BX" and "BY". However, when second-stage route switches are used, any number of junctions from one upwards can form a group. This group, however small, will always be accessible from any route switch "A", via every route switch "BX" or "BY" which has a free link from the route switch "A" of origin and a free outlet leading to the required second-stage route switch. Figs. 2 (*a*) and 2 (*b*) illustrate this.

CONTINUITY CHECK AND JUNCTION CLASSIFICATION
The router control now has access via the register to the negative and positive speech wires on the called side of the t.r.g. and can thus check the continuity up to the junction line circuit. The continuity check is made on both negative and positive speech wires simultaneously. It also gives a junction classification signal to the router control. Where the number of classification signals required exceeds the capacity of the two speech wires, additional signals are sent to the router control via the junction marker. These classification signals are received in the router control, which then instructs the register as to what further action is required for the outgoing junction which has been seized, for example:

Type of outpulsing—10 p.p.s., 20 p.p.s., multi-frequency, or revertive pulsing systems.

Number of digits to be sent—If the junction leads to an "end" exchange, only the last three or four digits will be required. A tandem exchange would require all digits dialled by the caller.

Bridge cut-out—For some types of outgoing junction the battery-feeding bridge in the t.r.g. is cut out, to give the caller a clean metallic circuit to the outgoing junction. When this facility is used, battery feed is supplied to the caller, and the call is held from the outgoing junction relay group.

When a continuity check has been made, the router control releases.

A second marking attempt is made if the call fails due to:
—marking failure
—all trunks busy (inside exchange)
—all junctions busy
—continuity failure.
—external line fault on junction

SENDERS

When the register receives instructions from the router control as to the type of outpulsing required, it seizes a "sender". The senders are in one or more common groups accessible to all the registers in the exchange. The type of sender seized by the register depends upon the "register language" required by the distant exchange to which the call is going. There are two main types of sender, namely:

(i) Loop-disconnect 10 p.p.s. or 20 p.p.s.

This is suitable for calls to Strowger exchanges (10 p.p.s.) or to other 5005 exchanges (20 p.p.s.).

(ii) Multi-frequency. This is suitable for calls to other 5005 exchanges, or to other register-controlled exchanges where multi-frequency signalling can be accepted. (Multi-frequency inter-register signalling is described on page 72.)

For outpulsing to systems requiring different register language, appropriate senders would be supplied.

The loop-disconnect sender has a relay pulse-generator which drives a relay counting chain, and at the same time pulses out over the junction via the register and t.r.g. (but without impulse repetition in either). The counting chain in the sender is connected, via the sender access relays, to the first-digit store in the register. When the sender counting chain reaches a count which matches the first digit stored in the register, the pulse generator is stopped, then the counting chain is reset and transferred to the second-digit store. In this way, each digit is sent out in turn. The inter-digit pause is typically 600 milliseconds if the sender is sending at 10 p.p.s., and 300 milliseconds at 20 p.p.s. Other pauses can be provided optionally. Normally the sender releases and causes the register to release when it has sent the "units" digit. If there is ambiguity in the number of digits to be sent, the loop-disconnect sender releases:

(i) after sending a number of digits known to be the maximum possible for the objective exchange.

(ii) four seconds after the register has received a number of digits known to be the minimum possible for the objective exchange if, meanwhile, no further digit arrives from the caller. In this case the sender "holds" the last digit dialled by the caller and sends it at the end of the four seconds time-out period. This ensures that the called subscriber will not be rung while the sender is still in circuit.

(iii) 30/60 seconds after the last digit dialled by the caller. (This is the normal register time-out.)

The multi-frequency sender is released by an end-of-selection signal from the objective exchange (or from the last multi-frequency exchange preceding the objective exchange if the objective exchange uses loop-disconnect signalling).

NUMBERS EXCEEDING SEVEN DIGITS

The register is designed so that it can be used in 4-, 5-, 6-, or 7-digit numbering schemes, or any mixture of these. The sender will always send the number of digits stored in the register which has seized it, unless instructed to omit certain digits by the classification of the outgoing junction.

If more than seven digits are used for some calls, for example on a national dialling number such as 012-345-6789 the register will store only the first seven digits (012-345-6). The sender can be arranged to store any "overflow" digits in excess of seven dialled by the caller, so that in this example, 789 would be received on the counting chain in the register, but passed to the sender for storage. The sender would then send out 012-345-6 from the register store, followed by 789 from its own store.

NUMBER OF SENDERS IN AN EXCHANGE

The number of senders depends upon the amount of outgoing junction traffic. In a 10 000 line exchange there would be, say, 100 registers. Senders would not be required on any terminating calls (local or incoming); they would be used only on outgoing junction calls. The average holding time of a sender is always less than that of a register because it is not seized until the caller has dialled sufficient digits for the register to recognise a junction call. Thus a typical number of senders in such an exchange would perhaps be 20 to 30. These might be all of the same type, or they might be in several small groups according to the register languages of other exchanges with which interworking was required.

Reference has been made to the use of the sender for storing excess digits. If, for example, there were 20 loop-disconnect senders for interworking with local exchanges, and five multi-frequency senders for handling national dialling calls to the trunk transit exchange, the storage relays for excess digits need only be provided in the multi-frequency senders. Any future digit storage requirement could be met by modifying or adding to these, leaving the 100 registers and 20 "local" senders untouched.

Thus the ability to store excess digits in the senders obviates the necessity for providing registers equipped with excess storage capacity throughout the exchange, which would be required only on a very small proportion of the calls.

The storage of excess digits in the senders has two advantages:

(*a*) it avoids the necessity for providing registers equipped with excess storage capacity throughout the exchange which would be required only on a very small proportion of the calls.

(*b*) it avoids the destruction of the stored information during sending, which occurs if a "re-circulating" storage system is used in the register.

OUTGOING JUNCTION CALL. TRUNKING SCHEME

In Fig. 12 the trunking scheme has been completed to show the connections between registers, router controls, coders, junction markers, route relays and senders.

A pair of junction markers ("X" and "Y") can serve a number of routes. If the total outgoing junction traffic exceeds about 100e, the junction routes are divided into a number of 100e groups, each with a separate pair of junction markers. The conversation traffic which a pair of markers can handle will be less than 100e if the calls are many but of short duration, and more than 100e if the calls are few but of long duration.

BOTHWAY JUNCTIONS

All junctions are suitable for single or bothway working. The most economical arrangement is to use single-way junctions for the early choices and bothway junctions for late choices.

INCOMING JUNCTION CALLS

GENERAL

Each incoming junction is terminated on an incoming t.r.g. which has access to up to ten incoming registers, or "Code Receivers".

The incoming registers can be of the loop-disconnect type as used for local calls, or they can be multi-frequency type, or they can be arranged to use any other register language to suit the distant exchange. The multi-frequency type incoming register is sometimes called a "Code Receiver".

LOOP-DISCONNECT INCOMING REGISTERS

If loop-disconnect registers are used, they can serve junctions incoming from both Strowger and 5005 type exchanges. The t.r.g. serving a junction incoming from a Strowger exchange must seize a register during the inter-digit pause.

Subscribers' and operators' dialling habits have been observed in Strowger exchanges using group selectors with 20 outlets per level and dials which provide a minimum inter-digit pause equivalent to two impulses. These observations show that on all but 3% of calls dialled by subscribers and 13% of calls dialled by operators, the inter-digit pause is at least 600 ms. Allowing 120 ms. for the release of the CD relay in the Strowger group selector and 330 ms. for hunting over 10 steps, this leaves 150 ms. for associating the 5005 register with the incoming junction. This is adequate. There remain to be considered the 3% of subscriber calls and the 13% of operator calls.

The proportion of calls on which a Strowger selector hunts over 10 steps is small. It varies with the size and type of grading. In most gradings 97% of calls are carried by the first 14 outlets (that is, the first seven steps on a 20 outlet grading). These calls would have adequate time to find a register if the caller gave the minimum possible inter-digit pause of 450 ms.

Thus the probability that the next digit will arrive before a register has been seized may be expressed as $0{\cdot}03 \times 0{\cdot}03$ for a subscriber or $0{\cdot}13 \times 0{\cdot}03$ for an operator. To cater for this probability, the circuit is so arranged that in the event of the next digit arriving before a register has been seized, which would cause mutilation of the digits, it will abandon the attempt to seize a register and will return busy tone to the caller. In other words, on a call from Strowger to 5005 there is an additional probability of loss of 0·001 for subscribers or 0·004 for operators to be added to the usually accepted grade of service of 0·002 at each switching stage. In the case of incoming junctions from Strowger exchanges having group selectors with 10 outlets per level and dials which provide a minimum inter-digit pause equivalent to one impulse, the above probabilities of loss would be greater.

In this case an alternative type of incoming t.r.g. can be provided, in which the first digit to arrive over the junction is stored on a "counting switch" (resembling a miniature uniselector) and transferred to the incoming register later.

MULTI-FREQUENCY INTER-REGISTER SIGNALLING

Multi-frequency registers or "code receivers" are more complicated and more costly than loop-disconnect registers but the number required is very much less. There are two reasons for this:

(i) The holding time of a m.f. register is only about 15% of the holding time of a loop-disconnect register.

(ii) The m.f. sender will wait for a "proceed to send" signal from the distant m.f. register before sending and it is therefore permissible to allow for a little delay in obtaining this register on a small proportion of calls.

Thus, for a router serving 160 incoming junctions, all of which use m.f. signalling, only two incoming m.f. registers would be needed. It would be possible to dispense with this type of register altogether by putting the multi-frequency digit receiving and storing function into the router control, which could be seized by an incoming junction call immediately on arrival. However, the grouping of the m.f. digit equipment as a separate unit, wired and mounted as a register, offers a more flexible arrangement because incoming junctions from many different types of distant exchange can all be terminated in the same router, each group being served by registers of appropriate type.

LIMITATIONS OF LOOP-DISCONNECT PULSING

There is no electrical limit to the number of 5005 exchanges through which a call can be set up by loop-disconnect pulsing. The digits are received, stored and retransmitted

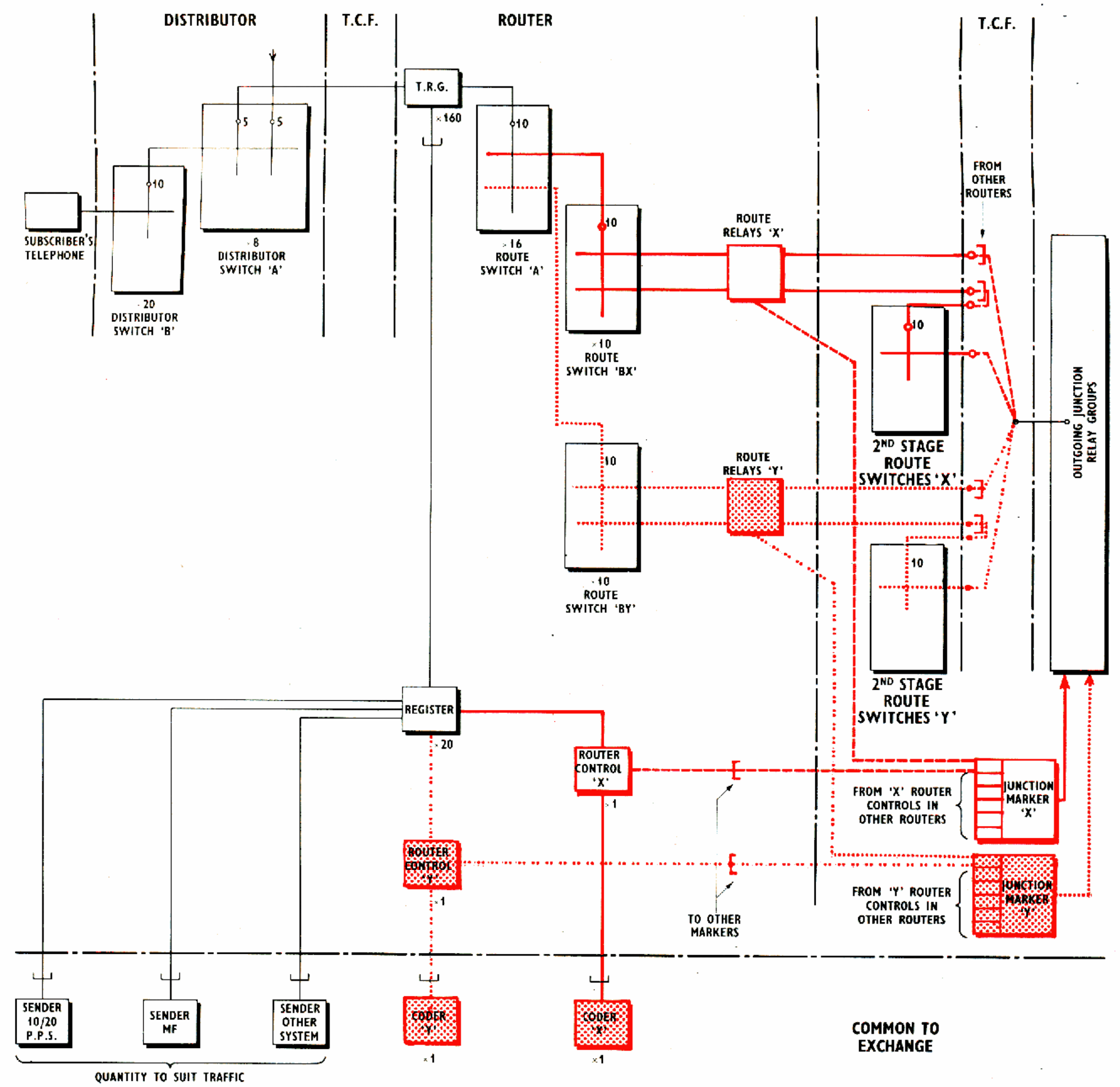


Figure 12. OUTGOING JUNCTION TRUNKING SCHEME

at each transit exchange.

The subscriber dials at 10 p.p.s. and the sender sends at 20 p.p.s., so there is a tendency for the sender to catch up with the dialled pulses. Thus on a call which goes direct from originating to objective exchange, the post-dialling delay introduced by a 20 p.p.s. sender would be only a few hundred milliseconds more than if multi-frequency senders had been used.

If the call had to pass through one transit exchange, the increase in post-dialling delay due to 20 p.p.s. sending would be somewhat greater—for an average number, say in the order of 2 seconds more than for m.f. sending.

For calls which pass through a number of transit exchanges, the difference is much greater.

In considering the economics of 20 p.p.s. and multi-frequency senders, it is necessary to estimate the proportion of traffic which passes through more than one transit exchange in order to assess the value of the time saved by using multi-frequency senders.

EARLY OR LATE MARKING OF OUTGOING JUNCTION CALLS

For outgoing junctions on which loop-disconnect pulsing is used, the register is arranged (by suitable straps) to seize the router control as soon as it has stored sufficient digits to enable the junction route to be determined. This enables the setting up of the call to the objective exchange to be started at the earliest possible moment, so that the sending will have a chance of catching up with the dialling while the latter is still in progress.

For outgoing junctions on which multi-frequency inter-register signalling is used, the register is arranged (by suitable straps) to delay seizing the router control until the caller has dialled all but the last one or two digits. This ensures that when an outgoing junction is seized there will be sufficient digits stored in the register at the originating exchange to ensure that the multi-frequency registers at the transit or objective exchanges will not be kept waiting while the subscriber dials the last few digits. In this way the holding time of multi-frequency senders and registers is kept to a minimum. The post-dialling delay which is introduced by restraining the setting up of the call until the subscriber has nearly finished dialling, would not normally be very great because the high speed multi-frequency inter-register signalling enables the call to be set up very rapidly.

GROUPING OF LOCAL AND INCOMING T.R.G.s

In most exchanges it is economical to fit the local and the incoming t.r.g.s on one router and to segregate them in groups of ten so that their register connectors are separate. This permits one group of 20 route switches "B" to serve mixed incoming and local traffic.

For exchanges having several routers, it may sometimes be convenient to provide some equipped with incoming junction t.r.g.s and some with local t.r.g.s. This arrangement is shown in Figs. 16 and 17.

SUB-EQUIPPED ROUTERS

A router can be equipped with any number of t.r.g.s in (typically) multiples of ten and sufficient route switches "A" are fitted to serve the number of t.r.g.s equipped. The full 20 route switches "B" are usually fitted, but this number may be reduced to 10 in a very small exchange.

Sub-equipped routers can be extended very easily by fitting additional shelves of t.r.g.s and route switches.

EXCHANGES UP TO 100 000 LINES CAPACITY

Two or more 10 000-line offices can be installed in the same building to form an exchange of 20 000, 30 000, etc. lines.

"Local second-stage routers" are provided for terminating traffic in order to increase the access from each router from the normal 20 groups of 20 terminating trunks each, up to 200 groups of 10 terminating trunks each. This enables a router to reach any one of 200 500-line distributors.

Two "office markers" ("X" and "Y") are provided for each local second-stage router. This enables the register to connect its "5-hundreds", "hundreds", "tens" and "units" marking wires to the 500-line marker in the required 500-line distributor. The office marker also controls the operation of the appropriate "X" or "Y" route relay to extend the marking wires between the router and the required 10 000 line office.

The time required, for setting up a call from a t.r.g. to one out of 100 000 lines, is about 200 ms. longer than the time required for setting up a call to one out of 10 000 lines.

EXTENSION OF A STROWGER EXCHANGE BY 5005 CROSSBAR

One or more 1 000-line crossbar units can be installed in the same building as a Strowger exchange. A 1 000-number block of directory numbers is allocated to each 1 000-line crossbar unit, within the 10 000-number block allocated to the Strowger exchange.

Calls from Strowger subscribers to crossbar subscribers leave the Strowger exchange on the outlets of the selectors preceding the penultimate selectors, using one level per 1 000-line crossbar unit.

Calls from crossbar subscribers to Strowger subscribers enter the Strowger exchange on penultimate selectors.

It is, however, economical to provide an alternative route within the exchange so that, when all incoming penultimate selectors are busy, a call from the crossbar exchange is routed to the Strowger exchange via an earlier rank of selectors. The alternative routing facilities of the 5005 system enable this to be done.

Similarly, small groups of early choice (high usage) outgoing junctions to other exchanges in the area can be provided for the crossbar subscribers, and, when these are all busy, calls can be routed via selectors in the Strowger exchange to the common outgoing junction groups.

Ultimately, when the Strowger exchange reaches the end of its life, the 1 000-line crossbar unit can form the nucleus of a 10 000-line crossbar exchange.

Since the 5005 system interworks with the Strowger system without requiring any special interworking equipment, the new crossbar exchange can be built as an extension to the Strowger exchange without involving the "writing off" of interworking equipment when the Strowger exchange is finally replaced.

PART 3 SECURITY

MEASURES TO ENSURE THE RELIABILITY OF THE SERVICE

There are four categories:

(*a*) Measures to prevent faults.
(*b*) Measures to limit the effects of faults.
(*c*) Measures to facilitate localisation of faults.
(*d*) Measures to facilitate testing.

MEASURES TO PREVENT FAULTS

DUST EXCLUSION

Each rack has capacity for 20 shelves, 10 per face. A well-fitting cover is provided individually for each shelf, but free circulation of air within the entire rack (both faces) is permitted, to ensure adequate cooling.

All normal testing, jumpering, etc., can be carried out without opening the dust-excluding covers.

INSTALLERS' WIRING AND JUMPERING

All installers' wiring and all jumpering is carried out with solderless-wrapped joints; the possibility of short-circuits developing is thereby reduced by the elimination of solder splashes, wire clippings or burned insulation.

JACK-IN EQUIPMENT

The use of jack-in or plug-in equipment is avoided almost entirely.

TEST LINKS

The use of test links is limited to places where a disconnection at the test link would not interrupt service.

PRECIOUS METAL CONTACTS

There is no single precious metal which provides, under all circuit conditions and in all environments:

(*a*) Low contact resistance.
(*b*) Complete freedom from dirty-contact faults.
(*c*) Freedom, throughout the life of the exchange, from so much wear as would cause a fault.

A choice has therefore to be made between using, throughout the exchange, one contact material which meets all conditions fairly well, but none perfectly; or using for each condition the contact material which suits it best. The latter method has been adopted in the 5005 system.

Pure silver gives a satisfactory performance if the following conditions are satisfied:

(*d*) Contacts are always "wetted" by direct current of at least 1 milliamp. derived through a suitable resistance from a voltage source of about 50 volts.
(*e*) Twin contacts are provided with adequate contact pressure. The minimum contact pressure varies between 11 grams and 20 grams per spring depending upon the other parameters of the relay design.
(*f*) There is some "rub" or "wipe" when the contacts close. The amount of "wipe" required varies inversely with the contact pressure.
(*g*) The contact life is adequate to meet the calculated total operations of the relay during the life of the exchange. (This depends, of course, upon the circuit parameters in which the contact is working.)
(*h*) Circuits are arranged so that there is no appreciable sparking when contacts open.

Where (*g*) and (*h*) are not met, pure platinum is preferred to pure silver.

Where (*f*) is not met, palladium, or palladium-silver alloy is preferred to pure silver.

Where (*e*) is not met, platinum or palladium is preferred, provided (*f*) is not met.

The liability of pure silver to the formation of silver sulphide on its surface due to the presence of sulphurous gases in the air, does not usually cause "dirty contact" faults if (*e*) and (*f*) are met.

The liability of pure palladium, or palladium-silver alloy to surface polymerisation due to the presence of organic gases (e.g. turpentine vapour from floor polish) is minimised if (*f*) is absent, and for this reason, the large-capacity long-life Type 501 relay is designed to have minimum "wipe" combined with adequate contact pressure so as to be suitable for either silver or palladium contacts.

The following are typical examples of the uses of different contact material in the 5005 system.

Crossbar switches	Silver
General purpose relays (light duty)	Silver
General purpose relays (heavy duty)	Platinum
Large-capacity relays (light duty)	Silver
Large-capacity relays (heavy duty)	Palladium
High-speed relays	Platinum

All contacts are twinned on keys, crossbar switches, and relays (except for the platinum contacts on high-speed relays), and the contact springs are mounted in the vertical plane (except in the case of the off-normal springs of crossbar switch select magnets).

"Atmite" non-linear resistors are used as spark quenching devices wherever necessary to prevent contact erosion. In addition, all circuits are arranged so that the crosspoint contacts of crossbar switches are never opened while current is flowing.

LIFE OF COMPONENTS

With the exception of consumable stores items, all components are designed to have a working life of 40 years under normal traffic conditions. During this time, no part should require replacement on account of wear or ageing.

With decentralisation of the common controls, the work of setting up calls is spread over large numbers of relays; in the life of each of these relays there is a correspondingly smaller number of operations compared with a highly centralised system of common control. This simplifies the manufacture of relays with the necessary long life for a crossbar system.

The select magnets and bridge magnets of the crossbar switches can be considered as a special kind of relay, and their moving parts are designed to have the same order of longevity as other relays. Thus the select magnets (which have to be provided in any case for selection of the crosspoints) can be used for the call steering function, instead of additional relays having to be provided for this purpose.

MEASURES TO LIMIT THE EFFECT OF FAULTS

CAUSES OF FAULTS

The elimination of wear removes the cause of the vast majority of exchange faults, but there will always remain a residual risk of failure from other causes.

In order that full economic advantage may be taken of the elimination of faults due to wear, provision is made to ensure that, if a component should fail due to a cause other than wear, the exchange would continue to give a satisfactory standard of service until the next scheduled visit of the maintenance officer, and would not normally require a "beck and call" service.

The objective is a system whose reliability does not depend upon the reliability of its components.

The following sections show how this objective is achieved in the case of all common apparatus. The individual subscriber's line circuit is not suited to the same security treatment as the common apparatus and has to be regarded as being in the same security category as the subscriber's individual cable pair or telephone instrument.

UNIT CONSTRUCTION

Each crossbar switch, with its associated control relays, is constructed as a unit whose external connections are limited almost entirely to the 10 incoming and 25 (or 28) outgoing speech trunks.

The failure of a component in a crossbar switch, or in its control relays, normally causes one or more of the inlets or outlets to test busy without affecting any other switch.

"FAIL SAFE" CIRCUITS

Fig. 13 is a typical "fail safe" circuit as used in a crossbar switch. The guard relay G is kept normally operated through its high-resistance winding and the chain of SM contacts. If the chain breaks, relay G releases, thereby giving an alarm and preventing the operation of relay M. Thus the switch is withdrawn from service and calls use other paths through the exchange (Fig. 2 (*b*)). During marking on a normal call, an earth is supplied from the marker (for distributor switches "A" and "B") or from the router control (for route switches "A" and "B") to hold relay G operated while the select magnet is operated.

If an earth fault should occur on a "M" wire, thus falsely operating a select magnet (SM), the breaking of the chain would release relay G. As a result, M cannot operate, thus ensuring that a genuine call which might be marked later, could not enter the faulty switch but would be set up over another path.

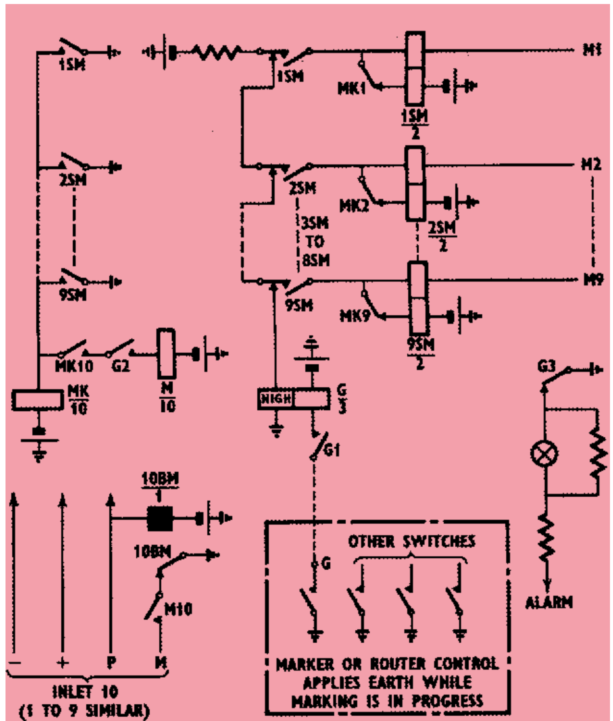


Figure 13. "FAIL SAFE" CIRCUIT OF CROSSBAR SWITCH, BASIC PRINCIPLE

It should be noted that all ten inlets to a switch normally test "busy" (that is, absence of earth on "M" wire) because relay M is normally not operated. During marking, relay M is operated by the operation of a select magnet (SM) and this unbusies those inlets whose bridge magnets (BM) are not operated. A fault in the switch or in its control relays (G, MK and M) would prevent the unbusying of the inlets and thus prevent the faulty switch from being used.

DUPLICATION OF ROUTER CONTROLS

Each router has two quite independent router controls whose primary function is to enable two calls to be marked simultaneously in each router and so minimise marking delay. A secondary function is in providing the safeguard that if one router control becomes faulty, the router will continue to provide service over half its outlets using the other control.

A further benefit from duplication is that if a call fails at the first marking attempt, the register automatically makes a second attempt using the other router control. This ensures seizing a different path through the exchange, or testing a different half of the group of outgoing junctions in the case of a large junction group.

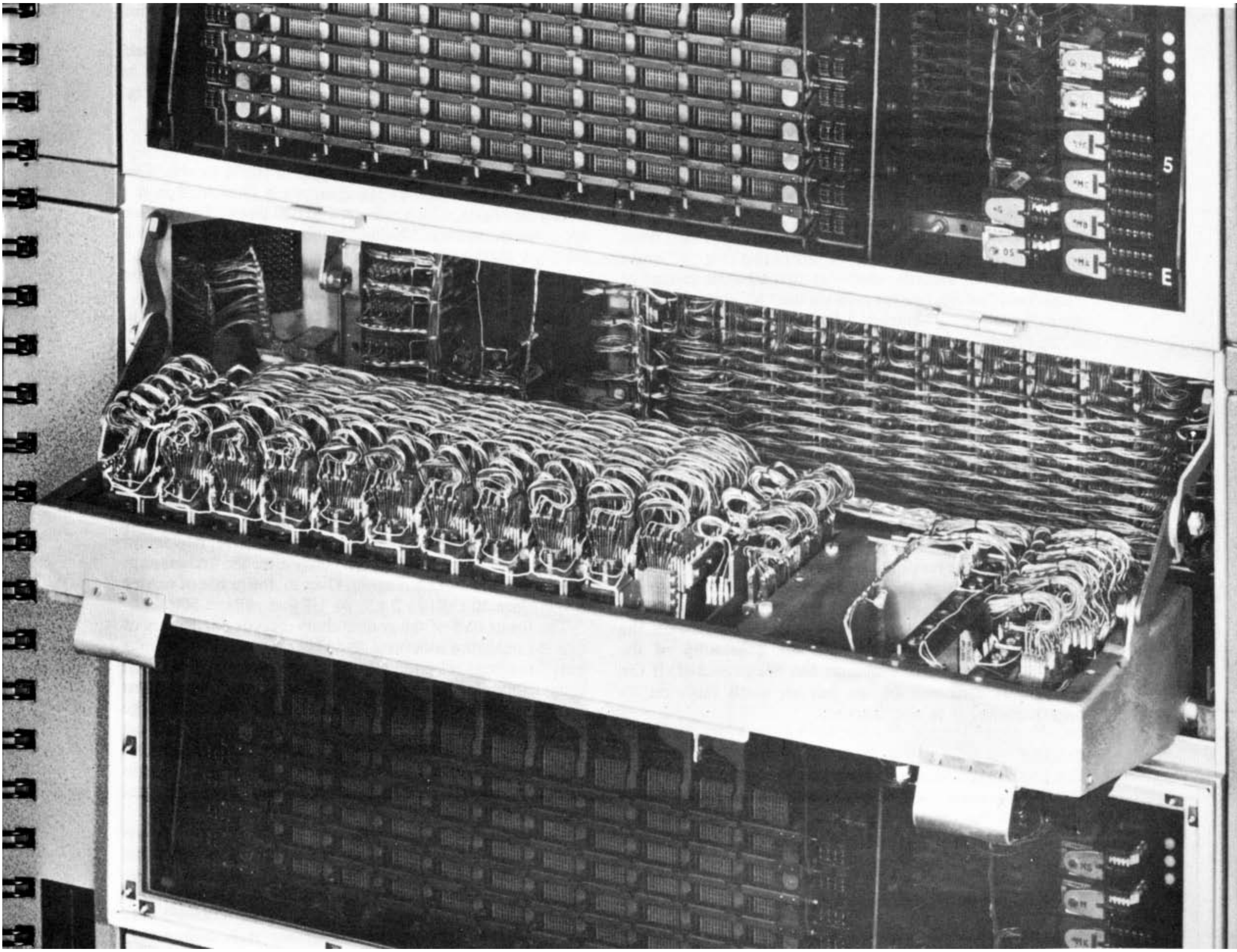


Figure 13 (*a*). SHELF-MOUNTED CROSSBAR SWITCH AND ASSOCIATED CONTROL RELAYS, IN HINGED DOWN POSITION

START-SHIFT

The start-shift was described on page 22. Its primary function is to distribute traffic evenly over the distributor switches "A". A secondary function is to ensure that the caller searches for a different t.r.g. and register at every successive attempt to call. The start-shift does not itself constitute a fault hazard because if it stops working the exchange continues to function but without the benefit of even distribution of traffic.

MARKERS

Each 500-line marker has a separate path of entry from each half router, that is, one "X" entry and one "Y" entry per router. For security, there are two separate groups of "hundreds" relays, one for calls via the "X" entries and one for calls via the "Y" entries. A fault in the entry relay, or in a "hundreds" relay, causes the register to seize the other router control and re-enter the marker via the other entry path. The 50 "tens" relays are not duplicated.

To provide security for outgoing junction calls, separate "X" and "Y" junction markers are provided.

CONTINUITY CHECK

It was explained on page 28 that when a call has been established, and before the router control releases, the classification of the called subscriber or outgoing junction is obtained by the router control over the speech path, thus checking its continuity. If the continuity check fails, the register releases the call and seizes the other router control to set up the call by another path. In the case of an outgoing junction call, the continuity check within the exchange cannot be made until the continuity of the junction to the distant exchange has been checked. If the junction is disconnected, or has an earth fault on its negative wire, it is not marked.

CODER

The coder has a group of relays for each digit. If a relay should develop a fault it would affect only a small proportion of the total codes which the coder handles. On faulty codes, the router control once more instructs the register to seize the other router control, which has access to the other coder. Coder failures are displayed on the path indicator or can be registered on the fault recorder.

MEASURES TO FACILITATE LOCALISATION OF FAULTS

UNIT CONSTRUCTION

The exchange is constructed of small functional units such as distributor switches "A" and "B", route switches "A" and "B", etc., each with its own individual group of control relays.

Any switch can be withdrawn from service by the removal of a test-link. It can then be tested by setting up calls from all inlets to all outlets, without causing interference to or suffering interference from "live" traffic on other switches. This testing can be performed without breaking the shelf dust seal.

If access to the wiring of the switch is necessary, the shelf cover is hinged down out of the way, and the switch is hinged forward through 90° to expose the wiring. (Fig. 13 (*a*).)

TRAFFIC ANALYSIS METERS

Each router and marker has a group of traffic meters. The information provided by these meters is illustrated in the following charts, which refer to a 10 000-line exchange with six routers, twenty 500-line markers and two pairs of junction markers.

Typical figures for numbers of calls are shown for the following traffic pattern:

Calling rate per line (originated calls)	0·04 e
Average holding time	3 min
Day to busy hour ratio	8 : 1
Percentage of originated traffic outgoing	50%
Ratio of incoming junction traffic to outgoing junction traffic	50/50

Examination of the router chart shows that about 10% of calls failed because the called subscriber was busy.

The first column shows that 100 calls out of 2 850 failed to find a free path through the exchange ("all trunks busy") at the first marking attempt; but on the automatic second attempt, 88 of these calls were effective, two found the wanted number had become busy after the first attempt was made, and 10 failed again. Overall, the grade of service is therefore 10 calls in 2 850 or 1·7 lost calls in 500.

The lower half of the router chart records particulars of calls to outgoing junctions. On this chart, the "all trunks busy" readings refer to calls which are lost due to internal congestion, plus the total of calls lost due to "all junctions busy", on all routes. Separate information about the loading of each junction route, independently of internal congestion, is given by a separate meter per junction route, which operates once every 6 seconds when all junctions in its route are busy. Readings from this meter are not shown on the chart.

The information provided by the router meters is supplemented by the line marker meters and outgoing junction marker meters. Comparison of figures on the router chart with the corresponding figures on the marker charts, enables congestion or faults to be localised very easily by the supervisory maintenance staff, before they order remedial action. The following are typical interpretations:

"All trunks busy" a.t.b. meters reading uniformly high. *Exchange is overloaded.*

a.t.b. meters reading high on second attempt "X" and "Y" in one marker, and on second attempt "X" and "Y" in all routers. *Distributor concerned is overloaded.*

a.t.b. meters reading high on first attempt "X" in one marker, and on first attempt "X" in one router. *Some or all of the ten terminating trunks leading from this*

CHART I
LOCAL ROUTER No 1

LOCAL CALLS	FIRST ATTEMPT ON X	SECOND ATTEMPT ON Y	FIRST ATTEMPT ON Y	SECOND ATTEMPT ON X
Effective	2,500	88	2,450	83
Sub. busy	250	2	240	3
Marking failure	0	0	0	0
All trunks busy	100	10	95	9
Continuity failure	0	0	0	0
TOTAL:	2,850	100	2,785	95
OUTGOING JUNCTION CALLS				
Effective	2,490	80	2,520	102
Marking failure	0	0	0	0
All trunks busy	99	19	120	18
Continuity failure	0	0	0	0
TOTAL:	2,589	99	2,640	120

Note: Each of the other five routers will have a similar chart.

CHART II
LINE MARKER No 1

	FIRST ATTEMPT ON X	SECOND ATTEMPT ON Y	FIRST ATTEMPT ON Y	SECOND ATTEMPT ON X
Effective	1,600	55	1,640	59
Sub. busy	158	1	162	2
Marking failure	0	0	0	0
All trunks busy	60	4	66	5
Continuity failure	0	0	0	0
TOTAL:	1,818	60	1,868	66

Note: Each of the other 19 line markers will have a similar chart.

CHART III
OUTGOING JUNCTION MARKER No 1

	FIRST ATTEMPT ON X	SECOND ATTEMPT ON Y	FIRST ATTEMPT ON Y	SECOND ATTEMPT ON X
Effective	8,000	236	8,100	270
Marking failure	0	0	0	0
All trunks busy	300	64	330	60
Continuity failure	0	0	0	0
TOTAL:	8,300	300	8,430	330

Note: The other pair of outgoing junction markers will have a similar chart.

router to this distributor, on "X" marking, are permanently "busied".

For simplicity the figures in the above examples refer to an exchange in which the only irregularities are caused by congestion, resulting either from overload or from the artificial busying of trunks by faults. Faults which caused marking failures or continuity failures would be recorded and interpreted in exactly the same way.

PATH INDICATOR

A cold cathode triode per switch is mounted on a panel which is called a "Path Indicator". Every time a call is set up through a switch, its cold cathode tube is fired. Normally the tube is extinguished as soon as the continuity check has been made.

If the continuity check fails, all glowing tubes are locked on, and all other tubes in the same half router and distributor are prevented from firing.

The glowing tubes show the maintenance officer the path taken by an unsuccessful call. They can be extinguished, and the path indicator restored to normal operation, by depression of a key. Similar cold cathode tube circuits are used for displaying details of failed calls in the coder, 500-line marker, junction marker and router control.

FAULT RECORDER

If required, the path indicator may be replaced by a fault recorder which records in permanent form the information shown on the path indicator and on the fault meters. In the case of an unattended exchange the fault recorder can be located at the maintenance control centre and the information passed to it over a junction.

ALARMS

Alarms are provided for:

Mains failure; Ringing failure (with automatic changeover); Fuse blown; G relay released (see "Fail Safe" Circuits, page 40); Path indicator; Group "p.g.", i.e. more than a certain number of line faults, the number being adjustable.

Alarms can be repeated to other buildings, or can be monitored by dialling certain code numbers.

MEASURES TO FACILITATE TESTING

GENERAL

It will be clear from the foregoing sections that the equipment is designed to "fail safe" and to provide indications of failures to the maintenance staff by means of the alarms, meters, path indicator and (for very large exchanges) the fault recorder. Automatic routiners are not required, but manual testing cannot be eliminated completely; for example, the alarm system itself requires a periodic functional check.

CROSSBAR SWITCH TESTER

A portable test set is provided optionally to enable a test call to be set up through a crossbar switch. This would be used for fault localisation within a switch after the fault indicating equipment had shown which switch was in need of attention.

T.R.G. TESTER

The t.r.g. requires a periodic check to ensure that all its functions (ringing, metering, reverse battery supervision, etc.) are in working order. This can be done in small exchanges by means of a portable manual test set.

ARTIFICIAL TRAFFIC EQUIPMENT

For larger exchanges artificial traffic equipment is provided optionally. This makes a call from and to a spare line in each distributor, that is, for 20 distributors it has a programme of $20 \times 19 = 380$ calls, and, in time, will test every t.r.g. and every first-choice register, taking them at random.

If the ringing, metering, reverse battery supervision etc., do not function correctly, the artificial traffic equipment holds the call, and gives an alarm and a lamp display, which enables the faulty t.r.g. to be traced. Details of the failed call are printed on a fault recorder if one is provided.

LINE FAULTS—AUTOMATIC ISOLATION OF "P.G." LINES

A line which has a "loop" or "earth negative leg" fault seizes a register. If no dialling is received within 30 to 60 seconds, *either* the register is released, and the faulty line is locked out of service ("parked") at its line circuit until the fault is removed, *or* the register sets up a call to an automatic howler relay group. The register then releases. On a loop fault, howler tone is applied at low level, gradually increasing to normal howler level. The howler is removed after 30 to 60 seconds and the line is parked at its line circuit in the "p.g." condition. If, however, the fault is due to an earth on the negative leg, the call is immediately parked at its line circuit in the "p.g." condition, without transmission of howler tone. This is to avoid creating a disturbance in other pairs in the same cable due to applying high level tone to a pair with an earth fault on it.

"P.G." ALARM

A group "p.g." alarm operates when the number of lines parked in the "p.g." condition exceeds a predetermined figure. The directory numbers of "p.g." lines can be displayed at the test desk.

PART 4 PHYSICAL CONSTRUCTION

EQUIPMENT MOUNTING

DOUBLE-SIDED RACKS

Each rack is made up of four vertical members of light channel section joined by horizontal members to form a box-like construction having minimum weight for the required rigidity. The use of specially rolled or extruded members is avoided. Each face of the rack is enclosed by ten hinged metal-framed transparent plastic covers (one per shelf), and the top and bottom of the rack have sheet metal covers. Each side of the rack is enclosed by a sheet metal panel, of approximately "W" section (Fig. 6). Each of these panels has 20 rectangular holes in each of the two main faces, that is, two holes per shelf, in which tagblocks or blanks can be fitted, thereby also completing the dust seal. (Fig 6 (*a*).) For dimensions see Figs. 14 and 15.

MAIN END PANEL

A main end panel is provided at the non-growing end of each suite and accommodates the miscellaneous equipment associated with the suite. (Figs. 6 and 15 (*a*).) This miscellaneous equipment is mounted on hinged panels as shown in Figs. 15 (*b*) and (*c*) and is wired to tagblocks on the associated "W" panel as for a standard rack. The main suite fuses are also located in the main end panel.

AUXILIARY END PANEL

This is provided to form a neat termination to the growing end of the suite. (Fig. 6.)

DUST SEALING OF EQUIPMENT

The hinged transparent covers are edged with extruded plastic material which provides a good dust seal. The covers are easy to open and close, and when a cover is opened, it hinges neatly down over the cover beneath it so that the problem of "parking" the covers of open shelves does not arise.

The inter-rack spaces are provided with hinged doors to give the suite a flush appearance, but, as the inter-rack space does not contain electro-mechanical equipment, it is not necessary for these doors to be completely dust sealed.

UNIT CONSTRUCTION

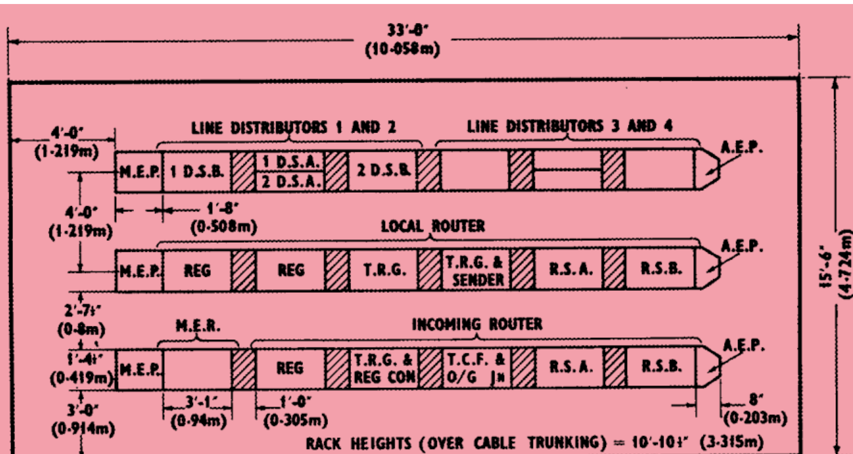
Each rack carries ten standard shelves and one hinged fuse mounting on each face, but can be sub-equipped as required. Fig. 15 (*d*) shows a typical sub-equipped suite of racks. The shelves are light alloy die-castings and are arranged to hinge outwards through 90° for easy access to the wiring. (Fig. 13 (*a*).)

A standard shelf can accommodate one crossbar switch and 21 relays, or 91 relays (13 strips of 7 relays each). Figs. 15 (*e*) and (*f*) show typical relay shelves in the open position.

Hinged boxes are mounted at the rear of the shelf for accommodating resistors, capacitors, etc., or, alternatively, a hinged tagblock for use as a strapping field can be mounted behind any adjacent pair of relay mounting strips. Figs. 15 (*e*) and (*f*).

Special shelf panels can accommodate 4 tagblocks with jumper rings, mounting two panels per standard shelf position and enabling a t.c.f. to be built up in a standard rack. Fig. 15 (*g*) shows a sub-equipped t.c.f. shelf assembly.

The shelf is assembled and wired as a complete unit, and the wiring is brought out to a maximum of four tagblocks.



ABBREVIATIONS:

M.E.P.	—MAIN END PANEL (COMMON SERVICES)
A.E.P.	—AUXILIARY END PANEL
M.E.R.	—MISCELLANEOUS EQUIPMENT RACK
D.S.B.	—DISTRIBUTOR SWITCH 'B' RACK
D.S.A.	—DISTRIBUTOR SWITCH 'A' RACK
R.S.B.	—ROUTE SWITCH 'B' RACK
R.S.A.	—ROUTE SWITCH 'A' RACK
T.R.G.	—TRANSMISSION RELAY GROUP RACK
REG	—REGISTER RACK
T.C.F.	—TRUNK CONNECTING FRAME
O/G JUNC	—OUTGOING JUNCTION RACK
T.R.G. & REG CON	—TRANSMISSION RELAY GROUP AND REGISTER CONNECTOR RACK
T.R.G. & SENDER	—TRANSMISSION RELAY GROUP AND SENDER RACK
REG & R.C.	—REGISTER AND ROUTER CONTROL RACK
(hatched box)	—INTER-RACK SPACE

Figure 14. FLOOR PLAN OF TYPICAL 2 000-LINE EXCHANGE (NOT TO SCALE)

Figure 15 (a). SUITE OF RACKS, SHOWING MAIN END PANELS ▶

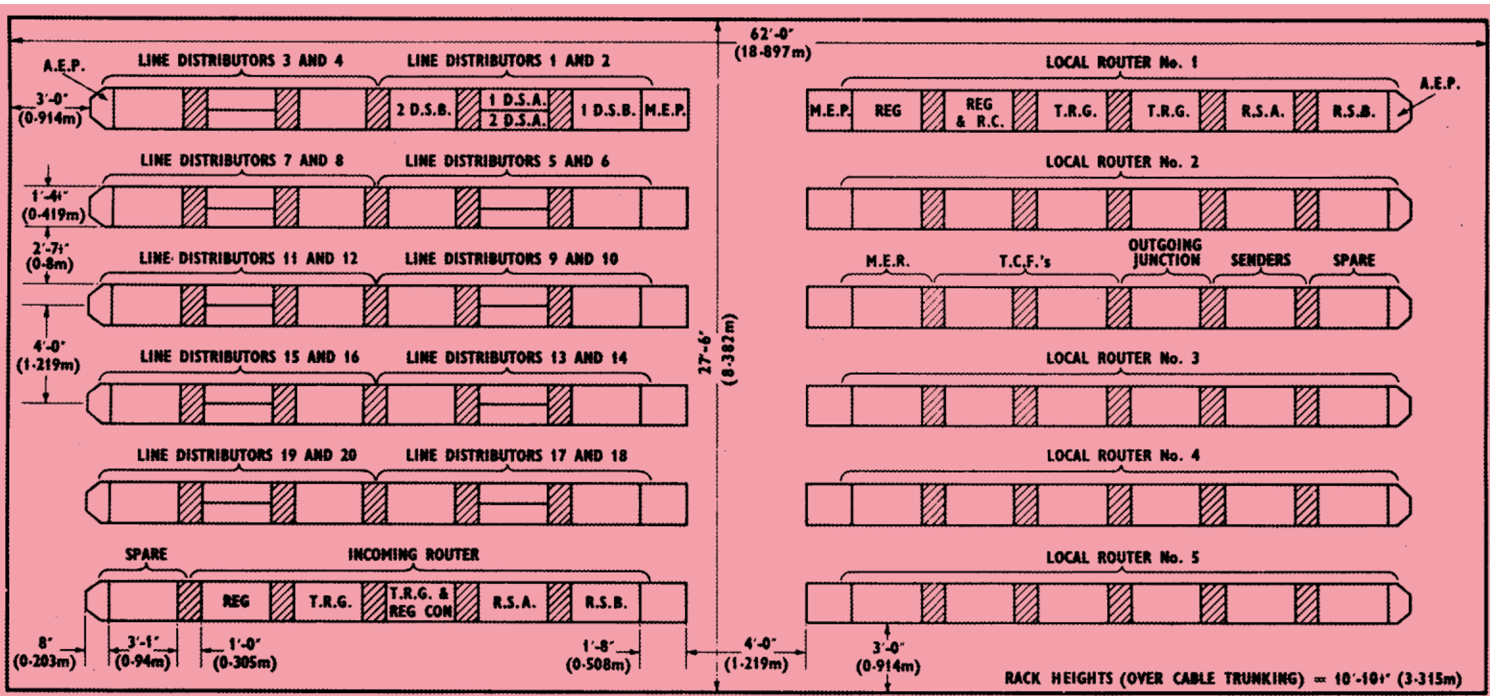


Figure 15. FLOOR PLAN OF TYPICAL 10 000-LINE EXCHANGE (NOT TO SCALE)

When the shelf is mounted in the rack these tagblocks are located in the "W" panel as described under "Double-sided Racks", page 47.

For maintenance purposes a switch can be withdrawn from service by the removal of a test link. The switch and its associated relays can then be fully tested as a complete unit without causing interference to, or suffering interference from, live traffic.

Each ringing machine is mounted on a sliding shelf that occupies one standard shelf position for the full depth of the standard double-sided rack. (Fig. 15 (*h*) shows the ringing machine shelf withdrawn for access purposes.)

CONTIGUOUS FUNCTIONAL LAYOUT

The use of double-sided racks enables the tagblocks for the shelves on four rack "faces" to appear, when seen in plan, on the four limbs of the "X" which is formed where two "W" panels face each other. (Fig. 6.)

By mounting shelves that have to be interconnected on these four faces, they can be wired easily by one straight vertical cable-form running through the centre of the "X", with wires feeding out along each arm of the "X" to the tagblocks at the level of each shelf.

CABLING

SUITE CABLES

Cables are accommodated in a covered cable trough which is an integral part of each rack and inter-rack space. The top of each inter-rack space opens into the cable trunking so that cable can be led down to the tagblocks on the "W" panels.

INTER-SUITE CABLES

All cables running between suites are accommodated in cable trunking joining the suite trunking at main end panels. External cabling from the suites to the m.d.f., meter racks, etc. is accommodated in cable trunking of similar design and no cable lacing is required.

FLOOR PLANS AND TRUNKING DIAGRAMS

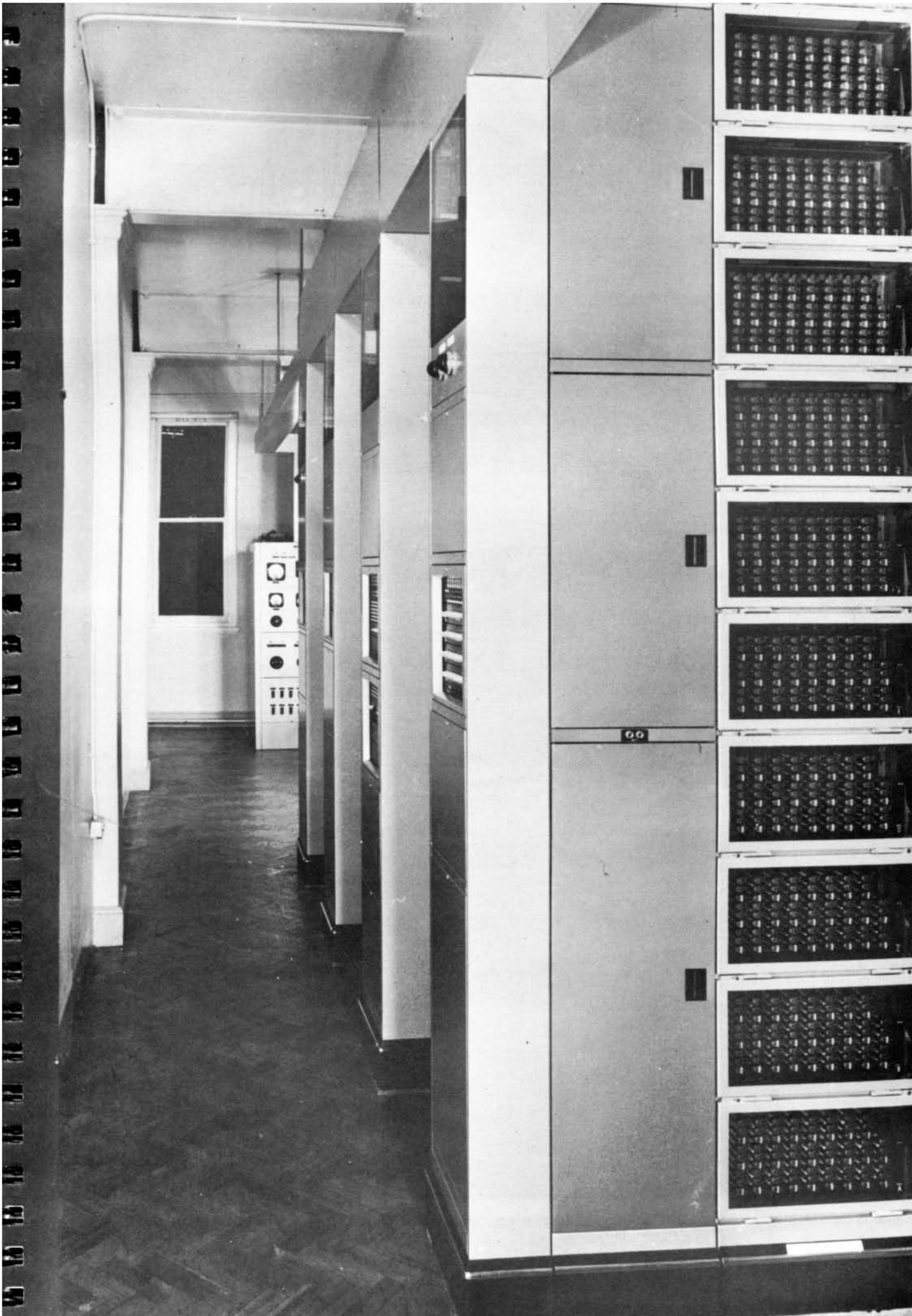
Figs. 14 and 15 are floor plans of two typical exchanges whose trunking arrangements and equipment quantities are given in Figs. 16 and 17.

In these two floor plans the layout of the shelves on the racks and the layout of racks on the floor have been arranged to provide the most economical use of floor space and of inter-rack cable; but the shelf and rack layouts can be varied as required to make the best use of the size and shape of the available building.

The dimensions of each rack are fixed; the aisle space shown on the floor plans is the recommended size, but can be altered if necessary.

FLOOR LOADING

For racks, cabling, test gear, personnel, and the usual contingencies, the floor loading does not exceed *180 lb/* square foot (880 kg/square metre). This is the limit normally used for Strowger exchanges.



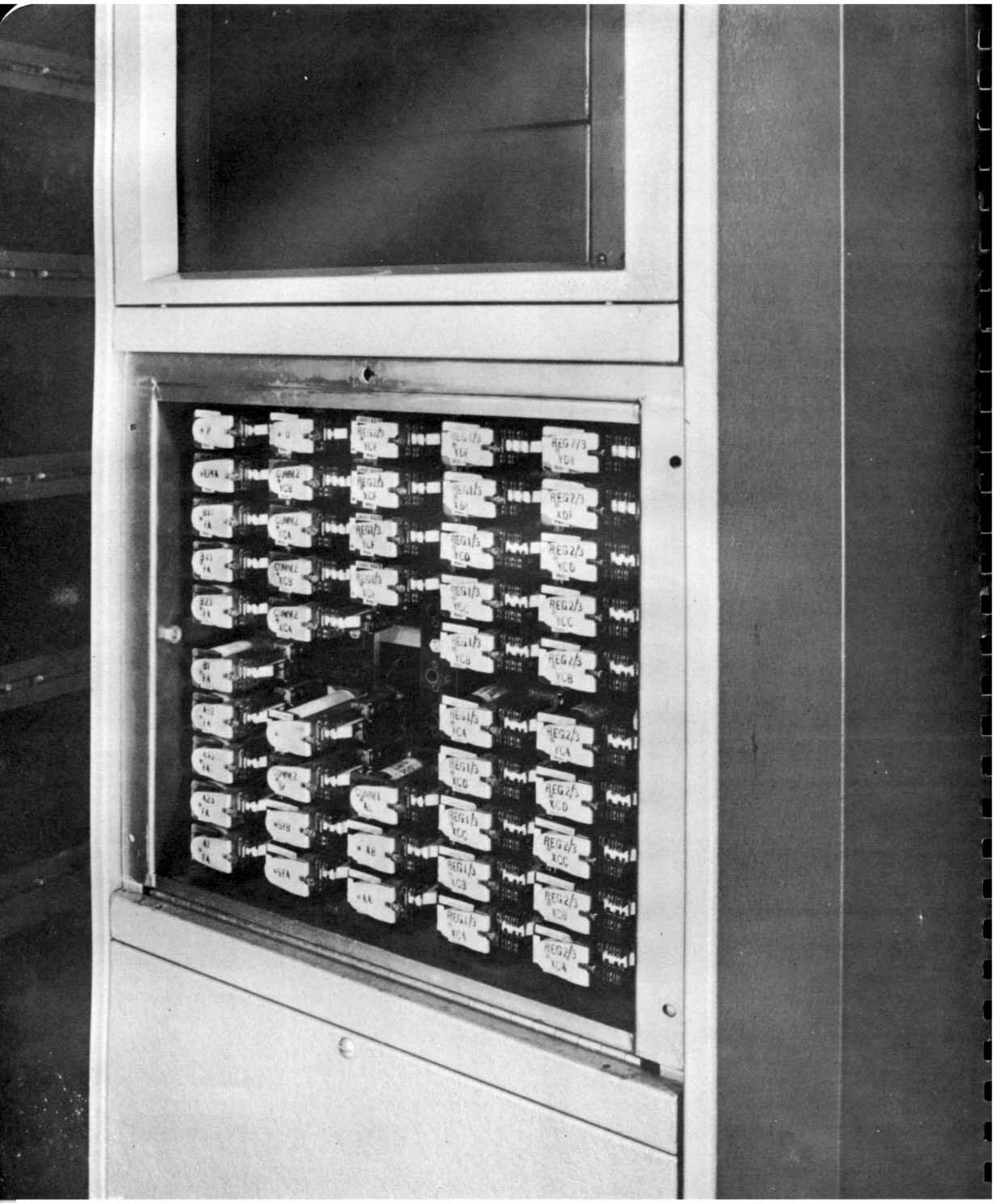


Figure 15 (*b*). MAIN END PANEL EQUIPMENT, ONE COVER REMOVED

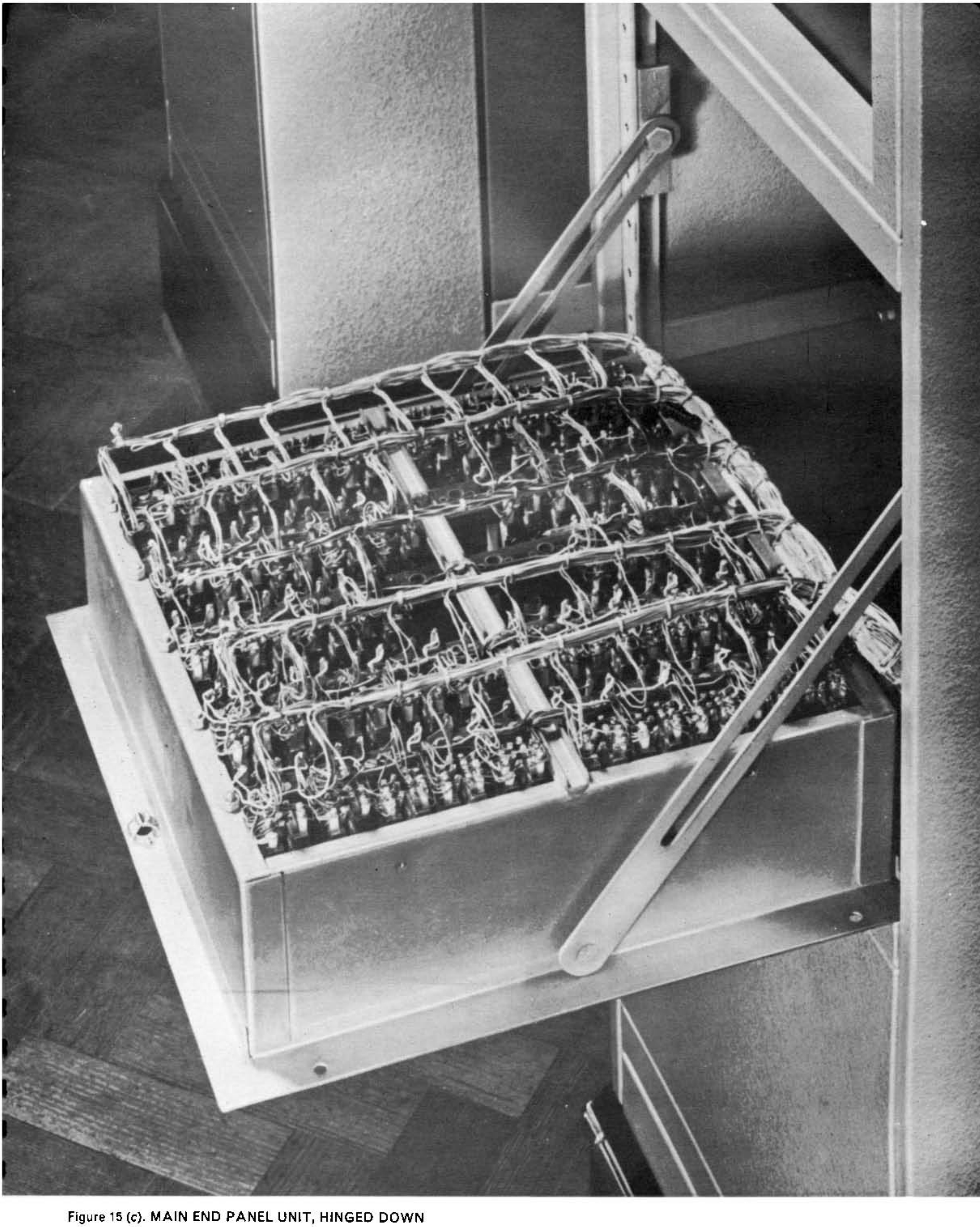


Figure 15 (c). MAIN END PANEL UNIT, HINGED DOWN

Figure 15 (*d*). TYPICAL SUB-EQUIPPED SUITE OF RACKS

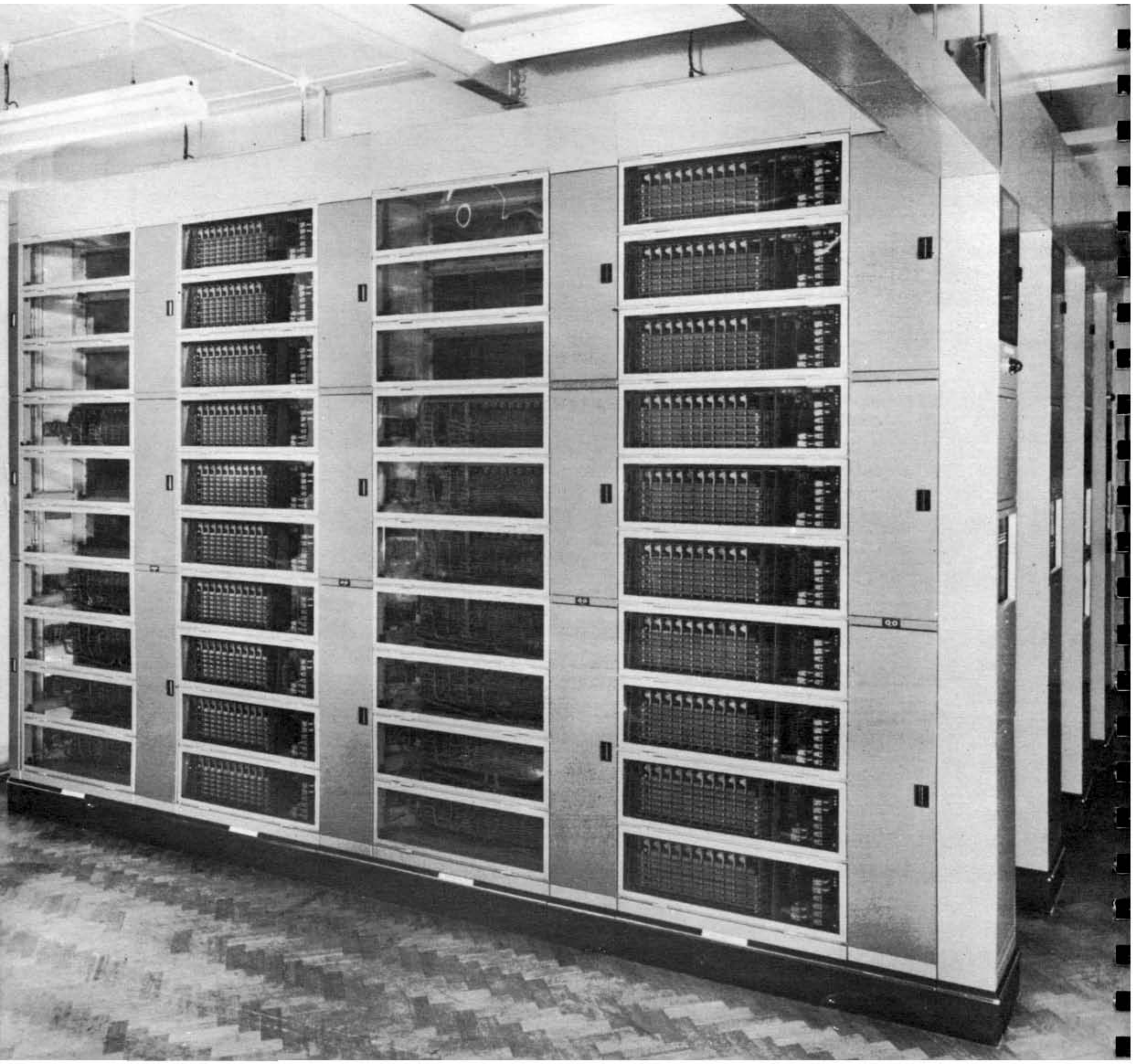


Figure 15 (*e*). TYPICAL RELAY SHELF WITH REAR-OF-SHELF TAGBLOCKS, HINGED DOWN (ONE TAG BLOCK HINGED UPWARD)

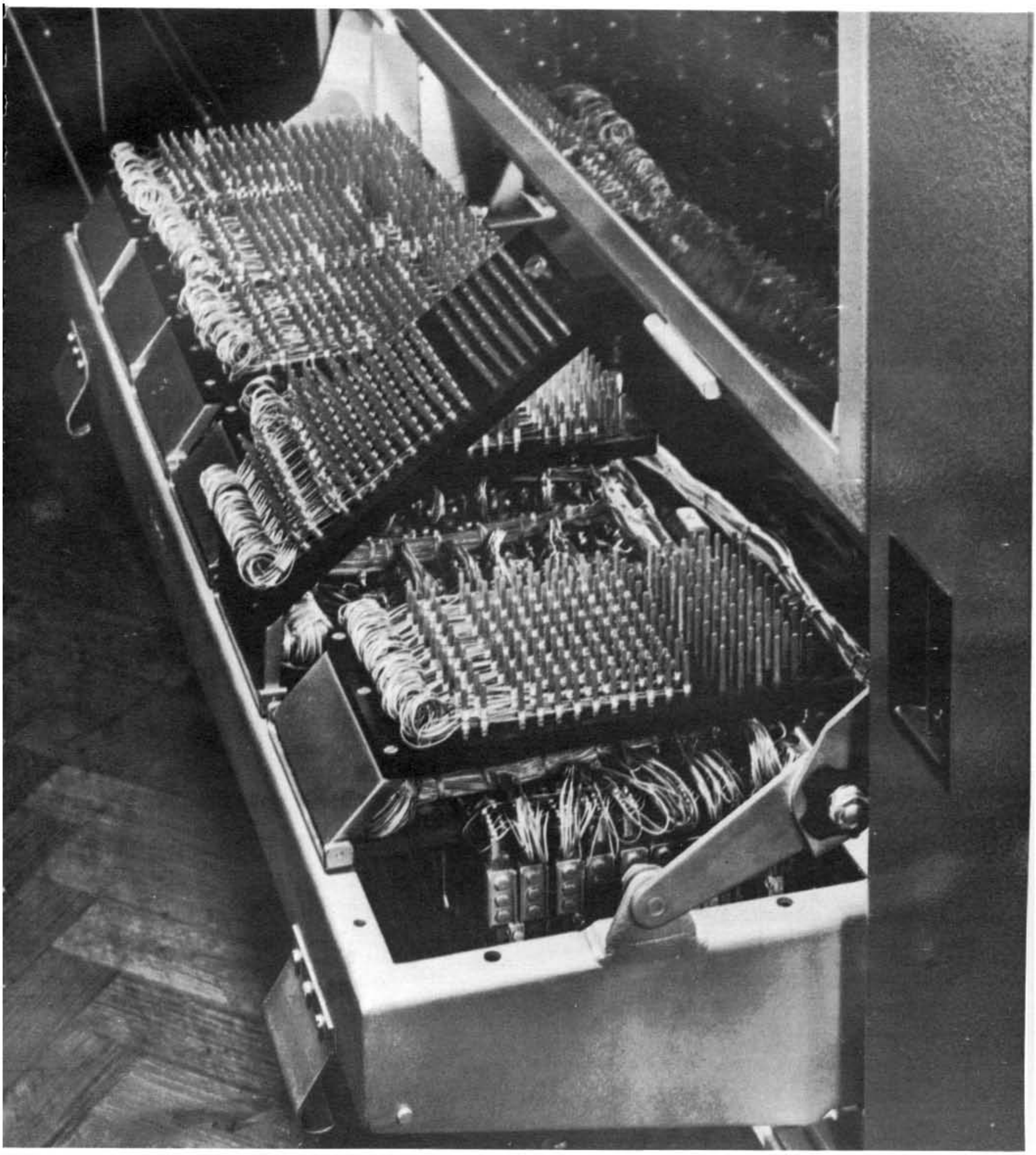
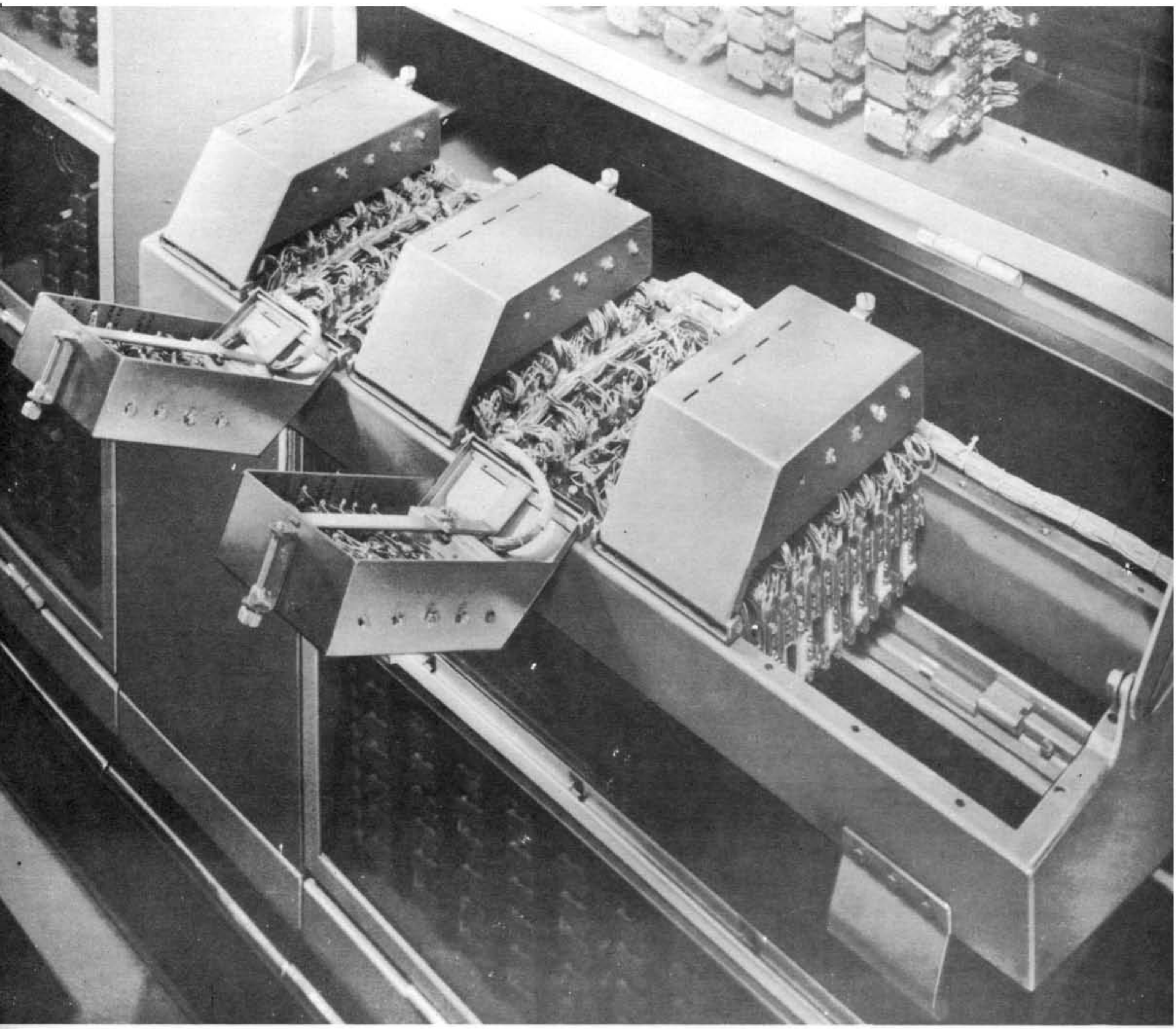
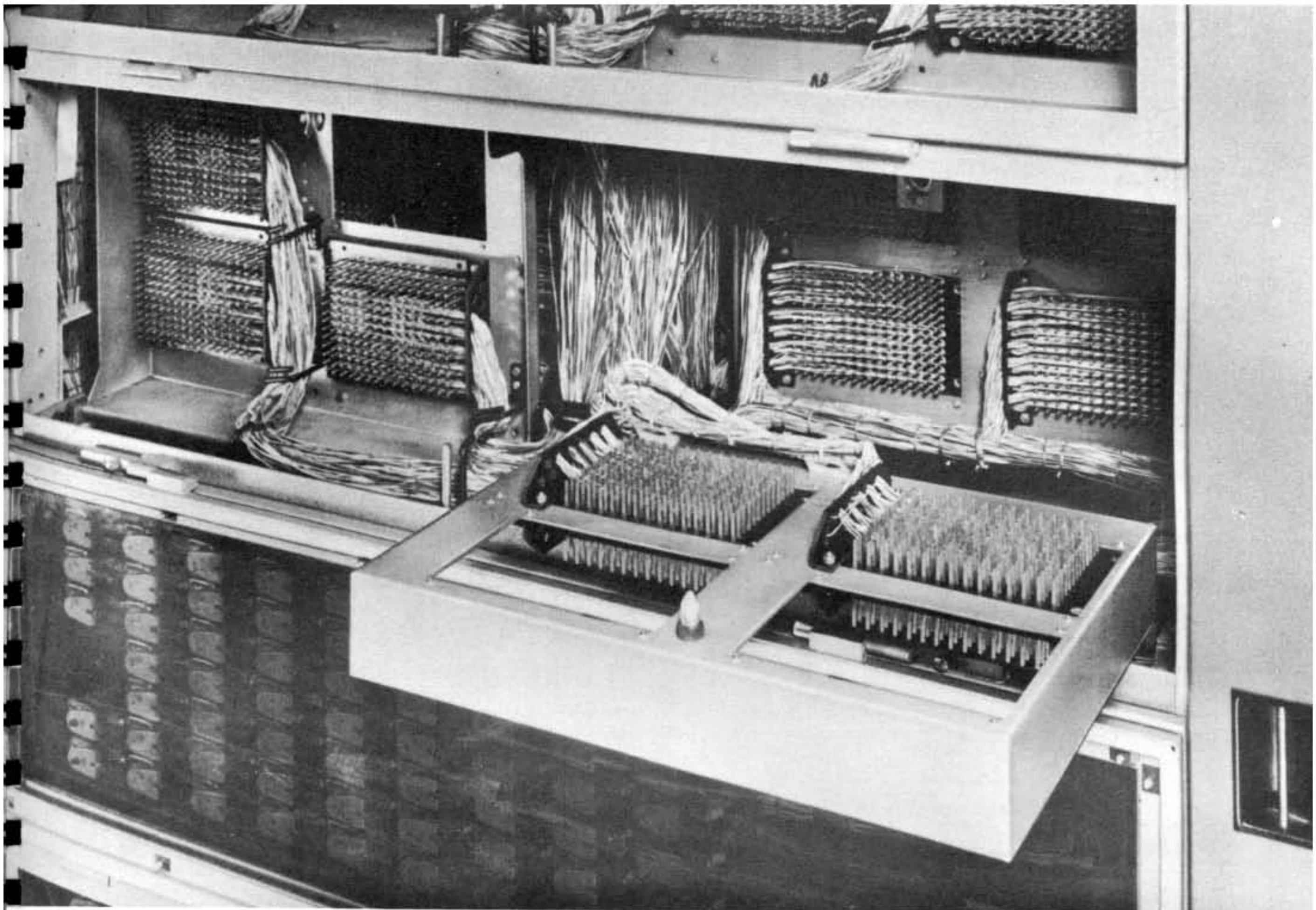


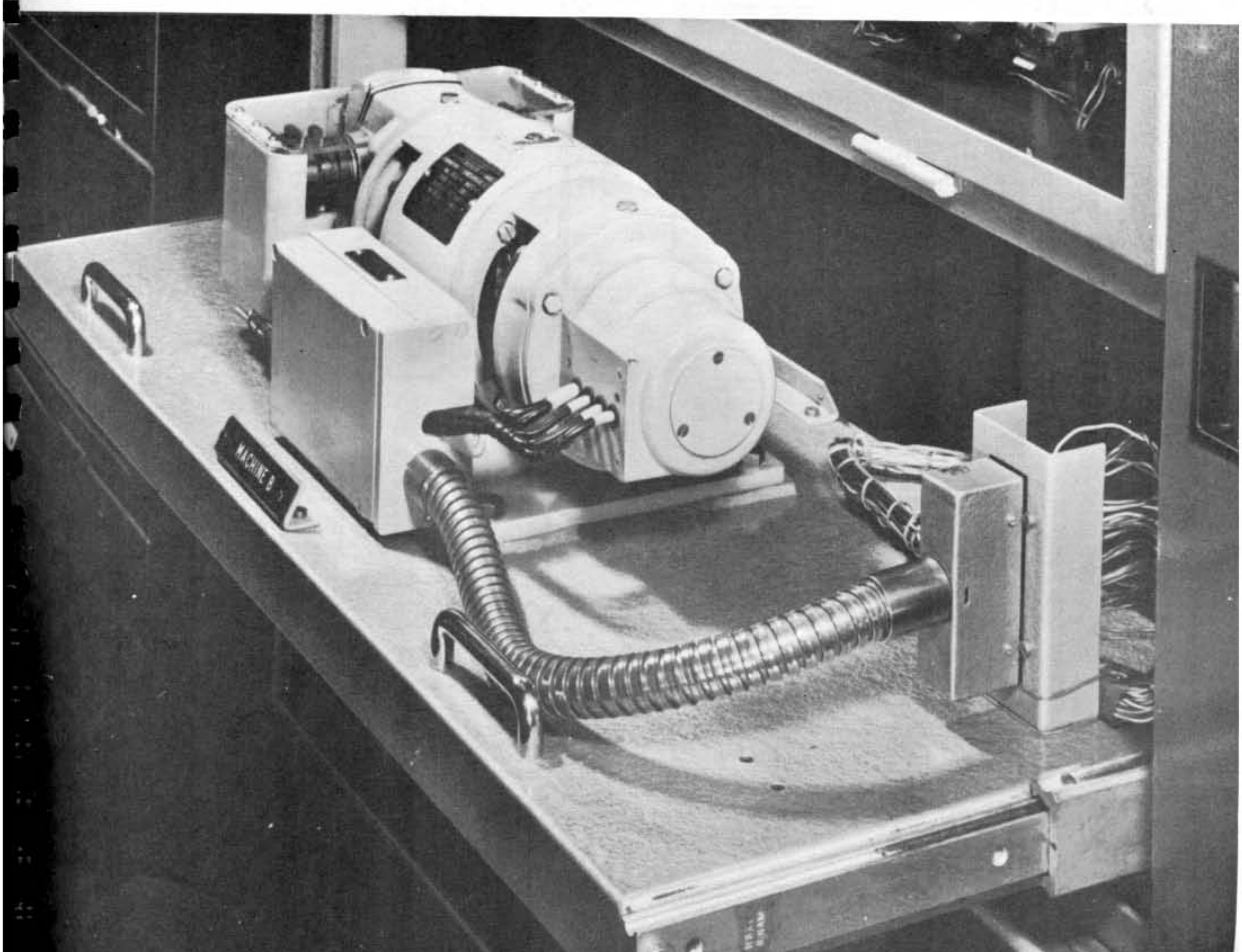
Figure 15 (*g*). T.C.F. SHELF, ONE SECTION HINGED DOWN ▶

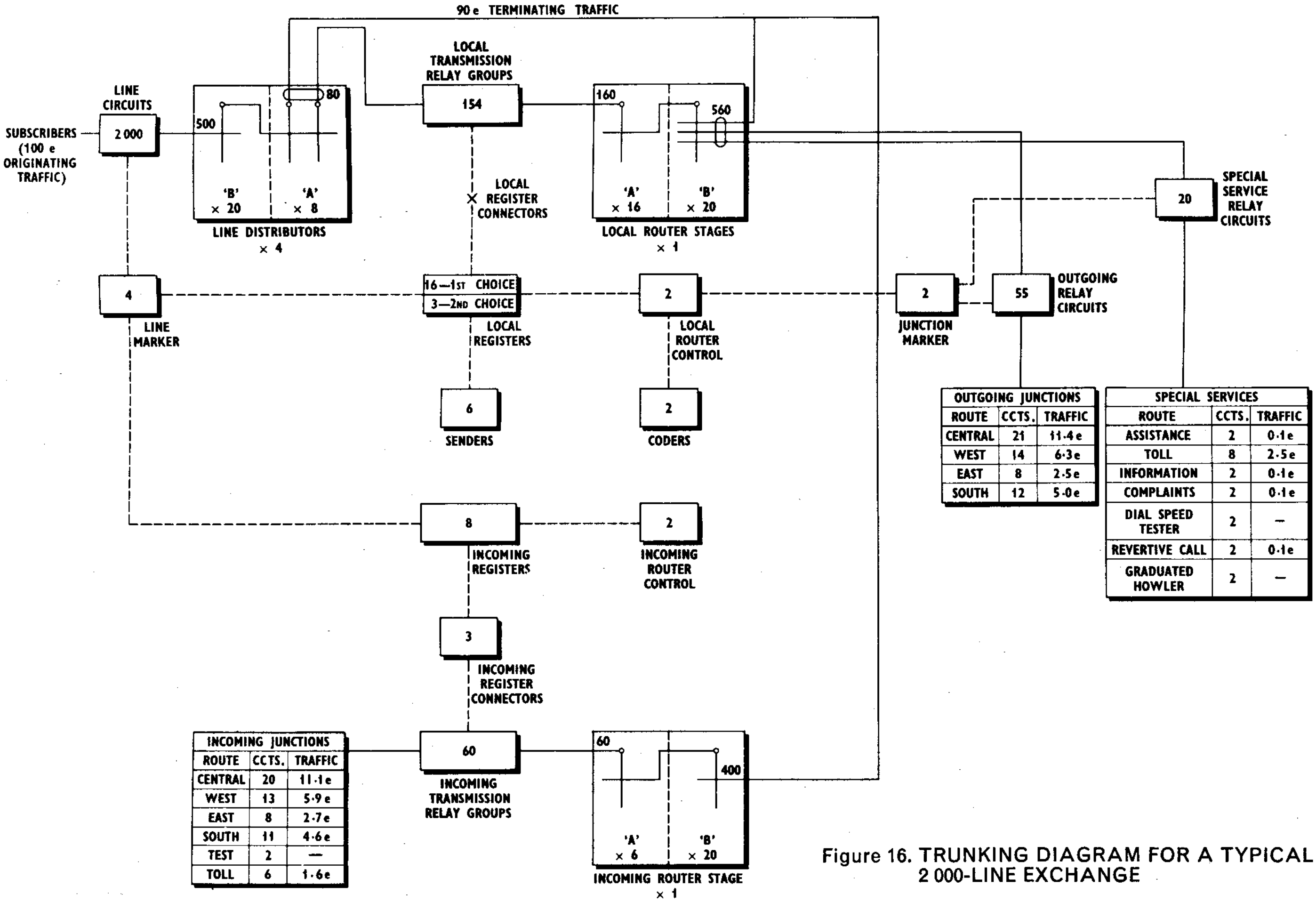


•Figure 15 (*f*). TYPICAL RELAY SHELF WITH CAPACITOR BOXES HINGED DOWN

Figure 15 (*h*). RINGING MACHINE SHELF, DRAWN OUT FOR ACCESS ▶




MACHINE B

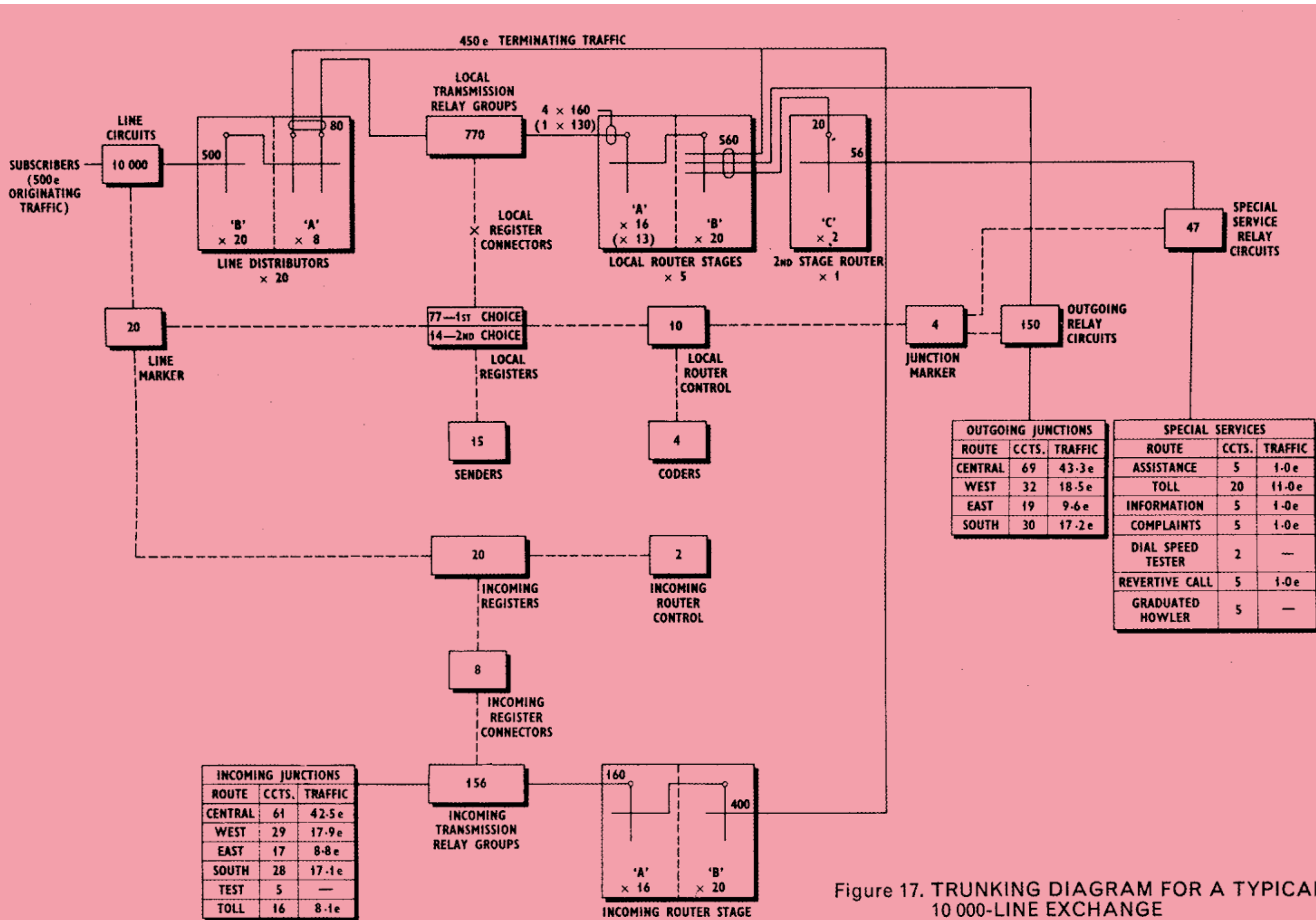


OUTGOING JUNCTIONS		
ROUTE	CCTS.	TRAFFIC
CENTRAL	21	11·4e
WEST	14	6·3e
EAST	8	2·5e
SOUTH	12	5·0e

SPECIAL SERVICES		
ROUTE	CCTS.	TRAFFIC
ASSISTANCE	2	0·1e
TOLL	8	2·5e
INFORMATION	2	0·1e
COMPLAINTS	2	0·1e
DIAL SPEED TESTER	2	—
REVERTIVE CALL	2	0·1e
GRADUATED HOWLER	2	—

INCOMING JUNCTIONS		
ROUTE	CCTS.	TRAFFIC
CENTRAL	20	11·1e
WEST	13	5·9e
EAST	8	2·7e
SOUTH	11	4·6e
TEST	2	—
TOLL	6	1·6e

Figure 16. TRUNKING DIAGRAM FOR A TYPICAL 2 000-LINE EXCHANGE



OUTGOING JUNCTIONS		
ROUTE	CCTS.	TRAFFIC
CENTRAL	69	43·3e
WEST	32	18·5e
EAST	19	9·6e
SOUTH	30	17·2e

SPECIAL SERVICES		
ROUTE	CCTS.	TRAFFIC
ASSISTANCE	5	1·0e
TOLL	20	11·0e
INFORMATION	5	1·0e
COMPLAINTS	5	1·0e
DIAL SPEED TESTER	2	—
REVERTIVE CALL	5	1·0e
GRADUATED HOWLER	5	—

INCOMING JUNCTIONS		
ROUTE	CCTS.	TRAFFIC
CENTRAL	61	42·5e
WEST	29	17·9e
EAST	17	8·8e
SOUTH	28	17·1e
TEST	5	—
TOLL	16	8·1e

Figure 17. TRUNKING DIAGRAM FOR A TYPICAL 10 000-LINE EXCHANGE

PART 5 OPERATING DATA

OPERATING DATA

GENERAL

Operating limits, such as voltage, line resistance, relay adjustments, etc., are interdependent. It is possible to set up in the laboratory, combinations of "all favourable" or "all unfavourable" tolerances which produce extreme differences in operating limits, but neither of these extremes is ever encountered in practice. In giving details of operating limits, therefore, the method which has been followed is to give the extreme value for the parameter under discussion, assuming medial values for all other parameters, unless otherwise stated.

MAIN BATTERY SUPPLY (Positive pole earthed)

(*a*) Nominal voltage	50V
(*b*) Limits maintained by charging equipment	46V-52V
(*c*) Satisfactory operation of exchange during test	42V-54V
(*d*) Current consumption per erlang	0·5A

AUXILIARY BATTERY SUPPLY (Negative pole earthed)

(*a*) Nominal voltage	50V
(*b*) Limits maintained by charging equipment	46V-52V
(*c*) Satisfactory operation of exchange during test	44V-54V

(*d*) Current consumption depends upon the type of metering system used. A battery capacity of 10 ampere-hours would normally be adequate.

NOISE

The main sources of noise in a telephone exchange are:

(*a*) Rectifier "hum".
(*b*) Switching operation: induced in the speech circuits.
(*c*) Crosstalk.

Measurements taken on the speech circuits under full-load conditions showed that the noise level due to (*a*), (*b*) and (*c*) at no time exceeded 0·2 mV when measured with a psophometer using the 1951 C.C.I.F. telephone weighting characteristics.

TRANSMISSION

The transmission loss in any exchange is a combination of the loss in the transmission feeding bridge, the loss in the switching train, plus the loss in the exchange cabling. The loss measured from m.d.f. to m.d.f. will vary, therefore, depending upon the size of the exchange and the length of the cable runs. In the 5005 system the loss measured from m.d.f. to m.d.f. is, under all normal circumstances, less than 0·8 db measured at 800 c/s.

SUBSCRIBERS' LINES (plus Telephone Instruments)

(*a*) Maximum loop resistance at 50V	2 000 ohms
(*b*) Maximum loop resistance at 42V	1 500 ohms
(*c*) Minimum insulation resistance, wire to wire, or wire to earth	15 000 ohms

LOOP-DISCONNECT JUNCTIONS

(*a*) Maximum loop resistance at 50V	2 000 ohms
(*b*) Maximum loop resistance at 42V	1 500 ohms
(*c*) Minimum insulation resistance, wire to wire, or wire to earth	15 000 ohms
(*d*) Maximum capacitance, wire to wire, or wire to earth	3·5μF
(*e*) Maximum number of junctions in tandem	No Limit

V.F. SIGNALLING JUNCTIONS

(*a*) Maximum attenuation for 1-v.f. or 2-v.f. or outband line signals, and for m.f. inter-register digital signals	20 db
(*b*) Maximum attenuation of junctions in tandem,	
(i) link-by-link working (per link)	20 db
(ii) end-to-end working (overall)	20 db

IMPULSING CHARACTERISTICS

20 P.P.S. REGISTER

(*a*) Dial speed	8-22 p.p.s.
(*b*) Impulse "break" ratio	47%-53%.

10 P.P.S. REGISTER (desensitized—see below)

(*a*) Dial speed	8-12 p.p.s.
(*b*) Impulse "break" ratio	60%-70%.

Note: The figures quoted for dial speed and dial ratio allow a margin of safety with all tolerances adverse.

With normal adjustment the pulse receiving relays in the 5005 register will respond to pulses at speeds well beyond 22 p.p.s. This high-speed response can be a disadvantage in certain circumstances, however, as is shown in the following example:

Consider a 5005 exchange which has to receive calls from an existing exchange using 10 p.p.s. If the pulse repeating relays in the existing exchange suffer from contact bounce, there is the possibility that a spurious pulse of very short duration may be generated immediately following each closure of the contacts of one of these relays. This short spurious pulse would be disregarded by equipment designed to respond to 10 p.p.s., but it might be counted as a genuine pulse by a register designed to respond to 20 p.p.s.

For this reason, the pulse receiving relays in the 5005 register are provided with a "desensitizing" circuit which can be connected when the register is used for receiving impulses from an existing 10 p.p.s. exchange or p.a.b.x.

RINGING, TONES, AND INTERRUPTED EARTH SUPPLY

The following typical supplies are provided:

TONE	FREQUENCY c/s	INTERRUPTIONS (sec.)			
		on	off	on	off
Dial tone	133	continuous			
Ringing tone	400/20	0·4	0·2	0·4	2·0
Busy tone	400	0·75	0·75		
All-trunks-busy tone (optional)	400	0·375	0·375		
Number-unobtainable tone	400	9	1		
Inverted ringing tone (for use by faultsmen, etc.)	400/20	0·2	0·4	2·0	0·4
Interrupted ringing (distributed over three sections)	20	0·4	0·2	0·4	2·0
Continuous ringing	20	continuous			
Interrupted earth supply (1)	d.c.	0·75	0·75		
(2)	d.c.	0·15	0·15		

Other frequencies and interruptions can be provided optionally.

PART 6 MISCELLANEOUS FACILTIES

DISTRIBUTORS TO MEET VARIATIONS IN CALLING RATE

NORMAL DISTRIBUTORS

The originating trunks from the distributor switches "A" are connected at the t.c.f. to the t.r.g.s in a simple form of grading using only "singles" and "pairs". Similarly, the outlets from the route switches "B" are connected at the t.c.f. to the terminating trunks on the distributor switches "A" through a form of grading. Adjustments to these gradings can be made as required from time to time to suit variations in traffic.

It is found that, for any given traffic, an increase in the number of distributor switches "A" enables the t.r.g.s to be more heavily loaded for the same grade of service. Heavier loading of the t.r.g.s also enables a saving to be made in the number of routers. It is therefore necessary to calculate the most economical combination of distributor switches "A" and t.r.g.s. Table II gives an idea of the number of distributor switches "A" per 500-line distributor which would be equipped initially for various calling rates.

The method of grouping various numbers of distributor switches "A" is shown in Fig. 18 (*a*), (*b*) and (*c*).

Fig. 18 (*c*) will be recognised as being exactly the same arrangement as that used in the router, where 16 route switches "A" are arranged with the outlets of each pair of switches connected in parallel to reduce the number of links from 400 to 200.

Space can be provided on the distributor "A" racks for fitting the additional "A" switches if the traffic should increase to an extent that could not be economically met by simple regrading of the originating and terminating trunks. However, if it is not convenient to allocate spare space in this manner, when traffic increases additional "A" switches can be fitted on a special rack located elsewhere.

An average calling rate of 0·08e for originating traffic is seldom exceeded in exchanges serving subscribers on single lines, and in small or medium-sized p.b.x. groups. Large p.b.x. groups would not ordinarily be connected to distributors as they can be more economically served in another manner, as explained under "P.B.X. Groups" page 64.

HEAVY-DUTY DISTRIBUTORS

In cases where the distributors serve large numbers of p.b.x. lines or other heavy traffic lines, the calling rate may exceed 0·08e per line. To meet this condition the trunking is modified to provide sufficient switching devices to give the required grade of service for any value of originating traffic.

An alternative arrangement, which is more economical, is to separate the heavily loaded p.b.x. lines into "outgoing" and "incoming" groups. The outgoing lines to these p.b.x.s can then be connected like outgoing junctions to the outlets of route switches "B" or second stage route switches.

The traffic in the distributor switches is thus reduced to a more normal value.

LINE I.D.F.

There is a line i.d.f. for each 500-line distributor. It consists of pairs of adjacent tags on tagblocks in the inter-rack space adjoining the line relays. These tags are normally strapped together so that all the lines in the "B" switches are arranged in directory number order.

To obtain even distribution of traffic, any line can be connected to any distributor switch "B", and still retain its original directory number within the same 500-line distributor by inserting jumpers instead of the direct straps. The jumpers are quite short, as they are within one inter-rack space.

A line i.d.f. is illustrated in Fig. 18 (*d*).

EMERGENCY CUT-OFF

On the shelf tagblocks serving distributor switches "B" there is an "originating calls" tag for each subscriber. This tag can be connected by a strap (or test link, if

TABLE II

Typical average calling rate per line. Originating calls (erlangs)	Number of originating trunks per 500 lines	Number of terminating trunks per 500 lines	Number of distributor switches "A" per 500 lines
0·04	40	40	8
0·05	50	50	10
0·06	60	60	12
0·07	70	70	14
0·08	80	80	16

preferred) to the "normal" originating call tag, in which case the subscriber always has service; or it can be connected to an "emergency cut-off" tag, in which case the subscriber will be prevented from making calls whenever the "emergency cut-off" key (one for a group of subscribers) is operated. This key provides a drastic means of stopping non-essential calls during a state of grave emergency. It does not disconnect calls which are already established, and it does not prevent subscribers from receiving calls. Emergency cut-off keys are mounted in the main end panel—the group of keys, which have a safety bar incorporated to prevent inadvertent operation, can be seen in the end panel of the nearest suite of racks in Fig. 15 (*a*).

An individual subscriber can be temporarily prevented from originating calls by the removal of the strap, or test link, from his line circuit.

P.B.X. GROUPS

SMALL AND MEDIUM GROUPS

Any line equipments in the same 500-line distributor can be grouped for p.b.x. service. This is arranged by connecting the marking wire of the subscriber's directory number to a p.b.x. marking relay instead of to his "M" terminal. When the marking relay is operated, a marking signal is applied via a chain relay selection circuit to one of the group of subscriber "M" terminals, according to the way jumpers have been connected. The call is then set up to the marked line. Each of the marking relays serves up to 10 p.b.x. lines, and two of these relays can be grouped together to serve p.b.x. groups of up to 20 lines. If all lines to a group are busy, earth is returned on the subscriber's "M" wire to the router control. If the call has originated from an operator with trunk offering facilities, the call can now be offered to one predetermined line in the p.b.x. group.

A separate directory number can be given to each p.b.x. line for night service. By using the night service number a trunk call can be offered to a particular p.b.x. line.

LARGE GROUPS

For groups exceeding, say, 20 exchange lines, it is more economical to treat the traffic outgoing to the p.b.x. as a junction route. This also allows the originating traffic of a large p.b.x. group to be spread over all the 500-line distributors. Separate directory numbers can be allocated to some of the lines in a group for night service.

METERING OF CALLS TO P.B.X. GROUPS

Terminals are provided on each p.b.x. marking relay, to which two meters can be jumpered when required. One meter records the total number of calls made to that subscriber, while the other records the number of calls lost due to all his lines being busy. Additional reference to p.b.x. traffic is made on page 82.

SHARED SERVICE OR TWO-PARTY LINES

Any two line circuits within the same 500-line distributor can be paralleled at the line i.d.f. to provide for two-party line service, with individual metering. This requires a small relay group per two-party line, which is jumpered in at the line i.d.f.

PARTY-LINE RING-BACK CIRCUITS FOR TWO-PARTY LINES

Ring-back relay groups can be provided for shared service or two-party lines, the number being based upon the traffic expected. These relay groups are connected to spare outlets on route switches "B" (or second-stage route switches). With this facility a subscriber obtains connection to a free party-line ring-back relay group by dialling a specified code. On hearing ringing tone he replaces his handset and the call is held by the relay group, which also applies ringing alternately to the positive and negative wires so that the bells of both parties are rung. When the called party answers, the ringing is tripped, thus indicating to the caller that he can lift his handset and speak.

When the caller lifts his handset, there is a delay of a few seconds before his meter is operated. This allows him to trip the ringing, without metering, by lifting and replacing his handset if he wishes to abandon an unanswered call. However, if the call is unanswered and the ringing is not tripped in this way, the ring-back circuit is forcibly released after about 1 minute.

The ring-back circuit is released normally when both parties replace their handsets.

When a call is set up to a party-line ring-back circuit, the battery-feeding relays are switched out of the t.r.g. (as a result of the outgoing junction classification). A clean metallic circuit is provided from the caller's line to the party-line ring-back circuit which supplies battery feed to the caller and holds the call.

MULTI-PARTY LINES

A multi-party line distributor is provided for 20, 40, 60, etc. party lines, and each party line can have up to 10 stations, identified by any one out of 500 directory numbers allocated for multi-party line service. Terminal-per-station intercept service is provided.

The system is suitable for use with code ringing or harmonic ringing. Revertive calls are made by dialling the directory number, replacing the handset then lifting it again when ringing ceases.

COIN-BOX LINES

The originating classification tag of the subscriber's line circuit at the line i.d.f. enables any line circuit to be used for coin-box service. The coin-box classification is stored in the register at the instant of seizure and, after dialling, is passed by the register via the router control into the coder,

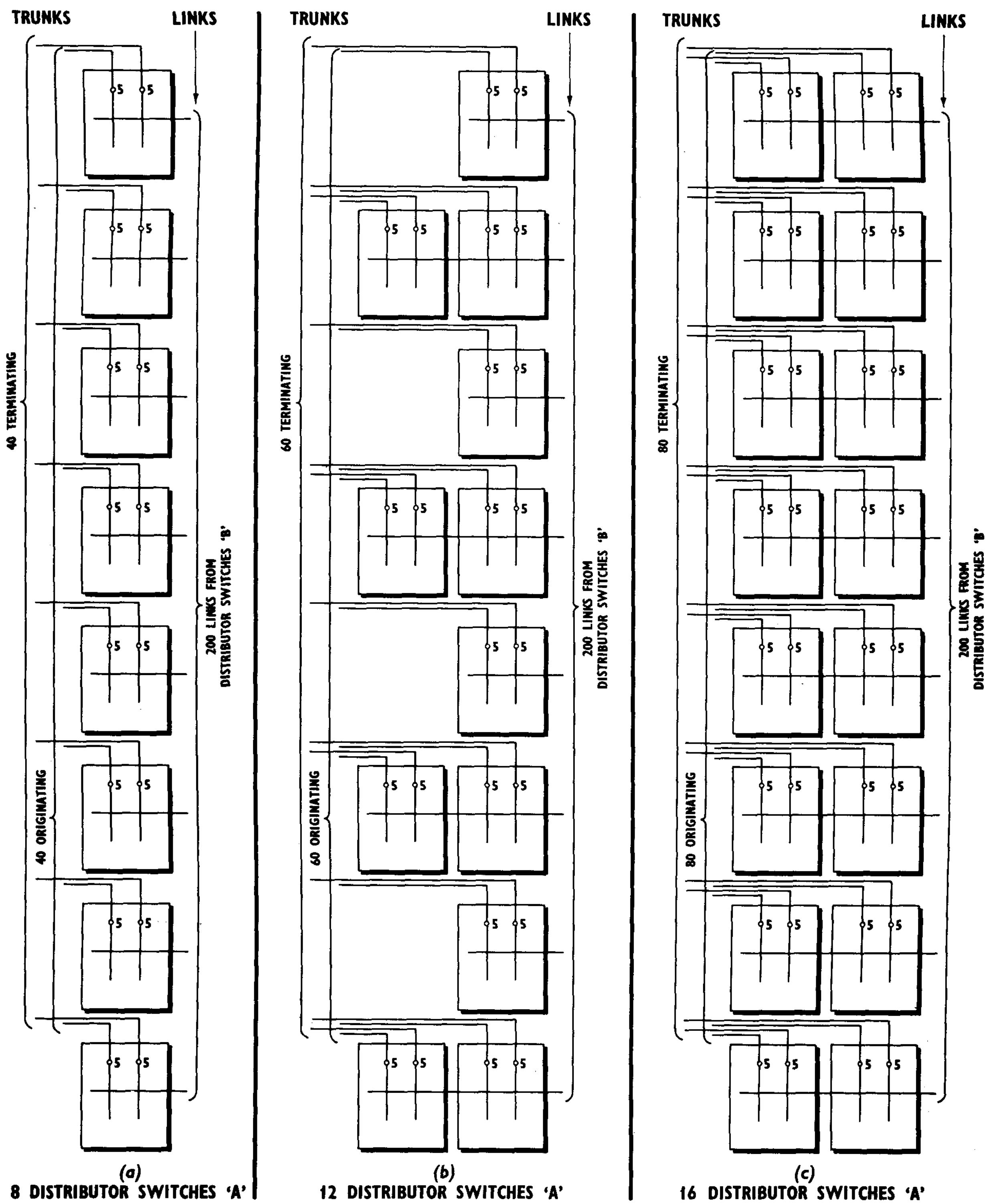


Figure 18. DUPLICATION OF "A" SWITCHES IN THE DISTRIBUTOR

so that it can prevent the call from being set up over a junction route which is barred to coin-box calls (or it can divert the call to another route). A call from a coin-box line to a manual operator can be identified by a pulse of coin-box tone when the operator answers. If the coin-box is of a type which requires revertive signals from the exchange, a suitable relay set is jumpered into the coin-box line at the line i.d.f. If these coin-box lines are lightly loaded, a small number of the relay sets can be jumpered into the links between DSA and DSB to serve a larger number of coin-box lines.

CENTRALISED SERVICE OBSERVATION

Provision can be made for observation by an operator of the service given to a subscriber by the exchange equipment and of the performance of the subscriber in dialling the number required. The operator is able to monitor the progress of the call and the quality of the tones and speech. The observation operator will be situated at some central point and will be connected by a special junction to the exchange under observation.

INTERCEPTION SERVICE (TERMINATING CALLS)

The marking wire of a subscriber whose terminating calls are to be intercepted, is disconnected at the line i.d.f. and jumpered to an "intercept" terminal. This causes a signal to be returned to the register, instructing it to abandon the attempt to set up a call to this number, and to set up a call to an operator or to an announcement machine (for changed number announcement, for example).

TERMINATING CALL DIVERSION SERVICE

A terminating call diversion relay is provided for each subscriber who requires terminating calls to be diverted to another number. It is arranged that this relay operates when the subscriber is in the "p.g." condition. Operation of the terminating call diversion relay diverts the subscriber's marking wire to the marking terminal of the diversion number, which must be in the same 500-line distributor.

When the subscriber wishes his incoming calls to be diverted he dials a code which causes his line to be released from the register and to be parked in the "p.g." condition at his line circuit. The subscriber then operates a key to maintain the loop on his line and replaces his handset.

If a more elaborate arrangement is required, a special call-diversion relay group is provided in each exchange. This enables any designated subscriber to dial a code number and cause subsequent calls incoming to him to be diverted to any other chosen number throughout the telephone network.

IN-DIALLING P.A.B.X.s

There are two methods of providing p.a.b.x. in-dial service:—

(*a*) By suffix digits, dialled by the caller after the normal telephone number to route the call to the required extension in the p.a.b.x. For example, the extensions on a 200-line p.a.b.x. could be given the numbers CENtral 1234-200 to CENtral 1234-399.

(*b*) By allotting to the p.a.b.x. extensions a block of numbers within the main exchange numbering scheme; for example, the extensions on a 200-line p.a.b.x. could be given the numbers CENtral 1200 to CENtral 1399. For internal calls the p.a.b.x. extensions would dial only the last 3 digits.

Method (*a*) requires that every register in every exchange in the network should have capacity to store the suffix digits, and that every register should be able to recognise those calls on which it must not release until the suffix digits have been dialled and re-transmitted. This may present difficulties in systems where the registers existed before in-dialling was introduced, or on systems to which subscribers in distant places may later be given direct dialling access under a national or international dialling scheme.

Method (*b*) overcomes these difficulties at the cost of extravagant use of telephone numbers.

The 5005 system is suitable for either method. If method (*a*) is used, the extra storage capacity for the suffix digits is provided in the senders so that ordinary registers can be used without alteration.

Lines to in-dial p.a.b.x.s are treated as outgoing junctions and are terminated on the outlets of the route switches "B" (or second-stage route switches).

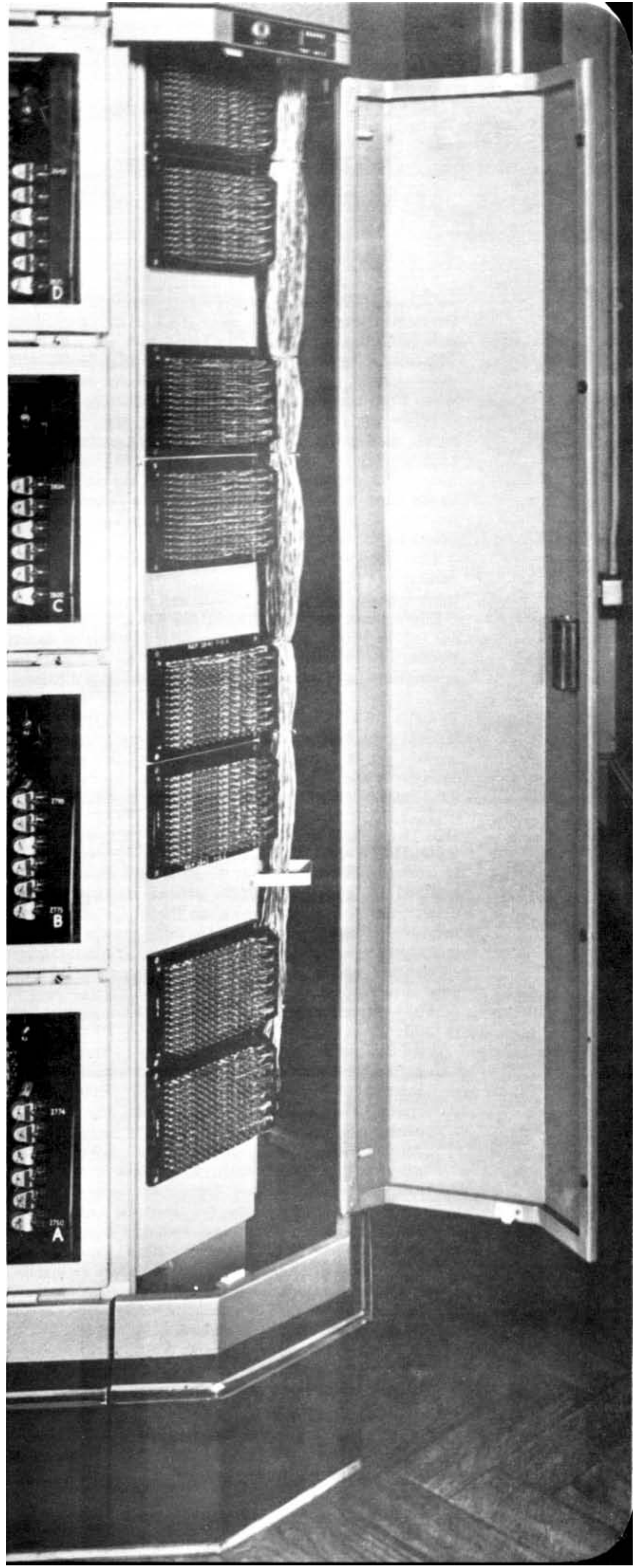
In the 5005 system, in-dial p.a.b.x.s must be given directory numbers whose thousands and/or hundreds digits are easily recognisable by the register (for example, it would be convenient if all in-dial p.a.b.x s had the same thousands digit). After the caller has dialled the "units" digit of a local call, the register seizes the router control and indicates to it that it is possible that in-dialling may be required. This causes the router control to seize the coder before proceeding to mark in the ordinary way. The coder then examines all the digits stored in the register to ascertain whether the number dialled is actually the number of an in-dial p.a.b.x. If it is, the coder instructs the router control to treat the call as a junction call. The outgoing junction classification indicates the kind of register language required by the p.a.b.x. and how many digits are to be sent.

MALICIOUS CALL HOLD-BACK

The line of a subscriber who receives malicious calls is jumpered to a malicious-call relay group. The called subscriber can, by dialling "0", signal the malicious-call relay group to give an alarm and hold the call if it proves to be a malicious one. As many malicious-call relay groups can be provided as may be required.

This facility requires a modification to each t.r.g. and if hold-back facilities over junctions are required, the outgoing t.r.g.s in the distant exchange must also be modified to receive the hold-back signals from the

Figure 18 (*d*). LINE I.D.F. IN AUXILIARY END PANEL



malicious-call relay group in the terminating exchange.

CALL TRACING

A chart is provided for each crossbar switch, shelf of t.r.g.s, shelf of the t.c.f., etc., and is accommodated inside the door of the adjacent inter-rack space.

The chart shows the origin of each inlet; for example, an outlet on a switch in the previous rank; and the destination of each outlet; for example, an inlet on a switch in a subsequent rank.

It is thus simple to trace a call in the backward or forward direction, starting from any point.

MULTI-METERING AND VARIABLE TIME INTERVAL (V.T.I.) METERING

GENERAL

Multi-metering or v.t.i. metering on outgoing junction calls is controlled by a relay group in each outgoing junction. These relay groups can be designed to provide any type of multi-metering or v.t.i. metering, of which the following are typical examples:

Multi-metering

(i) A fixed number of pulses is applied to the caller's meter when the called subscriber answers. Pulses are not repeated (that is, calls can be of unlimited duration for one charge).

(ii) As in (i) but the number of pulses is selected by the first digit or digits (up to seven) dialled by the caller.

V.T.I. Metering

(i) When the called subscriber answers, a pulse is applied to the caller's meter. Thereafter, pulses from the meter-pulse generating equipment are applied to the meter at intervals determined from the first digit or digits (up to seven) dialled by the caller. However, as the arrival of the first pulse from the generating equipment is random with respect to the start of a call, this pulse is suppressed to avoid charging for a short initial time-interval.

(ii) The meter-pulse generating equipment operates at six times the required meter pulsing rates. When the called subscriber answers, a pulse is applied to the caller's meter as before. The first six pulses to arrive from the meter-pulse generating equipment are now suppressed and the seventh pulse is applied to the meter. Thereafter, batches of five pulses from the generating equipment are suppressed and every sixth pulse is applied to the meter.

METHOD OF OPERATION

The multi-metering or v.t.i. metering relay group is connected to the "P" wire of the outgoing junction, at the originating exchange. During conversation, the speaking pair passes through this relay group without any series or shunt impedance, that is, there is a clean metallic circuit. When the call is being set up at the originating exchange, the router control receives from the coder the tariff code for the call. The router control signals this information to the multi-metering or v.t.i. relay group over the speaking pair (via the register and t.r.g.) in high-speed d.c. code. The relay group can accommodate up to 16 different tariff rates—that is, it can select one of 16 different meter-pulse wires from the meter-pulse generating machine.

When the called subscriber answers, the "off-hook" signal reaches the t.r.g. at the originating exchange. The t.r.g. applies one meter pulse to the calling subscriber's meter, and also applies a "start" signal via the "P" wire to the multi-metering or v.t.i. relay group in the outgoing junction. This relay group sends back the subsequent meter pulses to the caller's meter via the t.r.g.

This arrangement enables multi-metering or v.t.i. metering to be added to any 5005 exchange by fitting the metering relay groups in the outgoing junctions, and providing a meter-pulse generating machine. No alterations are required to t.r.g.s, registers, router controls or coders except for the insertion of the straps to associate the appropriate tariff with each combination of code digits.

TIMING OF LOCAL CALLS

If local calls have to be timed, a counting relay is fitted in the t.r.g. It is pulsed from the meter-pulse generating equipment and applies one pulse to the caller's meter at fixed intervals, for example, every three minutes.

MULTI-OFFICE NETWORK WITH COMMON GEOGRAPHICAL CENTRE

In a multi-office network in which several exchanges are grouped in one geographical centre, for meter tariff determination it is economical to install the meter-tariff determining equipment, the v.t.i. relay groups, and the meter-pulse generating equipment at one or more tandem exchanges through which all calls requiring metering must pass in order to leave their local area.

When this scheme is adopted, the following procedure is used:

(i) At the originating exchange on a call requiring v.t.i. metering, the battery-feeding bridge is switched out of the t.r.g. (by the outgoing junction classification) and the caller is connected to the outgoing junction via a clean metallic loop. The outgoing junction relay group supplies battery feed to the caller and applies a meter pulse to the caller's meter every time it receives a reverse current condition from the tandem exchange.

(ii) At the tandem exchange, the incoming t.r.g. serving each junction on which v.t.i. metering is provided, is arranged to transmit meter pulses back to the originating exchange by means of "silent reversals". It does not return normal answer signals. The silent reversal is produced by gradually reducing the current in the loop circuit to zero, gradually increasing it to the normal value in the reverse direction, then after a short pause, reversing the process to return to the normal loop current.

(iii) At the tandem exchange, v.t.i. relay groups are provided in those outgoing junctions which lead to places for which there is a v.t.i. tariff.

(iv) Silent reversal signalling can be used on physical junctions, or on carrier channels with out-of-band line signalling.

MULTI-METERING BY "COMPUTED IMPULSE" CONTROL FROM TANDEM EXCHANGE

If the tandem exchange is of the type which returns meter tariff information to the 5005 exchange by sending multi-frequency signals ("computed impulses") over the junction, the senders at the 5005 exchange are arranged to receive this information after completion of sending. On receipt of a "computed impulse", the sender applies a high speed d.c. signal to the outgoing junction relay group exactly as was done by the router control in "Methods of Operation" and the metering of the call takes place as there described. This computed impulse arrangement is more complicated than either of the arrangements described above and it would therefore be used only if the tandem exchange were of a type which required it.

QUEUEING SYSTEM

Queueing equipment can be provided to ensure that calls to operators (enquiry, trunk call booking, etc.) are not lost when all operators are busy, but are held in a queue and are answered in order of arrival as operators become free. The equipment is built in units or "fields", each comprising (typically) six crossbar switches with their controlling relays. Each field serves up to 20 operators, and has 19 queue positions in which calls wait when all operators are busy. As operators become free, calls are connected to them from the queue in the call arrival order.

The 60 inlets in the typical field of six crossbar switches are called, collectively, the "vestibule" and this serves the 20 operators plus 19 queue positions via a total of 39 outlets.

In a typical arrangement for a 10 000 line exchange with six routers, 20 outlets from each router (that is, 120 outlets) would be connected to the 60 inlets in a simple form of grading. A vestibule of 60 inlets, instead of 39, is provided primarily in order to ensure that access to the queueing system shall not be restricted by congestion in the router links. A secondary use of the vestibule is to provide a place in which calls can wait when the queue is full. Any calls waiting in the vestibule are allowed to enter the queue in random order when places become free.

If there are more than 20 operators, several fields can be provided and calls enter fields in a multi-field system as follows:

—at random when all queues are empty;
—fields with no queue in preference to those with queues;
—at random when there is queueing in all fields;
—fields with queue places free in preference to fields with full queues;

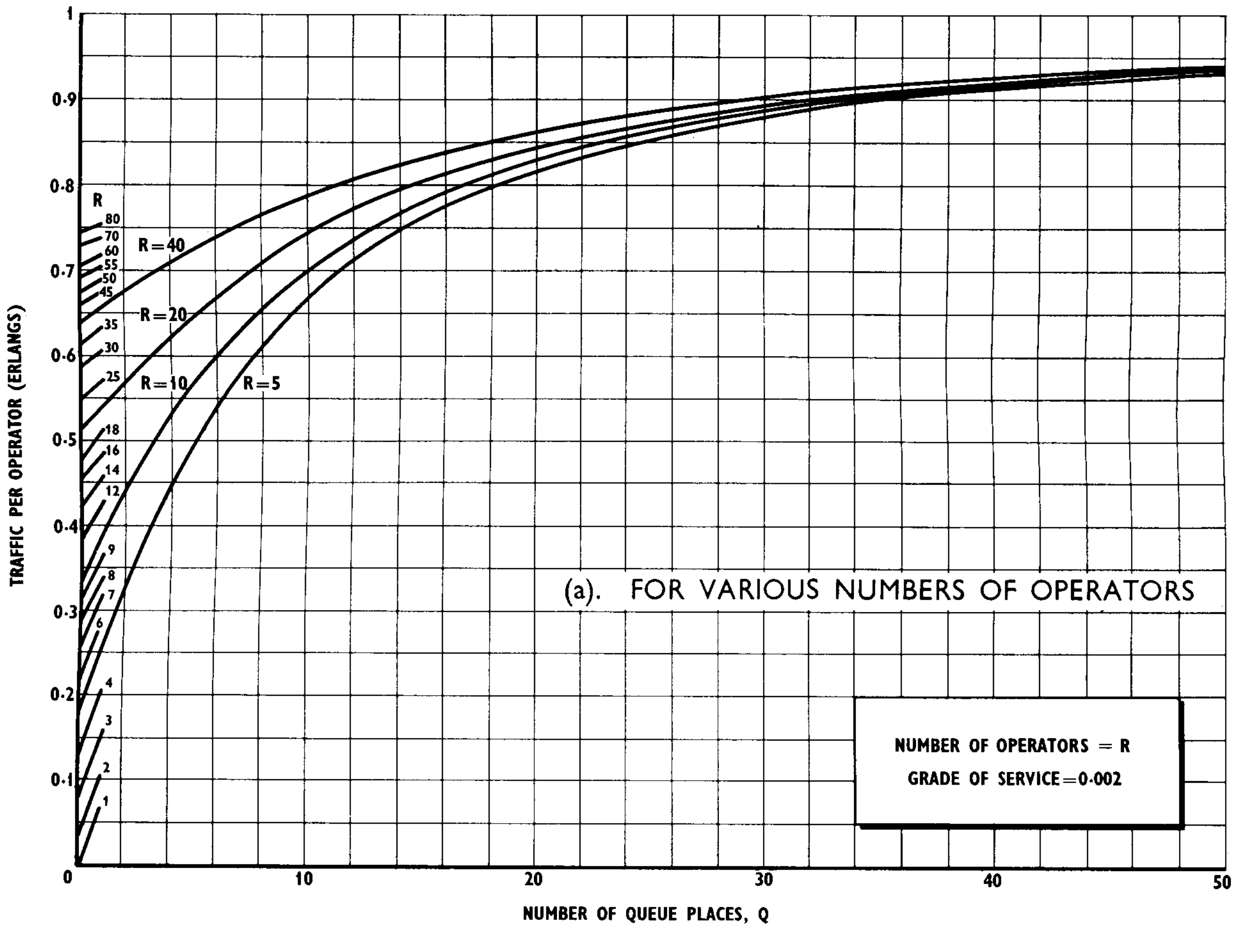


Figure 19 (*a*). GRAPHS OF TRAFFIC PER OPERATOR/NUMBER OF QUEUE PLACES

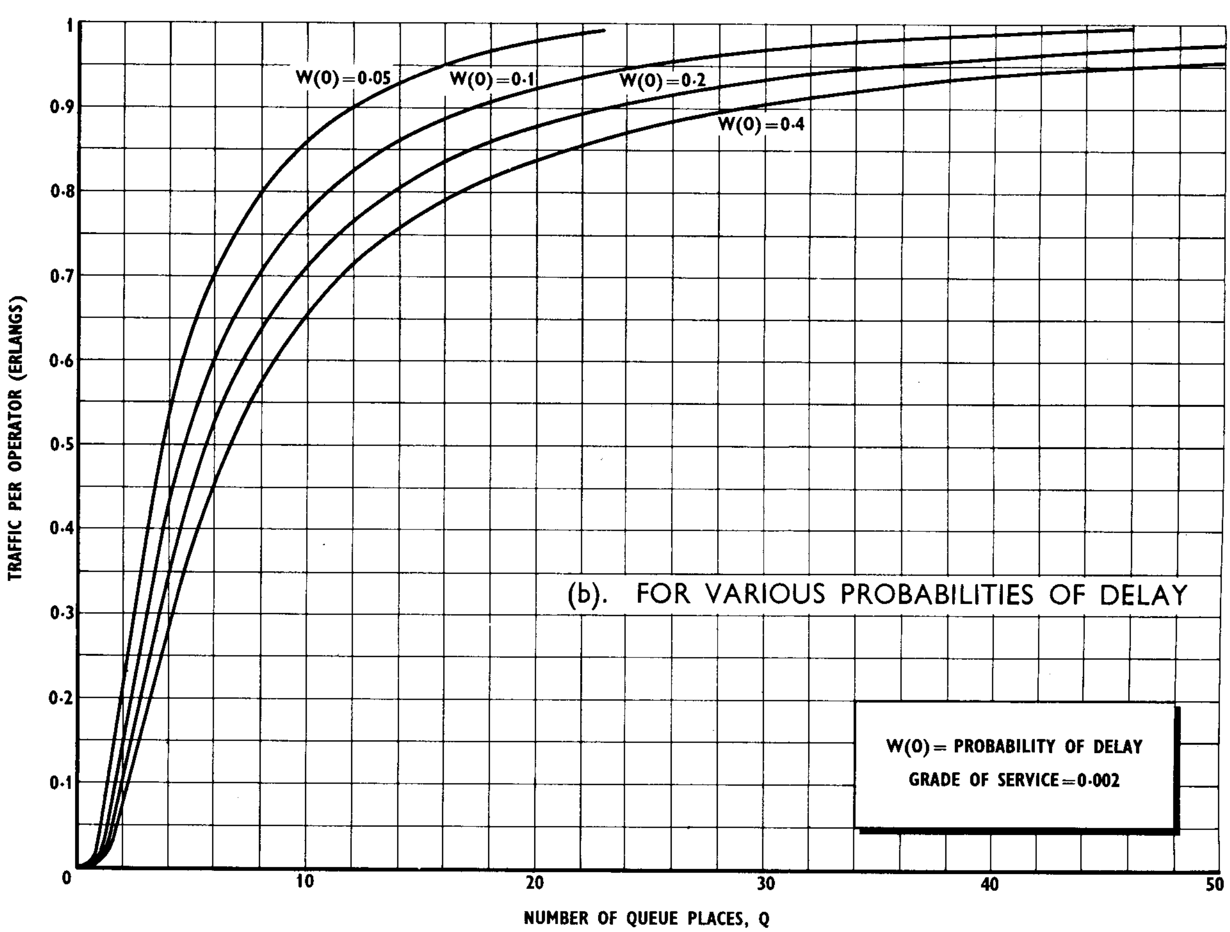


Figure 19 (*b*). GRAPHS OF TRAFFIC PER OPERATOR/NUMBER OF QUEUE PLACES

—at random when all queues are full. These calls wait in the vestibule.

—Some fields may be closed in non-busy hours.

Fig. 19 (*a*) shows the loading per operator for various numbers of operators (from 1 to 40) and a queue length of up to 50 places, for a grade of service of 0·002. If these curves are used for a queue of 19 places, then 0·002 is the probability that a call will have to wait in the vestibule, not the probability that it will be lost altogether.

It will be seen that queueing enables the load per operator to be quadrupled, without lowering the grade of service if the number of operators is small—say 5; but the improvement in operator loading is much less for larger numbers of operators.

Fig. 19 (*b*) shows the probability of delay on all calls, for a range of "traffic per operator" values and number of queue places.

Figs. 20 (*a*) to 20 (*d*) show the probability that delay on all calls will exceed various percentages of the average holding time per call, over a range of "traffic per operator" values and with various numbers of operators.

Fig. 21 (*a*) shows the mean waiting time (in proportion to average holding time) for all calls including those which do not wait at all, over a range of values of traffic per operator and for various numbers of operators.

Similarly Fig. 21 (*b*) shows the mean waiting time (in proportion to average holding time) for those calls which do wait.

Fig. 22 shows the average number of queue* places occupied, for the traffic per operator range considered in the previous figures. There are two points of interest in this figure. One is that, for an average of only 2 or 3 queue places occupied, there is a probability of 0·002 that all 19 places will be occupied so that the next call will have to wait in the vestibule.

The second point of interest is that the mean number of queue places occupied represents the number of erlangs of extra traffic added to the exchange as a whole, by the adoption of a queueing system.

From the queueing equipment, indications are given to the supervisor:

when queueing has started in each queue
how many calls are waiting in each queue
which queues are full.

*The mathematical theory of queueing, on which this information is based, is dealt with in detail in an article entitled, "Loss and Delay in Telephone Call Queueing Systems", by J. R. W. Smith and J. L. Smith, published in the *A.T.E. Journal*, Vol. 18, No. 1.

1-V.F., 2-V.F. AND OUT-OF-BAND LINE SIGNALLING SYSTEMS

GENERAL

Junctions can be operated over carrier channels by providing suitable outgoing relay groups in the outgoing junctions, and by providing suitable incoming t.r.g.s for terminating the incoming junctions. The outgoing and incoming relay groups can be interconnected for bothway working.

When an outgoing junction with the appropriate relay group is seized, the junction classification causes the battery-feeding relays to be switched out of the t.r.g. and a clean metallic circuit is provided from the caller's line to the outgoing relay group. This group supplies battery feed to the caller, holds the call, and also applies the appropriate meter pulses to the caller's meter.

OUTGOING RELAY GROUPS

Outgoing relay groups are of four types:

1-V.F. This uses a single frequency for all signals. A typical frequency is 2 280 c/s. Signals such as "seize", "impulsing" (at 10 or 20 p.p.s.), "answer", "clear back", "clear forward" and "release guard", are differentiated by length of signal.

2-V.F. This uses two frequencies, typically 2 040 c/s and 2 400 c/s, in various combinations to provide the signals as above.

Out-of-band. "E and M" signals are accepted from, and given to, the carrier channel.

3-wire. These are suitable for use on junctions which go to other exchanges designed for 3-wire junction working.

All four types of outgoing relay group give battery feed towards the caller, accept loop-disconnect signals from the caller, and return a reverse battery "off-hook" signal towards the caller.

The "out-of-band" outgoing relay set can be arranged to accept out-of-band signals from the distant exchange as meter pulses, analogous to the "silent reversal" multimetering scheme described on page 68.

INCOMING T.R.G.s

Incoming t.r.g.s are of two types:

(i) *Loop-disconnect.* These are suitable for physical junctions. They are also suitable for carrier junctions terminated on 1-v.f. or 2-v.f. relay sets which present loop-disconnect signalling conditions to the t.r.g. and accept reverse battery "off-hook" signals from the t.r.g. They can also be used, with a slight modification, for terminating 3-wire junctions.

(ii) *Out-of-band.* These are very similar to the loop-disconnect type, but are arranged to accept and give "E" and M" signals from and to the carrier channel.

LINE SIGNALS AND DIGITAL SIGNALS

Outgoing relays groups on all the above line-signalling systems can be used for all signalling purposes, including loop-disconnect impulsing at 10 or 20 p.p.s. or they can be used solely for the seizing, answering and clearing signals, leaving the digital information to be passed from senders to registers in multi-frequency code. M.F. code signal frequencies must not conflict with the frequencies used for the line signals.

Link-by-link working is always used for line signals.

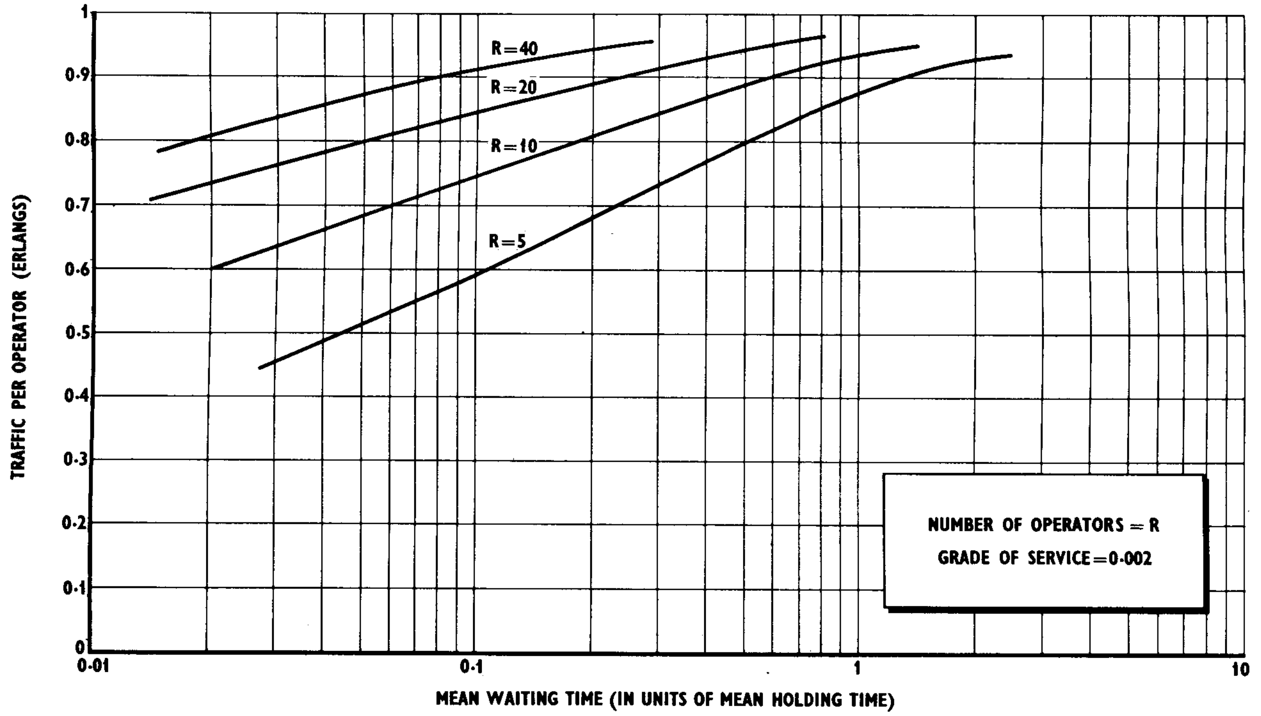


Figure 21 (*a*). GRAPHS OF TRAFFIC PER OPERATOR/MEAN WAITING TIME, FOR VARIOUS NUMBER OF OPERATORS

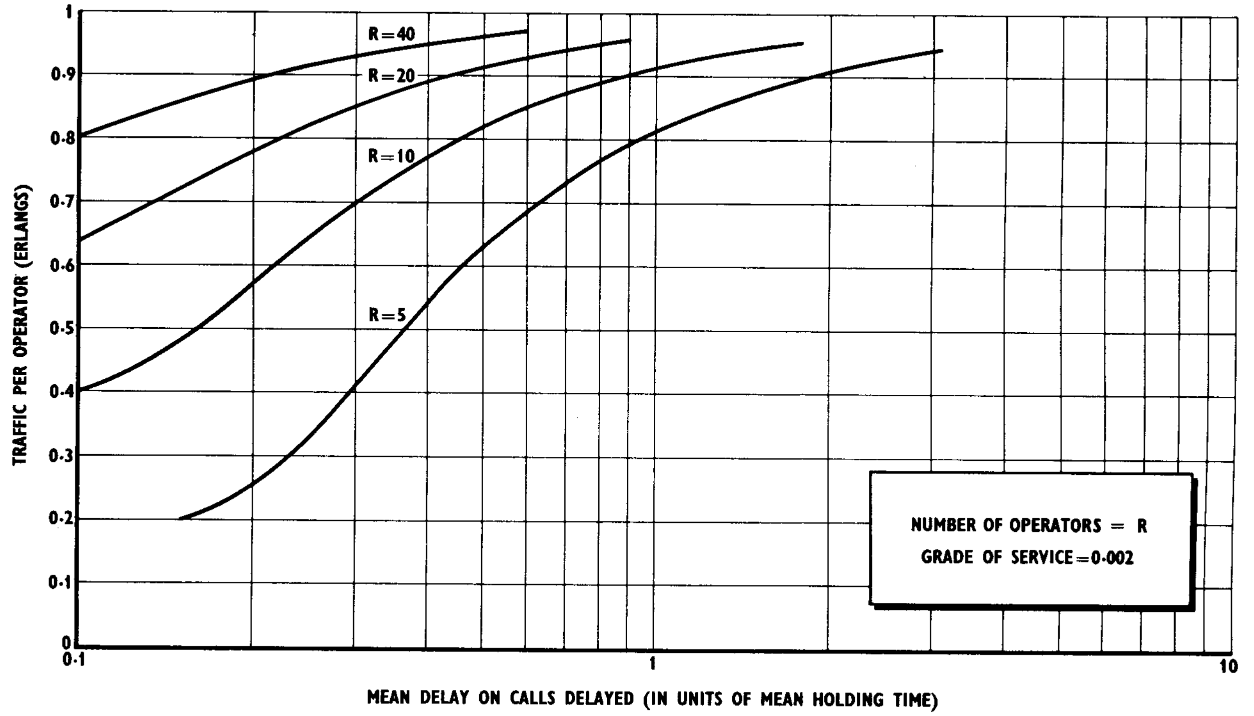
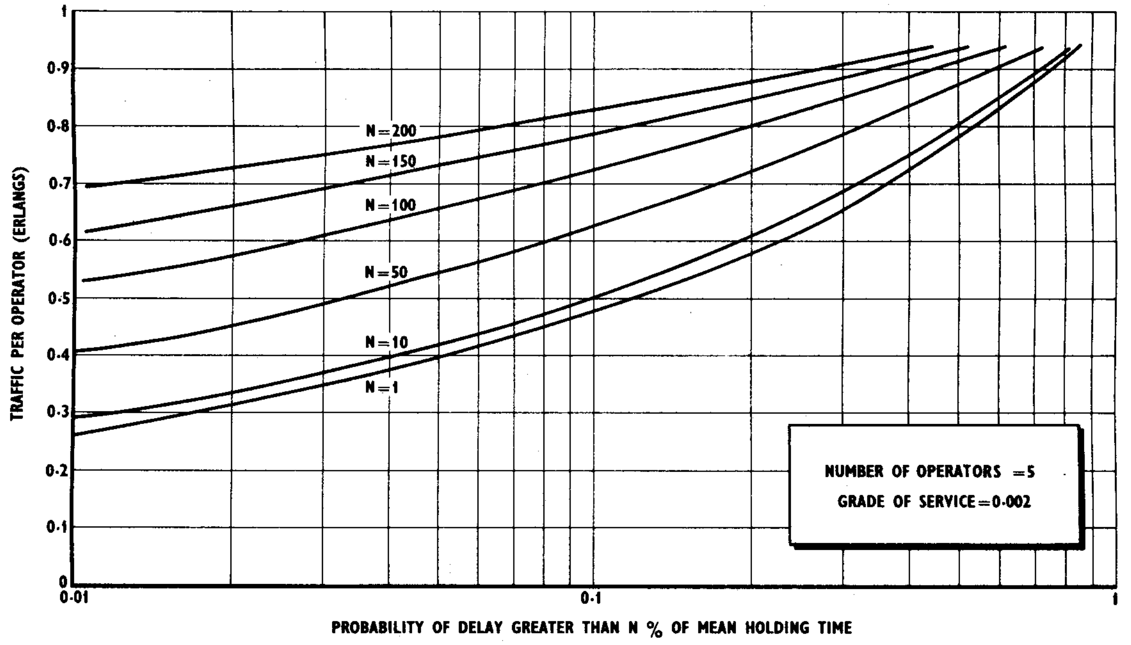
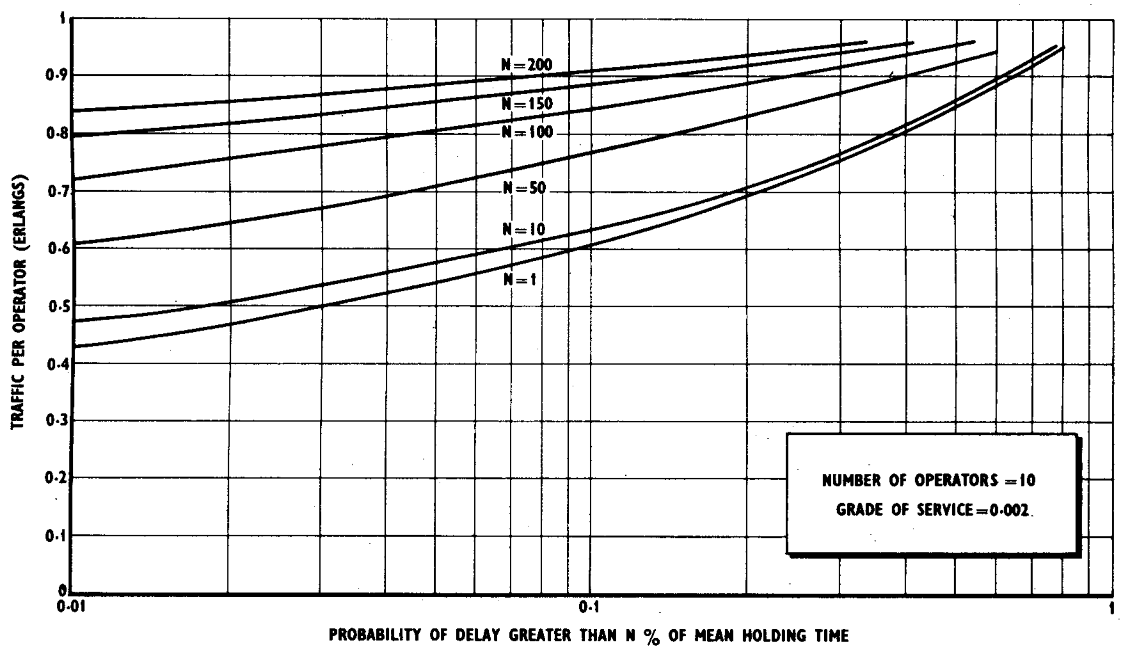


Figure 21 (*b*). GRAPHS OF TRAFFIC PER OPERATOR/MEAN DELAY ON CALLS DELAYED, FOR VARIOUS NUMBERS OF OPERATORS

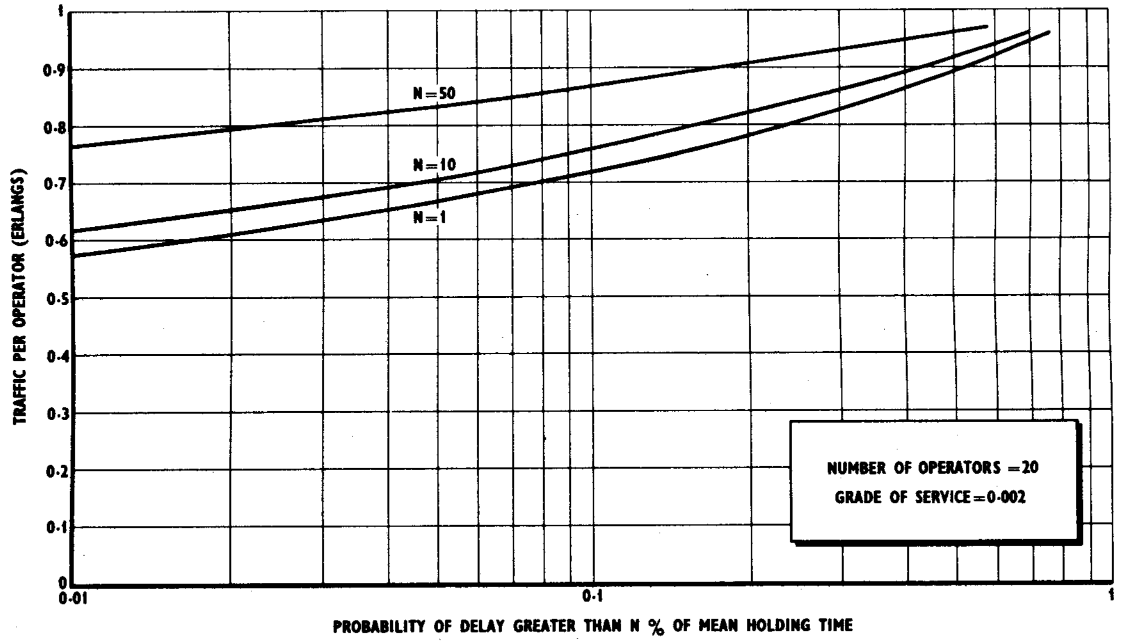
Figure 20. GRAPHS OF TRAFFIC PER OPERATOR/DELAY PROBABILITY



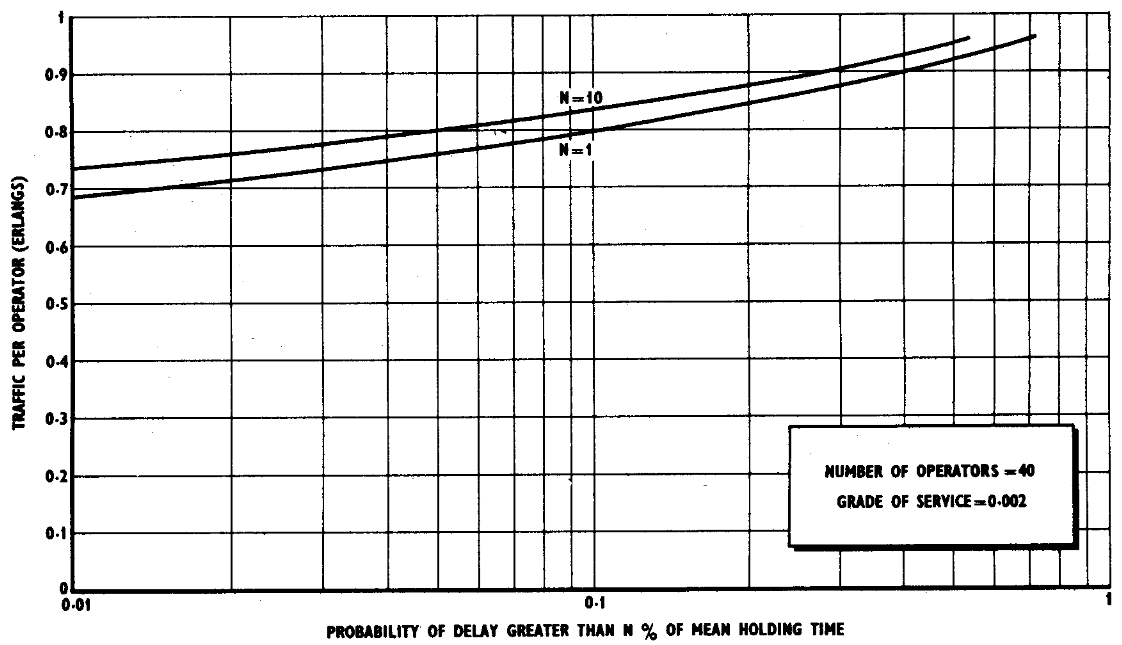
(a). FOR 5 OPERATORS



(b). FOR 10 OPERATORS



(c). FOR 20 OPERATORS



(d). FOR 40 OPERATORS

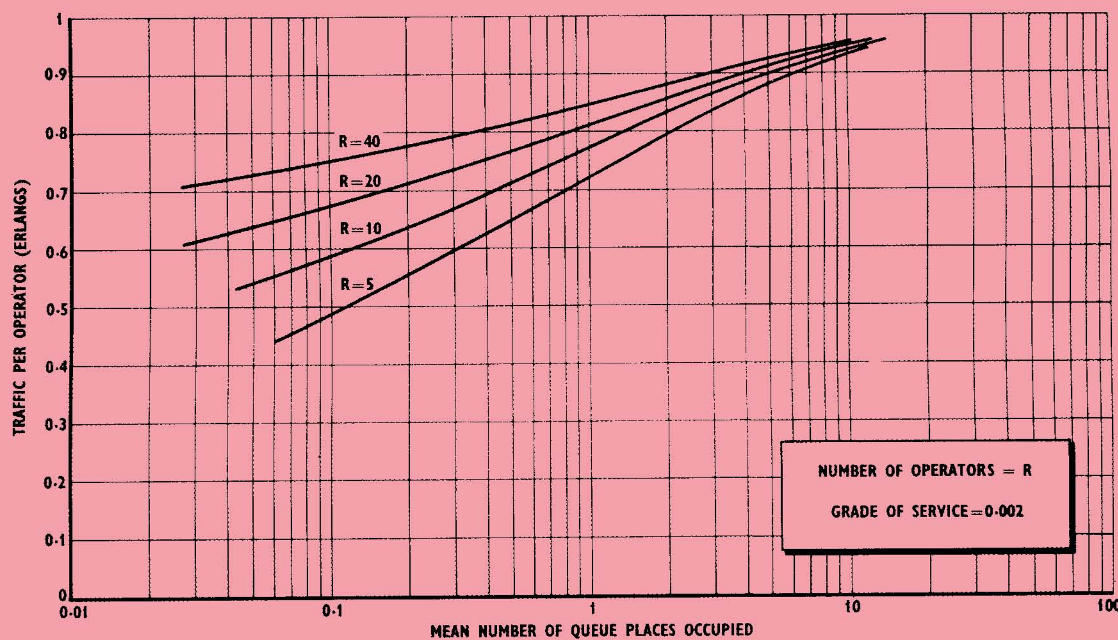


Figure 22.
GRAPHS OF TRAFFIC PER OPERATOR/QUEUE PLACES OCCUPIED, FOR VARIOUS NUMBERS OF OPERATORS

HIGH SPEED MULTI-FREQUENCY (M.F.) INTER-REGISTER SIGNALLING

GENERAL

The m.f. system requires the provision of m.f. registers for incoming calls and m.f. senders for outgoing calls instead of the loop-disconnect types in each case.

This makes very little difference to the cost of the exchange as a whole, because, although the cost of the m.f. register or sender is greater than that of the loop-disconnect version, the holding time of the former is shorter, so fewer are required.

The possibility of omitting incoming registers altogether and mounting the digit receiving and storing equipment in the router control is described on page 34, and reasons were given for preferring the separate identity of incoming registers, even when their holding time is of the same order as that of the router control.

The preferred m.f. system uses frequencies 700, 900, 1 100, 1 300, 1 500 and 1 700 c/s for forward digital signals in two-out-of-six code; and frequencies of 1 900 and 2 100 c/s for instructions in the backward direction. These frequencies are referred to as a, b, c, d, e, and f for the forward direction, and g and h for the backward direction.

The system can be used on any type of 2- or 4-wire physical line or carrier channel, in combination with any type of line signalling system, provided that the above frequencies do not conflict with the frequencies used for line signals.

There are two versions of the m.f. system:

(i) "Compelled signalling", in which each digit is demanded by a backward signal as soon as the distant register is ready to receive it.

(ii) "Non-compelled signalling", in which the register, when ready, initiates a backward signal to instruct the sender to start sending. The sender then sends out all digits unless restrained by a "stop send" signal from the distant register.

The facility for using "end-to-end" or "link-by-link" signalling for digital information is provided optionally by means of straps in the registers.

Other frequencies can, of course, be provided by changing the frequency generator and receiving filters.

TYPICAL NUMBERING SCHEME

For the purpose of examining the above signalling systems, a network with a typical 7-digit numbering scheme is assumed. The first three digits are the "code digits", for directing the call to the required 10 000 line exchange, and the last four digits are the "numerical digits", for selecting the wanted subscriber in that exchange.

COMPELLED SYSTEM

General

In the compelled system, the sender at the originating exchange sends the first digit on receipt of frequency "g" from the incoming register at the distant exchange. Subsequent digits are demanded successively by the transmission of frequency "h" from the remote register as soon as it is ready for the next digit.

Link-by-link Working

If link-by-link working is used, the complete number is sent from each exchange to the next one, and there stored and re-transmitted complete. When the call reaches an "end" exchange, the sender at the previous exchange omits the code digits and sends only the numerical digits.

End-to-end Signals

If end-to-end signalling is used, the call is set up through a tandem exchange on receipt of the code digits, and the register at the tandem exchange then releases. If the next exchange is an "end" exchange, it will require only the numerical digits of the telephone number. It will therefore send back frequency "h" to instruct the sender at the originating exchange to send the next digit. If, however, the call has to pass through a second tandem exchange, the register there sends back frequency "g" to demand the first code digit from the sender at the originating exchange. The other digits are then sent successively in response to frequency "h". This process can go on through any number of exchanges.

If the incoming register recognises a code which indicates that the number will have more than seven digits, it seizes a sender in which to store all digits after the seventh digit.

Speed of Sending

The speed of sending when using the compelled system depends upon the propagation time of the line or carrier channel, and upon the time required for recognition and storing in the register.

Over a carrier channel a few hundred miles long, it would be possible to send and store about 8 digits per second, but for distances of several thousand miles the maximum reliable sending speed would be 2 or 3 digits per second.

NON-COMPELLED SYSTEM

In the non-compelled system, the sender at the originating exchange sends all digits on receipt of frequency "g" from the register at the distant exchange. With this arrangement the call can be set up either link-by-link or end-to-end. The register at each tandem exchange returns frequency "g" to demand the entire number, starting at the first digit.

If the incoming register recognises a code which indicates that the number will have more than seven digits it sends back frequency "h" continuously, which means "stop sending" in the non-compelled system. The incoming register now seizes a sender in which to store the digits over and above seven, and then removes frequency "h" to allow the sender at the originating exchange to continue its interrupted sending. The speed of sending in the non-compelled system is about 8 digits per second and is independent of the propagation time of the line and thus of the length of the line.

SECURITY MEASURES

On setting up a call to an outgoing junction whose classification requires m.f. sending, the router control does not release until it has monitored the arrival of frequency "g" from the register at the distant exchange. If this frequency does not arrive within a "time-out" period of about one second, the router control instructs the register to release the call, and to make a second attempt using the other router control, and therefore choosing a different junction if one is available. The router control records details of the failure on traffic analysis meters or on a fault recorder if one is provided.

END OF SELECTION

If the objective exchange is 5005 type, and if m.f. inter-register signalling is used on all the junctions through which the call passes, the register at the objective exchange sends back frequencies "g" and "h" in combination to indicate to the sender at the originating exchange one of the following four conditions:

(*a*) Subscriber free, call established;
(*b*) Subscriber busy;
(*c*) Subscriber unobtainable;
(*d*) All trunks busy.

On receipt of signal (*a*), the sender and register at the originating exchange release. On receipt of signal (*b*), (*c*), or (*d*), the originating sender and register release after instructing the t.r.g. to release the outgoing junction and return the appropriate tone to the caller. If the objective exchange does not use m.f. inter-register signalling, the register at the last exchange which does returns the "subscriber free" end-of-selection signal as soon as it has established the call to an outgoing junction. If the subscriber is subsequently found to be busy or otherwise unobtainable, the appropriate tone is returned from the objective exchange over the junctions to the caller.

TRAFFIC RECORDER

The Traffic recorder enables the traffic to be read directly in erlangs in various portions of the common apparatus. It comprises two 5-bridge crossbar switches with control relays and a group of meters.

It is connected to tagblocks on the t.c.f. from which jumpers can be connected to the "P" wires of t.r.g.s, registers, etc. It has the following basic capacity which may be doubled, trebled, etc., by fitting additional equipment.

(*a*) 20 fields (long holding time) of 40 trunks each, scanned once every 24 seconds, for conversational paths, etc.

(*b*) 20 fields (long holding time) of 20 trunks each scanned once every 24 seconds, for conversational paths, etc. Adjacent fields of (*a*) and (*b*) may be connected to give fields of 60 trunks.

(*c*) 4 fields (short holding time) of 10 trunks each, scanned once every 4 seconds, for registers, etc.

(*d*) 4 fields (very short holding time) of one trunk each, scanned once every 200 ms. for router controls, etc.

A complete test cycle lasting for 40 minutes gives readings in erlangs to two places of decimals for the fields with the long and short holding times, and to three places of decimals for the fields with the very short holding times.

There is also a delay-sampling circuit which gives the average delay in seizing a register after applying a loop to a test line.

The traffic recorder may be set to record the traffic in "erlangs" or "unit calls per hour".

EXTRA-NUMERICAL DIGITS FOR CLASSIFICATION SIGNALS

All loop-disconnect registers and senders are capable of counting up to 12 impulses in one train. All m.f. registers and senders are capable of receiving and sending up to 16 combinations in two-out-of-six code.

The additional or "extra-numerical" digits are used for passing classification signals from one register to another, in the form of prefix digits.

PUSH-BUTTON DIALLING

Push-button dialling can be used instead of normal dialling by replacing the subscriber's dial by a push-button-operated digital sender, and providing registers having suitable digital receivers instead of, or as well as, the normal impulse counting circuits. All push-button-operated digital senders developed to date cost more than conventional dials, and this extra cost is not wholly offset by the saving in registers resulting from shorter register holding time.

The cheapest and simplest form of push-button dialling uses a d.c. code, with an earth connection and two rectifiers at each telephone. A system using this method can be supplied in place of normal dials and registers if required.

TRUNK OFFERING

The classification of calls from manual operators is signalled by the incoming t.r.g. to the register, and the register passes this information to the router control when the call is marked.

When the called subscriber's line is busy, the subscriber's "M" wire is connected to earth at his line circuit. On detecting this earth, the router control sends a "trunk offer" signal into the 500-line marker which temporarily unbusies the line which is being marked, to allow a second call to be set up in parallel with the first one, that is, the busy condition on the called subscriber's line is overridden.

The router control, via the register, instructs the t.r.g. not to complete the speech path from the calling to the called side but to return busy tone to the operator. The register and router control then release. On hearing busy tone, the operator can offer the call by applying earth to the loop of the outgoing junction. This causes the t.r.g. to remove busy tone and to complete a speaking circuit for the operator to the called subscriber via capacitors.

If the called subscriber now replaces his handset, his bell will ring and the offered call is automatically completed in the normal way. If the wanted subscriber did not originate the call which is being interrupted, the originator of it must also hang up. The operator receives normal on-hook/off-hook supervision during this procedure.

If, or when, the called subscriber replaces his handset again, the operator can re-ring his number, if necessary, by earthing the loop.

ACCESS FROM TEST DESK TO SUBSCRIBERS' LINES

A 4-wire test junction is provided from the test desk, and is terminated on a special t.r.g. designated "t.r.g. incoming from test desk" (t.t.r.g.), which is fitted instead of a normal incoming t.r.g.

If one test desk serves several exchanges, a separate 4-wire junction is required from the test desk to each exchange. These junctions can also be used as last-choice regular junctions incoming from their respective exchanges to the exchange where the test desk is located, that is, the 4-wire junction is a bothway junction which carries test desk traffic over four wires in one direction, and regular traffic over two wires in the other direction.

The test clerk can set up a call to any line via the regular switch trains by seizing the appropriate junction to a t.t.r.g. and dialling the last four digits of the number. The classification of the t.t.r.g. tells the register how many digits to accept, and also to provide trunk offering if the required number is busy.

When the call has been set up, it is held over two wires of the 4-wire junction from the test desk. The t.t.r.g. provides a clean metallic circuit from the test desk to the called subscriber's line over the other two wires.

If the called number is busy or in the "p.g." condition, the call is set up by trunk offering procedure but is not switched through at the t.t.r.g. The latter, however, returns busy tone to the test clerk who can then, at his discretion, cause the t.t.r.g. to switch through by depressing his "offering" key to earth the loop.

The test desk circuit provides ringing and battery feed, etc. to enable the test clerk to speak to the subscriber.

The distributor switch "B" handles both originating and terminating calls from and to the 25 subscribers' lines which it serves. When a call is set up from the test desk over the regular switch train to a subscriber's line, the subscriber's line circuit is in a terminating call condition and it is not therefore possible for the test clerk to simulate an originated call on this same circuit. The test clerk has facilities for testing through the subscriber's line circuit towards the line, but not from the line into the exchange. If he finds that the line and telephone are in order but that the subscriber is unable to make calls, he must order inspection of the line circuit.

However, if it is necessary to provide the test clerk with means of testing from the subscriber's line circuit into the exchange, a special switch train is provided to give him access to each subscriber's line for simulating originating calls.

AUTOMATIC TEST DESK

This desk is connected to ten spare junction outlets in parallel on route switches "B", or to one outlet on a second-stage route switch.

The classification of the junction to the automatic test desk causes the local t.r.g. to switch out its battery-feeding bridge and leave a clean metallic circuit from the called line to the desk, where the call is held by earth applied to the "P" wire.

A line maintenance officer can gain access to the automatic test desk by dialling a spare junction code (usually a 3-digit number), and when the call is set up he hears ringing tone. He then dials a further digit and replaces his handset. The desk holds the call and tests the line for wire-to-wire and wire-to-earth insulation. It then rings the line and when the maintenance officer lifts the handset he receives a tone which indicates the state of the insulation. Other tests which can be made include dial speed and dial impulse ratio tests. A constant level tone is transmitted to the line so that the attenuation of the circuit can be measured at the subscriber's premises with a portable db meter. Ringing can be applied to either wire, for test of party-line telephones.

AUTOMATIC LINE INSULATION TESTER

The automatic line insulation tester connects itself from a special t.r.g. to all subscribers' lines in directory number sequence, using the normal switch train. It tests the insulation via the telephone bell and capacitor, at the rate of about 20 lines per minute.

The directory numbers of lines whose insulation is below specified limits are recorded on a teleprinter or teletype for later attention by the test clerk.

Two insulation limits are imposed, the precise figures being adjustable between 50 000 ohms and 2 megohms; these limits are the "service" limit, for satisfactory operation of the circuit, and the "observation" limit, which indicates the desirability of attention in order to prevent the development of a fault condition.

CALLING LINE IDENTIFICATION (C.L.I.)

Calling Line Identification can be provided in order to identify the calling number on:—

- a call to an emergency number, such as "police" or "fire";
- a long distance call of which details have to be recorded, for automatic accounting purposes, on a "toll ticket".

The equipment for an automatic toll ticketing system is not necessarily fitted in the telephone exchange whose subscribers it serves; in fact, it is usually more economical to place this equipment in the trunk transit exchange. Automatic toll ticketing systems are not therefore described in this bulletin. However, these systems require calling line identification. There are three methods:—

Verbal: When the register at the trunk transit exchange has received the dialled digits from the register at the originating exchange, the caller is extended to an operator. The caller then advises his own number and the operator keys this into the automatic toll ticketing equipment (and checks back on a percentage of calls).

Dialling: When the caller has dialled the required number, he dials his own number. This latter number is stored in the automatic toll ticketing equipment. (As the caller may have to dial a total of 17 digits, this system is not widely used.)

Automatic: The automatic c.l.i. facility for the 5005 system will be described.

In a 5005 exchange in which c.l.i. is provided, the "P" wire on each subscriber's line is corrected via one rectifier to a "hundreds and units" wire (HU) and via another rectifier to a "thousands and tens" wire (MT).

There are 100 HU wires and 100 MT wires in a 10 000 line exchange.

These two hundred wires are connected via the contacts of access relays, to a number of identifiers (typically two).

Outgoing junctions on which c.l.i. is required are provided with outgoing junction relay groups which have access to the identifiers. On receipt of an "identify" signal from the distant exchange (this is usually the answering signal, but it can, for example, be a different signal, applied by a manual operator) the o/g junction relay group seizes an identifier. The identifier applies positive pulses to the "P" wire at the o/g junction relay group. These positive pulses are of short duration (about 2 milliseconds each) and do not therefore operate the caller's meter. The voltage of the positive pulses exceeds 50 volts (i.e. it is greater than the voltage used for positive battery metering).

These positive pulses pass via the rectifier matrix on to one MT wire and one HU wire, into the identifier. The two wires on to which the pulses pass form one unique combination, out of 10 000 possible combinations.

The identifier accepts this unique combination and passes the caller's number in two-out-of-five code into the o/g junction relay group where it is either

(*a*) perforated on a tape for subsequent use in the toll ticketing system

or (*b*) transmitted over the junction to the manual operator at the distant exchange, for display on a group of four cold cathode tubes, each having 10 cathodes in the shape of the ten numerals.

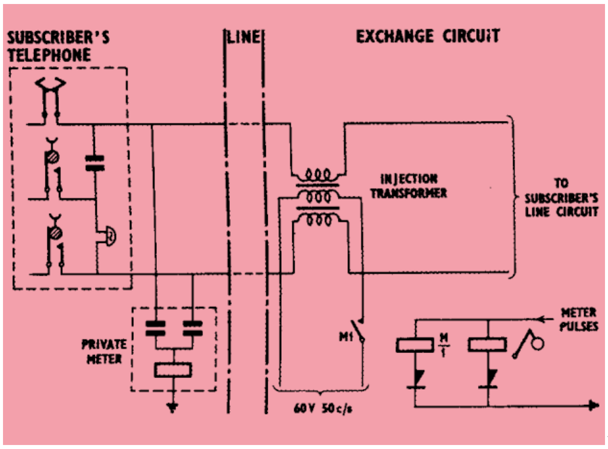


Figure 23.
CIRCUIT FOR METER AT SUBSCRIBER'S PREMISES

METERS AT SUBSCRIBERS' PREMISES

A meter can be fitted on a subscriber's premises if required. This meter is operated by pulses of 50 c/s current applied at the exchange via a series injection transformer to both wires of the subscriber's line in parallel. The pulses can be applied by an extra relay at the exchange, wired in parallel with the subscriber's meter. Alternatively, special subscribers' meters with pulse control contacts can be fitted at the exchange in place of the normal meters. The meter at the subscriber's premises is connected between earth and the subscriber's line via two capacitors (Fig. 23).

CALLS TO SPECIAL SERVICES

Calls to special services are made by dialling a code of one or more digits. Outgoing junctions to special services are connected to the outlets of route switches "B" (or to second-stage route switches). The register can be arranged, by means of the outgoing junction classification, to send forward a classification digit to route the call to a suitable answering circuit (for "coin box", "trunk calls barred" etc.), or the caller's own number can be sent forward if the exchange is provided with c.l.i. equipment.

Manual hold can be provided on calls to special service lines.

On these special service calls, the subscriber's meter operation can be automatic or controlled by the special service operator, or the meter can be prevented from operating on non-chargeable calls.

RECORDED ANNOUNCEMENTS

Two types of announcement machine are available suitable for connection to outlets of route switches "B" or second-stage route switches. The two types of machine are:

The ten-second announcement machine is intended for short, standard announcements in connection with the operating of the telephone system; typical announcements being—"The number has been changed, please ring the enquiry operator" or, "This number is no longer connected";

The three-minute announcement machine is intended for weather forecasts, sports results, etc., and fresh announcements can be recorded from a remote point to supersede existing announcements. The machine resets and starts again immediately at the end of each announcement, even if the duration is less than three minutes.

Connection to the ten-second machines would normally be automatic, and to the three-minute machines by dialling a digit or digits. Access to the latter machines could be classed as a chargeable call when necessary.

CALL DISPERSAL METERS

The traffic analysis meters described on page 42 include meters which record the total number of calls carried by each junction group.

The traffic recorder already described on page 73 has meters which record the number of erlangs carried by each group of trunks (outgoing junctions, etc.) to which it is connected.

In most exchanges, a single junction group carries calls for many different destinations, that is, several codes all cause calls to be established to the same outgoing junction route.

For network planning, particularly where alternative routing is used, it is necessary to know what proportion of the total outgoing junction traffic goes to each destination. This information is available in a very convenient form in the coder. It can be recorded by connecting to the coder a separate meter for each working code. These meters are called "call dispersal meters".

It is sufficient to connect a set of call dispersal meters to one coder only, as this gives a large enough sample of the total traffic to enable the proportion of traffic which goes to each destination to be estimated quite accurately. It should be noted that call dispersal meters register numbers of attempted calls, and do not record traffic in erlangs.

PART 7 TRAFFIC CALCULATIONS

TABLE III. **Number of second-choice registers per router for various traffic patterns**

Grade of Service	Bothway traffic per subscriber	Number of originating trunks per distributor	Register holding time as percentage of t.r.g. holding time (up to)	Number of second-choice registers per router*	x or y curve
0·001	all values	40 to 80	10%	1	
0·002	all values	40 to 80	8%	1	
0·002	all values	40	10%	2	
0·002	0·115 to 0·121	50	10%	1	
	over 0·122	60	10%	1	
	,, 0·125	70	10%	1	
	,, 0·139	80	10%	1	y
0·002	up to 0·115	50	10%	2	
	,, 0·122	60	10%	2	
	,, 0·125	70	10%	2	
	,, 0·139	80	10%	2	
0·005	0·096 to 0·100	40	10%	3	y
	0·116 to 0·128	50	10%	3	y
	0·123 to 0·144	60	10%	3	y
	0·135 to 0·148	70	10%	3	y
	0·143 to 0·153	80	10%	3	y
	0·143 to 0·150	60	13·3%	3	x
0·005	all values	40 to 80	5%	1	
	all values	40 to 50	8%	1	
	over 0·091	60	8%	1	
	,, 0·110	70	8%	1	
	,, 0·120	80	8%	1	
	,, 0·160	80	10%	1	
0·005	up to 0·091	60	8%	2	
	,, 0·110	70	8%	2	
	,, 0·120	80	8%	2	
	over 0·144	60	10%	2	y
	,, 0·148	70	10%	2	y
	,, 0·153	80	10%	2	y
	,, 0·149	60	13·3%	2	x
	,, 0·160	80	13·3%	2	x
0·005	up to 0·096	40	10%	4	y
	,, 0·116	50	10%	4	y
	0·098-0·123	60	10%	4	y
	0·114-0·135	70	10%	4	y
	0·127-0·148	80	10%	4	y
	over 0·085	40	13·3%	4	x
	0·137-0·143	60	13·3%	4	x
0·005	up to 0·098	60	10%	5	y
	,, 0·114	70	10%	5	y
	,, 0·127	80	10%	5	y
	,, 0·085	40	13·3%	5	x
	0·131-0·137	60	13·3%	5	x

* **Note:** For security at least two second-choice registers per router are always equipped.

TRAFFIC CALCULATIONS

CONGESTION FORMULAE

Grade of service can be calculated for "time congestion" or "call congestion".

"Time congestion" is the probability that all available paths are busy, so that should another call arrive it would not be set up.

"Call congestion" is the probability that a call actually will arrive while all available paths are busy.

In practice, the difference between the results of calculations made by these two formulae is small. For example, for a grade of service in the order of 0·002, the traffic from 25 sources which can be carried by 10 full-availability trunks comes out to about 5% less if calculated by the time congestion formula than if calculated by the call congestion formula. This difference approaches zero as the number of sources of traffic approaches infinity.

Since the mathematics of time congestion are simpler and the difference in the results is small, all traffic calculations for the 5005 system have been made on the basis of time congestion. The resultant error is on the side of safety.

DISTRIBUTION FORMULAE

If the grade of service is calculated for a small number of sources of traffic, it is necessary to allow for the fact that the greater the number of sources which are already busy, the smaller is the number of sources which are left to produce more traffic. The probability that a call will arrive in unit time is therefore dependent upon the number of calls already in progress.

On the other hand, if the grade of service is calculated for a number of sources of traffic which is so large that it can be regarded as infinite, then the probability that a call will arrive in unit time remains unchanged, however many calls may be in progress.

There are many distribution formulae applicable to one or other of these two cases, of which "Binomial Distribution" and "Erlangian Distribution" are typical. Both distributions are used in traffic calculations for the 5005 system.

LOST CALLS

Many different assumptions can be made about what happens to lost calls. In some formulae, of which Erlang's is the best known, it is assumed that a lost call vanishes and has no holding time. These are called "Lost Calls Cleared" formulae.

In other formulae, it is assumed that a lost call continues to demand service until service is given but its holding time is then considered as a normal holding time shortened by the time lost in waiting. These are called "Lost Calls Held" formulae.

Still further formulae deal with the cases of calls which, having obtained service after waiting for it, are then considered to have normal holding times. These are called "Delay" formulae.

LOST CALLS IN THE 5005 SYSTEM

Curves have been drawn to show the t.r.g. (or router link) occupancy for various subscriber calling rates and grades of service. Grade of service can be defined in this case as follows:—

- on originating calls, the probability that the caller will on lifting his handset find all registers (or paths leading to registers) busy:
- on terminating calls, the probability that the caller will, after dialling, find all paths leading to the called subscriber (or outgoing junction) busy.

GRADE OF SERVICE FOR ORIGINATING CALLS

The grade of service for an originating call is calculated as the arithmetical sum of the following three probabilities of loss:—

Loss I—probability that all links in the calling-subscriber distributor leading from the originating "B" switch to the "A" switches are busy (Binomial distribution).

Loss II—probability that, for every combination of free and busy links, all accessible t.r.g.s are busy (Erlangian distribution).

Loss III—probability that, for every combination of free and busy links with every combination of free and busy t.r.g.s, all accessible registers are busy (Binomial distribution).

Figs. 24 to 28 show the occupancy per t.r.g. over a range of bothway (originating plus terminating) calling rates per line, for various grades of service and numbers of originating trunks. For bothway calling rates up to about 0·08e per line, the occupancy of the t.r.g. is almost as high with the 5005 link trunking as with full availability, that is, the links do not introduce much blocking.

The bothway calling rate per line is used in these curves instead of the originating calling rate per line, because the links carry both originating and terminating traffic. Any blocking in the links is thus the result of bothway traffic, although the occupancy of the t.r.g.s depends only on the originating traffic. Curves x and y are used for exchanges in which the respective register holding time exceeds or does not exceed, 10% of the t.r.g. holding time.

NUMBER OF REGISTERS FOR ORIGINATED CALLS

Table III shows the number of second-choice registers per router.

First-choice registers are usually equipped at the rate of one per ten t.r.g.s. An originating call always seizes a t.r.g. with access to a free first-choice register in preference to a t.r.g. with access only to a free second-choice register. The 40 originating trunks from the distributor switches "A" are connected, via the t.c.f. to t.r.g.s in 40 different groups of 10, so that a caller has access, if all links and originating trunks are free, to 40 first-choice registers (or up to 80 if additional distributor switches "A" are provided).

If the ratio of register to t.r.g. holding times is about 1/10, the first-choice register occupancy is approximately the same as the t.r.g. occupancy. There is a small residue of traffic which overflows on to second-choice registers.

For low ratios of register to t.r.g. holding times, the first-choice registers are equipped on the basis of one per 20 t.r.g.s.

For higher register/t.r.g. holding-time ratios, the number of second-choice registers per router can be increased from two up to 16.

MARGIN OF SAFETY

If, at the instant the caller lifts his receiver, there is no access to a free register, the call is not actually lost until the caller himself abandons it. With access to 40 t.r.g.s, 40 first-choice registers and, typically, 16 second-choice registers, there is a good chance that a path to a register may become free so quickly that the caller will not notice any delay. Thus Figs. 24 to 28 could have been calculated for a grade of service on the basis of the "delayed" call ratio (instead of on the "lost" call ratio), and further curves could have been provided to show the proportion of calls which suffer delays of all values from zero upwards. It is, however, preferable to calculate Figs. 24 to 28 as described above for the following reasons:—

The method of calculation is in common use (for example, Erlang Tables) and thus Figs. 24 to 28 provide a basis for comparison with other systems which use the same method.

Experience shows, and mathematical investigation confirms, that in a register system an increase in calling rate above the designed figure causes greater degradation of service than would occur in a direct dialling system. In other words, a register system is more sensitive to overload than a direct dialling system.

Figs. 24 to 28 provide a margin of safety which allows for some increase in calling rate before congestion becomes serious. This margin varies according to the occupancy of the t.r.g.s. For a t.r.g. occupancy of 0·6e, the calling rate could increase by about 20% without causing very noticeable degradation of service, whereas for an occupancy of 0·8e, the margin is less than 5%.

Prudence dictates that, in calculating the number of t.r.g.s, this margin should not be tampered with. (See also "Undertrunking of New Exchanges" page 84.)

GRADE OF SERVICE FOR TERMINATING CALLS

In systems in which calls are set up through two or more switching stages in successive steps, it is convenient to express the grade of service for terminating calls in terms of the loss at each switching stage. For example, in a Strowger exchange with first, second, third and final selectors, the grade of service might be specified as 0·002 at each group selector stage, instead of quoting the overall figure of 0·006.

In the 5005 system, the grade of service for terminating calls is made up of the sum of the three losses within and between two switching stages. Since the call is set up through both switching stages at one time, and since these three losses are all interdependent, it is convenient to express the grade of service as one overall figure, instead of mentioning the loss at each stage separately.

The grade of service for a terminating call is calculated as the arithmetical sum of the following three probabilities of loss:—

Loss IV—probability that all links in the called-subscriber distributor leading from the terminating "B" switch to the "A" switches are busy (Binomial distribution). This loss is arithmetically the same as Loss I.

Loss V—probability that, for every combination of free and busy links in the distributor, all outlets of "B" switches in the router of origin which give access to the distributor of destination are busy. (Erlangian distribution.)

Loss VI—probability that, for every combination of free and busy links in the distributor with every combination of free and busy route switch "B" outlets, all accessible links in the router are busy. (Binomial distribution.)

Figs. 30 to 36 show the grade of service for a range of bothway calling rates per line—for 40, 50, 60, 70 and 80 terminating trunks per distributor, and for 10, 15, 20, 25, 30, 35 and 40 outlets from each router to each distributor. On each figure there are five curves for values of "X" between 0·75 and 2.

The parameter "X" is a function of the occupancy per terminating trunk (which depends upon the terminating calling rate per line) and of the occupancy per router link (which depends upon the t.r.g. occupancy minus the register and ineffective call traffic).

The nomogram in Fig. 29 enables "X" to be established from the bothway calling rate per line and the t.r.g. occupancy.

DETERMINATION OF OVERALL GRADE OF SERVICE

In designing an exchange, the t.r.g. occupancy is read from Figs. 24 to 28 for the bothway calling rate per line and the grade of service required for originating calls. This enables the number of t.r.g.s to be calculated.

The grade of service for terminating calls is read from Figs. 30 to 36 after determining the value of "X" from the nomogram (Fig. 29). The t.r.g. occupancy (for the originating traffic) may now require adjusting until the required grade of service (for terminating traffic) is obtained. The overall grade of service for the exchange is, of course, the sum of the grades of service for originating calls and terminating calls.

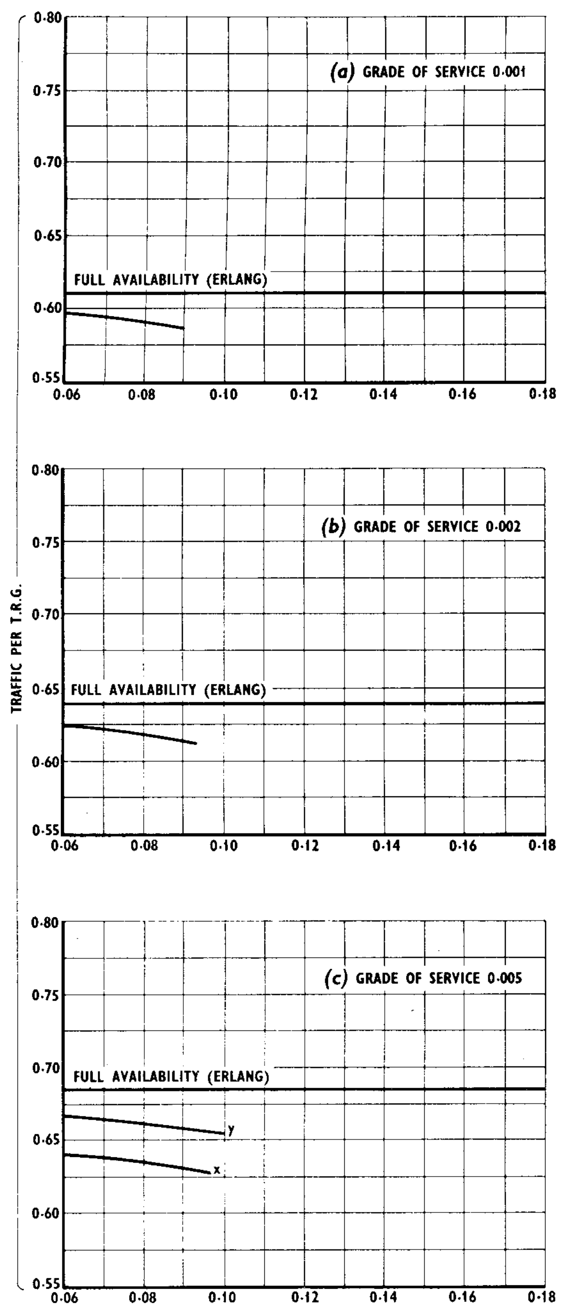


Figure 24. 40 ORIGINATING TRUNKS

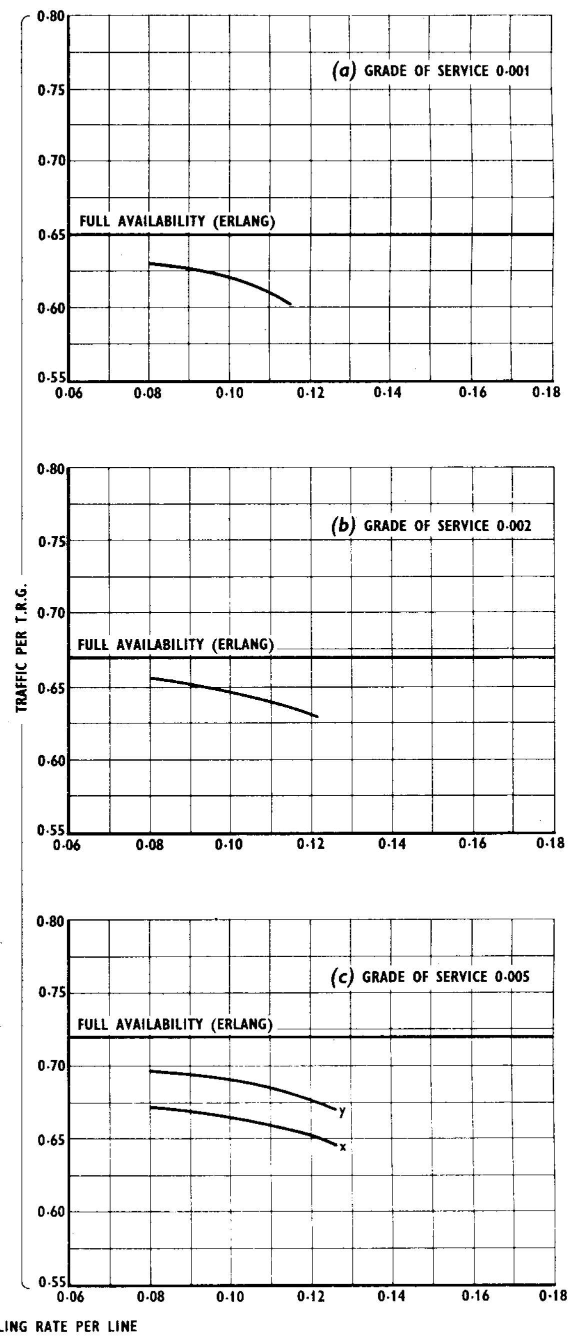


Figure 25. 50 ORIGINATING TRUNKS

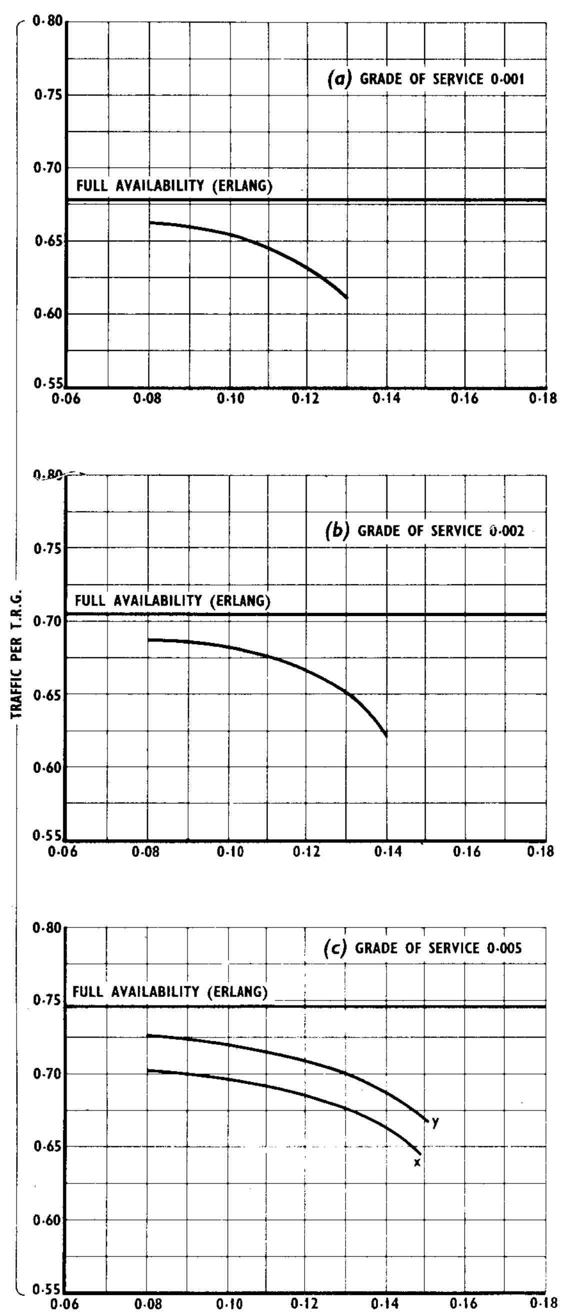


Figure 26. 60 ORIGINATING TRUNKS

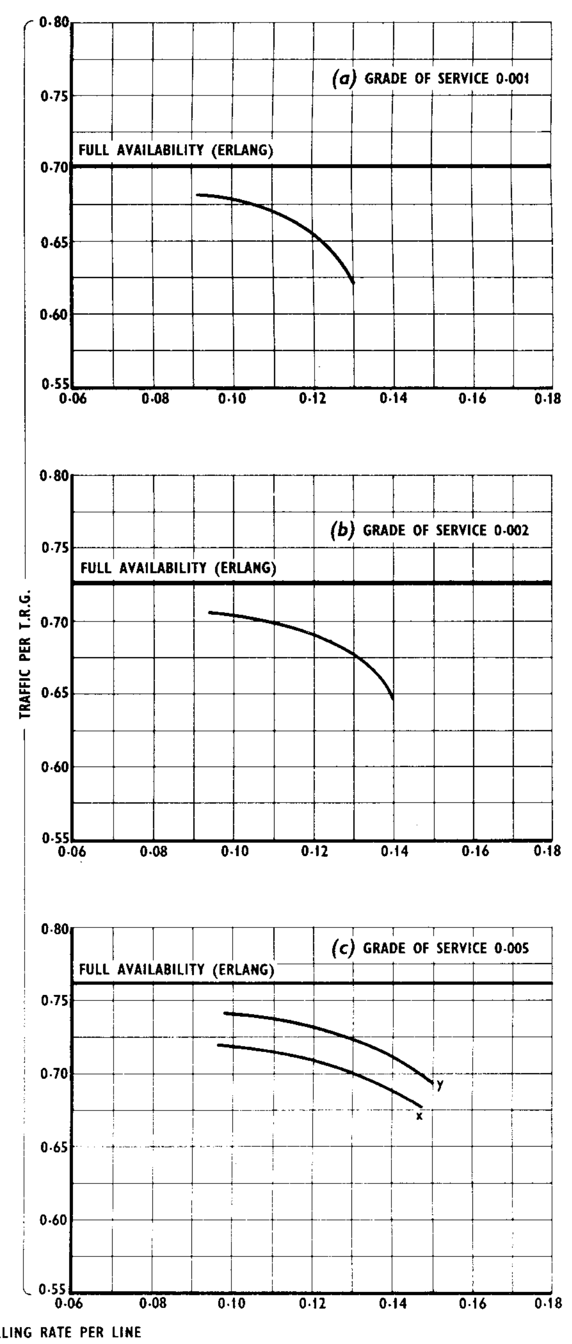


Figure 27. 70 ORIGINATING TRUNKS

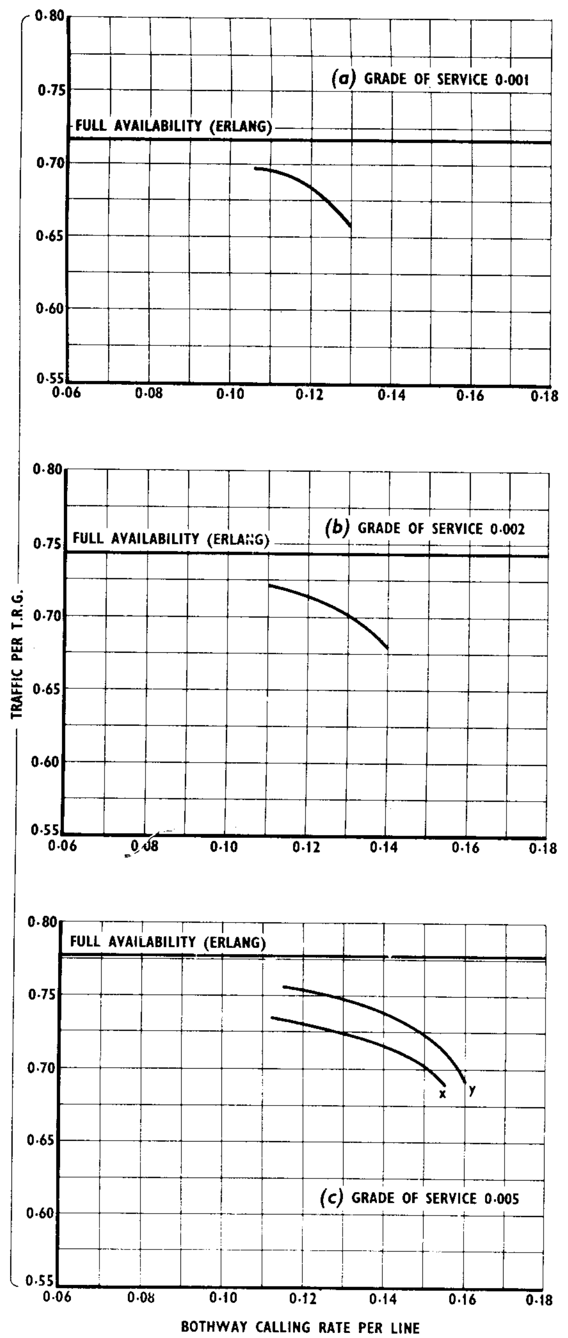


Figure 28. 80 ORIGINATING TRUNKS

Figures 24 to 28. GRAPHS OF TRAFFIC PER T.R.G./BOTHWAY CALLING RATE PER LINE, FOR VARIOUS GRADES OF SERVICE AND NUMBERS OF ORIGINATING TRUNKS.
TRAFFIC FIGURES ARE IN ERLANGS. SEE TABLE III FOR INFORMATION ON USE OF CURVE "X" OR "Y"

GRADE OF SERVICE TO OUTGOING JUNCTIONS

Curves showing the number of junctions required for ranges of total junction traffic are shown on Figs. 37 (*a*)-(*c*). The curves are calculated for grades of service of 0·01 and 0·005, and access of 10, 20, 40 and 60 outlets per router.

The additional loss in the links between route switches "A" and "B" is small and is of the same order as the loss in a Strowger exchange between first and second selectors. It is not therefore separately calculated.

If there are less than 20 junctions on a route, they can be served by 20 outlets per router with some of the outlets of route switches "B" paralleled; or they can be served by the exact number of outlets required from second-stage route switches. If the junction group has less than ten junctions and the junctions are lightly loaded, they can be served by ten outlets per router.

INCOMING JUNCTIONS SEIZING REGISTERS

MULTI-FREQUENCY INCOMING REGISTERS

An incoming junction on which multi-frequency inter-register signalling is used, seizes an incoming m.f. register as soon as a call arrives. When this register is seized, it sends back a "proceed" signal to the distant exchange. If all incoming m.f. registers to which the incoming junction has access are busy, the call is delayed but not lost. An incoming register is called a code receiver in some systems.

LOOP-DISCONNECT INCOMING REGISTERS

An incoming junction from a Strowger exchange seizes an incoming loop-disconnect register as soon as a call arrives. If all these registers are busy, the junction continues to hunt for one, and if one has not been seized by the time the caller dials the next digit, the hunt is abandoned and busy tone is returned to the caller. Alternatively the first digit to arrive over the junction can be stored in the incoming junction relay group for transfer to the register later.

The additional probability of lost calls which this introduces is dealt with on page 34.

CALCULATION OF NUMBER OF INCOMING REGISTERS

Each group of ten incoming junctions has access to ten registers, via five links.

Fig. 38 shows the number of incoming registers required for various values of register traffic per junction, where the total number of junctions does not exceed 160. For larger numbers of junctions, a separate group of registers is provided for each group of 160 junctions. The curves of Fig. 38 are calculated for a grade of service of 0·001.

GRADE OF SERVICE FOR SENDERS

A sender is not seized until the caller has dialled the code digits, so that its holding time is shorter than the register holding time. The difference is the pre-dialling time plus the time taken by the caller to dial the code digits.

The sender holding time can vary widely and depends on several factors, including:

(*a*) Whether the sender is seized after the 1st, 2nd or subsequent digit dialled by the caller (determined by straps in register).

(*b*) The number of digits to be sent out.

(*c*) Whether the sender sends 10 or 20 p.p.s. loop-disconnect signals or high-speed multi-frequency signals.

Each register has access to six senders. The latter can be all in one group, or they can be grouped 2-4, 3-3, or 2-2-2 as required, to provide for access to different types of sender (loop-disconnect, multi-frequency, etc.).

If all senders of the required type to which a register has access are busy, the register continues to search until a sender becomes free. If two or more registers are searching, when a sender becomes free it is seized by any register at random. Figs. 39 (*a*)-(*d*) show the sender occupancy for a range of probabilities of delay with different numbers of senders accessible. In the case of calls outgoing to other 5005 exchanges (20 p.p.s. or multi-frequency senders), there is a tendency for a small delay to be masked by the fact that the sender, once it has been seized, sends out the digits faster than they arrive from the caller.

CONGESTION

SUBSCRIBERS WITH SINGLE EXCHANGE LINES

If the occupancy per line is 0·052e originating traffic plus 0·048e terminating traffic (that is, 0·1e bothway traffic), on an average, one call in ten finds the wanted number busy. Since the caller usually makes at least one more attempt on finding a number busy, this leads to at least 10% extra traffic on the registers. It also leads to some extra traffic on the t.r.g.'s but since the holding time of calls which receive busy tone is short, the additional t.r.g. traffic would be less than 10%—perhaps 2%. It will be obvious that if the calling rate per line (not considering p.b.x. lines) exceeds about 0·05e originating traffic, a form of "chain reaction" can develop in which calls to busy subscribers increase the traffic on all subscribers and therefore again increase the number of calls which find subscribers busy, and so on. It is not possible to set an exact figure at which this chain reaction starts but obviously the effect will become progressively much greater as the calling rate per single line rises above 0·05e originated calls.

P.B.X. SUBSCRIBERS' LINES

The bothway traffic per line which can be carried, with a probability of losing one call in ten due to all lines in a p.b.x. group being busy, varies with the number of lines in the group and is shown in Table IV.

A loss of one call in five and one call in 50 is also shown in the table for comparison. It will be seen from the table that degradation of service due to an increase of traffic is

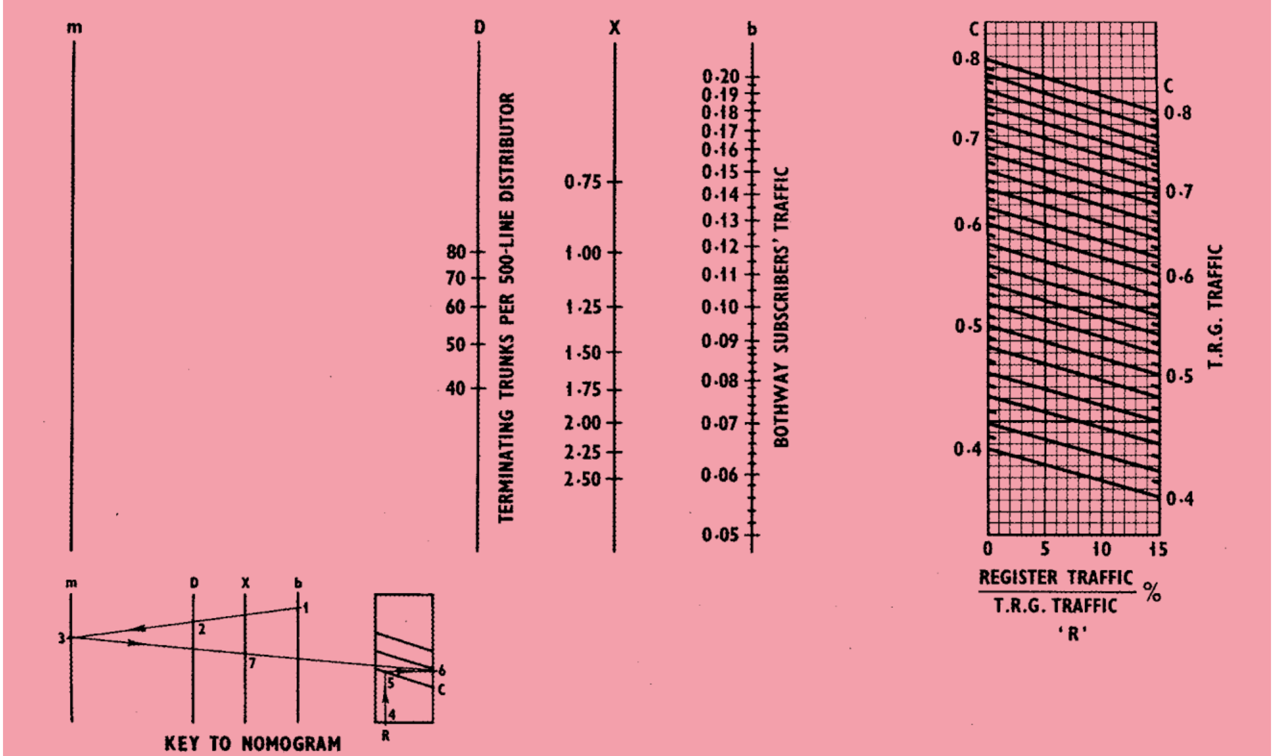


Figure 29. NOMOGRAM FOR DETERMINING PARAMETER "X" (A FUNCTION OF TERMINATING TRUNK AND ROUTER LINK OCCUPANCIES)

TABLE IV TOTAL BOTHWAY TRAFFIC PER LINE (ERLANGS)

Number of Lines	Grade of Service 0·2	Grade of Service 0·1	Grade of Service 0·02
1	0·2	0·1	0·02
2	0·5	0·3	0·11
3	0·7	0·43	0·2
4	0·75	0·5	0·28
5	0·8	0·6	0·34
10	0·97	0·75	0·51
15	—	0·83	0·6
20	—	0·88	0·66
30	—	0·93	0·73
40	—	0·97	0·76

much more serious in large groups than in small groups. From this it follows that if a grade of service of 0·1 is accepted for small groups, a better grade of service should be used for larger groups.

DEALING WITH CONGESTION

If calling should increase in an exchange designed for a calling rate of, say, 0·05e originating traffic per single line, or the corresponding figure for p.b.x. groups of various sizes, two courses are possible to give a suitable grade of service:—

(*a*) To provide more t.r.g.s and registers. (It may also be necessary to increase the number of "A" switches per distributor.) This will enable the exchange to deal with a higher calling rate per line.

(*b*) To provide more t.r.g.s and registers, and also to provide more distributors so that more lines can be connected to the exchange, thus reducing the calling rate per line.

If course (*b*) is adopted, it will be necessary for the Administration to approach those subscribers whose calling rate is excessive, with a view to providing more lines. The p.b.x. meters described on page 64 provide evidence to support this approach.

SUBSCRIBER WAITING LISTS

When the demand for lines cannot be met, a condition arises where the existing lines become overloaded because each line is shared by too many users. It will be obvious that in this case it is more advantageous both to the Administration and to the subscribers to provide a line extension for the exchange. This would liquidate the waiting list and reduce the calling rate per line, whereas providing a traffic extension would still leave the calling rate per line so high that the lost calls due to wanted numbers being busy would cause severe degradation of service.

UNDERTRUNKING OF NEW EXCHANGES

A new exchange is usually opened with between 10% and 25% spare line equipments to allow for future growth. The number of fully equipped and/or partially equipped routers is usually calculated for the traffic offered by 95% of the total number of subscriber line circuits fitted, and not for the number of line circuits actually working at the time the exchange is opened. The grade of service in a new exchange is thus likely to be very much better than the calculated figure. The calculated figure should be reached when 95% of the line circuits have been allotted to subscribers, and this may take a few years. If, due to underestimation of traffic, the exchange is undertrunked at the time of opening, no degradation of service is likely to be noticed at first, but it will become apparent as the number of subscribers grows. The traffic analysis meters page 42, reveal congestion after it has developed. The traffic recorder page 73 reveals the trend towards congestion in time for additional router equipment to be installed.

VARIATIONS IN CALLING RATE

It will be clear, from the above notes on traffic calculations, and from the reference on page 63 that distributors are adjusted to meet varying traffic values by altering the numbers of "A" switches and not by altering the number of links per 25 subscribers.

This method has been adopted because it allows an increase in calling rate in a working exchange to be met by fitting new shelves and interconnecting their tagblocks to the tagblocks of existing shelves, whereas an alteration in the number of links per 25 subscribers would have needed additions to the internal multiple wiring of the "B" distributor switches.

From the point of view of manufacture, the non-variable number of links is advantageous because it enables economies to be made in the cost of wiring. The fact that, in exchanges with a low calling rate, the links are less heavily loaded than they would have been if there had been fewer of them, makes only a small difference to the overall cost of the exchange, because the underloading of the links permits a correspondingly higher loading of the t.r.g.s, and associated equipment in the router, for the same grade of service.

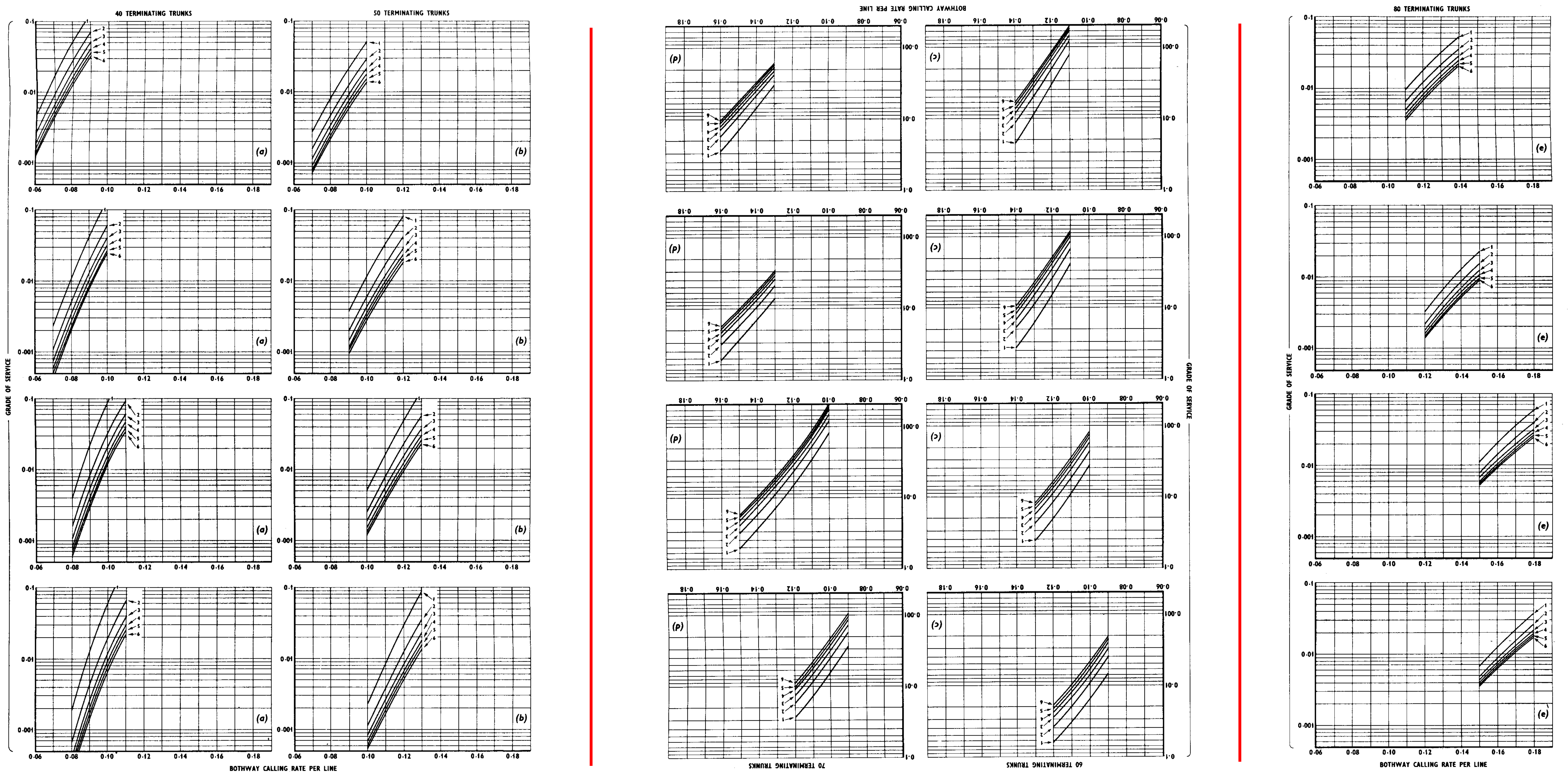


Figure 30.
10 ROUTER OUTLETS

Figure 31.
15 ROUTER OUTLETS

Figure 32.
20 ROUTER OUTLETS

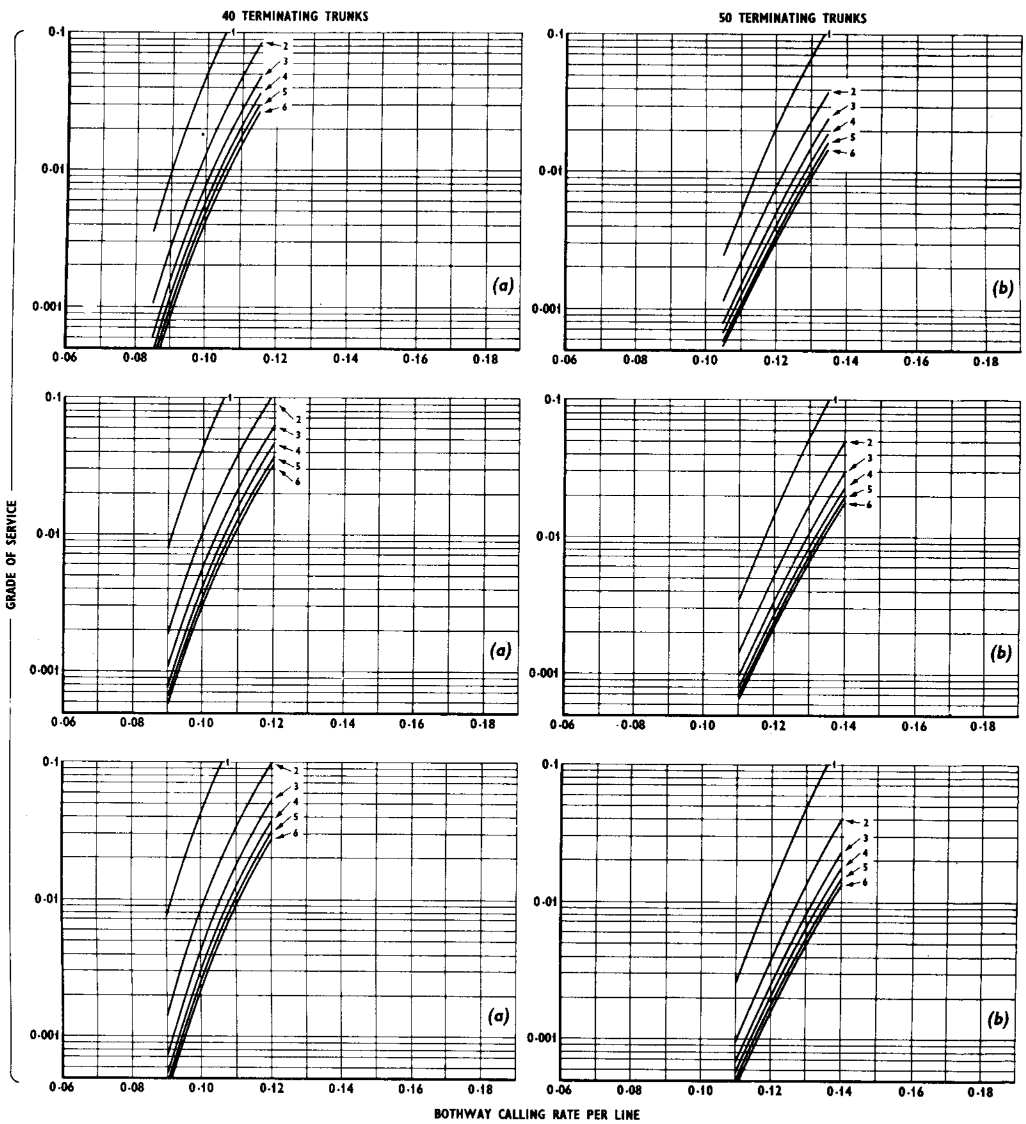
Figure 33.
25 ROUTER OUTLETS

N.B.

Curve No.	'X' value
1	0·75
2	1·0
3	1·25
4	1·5
5	1·75
6	2·0

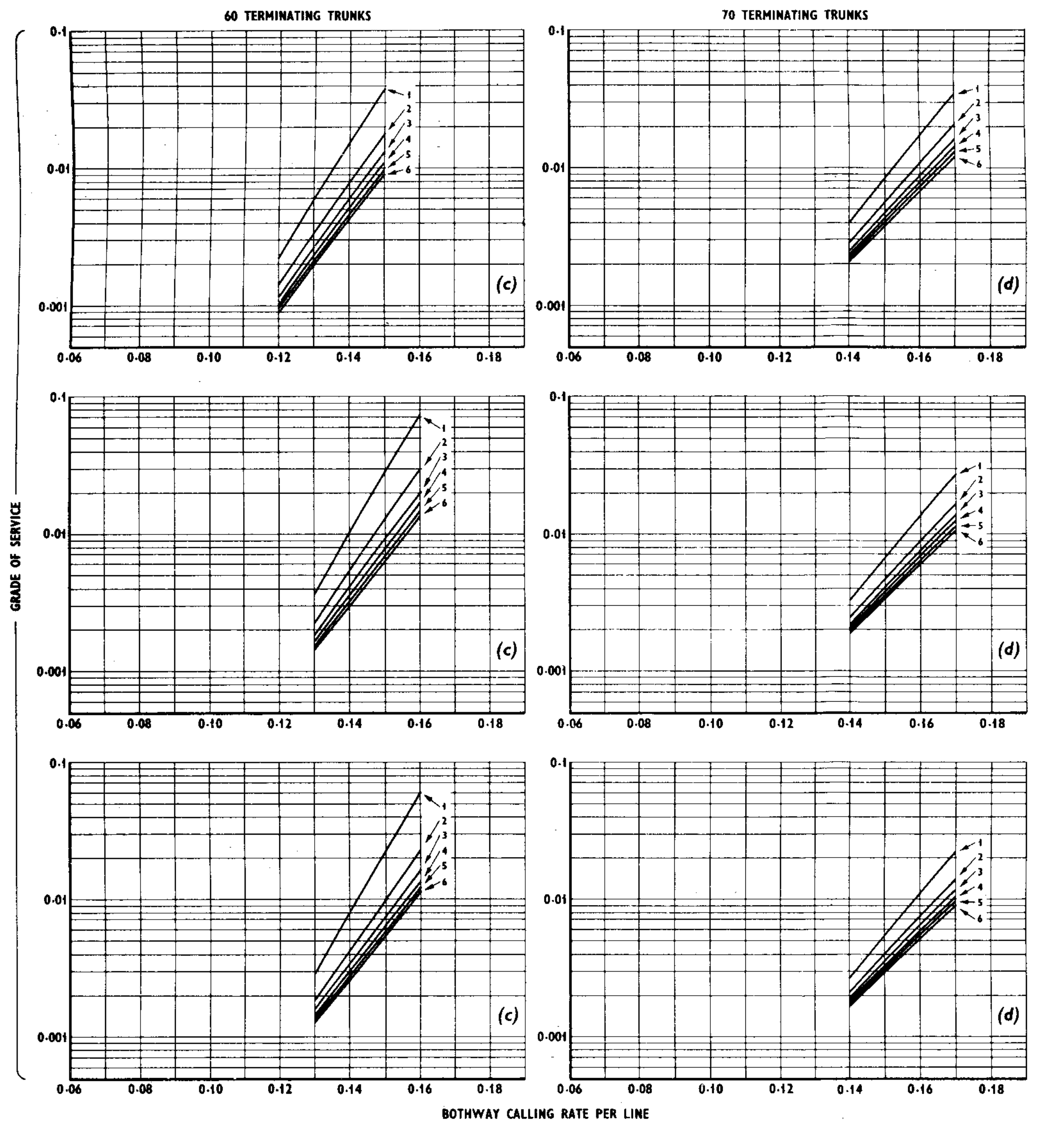
Figures 30 to 33. GRAPHS OF GRADE OF SERVICE/BOTHWAY CALLING RATE PER LINE. FOR VARIOUS NUMBERS OF ROUTER OUTLETS AND TERMINATING TRUNKS FURTHER GRAPHS ON THE FOLLOWING PAGES.

SEE FIGURE 29 FOR NOMOGRAM TO DETERMINE "X"



Figures 34 to 36. GRAPHS OF GRADE OF SERVICE/BOTHWAY CALLING RATE PER LINE, FOR VARIOUS NUMBERS OF ROUTER OUTLETS AND TERMINATING TRUNKS.

SEE FIGURE 29 FOR NOMOGRAM TO DETERMINE "X"



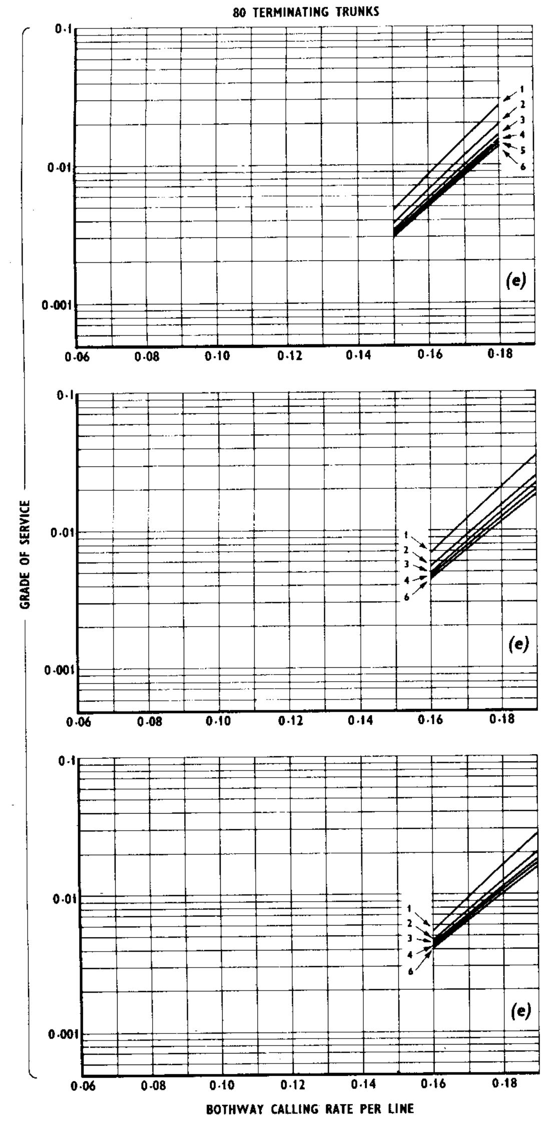


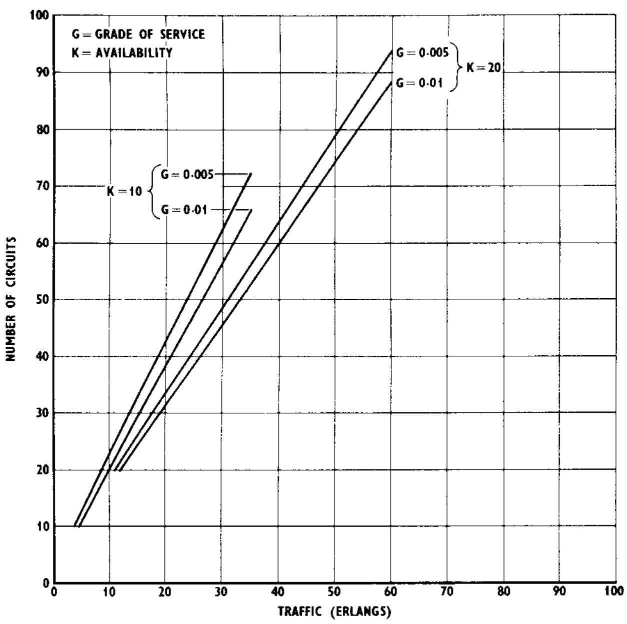
Figure 34
30 ROUTER
OUTLETS

Figure 35.
35 ROUTER
OUTLETS

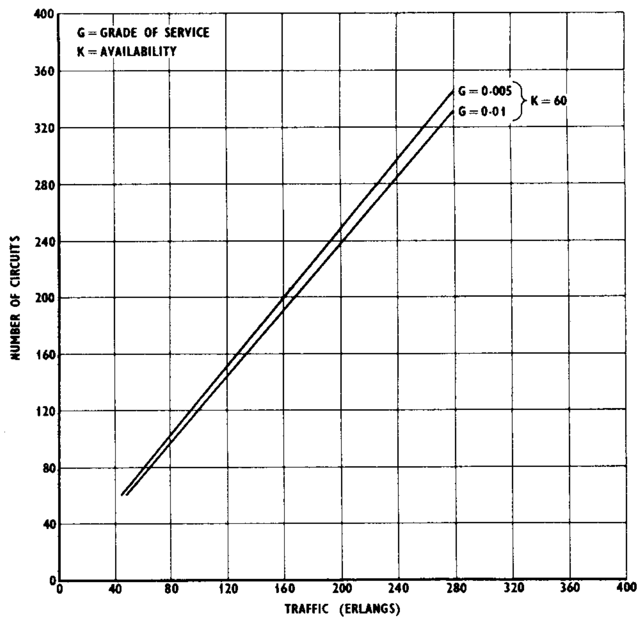
Figure 36.
40 ROUTER
OUTLETS

N.B.

Curve No. No.	'X' value
1	0·75
2	1·0
3	1·25
4	1·5
5	1·75
6	2·0



(a). AVAILABILITIES OF 10 AND 20



(c). AVAILABILITY OF 60

(b). AVAILABILITY OF 40

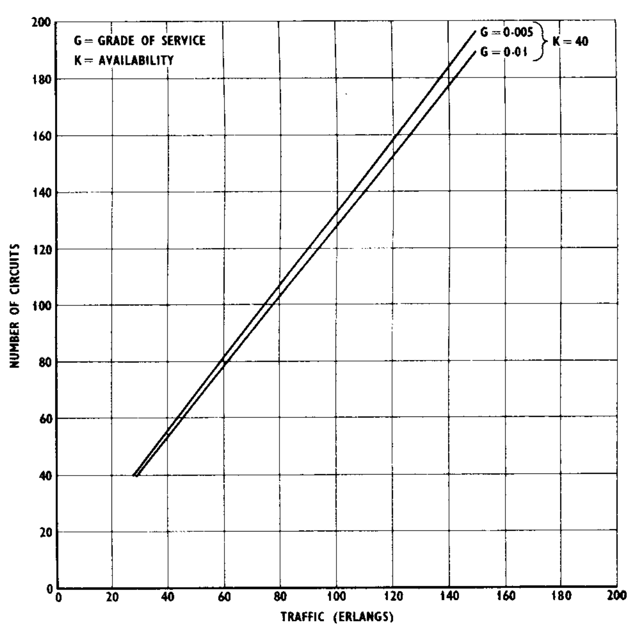


Figure 37. GRAPHS OF NUMBER OF JUNCTIONS/JUNCTION TRAFFIC, FOR VARIOUS AVAILABILITIES AND TWO TYPES OF SERVICE

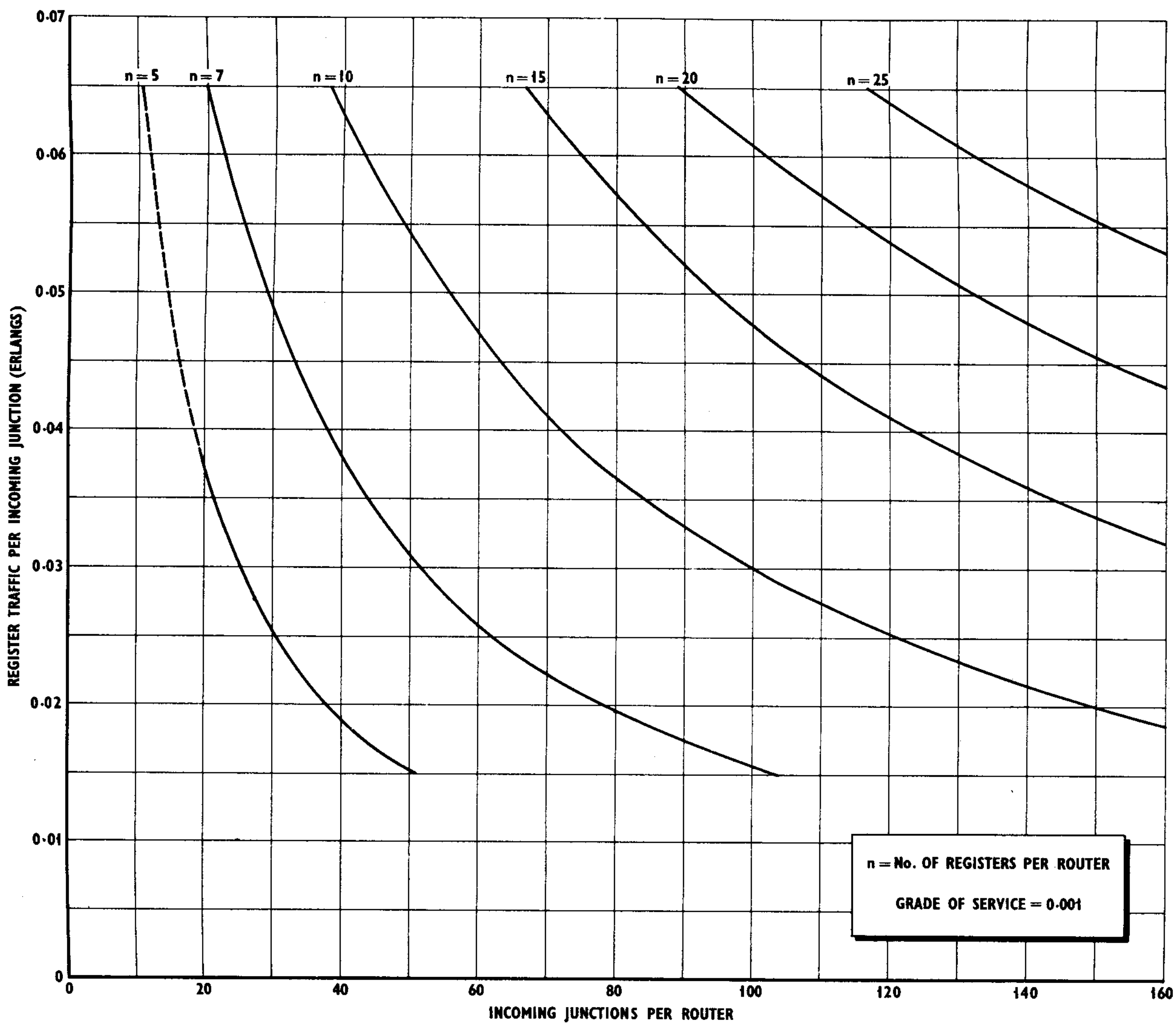
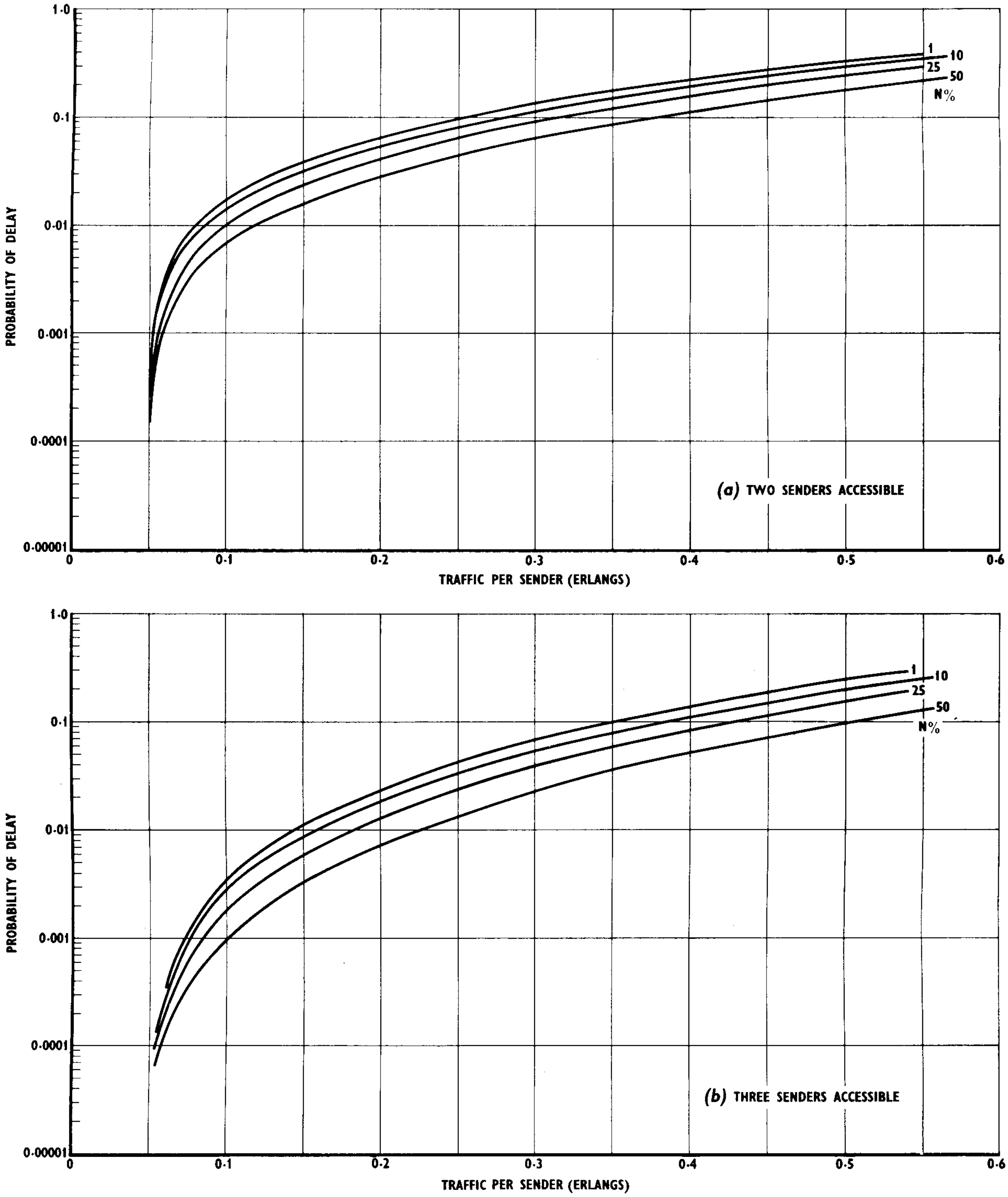
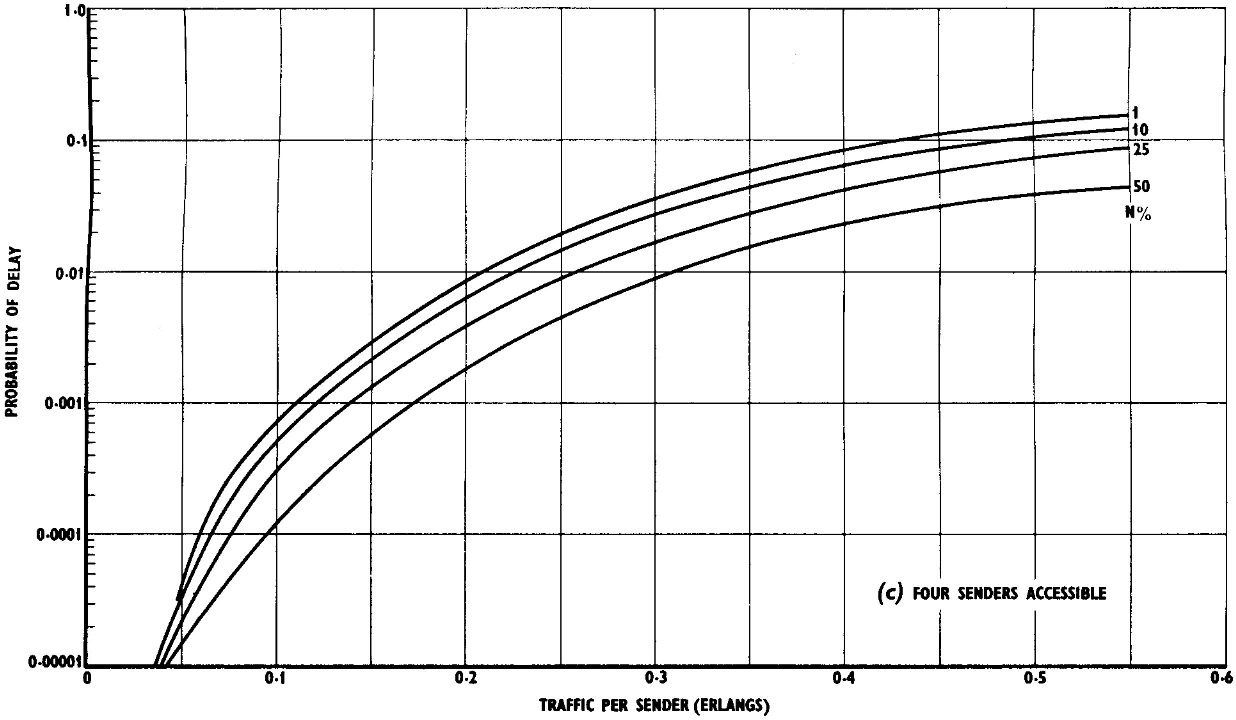


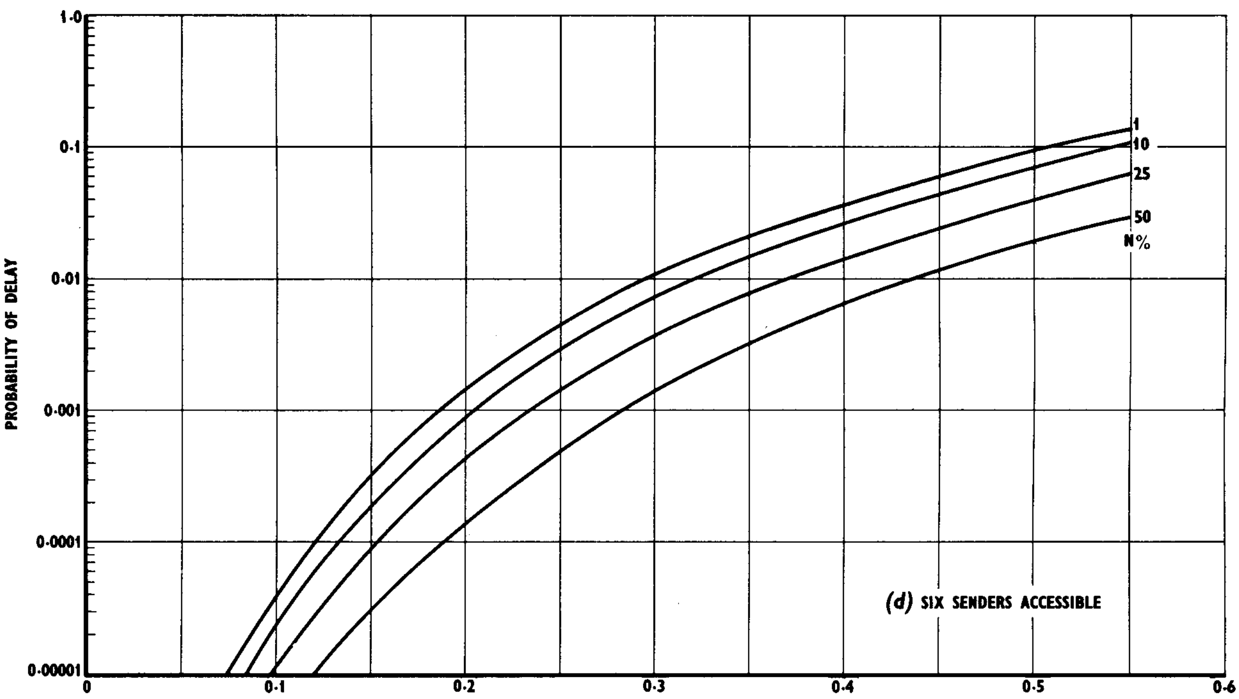
Figure 38. GRAPHS OF REGISTER TRAFFIC PER INCOMING JUNCTION/INCOMING JUNCTIONS PER ROUTER, FOR VARIOUS NUMBERS OF REGISTERS PER ROUTER

Figures 39 (*a*) (*b*). GRAPHS OF PROBABILITY OF DELAY GREATER THAN N% OF MEAN HOLDING TIME/TRAFFIC PER SENDER, FOR VARIOUS NUMBERS OF SENDERS



Figures 39 (*c*) (*d*). GRAPHS OF PROBABILITY OF DELAY GREATER THAN N % OF MEAN HOLDING TIME/TRAFFIC PER SENDER, FOR VARIOUS NUMBERS OF SENDERS





The Plessey Telecommunications Group
incorporates:

Automatic Telephone
& Electric Co. Ltd.

Ericsson Telephones Limited

Etelco Limited

Communication Systems Limited

Birkbys Limited

The Plessey Telecommunications Group has Associated Companies, Resident Representatives, Associates, Agents and Correspondents throughout the world

All enquiries should be addressed to:

The Plessey Company Limited
Telecommunications Group

Edge Lane,
Liverpool 7, England
Telephone: Stoneycroft 4830 Telex: 62267