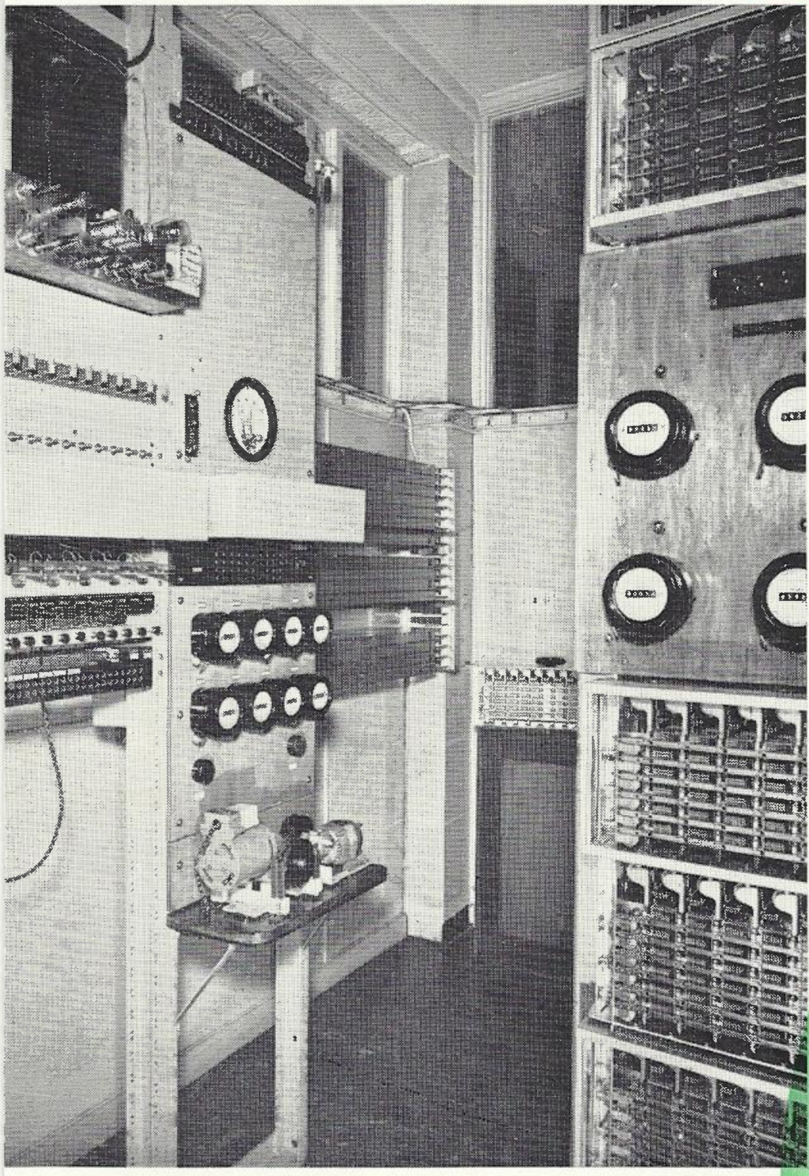
THE

Telecommunication Journal OF AUSTRALIA



CROSSBAR RELIABILITY TESTING, SYDNEY

IN THIS ISSUE

CROSSBAR—ARK
MAINTENANCE
MATERIALS
QUALITY ASSURANCE

POWER CO-ORDINATION

TELEPRINTER 100

EPOXY RESIN JOINT

SHORT BROADBAND BEARER

LINE INSULATION ROUTINERS

TRANSISTORS WITH RELAYS

SENIOR TECHNICIANS' EXAMS

VOL. 14, No. 4 Registered at the General Post Office, Melbourne, for transmission by post as periodical. JUNE, 1964

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The

TELECOMMUNICATION JOURNAL

of Australia

VOL. 14, No. 4 — *Registered at the General Post Office, Melbourne, for transmission by post as a periodical.* — JUNE, 1964

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The Journal is not an official journal of the Postmaster-General's Department of Australia. The Department and the Board of Editors are not responsible for statements made or opinions expressed by authors of articles in this Journal.

*For addresses see page 331. **See separate announcement on page 279.

NEW POST OFFICE HEADQUARTERS ORGANIZATION

In February, 1964, a new organization was introduced for senior levels of the Central Administration of the Postmaster-General's Department. The new structure (see Fig.) provides for a second position of Deputy Director-General and five positions of First Assistant Director-General. The latter are heads of Divisions in which the senior subordinate positions are designated in order of status as Senior Assistant Director-General, Assistant Director-General and Deputy Assistant Director-General.

It will be noted that in the new divisional structure two Engineering Divisions have been created, whilst the Personnel and Organization and Methods Branches have been added to the Finance and General Services Division to make up the new Management Services Division.

Mr. E. Sawkins, B.Sc., A.M.I.E.Aust., Engineer-in-Chief since February, 1957, has been promoted to the additional position of Deputy Director-General, where he joins Mr. B. F. Jones, B.A., B.Ec., on the first line under the Director-General.

Mr. C. J. Griffiths, M.E.E., M.I.E.E., M.I.E.Aust., previously Deputy Engineer-in-Chief, has been promoted to the position of First Assistant Director-General, Engineering Works, whilst Mr. L. M. Harris, B.Sc., has been promoted to the position of First Assistant Director-General, Engineering Planning and Research, Mr. Harris' previous position was Assistant Engineer-in-Chief, Research.

Mr. A. F. Spratt, B.A., B.Sc., D.P.A., A.M.I.E.Aust., has been appointed First Assistant Director-General, Management Services Division. Mr. Spratt, initially Cadet Engineer, Engineer and Divisional Engineer in the Victorian Administration, returns to the Department after a period in the Public Service Board, where he has been Public Service Inspector for Victoria for a number of years.

Mr. J. Skerrett and Mr. R. Page, B.Sc., B.Com., D.P.A., continue as heads of Divisions under the new appointments of First Assistant Director-General, Telecommunications, and First Assistant Director-General, Postal and Transport, respectively.

The Board of Editors, on behalf of the Telecommunication Society of Australia, congratulate the new appointees and offer them full support for the future.

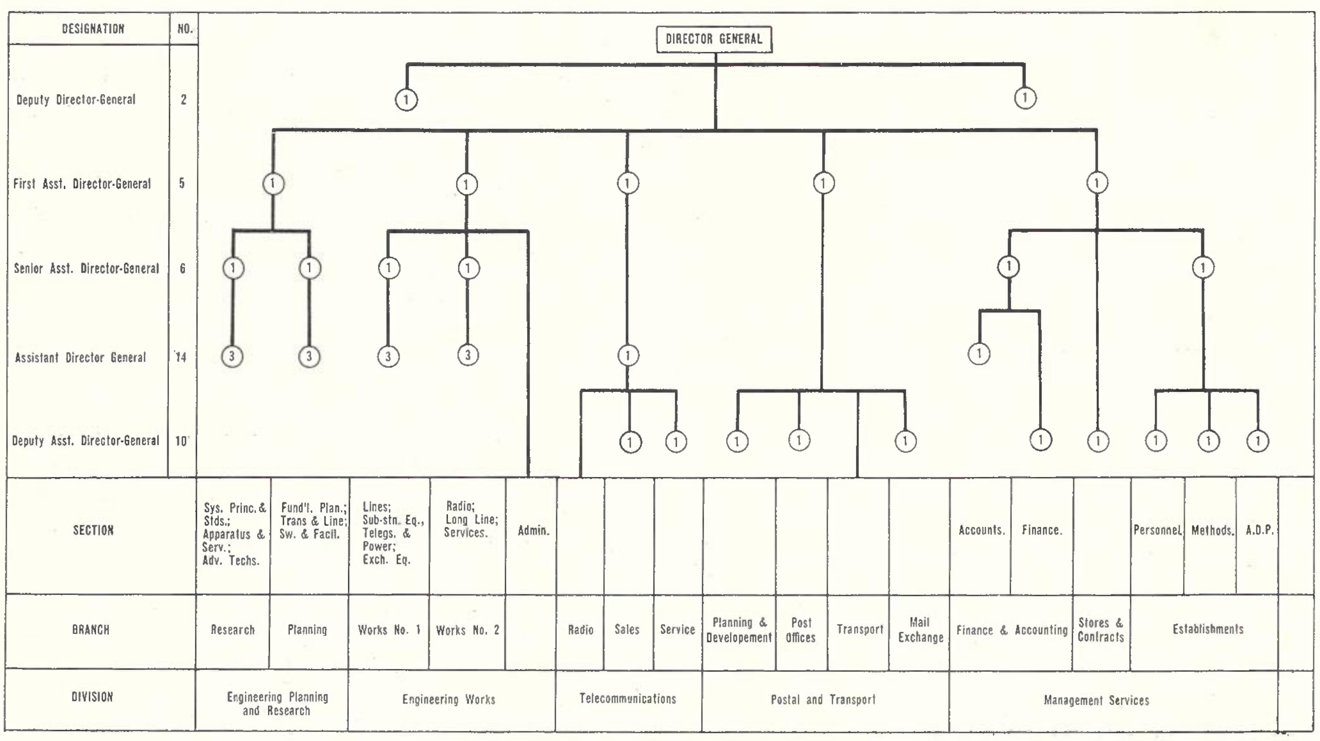

Fig. — New Post Office Organization for Senior Levels at Headquarters.

PILOT INSTALLATIONS OF ARK CROSSBAR EXCHANGES

K. M. BARTSCH, B.E. and B. R. KLOSE, B.E.***

INTRODUCTION

In 1959 the Australian Post Office adopted the type of crossbar system supplied by L M Ericsson of Stockholm, Sweden, as the future standard for Departmental exchanges in Australia. (1, 2, 3.) This system uses three main types of automatic switching equipment. There is ARM for major trunk switching centres, ARF for metropolitan and larger country exchanges and ARK for smaller country exchanges. Each type is further subdivided for different applications, for example, in ARK equipment there are ARK 511, ARK 521 and ARK 523 exchanges.

The smallest ARK exchange is the ARK 511 which has an ultimate capacity of 90 subscribers' lines and seven junctions, whilst the ARK 521 has 2,000 subscribers' lines and approximately 130 junctions, depending on local traffic requirements. Both the ARK 511 and the ARK 521 are terminal exchanges with no facility for transit switching. However, this facility is provided in ARK 523 equipment which combines an ARK 521 and a transit switching stage.

In this article, ARK 511 and ARK 521 equipment will be described. Particular reference will be made to an ARK 511 exchange installed at Reeves Plains, and an ARK 521 exchange installed at Gladstone, both in South Australia. The Gladstone exchange with an initial capacity of 300 lines was cutover on 30th November, 1963. This was the first ARK exchange put into service in Australia. Both of these exchanges were installed by the Department's technical staff, the ARK 511 in a small transportable, timber-framed, steel-sheathed building and the ARK 521 in a permanent masonry building.

ARK OPERATION

General

In the L M Ericsson crossbar system, as used overseas, ARK 511 and ARK 521 exchanges are terminal exchanges of ARM or ARK 523 group centres (4). In this system, all calls originating in the terminal exchange are established by central registers in the group centre. A multi frequency code (M.F.C.) is used to signal back to the ARK terminal exchange if the required number is available from that exchange. The ARK exchange is therefore equipped with code receiving and connecting equipment, but no registers are required at the ARK to set up a call. It is usual, however, to provide Local Registers (REG-L) which are used as overflow registers to accept calls originating in the ARK to numbers available from the ARK in the event that all junctions to the group centre are engaged. Two REG-L can be fitted to an ARK 511 and up to seven to an ARK 521.

A basic problem in introducing this type of ARK exchange to Australia was that the ARK exchanges would have to interwork with existing step-by-step automatic exchanges, which have no central registers. As the ARK could not do this using a closed numbering scheme, some alteration of design was required. Two possibilities existed:

1. To leave the ARK equipment unaltered and design a central register which would suit a step-by-step auto exchange.
2. To leave the step-by-step exchanges alone and modify the ARK equipment.

The A.P.O. decided to adopt the second alternative for the initial exchanges which would be installed before ARM 50 or ARK 523 exchanges were operational. Negotiation between the A.P.O. and L M Ericsson resulted in the design of a new type of discriminating register REG-D, which would be installed at the ARK terminal exchange. The new register retains the functions of the REG-L, i.e., it arranges local connections if all junctions to the auto

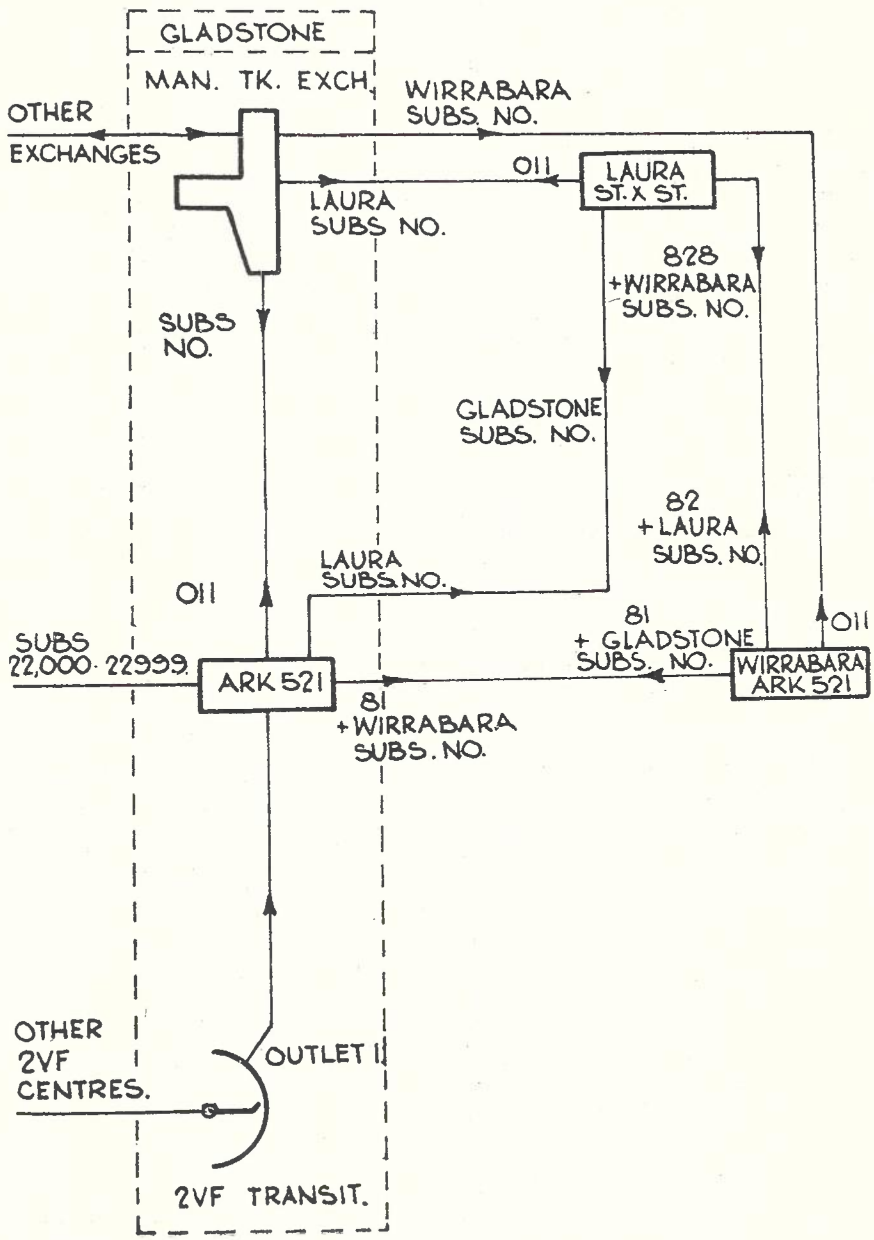

Fig. 1.—Inter-exchange Access from Gladstone ARK 521.

* Mr. Bartsch is Engineer, Class 2, Long Line and Country Installation Division, South Australia. See page 332.

** Mr. Klose is Engineer, Class I, Long Line and Country Installation Division, South Australia. See page 332.

parent are busy, but has, in addition, facilities to discriminate between local calls and calls for the auto parent. If the call is for a local subscriber, the REG-D immediately disconnects the junction, stores the local digit information and arranges to have the local call completed, whereas with an ARM 50 parent, all digits would be received at the parent and the local number information would have been returned to the ARK with M.F.C. All ARK exchanges now installed in Australia are equipped with REG-Ds. Code receiving equipment and REG-Ls are not used.

In a crossbar exchange, it is important to ensure that the time for which common equipment is held be kept to a minimum. Facilities for time release and line lockout are provided to prevent this equipment being held. Generally, there is only one marker in an ARK exchange and this may be used several times in setting up a call. This equipment will time release (i.e., disconnect itself from a holding loop) in 2-3 secs. The REG-D will time release if dialling has not been completed in 90 seconds. If a call has been made to a busy subscriber or junction, REG-D will time release after five seconds. Some other relay sets will also release after a predetermined time has elapsed.

Line lockout is a condition applied to a subscriber's line when equipment held by the subscriber time releases. The holding loop is disconnected from the equipment and try again tone is fed to the subscriber's line.

Interworking with other exchanges

The ARK 511 REG-D type terminal exchange can be trunked to either one automatic exchange referred to as the "advance occupancy" exchange or one manual exchange. The ARK 521 REG-D type exchange can have four direct routes to either automatic or manual exchanges in addition to its one "advance occupancy" automatic exchange.

The term "advance occupancy" is applied to the distant automatic exchange because all calls originating in the ARK seize a junction to this exchange when the subscriber lifts his receiver. Dial tone is fed from the advance occupancy exchange to the calling subscriber whose digit information is then repeated to both the junction and the REG-D in the ARK exchange.

The term "direct route" refers to the other exchanges which can interwork with the ARK terminal exchange. Before an ARK subscriber can be connected to a direct route junction he must dial a code of one or more digits. The REG-D then arranges for a new connection from the calling subscriber to the required junction. If the direct route exchange is automatic a second dial tone will be heard from this exchange, indicating that dialling can proceed. If the direct route exchange is manual, ring tone will be heard until the operator answers.

Should an ARK exchange interwork with only manual exchanges, dial tone is fed from the REG-D instead of the advance occupancy exchange. The REG-D will receive the initial code

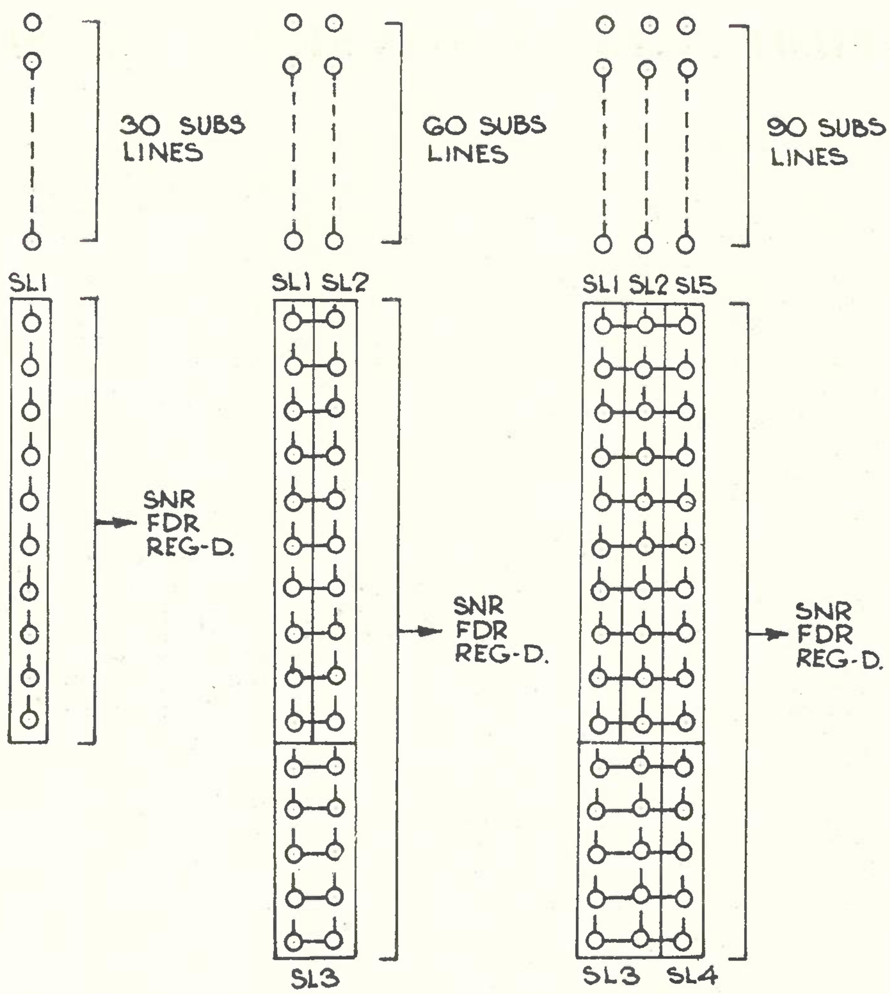

Fig. 2.—Grouping Plans for ARK 511 for 30-60-90 Lines.

for the required exchange and arrange a new connection from the calling subscriber to the required junction.

When the ARK exchange is connected to an advance occupancy automatic exchange, all the digits dialled by a subscriber of the ARK are repeated to this exchange, hence the calling subscriber dials only the directory entry number of the automatic subscriber. Similarly if the advance occupancy exchange has access to other automatic exchanges in say a metropolitan network, the ARK subscriber can be tandem switched by the distant exchange to any subscriber within the network by dialling only the directory number. If, however, a connection is required from the ARK 521 to a direct route automatic exchange, a prefix must be dialled by the ARK 521 subscriber who must then wait for a second dial tone from the direct route automatic exchange before dialling the directory entry number of the required subscriber.

Incoming calls from the advance occupancy automatic exchange to the ARK can only be directed to a subscriber of the ARK and not via the ARK equipment to any direct route junctions. Only the last digits of the directory number are required by the ARK exchange to complete a call from the advance occupancy exchange to an ARK subscriber. The preceding digits of the directory number may be used or else absorbed before the junction to the ARK is seized.

Calls on direct routes to the ARK exchange can only be directed to the ARK subscribers. Two methods of operation are possible. On calls incoming from other automatic exchanges on FIR-L-N, only the last digits of the directory number are required by the ARK exchange to complete the call, in a similar manner to calls from the advance occupancy exchange. On a call incoming from another auto exchange on a manual exchange relay set FDR-L-M, the full directory number must be dialled into the ARK exchange. In this case, the calling subscriber in the originating auto exchange must dial sufficient prefix digits to seize a junction to the ARK terminal exchange, then wait for dial tone, before dialling the full directory number of the ARK exchange subscriber. This second method must be used for calls on direct routes from ARK exchanges since in these cases the time needed to seize a junction to the ARK terminal may be larger than that allowed by the inter-digital pause.

A manual exchange similarly receives dial tone from the ARK before the operator dials the full directory number of the wanted subscriber. The access codes and routes associated with the Gladstone ARK 521 exchange are shown in Fig. 1.

In this network, Laura is the advance occupancy automatic exchange and thus Gladstone subscribers dialling Laura dial Laura directory numbers; similarly Laura subscribers dial Gladstone directory numbers, but Gladstone and Wirrabara subscribers dialling each other on the direct route must prefix the directory entry number by the prefix 81. In this trunking, an additional facility for overflow working is provided in the case of calls from Gladstone to Wirrabara. As Wirrabara is also available from Laura, calls will be directed from Gladstone via Laura selectors to Wirrabara if all of the direct route junctions are busy.

ARK 511 EQUIPMENT

Outline of Equipment

Selector Stage SL: The exchange has an initial capacity of 30 subscribers' lines which can be extended in units of 30 lines, to a total of 90 lines. A 30-line exchange has one crossbar switch SL1, with 10 verticals and 30 horizontals. The operation of an Ericsson crossbar switch having 20 horizontals, has been described by Strachan (5). A switch having 30 horizontals is similar, but, in addition, the unoperated position of the HA/HB bar is used for connection to a third set of contacts.

The outlets of the 10 verticals are horizontally multipled so that equipment connected to any one vertical may be switched to any one of the 30 subscriber lines. The 10 verticals (inlets) are permanently connected to either Junction Relay Sets (FDR), Local Connecting Relay Sets (SNR) or Discriminating Registers (REG-D), each of which may be switched through SL1 to any subscriber's line. The SNR, FDR and REG-D relay sets are referred to as "devices".

A 60-line exchange has in addition two crossbar switches SL2 and SL3. The outlets of the verticals of the switches are horizontally multipled so that each unit of 30 subscriber lines has access to 15 verticals. The verticals are also vertically multipled to give 15 inlets for connection to SNR, FDR and REG-D.

The multipling of verticals is best illustrated by "chicken diagram" also described by Strachan (5). The grouping of switches for 30, 60 and 90 line ARK exchanges is shown in Fig. 2.

It is seen that the 90-line exchange has additional switches SL4 and SL5, 15 verticals of which are horizontally multipled and also vertically multipled to the 60 line grouping scheme. In this case, there are still 15 inlets any of which may be switched to any one of 90 subscribers' lines.

Subscribers' line relays LR/BR/BLR: This is a set of three relays for each subscriber's line which calls in the marker to set up a call, or feeds try again tone under line lockout conditions.

Marker M: This relay set controls the selection of a path and establishes a connection through the SL stage between a subscriber and a device. It is the most complex item of equipment used in the exchange. There can be only one M per exchange.

Local Connecting Circuit SNR: This is the relay set used to connect the two subscribers in a local call. It consists of a transmission bridge; an A-side and a B-side to which the calling subscriber and called subscribers respectively are connected. The SNR occupies two verticals, one for the A-side, the other for the B-side. A maximum of six SNR's can be installed in a 511 exchange.

Junction Line Relay Sets FDR, FIR, FUR: These enable calls to be made between the ARK 511 and its parent exchange. FDR denotes both way working, FUR outgoing from the ARK, and FIR incoming to the ARK. Junctions to magneto manual, CB (Central Battery) manual, and automatic exchanges require different types of FDR, FIR, and FUR relay sets.

(a) FDR-L-N, FIR-L-N, FUR-L-N are used on junctions to an automatic exchange.

(b) FDR-V-M is required on junctions to a magneto manual exchange.

(c) FDR-L-M is used on junctions to a CB manual exchange. (In ARK 521, FDR-L-M is also used on direct route junctions to automatic exchanges).

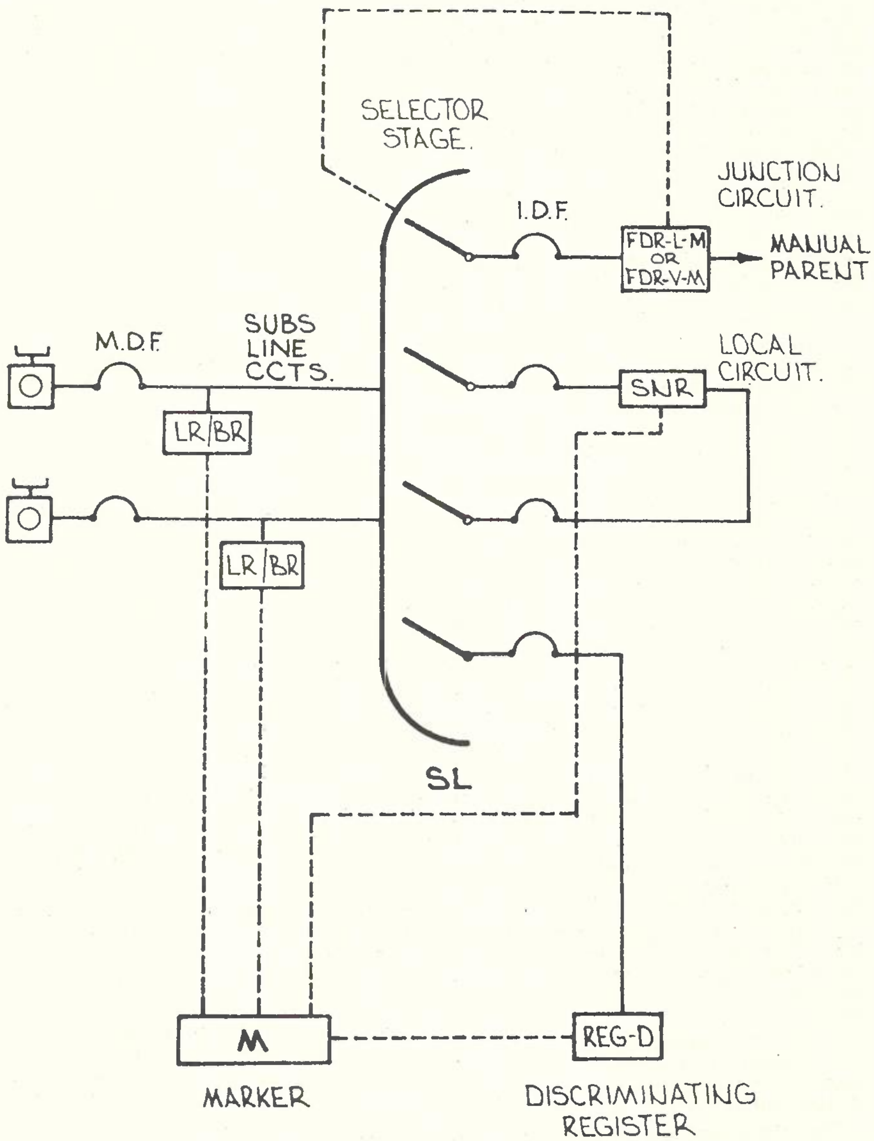

Fig. 3.—ARK 511 Trunking with Manual Exchange.

Register-Finder Connector RS: This arranges connections between an FDR, FIR or FUR-L-N and the REG-D for all calls in the case of an ARK 511 exchange with an advance occupancy automatic exchange.

Discriminating Register REG-D: This relay set may be connected across a junction line or directly to the SL stage. It can discriminate between local and outgoing calls. It stores local digits and initiates connections to the called ARK subscriber.

PBX, AX and LFR: These are miscellaneous relay sets. The PBX enables the connection of PBX subscribers, the AX enables subscribers to be allotted different classifications if required and the LFR is the alarm relay set.

Switching Arrangements—ARK 511 Trunked to a Manual Exchange.

Originating Calls: When a subscriber lifts his receiver the marker M (Fig. 3) is seized. M identifies the subscriber and operates the horizontals corresponding to the subscriber's position in the SL multiple. At the same time M tests for a free REG-D. If a free REG-D is found, M establishes the connection between the subscriber and REG-D by operating the SL vertical associated with the REG-D. The subscriber's loop holds REG-D which feeds back dial tone. M releases. If no free REG-D is found M is time-released after a few seconds and operates the subscriber's line equipment, which now feeds try again tone. The subscriber is put on line lock-out and will remain so until he replaces his receiver. However, assuming that there is a free REG-D, the subscriber dials the required number and the digits are stored and analysed in REG-D which determines whether the call is local or for the manual exchange.

(i) *Local Call:* When REG-D has received all digits it seizes M and instructs it to search for and select a free local connecting relay set, SNR. REG-D now transfers the called subscriber's tens- and units-digits to M which tests the B-subscriber's line condition. If the called line and an SNR is free, M establishes the connection to the B-side of the selected SNR by effecting the operation of the appropriate SL horizontals and vertical. M then reroutes the calling subscriber through the SL stage to the A-side of SNR—this re-routing is known as a "jump". M and REG-D release. SNR transmits interrupted ringer and ring tone to the B and A subscribers' lines respectively.

If the called subscriber is busy or there is no free SNR, the A subscriber receives try again tone from REG-D for a few seconds then the line is put on lockout from where the try again tone is continued. M and REG-D release.

Should the called subscriber be on line lockout or have a line fault, M time releases and the calling subscriber is also put on a line lockout.

The time required to effect a jump is a minimum of 400 mS. REG-D sends a burst of continuous ring tone to the calling subscriber after the last digit has been dialled until REG-D is released. The correct tone is then applied. If this tone were not provided, the calling subscriber would be without any tone in this post dialling delay and might terminate the call.

(ii) *Call to Manual Exchange:* After REG-D has received all digits of the manual code, it calls M which now searches for a free FDR. If a free FDR is found, M arranges the jump between the calling subscriber and the selected FDR. REG-D releases. After the initial burst of continuous ring tone from REG-D, FDR feeds interrupted ring tone. Should there be no free FDR, M time releases and puts the subscriber on line lockout.

Incoming Calls from Manual Exchange: An FDR is first seized by the manual exchange. The FDR, which has an appearance in the subscriber's multiple, now seizes M and a search for a free REG-D is made as for an outgoing call. The REG-D in this type of call must receive all the digits of the called subscriber's directory number. After the last digit has been received, REG-D, which has recognised that the call is incoming from an FDR, transfers the called subscriber's tens and units digits to M. M now tests the subscriber's line condition.

If the subscriber is free M arranges the connection of the subscriber to the FDR through the SL stage. The FDR now feeds interrupted ring to the subscriber and interrupted ring tone to the operator. M and REG-D release.

If the called subscriber's line is busy, on line lockout or faulty, M instructs FDR to feed try again tone to the operator. M and REG-D then release.

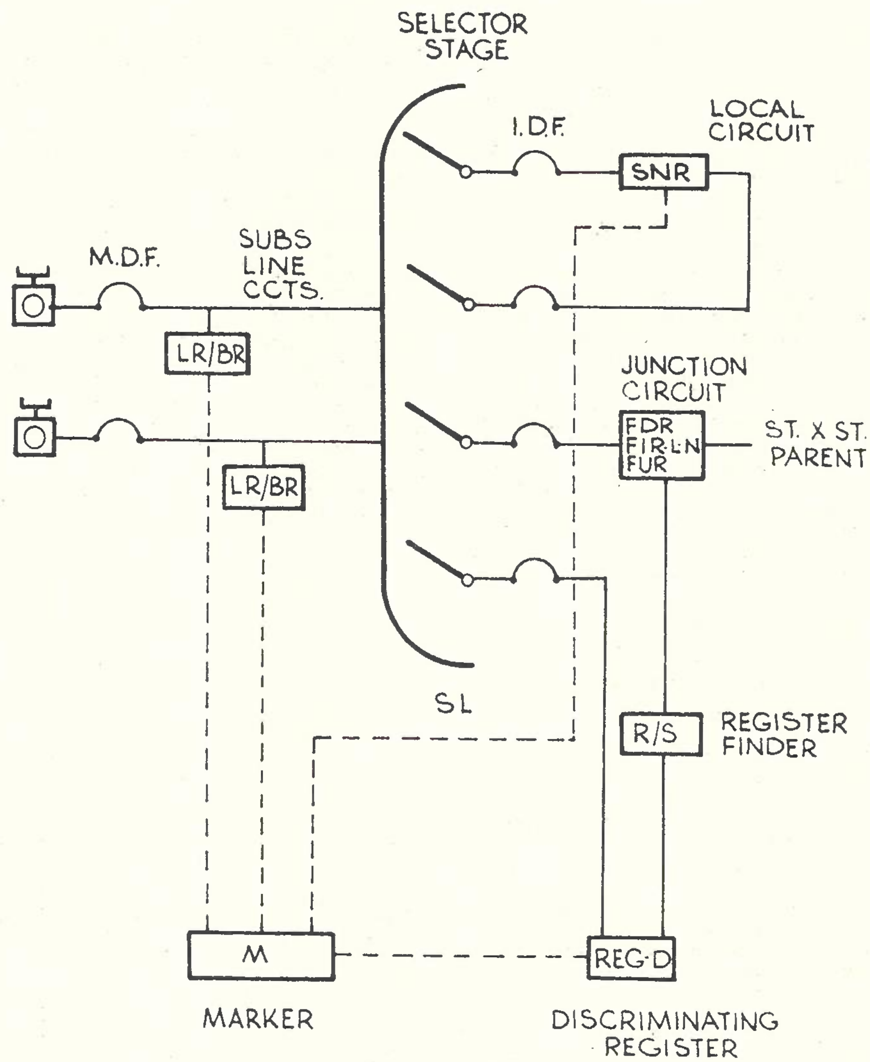

Fig. 4.—ARK 511 Trunking with Advance Occupancy Automatic Exchange.

Switching Arrangements—ARK 511 Exchange Trunked to Advance-Occupancy Automatic Exchange.

Originating Call: Whenever an ARK subscriber initiates a call, he seizes M (Fig. 4) and is identified as in the manual case, but now M tests for any free FUR or FDR-L-N. If any free junctions are available, M selects one, and then establishes the connection between the subscriber and, e.g., an FUR. The FUR then calls the RS relay set which selects a free REG-D.

If a free REG-D is available it is seized and connected to the FUR via a path through the RS; M releases. The FUR now extends a loop over the junction to seize the associated selector in the distant exchange. The subscriber receives dial tone from this exchange after which he dials the required number. The dial impulses are repeated by the FUR over the junction and also into REG-D via the RS connection. The REG-D determines the switching process required by analysing the dialled digits.

(i) *Call to advance occupancy exchange:* Should REG-D recognise that the call is to be routed to the advance occupancy exchange, it releases itself from the FUR and RS and the remainder of the digits are repeated over the junction.

(ii) *Local Call:* When REG-D recognises local code, it signals the FUR to release the junction. When REG-D has received the complete number it transfers the necessary digit information to M which tests the called subscriber's line condition. At the same time, M searches for free SNR.

If the called subscriber is free, and there is a free SNR, M arranges the connection between the B and A subscribers and the SNR as in the manual parent case. M, REG-D and FUR then release.

If the called subscriber is busy, on line lockout or has a line fault, or there is no free SNR, M signals REG-D to send try again tone for a few seconds after which the FUR places the calling subscriber on line lockout. M, FUR and REG-D then release.

Should there be no free REG-D available, M, which is still held at this stage, puts the subscriber on line lockout, then releases. The FUR is also released. Thus a call cannot proceed to the parent exchange when there is no free register even though free junctions may exist.

If M cannot find a free FUR it will then search for and select a free REG-D via the SL stage as in the manual case. A local call may still be effected. If REG-D recognises that the call is to the advance occupancy exchange, it returns try again tone for a short time after which it puts the subscriber on line lockout and then releases. REG-D is thus used as an overflow register.

In the case where M cannot find a free FUR or REG-D, it time releases and places the subscriber on line lockout.

Incoming Call: For an incoming call from the advance occupancy exchange, only the last two local digits are received by the terminal exchange, thus the seizure of the REG-D at the terminal exchange must occur within the interdigital pause before the last two digits are dialled. The incoming junction seizes an FIR-L-N (FDR-L-N) which immediately signals the RS to find, and connect it to, a free REG-D. When it has received both digits, REG-D transfers the number information to M which tests the subscriber's line condition. If the subscriber is free, M arranges the connection to the FIR. M and REG-D release. If the subscriber is busy on line lockout, or has a line fault, REG-D sends try again tone for a short time after which it disconnects itself and the FIR continues to send try again tone over the junction until the distant exchange releases.

Should no free REG-D be available, the FIR returns try again tone to the junction until it is cleared.

ARK 521 EQUIPMENT

Outline of Equipment

An ARK 521 exchange has an initial capacity of 100 subscriber lines and can be extended in units of up to 100 lines, to a total of 2,000 lines. The subscriber's line equipment and the devices FDR, FUR, FIR and SNR are identical and the PBX, AX and LFR perform similar functions to those used in ARK 511. The essential difference between the ARK 521 and ARK 511 equipment is that the SL stage is expanded into a number of partial SL stages. As a result, the marker equipment is more complex.

SL Partial Stages, SLA, SLB, SLC, SLD: (See Fig. 5.) The subscriber stage comprises two selector stages SLA and SLB (the term "partial" is usually omitted when describing ARK 521). Each 100 line subscriber group is served by two SLA crossbar switches, SLA1

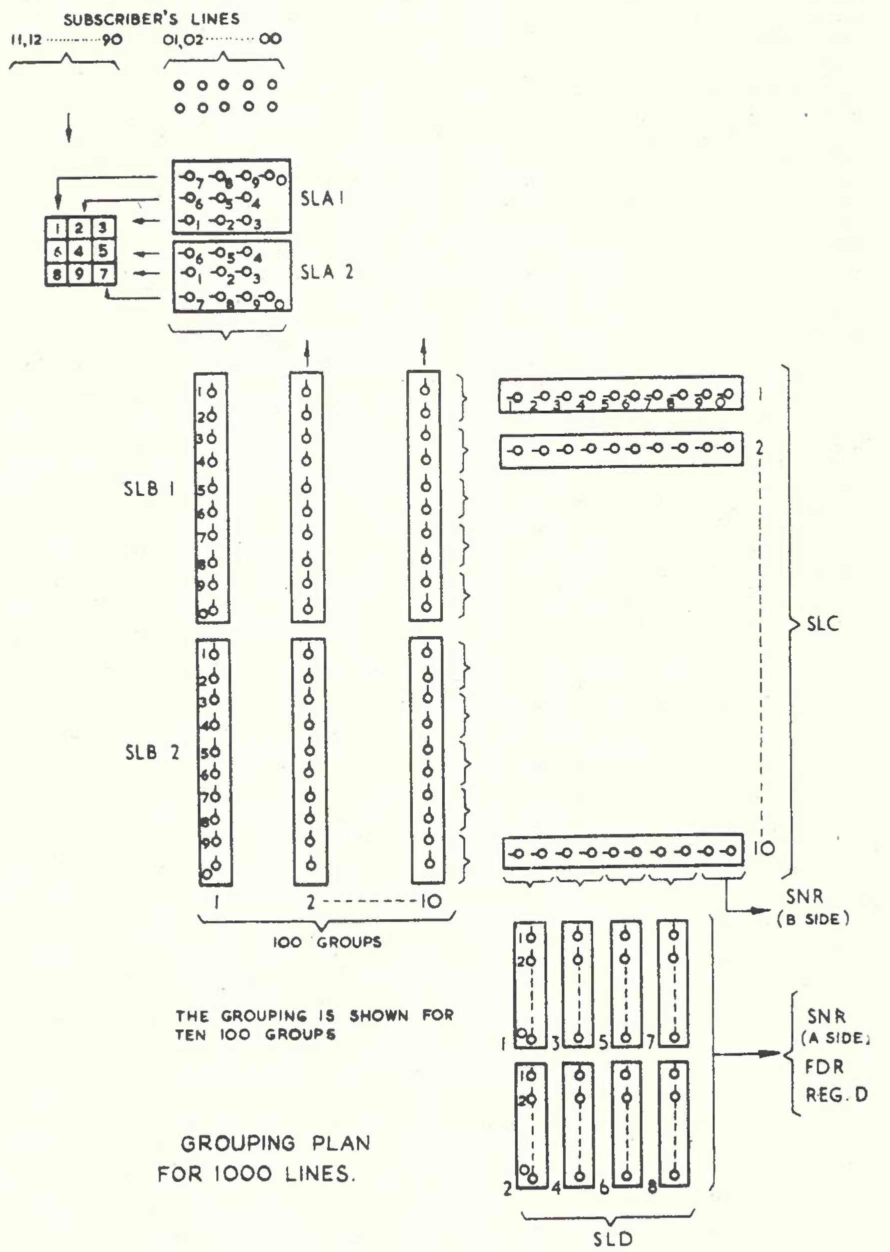

Fig. 5.—ARK 521 Grouping Plan.

and SLA2, and two SLB crossbar switches, SLB1 and SLB2. Each switch has 30 outlets per vertical. Ninety lines are connected to the SLA multiple. The SLA verticals are horizontally multipled in groups such that each subscriber has access to six or seven verticals (c.f. ARK 511 where each subscriber has access to all verticals, i.e., full availability). The remaining 10 lines of the 100 line group are connected directly from the first 10 outlets of the SLB multiple (horizontals), where they have full availability to all SLB verticals. The remaining 20 SLB outlets are connected to the SLA verticals. For maximum efficiency, lines connected directly to the SLB stage should be the busiest lines in the exchange. These lines are therefore usually allocated to junctions associated with an FDR-L-M or FDR-V-M and possibly some PBX subscribers.

The exchange capacity is increased beyond 100 lines by adding more subscriber stages. In exchanges up to 100 lines, only SLA and SLB stages are required, while normally an SLC stage must be introduced for a capacity beyond 100 lines. An SLD stage will usually be required when the capacity exceeds 400 lines. The maximum number of SLC and SLD switches for an exchange is 20 and 16 respectively.

The SLC and SLD stages are composed of units, each comprising one crossbar switch with associated relays for connection to the marker. There are 20 outlets per vertical on each switch (c.f. 30 for SLA and SLB) and the verticals are horizontally multipled to give a total of 20 outlets per switch. Each outlet is connected to a vertical of the preceding SLB or SLC stage.

The devices SNR, FDR, FIR, FUR and REG-D are connected to the SLC (SLD) verticals. If there is an SLD stage the B side of each SNR is connected to an SLC vertical.

The interconnection of the SL partial stages is a function of the exchange subscriber capacity and the traffic density. A grouping for 1,000 lines is shown in Fig. 5. A trunking diagram is shown in Fig. 6.

Marker: In ARK 511 the Marker M is a single relay set which is associated with the one SL stage. In ARK 521 the marker is divided into separate relay sets for each partial SL stage. The relay sets ABMA, ABMB, CM and DM are used for SLA, SLB, SLC and SLD stages respectively. CDM is the relay set which selects free devices and CMTD selects free links between the SLC and SLD stages. The ABMA and ABMB cater for 400 lines. For each additional 400 lines an ABMT relay set is required. The portion of the marker consisting of the relay sets ABMA, ABMB and ABMT is referred to as the ABM. Two identical sets of marker equipment may be installed in an ARK 521 exchange.

Discriminating Register REG-D: The ARK 521 REG-D is similar to the ARK 511 REG-D but with the additional feature that it can arrange switching to four direct routes.

Register Connector RS: This relay set is used to connect an FDR-, FUR- or FIR-L-N to the REG-D.

Register Connector Marker RSM: RSM is the marker for the RS. It searches for and selects a free REG-D. One RSM is required for every three RS.

Marker Connector MIR-REG: This is a common equipment relay set which connects SNR and REG-D with the marker. It will prevent the simultaneous operations of both a local connection and a jump.

Switching Arrangements

The switching operations of an ARK 521 exchange are basically similar to those of an ARK 511 except that, being a larger exchange, they are more complex.

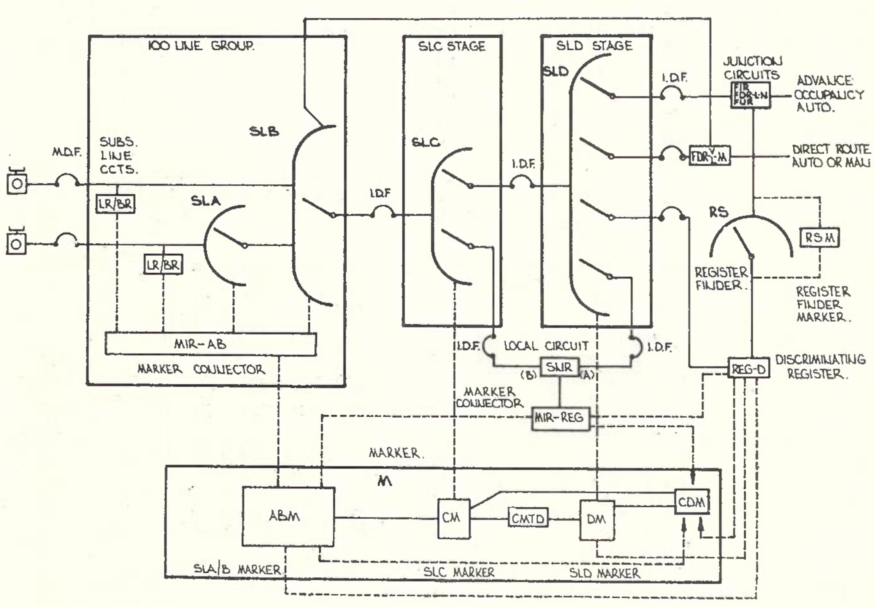

Fig. 6.—ARK 521 Trunking Diagram.

A major difference between ARK 521 and ARK 511 switching is the way in which the connection path between a subscriber and a device is established by the marker. In ARK 511 there is only one possible path between a particular device and the subscriber. This requires the selection of one horizontal position and one vertical of the SL stage. However, in ARK 521, the interconnection of the SL partial stages is such that a number of paths between a device and a subscriber are possible, one of which must be chosen. This choice is controlled by the marker relay sets, which interwork to operate appropriate verticals and horizontals in each SL stage. As an example of this path selection the initiation of an outgoing call from an exchange with an advance occupancy parent is described. (Fig 6 in which an SLD is the last stage, refers.)

On originating the call, the calling subscriber is connected through to ABMA by the corresponding MIR-AB. ABMA identifies the calling 100-line group and then the subscriber's tens and units digits. If the tens digit of the subscriber is in the range 1-9, a free SLA vertical with access to the subscriber is selected. The MIR-AB operates the SLA horizontal associated with the subscriber. Depending on the SLA vertical selected, ABMB and MIR-AB interwork to operate the correct SLB horizontals.

The marker now initiates the search for a free FUR-L-N (or FDR-L-N) to the parent exchange. ABM instructs CDM to find a free FUR. CDM through connects wires for all free FUR so that all SLD switches with a free FUR are "idle-marked". (The term "idle-marked" is used to describe the condition applied by the marker to a crossbar switch which is eligible for the required connection path). CMTD now through-connects wires for all idle-marked SLD switches to idle-mark all SLC switches which has a free vertical accessible from one of these SLD switches. ABM selects a free vertical from SLB1 and SLB2 which is accessible from an idle-marked SLC switch. This vertical nominates the SLC switch to be used. The horizontals in the SLC switch associated with the selected SLB vertical now operate. In the SLC switch CM selects a free vertical which has access to an idle-marked SLD switch. This vertical nominates the SLD switch to be used. Operation of the associated SLD horizontals follows immediately. Finally, in the SLD switch, DM selects an SLD vertical to which is connected a free FUR. The marker now operates the selected vertical in each partial stage thereby completing the connection path to the subscriber. The FUR, thus seized, is connected to a REG-D via the RS in a similar manner to that described in ARK 511.

This process of idle-marking and selecting a free path through the ARK 521 SL partial stages is repeated for each similar type of call as described for the ARK 511 case.

The additional feature of ARK 521 is the jump possibility to any junction in one of four direct routes when the exchange has an advance occupancy parent. If, in this case, a subscriber has initiated an outgoing call, he is connected to a free FUR to the parent and a REG-D. When REG-D recognises the code for a direct route exchange, it instructs CDM to search for a free FDR-L-M or FDR-V-M to the required exchange. The marker then selects a path between the chosen FDR and the calling subscriber. When the jump has been effected the marker and REG-D release.

Incoming calls from any one of the four direct route exchanges will be connected as described in the ARK 511 case.

Another facility of an ARK 521 exchange is overflow working via the advance occupancy automatic exchange. This is possible if a direct route exchange is also available from the advance-occupancy exchange. Suppose an ARK 521 subscriber has dialled the code for a direct route. If no free junction is available to this exchange, REG-D releases. The connection between the calling subscriber and the FUR-L-N is maintained and impulsing will proceed via the advance occupancy automatic to the required exchange.

INSTALLATION

General

A basic 30-line ARK 511 exchange consists of two racks of equipment. An additional rack is required for exchanges of 30-90 line capacity. These racks may be mounted back to back or against a wall. Wall mounted racks in the Reeves Plains building are illustrated in Fig. 7. As all inter-rack cabling is completed by plug-ended cables, the installation is simple; racks are mounted in position, M.D.F. and power cables are run and terminated, then the racks are plugged together. The only jumpering required in ARK 511 is that for the local circuits (SNRs) or Junction circuits (FDRs) which may vary in number with each exchange. (See Figs. 3 and 4.)

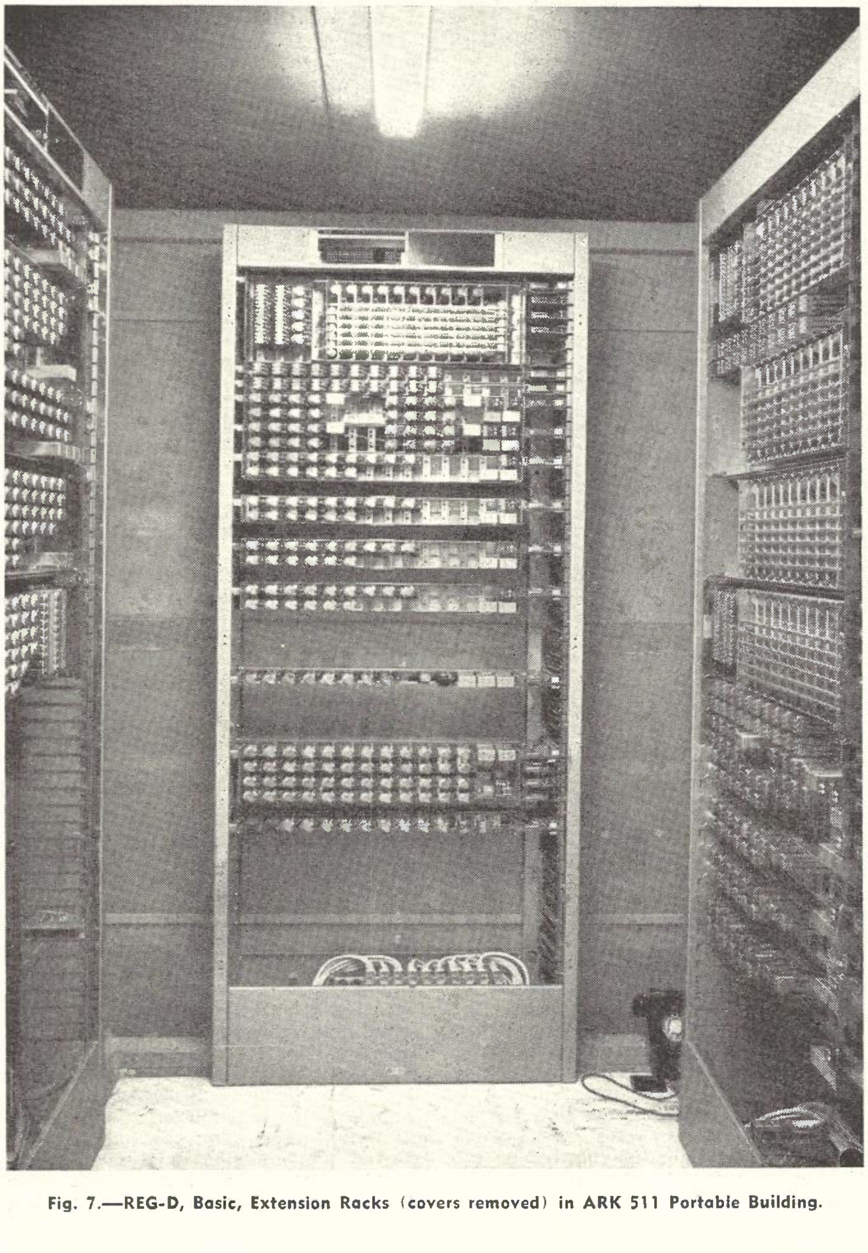

Fig. 7.—REG-D, Basic, Extension Racks (covers removed) in ARK 511 Portable Building.

In the ARK 521 case the equipment, though similar to ARK 511 (the SNRs and FDRs are identical), is not mounted in complete racks as ARK 511, but between rack sides, which must be individually fixed to the floor. These are bridged across the top with a steel bar called a top iron. There is one top iron for each row of racks. Tie bars are run at right angles across the top irons to wall plates. Troughing is then placed on the tie bar to contain the inter-rack cables. There is one row of troughing for two rows of equipment mounted back to back. Cables are not laced in the troughs, but may have a circumferential tie around each pack each yard or so. (See Fig. 8.) The cables are laced where they enter the racks and are then formed at the rear of the rack to terminate on tags of 80-point knife jacks, into which the relay sets and crossbar switches are plugged. The racks used in ARK 521 are called BDH racks. These are identical to the BDH racks used in ARF crossbar exchanges.

Tools for terminating BDH racks and also the forming boards used are described in an article by McMurray (6). In South Australian installations the cables are formed and stripped on the forming boards ready for terminating before the racks are erected.

As the ARK 521 equipment has several partial SL stages, flexibility is obtained by having the inlets and outlets of each partial stage, as well as some control wiring from the markers, cabled to an I.D.F. (See Fig. 5). The cables enter the top of the I.D.F. through vertical "fingers" (Fig. 8) from the troughing and simply hang behind the I.D.F. (See Fig. 9.) The I.D.F. tag strips may be either jumpered or strapped to give the required grouping scheme for the exchange.

The crossbar equipment, though dust tolerant, will perform better if an absolute minimum of dust is allowed to enter the equipment room. As the ARK exchanges may be completely cabled, terminated and jumpered before any relay sets or switches are unpacked, any dust which is then present can be removed before it enters the equipment. The exchanges are cleaned by vacuum cleaners fitted with hoses long enough to direct the air exhaust (which will contain small particles of dust not caught by the bag) outside of the equipment room. Generous use is made of cloths impregnated with an oil and water emulsion to clean all walls, floors and equipment racks before the relay sets and crossbar switches are jacked into position.

Once the equipment is installed, all persons entering the exchange room must change shoes for slippers in the

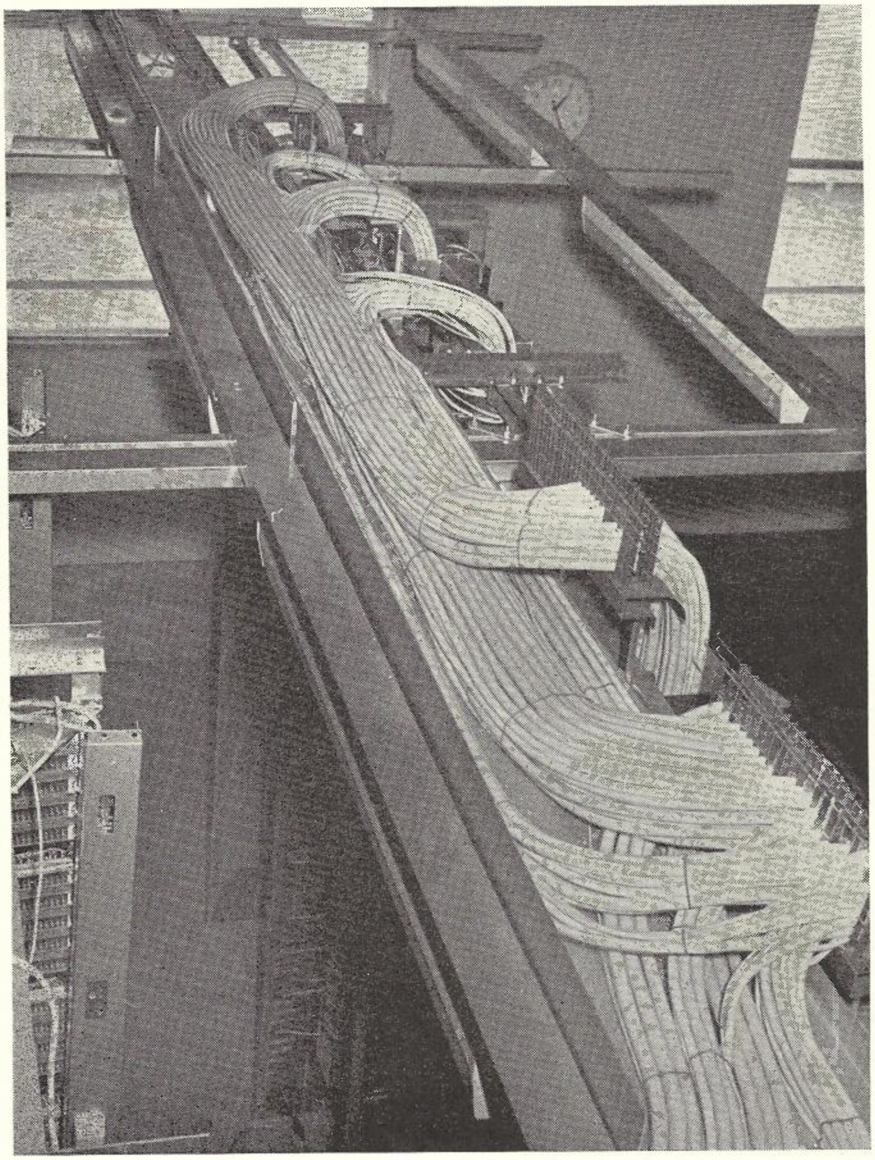

Fig. 8.—Cables in Trough above SLC and IDF—ARK 521.

doorway to minimise dust entry. Special precautions are also taken to prevent dust entry from other soures. In the permanent buildings doors and windows are sealed and if air-conditioners are required for temperature or humidity control, special filters are fitted.

Particular attention has been given to sealing equipment rooms in portable buildings, which will generally be in country locations more prone to dust than permanent buildings in built-up areas. In the portable buildings a pressurising fan is fitted to increase the pressure within the exchange. This results in small outward flow of air from the equipment rooms through any cracks or imperfect seals, further preventing dust entry. In the case of Reeves Plains portable, an effective pressure equivalent to 0.25 in. water was obtained using the pressurising fan technique.

A further important aspect, particularly with sealed portable buildings, is the control of temperature and humidity. The equipment will function satisfactorily if the ambient temperature does not exceed 120°F. and if humidity is kept between the limits of 35 and 75 per cent. As a portable ARK building may be installed in arid country away from water supply and other buildings, it may be impossible to shade the building without erecting screens. The building would thus be subject to direct sunlight when the outside temperature could well be in excess of 110°F. To minimise heat entry, the buildings are made much longer than they are wide and faced in an east-west direction with a large overhanging northern eave. Orientated in this way, a smal wall area is presented to the rising and setting sun's rays which would be approximately normal to the end walls and the large north facing wall is completely shaded by the eave when the sun is at its azimuth. Moreover, the walls and roof are insulated with four inches of rock wool and also double-sided sisalation to minimise heat transfer to the equipment room. With buildings constructed in this manner, the maximum internal temperature will not exceed 120°F. in the majority of locations. A more important problem, however, may be that of humidity control. As the crossbar room is sealed and hence there is only a minute transfer of air, the humidity will fall as the temperature rises. Tests at Reeves Plains indicate that the low limit of humidity will be reached before the high temperature limit. For this reason, it will be necessary in some hot, dry locations to provide an air-conditioner to limit the temperature to much less than 120°F. to give permissible humidity conditions. (See Fig. 10.)

Testing Equipment

One to One Traffic Route Tester (TRT): A TRT will set up one connection through an automatic exchange. It loops into the equipment as a normal subscriber would and automatically dials a local number. If the call is successful, ring is fed by the SNR to the called line thence back to the TRT which trips the ring thereby completing a cycle. Two meters are provided on the TRT; one records the total number of calls, the other the number of faults. The TRT can be set to repeat a cycle and so provide an indication of the quality of service. The instrument may be connected to the M.D.F. with normal test shoes or to specially allocated test numbers which appear in a jack field at the top of the ARK 521 racks.

Load Tester: This equipment is used to test the marker equipment of a crossbar exchange. Further, by the choice of suitable test numbers and the use of blocking keys, it can be used to test every link between the switching stages. The tester sets up a maximum of ten simultaneous calls and checks that they are completed correctly to ten chosen numbers in the same exchange. If no fault is encountered the connections are cleared and the process is repeated. Several thousand test calls can be made in a day. Should a fault occur, the load tester raises an alarm and camps on the fault until it receives attention.

Testing Procedures

A major portion of each crossbar exchange installation is the testing required. This is particularly so in ARK 521 where several paths are possible between the SL partial stages.

In the Gladstone and Reeves Plains pilot installations the testing proceeded in the following order. When all cabling and terminating had been completed, the wiring was buzzed for continuity. Each switch and relay set was then unpacked. Before being jacked into the racks, the equipment was visually checked for any dry joints or obvious defects, such as damaged or maladjusted components. Although very time consuming, this proved invaluable because several irregularities were found which were potential faults which may not have

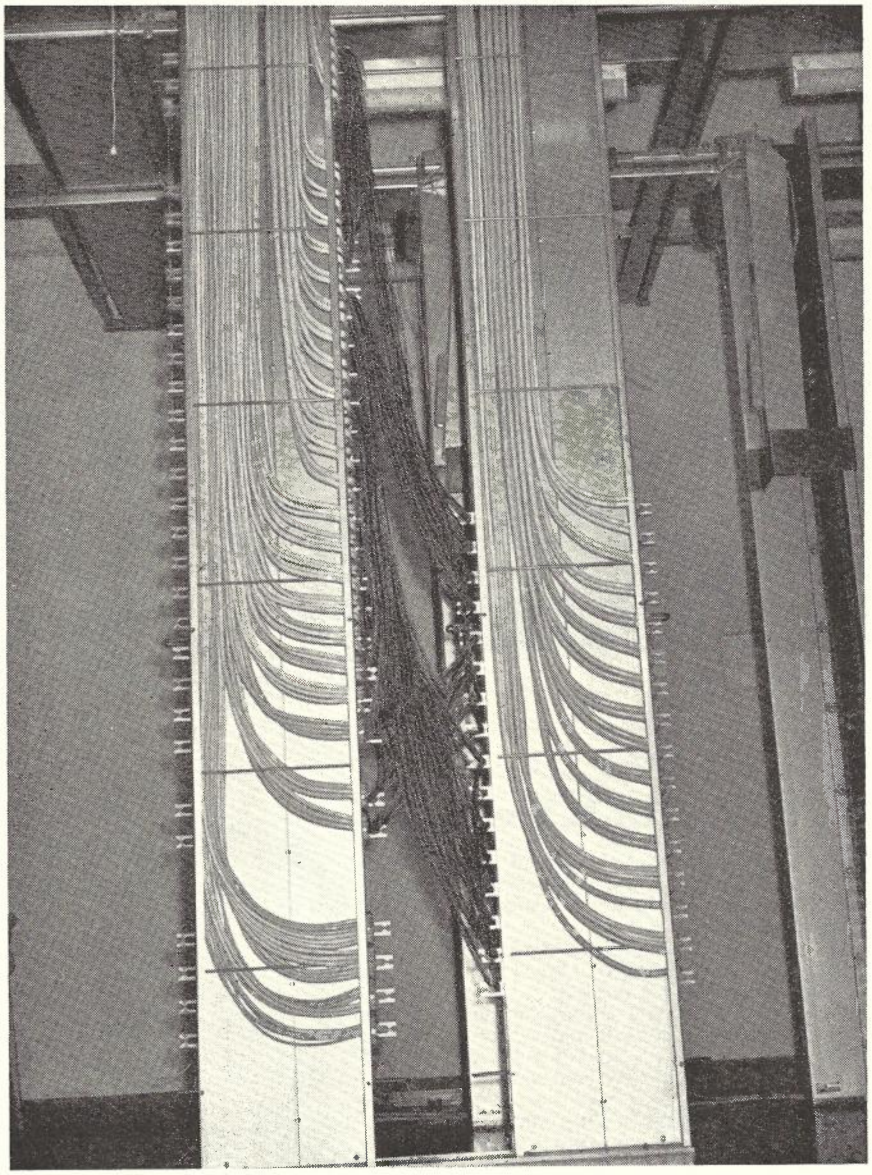

Fig. 9.—Cabling behind the IDF Type BAB 970—ARK 521.

been detected during electrical testing. With the crossbar switches in situ, further adjustments were made, particularly to the horizontal bars and fingers.

Each exchange was then powered and the following testing completed before cutover.

Operational Tests: A serial of manual tests were performed to provide a static check on the switching processes. The armatures of appropriate selecting relays in the marker equipment and connecting relay sets were pinned to establish particular paths through the SL stages to the devices. This ensured that the rack wiring, inter-rack wiring, and I.D.F. jumpering were correct for the particular grouping scheme.

Call Through: Local calls were set up from each subscriber's line to check speech and meter operation.

Route Testing: A one-to-one TRT was used to put several hundred calls through each SNR and REG-D. To test an SNR, all other SNR were blocked and, with all REG-D free, the TRT was set in operation. Similarly, a REG-D was tested by blocking all other REG-D and using the TRT with all SNR free. This testing checked the reliability of each SNR and REG-D as well as the possible connection paths between the calling line and the devices. The FDR-L-M could not be tested with the TRT because an FDR-L-M applies a loop condition on seizure. The TRT will only recycle if it has tripped ring. Numerous calls through each FDR-L-M were therefore made manually.

Load Testing: Because there were five REG-D at Gladstone, the load tester was used to complete only five simultaneous local calls. Appropriate test numbers were chosen to test every possible connection path through the SL stages. At Reeves Plains where there were only two REG-D, the load tester set up only two simultaneous calls. Further, being an ARK 511 any two test numbers were chosen since there is only one SL stage. The reliability of the marker equipment was proven by these tests. At Gladstone only three faults were observed in 10,000 operations of the ABMA and then it could not be determined whether these were irregularities in the crossbar equipment or the load tester itself.

The dynamic testing provided by the route testing indicated various faults such as dry joints, incorrectly adjusted relay armatures and crossbar switch horizontal fingers which were not detected in the visual inspection. The route testing was carried out first to ensure reliable operation of each device. Any fault then occurring during the load testing would more likely be confined to the marker equipment.

CONCLUSION

Crossbar exchanges are now the successors to step-by-step automatic exchanges in Australia. ARK 511 exchanges will be installed in lieu of type B or C R.A.X.s and ARK 521 exchanges in lieu of step-by-step exchanges of up to 2,000 lines capacity. In an automatic network the ARK exchanges are terminal exchanges which can be trunked to only one advance occupancy automatic exchange. A closed numbering scheme is available to this exchange. In addition, an ARK 521 exchange can switch to four direct route automatic exchanges if prefixes are dialled. This facility is not available for the ARK 511 exchanges.

ARK racks are wired for both REG-D and M.F.C. working. The initial exchanges are equipped with REG-Ds, but exchanges could be installed with M.F.C. and REG-Ls using the same equipment racks.

It is proposed to install an ARM automatic transit switching exchange at Gladstone. When this is completed, it will be necessary to install different FDR and convert the existing Gladstone ARK 521 exchange to M.F.C. working, to trunk to central registers in the ARM. As the ARM will be in the same building as the ARK, there will be no shortage of junctions between the two exchanges, thus REG-L will not be required in the Gladstone ARK terminal exchange. At the same time Wirrabara ARK 521 exchange will also be converted to M.F.C. to interwork with Gladstone ARM. In this case, the REG-L portion of the REG-D may still be used as an overflow register until REG-L are installed.

It is seen, therefore, that ARK REG-D type exchanges are suitable for working in a step-by-step network and that they can be easily converted to M.F.C. working as the Australian crossbar and subscriber trunk dialling programmes are further implemented.

Fig. 10.—Reeves Plains ARK 511 Portable Exchange.

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Mr. N. M. MACDONALD, B.Sc., M.I.E.Aust.

On 24 April, 1964, the Council of Control of the Telecommunication Society of Australia accepted, with considerable regret, the resignation of Mr. N. M. Macdonald from his position as Editor-in-Chief on the Board of Editors of the *Journal*. Mr. Macdonald has been a member of the Board since 1950, and has been Editor-in-Chief since the position was first created in 1960. His resignation brings to an end a period of outstanding service and members of the Society will no doubt join with the Board of Editors in this expression of appreciation for a job well done.

Mr. Macdonald's term of office coincided with a time of spectacular growth and dramatic technological change in the National Network and during this period he guided the *Journal* through many difficult developmental phases. Under his leadership, advertising, a new cover, Our Contributors, Technical News Items, Special Issues to mark major events and the new publication Australian Telecommunication Monographs have been introduced. The quality and quantity of the editorial content has improved and the *Journal* is now firmly established in international telecommunication circles.

Those Editors who have had the privilege to work with Mr. Macdonald considerably regret his decision to leave the Board. He brought enthusiasm and high capacity to a difficult and exacting task. He established, and vigorously maintained, an exceedingly high standard of editorial work which will remain as a continuing challenge in the future. He leaves the *Journal* with a strong, clearly established, editorial policy, and an enhanced reputation both in Australia and overseas.

The Society has recognised Mr. Macdonald's outstanding contribution to the *Journal* over a long period by electing him as Life Subscriber and Life Member.

Mr. Macdonald is succeeded by Mr. V. J. White, who served on the Board of Editors from 1959 to 1961 and was recently re-appointed.

Mr. N. M. MACDONALD, B.Sc., M.I.E.Aust.

MAINTENANCE OF TELEPHONE NETWORKS COMPRISING CROSSBAR AND STEP-BY-STEP EQUIPMENT

*G. MOOT, A.M.I.E.Aust.**

INTRODUCTION

The potential for low maintenance costs was one of the prime reasons for the Australian Post Office decision to adopt a switching system using the crossbar switch and common control equipment. Switching systems of this type have been in use in many parts of the world for a number of years and their high service reliability with low maintenance effort were well established before this Administration installed its first crossbar exchange in 1957.

One of the tasks now confronting the A.P.O. is to modify an established organisation and philosophy geared for the maintenance of step-by-step (bi-motional) switching networks to cope with large annual increments of the new crossbar equipment, much of which will be installed in the same switch room as existing step equipment. Within ten years the number of exchange lines will double to more than two million lines, 50% of which will be crossbar. For some years to come there will be very little scope for the development of wholly crossbar networks of any size and in the capital city networks in particular, the crossbar equipment will be closely interwoven with the existing step equipment.

Prior to the introduction of crossbar the A.P.O. had commenced a programme to introduce qualitative maintenance practices. Thus with the introduction of crossbar two major changes in maintenance philosophy began to flow together with some degree of interdependence. This article outlines the Service Quality Indicators and Plant Trouble Indicators which are used in the qualitative maintenance of networks comprising crossbar and step equipment and compares some of the distinctive service and maintenance features of these two types of equipment.

A detailed description of the test equipment, inbuilt service supervision devices and the maintenance techniques used in ARF 102 equipment is given by Pettersson (1). Broad references to these aspects are made in the text of the present article. An article in a subsequent issue of this *Journal* will report on field experience with the new crossbar system.

MEASURING SERVICE PERFORMANCE

The aim of the qualitative maintenance approach is to accurately direct maintenance effort to achieve a desired standard of service performance for minimum cost. In the first instance, so called Service Quality Indicators which will measure and detect trends in the quality of service given to the subscribers in a telephone network, are required. The commonly used indicators are service observation results, statistics of subscribers' trouble reports and the results of traffic route testing. These three indicators are applicable in any network, irrespective of the type of equipment.

Service Observations

Of the available indicators, telephone service observations give the most objective assessment of service quality by checking the end-to-end performance of all the items of telephone plant from the calling subscriber to the called subscriber, and taking into account subscriber habits in using the telephone service. In effect, service observations sample the finished product of telephone engineering activities and the results are important, not only to maintenance forces, but to engineering management.

In step exchanges, standard practice is to sample the traffic on a number of first selectors or DSRs. L M Ericsson provide an observation access to one or two Reg-Ls in an ARF 102 exchange, but this is not considered satisfactory because traffic handled by the other registers is not observed. The A.P.O. proposes to observe traffic on a sample of SR relay sets in a similar manner to the sampling of first selectors in step-by-step exchanges. Traffic-wise, the SR relay set is the approximate equivalent of the first selector. This will provide a uniform service observation access arrangement in the telephone networks, and give a more correct indication of subscriber experience in a crossbar exchange, because the sample will include some calls handled by each register in the exchange. The latter is most important because of the vital role of the REG-L in establishing a call.

At present, each exchange in a metropolitan network is observed for a short period, usually two or three days in each month, and from this, monthly statistics are compiled. New service observation access equipment has been designed which will enable calls to be observed in all exchanges each day as far as practicable, thus ensuring that the observation results do reflect more accurately the day by day service experience of subscribers. Completely automatic observation of "live" traffic is still something for the future, but automatic data processing (A.D.P.) of the results from manual observations is now being introduced by the A.P.O.

Subscriber Trouble Report Statistics

Up to the present this Administration has not used statistics of subscriber trouble reports as a measure of subscriber satisfaction with the service, but the highly successful development of the analysis of subscriber trouble reports to detect switching defects in a network has awakened interest in this type of statistic. Two statistics of particular importance are the number of repair reports, i.e., reports which require the attention of a testing officer or faultman, and the number of technical assistance requests, i.e., the number of requests for assistance by subscribers after difficulty has been experienced on certain calls, possibly because of a fault in exchange equipment. Although such statistics are subjective, they nevertheless give an important indication of subscriber satisfaction with the service. They will be derived for both crossbar and step exchange subscribers.

Traffic Route Testing

Traffic route testing is an important means of measuring service quality or performance of individual traffic routes, and is used extensively in both step and crossbar exchanges. When evaluating traffic route testing results, we must remember that they take no account of the subscriber's calling habits or defects in equipment at his premises, and hence performance as revealed by a TRT does not necessarily correspond to that received by the subscriber. The TRT, being a controllable test call generator, is a most valuable device to enable exchange service staffs to check the performance of individual traffic routes.

APPLICATION OF MAINTENANCE EFFORT

Measuring service quality is a simple matter compared with assessing when and where to apply maintenance effort to achieve the desired standard of service at minimum cost. So called Plant Trouble Indicators such as testing of items of plant, analysis of faults on equipment, analysis of subscriber trouble reports, and more recently, the inbuilt supervisory equipment of the common control crossbar system, all help to reveal individual items or sections of plant which need attention, either by way of fault clearance work or a specific maintenance project.

In the case of a single telephone exchange or a network comprising only a few exchanges it is not particularly difficult to determine, from the Service Quality and Plant Trouble Indicators, when and where to direct attention. However, this is certainly not the case for extensive multi-exchange networks such as the Sydney and Melbourne networks each with exchanges located in approximately 100 separate buildings.

The increasing size and complexity of modern telephone networks calls for a network oriented approach to the whole problem of plant performance supervision. In America and Canada, special trouble report analysis centres have been established to analyse customer and operator reports of service difficulty on trunk line calls. The data is analysed on a network basis often with the aid of automatic data processing (A.D.P.) equipment and information on suspected trouble spots is for-

* Mr. Moot is Engineer Class 4, Exchange Switching Equipment Section, Headquarters. See page 332.

warded to trunk and local exchanges throughout a region. The A.P.O. has set up similar analysis centres in each of the capital city networks.

Service Co-ordination Centres

The main functions of the Service Co-ordination Centres (S.C.C.) as the analysis centres are known in Australia are to analyse on a network basis, subscriber trouble reports, service observation results, and the results of traffic route testing and to pass information of fault patterns to the exchanges.

The centralised analysis of subscriber trouble reports is described by Mr. D. J. Omond (2). Experience to date indicates that subscribers' trouble reports do reveal defects even in crossbar equipment, particularly those troubles not detected by the inbuilt supervision equipment of crossbar common control units.

Of particular importance is the preparation of a programme of traffic route testing by the exchanges to ensure that each traffic route in the network is adequately supervised. In one large network this programme provides for each exchange to direct test calls to other exchanges in accordance with the normal dispersion of traffic.

In the extensive and complicated Sydney network detection of defects in tandem and terminating equipment has necessitated the analysis of service observation results and TRT results on a network basis similar to that used for the analysis of subscriber trouble reports. The raw data of service observations and TRT checks express plant performance on a call originating basis; however, it is necessary to express it on a "through-switching" and "terminating" basis in order to pinpoint some trouble spots.

The Administration is now in the process of extending the activities of the S.C.C. in each of the capital cities to cover the trunk network. Some progress has already been made and it is hoped within the next two years to provide a comprehensive coverage of the whole trunk network.

Inbuilt Service Supervision Equipment of Crossbar Exchanges

One of the service advantages of a common control crossbar system is the ease with which inbuilt self-checking or monitoring equipment can be applied to the common control units. The ARF 102 system has supervisory circuits built into the markers and registers to count the number of time-throwouts, i.e., the number of times a marker or register is forcibly released after a predetermined time interval because of an equipment failure or mis-operation by subscribers. These time-throwouts are counted on meters, and more important still, are measured by automatic service alarm units which bring up an alarm should the incidence of time-throwouts be excessive.

This service alarm system does not check every switching and signalling feature of the equipment, but it does give early warning of many of the commonly occurring troubles, particularly those in the common control units themselves which would hence cause serious interruption to service.

Another inbuilt monitoring device on the ARF 102 exchange is the route failure alarm which indicates when more than a predetermined number of junctions in a traffic route is blocked out of traffic by fault conditions or by maintenance staff.

Testing

Regular or routine testing of the individual items of plant in a telephone network, e.g., selectors, junction circuits, etc., has been a dominant feature of the maintenance philosophy for many years. Under qualitative maintenance the aim is to schedule testing in accordance with the service of the plant as revealed by other Indicators such as traffic route testing, subscriber trouble reports analysis and service observation results. In big networks in particular, experience has shown that there still is a need for regular testing of some items of plant, particularly junction circuits on main traffic routes. Regular testing of the individual items of equipment such as markers, registers and SR relay sets is not necessary once a new crossbar installation has settled down.

Another difference between the maintenance of crossbar and step equipment is that in the latter, individual items of plant, such as selectors and relay sets, can be tested in isolation from the rest of plant with which they interwork. While this is convenient it is important also to test items of plant on an "end-to-end" basis by setting up test calls under the conditions encountered in service. The introduction of traffic route testing into step exchanges has revealed plant defects not previously revealed by the elaborate automatic routiners. Some of the conditions imposed by automatic routiners are not vital from a service viewpoint, while no check is made of some quite important functions. The routiners are being modified to improve their effectiveness in this regard.

In the crossbar system it is necessary to employ the end-to-end testing technique at the outset. The nature of the system is such that individual items of plant such as SR relay sets, selector switching paths, markers and registers cannot be easily checked in isolation from other equipment.

Fault Analysis and Statistics

A new system of fault recording has been developed for use in all types of plant, including crossbar. It is intended to help reveal (a) individual items of plant having recurring troubles, and (b) any fault patterns which develop. Each fault is recorded on a 7.3 inch by 3.2 inch card which is placed in a special open type filing system designed to provide easy identification of faults on any individual rack of equipment. Each fault card is retained for 12 months; thus equipment having recurring trouble in that period is revealed. Prior to filing, the fault cards are flagged with a coloured metal signal to help reveal any common type of defect which may be present throughout the whole exchange, or to reveal any portion of the plant having an abnormally high incidence of faults. In itself, the incidence of faults in an exchange is not an indication of plant performance. Even with crossbar installations where most of the maintenance activity is of a corrective nature, trends and variations in fault statistics are significant only against the background of the actual service performance and maintenance activity in the individual exchange.

The aim is to establish the expected fault rate on each section of plant when it is performing satisfactorily as revealed by other indicators. An upper control limit will be set, and if this is exceeded, an investigation will be required. To assist field staff in the setting of local targets of performance, information on typical fault statistics obtained with various types of plant under specified conditions will be forwarded to exchanges.

Visual Inspections

A visual inspection to check specified mechanical adjustments of relays and switches is an obvious means of determining the need for maintenance attention. Any inspection of plant is bound to reveal defects; under qualitative maintenance such inspections should be restricted to the following two purposes:

(i) To determine the precise maintenance attention required to a section of plant which has been revealed defective by other indicators in the first place.

(ii) To check for defects which would not be revealed soon enough by the other indicators.

In the case of crossbar equipment the other indicators should give ample warning of impending defects and the visual inspection will only be required for (i) above.

Applying the Indicators in the Individual Exchange

Needless to say, it is not necessary to use all the indicators described above in each telephone exchange. The choice of indicators, particularly the Plant Trouble Indicators, is a matter for local decision, but to meet the wide range of conditions in this country, each of the indicators will have application in some exchanges.

INTERWORKING ASPECTS

The close integration of crossbar and step equipment necessitates a careful check of the signalling and switching boundary conditions between the two systems. The service engineer in particular is required to assist in the initial specification, if service requirements are to be met for interworking and to check that these are satisfactory in service.

Prior to the introduction of crossbar equipment, a considerable amount of detailed investigation into signalling and switching service problems had already been undertaken by engineers, particularly in the larger networks. This was necessary in the first instance to provide data for the design of a new group selector circuit when the SE 50 bi-motional mechanism was introduced in 1956-7. Secondly, the extensive use of stey-by-step switching for local and trunk networks, with the attendant impulsing and circuit guarding problems, called for extensive field investigations to determine the best maintenance procedures and to advise design engineers of service requirements.

Whilst it is too early to give a precise statement of the comparative performance of crossbar exchanges and comparable step exchanges in a city network it is clear that a well functioning ARF 102 exchange gives better performance than a similar step exchange. This applies to both local calls and calls to the network. The extensive direct routing of calls to terminal exchanges over a single junction route, the random selection of switching paths and junctions and the regeneration of dial impulses by registers, all contribute to better performance from crossbar exchanges.

MAINTENANCE NEEDS OF PLANT

Even with the most highly developed system of quality controlled maintenance, step equipment requires not only the attention to day-to-day faults (the corrective component of Qualitative Maintenance), but also the performance of maintenance project work such as switch lubrication, bank cleaning, wiper inspections, replacement and readjustment of badly worn parts (the preventive component of Qualitative Maintenance). In contrast, the service work in crossbar consists mainly in supervising service performance, and fault location and correction. However, it is probable that maintenance projects will be required on some of the heavily worked relays and switches in the crossbar common control units after some years of service.

Generally speaking, the incidence of faults in crossbar equipment is expected to be considerably less than that in comparable step exchanges, but the faults may be more difficult to locate. Even allowing for lack of familiarity with the crossbar system, understanding its complicated circuitry will call for the more skilled component of the technician work force. To summarise, in the crossbar system relatively simple relay type switching devices have replaced the mechanically complicated bimotional selectors of the step system, but this is partly offset by (a) the more complicated circuitry and hence longer time required to find some faults, and (b) the very heavy work load on some of the relay components in the common control units.

THE SERVICE EFFECTS OF PLANT DEFECTS

In the graded trunking of step exchanges, individual faults can seriously affect small groups of subcribers, particularly during periods of light traffic. On the other hand the service effects of faults in crossbar equipment tend to be more evenly shared by the subscribers. However, failures in crossbar common control units will cause serious interruptions to service normally not experienced with step equipment. The extent of interruption to service can be reduced by ensuring an adequate degree of skill in maintenance staff, provision of the correct test equipment and maintenance aids, ready availability of spare component parts, and, to a lesser extent, the use of duplicated or standby plant.

In the case of SL stages in ARF 102 exchanges, the first-in 1,000 line group will be provided with a duplicate working marker, relay sets of which can be used as substitutes when troubles occur in the remaining 1,000 line SL stage markers.

ARF 102 installations of 2,000 lines or less justify only one GVM to handle the traffic. In country areas, in the initial stages at least, a second GVM will be installed to provide a safeguard in the event of a service failure. This duplication is not proposed for metropolitan areas but the officer-in-charge of an ARF 102 exchange is required to determine the service effect of failure of each type of equipment and to ensure that his staff know which exchanges can supply a working spare relay set in those cases where a prolonged withdrawal of a relay set from traffic would cause a major interruption to service.

Spare relay sets should be "working spares"; it is very doubtful if relay sets left in store as maintenance spares could always be placed quickly in service in a time of emergency. The best approach is to ensure ready access to a full range of spare parts so that once the faulty component is identified, it can be replaced as quickly as possible and the equipment returned to service.

SPARE PARTS PROVISION

Only a few commonly used items such as fuses, lamps, relay armatures, relay spring lifting screws and relay residual staples will be held in small quantity at individual crossbar exchanges.

All other spare parts will be held at a central store in each State capital city. Although the actual quantities of spares required is small, the range of items is considerable as it includes condensers, rectifiers, diodes, resistors, relay coils, etc. Spare printed circuit boards, (ROA units) associated with the M.F.C. signalling equipment will also be held at the central store.

A single store in each State will be adequate to meet all urgent demands from the capital city area and its environs and all non-urgent demands in country areas. Experience will determine if it is necessary to set up regional spare parts centres to reduce the time required to transport urgently required spares to a remote town.

STAFFING ARRANGEMENTS

The situation in Australia is such that in many exchanges, indeed most, the same staff will maintain step and crossbar equipment. In metropolitan areas, this should not present a great problem, but in country areas, the introduction of crossbar equipment is another major addition to the already comprehensive range of plant for which maintenance staff is responsible. The variety of plant likely to be installed at any one centre is such that some degree of specialisation is unavoidable. Up to ten years ago a technician-in-training was given comprehensive training in most types of telephone and long-line equipment. Today, detailed training is limited to equipments nominated by the controlling engineer. This means that crossbar equipment is only one of a number of types of plant for which skilled attention is required, and if, as might reasonably be expected, the attention required is infrequent, no one technician at a station will have ready opportunity to become highly experienced in the plant. It would be unwise to rely too heavily on specialist staff who could be called in as required, to handle difficult faults. If a serious fault occurs, on-the-spot skill and experience is required if a prolonged interruption to service is to be avoided.

One consequence of this is the need to develop effective aids such as relay sequence charts, call-through diagrams and service instructions setting out, in attractive style, the best methods for detecting and analysing fault conditions.

CONCLUSION

Most of the past experience of the Australian Post Office has been confined to the bi-motional switching equipment in the local switching field and the Siemens motor switching equipment in the trunk network. The latter introduced the use of common control equipment, although some experience with this technique had been gained through the 2,000 type bi-motional line finder system. The crossbar system is certainly quite different to these equipments but there is no doubt that staffs will cope with the changed outlook and techniques required for the new system. The use of the crossbar system will serve well to prepare service people for the subsequent introduction of more sophisticated electronic switching systems which must surely come in the future.

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MAINTENANCE OF ARF 102 CROSSBAR EXCHANGES

*A. D. PETTERSSON, AM.I.E.Aust., A.M.I.R.E.Aust.**

INTRODUCTION

L M Ericsson's ARF 10 crossbar exchange equipment has been in use in Australia for nearly four years, the first installation being 6,300 lines of ARF 101 equipment at Toowoomba, Queensland, which was brought into service in 1960. In May, 1963, the first multi-frequency code signalling exchange, system ARF 102, was established at Petersham, N.S.W. It is expected that 130,000 lines of ARF 102 equipment will be in service by June, 1964, and that an additional 160,000 lines will be installed by June, 1965.

Although experience with this new system is limited, it is obvious that very good service performance can be obtained for very little maintenance effort. This article describes the important service features of the system and the supervisory and maintenance techniques at present employed in Australia.

SERVICE FEATURES

System performance and maintenance costs are primarily determined during the design and manufacturing phases. These factors can, of course, be influenced, indeed quite substantially, by maintenance policies and practices, but basically, good quality performance and the possibility of low maintenance costs must be engineered into the plant prior to delivery by the manufacturer. No amount of maintenance effort can overcome inherent design and manufacturing weaknesses.

A major component in the maintenance costs of all systems, and in crossbar exchanges probably the largest component, is the cost of supervising the performance of the plant and detecting when plant failures occur. Economic maintenance of crossbar exchanges requires the extensive use of automatic supervisory and test equipment. A comprehensive range of this equipment is available for the ARF 102 system.

It must be expected that any mechanical switching system will involve some amount of preventive maintenance to avoid rapid deterioration of the plant. This is most obvious in bi-motional switching systems which use a relatively complex and exact wiper positioning mechanism. Less preventive maintenance effort may be expected from uniselector systems which use a simpler mechanical action. Although crossbar exchanges employ a mechanical switching device, the switches are fundamentally relays, and well designed relays are capable of many millions of fault free operations without requiring periodic cleaning, lubricating, or adjustment. Fault free operation of relays of course will only be obtained if the associated electrical contacts are safeguarded against rapid deterioration. A feature of the ARF 10 system is the extensive use of arc suppressors and enlightened circuit design techniques to minimise contact deterioration.

Experience to date indicates that there is no reason to perform any preventive maintenance in a crossbar exchange to guard against rapid plant deterioration due to mechanical or electrical wear. Maintenance effort, therefore, is limited to that required for supervision of the performance of the plant, and corrective action when plant failures occur.

DESIGN ASPECTS

In common control systems the selecting and switching functions are concentrated into a few items of common control equipment which serve many associated devices. Inherent in any such system is the possibility of major traffic losses occurring due to failure of the common control equipment. For example, failure of the group selector marker which serves 160 GVA inlets causes simultaneous failure of all the 160 group selectors.

The ARF design includes several features to minimise traffic losses due to failure of the control equipment and these will now be described.

Duplicated Equipment

The principle of duplication of common control equipment (C.C.E.) with automatic changeover from the working to the standby unit, adopted with the ring supply in all automatic exchanges is applied to several other items in the crossbar exchange. For example, the duplicated multi-frequency tone generators and the duplicated reed relays in GVM. Automatic changeover normally prevents disturbance to traffic when a fault occurs.

The effect of C.C.E. failures may also be reduced by having duplicated control equipment, with both units in use and sharing the traffic. This principle applies in the first-in 1,000 group in a crossbar exchange where two SL markers are provided, each marker handling 50% of the traffic.

Should a major fault develop in one SLM it will normally still attempt to handle traffic and this traffic will fail. The other marker, however, will normally handle its traffic successfully and the loss in the SL stage will, therefore, be 50%. In 1,000 groups where only one SLM is provided, a similar fault will cause complete loss of all traffic.

Selection of Outlets

Selecting systems which employ a fixed order of search over the outlets are subject to a high degree of disturbance. particularly in periods of light traffic, when an early choice outlet is faulty. The ARF 102 system employs allotters (Call Distributors) and random selection methods to obtain a rotating or random selection of outlets. This ensures that the effect of faulty devices is spread evenly over the offered traffic, even during periods of light traffic. A subscriber whose call has failed due to encountering a faulty device will probably be successful on the next attempt as the selection system will normally allot him different equipment for each attempt.

Effects of Faults on Service Performance

Common control equipment is designed to handle calls from a comparatively small number of devices. Where substantial traffic is to be handled, several groups of devices, each with its own independent common control equipment are used. Failure of one unit of control equipment therefore only effects a percentage of the calls offered to all the devices in the switching stage.

The number of calls lost is inversely proportional to the number of units of common control equipment installed. For example, two or three code receivers (CD-KM) are normally required to handle the incoming traffic to a 1,000 group. In the case of 3 CD-KM's complete failure of one unit would result in the loss of about 1/3 of all incoming calls offered to the 1,000 group. Similarly, failure of one register in an exchange with 40 registers would result in the loss of about 1/40 of all outgoing calls.

The actual proportion of calls lost is not given exactly by the ratio of faulty to good units as it is also dependent upon the relative occupancy time of the devices under normal and call failure conditions. A subscriber encountering a no-progress condition may be expected to restore after say, ten seconds, releasing the faulty device, while, if the call had been successful, he may have occupied the device for say three minutes. Faulty devices will therefore be idle for a large percentage of the time and subject to re-seizure for other calls, whilst the good devices tend to become occupied on successful calls. When faulty devices have reduced holding times, these *faulty devices attract calls.*

Automatic Blocking of Faulty Equipment

Since faulty equipment causes traffic to fail, it should be blocked to traffic as soon as it is identified. Similarly, when a fault develops in the common control equipment which prevents it from successfully handling any traffic, it should be taken out of service either by blocking it, or all its associated devices, as required. A fundamental principle of "operating" a crossbar, or any type of automatic exchange, is that faulty equipment should be blocked to prevent it being subjected to traffic. About 2,500 "blocking" keys are provided in a 5,000 line ARF 102 exchange.

It is desirable that faulty equipment should automatically block itself. One indication of faulty equipment, of course, is failure of the power supply due to an operated fuse, and automatic blocking is normally provided under these conditions. In some cases loss of voltage can also be detected and used to provide automatic blocking.

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* Mr. Pettersson is Engineer Class 3, Toowoomba, Queensland. See page 331.

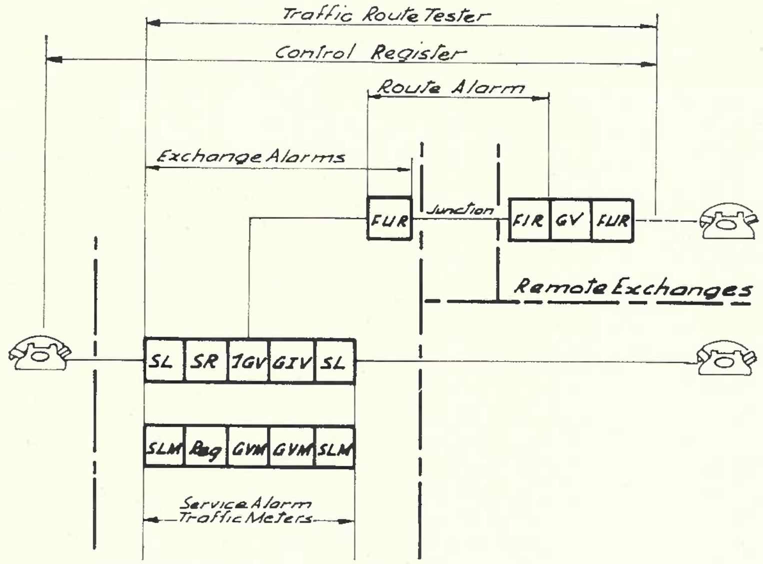


Fig. 1.—Supervision of the Equipment.

EQUIPMENT FAILURES

Ideally, faults in the system should be detected before subscribers' inconvenience occurs. This ideal is not yet practicable but may be approached with the supervisory equipment being provided with the larger ARF 102 installations. Equipment failures can be subdivided into three categories:—

(i) Failures that cause major traffic losses.
(ii) Failures that cause a small percentage of traffic to fail.
(iii) Failures that cause complete, or high percentage, traffic loss to one or a small group of subscribers.

Major traffic losses are unique to, and inherent in, any common control system. Although these losses only occur infrequently, special supervisory equipment should be employed to continuously check the performance of the common control equipment and to give immediate alarm to the service staff when serious malfunctioning occurs. These facilities are provided in all ARF 102 exchanges.

Most equipment faults occur in the more numerous devices such as SR, FIR, FUR and register relay sets, etc. Due to the rotation of selection principle used throughout the ARF 102 system, the effect of these defects is spread over a large number of subscribers and cause only a small percentage of any subscribers' calls to fail. As the subscribers are not seriously inconvenienced, subscribers' trouble reports are not a sensitive indicator of this most common type of fault. These defects will normally only be detected by the resultant deterioration of service quality or when tests are performed on the equipment. These tests are normally performed regularly by automatic test equipment such as the Traffic Route Tester or the Automatic Exchange Tester.

Faults which affect one or a small group of subscribers' services can not normally be detected by the exchange supervisory equipment. Unless they are reported by the subscriber, these faults will remain in the system. Certain of these faults however, such as low subscribers' line insulation, can be detected by the supervisory registers.

OUTLINE OF SUPERVISORY EQUIPMENT

General

A comprehensive range of supervisory equipment has been developed for ARF 102 exchanges. Indications of plant performance may also be obtained from subscribers' trouble reports, service observations, etc., but the supervisory equipment will normally detect, and report, important plant defects before subscribers' inconvenience is sufficient to cause complaints.

The equipment is supervised by supervisory units built into the common control equipment, by special supervisory devices, and by subjecting the equipment to artificial traffic. The general aplication of this equipment is shown in Fig. 1.

The following items of supervisory equipment will be found in all large exchanges, and most items are included in exchanges of all sizes:—

Traffic Route Tester (TRT): TRTs are designed to generate artificial traffic of similar form to the live traffic from subscribers, and to determine, by testing, whether the established calls would be satisfactory to a subscriber. TRTs are an excellent device for exchange and network supervision and are widely used in the existing Australian network. The TRT is considered to be the most important aid for correct and economical maintenance of crossbar exchanges and networks.

Control Register (Reg-K): This is a local register to which additional supervisory equipment has been added to permit it to supervise a percentage of the traffic from every subscriber. Reg-K may also be used as a service observation point.

Route Alarm: This supervisory unit gives alarm when junctions become faulty. Urgent alarm is given if the number of faulty junctions on any route exceeds a predetermined figure.

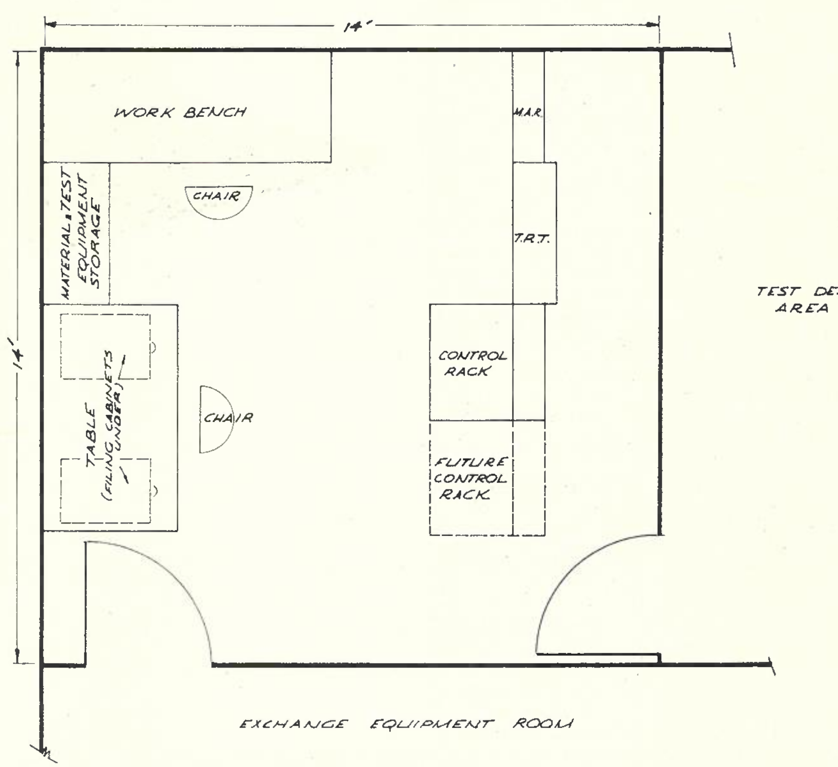


Fig. 2.—Typical Layout of Maintenance Control Room.

Exchange Alarm: These are indications of fuse and power failures and certain equipment fault conditions.

Service Alarm, Traffic Meters, Fault Counters: The meters record the number of times the common control equipment is seized, the number of times a connection can not be completed, and the number of times congestion occurs. The service alarm counts the unsuccessful connections and gives alarm when the failure rate is excessive.

The indications from the supervisory equipment are extended to the maintenance control room. The aim is to transmit all information required for maintenance of the exchange to the control room so that it is unnecessary to enter the equipment room except to remove a proven fault. In many cases the approximate location of the fault will be known from an analysis of the indicator information available in the control room.

Fig. 2 shows a typical layout for a maintenance control room in a medium size crossbar exchange. It will be seen that entrance to the equipment room is via the control room which is also located adjacent to the test desk area. A typical control rack for an initial 2,000 line installation is shown in Fig. 3.

DETAILS OF INBUILT SUPERVISORY UNITS

General

Each item of common control equipment in the ARF 102 system is equipped with an inbuilt supervisory unit which continuously checks the performance of the parent unit and gives an alarm when malfunctioning is detected.

The control equipment is "common" to a large group of devices, that is, it serves all the devices in the group. It is, therefore, essential that it should not be monopolised by one device and thereby excluded from serving the other devices in the group. The inbuilt supervisory units are designed to supervise the time the common control equipment is occupied by any one call and forcibly free the control equipment if the occupancy time becomes excessive. The supervisory units are of vital importance as they determine the manner in which the common control equipment, and therefore the exchange, will work under fault conditions.

The limitations of these supervisory units must also be understood. Fundamentally they check whether the control equipment handles the calls within a predetermined interval of time, not whether the call is handled correctly. For example, the supervisory unit in the SLC/D code receiver will give alarm if the calls are not cleared from the code receiver quickly enough, but should every call be connected to a wrong number, alarm may not be given as correctness of operation is not checked. These faults must be detected by other indicators.

The principle of operation of the inbuilt supervisory units is shown in Fig. 4.

Each time the C.C.E. is called by a device, the appropriate identification and connecting relay operates to connect the control equipment to the calling device. Secondly the A relay operates and the number of times the C.C.E. is seized is recorded on Traffic Meter AM. Operation of the identification relay also breaks the operate circuit of the normally operated supervisory relay, K,

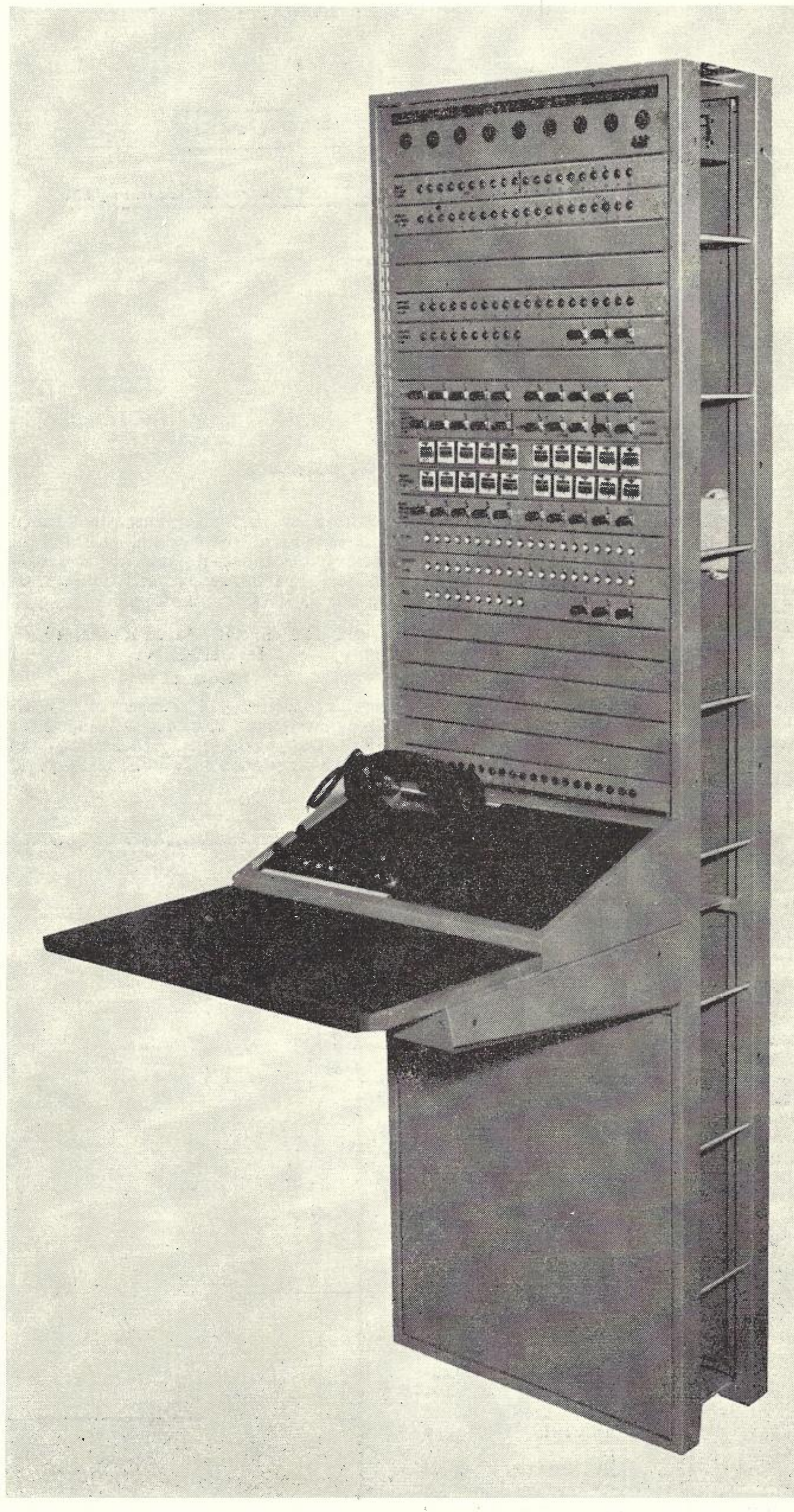


Fig. 3.—Typical Maintenance Control Rack.

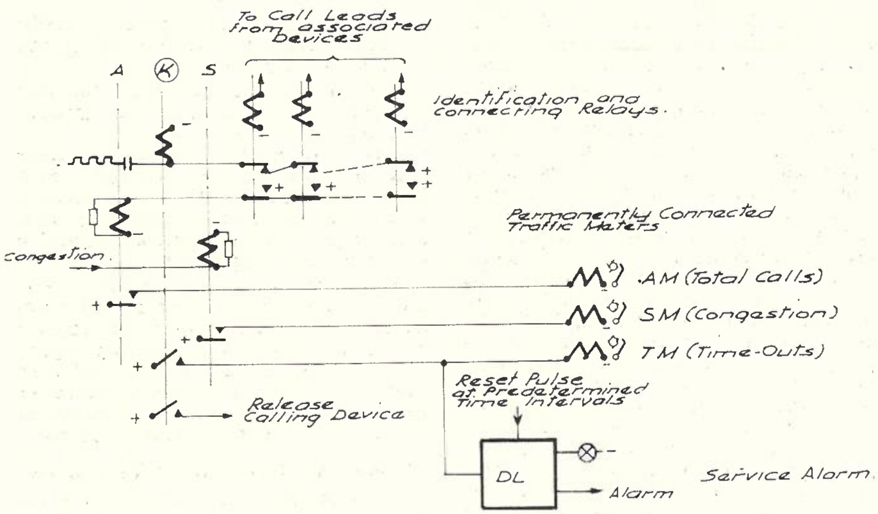


Fig. 4.—Inbuilt Supervisory Unit and Indicating Equipment.

which is slow to release due to the RC circuit across the coil. Under normal conditions K does not release, but if the C.C.E. fails to handle the call within a predetermined period of time, which varies from about 0.5 seconds to 45 seconds in different supervisory circuits, the K relay will release, force releasing the control equipment so that it may become idle and attempt to handle calls from other devices. The number of times the control equipment is forced released, or "times-out", is recorded on Traffic Meter TM. Many of the supervisory units can detect when failure to establish a connection is due to congestion and this information is recorded on Traffic Meter SM. In addition to the AM, TM and SM metering leads some of the supervisory units provide additional metering leads which supply more detailed information as to the stage at which malfunctioning occurred. The AM, TM and SM metering leads, however, provide the overall supervision of the common control equipment and Traffic Meters are permanently connected to these leads. Traffic Meters should not be fitted in staffed control rooms as they generate considerable noise.

Traffic Meters

These meters are permanently connected to leads from the supervisory units and record the total number of calls, and the number of calls lost due to faults and congestion. The traffic meters are a most sensitive indicator of the performance of the common control equipment and, in many cases, of its associated devices. While a crossbar exchange is free of major faults, the traffic is evenly distributed over all devices and all units of common control equipment. Uneven traffic distribution is therefore evidence that faults exist and the Traffic Meter analysis aims at detecting when the equipment ceases to be in its normal state of equilibrium. Identical units should have similar high quality performance, all handling about the same number of calls (AM), giving the same amount of congestion (SM) and causing the same number of timethrowouts (TM). The Traffic Meter analysis therefore involves consideration of both the magnitude of the recorded defects and whether the performance of one item of equipment is significantly different to that of other identical units.

The Traffic Meters should be read, recorded and *analysed* daily, during the settling-in period of a new exchange. When a satisfactory service quality is attained, regular weekly, monthly or quarterly readings and *analysis* will suffice. Special readings will, of course, be taken when the information is required for fault localisation work.

Service Alarm (DL) and Fault Counters (FM)

Continuous supervision of the performance of the common control equipment is performed by the Service Alarm equipment. Service alarm is normally the most immediate indication of serious malfunctioning of the common control equipment and permits service staff to initiate corrective action quickly. Normally this action will be commenced, and frequently completed, before any subscribers' trouble reports are received.

When serious malfunctioning occurs in the common control equipment a large number of time controlled releases occur. The time-out pulses from the inbuilt supervisory units are recorded on the TM traffic meters and may also be counted on pulse counting equipment which will give alarm if the number of pulses received within a predetermined time, or while the control equipment is handling a predetermined number of calls, is excessive. This pulse counting equipment is called the "Service Alarm".

Initial installations of this equipment has been of the "fixed time interval" type in which the counting chain is restored to normal at predetermined intervals by reset pulses. (See Fig. 4). A "percentage" type service alarm is at present being developed which generates its own reset pulses after a predetermined number of calls have been handled.

To reduce the cost of provision of service alarm equipment, the time-out pulses from several common control supervisory units are counted on the one service alarm unit (See Fig. 5). When a service alarm is given, resettable type meters called "Fault Counters" are connected to identify which supervisory unit in the group is generating the abnormal number of time-out pulses. The "Fault Counters" are connected by operating a key on the control rack.

Service Alarm supervision is normally provided over SLMs, GVMs, SS, KSR and Registers.

The resettable fault counters are also used to collect statistics from metering leads from various devices as required.

Route Alarm

Outgoing junctions from a crossbar exchange are supervised by a "Route Alarm". Each outgoing junction relay set (FUR) contains a high resistance supervisory relay which checks for current from the distant exchange equipment, while the FUR is idle. Non urgent alarm is given when any junction on a route becomes blocked, and

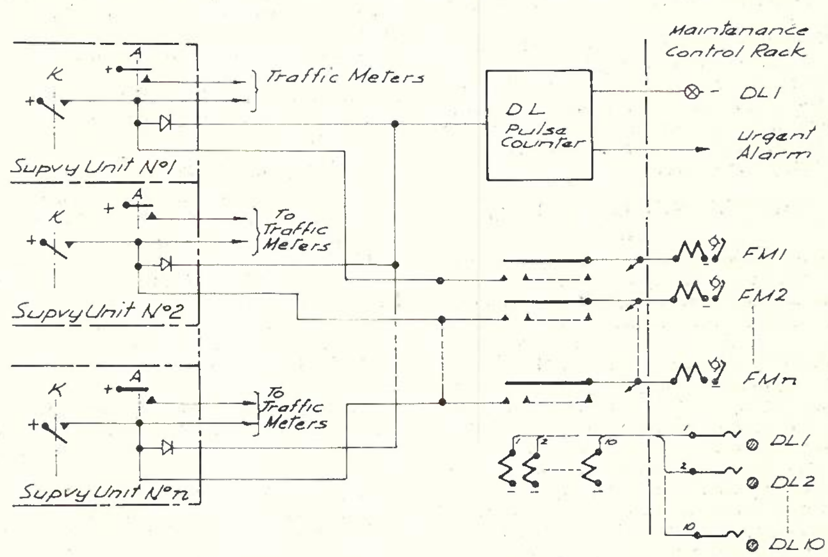


Fig. 5.—Service Alarm and Associated Fault Counters.

urgent alarm is given should more than a predetermined number (adjustable in steps from 2 to 18) becomes blocked. The route alarm will detect junction cable failure and serious junction blocking by remote exchanges.

As blocking of junctions occurs normally due to day-by-day maintenance operations, the urgent alarm level is normally set at about 4. Small junction routes are combined into groups of a minimum size of 10 for supervision by one route alarm circuit.

Control Register (Reg-K)—Service Observation Facilities

Continuous supervision of plant performance is also provided by Reg-K which comprises an ordinary local register to which an additional test relay set (RKR) is attached. One Reg-K is provided per 5,000 lines, and graded so that it will handle, and therefore supervise, a percentage of every subscriber's calls. When the Reg-K is seized, RKR performs an insulation resistance test of the subscriber's line and an electrical test of the subscriber's meter. If these tests are satisfactory, the subscriber is through-connected to the register and receives dial tone. During multi-frequency signalling the register is supervised to ensure that a revertive signal is received within about 7 seconds of sending any forward signal. Statistics of the number of times the control register is seized, the number of time releases, the number of times the group selector is called, revertive signalling failures, insulation resistance and meter defects are recorded on permanently connected meters. The control register may be set to hold the connection when defects are detected and telemeter the information to the maintenance control room rack.

The control register is also designed to permit observation of actual traffic to be performed. The two Reg-K's in a 10,000 line exchange can be coupled via a KOB relay set to OBR (impulse counting) relay sets and the observation position at the observation centre. The setting up and progress of the call may be manually observed in the normal manner.

With this method, service observations are confined to one register only. To permit calls handled by all the registers in the exchange to be observed, a trial installation involving observation of traffic handled by selected SR relay sets is being undertaken.

TRAFFIC ROUTE TESTING

General

Most major defects in the system will be detected and signalled by the continuous supervisory equipment, such as the service and exchange alarms. Due to the random and rotating selecting systems employed in the ARF 10 system, equipment defects are spread over large groups of subscribers and, in general, minor defects, such as faulty devices, cause only a small percentage of any one subscriber's traffic to fail. In consequence the subscribers are not seriously inconvenienced and subscribers' trouble reports are not a sensitive indicator of these types of exchange defects. These defects, however, can be detected by the resultant deterioration of service quality. Frequent measurements of exchange and network switching quality is made by automatic Traffic Route Tester (TRT) equipment.

Adequate access facilities to obtain the desired coverage of the exchange equipment must be provided. Normally one subscriber's number per 100 lines is reserved in the crossbar exchange for test purposes. These test numbers are used to reproduce every class of service existing in the exchange. Where the facilities exist, some of the numbers will duplicate traffic to and from PBX, PT, non-metering, restricted access, and last party release, services, etc. The TRT makes calls from one of these numbers to another number and performs functional and marginal tests on the completed call, recording defects on meters or on a paper tape print-out. This print-out records information as to the calling and called numbers and as far as can be detected, the reasons for defective calls. An analysis of this print-out will frequently indicate the probable location of the defective plant units.

On completion of each call, another call is made automatically, using a different combination of the test numbers. Because the switching devices are selected at random, or by rotation, in a crossbar exchange, the TRT will eventually use all devices and give a very accurate determination of the service quality of the exchange. Even during periods of light traffic, nearly all devices will be used. Analysis of the distribution and percentage of the faults will give a good indication of where faulty plant is to be found. The TRT is also used for fault tracing as it may be set to hold and give alarm when faulty connections are encountered.

Service Engineers should endeavour to programme the TRT so that *no substantial defect can occur in the crossbar exchange which will not be detected by the regular Traffic Route Testing.* If this is done, obviously there is no need for expensive manual routining. A suitable TRT, if properly applied, performs three essential functions in a crossbar exchange:—

1. It accurately measures service quality, and concurrently
2. performs complete routine testing;
3. permits staff requirements to be minimised.

Grouping of the Test Lines

The test lines are suitably divided into groups determined by the capacity of the TRT. In TRTs manufactured by L M Ericsson the group size is ten. The new standard TRT developed by T.E.I. Pty. Ltd., to A.P.O. specifications, provides automatic access to 96 local numbers with facilities for calling to 24 different exchanges in the one test run.

The traffic generated by the TRT is used for three purposes which determine the detailed grouping of the test numbers. These purposes are:—

1. Regular determination of the performance of the local exchanges.
2. Regular determination of the performance of all junction routes outgoing from the exchange.
3. Concentration of artificial traffic into individual routes for testing and fault localisation work.

In small exchange networks, functions (1) and (2) above may be grouped together, but in larger networks it will normally be necessary to prepare three different groupings, one to cover each function required. The test numbers should be allocated to obtain as wide a coverage of the equipment as possible on each test programme.

All outgoing junction routes should also be regularly routined by the automatic TRT which should be capable of working to code answering equipment installed at each distant exchange. The code answer or numbers should be chosen so that the TRT is required to use as many different digits as possible.

Number of Test Calls in Programme

The number of test calls to be made in each programme is determined by the degree of accuracy to which it is desired to determine the service quality or the type of defect it is desired to detect on each test run. This latter requirement normally determines the number of calls to be made. Obviously a serious fault affecting a large percentage of the traffic will be detected more readily than a fault that only affects an occasional call. Due to the random and rotation selection employed in the system, traffic through a crossbar exchange approaches pure chance conditions. It can be shown that, under pure chance conditions, the minimum number of test calls "n" required to ensure with probability "a", that at least one call is made to every outlet in "q" outlets is given by the formula:—

$$a = 1 - \left(1 - \frac{1}{q}\right)^n$$

For 95% confidence $n \approx 3q$, and for 99% confidence $n \approx 4.5q$.

If the exchange contains 40 registers, and the test programme is designed to ensure with 99% confidence that every register will be used at least once on each test run, the size of the test programme required is $4.5 \times 40 = 180$ calls. If it was only desired to ensure that all of say, 5 group selector markers were functioning, it would only be necessary to make $4.5 \times 5 = 22$ calls.

In periods of heavy traffic, the characteristic attraction of calls by faulty devices materially reduces the number of test calls required to detect faulty plant.

The frequency at which the service quality should be measured is determined by the reliability of the plant and the length of time defects in the system can be tolerated. It must be realised that many plant defects will not be detected other than by traffic route testing. TRT traffic should, therefore, be generated at frequent intervals to ensure that plant failures are detected quickly; if possible before their effect on service is sufficiently serious to cause inconvenience to the subscribers. Ideally, it should only be necessary to rely on subscribers' complaints to ascertain defects in items individual to each subscriber's service.

Junction routes to manual operators should also be checked. This can be done either by a manual routine of BLRs, which is not satisfactory as the GVB section is not checked; by forcing calls into all BLRs by blocking the BLRs as they are used, in periods of light traffic; or by the normal method of making test calls and relying on the exchange spreading the calls over all BLRs. The test calls can be made by the TRT if the calls are identified by a distinctive tone, so that the operators can manually connect each test call to a code answering device.

Recording of Results

TRTs are provided with meters, and in some cases with a printer, to record the results of each test run. This information is then recorded on forms for analysis, and graphs are also prepared so that significant trends may be readily apparent. Many different ways of presenting this information are available, each aimed at assisting the service staff to arrive at a statistically sound conclusion.

The simplest way of graphing this information is by plotting the result of each TRT test run on a "control chart" similar to that shown in Fig. 6.

As the TRT only generates a small percentage of the traffic handled by the exchange equipment, the way its calls are handled does not indicate *exactly* how all other calls were handled. Actually, the TRT makes a small "sample" of the switching quality and, as would be expected, some of the recorded results will be better than the true quality and others will indicate that the performance of the exchange is worse than it actually is. If the exchange's performance was actually 1% lost traffic, the TRT would record results fluctuating around this figure. Some test runs would indicate that the service was fault free whilst others would indicate that 1%, 2%, 3% or even higher losses were occurring. While the true quality level is 1%, the TRT sample can only indicate losses, such as 3% or 5%, etc., very infrequently, and this fact is used as a control to warn when the actual service quality has deteriorated.

For a given service quality level, it can be shown that, on an average, only one sample in 20 will show a loss exceeding a certain level known as the "warning" level, and only one sample in 500 will exceed another level known as the "action" level.

The warning and action levels are determined by the true service quality of the exchange and the number of test calls the TRT makes while it is taking the sample. The relationship between these factors is shown in Table I, which gives warning and action levels for 1 in 20 (95%) and 1 in 500 (99.8%) confidence limits based on a Poisson distribution.

When a control chart is prepared, the service quality level to be maintained in the exchange, or on junction routes, etc., is determined, and the Warning and Action lines are drawn, their position being determined from Table I.

The control chart, Fig. 6, has been prepared for an exchange which is to be maintained at a quality level of better than 1% lost traffic, the service quality being determined by a TRT which is to take a sample of 200 calls on each run. From Table I the warning and action limits are 2.5% and 3.8% lost traffic respectively. After each TRT run the results are plotted on the graph.

Now, by definition, on an average not more than once in every 20 runs should the TRT ever experience more than 2.5% failure if the true service quality is not worse than 1%. Any reading that falls between the warning and action lines is a warning that service quality *may have deteriorated* and an additional sample should be taken to determine whether this one reading occurred due to service deterioration or was just due to the occasional, expected, substantial variation that occurs with small samples.

Also by definition, on an average not more than once in every 500 runs should the TRT ever experience 3.8% or more lost traffic if the true service quality is not worse than 1%. Four hundred and ninety-nine times out of five hundred any reading which exceeds the action limit will be prima facie evidence that service quality *has deteriorated* beyond the level to which the exchange was to be maintained.

The "warning" and "action" control lines permit a statistically sound judgment to be made as to whether the variations in the service quality, as observed by TRT sampling, result from the normal fluctuations that occur with small sized samples or from actual deterioration of the service quality of the exchange. The exchange maintenance work should be initiated as a result of actual service quality deterioration, and not occur just because, by the laws of chance, the TRT lost a few calls on one occasion.

The actual average service quality can be obtained quite accurately by taking the average of the readings progressively recorded on the control chart. Should the service quality deteriorate, the average of the control chart readings will increase and the sampling results will fluctuate above and below this higher average.

Where the reasons for substantial observed service quality variation can be determined, e.g., some specific equipment fault, the details should be included on the chart. Details of the symptoms of faults causing observed service quality variations within the permitted limits should also be entered on the graph to assist with identification of the faulty units when fault repair work becomes necessary.

New A.P.O. Qualitative Maintenance Engineering Instructions, to be issued shortly, propose that in lieu of the "warning" and "action" control levels described above, a single "Upper Control Limit", determined by the Service Engineer, should be used on the control chart. This limit would no doubt be selected somewhere between the 95% and 99.8% confidence limits.

TABLE I: WARNING AND ACTION LEVELS

True Quality (% Lost Calls)	Sample Size (No. or Calls)	% Lost Calls	
		Warning Level	Action Level
1%	100	3.4%	5.3%
	200	2.5%	3.8%
	300	2.2%	3.2%
	400	2.0%	2.8%
	500	1.9%	2.6%
	1000	1.6%	2.1%
2%	100	5.0%	7.6%
	200	4.0%	5.7%
	300	3.6%	4.9%
	400	3.4%	4.4%
	500	3.2%	4.2%
	1000	2.8%	3.6%

TEST SETS

General

Various testers, mostly portable, are available for use in ARF exchanges. It is not practicable to test items of equipment such as markers, SR relay sets, registers and GV equipment as individual units with an input and an output, as is done with bi-motional equipment. Units of crossbar equipment must be tested by checking their interworking with the other units in the system. For this reason the equipment is subjected to functional tests by setting up test calls either from it, or through it, to B subscribers' numbers (test lines).

Automatic Exchange Tester—LTR 10313

A comparatively large, and expensive, mobile instrument containing LR/BR, SR, Register, KSR, TG, FUR, decadic impulse generator and test relay sets to permit the establishment of through test connections to either a subscriber's number or code answering device from:

1. A subscriber's line (test line).
2. Inlet to SR.
3. Inlet to 1GV.
4. Inlet to GIV.
5. Inlet to SLD.
6. Inlet to FIR.
7. Inlet to FUR.

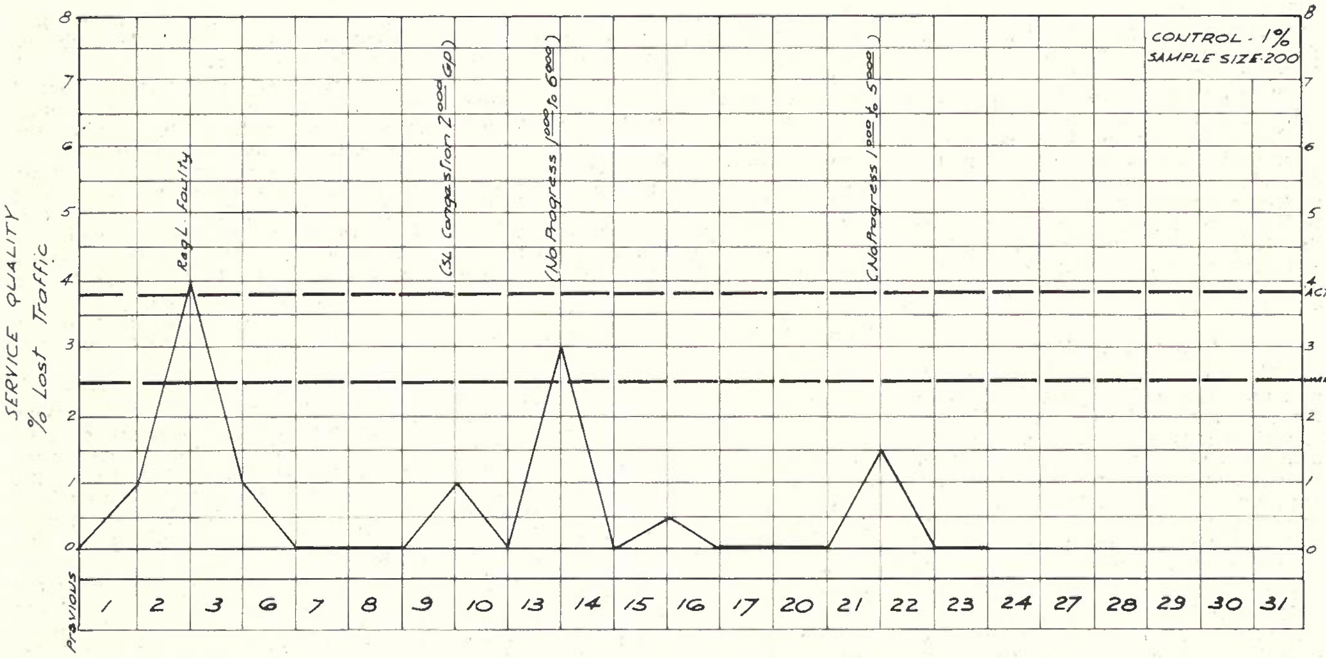


Fig. 6.—Control Chart for recording results of T.R.T. Test Runs.

By key control, this tester will make single or automatically repeated test calls, either stopping, and giving alarm, when a faulty connection occurs, or, if desired, registering the number of faulty connections and then making further attempts. If desired the tester can be set so that it will make continuous attempts, irrespective of the progress attained by each attempt, and this facility is used when fault finding in the common equipment. When used to generate traffic from a subscriber's line, the automatic exchange tester is a "one to one" TRT and is used for systematic routining in the smaller exchanges where a large TRT is not justified. Photographs of the automatic exchange tester were published on page 210 of the previous issue of this *Journal*.

In order to inject calls at any desired point of the crossbar system, it is necessary to convert the decadic signals to the signalling employed at the injection point. The automatic exchange tester, therefore, contains all the signalling equipment that exists in an exchange and substitutes its built-in equipment for the normal exchange equipment that is bypassed when calls are injected other than into a subscriber's LR/BR relay. For example, if test calls are made into a 1GV inlet, the automatic exchange tester must use its inbuilt LR/BR relay set, SR relay set, Register, KSR and Tone Generators, to replace these items of the normal exchange equipment which have been bypassed. If the tester was being connected to an SR relay set, it would only need to substitute its LR/BR relay and call RSM facility for the bypassed exchange LR/BR relay and SLM.

As the KSR relay set in the automatic exchange tester is identical with KSR relay sets used in the exchange equipment, the exchange relay sets may be tested by connecting them by a test cord to the automatic exchange tester so that they are used by the tester while it is establishing calls that require the use of the tester's KSR relay set.

Manual Register Tester—LTR 13113

This tester permits access to any required local register for test purposes. The tester comprises a "manual" LR/BR relay and an SR relay set, and connects by cords to the register test jack. A spare 1GV inlet must be connected to the tester's inbuilt SR relay set.

The test calls are established by manual dialling from the test set to a test number which is cord connected to a bell in the tester. Line resistance and leakage and various classes of subscribers' categories can be connected by key control.

A modified version of this tester has facilities to permit connection of either the automatic exchange tester or TRT to generate the calls. This facility is desirable in exchanges which are not equipped with an automatic register tester as it permits any register routining to be performed automatically.

SR Tester—LTR 13109

This is a small test box containing essentially a "manual" LR/BR relay and speak and dial facilities. As the tests performed by this device can also be performed by the essential automatic exchange tester, this tester is not normally provided.

Subscribers' Line Test Access

Test access to subscribers' lines is obtained via a separate GIV inlet using an access relay set known as FIR-P. This inlet in a crossbar exchange corresponds to the test distributor circuit in stey-by-step exchanges and interworks with an A.P.O. test desk. Test calls are handled on a priority basis by two of the normal Reg-Is which are especially modified to handle test calls. These registers handle normal traffic as well but give priority attention to calls incoming from FIR-P. Access is gained to the subscriber's line through the normal GIV stage and SLC/D stage.

Automatic Test Desk or Robot Tester (APR)

Much of the test desk load arising from sub-station and lines staff can be eliminated by using an automatic test desk (APR) which performs specified tests upon receipt of dialled instructions, and signals the result of the tests by various tones. The testing officer gains access to the APR by dialling a special access code and the Reg-L then attaches the line to the APR. The method of operation is shown in Table II.

FAULT FINDING

General

Fault finding in a crossbar exchange is at times difficult due to the complex circuitry and the use of common control equipment. Staff engaged on the work require a thorough knowledge of crossbar principles and circuitry details.

Indications of Faults

The more serious faults will normally be revealed by the service alarm and exchange alarm equipment or by subscribers' trouble reports. The regular TRT testing, analysis of the traffic meter readings and service observation results, etc., will reveal troubles which cause deteriorated service, but which do not necessarily cause subscribers' trouble reports.

Identifying the Faulty Units

The indicating equipment will, in many cases, also identify the faulty unit. For example, when a Service Alarm is received, the Fault Counters are connected and positively identify which of the units grouped into that service alarm is faulty.

TABLE II: OPERATION OF AUTOMATIC TEST DESK (APR)

Tone	Dial Code	Handset	Tones		
			Ring	N.U.	Flicker Busy
Dial Speed	10	Off	Slow	$8\frac{1}{2}$-$12\frac{1}{2}$	Fast
Cont. Ring Full Voltage	3	Restore	—	—	—
Int. Ring Half Voltage	4	Restore	—	—	—
I.R. a leg	5	Restore	Below 0.5 meg	0.5-1 meg.	Over 1 meg.
I.R. b leg	6	Restore	Below 0.5 meg.	0.5-1 meg.	Over 1 meg.
I.R. a—b	7	Restore	Below 0.5 meg.	0.5-1 meg.	Over 1 meg.
Loop*	8	Off	Below 200 ohms	200-1200 ohms	Over 1200 ohms
Tone Clear	9	Off		1000 cps.	

* For line loop S/c terminals within 5 secs. and remove after 5 secs.

With less specific indicators it is frequently necessary to *trace calls* to identify the faulty unit. If several faulty calls are traced and it is found that on each of the calls one particular unit of equipment has been used, it is reasonable to conclude that that piece of equipment is probably at fault. Call tracing is not always possible as the equipment design attempts to release all faulty calls and give the subscribers "try again" tone. When call tracing is attempted under these circumstances, it will be found that the call does not extend beyond the LR/BR relay.

A comparison of the occupancy of the devices will frequently identify which unit of control equipment is faulty. As faulty control equipment often has the effect of making all its associated devices either inoperative or faulty, significant under occupation of all devices served by one control unit would suggest that the control unit would be faulty.

The percentage of lost traffic will in many cases give an indication of which type of unit is probably faulty. If about 4% of failures occur in an exchange with 25 registers, the presence of a faulty register may be suspected, and 50% loss into a 1,000 group would normally be due to failure of one of the two code receivers or markers.

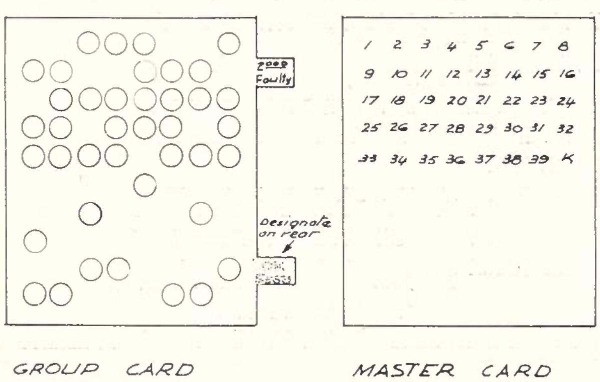
The distribution of the disturbances caused by faults will frequently indicate the location of the faulty unit. As all the equipment is not available to every subscriber, failure of one item of equipment may only affect certain groups of subscribers. Knowing which group of subscribers are affected may therefore indicate which equipment is faulty. For example, each subscriber in an m = 8 system has access to only, nominally, 40 of the 100 SRs. Furthermore, perusal of the grouping plan will show that the 100 SRs are divided into groups of 10, each 10 group serving two SLA racks. From this availability of SRs it is obvious that:—

(a) A faulty SR can only affect traffic from the particular SLA racks and conversely,
(b) If traffic is only affected from two SLA racks the fault could be in one of a particular group of 10 SRs.

The type and percentage loss caused by the fault would indicate whether it probably was caused by an SR.

This type of analysis is particularly applicable to the identification of faulty registers and is done conveniently by using a punched card analyser prepared as follows:—

A card is prepared for every 1,000 group and register finder, the top of each card containing punched holes to correspond with every register that is available to those units. This section of the card is designated with the unit's designation followed by "Faulty". The cards for the 1,000 groups are then reversed and inverted and holes are punched corresponding with the registers which are *not* available from each 1,000 group. This section of the card is designated with the unit's designation followed by "O.K.". One master card is then prepared showing the position of each register. Typical cards for an exchange with 40 registers are shown



GROUP CARD MASTER CARD

Fig. 7.—Card Analyser for Registers.

If the group card is placed on top of the master card the numbers still visible show which registers are available to the subscribers in that group. If the group card is inverted and placed over the master card, the numbers of the registers available in that group will be obscured.

To use these cards, information is accumulated as to the groups from which faulty calls (a) can, or (b) cannot, be originated, and the corresponding group cards are placed over the master card with the "faulty" or "O.K." designation respectively to the top. Each time an additional group card is added, more of the register numbers become obscured thereby eliminating those registers which could not cause the known fault distribution. Before inserting any cards in the analyser in the "O.K." position it is necessary to make adequate test calls to prove that the faulty register cannot be reached from that particular 1,000 line group. During accumulation of the fault distribution information a trial use of the uncommitted cards in the "O.K." and "faulty" positions will indicate those groups which will supply the most useful information if they are subjected to further testing to determine positively whether they do, or do not, have access to the faulty register. Certain combinations of the analyser cards may result in all register numbers becoming obscured. This indicates that one faulty register could not cause the known fault distribution or that the assumption that certain groups do not have access to the faulty register is not valid. Three or four group cards will normally be sufficient to either definitely identify the faulty register, or determine that it must be one of two or three registers.

The register finder group cards are used when call tracing has been performed and the identity of the register finders which have access to the faulty register is therefore known. The tracing of three or four calls to various register finders will normally supply sufficient information to permit the faulty register to be identified.

Positive identification of a faulty unit can usually be obtained by noting whether blocking of the suspect unit eliminates the traffic loss. If traffic still fails, after a unit is blocked, it is most unlikely that the blocked unit would be faulty.

Complete failures of equipment will normally be quickly detected and the faulty unit identified without difficulty. It is more difficult to identify the equipment responsible for the occasional disturbances which occur due to sporadic faults or only when certain combinations of the equipment are used. Frequently, faults of this kind can only be located by statistical methods, including an analysis of the record of the plant used on faulty calls. Identification of the faulty unit may be so difficult, and involve so much effort, that it is not worthwhile unless the effect is reasonably serious. As wear occurs the sporadic disturbances become more frequent until in time a permanent fault will exist and the source of the defect will become more obvious.

As fault rectification work inevitably involves some disturbance to equipment which is functioning satisfactorily, it is usually preferable to leave faults that have little effect on traffic in the system, rather than risk the creation of other, and possibly more serious faults, while insignificant defects are being removed.

Locating the Faulty Section of the Unit

Each device and item of control equipment contains relays to perform certain functions and performances of each function is signified by the operation and, or, release of the corresponding relay. Fault localisation work fundamentally consists of determining which function has not been performed and then, by inspection or testing, ascertaining why it was not performed. The "symptoms" of the faults will frequently indicate which functions are not being performed. For example, should SLM work normally except on calls from one of the five SLM racks, the fault must lie in equipment which is only used when that rack is being served.

The easiest way of determining where malfunctioning is occurring is to obtain a record of the operation of each relay in the faulty relay set, and to compare this with a record of the relay operations when no fault existed. The stage at which malfunctioning commenced can readily be determined by this method. Most marker relay sets are provided with jack access facilities to permit the use of a multi-recorder, which can record simultaneously, on electrosensitive paper, the operation of up to 29 relays. The record is in the form of an operational sequence diagram similar to that shown in Fig. 8.

The multi-recorder method of fault finding is not normally used in an exchange, and the normal procedure is as follows:—

1. Subject the faulty unit to traffic—preferably artificial (normally generated by the Automatic Exchange Tester).
2. Determine the approximate stage at which failure occurs by watching those relays which signify completion of each main function.
3. Commencing at the last completed main function, check for the operation of each subsequent relay until one relay is found which does not function correctly.
4. Use the circuit or "functional" diagram to trace the circuit of the particular relay.

To simplify the determination of which relays had been operated prior to the time release, the time release of the unit could, of course, be prevented by manually preventing the release of the normally operated supervisory relay. This must not be done, where the unit is carrying subscribers' traffic, as the supervisory control is necessary to free the unit after an unsuccessful call so that it may attempt to handle other calls. If the unit has been blocked to live traffic and is only handling artificial test traffic, mechanical holding of the supervisory relay may be permissible, but this should only be done when absolutely necessary as the prolonged holding time of the equipment may subject various components to stresses beyond their design limits.

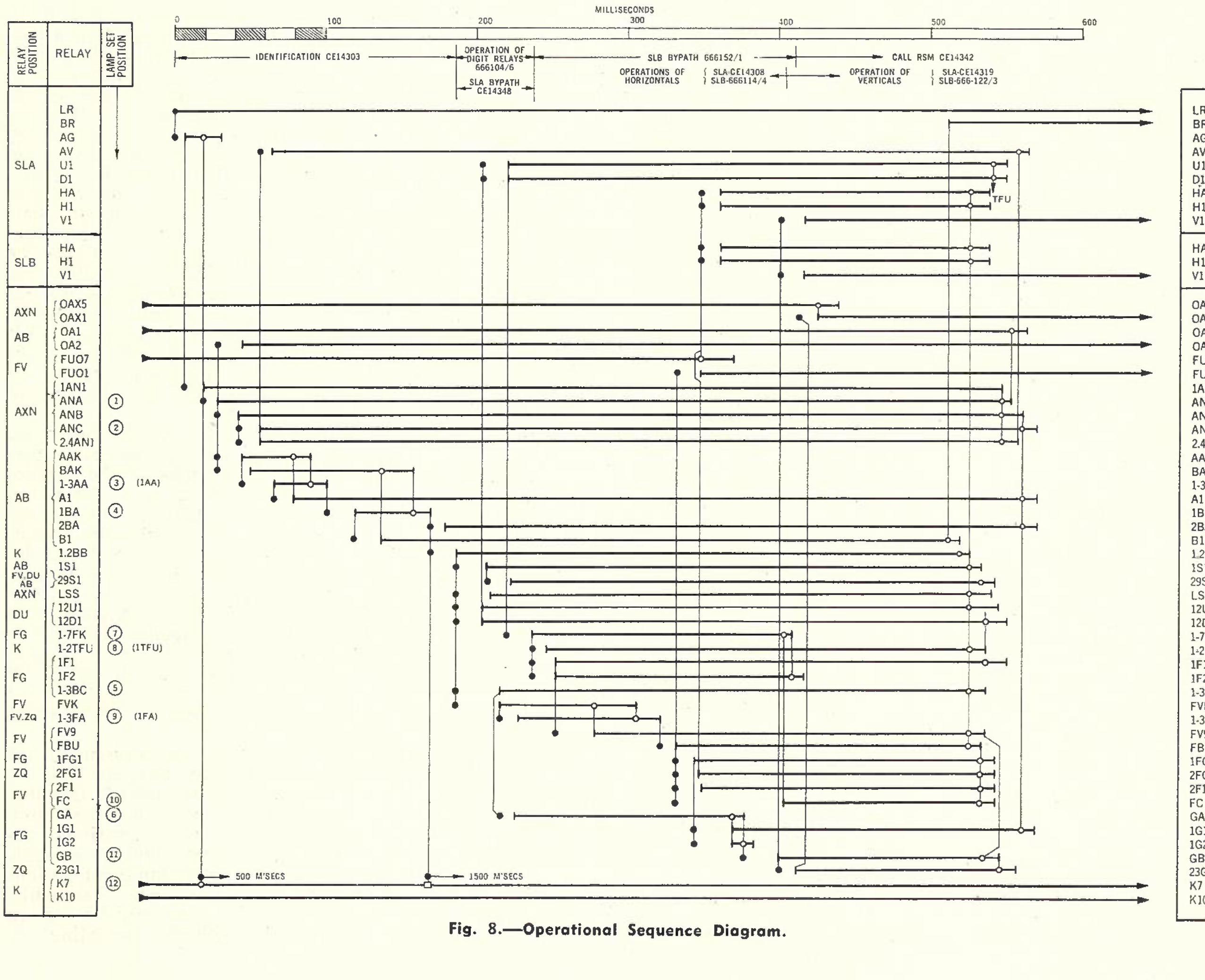


Fig. 8.—Operational Sequence Diagram.

Lampset

Fault finding can be expedited and simplified by using a lampset and sequence diagrams. Lampset access is normally provided for SLM and GVM, and sequence diagrams covering these units are available. Sequence diagrams for additional units are being prepared.

The lampset is a portable unit containing 30 recording relays operated from the extra make contact fitted to many of the relays in the markers. Each time the observed relay in the marker operates, the corresponding recording relay in the lampset operates and locks, giving a lamp display. If the call is successful the recording relays are released. Should a time-out occur, the lamps remain illuminated, and the lampset is disconnected from the marker so that a follow-on call will not disturb the recording relays. The lampset may also be operated and observed from the maintenance control room.

CONCLUSION

This article has described present Australian practices in the maintenance of L M Ericsson's ARF 102 crossbar exchange system. Further information on this subject is available in the author's "ARF 102 Service Manual" prepared for the Australian Post Office and the Telephone Organisation of Thailand. As further operational experience is obtained, and as more staff become involved in crossbar maintenance, further developments and refinements to the supervisory and maintenance techniques described will eventuate, no doubt including the development of centralised automatic supervision of exchanges and networks.

THE JOURNAL — TWO PUBLICATION CHANGES

Numbering: Hitherto, a volume of the *Journal* has been issued as six numbers over a period of two years, with a new volume commencing every alternate June. Publication dates were June, October and February.

As from February, 1965, a volume of the *Journal* will comprise three numbers (February, June, October), issued over a calendar year. Thus Volume 15 (Nos. 1-3) will be those numbers issued during 1965, Volume 16: 1966, and so on.

To change over to the new system, Volume 14 (of the old series) will have five issues, terminating in the October, 1964, issue, in which the Volume 14 index will appear.

Overseas Subscriptions Increase: Whilst Australian subscriptions will remain unchanged, increased weight of the *Journal* over the past few years has made it necessary to increase the subscription rate **for overseas subscribers** to offset the increased postage charges. As from Volume 15, No. 1 (February, 1965), the annual subscription for overseas subscribers will be increased from 10/- (ten shillings) to 13/- Australian currency post free. (See table.)

Overseas subscribers wishing to renew their subscriptions as from June (Volume 14, No. 4) will be offered the choice of renewing only for Volume 14, Nos. 4 and 5 at the cost of 8/- Australian currency post free, or of renewing for Volume 14, Nos. 4 and 5. and Volume 15, No's 1-3, at an inclusive cost of £1 Australian currency post free.

Subscribers and agencies who have standing orders with the Society will be invoiced under the second alternative, their renewals for 1966 will then fall due in October, 1965.

Subscriptions paid in advance at the old rate will be credited to subscribers; e.g., a subscriber who has paid 10/- Australian currency for Volume 14, Nos. 4-6 will be credited with 3/4 Australian currency on account of Volume 14, No. 6, which will not now be issued, and this amount will be deducted from his account for Volume 15, Nos. 1-3, or it will be refunded as desired.

Orders for less than three consecutive *Journals* will be charged at the rate of 5/3 each, Australian currency post free as from February, 1965.

A subscription renewal form will appear in the October (No. 3) issue of each *Journal.*

The Society is a non-profit organisation. Its officers receive no remuneration for their services, and the publication of the *Journal* is subsidised by the Australian Post Office. Even the increased subscription is much less than the net production cost of the *Journal.* It is, therefore, not possible to offer discounts to booksellers or subscription agencies.

CURRENCY CONVERSION TABLE

Australian	Sterling (U.K. and New Zealand)	U.S. $	Canadian $
13/–	10/6	1.46	1.58
8/–	6/6	0.90	0.97
£1	16/2	2.25	2.43
5/3	4/3	0.59	0.64

AUSTRALIAN TELECOMMUNICATION MONOGRAPHS

Monograph No. 1, comprising a theoretical paper on telephone traffic engineering presented by Mr. N. M. H. Smith, B.E.E., at the Third International Teletraffic Congress in Paris, will be available shortly. A summary of this paper appeared in Volume 13, No. 6 of the *Journal.*

Monograph No. 2, already published, deals with the preservation of wooden poles and covers a series of papers presented at a symposium held in Melbourne in March, 1963.

Copies of these Monographs may be ordered through State Secretaries* (Australian residents), or through the General Secretary.*

*For addresses see page 331.

MATERIALS AND COMPONENTS IN CROSSBAR

*W. R. DEDRICK, B.Sc., A.M.I.E.Aust., A.F.A.I.M.**

INTRODUCTION

The reliability of a telephone exchange network depends on the quality of its circuitry, the quality of its materials and components and the quality of the workmanship of its installers and maintainers. Telephone equipment is made from many materials —metals and alloys, plastics, textiles, papers, ceramics, paints and enamels and so on—each of which is carefully selected taking into account the electrical and mechanical performance required, the climate and location in which it is used, and the over-all effects when various combinations of materials are used in close association.

Trouble has occurred in the past when new or modified equipment has been accepted without taking all the time (sometimes up to two years) needed to thoroughly investigate it. Silver migration on silver-plated selector jacks, burning of PVC selector bank insulation, and contact troubles with nickel-silver to nickel-silver contacts are examples.

As a result, before adopting the L M Ericsson crossbar system, the main materials used were critically examined, particularly those in the crossbar switch and the relay, as these are the most important and major items involved. Many cases were found where L M Ericsson specifications differ from the Department's specifications. Some are not as severe as existing Departmental specifications, possibly because in some cases too high a quality had been sought in parts of the switching equipment. L.M.E. equipment is operating satisfactorily in various parts of the world, and it was decided to accept L.M.E. specifications for the time being until more experience was gained under Australian climatic and operating conditions.

When the two Australian manufacturers (Standard Telephones and Cables Pty. Ltd. and Telephone and Electrical Industries Pty. Ltd., Sydney) started to manufacture equipment to the Ericsson specifications they found many opportunities to use different materials and different manufacturing techniques. This was to be expected, as the materials and techniques used by L.M.E. in Sweden are based to a large extent on their existing factory facilities, on their suppliers of raw materials, and on the other products apart from telephone equipment that they make. Consequently the Sydney factories have been able to introduce some very modern production techniques, and alternative and more readily available materials and components. The attitude of the Department in this regard is that maintenance piece parts and sub-assemblies made by all manufacturers must be physically interchangeable, and quality and performance must at least meet the L.M.E. specifications.

* Mr. Dedrick is Engineer, Class 4, Exchange Switching Equipment Section, Headquarters. See page 333.

L.M.E. has of course continued to improve and modernise the equipment. In particular the general purpose (RAF) relay and the crossbar switch have been redesigned to improve their efficiency and reduce manufacturing and operating costs. Figs. 1, 2, 3 and 4 compare the new and old designs for these items. In addition the key, lamp and jack strips included in rack jack boxes will in future be moulded in one piece instead of being assembled from small piece parts.

To understand and apply L M Ericsson specifications it was necessary to solve the problems of translation of texts from Swedish into English and then relate L.M.E. test methods and results with data from Departmental, S.T.C., and T.E.I. sources.

ELECTRICAL ASPECTS

Contacts: One of the most important materials in a switching system is the material used for relay and switch contacts. Much research in this field has been undertaken throughout the world, but because of the number of factors influencing the choice of contact materials, experts still agree to differ.

The crossbar contact is made from a silver/copper alloy (10% copper), the advantages compared with pure silver being:—

It is harder.
It wears better.
It has less tendency to silver migration.
It is cheaper.

The silver/copper alloy used for switch and multi-coil relay contact strips is roll-plated to a copper layer to reduce the risk of silver migration.

When used in conjunction with the CR spark-quench unit it makes a very reliable contact.

Insulating Materials: Insulating materials used in crossbar equipment cover a wide range, but in general they are similar to those used in other types of telephone equipment with which we are familiar. PVC insulation on wiring, high quality phenolic laminated sheet (S.R.B.P.), and various plastics are widely used.

The L.M.E. switch and relay springset spacer is made from a specially moulded high quality material, but the Australian manufacturers are continuing to use the specially selected high quality S.R.B.P. which has been so successfully used in the past.

Wire Used in Relay Coils: L.M.E. specifications for relay coils call up millimetre wire sizes and these are not readily available in Australia. However, when millimetre sizes together with their tolerances are compared with S.W.G. sizes and their tolerances, sufficient overlapping occurs to enable S.W.G. sizes to be used. The final check, of course, is that the completed relay set performs its functions within the prescribed test limits.

Soft Magnetic Iron: Soft magnetic iron is an important material, and the design of crossbar relays and switches is based on the characteristics of a particular quality non-ageing Swedish iron.

Development of a comparable Australian iron has been undertaken in conjunction with the local manufacturers, and good progress has been made. The two main stages in this project are:—

(a) to develop the manufacturing techniques involved in producing satisfactory iron in the sizes required, and
(b) to develop acceptance testing techniques so that maintenance of quality is assured.

Each of these stages involves difficulties and problems which are steadily being overcome. So far, small quantities ot strip iron have been approved for use in relays and switches, and small quantities of rod iron for use in switches only.

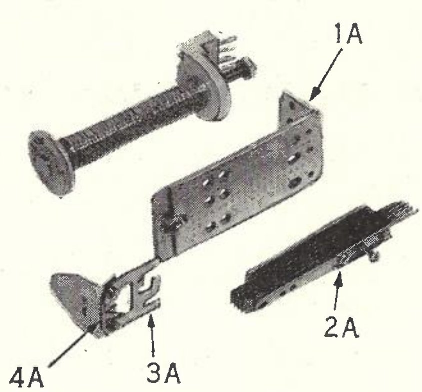


Fig. 1.—New RAF Relay showing Two Hole Mounting (1A), Channelled Springset Top Plate (2A), Springset Lifting Tongue (3A), and Straight Armature Pressure Adjusting Tongue (4A).

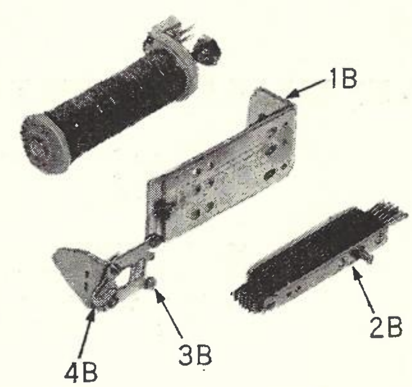


Fig. 2.—Old RAF Relay showing Single Hole Mounting (1B), Solid Springset Top Plate (2B), Springset Lifting Screws (3B), and "U" shaped armature Pressure Adjusting Tongue (4B).

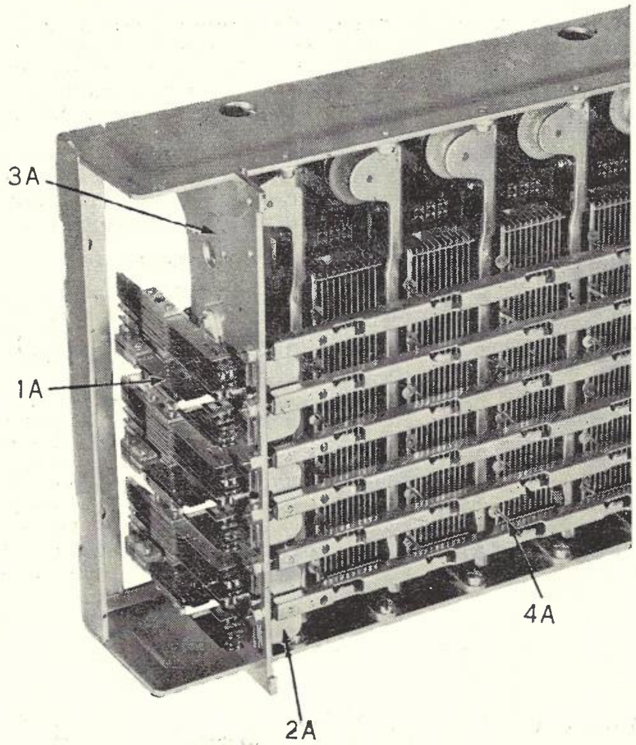


Fig. 3.—New Crossbar Switch showing Plain Buffer Springs (1A), New Shape of Horizontal Armature (2A), New Shape of End Plate (3A), Selecting Finger with Damper (4A).

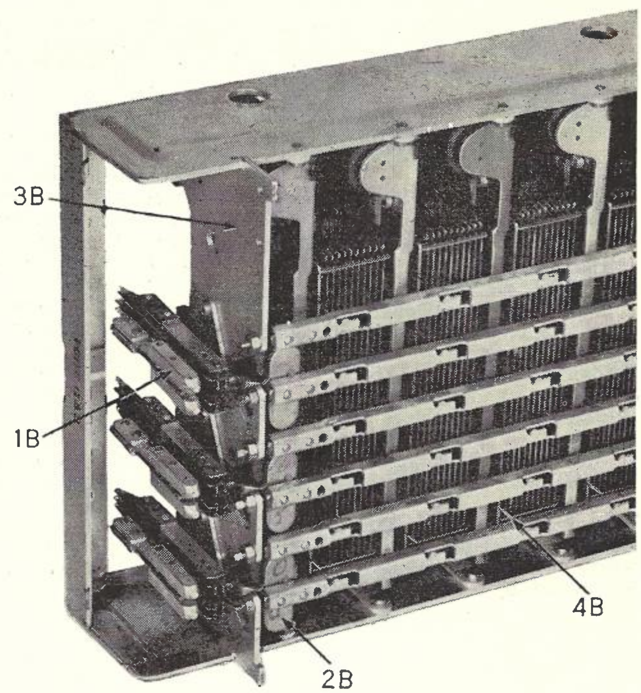


Fig. 4.—Old Crossbar Switch showing Loaded Buffer Springs (1A), Old Shape of Horizontal Armature (2B), Old Shape of End Plate (3B), Selecting Spring without Damper (4B).

A more detailed article on this important material will appear in a later issue of this *Journal.*

MECHANICAL ASPECTS

Zinc Plating: Many iron crossbar piece parts are zinc-plated to prevent rusting. The steps in the treatment are broadly:—

- Zinc plating to protect the iron from rusting.
- Chromating (or passivating) to protect the zinc surface (piece parts after chromating have colours ranging from blue to yellow to brown).
- Bleaching of the chromate layer to produce a uniform silver color and appearance, and lacquering to reduce staining from sweaty fingers during assembly.

The bleaching process was eliminated because it tends to reduce the protection provided, and the colours of unbleached piece parts are acceptable from an operational point of view.

The position then became somewhat confused because some initial production problems were experienced in a new plating plant in Sweden, and some unsatisfactory bleached piece parts were supplied to the Department and to the Australian manufacturers. Investigation showed that the products of corrosion are not likely to seriously affect the operation or service life of the exchange and the equipment was accepted, subject to replacement of the more unsightly parts, particularly multicoil relay armatures and some parts of the crossbar switch.

Fork Jack and Knife Jack Units: These 20 point assemblies are widely used as connecting points, for example, between relay sets and rack wiring and for the connection of exchange cabling to racks. Materials used are:—

- L.M.E. — Phenolic.
- S.T.C. — Acrylonitrile Butadiene Styrene (A.B.S.).
- T.E.I. — Polycarbonate.

One reason for S.T.C.'s choice of A.B.S. is that this material is also used for the Department's 801 telephone instruments which are made by that Company.

Jack Box Supports: These are machined from aluminium by L.M.E.; S.T.C. and T.E.I. are moulding them from delrin.

Jack Box Filling Strips: L.M.E. uses wooden strips which are faced with phenolic. Whilst Scandinavian timber is suitable for this purpose, even the best Australian timber absorbs moisture and is difficult to machine within the tolerances required. Filling strips moulded from high impact polystyrene are being used by the Australian manufacturers.

Crossbar Switch Transport Detail: Switches sent from Sweden for inclusion in initial crossbar deliveries were strengthened with packing pieces made from a Scandinavian long grain timber. These packing pieces were at first reused by the Australian manufacturers, and cases of fungus growth on switches reported from Queensland were found to be caused primarily by moisture absorbed by the timber when it had been removed from sealed packages and stored in Sydney. Fortunately a decision had already been made to use a moulded transport detail instead of the timber for future Australian production.

Relay Residual Plates: Residual plates of various thickness are identified as follows:—

Thickness	L.M.E. (coloured stripe)	Department (number of notches in side)
.05 mm.	yellow	3
.1 mm.	red	1
.25 mm.	clear (no stripe)	—

COMPONENTS

Crossbar equipment uses a wide variety of pigtail components and relatively large quantities of electrolytic capacitors. Experience in Australia with electrolytic capacitors has not been very satisfactory, and we have avoided using them because of their lower reliability, their tendency to drift with time, their larger initial tolerances compared with other components and the need to re-form them after storage. However, the particular makes and types of electrolytic capacitor used in the crossbar system are of satisfactory quality and reliability and they are only used in instances when their characteristics make them satisfactory. The use of pigtail components, of course, involves different types of mounting arrangements, and particular care must be taken when locating faults, unsoldering wires, replacing components, etc., not to damage or overheat these components. The Australian manufacturers are using Australian-made components instead of imported ones as far as is practicable. Satisfactory arrangements have been made with Australian component manufacturers for the supply of high stability cracked carbon resistors, CR units and metallised paper capacitors, and the range of Australian-made components is increasing steadily.

APPLICATION OF CROSSBAR STANDARDS AND SPECIFICATIONS TO OTHER EQUIPMENT

The Australian manufacturers are continuing to make other types of equipment for the Department and for other customers, and it is logical to try to adopt common manufacturing standards and specifications for all telephone equipment.

Some typical examples are:

3000 Type Relay Contact Materials: It was decided to retain pure silver contacts and not to use the crossbar silver/copper alloy because of the limited quantities of 3000 type relays required in the future and the increased wear on existing tools which would be caused by the harder material.

PVC Wiring for Step-by-Step Relay Sets and Switches: Crossbar equipment uses plain PVC insulated wire for wiring forms whereas step-by-step equipment uses textile lapped and lacquered PVC insulated wire, wiring forms and rules are, however, different. Particular care must be taken to avoid insulation run back when soldering plain PVC wire, and wires must not be drawn too tightly around adjacent tags, as the PVC will cold flow. Overseas manufacturers have experimented with plain PVC wire in step-by-step equipment and examples can be seen in some imported P.A.B.X.'s. Protecting devices such as insulating troughing between rows of tags and insulating sleeves on tags have been used but satisfactory results have not yet been achieved.

As future production of step-by-step equipment will be relatively small it is not economic to change over to plain PVC wire, but the requirements for colour coding have been relaxed and alternative supplies of textiles suitable for lapping are being sought.

Pigtail Components: Pigtail components such as resistors, capacitors and CR units have been approved for use in relay sets but not in electromechanical selectors because of difficulties due to vibration.

Unbleached Zinc Plating: Bleaching of chromated zinc plated surfaces has been discontinued on many items, resulting in piece parts of varying hues and colours.

CONCLUSION

The quality of materials and components used in the crossbar system will give satisfactory and economic over-all performance under Australian conditions.

The successful manufacture in Australia of this modern type of equipment is essentially the work of a team which includes staff of the equipment manufacturers and their sub-contractors for materials and components, and many people in various parts of the Department. The author is indebted to all who have contributed and are still contributing to this project.

Mr. J. R. H. HUTCHISON, B.E.(Hons.)

MR. J. R. H. HUTCHISON, B.E.(Hons.)

Mr. J. R. H. Hutchison, B.E.(Hons.), retired from the position of Director, Posts and Telegraphs, New South Wales, on 6th March, 1964, after a brilliant career which commenced in 1918 with appointment as Telegraph Messenger. After training as a Telephone Mechanic he qualified as Senior Mechanic and during this period also passed the Leaving Certificate and Matriculation Examinations and completed three years of a Diploma Course in Electrical Engineering at the Sydney Technical College. In 1927 he was selected as an Engineering Cadet. As well as completing his Cadetship he undertook an Engineering (Electrical and Mechanical) Degree Course at Sydney University and graduated with Honours.

On appointment as Engineer, he participated in the installation of the Central Telegraph Office, the first picturegram service and the first programme carrier system (Sydney-Melbourne). He was then seconded for duty to the Radio Research Board where he worked for some time on radio propagation studies and lectured to Fourth Year Engineering Honours Students at Sydney University. He was next transferred to the Department's Central Office where he was engaged on the development of broadcasting studio equipment at the Research Laboratories. He was subsequently concerned in developing the revised course of training for Junior Mechanics (as he was much later in his career with the current form of the training system).

After experience with the installation and maintenance of automatic exchanges he was appointed Divisional Engineer, Radio and Broadcasting, in Queensland, where he was responsible for the installation and maintenance of radio facilities throughout Queensland for some years. His activities included the installation of radio facilities at Rabaul and Port Moresby for the R.A.A.F. From there he returned to a similar position in New South Wales which, during the war years, involved an extensive programme of facilities for the Navy, R.A.A.F. and the Department of Civil Aviation. After a relatively short period on transmission radio in Sydney he became the Supervising Engineer, Radio and Telegraphs, where he established the present excellent relations between the Department and the Australian Broadcasting Commission. Then followed promotion to Deputy Superintending Engineer, Country Branch (1955) to Superintending Engineer, Country Branch (1956) and to Assistant Director, Engineering (1957). In 1960 he became Director, Posts and Telegraphs, New South Wales, in which position his long-held interest in the fundamentals of leadership and management attained its widest scope. During his busy life, Mr. Hutchison has retained a keen interest in people, in literature, history and philosophy.

The Board of Editors, on behalf of the Society, wish Mr. Hutchison best wishes for his retirement and trust that he will enjoy good health and happiness for many years to come.

QUALITY ASSURANCE OF CROSSBAR EQUIPMENT MANUFACTURED IN AUSTRALIA

*R. LANGEVAD, B.E., A.M.I.E.Aust.**

INTRODUCTION

Quality control and quality assurance, like many engineering principles, are not new; the terms themselves, however, are of relatively recent origin, as are the co-ordinated programmes with which they are now associated. The terms appeared about 40 years ago, but quality in engineering processes has been controlled successfully for many centuries, as may be seen in buildings and ships, weapons and coins, and in more recent times, clocks, motor vehicles and telephone systems. All of these things originally had quality built into them by craftsmen, but it is the combination of increasing complexity, the demand for high production quantities, and the loss of hand craftsmanship in the manufacturing industry in more recent times that has made the new specialised techniques for controlling quality necessary.

It is of interest to note that two important elements in statistical quality control—quantity production and statistical concepts—have also been associated for many years with the design and operation of telephone systems. It is not surprising, therefore, to find that the development of modern quality control procedures has received considerable impetus from the telephone industry. Evidence of this is to be found in the many contributions to the established literature on quality control from the Bell Telephone Laboratories, Western Electric Co., and many other organizations and by the work of individual specialists in the telephone industry such as Dr. W. A. Stewart, Harold F. Dodge and Harry Romig.

The principles of quality control are now well established. A great deal of experience in their application has been gained, particularly in the U.S.A., whilst in recent years the Australian Post Office, in co-operation with the Australian telephone equipment industry, has been investigating their application to the manufacture of engineering equipment. The decision to manufacture L M Ericsson crossbar switching equipment in Australia, involving, as it did, the establishment of a whole new manufacturing set-up, including new buildings, machines and procedures, new materials and ideas, new training of staff and operators, provided the opportunity for the consolidation of the results of this investigation into a co-ordinated Quality Assurance Scheme.

In the application of this quality assurance scheme to the manufacture of crossbar equipment, a considerable contribution was made by Mr. K. B. Olsbro, manager of the component laboratory, L M Ericsson Pty. Ltd. Sweden, who was made available to the Postmaster-General's Department during the first year of the manufacturing programme. This contribution was particularly valuable in the setting up of the reliability testing programme, training of inspecting officers in the techniques associated with crossbar, and determination of equipment quality requirements in terms of the local system.

Quality Assurance

Quality Assurance is a term coined by the Bell Telephone Laboratories some 40 years ago (1) and as practised by the Bell System is the customer contribution to the over-all quality picture. The application and interpretation of Quality Assurance in industry generally are somewhat varied, but the scheme used in the Department is based on the following definition:

The total effort, by all those associated with the design, manufacture, inspection and use of a product, directed to ensure optimum quality in terms of specification, reliability and cost.

Quality Assurance and Quality Control are often regarded as synonomous. However, quality control is essentially a manufacturing responsibility and can be defined as:

An integrated system of control of quality employed by a manufacturer to ensure production of goods to the customers' specified requirements, at minimum cost.

THE DEPARTMENT'S QUALITY ASSURANCE SCHEME

The Department's Quality Assurance Scheme has been designed so that the following conditions will be met:

(a) Equipment will function correctly at the time of delivery into store.
(b) Equipment will continue to function correctly for its designed life.
(c) Components required to be interchangeable are in fact interchangeable.
(d) Equipment will be of acceptable appearance.

To meet these requirements the following seven point programme was developed:

Classification of Defects into Five Categories: Critical, special, major, minor, incidental.

Determination of Acceptable Quality Levels for special, major, minor, and incidental classifications. (Critical defects require 100% inspection.)

Control of Quality of piece parts, components, sub-assemblies and assemblies to specified quality levels by statistical and other means.

Final Functioning Tests in factory of assemblies to test instructions.

Surveillance of Manufacturer's Quality Control System including statistical and other control methods and inspection instructions to ensure that control is maintained. Product audit is also carried out as necessary.

Reliability Testing in Departmental laboratory of random samples from production including life and environmental testing.

Feed-back of Field Experience by way of complaint reports.

CLASSIFICATION OF DEFECTS

In setting up an inspection scheme with a sound statistical basis it is necessary to classify all various possible defects in order to differentiate between defects of varying importance. This enables all the possible defects of an article to be grouped together in classes, according to their relative importance, to each of which classes can be given a level of quality to be achieved.

The number of classifications is somewhat arbitrary and several published schemes exist, a typical case being the three classification group, critical, major and minor, of the U.S. Defense Department Standard MIL. STD. 105 (2). Both for the sake of uniformity with other Government Inspection Agencies (3), and the improved flexibility obtainable, a five group classification has been adopted by the Department each defined as follows:—

Critical Defects: Those which in handling, storage or use could directly cause loss of life or serious bodily injury.

Special Defects: Those which make the item useless for the purpose for which it was designed.

Major Defects: Those which could seriously affect the proper functioning or performance of an item, or which for specific reasons, would make the item unacceptable.

Minor Defects: Those which will not affect the functioning or performance, but involve a minor departure from drawings and specifications.

Incidental Defects: Those caused by departure from good workmanship and, though not having any ill effect on functioning or use, are nevertheless undesirable.

While a five group classification has been adopted, this was for general application to the Department's equipment, and it is not expected that the critical classification will be used for crossbar equipment. For the latter then, only the four classifications — special, major, minor and incidental — need to be considered.

Defects can be further classified in two ways, (a) those which affect the end use of the item and, (b) those which affect production during intermediate processes such as assembly. In case of (a) it is necessary for the Department to determine the classifications, while in the case of (b) the manufacturer is at liberty to classify defects into any group he chooses at a level of importance to suit his particular manufacturing process. In the manufacture of crossbar equipment in N.S.W., the manufacturers have however, used the Department's classifica-

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* Mr. Langevad is Engineer Class 4, Supplies and Training, New South Wales. See page 333.

TABLE I—CROSSBAR SYSTEM—R.A.F. RELAY ADJUSTMENT

Characteristic	Defect Classification		
	Special	Major	Minor
Teeth on the combs	Cracked or teeth broken off	—	Broken corner
Pressures of movable lower springs	Spring floating	< 3 grm.	3-5, > 15 grm.
Pressures of fixed springs	Spring floating	< 15 grm.	≥ 15 > 25 grm.
Twinning	—	One contact not made (fully operated).	One contact is making 2 mils. before the other.
Check lift of springs from supporting comb (a) Short springs 20 grm.	—	Not making with 8 mils.	Make with 8 but not with 10 mils.
25 grm.		Not making with 10 mils.	Make with 10 but not with 12 mils.
(b) Long springs 20 grm.		Not making with 12 mils.	Make with 12 but not with 15 mils.
25 grm.		Not making with 15 mils.	Make with 15 but not with 18 mils.
Contact clearance (25 grm. adj.) (20 grm. adj.)	< 6 mils. < 4 mils.	≥ 6 < 8 mils. ≥ 4 <6 mils.	≥ 8 <10 mils. ≥ 6 <8 mils.
Lifting springs (provided with damper) from supporting comb. (a) Short springs (making for 14 mils.)	—	making for 20 mils. or more not making for 12 mils. or less	making for 18 mils. but not 20 making for 12 mils. but not 14
(b) Long springs (making for 20 mils.)	—	making for 26 mils. or more not making for 18 mils. or less	making for 24 mils. but not 26 making for 18 mils. but not for 20
Distance in sequence sets having projection springs. Make function.		—	Projection springs actuated before normal spring makes
Break function.	No sequence	1-4 mils.	5-8 mils.

tions, once again for the maintenance of uniformity of practice.

Typical of the characteristics which are classified by the Department are relay adjustments and Table I gives some of the important relay adjustments for R.A.F. relays classified in this way.

In practice the number of possible special defects can be very large, e.g., the absence of a component in a complex assembly will probably make the assembly useless. For this reason, it is not possible to specify all special defects and with the exception of those that are not so obvious, they are identified in accordance with the definition as they occur.

While major defects can sometimes be identified by definition, they are usually not so obvious; in the general case it is necessary for the designer to specify the relative importance of this class of defect. Typical of this class of defect are:

Dimensions affecting interchangeability.
Dimensions affecting strength.
Adjustments.

As stated in the definition a minor defect will not affect functioning or performance, but such a classification is imposed, for example, where control is considered necessary for uniformity or to ease inspection difficulty where marginal conditions arise.

The latter case occurs whenever an "attribute" type of inspection plan is used with direct measurement of characteristics, rather than with GO-NOT GO gauging, and a variables type plan would be too complex and expensive to operate. A typical case is the measurement of relay spring tensions, where the natural limitations inherent in the methods of making practical measurements of this kind on the production line results in differences of opinion between inspectors. The application of the minor classification to small departures in an otherwise major situation considerably eases this difficulty. The application of this principle is evident in Table I.

[An "attribute" type of inspection plan is one in which items of a sample are regarded as 'good' or 'bad' depending upon whether the characteristic under consideration is within or outside the specification limits. This is in distinction to a "variables" type of inspection plan in which the actual value of the characteristic for all items of the sample is taken into consideration, when considering acceptability. The attributes type plan is most commonly used because of its simplicity, but the variables plan provides more useful information.]

Incidental defects, like special defects, can occur in a very large number of ways, and except for particular cases, are generally left unspecified to be identified against the definition as they arise.

DETERMINATION OF ACCEPTABLE QUALITY LEVELS

Acceptable Quality Level, A.Q.L., can be defined in several different ways:

(a) The minimum quality that the consumer is normally prepared to accept.
(b) A specified quality of product such that the sampling plan will have a given probability of accepting a lot, of the stated quality.
(c) The minimum quality considered satisfactory as a process average.

While the finer points of difference in these definitions are somewhat academic the determination of the actual value of the A.Q.L. must meet two main conditions:

(a) The A.Q.L. should reflect the real needs of installation and maintenance of the telephone system, and
(b) The ability of manufacturers to manufacture equipment to the stated quality level.

In the case of telephone switching equipment complete field statistical data, capable of being translated into an A.Q.L. value, is not presently available, so that the A.Q.L. values currently being used are related primarily to the capability of local industry.

These values have been determined in the case of crossbar equipment, having regard to the considerable experience gained during the manufacture of 2000 type equipment, modified in order to conform to the range values specified in the U.S. Defense Department Document MIL-STD-105 (2). MIL-STD-105 is a very widely accepted sampling inspection scheme and a degree of uniformity would be achieved by using the A.Q.L. values listed therein. It was also thought desirable, for the sake of uniformity to use the same ratio of values for the various defect classifications as are used by the Australian Army Inspection Service (3), i.e., the ratio of specials to majors, majors to minors and so on.

In addition, it was a contractual requirement that local manufacture of crossbar equipment should be of the same quality as that manufactured in Sweden. The L M Ericsson System of control was different to that being used in Australia and direct comparison of the methods of stating quality requirements was not possible. However, large scale sampling of imported equipment indicated that it largely conformed to acceptable quality levels separately established by the Department.

For telephone switching equipment the A.Q.L. values currently being used are:

Special defects	.15%
Major defects	.65%
Minor defects	2.5%
Incidental defects	6.5%

CONTROL OF QUALITY

Contractors are obliged under the terms of their contracts with the Department to produce goods fully in accordance with their contract conditions; because of this, control of quality is essentially a manufacturing responsibility, and when properly applied makes the greatest single contribution to over-all quality assurance. In order to be sure that all contractual requirements have been met, it is the usual practice for Departmental inspectors to sample all deliveries of material and equipment. In recent years, however, as a result of the development of satisfactory quality control procedures at some factories, detailed inspection is waived where it is demonstrated that adequate control of product quality to the Department's specification exists. This applies particularly in those cases where production is continuous. Where equipment is produced in short runs Departmental inspection of all manufactured lots to MIL-STD-105 sampling plans is still carried out.

While the Department is vitally concerned with the quality control systems of individual manufacturers, the possible variations in these systems are so wide that no attempt is made to dictate the system to be used. Rather an assessment is made to determine the conformance of the system to certain general basic requirements. Deficiencies in any of these requirements are brought to the attention of the contractor, who is expected to take corrective action if he desires to have his system accepted.

Basic Requirements of a Quality Control System

The following general requirements of a quality control system have been adopted:

1. In order that a quality control system can be fully understood and evaluated, it is essential that a quality control manual should exist. This manual may consist simply of an agglomeration of instructions (see Appendix I), recording cards, report forms and the like. This is considered as basically satisfactory, but it is expected that this document will also include a statement of the manufacturer's quality policy (see Appendix II), organisation for quality control and the quality responsibilities of the various branches.

2. The company organisation should have provision for direct access to top management by the quality control manager or equivalent, independent of production.

3. The inspection function should consist of a primary inspection component and an independent quality audit. While the primary inspection (process control inspection, incoming material inspection, etc.) is usually a function of a separate inspection department, it can be made a responsibility of production and indeed there is sound argument to support this arrangement, providing provision has been made for an inde-

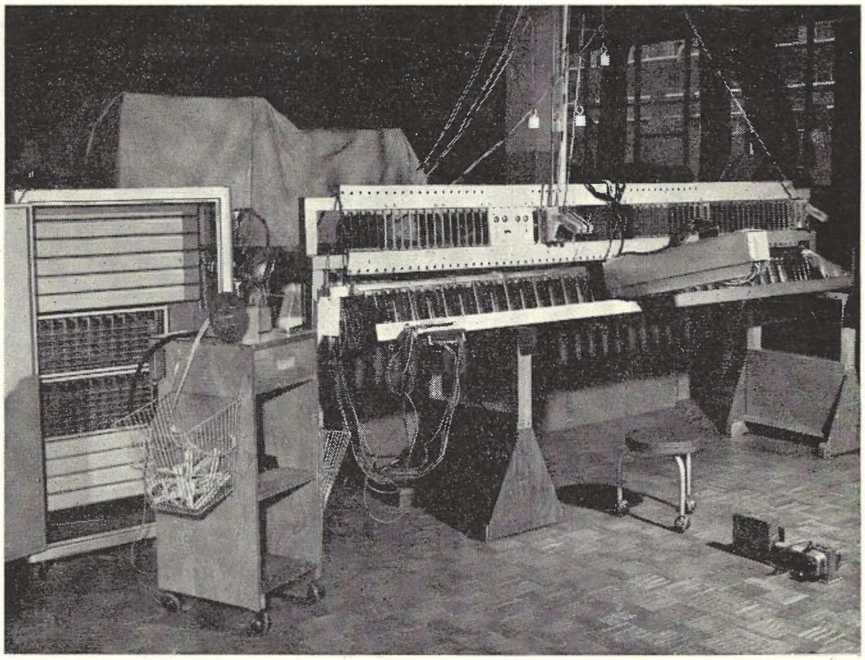

Fig. 1.—Automatic Testing of BDH Rack using Tape Controlled Test Set (in Cabinet).

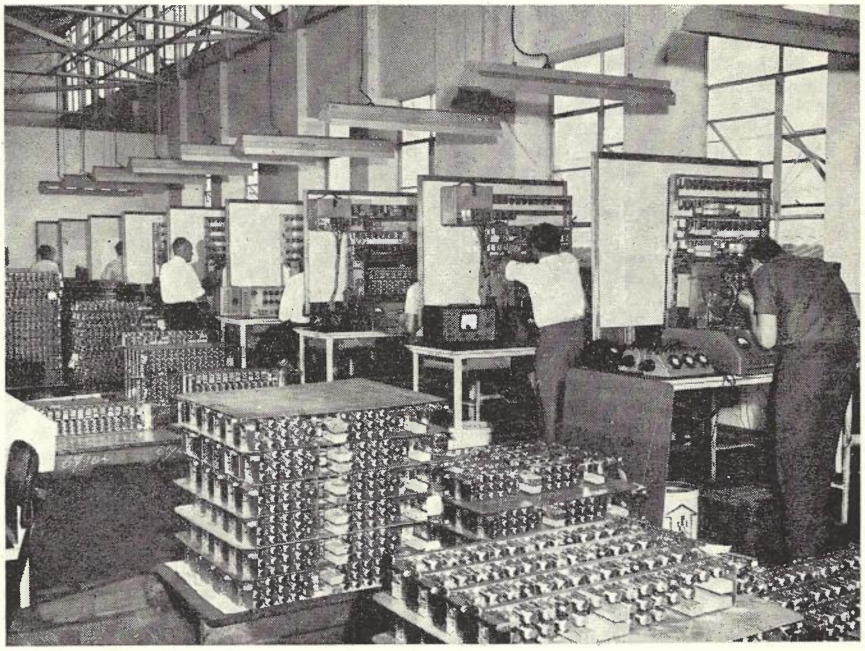

Fig. 2.—A Group of Semi-Automatic Relay Set Testers.

pendent audit type inspection, under the control of the quality control manager and accordingly reporting direct to top management.

4. Inspection programmes, both primary and audit, should have a sound statistical basis.

5. Provision should be made for feedback of inspection information. This is the characteristic which differentiates between the old type inspection programmes and the modern concept of quality control. Clearly without feedback, and the planning for improvement that goes with it, full control cannot be said to exist.

6. Complementary to feedback of inspection information is the need to take corrective action where this is called for. The quality control system should be so designed that the taking of this action cannot be avoided.

In an inspection of a factory's quality control system, what will be most obvious to the casual observer are the methods used on the production line to appraise conformance to quality standards. Where quality control is practised there will be ample documentary evidence of the use of these methods. While the possible variations in detail of application as between different systems are large, the well-known statistical tools will be seen to be present. Typical of these are:

- Applications of the frequency distribution to process capability studies.
- Application of average and range control charts to process capability studies and actual production runs.
- Use of fraction defective control charts.
- Use of small size sample inspection plans to continuous production.
- Use of normal size sample inspection plans to check product from short production runs or audit product from continuous production runs.

Some examples of inspection documentation and charting, taken from actual production situations at the factories of Standard Telephones and Cables Pty. Ltd. and Telephone and Electrical Industries Pty. Ltd., are presented in Appendices III, IV and V.

FINAL FUNCTIONING TESTS

The manufacturing set-up for crossbar equipment provides for extensive testing of sub-assemblies and assemblies of relay sets, switches, and racked equipment by automatic and semi-automatic test equipment.

By means of common test instruments complemented by plug-in units and connecting cord and plug units, final testing to predetermined test programmes is carried out on all:

- Relay set racks (BDH racks) for continuity and insulation resistance of wiring (Fig. 1).
- Relay sets for circuit functioning and continuity and insulation resistance of wiring (Fig. 2).
- Switch vertical adjustments (Fig 3).
- Switch assemblies (Fig. 4).
- Switch racks (BDD racks) for functioning and continuity and insulation resistance of wiring (Fig. 5.)

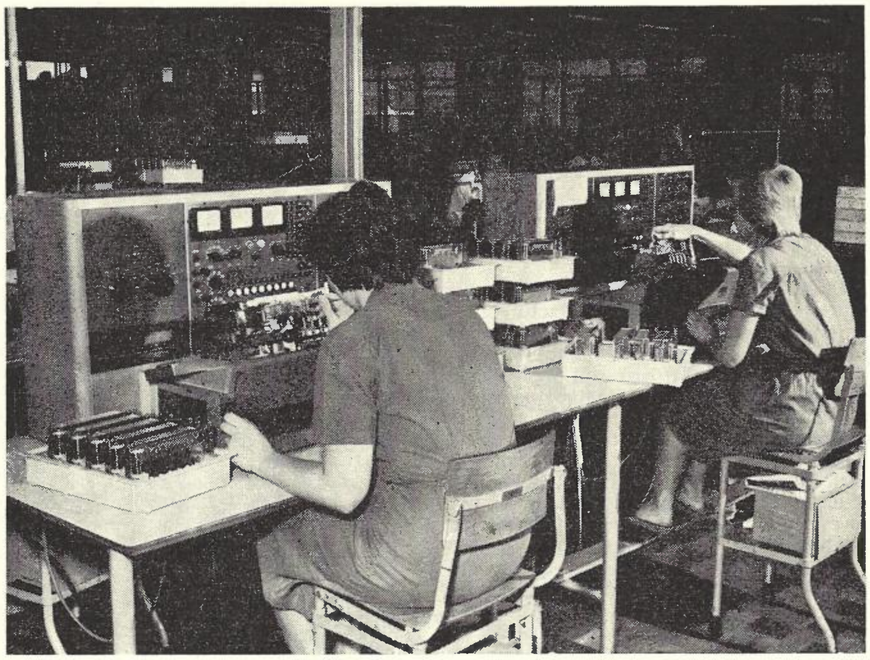

Fig. 3.—Testing and Adjustment of Crossbar Switch Vertical Units.

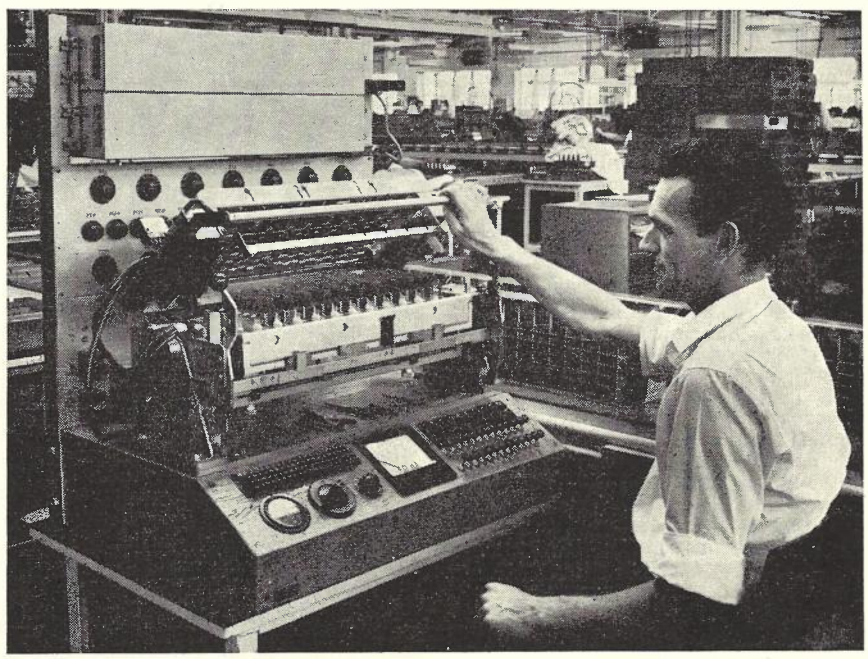

Fig. 4.—Testing of Crossbar Switch. The contact head is seen being lowered into position where it will make contact with the terminal array on the rear side of the switch.

SURVEILLANCE OF QUALITY CONTROL SYSTEM

The preferred system of Departmental inspection is one involving both manufacturer and Department's inspectors in clearly defined but separate areas. It is uneconomical to duplicate inspection unnecessarily, so that where the manufacturers' inspection system is demonstrated to contain the features necessary for adequate control of product quality, Departmental inspection can confine itself to checking that the system is being correctly operated. Some product inspection may be necessary at times, either in the nature of an audit, or added control where trouble spots are detected.

Considerable economic advantage accrues from such a system. The number of Departmental inspection staff is no longer a function of production volume but instead depends only upon the reliability of the manufacturer's quality control system, and accordingly can approach zero under the right conditions.

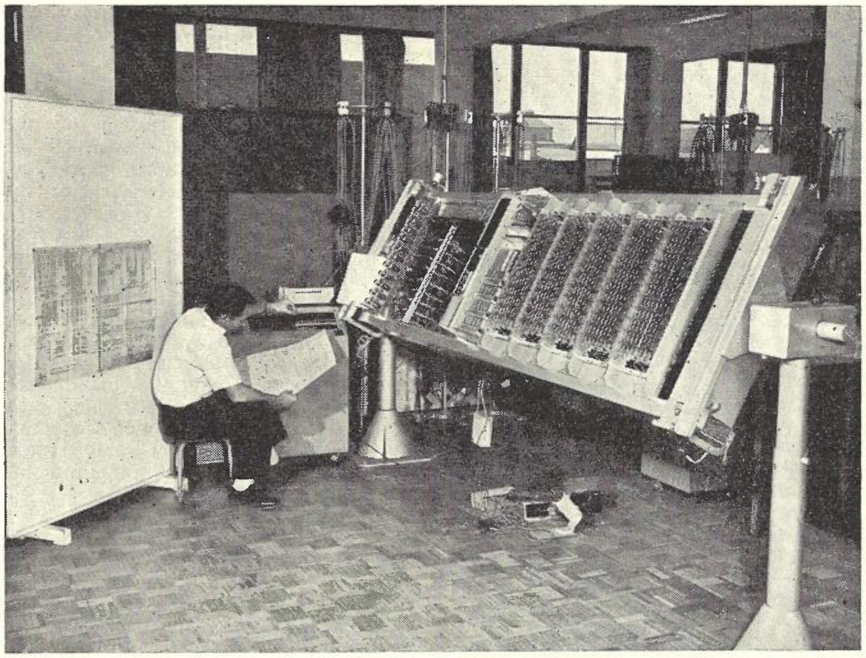

Fig. 5.—Semi-Automatic Testing of Assembled BDD Rack.

check that the design and manufacturing data do in fact result in the production of equipments with the desired life qualities. Because of the existence of this procedure in Sweden, it was decided that it should be introduced in Australia at the outset of manufacture.

In Sweden the reliability testing work is intimately associated with the design as well as manufacturing stages, and new designs with unknown life properties are tested, to determine these properties in the component laboratory before manufacture commences. Because all design work is at present conducted in Sweden, the primary aim of reliability testing in Australia then is to determine that the manufacturing processes and materials used do result in a product of the desired life characteristics. These are somewhat arbitrary and as yet are not related directly to a real Australian field requirement and it is a task for the future to convert field experience together with laboratory and manufacturing experience into a feasible reliability specification.

In the meantime routine testing of samples is carried out in a laboratory provided for the purpose (Fig. 6) to the

The Department's factory located inspection effort in the case of crossbar equipment manufacture is utilised in:

(a) Carrying out a bi-monthly large sample audit of relay adjustments.
(b) Examination of company inspection records.
(c) Check inspection on the production line where this is shown to be necessary.
(d) Surveillance of final functioning tests on completed equipment.
(e) Statistical examination of wiring terminations.
(f) Lot by lot inspection of equipment from short production runs.

A typical inspection programme indicating the surveillance maintained over the testing of relay sets is given in Appendix VI. The programme includes a sampling plan for the inspection of wiring terminations, a critical reliability consideration in this type of equipment.

RELIABILITY TESTING

The first six items of the quality assurance programme are directed towards ensuring that equipment leaving the factory is in working condition and has been made in accordance with all contractual conditions.

Reliability in terms of the ability of crossbar equipment to meet particular environmental conditions and operate satisfactorily for a given time has not as yet been quantitatively specified as a contractual requirement of the Department.

Within the L M Ericsson manufacturing organisation, however, special attention is given to the life properties of telephone equipment in order to

TABLE II—RELIABILITY TESTING—SAMPLING PLAN

Item	Month 1	2	3	4	5	6	7	8	9	10	11	12
NFS 211 Fuse Unit		5			5			5			5	
NFS 212 Fuse Unit		2			2			2			2	
NGK 10 Fuse Wire	20		20		20		20		20		20	
RAB Relay	5		5		5		5		5		5	
RAE 72-74 Pol. Relay			5						5			
RAF Relay	10	10	10	10	10	10	10	10	10	10	10	10
RAG 40 Pol. Relay			5						5			
RAG 50 Min. Relay	5		5		5		5		5		5	
RAH 11 Relay Unit	5		5		5		5		5		5	
RAM 11 Multi Coil Relay	2		2		2		2		2		2	
RBB 13 Thermal Unit			5						5			
RCA 20, 42, 43 92 Relay Coil	5	5	5	5	5	5	5	5	5	5	5	5
RCB Relay Coil	5		5		5		5		5		5	
RCE 79-80 Coil for RVD	5		5		5		5		5		5	
RCR 13 Wire Resistor			10						10			
RCR 18 Wire Resistor			10						10			
REA 26 Transformer		2			2			2			2	
REK 10 Transformer		2			2			2			2	
REP 20 Resistor		20			20			20			20	
RJE 50 Capacitor		5			5			5			5	
RJK 3, 7, 9 Capacitor		5			5			5			5	
RKA 14, 24 Capacitor		5			5			5			5	
RKG 10 Capacitor		5			5			5			5	
RKT 10, 12 Rectifier		10			10			10			10	
RKT 13, 20 Rectifier		10			10			10			10	
RKT 83, 84 Diode		10			10			10			10	
RKV 40 Rectifier		10			10			10			10	
RNG 11 Lamp		10			10			10			10	
RNK 90 Lampholder		2			2			2			2	
RNV 20 Fork Cont. Unit		2			2			2			2	
RPV 20 Knife Cont. Unit		2			2			2			2	
RVD Crossbar Switch	2		2		2		2		2		2	

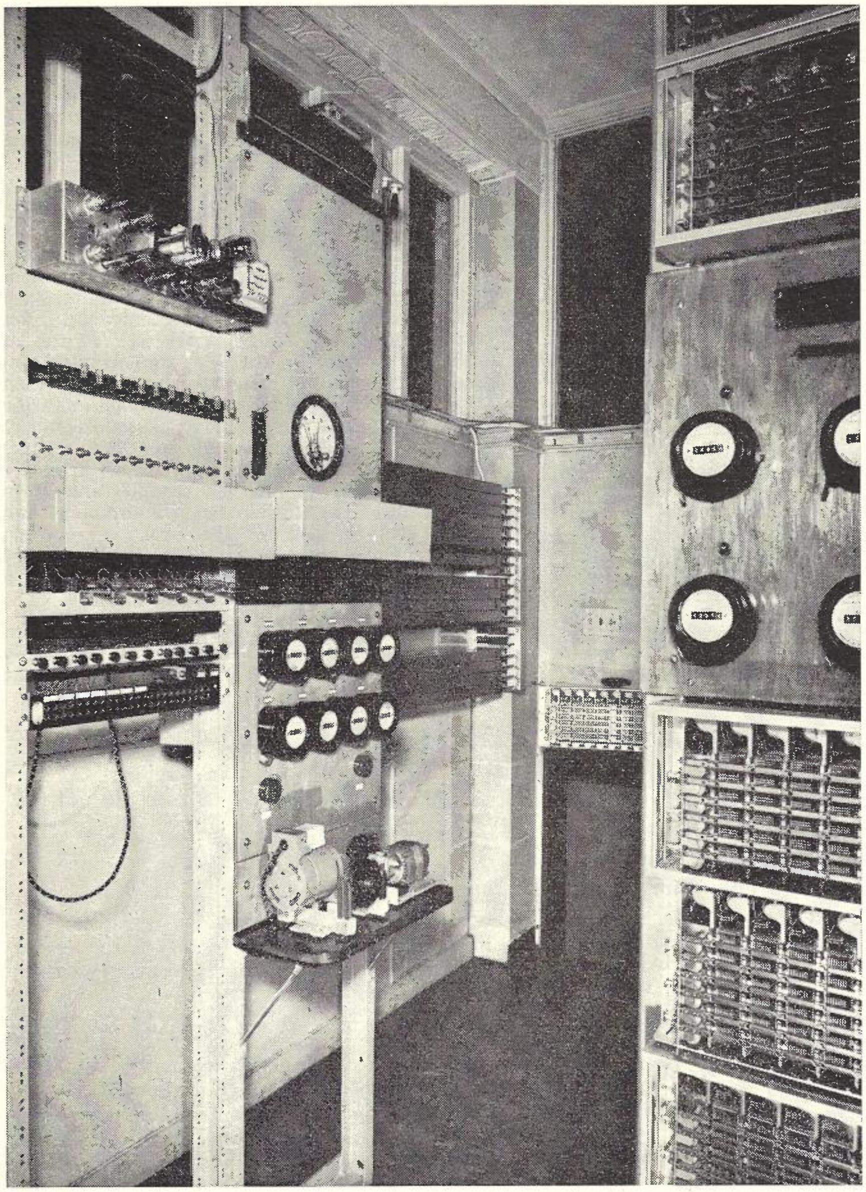

Fig. 6.—Departmental Testing Laboratory, Sydney, showing Switches, Relays (at rear) and C-R Spark Quench Units (top left) Undergoing Life Test.

sampling programme of Table II. In Fig. 6 can be seen relays switches and C-R units under test together with impulse generators, time clocks and control apparatus.

Test programmes generally cover:

(a) Visual inspection, including detail check to the descriptive document known as an "Article List", which gives dimensional and other required characteristics.

(b) Check of electrical properties.

(c) Check of adjustments to the respective L.M.E. Adjustment Instruction, e.g,, 1518-RVD100-300.

(d) High voltage test.

(e) Climatic or environmental test.

(f) Life test.

Appendix VII is a reproduction of the reliability test programme for RVD100-300 crossbar switches and included in graphical form is a typical test result of the important characteristics of the switch.

Reliability testing is presently being carried out in the Department's laboratory in Sydney and feedback of the results of this testing to the two manufacturing companies and the Department's Headquarters' organisation is made continuously at the start, on completion, and during the currency of the testing by a system of continuous reporting. Corrective action is then able to be taken at the earliest possible time after the need is known.

FEED-BACK OF FIELD EXPERIENCE

Complaints from the field cannot be regarded as a completely reliable indicator of quality, because of the inherent inaccuracy and incompleteness of the information and its dependence on the varying characteristics of the people supplying it. However, the ultimate arbiter of quality is the man in the field and the feedback of his experience is a valuable link in the quality assurance chain providing its limitations are well understood. Because of the importance of this feedback, the Department is currently investigating methods for obtaining this information in a form that can be used statistically both in the determination of acceptable quality levels for factory quality specification and the determination of reliability requirements.

CONCLUSION

The introduction of crossbar equipment into the Postmaster-General's Department has contributed largely to the development and extension of the scientific control of quality in an important sector of Australian industry. By demonstration of the economies accruing to both manufacturer and consumer, coupled with controlled quality to specified levels related to both customer requirements and manufacturing capability, it will no doubt have considerable influence on further extension into other fields of manufacture, particularly to those fields associated with equipment used by the Department.

ACKNOWLEDGEMENT

The author wishes to acknowledge the help given by personnel of Standard Telephones and Cables Pty. Ltd. and Telephone and Electrical Industries Pty. Ltd. in the preparation of this paper.

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FURTHER READING

J. M. Juran, "Quality Control Handbook"; McGraw Hill, 2nd Edition, 1962.

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APPENDIX I.

The Quality Control Manual will contain general instructions giving the important common features of inspection for the various production situations in the factory; e.g., there will be instructions for inspection of piece parts from the machine shop, and instructions for inspection of assemblies. At the factory of Standard Telephones & Cables Pty. Ltd., piece parts are inspected by inspectors, responsible to production, to a small size sampling plan designed by the independent Quality Control Department. A check inspection of all batches of component parts before entering a store is made by the Quality Control Department and the instruction for carrying out this latter inspection is reproduced below as a typical example of the form these instructions take.

Machine Shop Inspection Sampling of Finished Parts A.Q.L. 2.5%

1. Inspection Department shall sample check all finished piece parts ready for store or the assembly lines.
2. Inspection Department shall prepare a separate Quality Control Inspection Sampling Record card for each piece part.
3. The Quality Control Inspection Sampling Record cards will show:—
   Part No.
   Description
   All possible defects which will be checked as stated on the Inspection Layout.
   A.Q.L. required, i.e., 2.5% (Normal, Tightened, Reduced).
4. On receipt of parts Inspection Department shall inspect as follows:—
   (a) Use Engineering Standards sheet page 1009.2 for MIL-STD-105B. Normal Single Sampling Plans and select required sample size, acceptance and rejection numbers.
   e.g.: Lot size—2500
   Sample size—150
   Acceptance No.—8
   Rejection No. 9

NOTE:

Sample Size—The number of units to be selected and examined from each batch or lot.

Acceptance No.—The maximum number of defectives in the sample that will allow acceptance of the lot.

Rejection No.—The minimum number of defectives in the sample that will cause rejection of the lot.

(b) Select at *random* the required sample size MIL-STD-105B quotes: "Basic in the drawing of any sample is the requirement that the procedure used to select items from the Inspection Lot should be such that each item has an equal chance of being included in the sample.

Inspectors should avoid taking items from the same position in containers, taking all items from the top of the box, or taking items that appear to be defective.

Occasions arise when obviously defective items appear in the lot presented for inspection.

When such items appear they should be suitably identified, but not removed until after the sample has been selected.

Where items are placed in racks, trays or containers a table of Random Numbers may be used to select sample items."

(c) The required sample shall be taken and checked for all possible defects listed on the Inspection Layout or as modified on Form NC.1426 for one batch only.

NOTE:

Defect—is any one characteristic being checked.

Defective—any one *part or unit* is defective if it has one or more defects.

When a defect is found, terminate any further inspection of the part or unit. Continue inspection on the remainder of the sample for other possible defects.

(d) The following information shall be entered on the Quality Control Inspection Sampling Record cards:

Order No.
Date
Insp. Signature
Type of sampling plan used, i.e.,
Tightened (T)
Normal (N) or Reduced (R)
Batch size
Sample Size
Acceptance No.
Number of defects found
Defect characteristic number
% defective found

5. When a batch has been rejected, it shall be returned to Machine Shop for 100% inspection and rectification.
6. After Machine Shop has 100% inspected and rectified the batch it shall be returned to Machine Shop inspection for a further sampling check.
7. The Quality Control Inspection Sampling Record Card shall be sent to the Quality Control officer after each 10 entries for computation of the Process Average.
8. **Tightened Inspection** (See Engineering Standards Sheet Page 1009.4 for tables).
   Tightened inspection shall be instituted when the estimated process average is greater than the applicable upper limit shown in MIL-STD-105B Table 11-C. The Quality Control Officer will notate the Quality Control Inspection Sampling Record card as required.
9. **Normal Inspection.**
   Normal inspection sampling plans will be used initially.
   When tightened inspection has been instituted, normal inspection shall be reinstated if the estimated process average of lots under tightened inspection is equal to or less than the A.Q.L. required. The Quality Control Officer will notate the Quality Control Inspection Sampling Record card as required.
10. **Reduced Inspection** (See Engineering Standards Sheet Page 1009-3 for tables) may only be instituted provided:—
    (a) The preceding 10 lots have *not* been rejected under normal sampling inspection.
    (b) The estimated process average is less than the applicable lower limit shown in MIL-STD-105B Table 11-A.
    (c) Production is at a steady rate.
    Normal inspection must be reinstated when
    (a) A lot is rejected.
    (b) The estimated proceess average is greater than required A.Q.L.
    (c) Production becomes irregular or delayed.
11. **Audit Inspection** of parts during manufacture shall be carried out by Insection Department on any section of the Machine Shop.
12. Where a reject batch is accepted, The Engineer or his delegate must sign the Inspection Sampling Record card in column provided. These cards are kept in numerical order in the Inspection Dept.

APPENDIX II

The following extract is taken from the Quality Control Manual of Telephone & Electrical Industries, and while it takes the form of an introduction to the manual, it also serves the purpose of stating the company's quality control policy.

"1. **INTRODUCTION**

1.1 The Quality Assurance Dept. is set up by the Management with the following main objects.

1. To assure the predetermined quality level of all products in accordance with Engineering Specifications and Customer Requirements.

2. To raise warning when the trend of quality level deteriorates or when possible hazards and obstacles are seen in the contingency stage.

3. To prevent any defective work or products from being passed into stock or on to the customer.

4. To report, at regular intervals, the state and trend of the quality level of products in each stage of manufacture.

The foregoing aims can only be successfully achieved through the medium of an efficiently planned system of Quality Control, the principles of which are well founded and which are always borne in mind and carried into effect by all officers and personnel associated with production either directly or indirectly.

Of all the principles engendered in the Quality Control system, the one most outstanding in importance and worthy of enunciation in this preamble is—

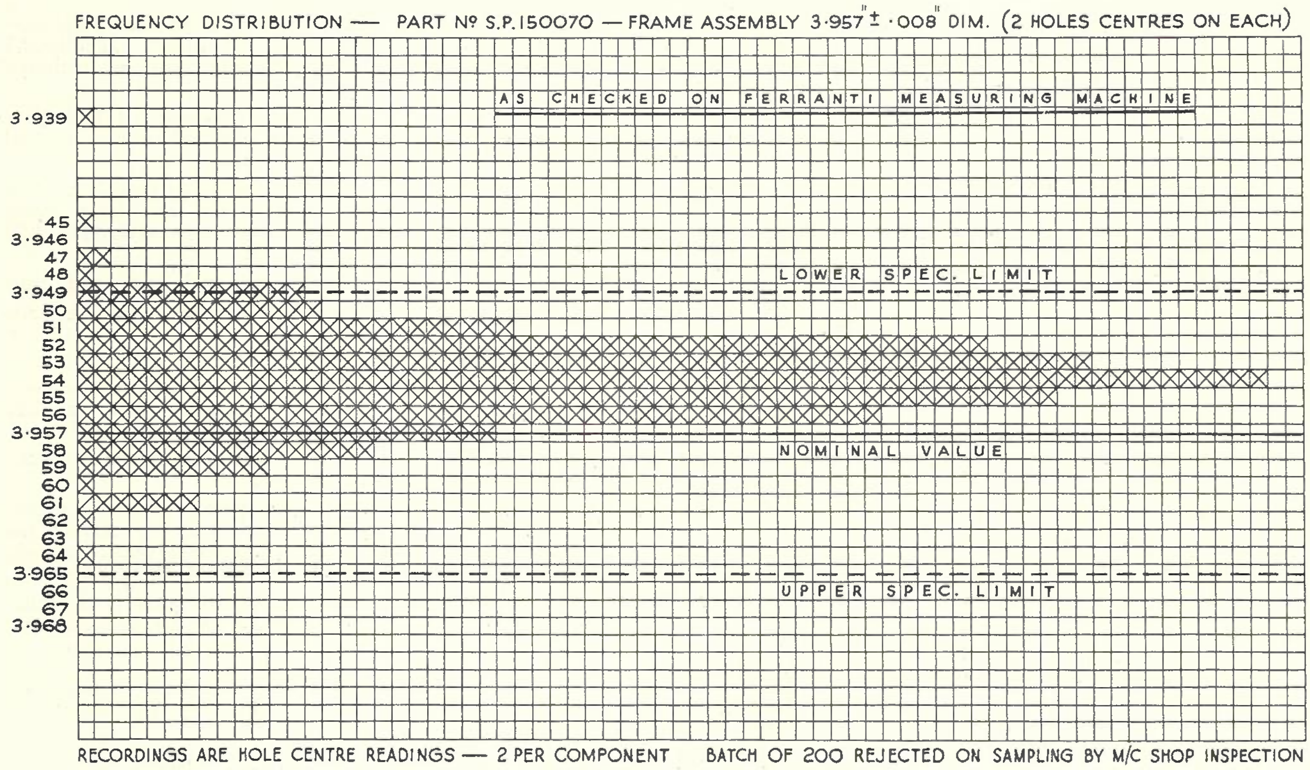

Fig. 7.—Frequency Distribution applied to solving Production Problem arising from Excessive Rejection of Components.

'That all queries relating to the interpretation of standards in any form and all requests for variation must be directed through the right channels to the point of control of the system from where such decisions can be logically and rationally given.'

1.2 Incorporate in an efficiently and well-operated system of Quality Control are several sources from which can readily accrue valuable information to assist Management in all phases to achieve greater efficiency and economy in product manufacture. Some of these factors come under the following headings.

1. The assurance of a predetermined quality level in accordance with Engineering and Customer requirement.

2. The collection and collation of data on product and process efficiency such as operational deficiencies on piece parts and tool breakdowns which are available to Methods and Production Departments for their action.

3. To provide Management with information for action on:

1. Improvement in product quality if necessary.
2. Improvement in product design.
3. Reduction in operating costs.
4. Reduction of production line bottlenecks.
5. Reduction of rectification and scrap.

1.3 Quality is not necessarily the most perfect article that can be produced, but the article which will perform its function satisfactorily, permit economic production and satisfy the customer.

This quality can only be built into production by the operator, but its establishment and maintenance is everybody's business, but because it is everybody's business it must be co-ordinated from a central source.

Therefore, while everybody should be on the lookout for more economical ways of production, the final approval of such action must be the decision of Top Management through its Quality Assurance Department."

APPENDIX III
USE OF FREQUENCY DISTRIBUTION IN PRODUCTION PROBLEMS

Case 1

Frame assemblies were being rejected by the Machine Shop Inspection Department as a result of failure of the parts to meet the 2.5% A.Q.L. on a centre to centre dimension of two holes.

Two hundred (200) such items were checked on a Ferranti Co-ordinate Measuring Machine and the results plotted in the form of a frequency distribution (Fig. 7).

Conclusions

1. Out of 400 readings (2 per item) only five were outside specification limit and hence this batch was not rejectable.

2. Because production line measurement had rejected batches consistently, the inadequacy of the measuring equipment was highlighted.

3. The fact that the machine was so set that the distribution was not centrally located in the specification range also contributed to erroneous decisions made as a result of poor measuring technique.

4. A change in the measuring technique and machine setting resulted in the production run proceeding to a satisfactory conclusion.

Case 2

A study of a broaching process was required to determine the capability of the process to produce parts within the specification limits 2.758″ $\pm \begin{matrix} .002'' \\ .004'' \end{matrix}$.

The initial setting of the machine produced components whose average was 2.7608″ and spread 2.757″ to 2.764″. With this setting it can be seen (Fig. 8a) that 38 items out of the total 52 measured were outside the top tolerance of 2.760″, the average 2.7608″ was also outside the top tolerance and 6 x standard deviation or 6σ (in the normal distribution it is expected that 99.7% of all readings will lie with $\pm$ 3 standard deviations of the average) was .0115″, which was far greater than the specification range of .006″.

Further adjustment of the machine succeeded in shifting the average to a point very close to the specification nominal or central value of 2.758 (Fig. 8b). However, it was not possible to adjust the machine to reduce the range, in terms of 6σ limits, to less than the specification range of .006″, which would mean a high proportion of batches rejected with the consequent high cost of sorting.

The action taken in this case was to widen the specification range to .010″ and adjust the subsequent operation so as to correct the small number of components with the larger dimension.

APPENDIX IV

USE OF VARIABLES (AVERAGE AND RANGE) CHART TO SET MACHINE

A machine carrying out a turning operation is to be set to a dimension of 2.001″ ± .005″.

A variables control chart for both average and range using 3 x standard deviation (3σ) control limits is set up using a sample of 4 items (Fig. 9). The average and range of the first 20 samples are shown plotted between A & B and from these results the control limits are calculated and inserted on the chart. (4).

A study of the first part of the chart between A & B indicates that—

1. The average of 4 items is in control but the lower 3σ control limit is well outside the lower specification limit.
2. The range of 4 items indicates that the process is somewhat out of control with respect to its ability to maintain the range of dimension within 3σ limits. In addition, the range of values is much greater than the specification range and hence unacceptable.

At this stage the machine was modified and samples of 4 items taken continuously (see B-C in Fig. 9) until the average and range were seen to be in control between narrow limits inside the specification limits. Control was maintained near the lower specification limit to allow for maximum movement due to tool wear which was in the direction of the upper tolerance.

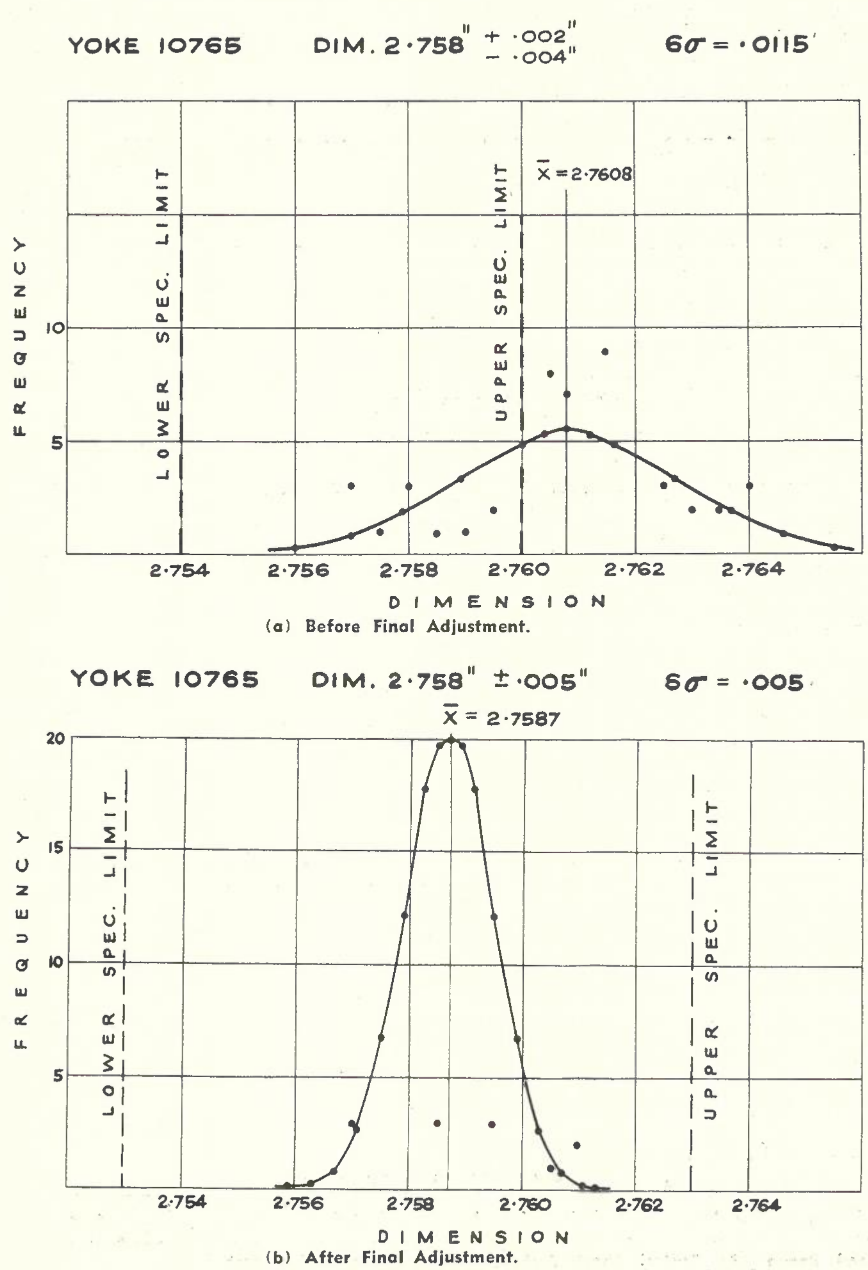

Fig. 8.—Frequency Distribution Applied to Check of Machine Set Up.

APPENDIX V

In a telephone system, the relay is the most critical component and the control of its adjustment consequently assumes considerable importance. The method of control depends upon a number of factors including the production layout. At Telephone and Electrical Industries Pty. Ltd. adjusters are fed with work from a moving conveyor (Fig. 10). This poses limitations on the method of inspection and in this case each of the two conveyors and associated adjusters is considered as a single process, and inspection, under the control of the Quality Assurance Department, is related to the process as a whole. The inspection station can be seen at the far end of the adjustment line of Fig. 10, and at this point continuous inspection of relays is made to the following scheme:

Inspection Procedure

Crossbar Relay Assembly and Adjustment

1, Crossbar relays characteristics checked at this inspection station shall be divided into Single Occurring and Recurring characteristics.

1.1 **Single Occurring Characteristics (occurring once per relay) are:—**

1.1.1 Closing of Armature.

1.1.2 Oiling.

1.1.3 Armature travel.

1.1.4 Armature pressure.

1.1.5 Armature seating.

1.1.6 Armature free stroke.

1.2 **Recurring Characteristics (occurring more than once per relay) are:—**

1.2.1 Contact pressure.

1.2.2 Fixed spring pressure.

1.2.3 Movable lower spring pressure.

1.2.4 Distance between top spring and lock plate.

1.2.5 Distance between break spring and operating comb tooth.

1.2.6 "Air" between underneath comb tooth and spring.

1.2.7 Distance between extraneous springs.

1.2.8 Contact clearance.

1.2.9 Spring lift.

1.2.10 Twinning.

1.2.11 Tightness of screws.

1.3 Special requirements characteristics, as listed in the Defect Classification Crossbar Relays Assembly (A.P.O. Engineering Instruction D1003) and Adjustment are all of recurring nature.

2. **Checking of Single Occurring Characteristics**

2.1 All single occurring characteristics in the sample shall be checked.

3. **Checking of Recurring Characteristics**

3.1 On each relay in the sample, three (3) recurring characteristics of each kind shall be checked.

3.2 Some types of relays will have only two or even one "recurring characteristic". Only this characteristic shall be checked—no additional relays will be taken from the sub-lot for the purpose of checking this particular characteristic.

3.3 Recurring characteristics on each relay in the sample shall be chosen "at random".

3.4 No more than three (3) "recurring characteristics" shall be checked on any one relay unless the Inspector is instructed otherwise by his superior.

4. **Determination of Sample Size**

4.1 Sample size shall be determined from Mil.-Std.-105 tables.

4.2 "Lot" shall be number of relays produced by entire group of operators during one day (shift).

4.3 Extract from Mil.-Std.-105 tables:

5. **Filling in of Inspection Card**

5.1 Inspection of relays consists of two distinctive checks, armature assembly and adjustment, and spring assembly and adjustment.

5.1.1 The same Inspection Report Form shall be used for noting the Daily Inspection results of armature assembly and adjustment and spring assembly and adjustment.

5.2 **Steps to be followed in filling in of the Daily Inspection Report**

5.2.1 Fill in operators' numbers, starting on the left of the Operator No. column.

5.2.2 After receiving first sub-batch of relays, enter Relay Number on top of the card.

5.2.3 Enter number of relays in sub-batch, number of samples taken and relay identification symbol in the column below Operator's No.

5.2.4 Inspect.

5.2.5 Note defects found in respective column, using Operator's No. and relay identification symbol.

5.2.6 Notification of Inspection results of subsequent sub-batches shall be done as in paragraphs 5.2.2 to 5.2.5 inclusive.

5.3 *At the end of the shift,* the Inspector shall sign and date the Daily Inspection Report in spaces provided.

5.4 *Inspector shall* note in respective columns the following:—

5.4.1 Total armatures and/or relays adjusted by all operators.

LOT	SAMPLE	ACCEPTANCE AND REJECTION NUMBERS							
		Single Occurring Char.				Recurring Char.			
		Major		Minor		Major		Minor	
		Ac.	Re.	Ac.	Re.	Ac.	Re.	Ac.	Re.
1301-3200	75	3	4	4	5	3	4	8	9
301-800	110	1	2	6	7	4	5	10	11
801-1300	150	2	3	8	9	5	6	14	15

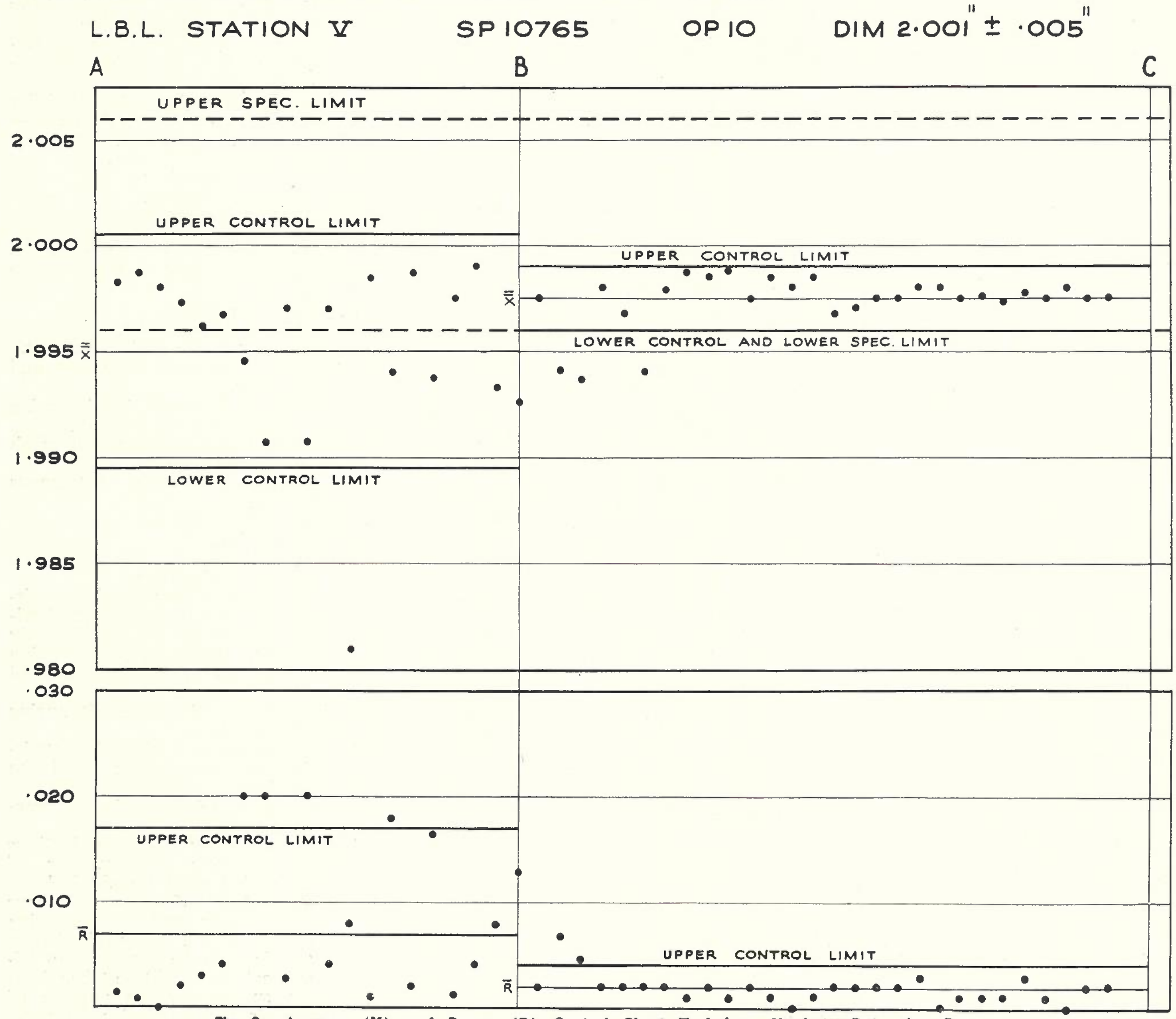

Fig. 9.—Average (X) and Range (R) Control Chart Technique Used to Determine Best Machine Set Up in the Early Stages of a long Production Run.

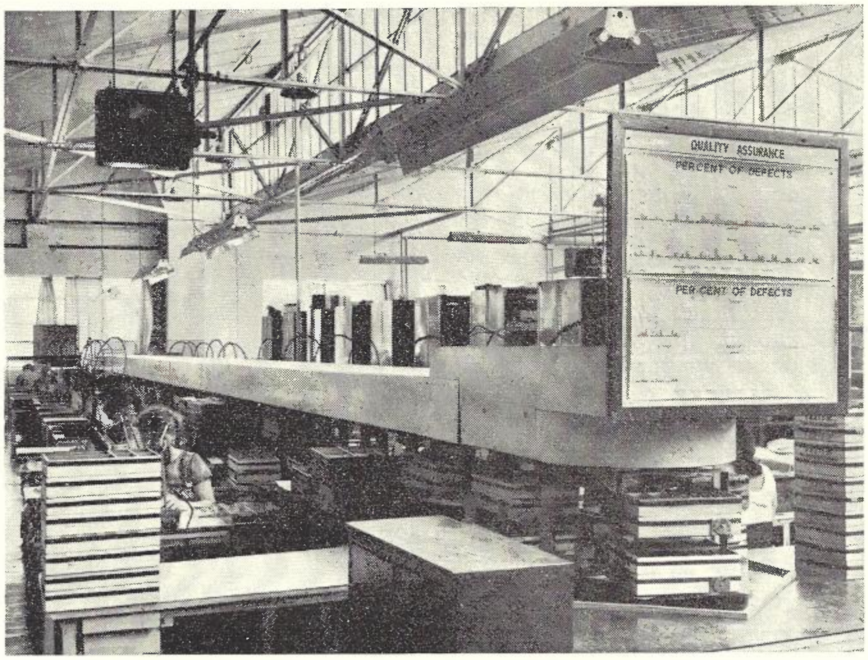

Fig. 10.—Relay Adjustment Line showing Position of Operators and Inspector (back to camera at rear) Relative to the Conveyor. The quality performance display appears at each end of the production line.

5.4.2 Total samples taken during the shift on armature and/or relay adjustment check.

6. **Rejection of sub-lots.**

6.1 If any defect is found in the sample taken from any given sub-lot, the sample and the sub-lot shall be rejected.

6.2 Inspector shall hand the sub-lot to the Production Charge Hand. (N.B. a sub-lot is a box of relays as can be seen in Fig. 10).

6.3 Charge Hand shall return the sub-lot to the Operator, who shall check and correct all defects in this particular sub-lot.

6.4 The Charge Hand shall satisfy himself that all defects in the sub-lot have been corrected before re-submitting personally the sub-lot for re-inspection.

7. **Re-inspection of rectified sub-lots.**

7.1 Inspector shall take a sample from the sub-lot and check it in the same manner as during original inspection.

7.2 If any defects are found during re-inspection, the sub-lot shall be returned to Production Charge Hand as in paragraph 6.2. The Inspector shall notify his foreman who shall take up the matter with the Production Foreman.

7.3 Results of re-inspection shall not be noted on the Daily Inspection card.

8. **Rejection of the Process.**

8.1 If the sampling inspection indicates that any one controlled characteristic shows excessive percentage of defects, the process shall be rejected.

8.2 **Procedure of Rejection.**

8.2.1 Inspection Foreman shall notify Production Supervision.

8.2.2 All adjusted relays awaiting inspection shall be returned by Production Charge Hand to the Operators, who shall make a 100% check and rectify all faulty adjustments.

8.2.3 Production Supervision shall satisfy itself that the cause of rejection of the process is removed.

8.2.4 The relays shall be submitted to Inspection, which shall check them for conformance with A.Q.L's.

The elements of control resulting in corrective action can be seen in—

Paragraph 6.1—Operators are required to correct all defects in the sub-lot inspected.

Paragraph 8—The whole process is rejected and Production Department is responsible for inspecting every adjusted relay on the production line, and determining cause for rejection before any relays can be further inspected and released to relay set assembly.

The weekly results of inspection of important adjustment characteristics in the form of process average figures are plotted on a display chart, see Figs. 10 and 11, which results in further

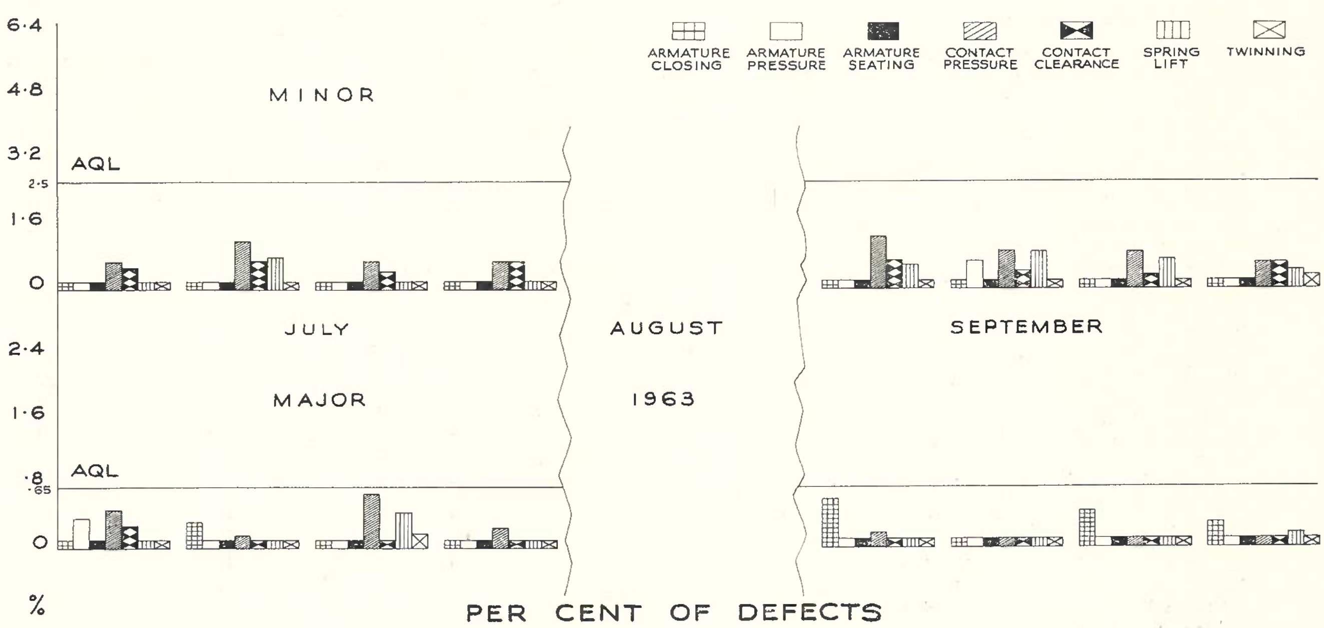

Fig. 11.—Quality Performance Display Indicating Quality of Important Relay Adjustment at Weekly Intervals.

action being taken where particular characteristics are shown to be unsatisfactory relative to the Department's specified acceptable quality levels.

APPENDIX VI.

Final Functioning Test — Departmental Inspection

Crossbar System Relay Set Types BCD, BCG, BCH

Summary of Tests

1. Visual inspection.
2. Re-test.
3. Check of relay adjustments.

Details of Test

1. This test covers the general visual examination of relay set for:—

1.1 **Condition of Plating**
Plating should be inspected for surface condition only, such as unplated areas, dirt and stains.

1.2 **Mounting of Components**
Components on relay sets looked at should be examined only for damage, looseness, etc., and not for quantity present. Pay particular attention to surface condition of surface layer resistors Type REP 200-209. It is the contractor's responsibility that the correct type and number of components have been included in the assembly. Although no statistical criterion for acceptance or rejection is provided, any cause for dissatisfaction should be referred to the contractor and/or the engineer. Generally the contractor will be expected to correct defects found.

1.3 **Wiring**
The wiring should be checked as follows:—

1.31 Tidiness.

1.32 Wires should not rest against other terminals or other sharp edges with pressure.

1.33 Insulation should end as close to the terminal as possible.

1.34 Check that insulation on wires is not damaged by heat from the soldering iron.

1.4 **Soldering**

1.41 Relay Sets should be inspected for defective points as follows:—

On each relay set looked at, 25% of terminations will be inspected for dry or unsoldered joints; if more than one such joint is found, the relay set will be referred back to the factory for 100% inspection.

Initially every relay set will be inspected as above. If 25 relay sets inspected are accepted consecutively then 25% of the relay sets will be inspected until one is rejected when all relay sets will again be inspected.

However, if the quality is so good that no relay set is rejected after 50 relay sets are inspected, 10% of the relay sets will be inspected until one is rejected when the inspection again will be increased.

1.42 Observation should also be made that the soldered end of the wire is fully covered with solder, that there are no sharp excrescences of solder or wire.

2. **Re-Testing**
Under normal conditions it will be sufficient to observe the Company Inspection's testing of relay sets, and re-testing of relay sets on which Company testing has been completed will only be made where there are very strong reasons for doing so, and then only at the discretion of the Supervising Technician. Re-testing where special setting up is required must receive Engineer's approval.

3. If it is necessary to check relays for adjustment after the set has been tested for correct functioning they will be *checked* to the L.M.E. Common Instruction for relay adjustments 1521-R.A.B., R.A.F. as follows:—

3.1 Check of free travel (distance between lifting tongue and lifting comb).

3.2 Check seating of armature on yoke.

3.3 Check lift of springs from supporting comb.

3.4 Measurement of contact pressure.

3.5 Check when the armature is pressed against the pole face and parallel with the pole face it is not leaving its bearing.

3.6 Check contact clearance.

3.7 Twinning.

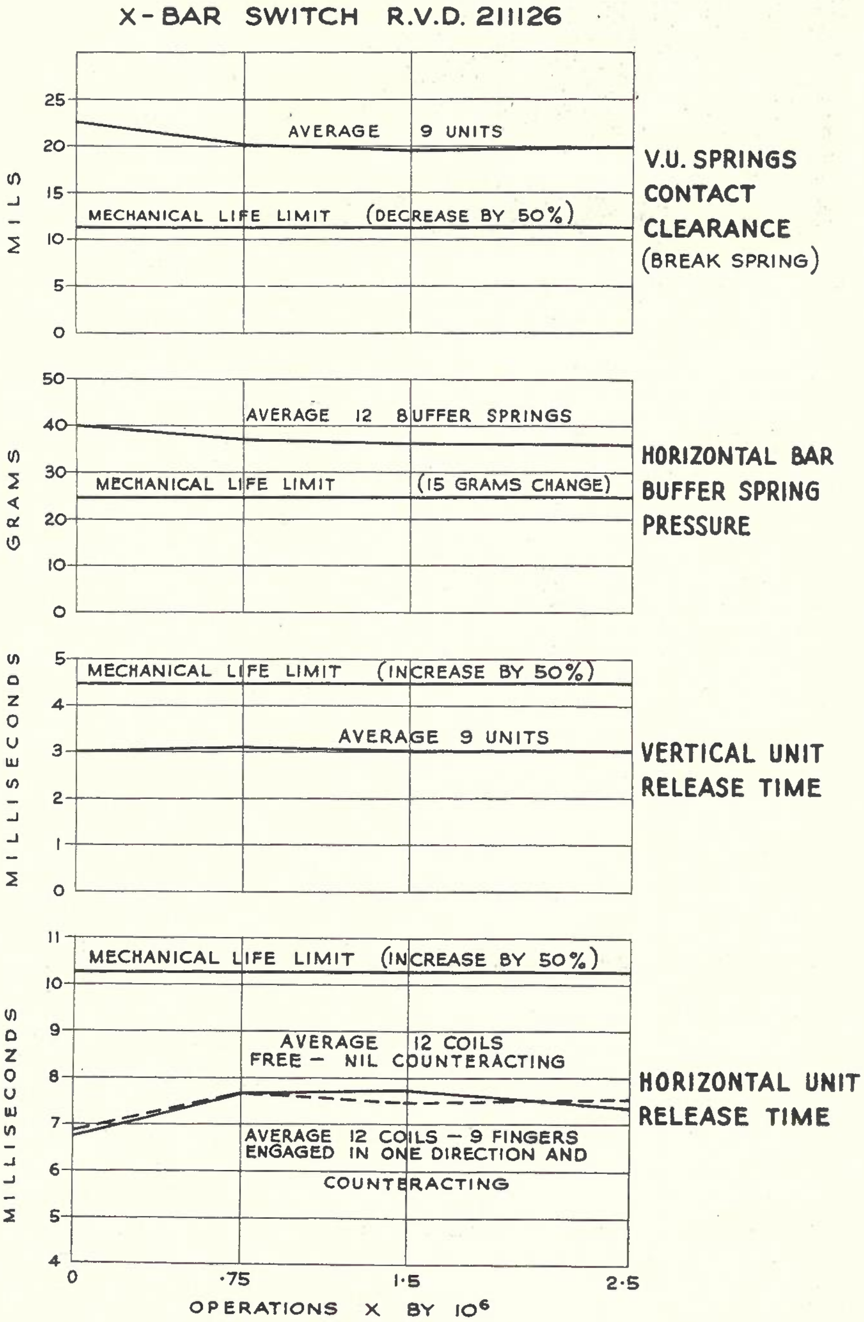

Fig. 12.—Graphical Representation of Life Test Results for Crossbar Switch.

APPENDIX VII

The following is a reproduction of the reliability test programme for Crossbar Switch Type RVD. 100-300:—

Summary of Tests

1. Visual examination.
2. Check and measurement of the adjustment of the vertical units.
3. Check and measurement of the adjustment of the horizontal bars.
4. Measurement of operating and release currents.
5. Measurement of operating and release times.
6. Measurement of resistance.
7. High voltage test.
8. Measurement of insulation resistance.
9. Climatic test.
10. Life test.

Details of Tests

1. This test covers:—
—marking in accordance with article list.
—condition of plating.
—condition pole faces (free from burns and deformation marks).
—mounting.
—riveting.
—winding.

2. The vertical units will be checked for adjustment to L.M.E. Instruction 'Assembly and Adjustment Specification for Crossbar Switch Type RVD-100-300' No. 1518—RVD-100-300Ve as follows:—

2.1 Measurement of armature travel.
2.2 Measurement of holding bar distance.
2.3 Checking operating spring pressure in vertical unit springset.
2.4 Checking of locking spring pressure.
2.5 Checking of fitting of the vertical unit armatures.
2.6 Check and measurement of the adjustment of the vertical unit springset.
2.7 Check the simultaneity in making of contacts and the position of the contact springs.
2.8 Check the remaining lifting of the springs when contact is made in the multiple.

3. The horizontal bars will be checked for adjustment as follows:—

3.1 Measure travel of horizontal bar armature.
3.2 Check the pressure of the buffer springs against the stud.
3.3 Measure the axial and radial play of the horizontal bars.
3.4 Check the position of the radial fingers.
3.5 Check and measure the adjustment of the horizontal bar springsets.

4. Measurement of operating and release current has to be made on all vertical units (relays) and horizontal bar relays.

5. Measurement of the operating times and release times has to be made on all relays with nominal voltage 48V ± 2V.

6. Measurement of resistance has to be carried out on all coils. The value must be within ± 8% of the values in the winding data provided no other tolerance is stated in that data.

7. High voltage test, 500V a.c., shall be applied for at least 0.3 secs. at normal room conditions (temperature 85°F. max. and humidity 75% R.H. max.) with maximum leakage current 1 mA, between—
—springs and between springs and bracket in horizontal bar springsets and vertical unit springsets.
—windings and between windings and core in all coils.
—all contact strips and frame.
—contact springs and between contact springs and the frame in the multiple (at least 25% taken at random).
—contact strips and contact springs in the multiple (at least 25% taken at random).

8. Measurement of insulation resistance will be done on one switch for test. Insulation resistance has to be tested as follows:—
—between contact strips and the frame. (At least 25% taken at random).
—between contact springs. (At least 5% taken at random).
—between contact springs and the frame. (At least 5% taken at random).

The insulation is measured with a direct voltage of 500V. The measurement is made in normal room conditions. The insulation resistance must be not less than 1000 M. ohms after one minute electrification.

9. The climatic test shall be made on at least two switches per year. The switch shall be kept at 104°F. ± 3°F. and 90-95% R.H. for 21 days. At the end of this period the switch shall be allowed to dry in normal room conditions for 24 hours. The switch shall then be re-tested in accordance with points 1-8.

10. Complete life test shall be made on at least six switches in a year. During the life test the switches are operated as in normal working conditions in a telephone exchange. The 'setting' of the switch is done with a speed of 5 impulses per second on the horizontal relays. Switches with 5 horizontal bars have to perform 15 x 10^6 settings per vertical unit and switches with 6 horizontal bars have to perform 2.5 x 10^6 settings per vertical unit. The functioning of the switch is controlled automatically during the life test by the test relay set. The adjustment of the switch is measured at least three times during the life test.

Item 2, 3, 4 and 5 are checked at the beginning of the life test, at the conclusion of the life test and also at intervals during the life test and for the purposes of reporting performance the variation in important characteristics is charted (Fig. 12) for circulation to manufacturer and the Department.

In Fig. 12, the end of life requirement is shown in each case as an allowable change in the characteristic, e.g., vertical unit release and time increase by 50%. In this case the test was concluded after the minimum specified time without the operational limitations having been exceeded.

RING AND SERVICE TONE EQUIPMENT FOR CROSSBAR EXCHANGES

*A. HOLDERNESS, A.M.I.E.Aust.**

INTRODUCTION

It was decided that the Postmaster-General's Department would provide the ring and tone equipment for metropolitan ARF exchanges and rural ARK exchanges by contract after calling tenders rather than by purchasing direct from the switching equipment manufacturer.

Factors influencing the decision were:

(i) The locally made equipment was equal to or better than that available from overseas.

(ii) The existing standards for ring and tone outputs would be conformed to.

(iii) The small machine ringer was considered the best proven method of providing ring and tone supplies in rural ARK exchanges.

(iv) The desirability to maintain local production of this class of equipment.

Although the ring and tone supplies for crossbar equipment are essentially the same as that for step-by-step equipment, they differ in that crossbar equipment is fed with battery behind the ring, and earth behind the tones. Step-by-step equipment is fed with earth behind the ring, and tones are wetted with a positive voltage. The standard ring and tone outputs for crossbar are listed in Table 1.

Ring and tone equipment has been developed to meet the needs for metropolitan ARF exchanges, rural ARK 51 and 52 exchanges and hybrid (combined step-by-step and crossbar equipment) exchanges.

RINGER RACK

It was decided to produce a modified design of the Department's existing standard ring and tone rack as an interim measure. This would ensure continuity of deliveries and enable the development of a new crossbar rack when design data and components were more readily available.

The interim design of rack for ARF exchanges is shown in Fig. 1 and consists of a crossbar BDD type (798 mm. width) rack on which are mounted the following components:—

(i) Two D.C. driven machines with appropriate tone windings and interrupter gear, of which one is a standby unit.

(ii) Control panel containing the protection, monitoring and supervisory gear for the machines.

(iii) Relay and miscellaneous strip containing relays, etc., for the necessary control and changeover functions.

(iv) Marker (MRG) supply panel complete with supervisory equipment.

All the supplies listed in Table 1 are provided and fed to the racks via the suite distribution boxes. The MRG supply provides an output of 17 c/s. at 94 volts and is used for the selection of markers while the APR supply of 50 c/s. at 42 volts provides a reference frequency for checking dial speed. The APR reference frequency supply transformer is mounted on the A.C. distribution board and its output fed to the ringer rack.

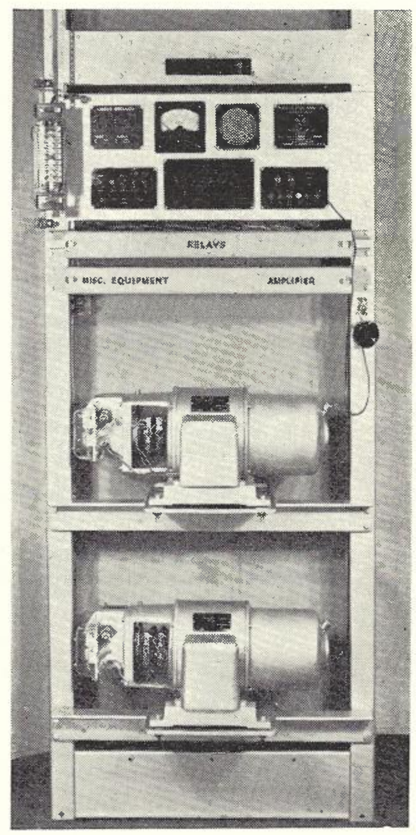

Fig. 1.—Interim Crossbar Ring and Tone Rack.

HYBRID EXCHANGES

Where an extension to a step-by-step exchange is to be made with crossbar equipment and the existing ring and tone supply rack has ample capacity, a transformer panel is added to this rack to provide the outputs for the crossbar part of the exchange. As mentioned earlier the ring and tone supplies for crossbar differ from step-by-step practice only in the way their outputs are referenced to the D.C. supply. Isolating

TABLE I: STANDARD RING AND TONE REQUIREMENTS FOR THE DEPARTMENT'S CROSSBAR EXCHANGES

Designation	Code	Frequency Cycles/sec.	Interruptions	Full Load/ no load/volts
Continuous Ring	RG	16 2/3	Nil	75/100
Interrupted Ring	RGi1, 2, 3	16 2/3	0.4 sec. Ring 0.2 sec. off 0.4 sec. Ring 2.0 sec. off	75/100
Try Again (Busy) Tone	TON 1 (SU1)	400	0.75 sec Tone 0.75 sec. off	1.5/3.0
Dial Tone	TON 2 (SU2)	33 1/3	Nil	1.5/3.0
Check Number (N.U.) Tone	TON 7	400	2.5 sec. Tone 0.5 sec. off	1.5/3.0
Ring Tone	TON 3 (SU3)	400/16 2/3	0.4 sec. Tone 0.2 sec. off 0.4 sec. Tone 2.0 sec. off	1.5/3.0
Continuous Ring Tone	TON 13	400/16 2/3	Nil	1.5/3.0
P.T. Tone	TON 17	900	0.075 sec. Tone 0.15 sec. off 0.075 sec. Tone 2.7 sec.	
Flicker Earth			0.2 sec. Earth 0.2 sec. off	
Interrupted Earth			0.75 sec. Earth 0.75 sec. off	
Marker supply	MRG	16 2/3	Nil	94/100
Reference frequency Supply	APR.	50	Nil	42/46

* Mr. Holderness is Engineer, Class 3, Telegraphs, Power and Subscribers' Equipment Section, Headquarters. See page 333.

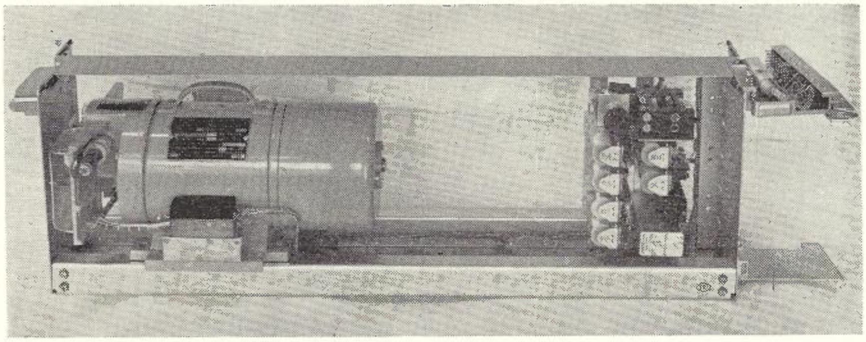

Fig. 2.—ARK 51 Ringer Relay Set.

transformers are used to separate the step-by-step and crossbar supplies. The continuous ring (RG) and each interrupted ring (RGi1, RGi2, RGi3) output are provided with transformers of ratio approximately 1 : 1. A smaller number of transformers could have been used, but this would have entailed modification to the interrupter gear and wiring of the machines; the method adopted simplifies the installation considerably.

Care in the design of the ring transformer was essential to ensure good voltage regulation from full load to no load as the over-all voltage regulation of ringing machine and transformer had to be considered.

Transformers are also provided to isolate the positive battery wetting of the step-by-step tone supplies from the crossbar supplies. Ringing tone, Try Again tone and Check Number tone are so isolated. Dial tone is not wetted and is not isolated.

The transformer panel containing the isolating transformers, marker (MRG) supply and supervisory gear mounts on the ring and tone rack immediately above the control panel.

ARK RINGER RELAY SETS

Experience has shown that the modern machine ringer is more reliable and economical than other methods available, particularly in the provision of the necessary interruptions and it was decided to use the small machine ringer as the basis for the new relay sets. Various changes were made to the machine. Its output was raised to approximately 8 watts, cam interrupters were increased to twelve, tone outputs were increased substantially and L.M.E. 20 way knife jack units were fitted to the machine for easy removal of the machine from the relay set.

Fig. 2 shows the single machine ARK 51 relay set and Fig. 3 the two machine ARK 52 relay set. Automatic changeover from the running to standby machine is provided in the latter case. It was possible to mount two machines in a BCH. type relay set although the relay set projects about one inch more than normal. The single machine ARK 51 relay set and associated alarm, monitoring and control gear requires six units of space on the rack and the ARK 52 unit seven. In the latter case the monitoring, supervisory and changeover equipment is mounted on a relay strip which takes up the additional space.

The two relay sets are interchangeable as are their ringing machines. The relay set may be jacked into a rack or a suitable wall mounted frame.

FACILITIES

The circuit for the ARK 52 relay set is shown in Fig. 4. The ARK 51 circuit differs only in that the changeover arrangements have been eliminated.

Facilities provided by the ARK 52 relay set:—

(i) Provides continuous ring, interrupted ring and tone outputs as detailed in Table 1.

(ii) Automatic changeover to the standby machine on failure of the ring output.

(iii) Starting of the machine when a call enters the exchange. Alternatively the main machine may be run continuously.

(iv) Stopping of the machine with no call to the exchange after a preset delay.

(v) Extend a major alarm if ring current is not provided when required or if its output is unduly low.

(vi) Extend a minor alarm on changeover to the standby machine.

(vii) Provision for checking the idle machine during normal service.

(viii) Remote reset of the alarm relay.

(ix) Monitoring of the ring and tone outputs.

(x) Fuse alarm on operation of supply fuses.

CIRCUIT DESCRIPTION

When a call enters the exchange, positive is applied to tag 260 (Fig. 4), relay R5 operates and connects relay R4 which holds over its own contact R4 24/23. Relay K1 is energised and the main ringing machine starts. The electrolytic capacitor in the relay R11 circuit will hold R11 operated, until the ringing current from the machine holds R11 operated.

The machine stops when positive is removed from the start lead, relay 5 releases and the thermal group T4 is heated and operates after a delay of 30 seconds. The coil of R4 is shunted and it releases. Relay K1 releases and stops the machine. The supervisory relay R11 is then held operated via one side of the recifier bridge, ringing machine armature to negative.

If the ringing current disappears relay R11 releases. Relay R11 contacts 21/22 provide positive from the switch BK1 to relay R9 which operates and holds over its own contact.

Positive is also given to the thermal group T8 which operates the contact T8 12/13, alarm relay R8 releases provided that the ringing current has disappeared for a longer period than 30 seconds. If the standby machine operates satisfactorily this, of course, does not happen. When relay R9 operates, relays R1 and R2 are energised. The standby machine starts and the load is transferred to the standby machine by the changeover contacts of relays R1 and R2. When the machine is started relay R11 operates and breaks positive from the thermal group T8. Relay R9 operates over its own contacts and can be released manually by the reset switch BK1.

If the D.C. supply fuse to the main machine fails, a changeover to the standby machine occurs, the standby machine being fed from a separate fuse. Fuse alarm relay R7 operates and raises an alarm. Provision is made for checking the idle machine during normal

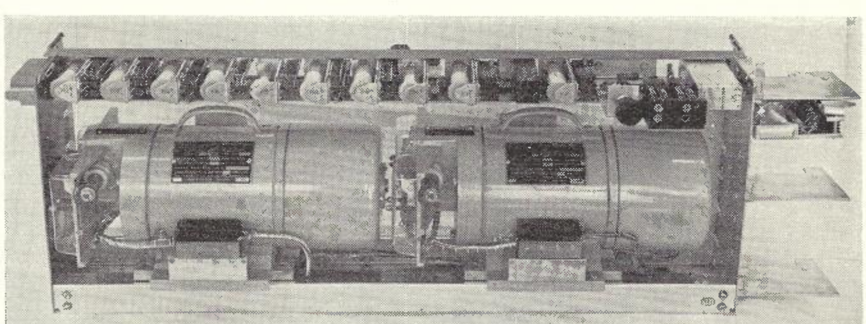

Fig. 3.—ARK 52 Ringer Relay Set (Cover removed).

service by operating the switch BK3. P.T. tone is derived from a transistorised oscillator and is energised via contacts of the start relay R4.

The relay set is supplied via three fuses, one fuse for each machine and its associated control relays and one fuse for the common control and alarm relays. Should any fuse blow, positive is extended to the fuse alarm relay R7 and a major alarm is extended.

CONCLUSION

Every effort has been made to produce ringing equipment to the standards required and it is confidently expected that the design objective of producing simple and reliable plant will be proven in practice.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the co-operation of Telephone and Electrical Industries Pty. Ltd. (the developing contractor for ARK relay sets), L M Ericsson Pty. Ltd., and McColl Electric Works Pty. Ltd., and colleagues of the P.M.G.'s Department in the development of this equipment.

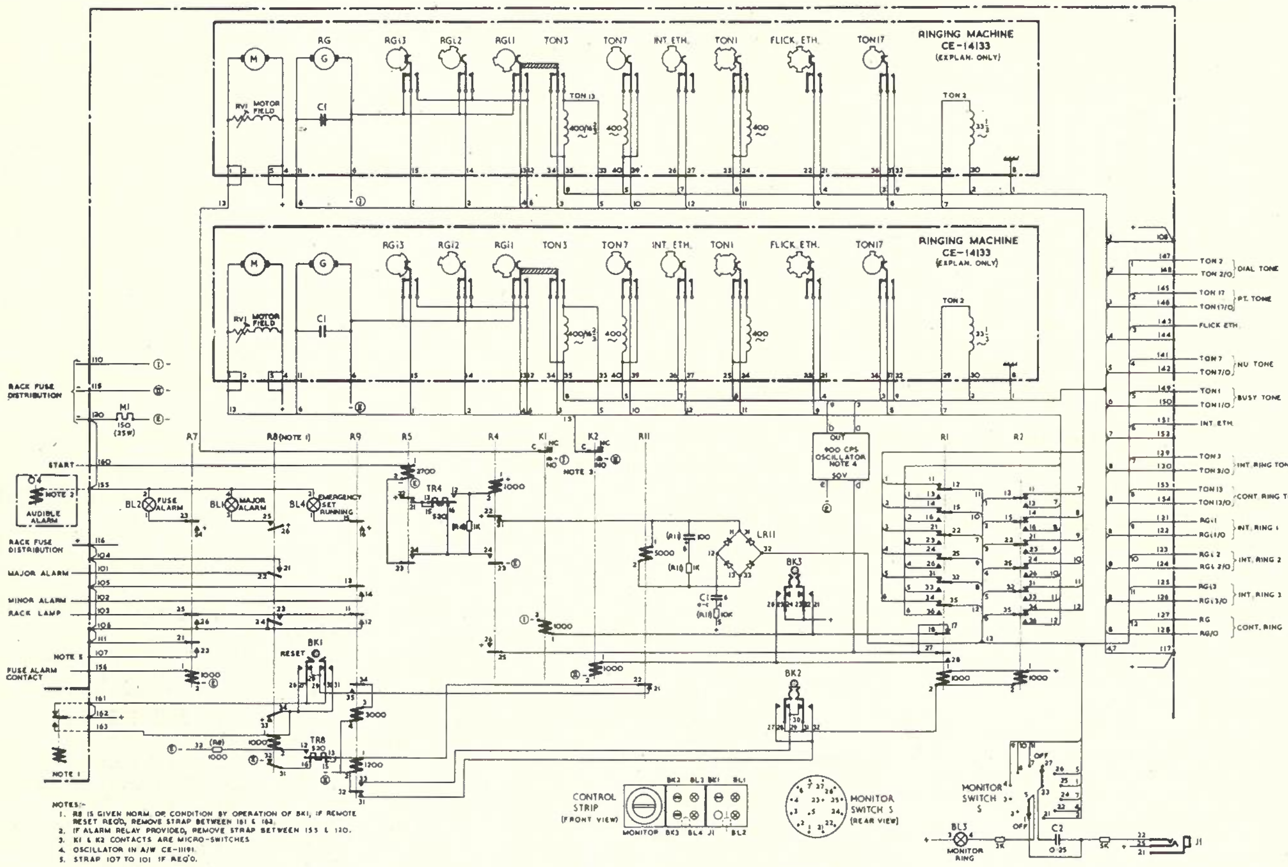

Fig. 4.—ARK 52 Ringer Relay Set Circuit.

PLUG TERMINATING AT PETERSHAM CROSSBAR EXCHANGE

S. J. MOFFAT*

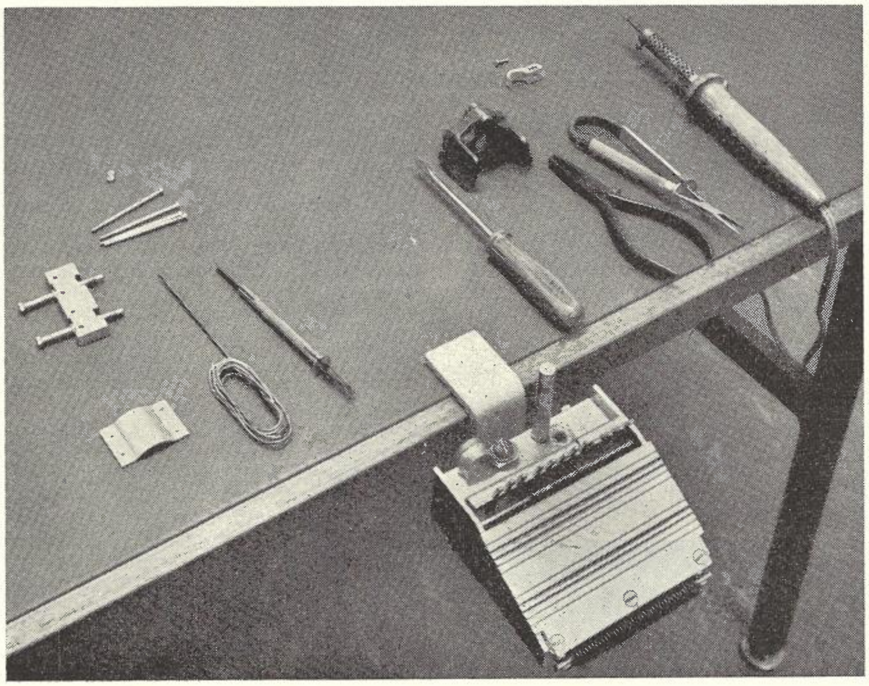

Fig. 1.—Layout of Tools and Parts.

INTRODUCTION

It was quite evident early in the Australian crossbar programme that cable terminating, particularly on knife plug units, would represent a large proportion of the total labour component. (The Petersham material contract included 2,300 20-pin knife plug units.) Consequently the Headquarters Engineering Management Services Section undertook a work study analysis of the L M Ericsson standard method which:—

(i) Classified the various operations and identified left and right-hand sequences.
(ii) Sought an optimum layout of tools and parts.
(iii) Established ideal seating and lighting conditions.
(iv) Used work simplification techniques to give an optimum utilisation of LME developed jigs and tools.
(v) Provided a basis for more efficient teaching.

Fig. 1 shows the basic layout of the working tools and parts as set down in the study. It will be readily noted that some form of container could be used to hold the various parts. It has been suggested that a semicircular tray of suitable material may be obtained for this purpose. Such a tray if fitted with a suitable clamping device would be an invaluable aid where it was necessary to terminate plugs in an elevated position such as on run-way or other situations at the top of racks. As time did not permit the making up of such a tray for the Petersham installation, separate small trays were used for the parts.

INSTRUCTION

Terminating instruction was given to all staff in accordance with the procedure set out in the Method Study Report (1) and little difficulty was experienced in acquiring the new technique. Although relatively unimportant characteristics did appear in the work procedure of various individuals under actual work conditions, strict adherence to the procedure during training did result in a very uniform standard of finished work in respect to the actual terminating.

LARGER CABLES

It was found that for the terminating of the larger cables, such as 21 x 3, 21 x 4 and 21 x 5 wire cable, it was necessary to change the procedure somewhat because of the bulk of wire to be dealt with.

The main change in method for these cables involved an auxiliary clamp used with the 120 point terminating jig. In this method the cable is first butted, then clamped into position and fanned out through the forming comb on the jig (Fig. 2).

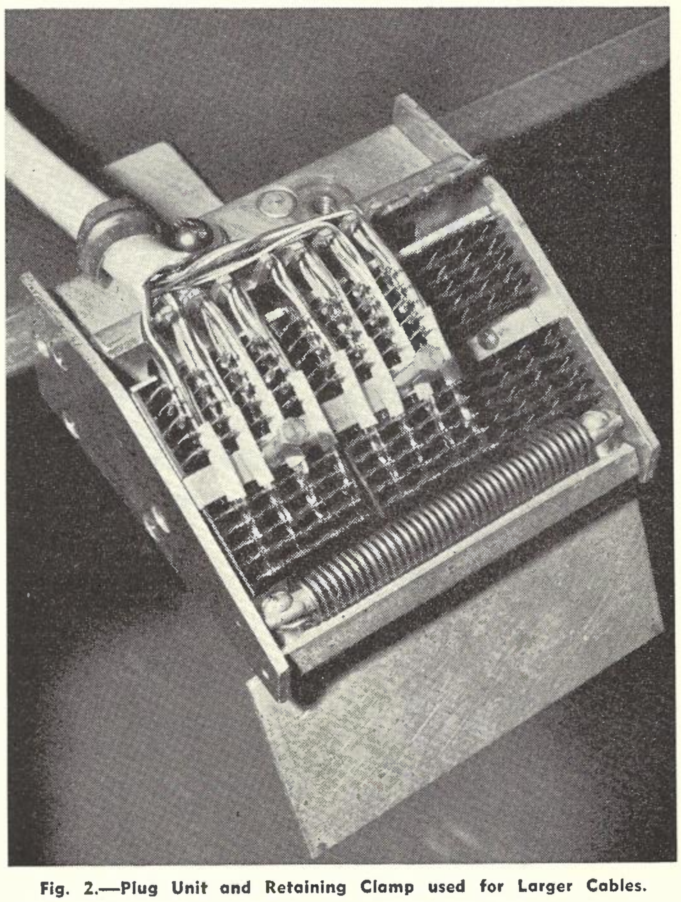

Fig. 2.—Plug Unit and Retaining Clamp used for Larger Cables.

* Mr. Moffat is Supervisory Technician, Exchange Installation, N.S.W. See page 333.

As with the 21 x 2 wire cable, care should be taken to position the lay of the cable so that the various color groups fan out without excessive twisting. After fanning out, the wires can be held in place in the comb by the use of a piece of string or plastic across the wires and the jig. When all wires have been terminated the form can then be bent and attached to the bracket by means of the saddle.

It was found that two potential fault points can be avoided during the terminating and assembling of the plugs. Firstly, by the use of plastic protective tubing covering the wires which terminate on the lower blocks. This prevents wires from being caught under the washer of the plug securing screw. During testing it was found that there were some faults of this nature on plugs assembled without protective coverings.

Secondly, with the larger cables it was found that it was possible for the weight of the cable to force the saddle to turn slightly, thus jamming wires under the saddle to frame. This can be avoided by mounting the saddle so that the open or holding end is uppermost with the plug in situ. This should be considered when positioning the forming clamp on the terminating jig.

All plug terminating, except sundry miscellaneous plugs such as suite-control, was carried out in a separate workroom adjoining the main equipment room. Fig. 3 shows a completed 80 pt. plug unit.

Particular attention was given to lighting and seating arrangements, and it was found that cables could be conveniently cut to a required premeasured length and plug-terminated before being brought to the equipment room. This, of course, greatly reduced the dust problems, etc., which are associated with the opening and rolling of cable drums in the equipment room.

B.D.H. RACK TERMINATING

To overcome the obvious difficulties involved in wiring B.D.H. racks direct from LME type wiring charts, the wiring diagram translation chart was devised showing jack, terminal, hole and length which simplified the fanning out operation. These charts were used in conjunction with the B.D.H. forming board having 16 holes per jack position and now being manufactured in Departmental Workshops.

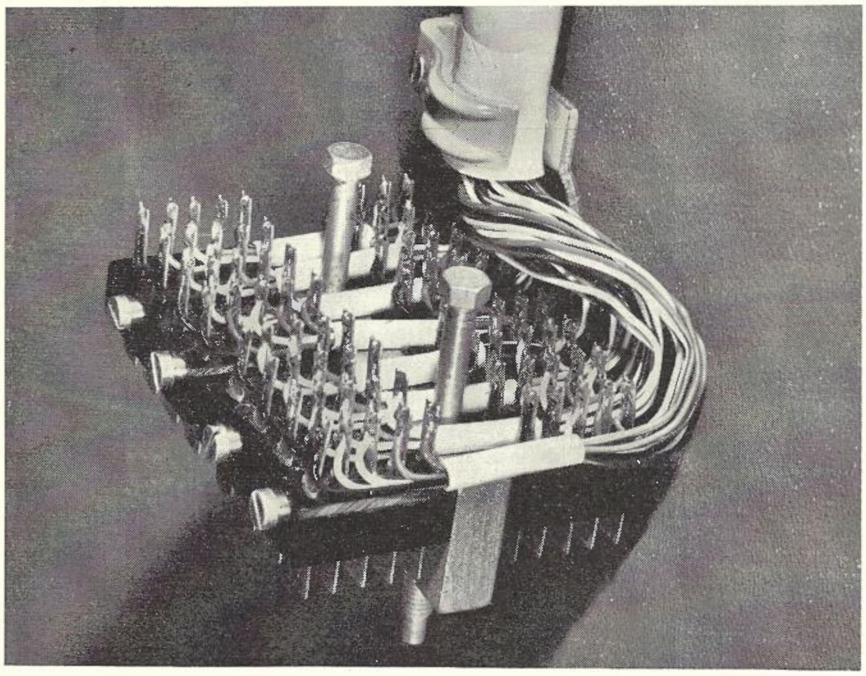

Fig. 3.—Completed 80 Pt. Plug Unit.

Actual terminating procedure was similar to that used in plug terminating except where wires had to be double banked on terminals with other wires already terminated and soldered. Some wires were difficult to keep positioned because of the excess solder on the terminal. This was overcome by reducing the excess solder on all tags prior to the terminating operation. In other cases where company wiring was already terminated it was necessary to solder each tag as the wires were terminated to prevent the wires becoming dislodged from the tag.

Terminating was carried out from the top of the rack down, to prevent wire stripping, etc., from falling into completed work.

SOLDERING

It was found that because of the cramped nature of the wiring and light structure of the terminals used, extreme care should be taken during soldering operations. Potential trouble points can be eliminated by the use of small soldering bits which lessen the risk of damaging the plastic wire insulation due to excessive heat. Best results were obtained by the use of the small 20 watt and 26 watt lightweight soldering tools. Due to the shape and relatively small bulk of the terminals, the most effective solder was the thin resin-cored type.

OBSERVATION

It was noticed that the highly repetitive nature of the work involved in terminating operations gave rise to a feeling of boredom, in addition to the element of fatigue peculiar to this type of terminating work. As a general rule, the effect was not so great on the less highly trained man as on the trained technician who was accustomed to less routine type of work. The fatigue element can be limited to some extent if proper attention is given to seating and lighting conditions.

REFERENCE

1. D. L. Elsum, "Terminating Onto Crossbar Equipment"; Method Study No. 23.

POWER CO-ORDINATION IN THE SNOWY MOUNTAINS AREA

R. J. MUIR, B.E.(Hons.) and R. A. LOCHHEAD, Dip.E.E., A.M.I.E.E., A.M.I.E.Aust.***

INTRODUCTION

The Snowy Mountains Scheme is the largest engineering works ever attempted in Australia and is one of the largest in the world. It involves the construction of seven major dams, 11 power stations, over 80 miles of large diameter tunnels, miles of aqueducts, shafts ranging up to 1,100 ft. deep and hundreds of miles of mountain roads in rugged alpine country. Its purpose is power generation and diversion of waters inland to provide irrigation. By 1970 it is anticipated that 2,555 megawatts of power will be available from the area. Fig. 1 shows the general layout of the scheme including the disposition and capacity of the generating stations. Table 1 lists for comparison some data about power generating capacity in Australia.

Because of the remoteness and poor accessibility of the working sites, good communications have been essential to the Scheme since its inception. Reliability of service is paramount and is complicated by the rugged terrain and the extremely severe climatic conditions. Within the Snowy Mountains Hydro-Electric Authority's (S.M.A.) own organisation, radio circuits are used to maintain contact throughout the area to construction sites and to vehicles; radio provides a high degree of flexibility enabling equipment to be recovered and reinstalled at new sites as required, and avoids the need for special land lines designed to withstand the severe winter condition at high altitudes. Public telephone service in the area is the responsibility of the Postmaster-General's Department. This is provided by aerial wires or cable in most cases, both for economic reasons and because radio would not cater fully for local reticulation to subscribers in exchange areas which are sometimes only separated by radial distances of up to 10 miles. Radio is used, however, for communication between some of the major exchanges in the area.

The choice of location of telephone circuits has proved difficult, especially in the mountainous regions, because of the need for adequate separation from power lines and H.V. switching stations to avoid power interference and because of the need for a route which is relatively accessible for maintenance purposes. The position is worsened by the high soil resistivity of the region which aggravates the coupling between telephone routes and adjacent power plant. Even with wide separation of telephone and power plant the induced voltages can be high as a result of the high earth resistivity when combined with the high fault current levels which exist on most of the power lines. Apart from the obstacles imposed by the geography of a mountainous area, the combined growth of telephone and power lines has increased the difficulty of keeping these lines mutually separated. At the present time the total length of power transmission lines in the Snowy is 290 miles, including 40 miles of 330 KV steel tower routes while main telephone trunk routes extend for a distance of 215 miles. This distance does not include subscribers' lines.

The technical difficulties which have to be overcome in developing a telephone network for the Snowy Mountains area and to ensure that telephone plant is properly safeguarded from power interference have necessitated a high degree of co-ordination and special consideration in the design of all telephone plant. The standards adopted are those laid down in the Directives of the International Telephone and Telegraph Consultative Committee (C.C.I.T.T.) for the protection of telecommunication lines against the effects of longitudinal voltages caused by nearby power lines. These Directives recommend that the longitudinal voltage should not exceed 430 V R.M.S. or, in the case of high security power lines, 650 V R.M.S. if hazard to personnel or undue stress on equipment is to be avoided.

Most HV power lines in Australia operating at 66 KV or higher fall in the category of high security by virtue of their high standard of electrical and mechanical construction. Further safeguards are provided by the preventive maintenance techniques adopted by most power authorities and the high speed fault clearance equipment fitted to their main transmission lines. On power lines operating below 66 KV the average fault clearance time may vary between ½ sec. to 2 sec. and lines so protected are not considered to come within the high security category.

GENERAL CO-ORDINATION ASPECTS

Co-ordination of power and telecommunication construction is required to avoid noise in telephone circuits, and to prevent creation of potentials on telephone lines which may endanger telephone plant, telephone users, or workmen in contact with telephone lines or equipment.

The noise is usually associated with the normal operation of the power lines and results from the presence of unbalances and harmonics in the power system, concurrent with the presence of unbalances in the telephone system. As power lines in the Snowy Region carry well balanced currents, and have a low harmonic content, little noise interference is experienced. On the other hand, dangerous voltages on telephone lines result from fault conditions on the power system, and are a function of the capacity of the power source and the mutual impedance between the power and telephone circuits. The mutual impedance is primarily dependent on the separation between the two circuits and on the resistivity of the earth. The value of the mutual impedance increases with increasing soil resistivity. These problems have been discussed in detail by various authors (1), (2), (3), (4), (5).

In the Snowy Mountains area most difficult conditions for power co-ordination exist because, firstly, large amounts of power are being generated at the hydro-electric power stations and distributed at extra high voltages; secondly the rugged terrain restricts

TABLE 1.—PUBLIC POWER GENERATING CAPACITY AND MAIN POWER STATIONS IN AUSTRALIA AT 30/6/62

Location of Station	Capacity of Main Stations	Total Capacity
New South Wales		2,989 megawatts
Snowy Mountains	660 megawatts	
Bunnerong	375 ,,	
Other Stations in Sydney	479 ,,	
Wangi	330 ,,	
Tallawanna	320 ,,	
Victoria		1,676 ,,
Yallourn	621 ,,	
Stations in Melbourne	408 ,,	
Queensland		767 ,,
Stations in Brisbane	518 ,,	
South Australia		559 ,,
Port Augusta	270 ,,	
Western Australia		331 ,,
Tasmania		594 ,,
Commonwealth Territories		43 ,,
Total for Commonwealth		6,959 ,,
Major Stations under Construction		
Vales Point (N.S.W.)	875 megawatts	
Munmorah (N.S.W.)	1,000 ,,	
Hazelwood (Vic.)	1,200 ,,	
Ipswich (Q'ld.)	360 ,,	
Snowy Mountains	1,900 ,,	

* Mr. Muir is Engineer Class 3, Transmission Planning, N.S.W. See page 334.
** Mr. Lochhead is Engineer Class 2, Transmission Planning, N.S.W. See Vol. 12, No. 4, page 298.

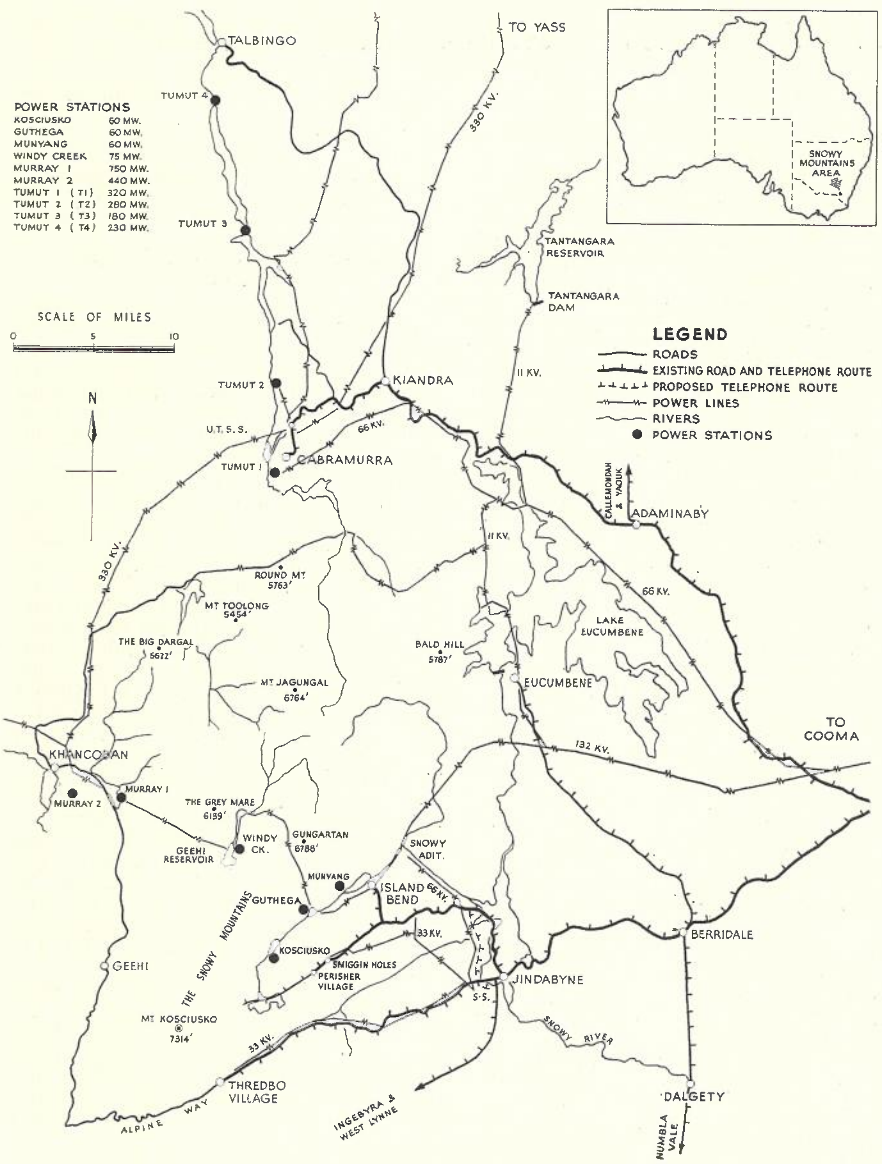

Fig. 1.—General layout of the Snowy Mountains Hydro-Electric Scheme.

the choice of practical routes, and necessitates close parallels between power and telephone lines for long distances; and thirdly the earth has been leached of its natural salts and is of very high resistivity.

At the time of writing Tumut 1 (T1), Tumut 2 (T2) and Guthega Power Stations are already commissioned and supply power to the Upper Tumut Switching station (U.T.S.S.) from where it is transmitted to New South Wales and Victoria at 330 KV. (Fig. 1). There are two 330 KV steel tower transmission lines which extend north to Yass in New South Wales and a single tower route to Dederang in Victoria and a number of 132 KV and 66 KV transmission lines feeding power within the Snowy Mountains area for consumption within the area.

The most serious danger to telephone plant in the Snowy area is due to electromagnetic coupling under power earth fault conditions which can give rise to longitudinal potentials of several thousands of volts on telephone lines. Particular cases of this, and the remedies applied, are discussed hereunder. The problem will be worsened in the coming years as the Snowy Scheme is more fully implemented to its total generating capacity.

EARTHING PROBLEMS

Earth Resistivity

The Snowy Mountains are located in an area of high soil resistivity where values in excess of 9000 meter ohms are not uncommon. Lower figures of the order of 500-2700 meter ohms have been measured in the Swampy Plains Region in certain valleys and along creek beds; these figures increase rapidly at relatively low altitudes because of the rocky and leached-out nature of the terrain. Geological faults which are common throughout the area also tend to worsen the situation. Earth resistivity figures measured at a number of localities in the Snowy Mountains area are shown in Fig. 2. For comparison, measurements carried out near Tamworth on the northern Tablelands of New South Wales showed uniform earth resistivity figures over a wide area of less than 40 meter ohms and in the Murrumbidgee irrigation area the earth resistivity varies between 10-15 meter ohms.

High earth resistivity has three manifestations from a power co-ordination aspect. It increases the extent of power interference by increasing the mutual inductance between power lines and telecommunication lines, and secondly increases the conductive coupling between earths on the power system and earths on nearby telecommunication lines. Thirdly it causes difficulty in the provision of low resistance earths for protective equipment which is required to safeguard telecommunication plant against the effects of lightning and of earth faults on the power system; either of these can cause a dangerous potential on the telephone line which must be discharged to ground via the protective apparatus and the earthing system. If the earthing system is not of a significantly low value of resistance with respect to the self impedance of the line a high potential difference will remain between the plant and the main body of the earth.

Generally, the poor conductivity of the soil in the Snowy Mountains region has made it difficult to provide low resistance earths at the majority of the power stations. Figures ranging between 0.5 and 4 ohm have been stated as typical values for power station earths by the S.M.A., whereas in other parts of the State figures as low as 0.05 ohms are common. The earth resistance of the feet of the steel towers carrying 330 KV transmission lines is known to be as high as 25 ohms in certain locations.

As examples of the problems caused by these high earth resistivities the fault current level at the busbars in the Upper Tumut Switching Station will ultimately reach 16,000 amps; hence with an earth resistance of 0.5 ohms the voltage rise of the station above the general mass of the earth during a fault would be:—

$V = IR = 16{,}000 \times 0.5 = 8000V.$

At the Jindabyne Zone Sub-station a minimum resistance of the station earth has been stated as 4.0 ohm. The fault current level at the busbars is 1000A so that during a fault this sub-station can rise 4000 V above the main body of the earth.

Ground Potentials

When a current enters or leaves the main body of the earth via an earth electrode, a potential is set up around the electrode. The potential above true earth of the electrode will be the product of the current flowing through it to earth and the resistance of the electrode.

A potential gradient will also exist round the electrode while current is passing through it which extends over a definite area around the electrode.

The formula accepted for use in determining the extent of the gradient area is:

$$V = \frac{I\rho}{2a}$$

Where V volts is potential of the earth at a distance 'a' metres from the earth electrode in soil of resistivity ρ metre ohms when a current of I ampere is flowing to earth via the electrode. This formula gives a voltage for small values of 'a' in excess of the maximum earth mat potential rise, which equals IR_e where R_e = resistance of the earth mat to earth, for the normal installations where $R_e = 0.5$ ohms. The formula therefore provides a margin of safety for distortion of the gradient due to geological irregularities, buried conductors such as water pipes, etc. For accurate application of the formula it is necessary to determine the earth resistivity at the depth of the actual main current path, whereas normal measurements, using an earth megger, give values for nearer the soil surface. An alternative approximation is that the potential drops to one half at a distance from the earth mat perimeter equal to half the diagonal. The extent of the potential gradient increases with increased soil resistivity.

Wherever possible, actual measurements of gradient distribution are made by passing a known current to earth through the station mat and measuring the potential rise of earth stakes with respect to remote earths.

Effect of Ground Potential on Communication Circuits

When a fault current flows to the neutral ground at a power station the potential of the station ground rises relative to remote earth. As far as the power system is concerned there is no particular harm in this unless the potential gradient within or near the station becomes so great as to constitute a danger to the personnel by way of potential differences in the station area.

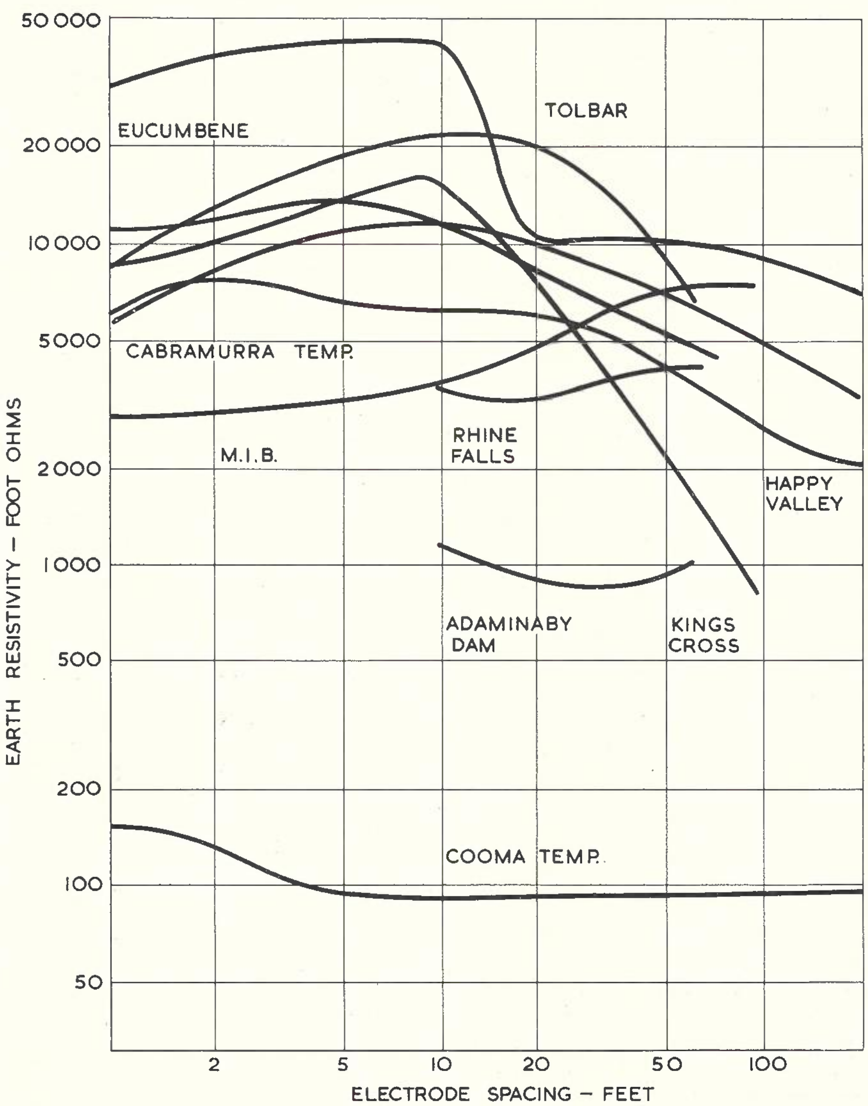

Fig. 2.—Earth resistivity figures measured at a number of localities in the Snowy Mountains.

For telephone plant in the vicinity, however, the rise in ground potentials can create hazards, which must be considered under separate categories as follows:—

(a) Cables passing through the gradient area.
(b) Aerial routes passing through the gradient area.
(c) Telecommunication earths, located within the gradient area, and used for protection of circuits through arrestors.
(d) Lead-ins to services within the power installation area.

A typical case illustrating most of the principles involved is that of the Khancoban area where an existing telephone aerial route will be inundated by waters of the proposed Khancoban Pondage, and must be replaced. The most suitable route for construction and maintenance for the replacement plant is along the proposed new road, but this will run, in part, along the boundary fence of the Murray Switching Station, for which the ultimate maximum fault current is calculated to be 25,000 amps, and the earth resistance of the station earthing system, 0.5 ohms. This could result in a potential rise of 12,500 volts at the switching station, with a widespread gradient such that, at a distance of 2,000 feet, the earth would be 900 volts above true earth potential.

If metal sheathed cable were laid through this gradient area, the sheath would assume the potential of the earth through which it passed, whilst the conductors remained at approximately true earth potential due to connection to earth at the Khancoban Telephone Exchange. When the earth potential rise exceeded the breakdown voltage of the cable, i.e., 2 KV, failure would occur. Alternatively a plastic cable, with plastic of sufficient thickness to withstand the potential rise, could be used. In any case, however, a jointer working on the cable in the gradient area, unless adequately insulated from earth, would experience the full potential rise if a power fault occurred while he was touching a conductor. Adequate insulation of the man from earth would be extremely difficult to achieve in practice. If the dangerous potentials were not as widespread as in this case, joints in the gradient area could be avoided in the initial construction, but the possibility cannot be overlooked of a fault requiring subsequent attention and installation of joints in the gradient area. Considering all possibilities, the only completely safe solution is to avoid underground construction in such areas.

Similarily, if aerial construction is used, a wet pole or wet ladder will provide a conducting path to earth, and the same hazards exist, particularly when running new wire. If lightning arrestors are fitted to lines, and connected to earth within the gradient area of the switching station, a rise in earth potential above the striking voltage of the arrestor due to a power fault will connect the high potential to the line, creating a hazard throughout its length.

It is obvious, then, that telephone routes should be selected to avoid, by the greatest distances possible, any power installations capable of passing heavy fault currents to ground, particularly in high earth resistivity areas. In the case of Khancoban, these considerations have dictated selection of a route remote from the road, and, therefore, more difficult to maintain.

PROTECTION OF TELEPHONE CIRCUITS ENTERING POWER INSTALLATIONS

General

Where telephone lines are required within the power installation area, construction must be provided in the potential gradient area, and special precautions taken. Underground cable is generally chosen for the lead in, although aerial construction would have some advantage in reducing potential stress between conductors and sheath under earth potential rise conditions. Underground construction provides some degree of shielding against electrostatic and electromagnetic induction from high tension lines and permits greater flexibility in power route layout. Irrespective of the protection method adopted, a dangerous potential can exist between conductors and earth at some locations along the route as Fig. 3 illustrates and, because of this, it is necessary to use plastic insulated cable which has substantially greater dieletric strength than paper insulated cable.

The alternative conditions applying for lines into power installations are:—

(a) For normal telephone services, the cable conductors and telephone equipment have no local connection to earth, and so tend to remain at remote earth potential. When a power fault occurs, the whole environment is raised to a high potential, creating a hazard to the telephone user and equipment.

(b) For lines connected to local earth at the power installation, such as where local earthed battery supply is provided, the full potential rise is transferred through the line to its termination at an exchange or external extension location.

Use of Gas Arrestors

Protection for condition (a) can be provided by ensuring that the telephone equipment is only accessible in a situation well insulated from local earth potentials, or by equalising the potentials between line and local earth. The latter can be most simply done by fitting gas arrestors between each wire and the earth mat (Fig. 3a). These will fire at approximately 250 V and short circuit the line to earth for the duration of the potential rise. This converts the situation to that of condition (b), wherein the potential rise is transmitted along the line. Provided that gas arrestors are fitted at a remote point, and connected to a low resistance earth, the potential at the remote end will be held within safe limits—being the voltage drop across the resistance of the earth electrode only. The potential on the cable pair will, of course, increase towards the power installation, and may endanger jointers or cable insulation. For this reason the gas arrestor method of protection is used only where the potential rise is comparatively small (to about 1200 V). It should be noted that, with arrestors operated, the full potential would never be found between the conductors and earth, at any particular point, because the earth itself has risen in potential.

In conjunction with arrestors, fuses are fitted at the power installation to disconnect the line if excess current flows. The subscriber must, therefore, agree that interruption to the service under these circumstances is tolerable. Dummy fuses must be fitted at the remote end (exchange, etc.) as fuse operation there would disconnect the arrestors, leaving the full earth mat potential rise on the line.

Alternative Protection

Where this simple protection is not applicable, two other remedial measures are possible:

(a) Complete isolation from earth using isolating transformers.

(b) Injection of an equalising potential using a neutralising transformer.

The cost of a neutralising transformer is £580 for a typical installation handling 25 pairs. In cases where D.C. signalling is not imperative the use of an isolating transformer may be practicable and its use does away with the necessity for a remote earth point.

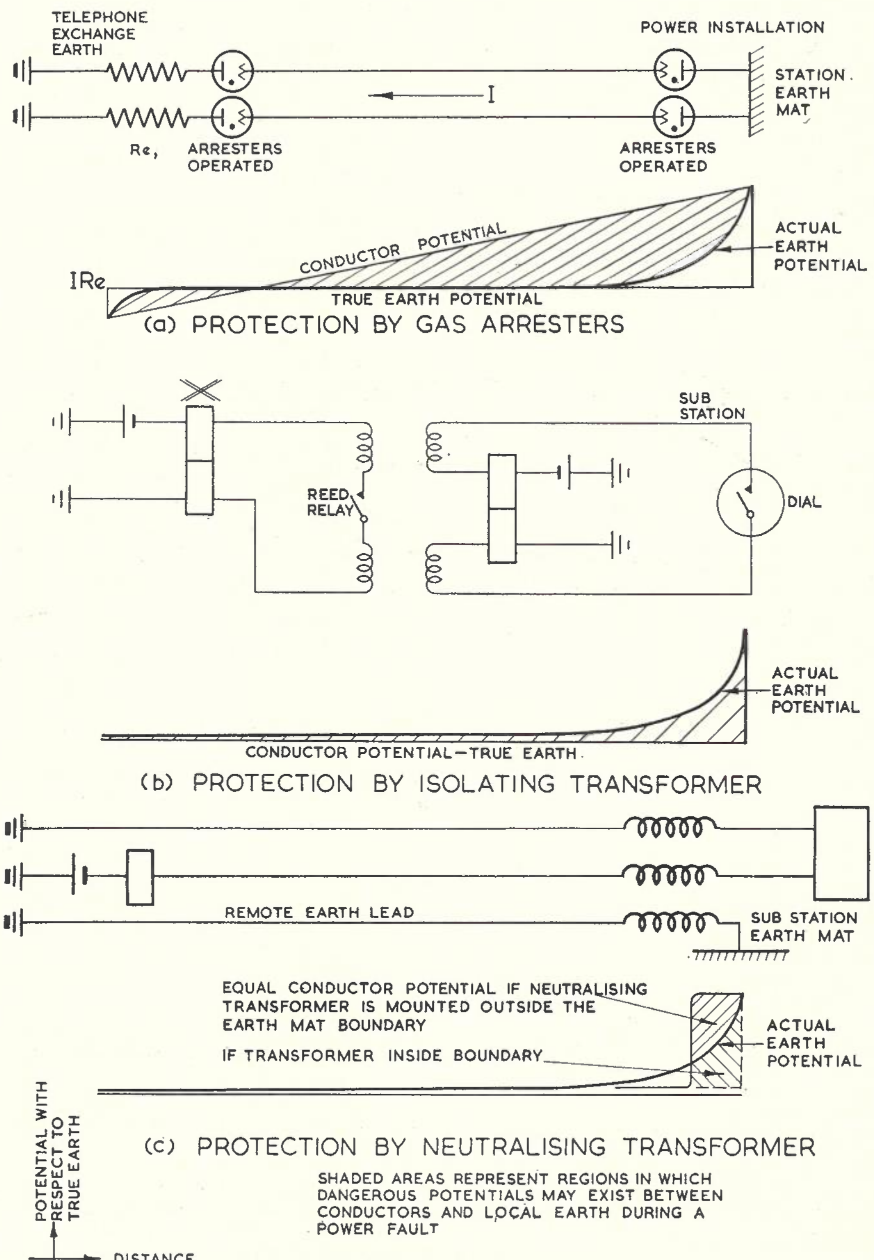

Fig. 3.—Protection methods for Telephone Circuits entering Power Installation.

Isolating Transformers. (Fig 3b): A 2-winding 1.1 ratio transformer, in conjunction with a suitably insulated cable sheath, enables the telephone pairs to be completely isolated from the station ground and the effects of the potential gradient existing in the vicinity during a fault. The transformer can be suitably designed to pass magneto ring current but elaborate and expensive provision is required for D.C. Loop Signalling which will be usual in the Snowy Mountains area.

A typical isolating transformer for one line costs approximately £12 for installation but the provision of VF signalling equipment adds a further £370 per channel to the over-all cost. An alternative method for loop signalling is by the use of bridging relays which repeat the telephone dialling impulses around the transformer. No costs are available for installations of this type; they are used extensively in Europe, but are not yet available in Australia.

Neutralising Transformers. (Fig. 3c): In its simplest form a neutralising transformer consists of three windings, a primary and two secondaries designed with a 1.1 ratio. The primary winding is connected between the station ground and a remote earth point which should be located well outside the gradient area so that the full potential rise of the station ground appears across the primary. The secondary windings are connected in series with each incoming conductor for the purpose of producing a voltage equal to the potential rise of the station ground. Equal voltages will thus be added to conductors without altering the voltage difference between the conductors. Hence the neutralising transformer has no effect on the signal to be transmitted. Since the windings inserted in the speech circuits produce voltages equal to the potential rise of the station, all communication circuits will be at the potential of the station ground at the station end and at zero potential at the remote or exchange end. Hence no potential difference will exist between the communication circuits and ground at either terminal. There will be a potential difference, however, between the conductors and ground in the vicinity of the neutralising transformer. The reason is that at the neutralising transformer the potential of the conductors changes abruptly from station potential to zero whereas the potential of the ground around the station decays gradually.

To provide the most effective protection with a neutralising transformer, careful installation procedures are necessary. They require a remote earth outside the gradient area; no coupling should exist between the station side and the exchange side of the transformer; and sheath currents should be kept to a minimum since the neutralising transformer will not neutralise the resultant voltage which will appear between the conductor and the sheath from this source.

In suitable cases a neutralising effect might be achieved by enclosing the cable in a highly conductive iron pipe over sufficient length to extend outside the gradient area. This method is to be tried during some proposed field tests to determine the actual degree of coupling and the effect of saturation of the magnetic material.

Safety Aspects: Comparing neutralising and isolating transformers from the safety aspect, a hazard will exist with a neutralising transformer only if its windings or the remote earth connection becomes open circuit or otherwise faulty. The maintenance of the remote earth connection is vital in this regard since this constitutes portion of the primary winding across which the station earth potential is developed. With isolating transformers there is no significant risk so long as the cable remains insulated from the station ground potential.

Maintenance on either isolating or neutralising transformers installed at power station premises should only be carried out by personnel trained in high voltage techniques, since, during a power fault, dangerous voltages could appear on either type of transformer.

INTERFERENCE ON KIANDRA CABRAMURRA ROUTE

Between Kiandra and Cabramurra a specially constructed telephone trunk route has been erected and is connected into the trunk route to Cooma, at the Kiandra cable pole. For nearly its full distance of approximately ten miles it is exposed to a 330 KV power transmission line which feeds power from T.1 Power Station to Yass via the Upper Tumut Switching Station (U.T.S.S.). The average separation between the telephone route and the power line is 3,350 feet or 0.625 miles. Near the U.T.S.S. the separation decreased to less than 1,000 feet for a short distance. The fault current levels on this power line can exceed 7,950 amps. The average value of earth resistivity near the U.T.S.S. has been measured at approximately 1,000 meter ohms. Near Cabramurra figures of 1,500 meter ohms have been recorded. Along the telephone route between Cabramurra and Kiandra the earth resistivity averages 1,000 meter ohms. Electrode spacings of 100 feet were used for these tests.

From this data the estimated induced voltage on the telephone route during a phase to ground fault on the power line close to Kiandra can be calculated from the formula given in Reference 6.

$$E = CILK$$

where

E = the voltage induced in a telecomunication conductor during a power fault (volts).

C = the coupling factor (ohms/mile).

I = the earth fault current on the power line (amperes).

L = the length of the exposure or section of it (miles).

K = the shielding factor, normally 1 for open wire lines.

whence

$E = 0.13 \times 7{,}950 \times 10 \times 1 = 10{,}300$ volts.

The surest way to reduce this induction to a safe figure would be to arrange for greater separation between the power lines and the telephone route. But in this area, due to high soil resistivity and great concentration of fault current, an average separation of greater than three miles would be required for this particular exposure to limit the induced voltage to 650 volts. The rugged nature of the terrain and the need for feeding a common location made it impracticable to arrange for such a separation and both the power and telephone routes are confined to relatively close paths.

A normal method of protection against voltages liable to be induced in these circumstances is to fit gas arrestors or arrestor relays between each line wire and earth at such intervals that, when the arrestors operated, the line voltage is reduced to within the limit of 650 volts to earth (for high security power lines)). This, however, necessitates that the earth connection for the arrestors should be of low resistance so that the voltage drop does not exceed 650 volts when current passed to earth. Soil resistivity in the area is, however, so high that the required earth resistances could not be obtained. Special methods were, therefore, required to protect the telephone plant from the excessively high induced voltages which could occur.

The methods devised were:—

(a) To reduce the induced voltage in the telephone line by decreasing the area enclosed by the line wires and the earth return path, a copper earth wire was ploughed into the ground under the route.

(b) To provide a barrier to prevent the transfer of induced voltages into the trunk system beyond Kiandra, the point where the exposure ceases, by fitting drainage coils capable of carrying 200 amps for two seconds between the line wires and earth at the Kiandra cable pole.

(c) To sectionalise the route by means of series condensers and drainage coils, effectively shunting the lines to earth at 50 cycles per second. This increased the transmission loss at voice frequency and prevented its use for physical circuits but the attenuation at carrier frequencies remained suitable for the use of 1 + 4 and 12 channel systems.

When the telephone route was equipped, field tests were carried out to test the efficiency of the arrangement. A simulated fault current of approximately 140 amps was fed over the power line into the ground at the U.T.S.S. from the 330 KV sub-station at Yass to provide a disturbing electromagnetic field over about three-quarters of the length of exposure.

The telephone line was grounded at Kiandra and voltage-to-earth measurements were carried out at the end of each isolating section. As induced voltage is directly proportional to disturbing current, these figures, divided by the current, gave the effective mutual impedance in volts per ampere which was then projected for the ultimate

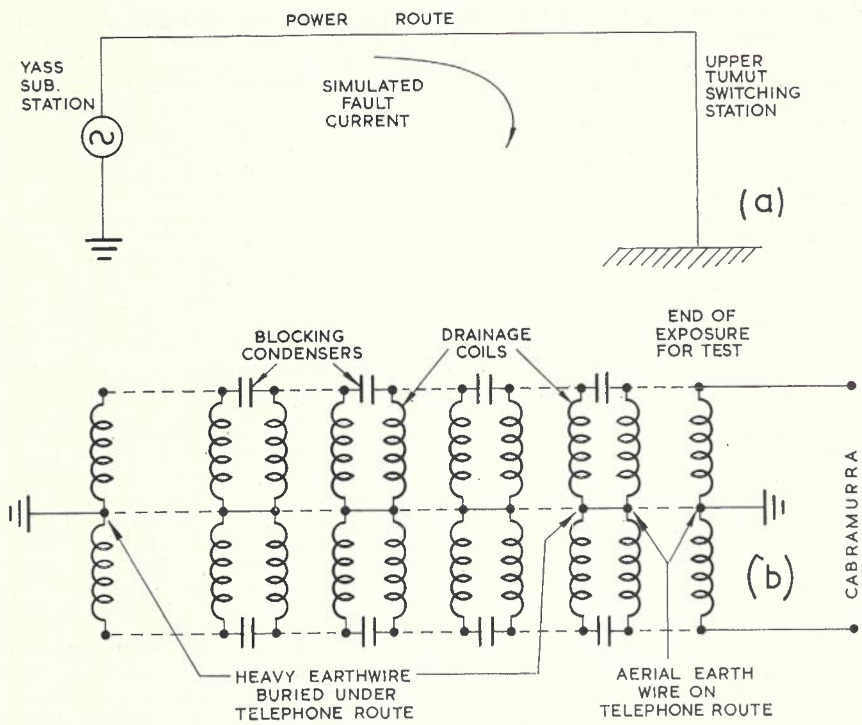

Fig. 4.—Kiandra—Cabramurra Low Frequency Induction Test.

fault current levels. These figures showed that:

(a) The voltage induced for an 8,000 amp fault near Kiandra would be approximately 1,100 volts between the telephone wires and ground.

(b) At Cabramurra, which is outside the exposure, a voltage rise of the order of 3,000 volts could be expected.

These facts emerged:

(a) While the induced voltage on the telephone line had been substantially reduced by isolation and drainage, the difficulty of obtaining sufficient good earths along the route meant that the danger had not been completely removed.

(b) At Cabramurra, which is 1¾ miles past the end of the exposure, the voltage reading was considerably higher than at the end of the exposure, which is inconsistent with the fact that no additional voltage could have been induced into the line.

Complete explanation of the highly complex factors influencing the potential distribution is not possible without further extensive tests but a possible theory, illustrating some of the complexity of power co-ordination problems in general, is given below. In simple form, neglecting the variations in separation between power and telephone routes, the circuit conditions during the tests were as shown in Fig. 4. Voltage measurements using high impedance meters were made between telephone line wire and earth at Cabramurra and at each section end. The component and resultant voltages in the ground, and on the telephone earth and line wires are shown in Fig. 5, and an explanation for the higher measured voltage at Cabramurra follows:—

The factors influencing the voltages measured are: —

(a) The voltage induced into the line wire.

(b) The voltage induced into the earth wire, which would be essentially equal to (a).

(c) The earth potential rise due to the passage of fault current through the switching station earth mat. This is important because the test point at the end of the exposure was close to the switching station.

Voltages (a) and (b) would be approximately 90° out of phase with (c) Because of the high resistivity, the earth wire was at appreciably different potential from that of the earth adjacent even in the buried section. Its actual potential with respect to remote earth is the resultant of its induced voltage (curve A of Fig. 5), the earth potential rise (curve D) and the voltage drop across its earth leakage. The resultant is shown as curve E, which changes slope where the aerial earth wire joins the underground section, due to differing earth leakage.

The graph of induced line voltage, curve A, is shown as a straight line to the end of the exposure, with slope equal to a mutual impedance which assumes uniform separation between the two routes and uniform earth resistivity along the route. The effect of the drainage coils is also neglected. Curve C shows the resultant line potential after allowing for the shielding effect of the earth wire. Outside the exposure the graph is horizontal, as no further induction takes place. This means that the line potential, with respect to remote earth, remains constant. The measured potential, however, was 60 volts at Cabramurra and only 2 volts at the end of the exposure with a fault current level of 140A on the power line because:—

(a) Near the switching station the earth was raised in potential by the passage of fault current. The earth point to which the measurement was made was closer to the earth point of the earth wire on the telephone route so that the voltage induced in the earth wire was further superimposed leaving only a small difference in potential between local earth and the line wire.

(b) The earth at Cabramurra being 1¾ miles out on the gradient, was closer to true earth potential.

This explanation is intended mainly to illustrate the complexity of power co-ordination situations, where conductive and inductive effects invariably exist together, and to emphasise the fact that the most important potential difference between line wires and local earth can occur outside the exposure, or in fact,

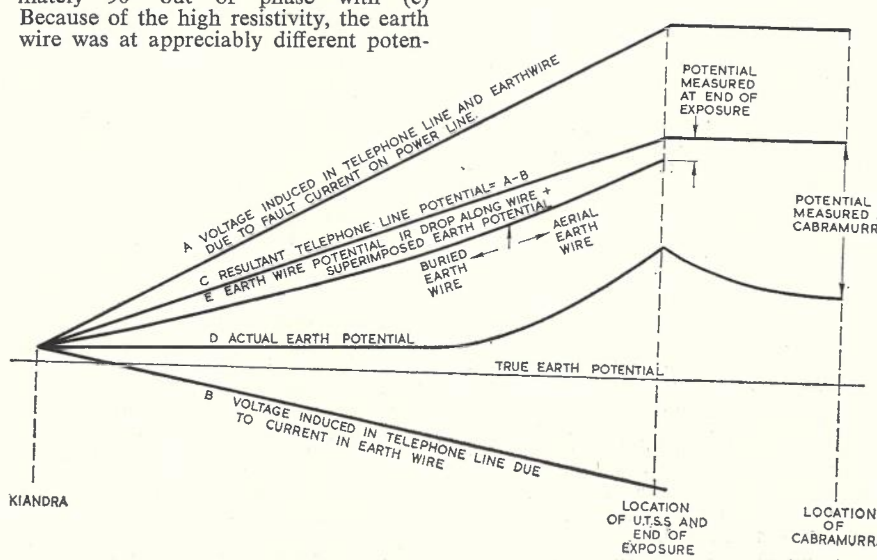

Fig. 5.—Kiandra—Cabramurra Induction Tests. Component Potentials.

at any point within the exposure, depending upon the location of the power fault. This point is of particular importance in designing protection, so that arrestors are so located as to obviate the possibility of big differences in potential between lines of differing lengths along the same pole route.

The validity of the theory outlined above still remains to be confirmed by further field tests as the case has been oversimplified by neglecting the varying separation, varying earth resistivity, the drainage effect of the shunt coils, and, in addition, the actual phase relationships between the voltage components on both line and earth wires.

Pending further tests the line will be split into completely isolated sections by isolating transformers. Thus the line will "float" with respect to earth and no potential difference can exist.

EXPOSURE TO PROPOSED 66 KV POWER LINE—SNOWY ADIT TO JINDABYNE

For a distance of 5.3 miles and proceeding in a northerly direction from Jindabyne, the Island Bend-Jindabyne trunk route is exposed to a newly constructed 66 KV power line connected between the Snowy Adit and Jindabyne. Over this portion of the route it is estimated that a voltage of 1,650 volts to ground will appear on the telephone plant should a phase to ground fault occur on the power line at Jandibyne.

Assuming gas arrestors were fitted on each end of each wire and connected to earths of 5 ohms each, the magnitude of the current circulating in the telephone lines during a fault after operation of the arrestors is given by—

$$I_{ab} = \frac{E_{ab}}{Z_{ab} + R_{ea} + R_{eb}} \text{ amps}$$

where E_{ab} = the induced longitudinal voltage between points A and B.

Z_{ab} = the parallel impedance of all telephone conductors in the exposed portion

$= \sqrt{R^2 + (W^L)^2}$

w^L = Inductive reactance of conductors

R = resistance of all wires in parallel.

R_{ea} = the electrode resistance at point A

R_{eb} = the electrode resistance at point B

The equivalent circuit is shown in Fig. 6.

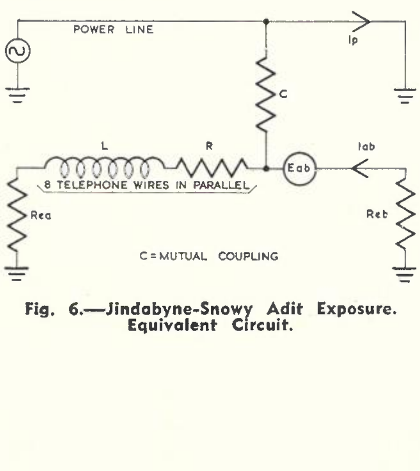

Fig. 6.—Jindabyne-Snowy Adit Exposure. Equivalent Circuit.

For more than four conductors on a route it is a sufficient approximation to take account of the inductive reactance as being 1 ohm/mile. In this particular case eight 237 lb. cadmium copper wires are involved with a resistance of 4.5 ohms/mile each.

$$Z_{ab} = 5.3 \sqrt{1^2 + \left(\frac{4.5}{8}\right)^2} = 6.07 \text{ ohms}$$

R_{ea} = 5 ohms

R_{eb} = 5 ohms

then, from the formula above:

$$I_{ab} = \frac{1650}{6.07 + 10} \text{ amps}$$

$$= \frac{1650}{16.07}$$

$$= 103 \text{ amps}$$

This current will divide between the eight wires on the exposed section of the route so that the current per wire will be 13 amps, this current value determining the type of arrestor required.

The residual voltage at A after the protection has operated is given by—

$$E_a = I_{ab} \times R_{ea}$$

$$= 103 \times 5$$

$$= 515 \text{ volts}$$

Similarly for point B residual voltage will be 515 volts. Both voltages are in excess of the allowable limit of 430 volts.

With this method of protection, using gas arrestors, three alternatives remain to reduce the residual voltage:—

(i) Improvement to the earth connections so that their voltage drops are reduced.

(ii) Fitting of additional protectors at intermediate points along the route.

(iii) Provision of shielding by a parallel earth wire in addition to the arrestors.

Neither of the first two courses offer a straightforward solution for a short exposure to high fault current, as in this case.

The first because the combined impedance of the lines (6 ohms) is comparable with the resistance of the earth connection (assumed 5 ohms) a decrease in earth resistance to say 4 ohms at each end results in an increase in circulating current from 103 to 117 amps. Across the 4 ohms earth resistance this gives a line potential of 468 volts. The cost of improvement below 4 ohms would be prohibitive, so the desired reduction in induced potential cannot be achieved by this means.

It might be thought that fitting an additional set of gas arrestors at the mid-point of the route, by halving the exposure length, would halve the residual voltage on the lines. This, however is not the case. In fact, if the separation is uniform and the earth resistivity constant throughout the exposure (as is approximately the situation on this route) an arrestor at the mid-point would contribute nothing whatsoever to the protection when the power fault is beyond the exposure.

Fig. 7 shows the induced potential, the voltage drop along the lines and the resultant potential on the lines after the operation of the arrestors at each end for such a uniform exposure. It will be seen that at the mid-point, the resultant potential after the operation of the arrestors is nil, therefore, an arrestor at this point will not operate, and even if it could be made to operate no current would flow to earth.

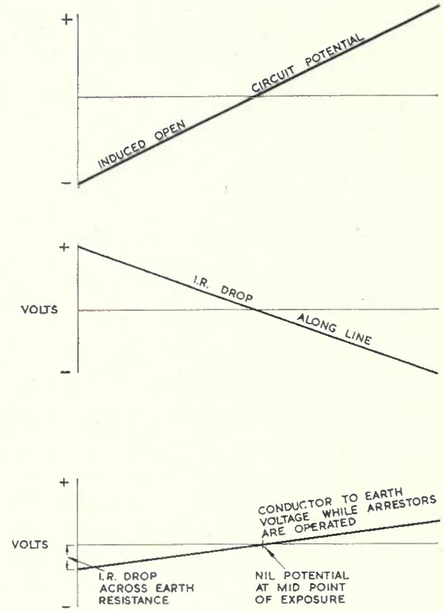

Fig. 7.—Line Potentials—Arrestors at Each End.

If arrestors are fitted at the one third points or 1/6th points along the route, the situation will be approximately as shown in Fig. 8. The potentials induced into the three sections of the line will be equal ($E_{ab} = E_{bc} = E_{cd}$) and the line impedances will be equal ($Z_{ab} = Z_{bc} = Z_{cd}$).

The current I_a through the earth connection R_b from E_a will be opposed by I_b, reducing the drainage effect of this connection. By solving simultaneously the Ohms Law equations for the three sections—

$$E_{ab} = I_{ab}(R_A + R_B + Z_{ab}) - I_{bc} R_B$$

$$E_{bc} = I_{bc}(R_B + R_c + Z_{bc}) - I_{ab}R_B - I_{cd}R_c$$

$$E_{cd} = I_{cd}(R_c + R_D + Z_{cd}) - I_{bc} R_c$$

it will be found that the current at the two ends is reduced by only about 3½% and the residual voltage by the same amount, leaving it still about 497 volts.

Use of Insulated Aerial Earth Wire on Telephone Routes

If a heavy copper conductor is erected close to the telephone wires and permanently connected to ground at each end, it will carry a substantial current when power induction occurs. This current will create its own electromagnetic field, and induce a voltage in the line wires in opposition to the direct induction from the power fault. The wire must be insulated throughout its length as there may be appreciable differences in potential between it and the line wires (for example, the potential drop across the gas arrestors in the line wires, differing voltage drops across their respective earth connections, etc.).

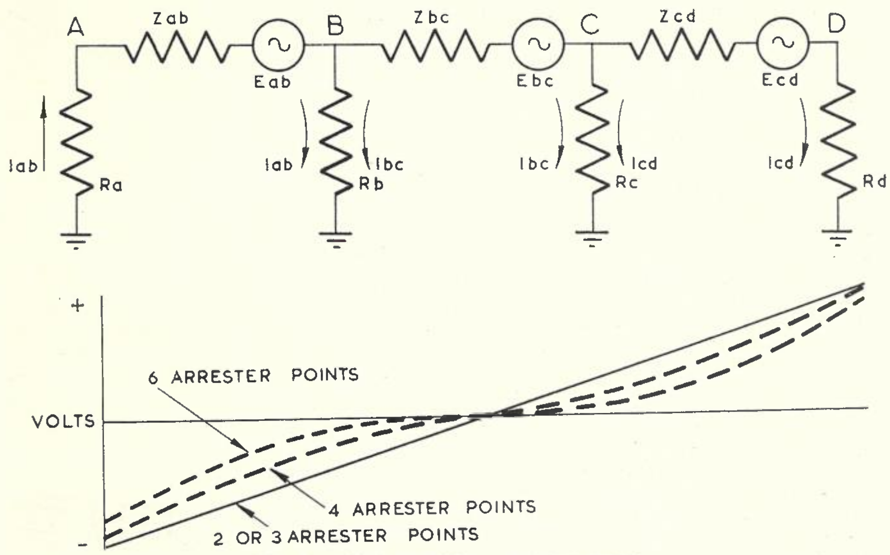

Fig. 8.—Effect of Multiple Arrestor Points.

Assuming that in addition to the provision of gas arrestors an insulated copper wire was run on the same poles but 2½ feet mean distance from the line wires and connected to separate 5 ohms earths at each end, the resultant potentials are calculated below:—

Resistance of earth wire $R_{ew} = 4.4$ ohms/mile

$= 23.3$ ohms for 5.3 miles.

$\therefore$ Loop resistance $= R_{ew} +$ Rearths $= 23.3 + 2 \times 5 = 33.3$ ohms

$E = 1{,}650$ volts

$\therefore I = \dfrac{1650}{33.3} = 50$ amps

Coupling factor between earth wire and line wires at 2.5 feet spacing $C = 0.85$

$\therefore$ Opposing voltage induced in the line wires $= C\ I\ L\ K = 0.85 \times 50 \times 5.3 \times 1 = 226$ volts.

$\therefore$ The resultant open circuit voltage on a line wire, before operation of the arrestors, will be 1650—226 volts = 1424 volts. This means that the aerial earth wire has achieved shielding to the extent of 13.7%.

This same percentage reduction will apply to the circulating current and the residual voltage after protector operation, which will now be 87 amps and 444 volts respectively.

As 444 volts is still above the limit it would be necessary to reduce the resistance of the earth wire by the use of 300 lb./mile wire. The earth wire must, of course, be connected to earths at each end which are separate from the gas arrestor earths, otherwise the earth wire current would add to the IR drop across the earth connection increasing the potential of the line wire.

It should be noted that this overhead earth wire may only be applied in particular circumstances due to the following factors:—

(a) An earth wire on a pole route will vary the line characteristics with respect to earth, and may produce third circuit effects for carrier working.

(b) If the protection earth system is within the potential gradient area of the power earth system, part of the power fault current will flow through the telephone earth wire and line wires, increasing the IR drop across the earth connection at the far end thus increasing the line potential.

These two factors must be studied in each case and if their consequence is serious the only remaining solution is to isolate the line using two winding transformers designed to withstand the expected potentials. Since such transformers would interrupt the D.C. loop, V.F. signalling or bridging relays with remote batteries must be fitted as required.

Some shielding can be achieved by the provision of earth wires on the power routes. Earth wires are fairly common on E.H.T. lines for lightning protection, but they are usually of steel for mechanical strength. Their impedance is therefore too high to provide worthwhile shielding.

For aerial earth wires of low impedance, copper or aluminium conductors of greater cross sectional would be required. The increased sag liability under ice loading would require greater tower height and/or shorter spans, adding greatly to the cost of power routes. The shielding effect of such earth wires is also limited by the minimum spacing from the phase wires that can be provided.

ACTUAL PROTECTION ON JINDABYNE-ISLAND BEND TRUNK ROUTE

From the foregoing it will be seen that complete protection of this and other routes exposed to high power fault currents can be complicated and expensive. In this particular case the route will be inundated by flooding of the Jindabyne Dam, and must therefore be removed. For this reason no action other than fitting of gas arrestors at the two ends will be taken pending removal. The new construction would normally have been provided along the proposed road deviation, but this is even closer to the power route and adequate protection against induced voltages would be impossible.

It is, therefore, proposed to use underground cable laid across country with the greatest possible separation. Armoured cable will be used to take advantage of its additional shielding effect, but gas arrestors between each wire and earth at each end will still be necessary to achieve a satisfactory reduction in induced voltage.

TYPES OF ARRESTORS

Ericsson Gas Arrestors, Type NGC 3133, are normally used for protection against induced voltages. These arrestors can carry a current of up to 18 amps for periods up to one minute. Where the circulating current per line is likely to exceed 18 amps, arrestor relays are fitted in the earth lead. The relay contacts shunt the gas arrestors during passage of current.

INCIDENCE AND DURATION OF POWER FAULTS

Most power faults capable of producing heavy earth currents are due to line breakage, pole breakage by collision, etc., and flashover across insulators, particularly from lightning strikes. In the Snowy area an additional hazard is climatic severity and a number of faults has been due to excessive sag of line and earth wires, coupled, in some cases, with snow build-up on the ground.

Protective equipment on the E.H.T. lines is designed to disconnect a faulted phase wire within six cycles (about ⅛ second), testing again for six cycles after ½ second delay before finally disconnecting all three phases.

The statistical probability of any person being in a dangerous situation on a telephone line when the hazardous voltage occurs is therefore low, but nevertheless cannot be overlooked and adequate protection is essential to safeguard both staff and telephone equipment.

CONCLUSION

The necessity of good protective earths in the Snowy region is vital to safeguard telephone plant and staff. The difficulty in obtaining earths of low resistance makes special protective devices necessary in this region. The high earth resistance also reduces the shielding effect of cable sheaths, in certain areas to an insignificant level. Cases have been examined which show that the residual voltage is still excessive after protection has been provided and shielding taken into account. In these cases greater separation or electrical isolation from earth is the only solution. Near switching stations and power stations, conductive coupling has shown itself to be just as great a hazard as closely coupled inductive exposures.

Investigations are being made with a view to providing low earth resistance by the use of a chemical substance known as Sanick-Gel. This is claimed to effectively increase the diameter of an electrode in contact with the soil and thereby lower its resistance. Unlike the soluble salts which have been used for this purpose Sanick-Gel forms a jelly-like substance in the ground. Where soluble salts would leach out, the jelly is reputed to remain indefinitely. Results of these tests are not yet available but if successful this would greatly simplify the protection against power induction in high resistivity areas.

The likelihood of a maximum fault to ground must be considered in the light of the fact that power line construction is mainly of high security design. Furthermore most contacts will occur through some finite earth resistance which will restrict the flow of current through the circuit and reduce the severity of induction on telephone plant. To date the protection provided for telephone lines in this area has proved adequate but consideration must be given to the future when the Snowy Scheme is operating at its full capacity so that each new aerial or cable installation must be carefully investigated against all aspects of power interference.

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Mr. T. SKELTON

The Board of Editors, on behalf of the Society, congratulates Mr. T. Skelton on his appointment as Director, Posts and Telegraphs, New South Wales.

Mr. Skelton commenced duty in the Department as a Junior Mechanic-in-Training in 1922, and had wide experience in senior technical positions in telephone, long line equipment and Radio Broadcasting before entering the Department's Research Laboratories in Melbourne in 1935 as an Engineer in the design of studio equipment for the National Broadcasting Service. From 1940 to 1942 he was in charge of Radar production at the Research Laboratories and was loaned to the Ministry of Munitions shortly after the Radio and Signals Directorate was formed in 1942. During that year Mr. Skelton visited the United States of America as representative of the Directorate, to assist in the procurement of materials and components for Australian Radar production.

In 1943 he transferred as Chief of the Radio and Signals Section of the Australian War and Supplies Procurement Office. In 1944 he was appointed Australian Government Representative on an Australian Radio mission which visited the United States and the United Kingdom. After returning to the Australian Post Office at Headquarters, Melbourne, in 1947, Mr. Skelton was closely associated with the co-ordination of the Post Office rehabilitation programme and became head of the Engineering Materials Section at Headquarters. In 1958 he was promoted as Controller of Stores and Contracts Branch at Headquarters and remained in this position until September, 1963, when he took up duty in Sydney as Assistant-Director, in charge of Post Office engineering activities in New South Wales.

Mr. E. C. LATHER

Congratulations are extended to Mr. E. C. Lather on his appointment as Director, Posts and Telegraphs, Queensland.

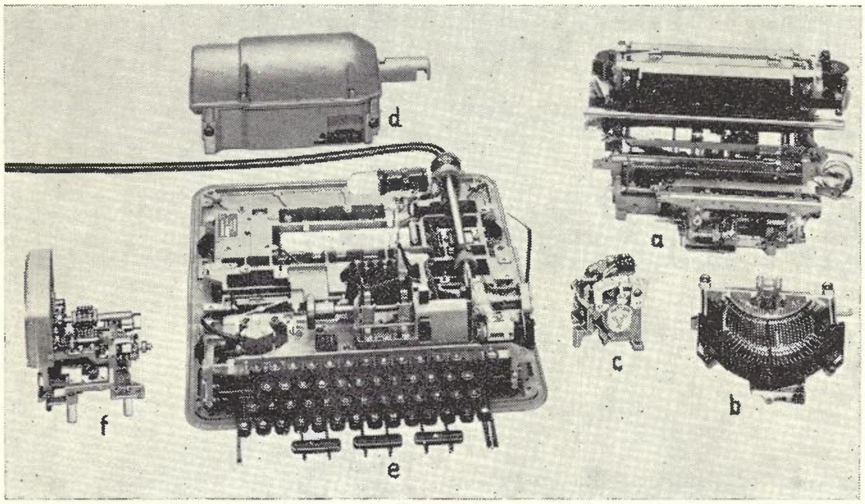
Mr. Lather commenced in the Department as a Junior Assistant Engineer in 1917 and later qualified as an Engineer.

From 1944 to 1953 Mr. Lather was in charge of all telephone equipment installation and maintenance in the State of Queensland. In 1956 he was appointed Superintending Engineer, Metropolitan and Engineering Services Branch. He continued in that appointment until 1963 when he was appointed Assistant Director, Engineering. During his service in the Equipment Sections Mr. Lather was associated with many "firsts" in Queensland, the principal one being the installation of the first automatic exchange in Queensland in 1935 and the installation of the first 2,000 type equipment in Queensland which was installed at Rockhampton. During the war he directed much departmental effort in providing the telephone network for the Australian and American armies in Queensland.

Mr. Lather was a foundation member of the Queensland Telecommunication Society which is now the Queensland Branch of the Australian Telecommunication Society. He has held several positions including President in the Professional Officers' Association He is a Rotarian and a Fellow of the Institute of Public Administration.

QUALITY CONTROL DURING ASSEMBLY OF TELEPRINTER MODEL 100

G. FEIGE*



a—Printer base.
b—Type basket.
c—Receiver.
d—Motor.
e—Mounting frame with keyboard.
f—Transmitter.

Fig. 1.—Constructional Units of Teleprinter 100.

Editorial Note: This article, an English translation of a paper in FIENWERKTECHNIK, refers to manufacture of Model 100 Teleprinters by Siemens and Halske A/g. in Berlin. Current supplies of these machines are being assembled and partially manufactured by Siemens Halske, Siemens Schuckert (A/sia) Pty. Ltd., in their factory at Richmond, Victoria, where similar quality control methods have been adopted.

INTRODUCTION

Efforts are made in all engineering fields to organise production so that, in spite of the present manpower shortage, a high standard of quality is ensured by improving jigs, fixtures, and similar production aids. In communication engineering too, the trend is now towards assembly line production wherever possible. Quantity production makes this method all the more attractive. To give a typical example of high-precision engineering in the communications field, this article describes the measures taken by the Siemens & Halske Company to assure uniform quality of their Teleprinter 100.

Early in 1958, the Berlin factory started to turn out its first machines. Preparatory work included planning, efficient inspection and quality control. The task was greatly facilitated by the design features of the machine whose major assemblies consist of self-contained constructional units. Assembling them into complete machines is only a matter of minutes. It is worth mentioning that the number of adjustments required for individual units is also very small.

This provided the working basis in the large and important field of mechanical and electrical tests along the production line, to be carried out in addition to accurate checks of all components during parts manufacture. Additional test benches and continuous test facilities have been developed specifically for the assembly of machines. To this must be added test benches for electrical acceptance tests of the completely assembled machines.

This paper is intended to afford the reader a glimpse of the testing procedures applied during manufacture of constructional units and final assembly of the standard version of the machine.

CONSTRUCTIONAL UNITS OF TELEPRINTER MODEL 100

The self-contained constructional units (Fig. 1), each being fully functional and interchangeable, are the following:

(i) printer base
(ii) type basket
(iii) motor
(iv) transmitter
(v) mounting frame with keyboard
(vi) receiver.

These units are manufactured and tested on separate production lines.

Mounting frame and individual units are provided with aligning pins and stop faces. Proper engagement of individual members of adjacent units, as well as accurate meshing gears, are, therefore, built-in features.

Thanks to the functional layout of the teleprinter described above, each constructional unit can be treated as a self-contained test piece.

The finished parts are routed through intermediate stores to the workplaces where they are assembled into constructional units (Fig. 2). Electrical and mechanical test benches have been provided at important points between individual workplaces to permit possible faults to be detected and remedied at a very early stage. The fully assembled machines are subjected to an acceptance test in a test room which is not associated with the production line. Skilled technicians from this test room are

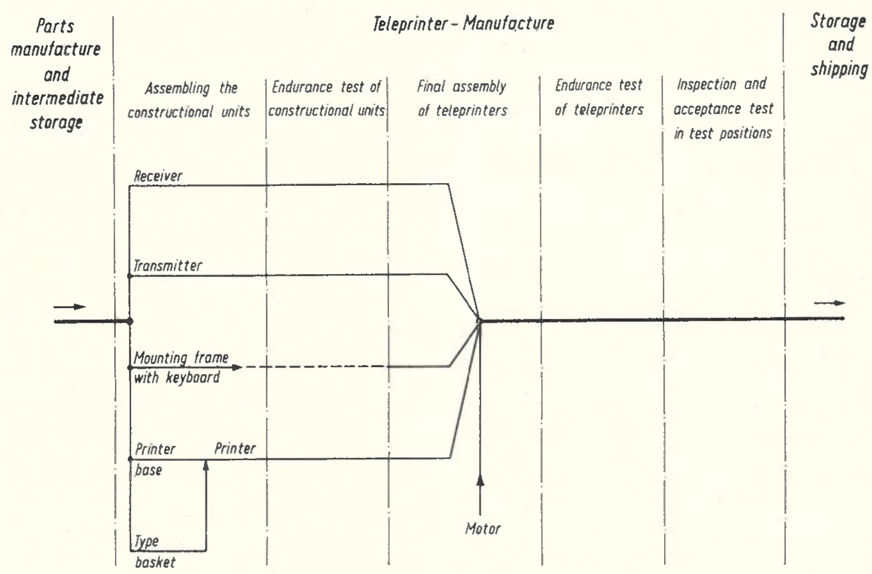


Fig. 2.—Schematic Representation of Teleprinter 100 Assembly on Separate Assembly Lines for Different Constructional Units.

*Mr. G. Feige is a member of the Siemens & Halske Staff in Berlin. See page 334.

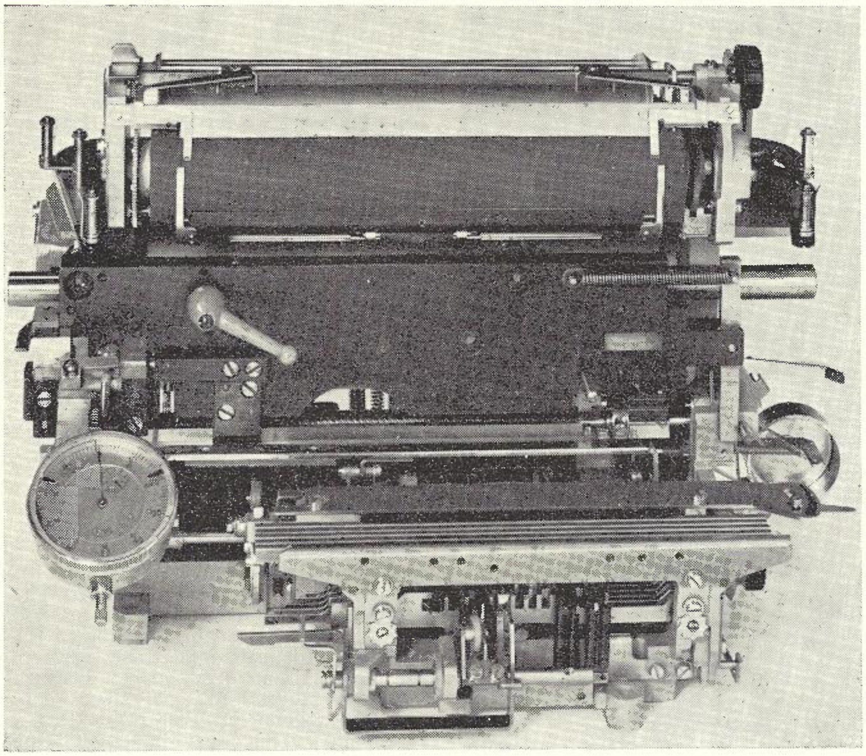


Fig. 3.—Adjustment of Beginning-of-the-Line-Unit in Printer Base (Test Piece Below) for Type Basket (Fixture on Top).

already at the ends of the production lines busy inspecting individual constructional units after their assembly.

The following is a description of some interesting details of the testing of individual units.

Printer Base and Type Basket

Being self-contained units, printer base and type basket are assembled on separate lines. The printer is completed only after these two units have been fully assembled. Up to this point test jigs and fixtures have been used to permit accurate adjustment of units.

Adjustments which have to be made on the **printer base** along the assembly line concern the type basket. The gauge shown in Fig. 3 is inserted in the base of the printer in place of the type basket. It serves, among other things, for correct beginning-of-line adjustment of the type basket to be mounted later.

The machine is normally designed to print 69 characters per line. The type basket is moved across the page by means of a feed screw and a toothed mating segment. Some machines, however, are required to print a larger number of characters per line. One version, for instance, prints 104 characters per line. The feed screws used here have different pitches. Adjustment and tests of different feed screws are performed with accessories which can be inserted in the type basket gauge.

The fixture shown in Fig. 4 permits uniform adjustment of the **type basket** for the printer base. It is an exact replica of the functional parts of the printer base which co-operate with the type basket. Here the displacement of the code segments in the type basket is checked with the code bars simulated by the fixture and the segments are centred with respect to the pull bars. The special gauges shown in Fig. 4 are used for positioning ribbon lifter and pusher. The latter controls the movement of individual type bars above the previously mentioned pull bars.

Printer

The printer base and type basket, manufactured and tested separately, can now be assembled without further adjustments to form the printer and are tested as one single unit. Fig. 5 shows how a printer base and a type basket are placed on a testing fixture located on the assembly line. This fixture includes a keyboard, a transmitter, and a receiver. The lever on the left is used to clamp the printer down and to release it by one hand motion. This first function test includes a check for proper operation of the type basket with the code combinations LTRS, FIGS, CR (Carriage Return) and LF (Line Feed). Besides, ribbon reversal is also checked. Paper feed and correct typing during operation are also observed in the course of this test.

The complete printer is then subjected to an endurance test. For this purpose special clamping fixtures have been designed. The printer is placed on a mounting frame with motor and gears and pushed against stop pins, as in the case of its later installation in a regular teleprinter. Special clamping devices permit rapid mounting. Associated with each mounting frame is a receiver. The test code received during several hours of continuous operation must be recorded correctly. Operation is at a telegraph speed of 75 bauds, corresponding to 10 characters per second. To reduce operating noise, the whole set-up is covered by a perspex cap which permits convenient observation of all mechanical processes. At the end of this endurance test all adjustments on the printer are rechecked and the printer released for final installation.

Camshaft of Printer

From the processes so far described it is obvious that the individual parts of constructional units of the teleprinter

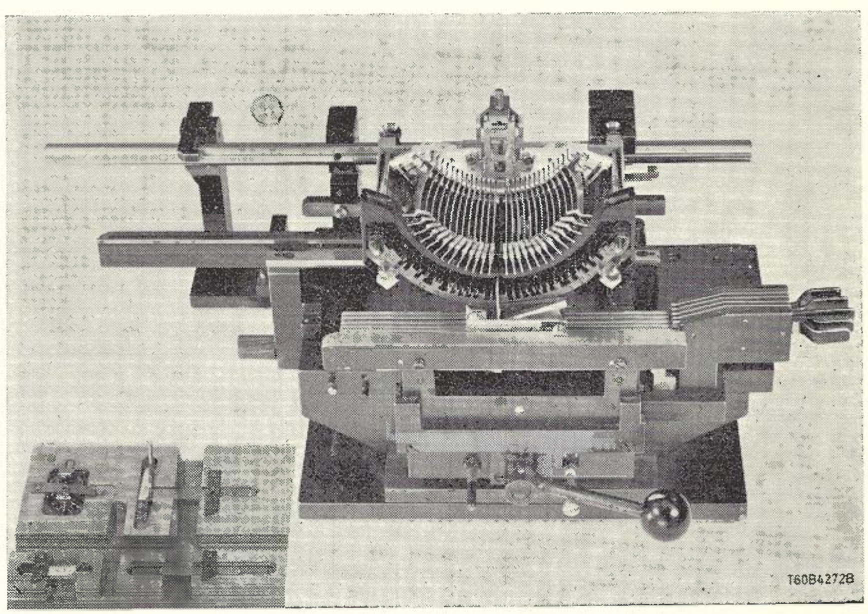


Fig. 4.—Adjustment of Type Basket (test piece) to Code Bars. (fixture) of Printer Base. On the left: Adjusting Gauges.

Fig. 5.—Printer Base and Type Basket. Both test pieces have been assembled into a printer and placed in a test fixture (with keyboard). The lever (left) is used for easy clamping and releasing of test pieces.

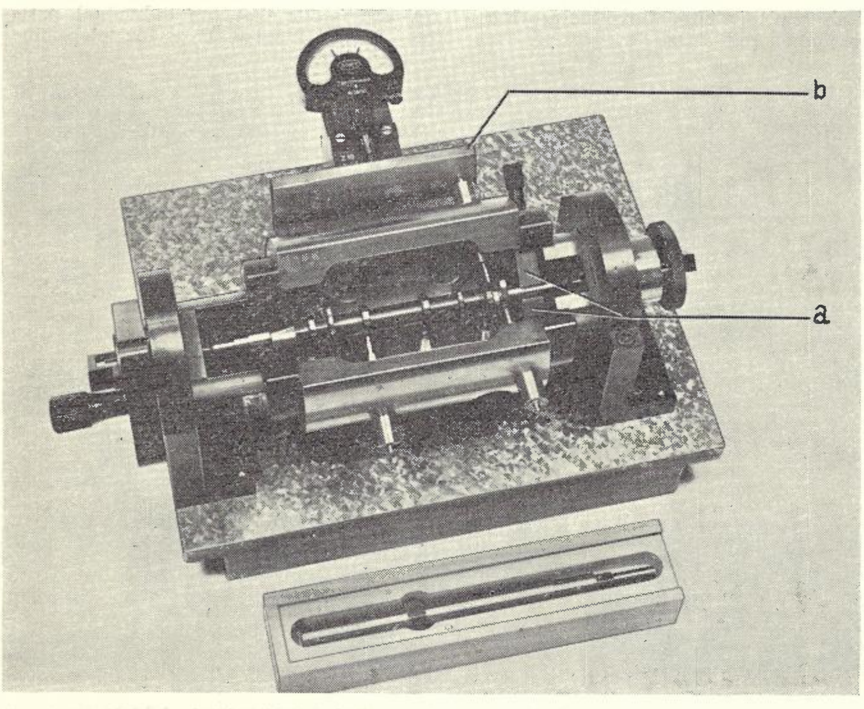


Fig. 6.—Text Fixture with Dial Indicator for Checking Printer Camshaft. In front: Measuring gauge for basic adjustment of fixture.

must be finished to accurate dimensions before they can be installed. They are, therefore, subjected to a final test before being supplied to the workplaces along the assembly lines. In the large field of parts manufacture and testing only one testing process for a functionally important part shall be mentioned in this connection. This essential part is the camshaft of the printer which controls a number of inter-related motions of brief duration. Special attention is, therefore, devoted to testing this component in the manufacturing shops.

The fixture shown in Fig. 6 is used at one stage of the acceptance test for camshafts. During this stage checks are made on cams which have an important function point on their circumference and whose exact position and dimensional accuracy are a precondition for reliable operation of the machine.

The camshaft has two reference planes which serve as a base for subsequent production steps. These two parallel surfaces are also used for chucking the shaft in the fixture. The camshaft under test is pivot-suported and the movable centre portion of the fixture is aligned with these surfaces of the camshaft and clamped down (point **a** in Fig. 6). This determines accurate angular position of the feeler pins which come into contact with the function points of the cams.

During tests the centre portion of the fixture with the feeler pins and the rigidly clamped camshaft are turned one at a time. During one revolution the outer ends of the feeler pins come into contact with a common measuring bar (**b** in Fig. 6). The measured values are indicated on a dial whose limit marks are so arranged as to enable the inspectors to see at a glance whether or not the camshaft meets specified tolerances.

Motor

The motors intended for installation in the teleprinters are supplied to the assembly shop where they have to pass through a number of workplaces and test benches before they can be assembled.

Commutator motors have to be provided with centrifugal contact governors and are subsequently balanced dynamically. Any unbalance of the motor with governor is thereby reduced to a minimum.

Having been installed in their casings, the motors are subjected to an electrical acceptance test. It might be mentioned at this point that the teleprinters can also be powered by synchronous motors.

The test fixture shown in Fig. 7 is intended for subjecting various motors to electrical tests. It has been designed so that individual testing processes can be started by simple operation of push-buttons. Tests are terminated by a short trial run at the prescribed voltage. A perspex cover is provided to eliminate any shock hazards.

Transmitter

The transmitter unit is assembled on another line. After assembly, this unit is also subjected to a test run for several hours. The small size and compact design of the transmitter make

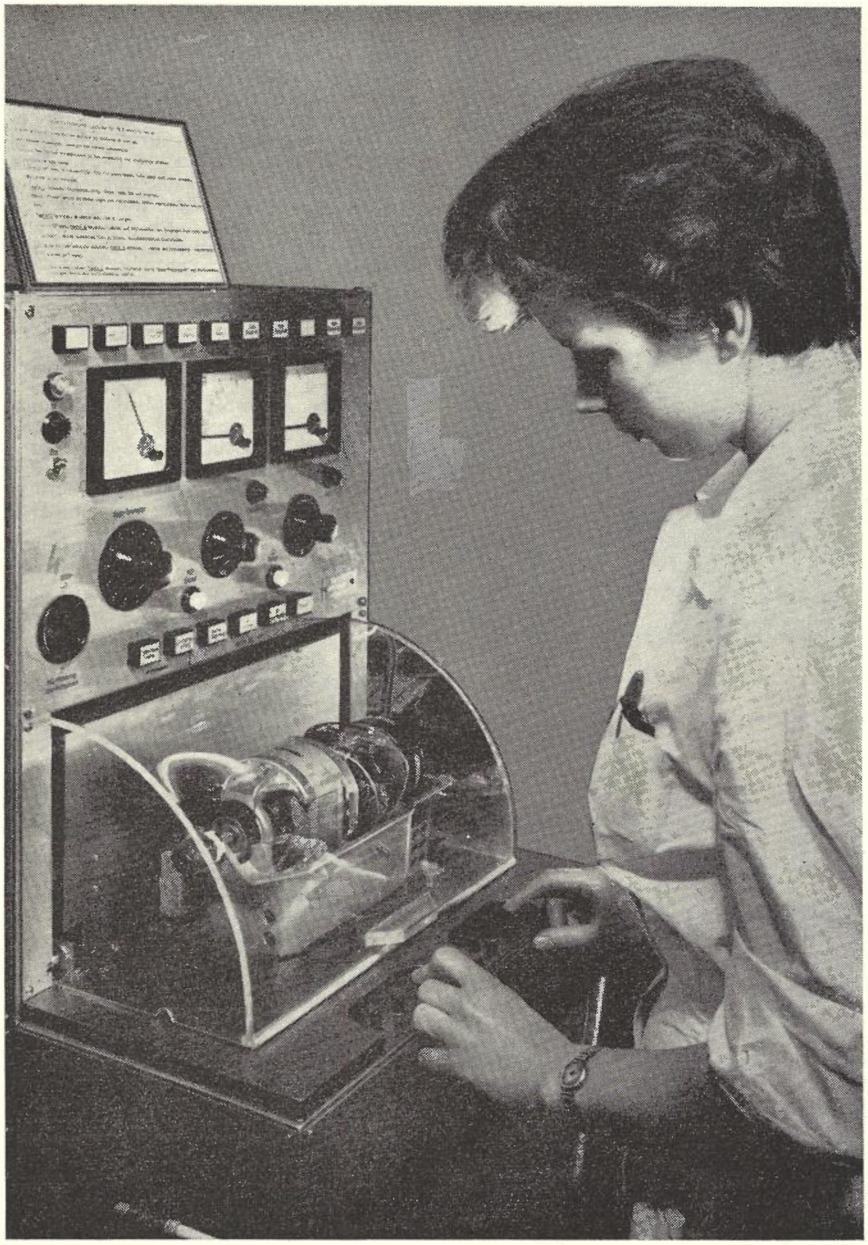


Fig. 7.—Facilities for Electrical Tests of Different Kinds of Motors.

it possible to engineer the test run fixture in such a way as to accommodate ten units at a time. As in the regular teleprinter, the transmitter is pushed against stops so that its position with relation to the drive and tripping elements is accurately fixed. When continuously operated, the unit is run at a telegraph speed of 75 bauds, with characters "R" and "Y" being transmitted in alternate succession. These two code combinations cause all functional members of the transmitter to be engaged. The whole set-up is covered with perspex caps to reduce operating noise and permit ready observation. After the trial run all adjustments are checked again. This is immediately followed by electrical adjustments and tests.

At the test bench (Fig. 8), the send contact of the transmitter is adjusted for minimum distortion with the aid of an electronic measuring set. This test bench has a keyboard which enables the inspector to run the transmitter, as with a regular teleprinter, through all subsequent test phases. The test code applied is monitored by the teleprinter shown on the left. After this test the transmitter units are ready for installation in teleprinters.

Mounting Frame

The mounting frame contains, among other parts, electrical components and their connecting leads. It is provided with a keyboard on another assembly line. As previously mentioned, the various functional units are placed on this frame, pushed against their stop pins or stop planes and secured by means of screws.

Receiver

The receiver unit of a teleprinter scans incoming code combinations and stores them in a corresponding set-up of mechanical members. Depending on whether a current pulse or a no-current pulse has been detected, sword-shaped levers, five in all, are moved by intermediate members into one of two fixed end positions. As the receiver camshaft continues to rotate, these swords transfer their settings to the code bars of the printer unit.

The fixture shown in Fig. 9 is used to check the swords in either of their end positions. This ensures that the transfer members of the receiver, which will later engage with the code bars of a printer, are adjusted to correct starting positions.

Endurance tests again are made on a number of receiver units combined in one test fixture. Placing and aligning the unit with the stop pins and meshing the gears between receiver clutch and drive assembly are accomplished in the same way as in the fully assembled teleprinter.

During continuous trial runs the receivers under test are supplied with a certain code combination which causes all functional members to operate. Operation again is at 75 bauds. After this trial the units are subjected to a mechanical check.

Special test benches have been developed for performing electrical tests and adjustments on receivers. Here, quite a number of exactly defined tests can be carried out (Fig. 10). As already mentioned, the receiver scans the incoming code combinations. In practice, however, the signals received may be affected by distortion. The receive margin is the range within which the receiver of a teleprinter is still capable of reproducing correctly a signal affected by leading or lagging distortion.

The magnitude of distortion of the signals applied to the receiver is adjusted in steps on crystal controlled electronic distortion generators installed in the test benches and the receive margin is thereby accurately determined. At the same benches the tripping delay of receivers can be measured in fractions of milliseconds with the aid of an electronic meter.

These facilities permit both neutral and polar current types of receivers to be tested. They can quickly be adapted to different telegraph speeds. These modern test benches, where all electrical measurements on receivers are combined in one fixture, contribute a great deal towards reducing the time required for testing. All facilities are arranged in a most convenient and functional manner so that job-trained female workers can be entrusted with carrying out these important measurements and adjustments.

Functional Units at the Ends of Assembly Lines

The foregoing description has given an outline of the tests provided for individual constructional units of the standard-version teleprinter.

Fig. 8.—Test Bench for Adjusting Transmitter to Minimum Distortion.

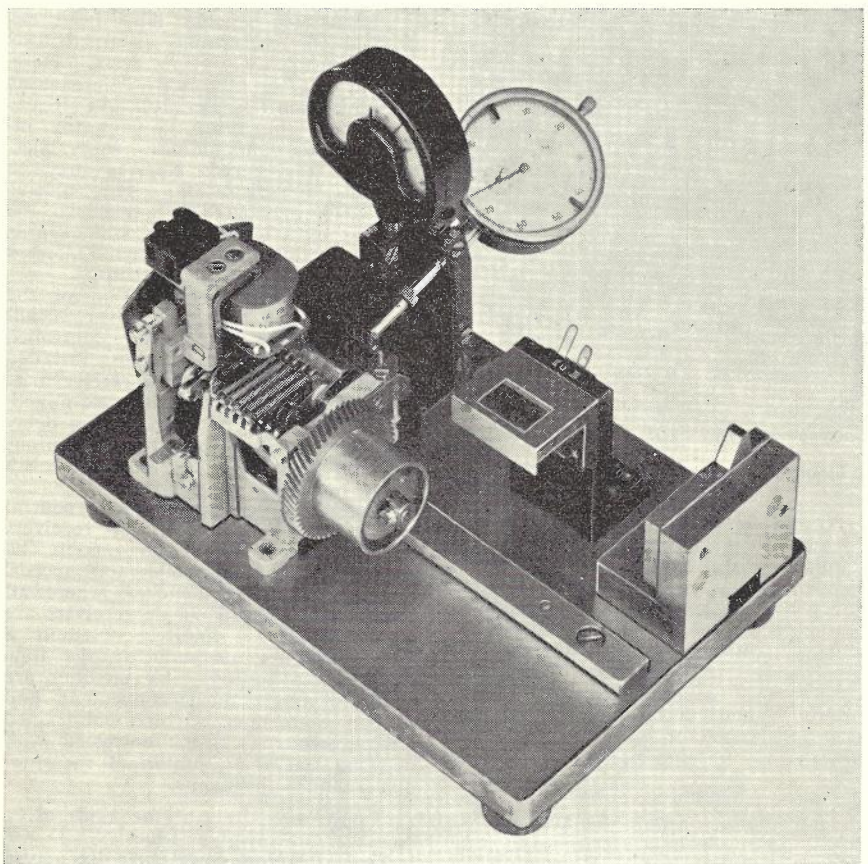


Fig. 9.—Fixture for Testing Final Positions of Swords in a Receiver Which Are Later to Engage into the Printer Code-Bars.

Development of testing facilities for individual constructional units has been based on the principle that the units should be tested in the same operating position which they will later take up in the regular machine. The electrical and the mechanical control functions have also been adapted, as far as possible, to the actual functions of the teleprinter. In this way the units are functionally adjusted and mechanically and electrically tested at the end of the assembly lines, i.e., before they are assembled to form the complete teleprinter.

ASSEMBLY OF TELEPRINTERS

The final assembly is also performed on an assembly line. No further fixtures are required. Each workplace is provided with a switchboard for electrical connection of the machines. Several DC and AC voltages are available for power and telegraph circuits to cater for the different types of teleprinters. These rather generously designed workplaces have paid off. Teleprinters with different electrical data can be tested without interrupting the smooth flow of work along the line.

The machines are subjected to a continuous test of several hours' duration. Following this, they are once more checked for proper mechanical operation and finally passed on to the acceptance test benches (Fig. 11). Each of these benches permits a comprehensive electrical acceptance test to be made in a very convenient manner. Individual tests are controlled electronically by pushbutton. A total of ten measurements are made on the machine in a predetermined sequence. The test benches are provided with variable power supply to obtain the necessary power and telegraph voltages. Their power frequency can also be adjusted.

Special models with all types of circuitry can be tested. Receive margin and start-stop distortion can be measured at telegraph speeds ranging from 44.45 bauds to 75 bauds, simply by exchanging the crystal of the test oscillator.

The use of these test benches proved to be a great advantage. Thanks to the fact that all final electrical measurements are now taken on one single bench, test time has been reduced considerably, compared with earlier methods when measuring instruments were distributed over several test benches. It has been possible to use job trained personnel for staffing these test positions.

Measurements taken during acceptance tests are entered on the work progress cards assigned to the relative machine. These cards are used as a permanent record, the figures thereon being evaluated chiefly for statistical purposes. They provide a further means for regular and thorough quality analyses over short and over long periods of time.

Besides, spot checks are made on part of the fully assembled machines to ascertain whether r-f interference suppression methods are adequate. These measurements have shown again and again, that due to the liberal rating of suppression components and metallic encapsulation of motor and transmitter, r-f suppression of the machine is better than applicable specifications stipulate.

Fig. 12 shows a complete machine after its final test. The machines are now routed through intermediate stores and packing shop to the shipping department.

Fig. 10.—Test Benches for the Electrical Test of one Receiver. Receive margin and tripping delay, among other functions, are tested here.

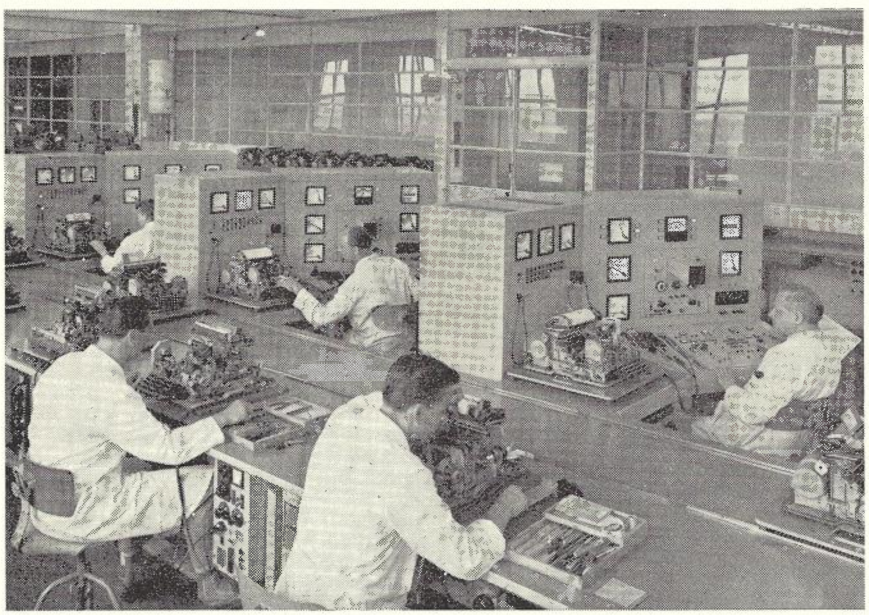


Fig. 11.—Workplaces and Test Benches for the Electrical Acceptance Tests of Teleprinter 100.

CONCLUSION

This article can give only a rough outline of the tests carried out between the various production stages. Further testing equipment with many interesting features could not be described in detail within the limited scope of this paper.

Besides the basic model 100 teleprinter, there is a large number of different versions and attachments (1) which permit adaption to a wide variety of special applications. These different versions are also subjected to continuous quality controls with the aid of further jigs and test fixtures.

Fig. 12.—A Model 100 Teleprinter after its Final Test.

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EPOXY RESIN BASED JOINT FOR LARGE SIZE CABLES

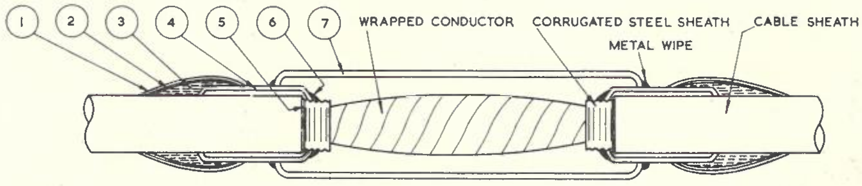
*F. HERBSTREIT**

INTRODUCTION

In recent years experimental installations have been made of large size outdoor cables with sheathing made of material other than lead. These materials include aluminium, steel, and polythene in various combinations as listed in Table I. Difficulties have arisen in the field with some of these cables as there is no well established method of sheath jointing for them such as the familiar wiped lead sleeve joint used on lead sheathed cable. Aluminium and steel sheathed cables are jointed by a wiped lead sleeve in a variation of the technique used for lead sheath cables (1) and it is found that jointers competent in jointing lead sheaths can satisfactorily joint aluminium and steel sheaths. The other types such as alpeth and stalpeth do not lend themselves directly to lead wiping techniques because of the absence of a firm metal base for the joint.

TAPING METHODS

The sheaths of the first trial stalpeth installations were jointed with the tape method used in America (Fig. 1). This method consists of using tapes to secure an auxiliary lead sleeve to the polythene sheath to form a base for a conventionally wiped lead joint. The auxiliary lead sleeve is made to fit firmly onto the polythene sheathing by beating one end down onto the cleaned steel sheath and soldering, and by beating the other end onto the polythene sheathing. The surface on which the tapes are to be applied is thoroughly cleaned and flame treated, and application of rubber solution type cement is followed by a build up of $\frac{3}{4}''$ rubber mastic tape, over which two layers of 2″ rubber mastic tape are applied. Next a layer of strips of adhesive aluminium tape placed longitudinally is formed, followed by a lapped layer of the same aluminium tape. A protective layer of glass cloth tape completes the taping and the main sleeve is plumbed to the auxiliary lead sleeve by conventional means. It was found that joints made in this fashion could not be depended on to be airtight if the polythene sheathing had been deeply scored longitudinally during hauling operations as usually happens. When the tapes are pulled on tightly they bridge over the scores and allow air leakage paths.



1. Glass Cloth Tape.
2. Adhesive Aluminium Tape.
3. Rubber Mastic Tape.
4. Auxiliary Lead Sleeve.
5. Tie Wire.
6. Inner Auxiliary Sleeve Seal.
7. Main Lead Sleeve.

Fig. 1.—Stalpeth Sheath Taped Joint—U.S.A.

Fig. 2 is an example of a taping technique developed in Japan for jointing alpeth sheathed foam polythene cable; here again the tapes are used to secure a stepped auxiliary lead sleeve to the sheath to form the base for a conventionally wiped lead joint. The stepped auxiliary sleeve is considered to improve the joint closure technique as compared to the American method as the stepped sleeve gives almost uniform diameter conditions for taping, whereas the American practice of dressing down on to the sheaths gives quite a difference in the diameters of the sleeve and cable which requires building out with self bonding tapes. The method illustrated consists of first wrapping the polythene outer jacket of the alpeth sheath with polythene tape. Next a prefabricated auxiliary lead sleeve is positioned over the taped area. The end of this sleeve where in contact with the tape is perforated with numerous small holes. The lead in the perforated area is heated until the polythene fuses and flows out of the holes. This operation is very important to maintain the mechanical strength of the joint. It also assists to seal the leakage paths via the longitudinal score marks mentioned in the previous paragraph. Glass tape is then wrapped around the holes to flatten the molten polythene; this ensures a flat surface for the following tapes. The auxiliary sleeve and adjacent cable sheath are cleaned, the sheath flame treated, and then taped for gas and water tightness using in turn vulcanised neoprene (V.N.), aluminium and protective P.V.C. tapes.

The main lead sleeve is then plumbed to the auxiliary sleeve by conventional means.

Apart from the trouble already mentioned about longitudinal score marks and other blemishes in the surface of the polythene over which the tapes might bridge and leave an air leakage path, reservations are held about taped joints on several other accounts; for instance, in the joint shown in Fig. 2 four different types of tapes are required as well as a prefabricated lead sleeve which must be the correct size for the cable. Hence this, as other taped joints, requires more stock items than a wiped lead sleeve joint and a material supply problem can arise. Further, taping is a skilled operation which Australian jointers are not normally taught; and, if taught, it is doubtful if they would have sufficient taping work to hold their skill. Finally both labour and material cost of these joints are high compared to a wiped lead joint.

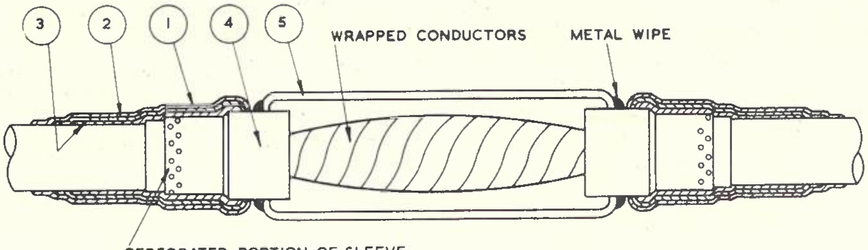
OTHER METHODS

A mechanical joint closure for stalpeth cable has been investigated. The method consists of fitting expansion

* Mr. Herbstreit is Technical Instructor, Lines Section, Headquarters. See page 334.

TABLE I—EXPERIMENTAL CABLE INSTALLATIONS—DETAILS OF CABLES

Name	Conductor Insulation	Details of Sheath Construction
Aluminium sheathed	paper	welded or extruded aluminium sheath of substantial wall thickness; deep helical corrugations on sheath; plastic jacket extruded overall; adhesive compound between metal sheath and plastic jacket.
Steel sheathed	paper	welded steel sheath, .012 in.-.020 in. wall thickness; otherwise similar to aluminium sheathing.
Stalpeth	paper	soldered .007 in. tinned steel sheath with extruded polythene jacket; adhesive compound between sheath and jacket; .008 in. aluminium tape longitudinally applied between core and sheath as electrical screen. The aluminium screen and steel sheath have shallow transverse corrugations.
Alpeth	P.E.F. (foam polythene)	.008 in. aluminium tape applied longitudinally as an electrical screen, flooded with adhesive compound; polythene sheathed extruded overall.
Glover Barrier	paper	.003 in. aluminium tape backed with .0015 in. polythene film laid over core of cable with polythene sheath. The aluminium foil welds to the polythene to form a partial water vapour barrier.
Plastic	polythene	polythene sheath only. Aluminium foil electrical screen may be provided.



1. Adhesvie P.V.C. Tape.
2. Adhesive Aluminium Tape.
3. Adhesive V.N. Tape.
4. Stepped Auxiliary Lead Seal.
5. Main Lead Seal.

Fig. 2.—Alpeth Sheath Taped Joint—Japan.

plugs on the cable on each side of the joint, then a brass sleeve is placed over the two plugs. The plugs consist of a neoprane annulus which is sandwiched between two brass pressure plates, held by six bolts which pass through holes in the pressure plates and the annulus. After the conductor jointing is completed, the brass sleeve is passed over the joint so as to enclose the neoprene assembly on each end. The bolts are tightened and the neoprene is compressed and expands radially applying pressure inwards on the cable and outward on the metal sleeve. A trial joint made in this way failed to hold air pressure and examination showed that the failure was due to leakage paths provided by score marks on the polythene sheathing; in addition the cable tends to deform when sufficient pressure is applied to the nuts to enable the joint to become airtight. A modified version of the jointing was developed incorporating a steel bush placed under the polythene sheathing with the expanding plug placed over the steel bush; this method has proved somewhat more successful in tests providing the temperature is not too high but it is not proposed to proceed with the method.

A method of sealing polythene sheathed cables by means of welding a sleeve of similar material as that of the sheath has been developed in the Research Laboratories. To do this spacer pieces must be provided, as this type of sleeve cannot be dressed to conform to shape; these spacers are fitted on the cable at each end of the joint and are welded by inserting a split-type hot tool heated by gas to the appropriate temperature between the spacer and the sheathing; the tool is then withdrawn and the surfaces are forced together. Once this weld is cooled off the main sleeve is slipped over the spacers, and the ends are welded by the same method using a larger size tool. This method has proved excellent for welding the plastic protective jacket on aluminium and steel sheathed cable which, because of the stiffness of the basic sheath, can be made to rigid tolerances in respect to diameter and roundness. Soft sheathed cables, such as alpeth, however, are usually too deformed in section from a perfectly round shape to fit to either the tool or the spacer pieces and it is difficult to obtain welds of adequate integrity.

EPOXY METHOD

Because of reservations about the use of tape, mechanical and welded joints it was desired to develop a sheath jointing method applicable to any type of cable sheath and which used manipulative techniques familiar to Australian jointers and if possible, standard items of material.

Accordingly a method employing auxiliary lead sleeves sealed to the polythene sheath by means of poured epoxy resin has been developed. The method (Fig. 3) as applied to alpeth sheathing requires that a length of polythene sheath and a small length of the aluminium screen are thoroughly cleaned and the polythene flame treated or oxidised for a better bond. An auxiliary lead sleeve is formed and the surfaces which will come into contact with the epoxy resin are thoroughly cleaned. The aluminium screen is tinned with aluminium solder. A lead mould is formed, fitted to the auxiliary lead sleeve, and soldered together. The combined auxiliary sleeve and mould is placed in position and the end bearing on to the aluminium sheath is soldered. The functions of the soldered joints are to give electrical continuity to the sheath and mechanical stability to the positioned auxiliary sleeve. The pour is made through a hole in the lead mould using the standard epoxy resin field pack (2) and is poured as soon as possible after flame treating the polythene. To prevent air locks inside the mould, an escape hole is made in the auxiliary sleeve. After the epoxy resin has cured and the conductor jointing is completed the main lead sleeve is plumbed to the auxiliary sleeve in the conventional manner.

Proper cleaning of the areas to be in contact with epoxy is essential. The polythene sheath is cleaned with light application of a wood rasp to remove all unclean surfaces and at the same time to roughen the surface, which helps the epoxy adhere to the polythene. The aluminium screen in alpeth cable is cleaned with light application of a wire brush followed by a final cleansing with a petrol (or suitable solvent) soaked rag. With stalpeth the bituminous compound over the steel sheath is removed by heating with L.P.G. torch and wiping with kerosene and waste when most of the bituminous compound is removed, a wire brush and petrol is used to complete the cleaning.

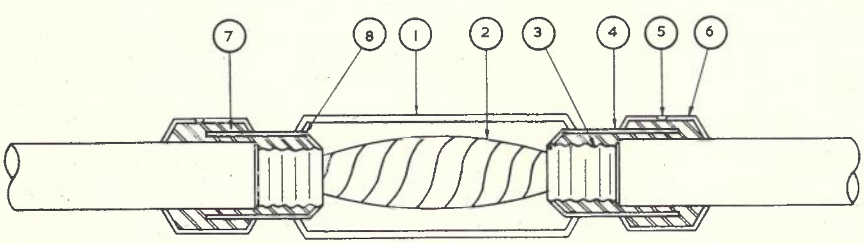
Sample joints made in this way have been held under 25 lbs. per sq. in. air pressure for various periods without any loss of pressure. During the test period lead sleeves were removed and remade on the joints six times without loss of ability to hold air pressure. Long-term laboratory and field tests are now in hand but no deterioration of the joints is expected as all of the individual components and operations have been under investigation for several years in connection with the use of epoxy resin for jointing small plastic cable. About six years' field experience is now available with the use of epoxy resin for small cable jointing and this indicates that the joints made by the method described will be satisfactory for the life of the cable.

The success of the joint depends on a shrink fit between the epoxy and the polythene sheath rather than on adhesion although the polythene is flame treated to promote adhesion. Epoxy shrinks 2%-3% by volume on setting and the pressure test figures quoted suggests that this provides a satisfactory airtight joint. Nevertheless, it is proposed to confine the use of this jointing method to cables held under gas pressure. The advantages of the method are that standard epoxy field packs and other standard items can be used and no special materials are required. The manipulative techniques are familiar to all jointers. The epoxy resin fills up the score marks in the sheathing and, as tests have shown to date, this has prevented air leaks. The method is an extension of one described by Johnston (3).

The major design refinements have been aimed at—

(i) allowing the epoxy resin pour to be made with the cable in its housed, horizontal position;

(ii) the total immersion of the open end of the auxiliary sleeve in epoxy resin to give a more secure seal



1. Main Lead Sleeve.
2. Wrapped Conductor Joint.
3. Metallic Undersheath.
4. Auxiliary Lead Sleeve.
5. Hole for Pouring Epoxy Resin.
6. Lead Mould.
7. Epoxy Resin.
8. Breathing Hole.

Fig. 3.—Epoxy Based Joint.

which will be less susceptible to the effects of heat due to plumbing operations.

If successful in field trials the method will have an application for the jointing of stalpeth, alpeth and plain polythene sheathed large size cables and with slight modification to metallic sheathed cables. It is also expected to be suitable for Glover barrier sheathing.

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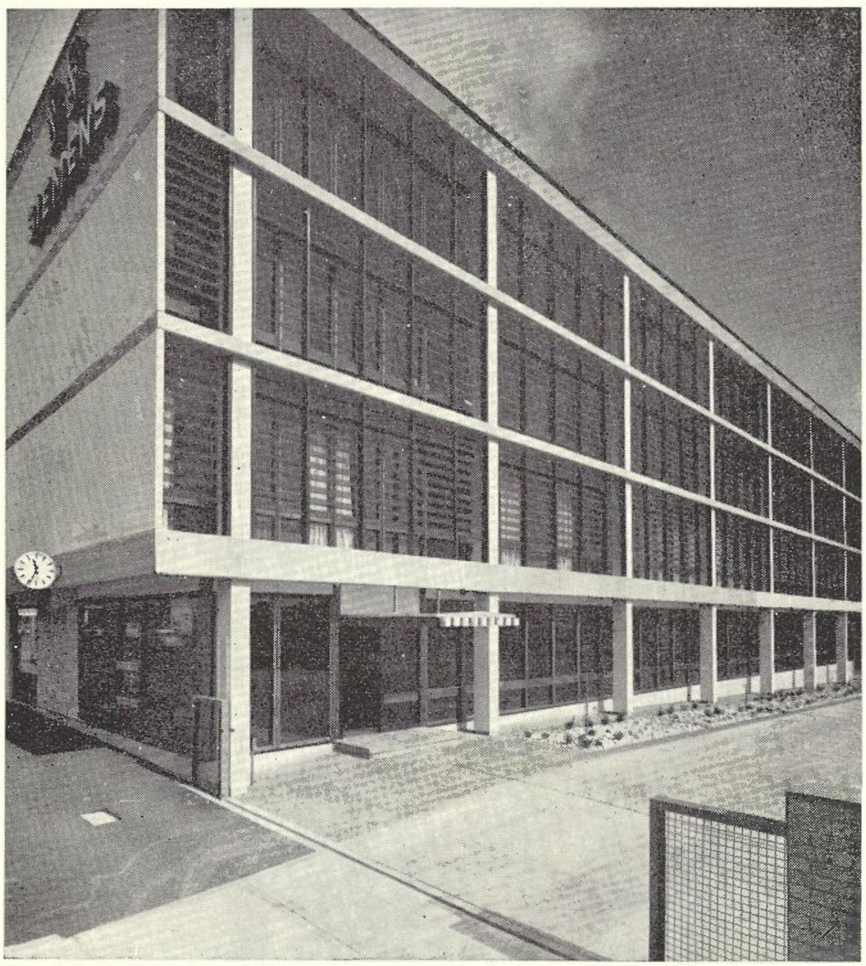
TECHNICAL NEWS ITEM

NEW SIEMENS FACTORY IN AUSTRALIA

The new Head Office of Siemens Halske, Siemens Schuckert (Australasia) Proprietary Limited, completed in 1963, comprises a three-storey administration block, store and factory buildings on a two-acre site at Richmond, a suburb of Melbourne. The office building was designed to be functional yet aesthetically pleasing and at the same time allowing maximum flexibility for future re-arrangement of office layout and manufacturing facilities. It was highly commended by the judges in the Royal Victorian Institute of Architects' 1963-1964 awards for outstanding commercial buildings.

Speed of construction was achieved by making extensive use of pre-fabricated components and the use of the lift-slab method of construction which has been used so successfully on other recent buildings. Working conditions, aimed to achieve maximum comfort and efficiency, include air-conditioning, high natural and artificial light levels with floor to ceiling windows and strip lighting, balanced control of glare and sunlight with tinted glass louvres protecting the northern windows on upper floors, and well controlled acoustics.



Administration Block, Siemens Halske, Siemens Schuckert (Australasia) Pty. Ltd., Richmond.

A theatrette has been included on the ground floor with accommodation for approximately 50 people and is used to screen technical films for staff training and special shows for customers.

The factory and store are located in a single-storey building covering the entire western side of the block. It was designed as a universal structure with standardised components on a 50 ft. by 40 ft. grid. The factory area is fully air-conditioned and natural lighting is provided by continuous skylights let into the steel deck roofing. In addition, high artificial illumination levels are provided for.

The selection by the Australian Post Office of the Siemens Model 100 Teleprinter for use in the public Telex network led to the establishment of a teleprinter assembly line. The first machines were delivered at the end of 1960 and up to the present time approximately 2,500 machines have been assembled in Australia. A machine shop equipped with specialised machine tools is being set up to increase the Australian content of the machine being assembled here. Work places have been carefully designed to minimise movement of parts and sub-assemblies during assembly operations. These include three circular work-benches with rotating tops to permit operators to perform successive operations whilst remaining seated at one position.

Transistorised carrier telephone equipment, low voltage switchgear, switchboards and control cubicles of various types are also manufactured in the new Melbourne factory.

In keeping with the trend to beautify surroundings of business establishments, a Japanese style garden has been established along the northern side of the office block, separating it from the car park which has accommodation for 60 customers and staff cars. An attractive courtyard, located adjacent to the factory, with trees and shrubs provides an ideal outdoor lunch area.

THE SHORT HAUL BROADBAND RADIO BEARER

*J. E. LONGFOOT, M.E.**

INTRODUCTION

In recent years medium and long-distance communications have been revolutionised by the introduction of broadband bearer systems capable of carrying a large number of telephone channels or a limited number of television channels. These bearers may be provided by either radio or cable systems.

The radio bearer has played a large part in this development, but has not been universally adopted due to several limitations. In general, radio is best suited to long uninterrupted routes such as through bearers between capital cities and less suitable for short hops or long routes with a large number of drop outs; coaxial or quad cable has been used where these latter conditions are encountered. Until recently, radio broadband bearer equipment has been unsuitable for short hops as conventional terminal equipment is both expensive and complex, being designed to give optimum performance on long paths. On long routes, drop outs are not used as the repeaters are often located on remote mountain tops and more important the bearer must be demodulated and re-modulated every time a group of circuits is to be inserted. This introduces extra intermodulation distortion into the system each time it is performed and for this reason long systems are usually equipped with non-demodulating repeaters, most of the amplification being carried out at the intermediate frequency of the receivers.

The recently developed broadband radio short haul system is designed to supplement and overcome some of the drawbacks of the existing longer bearers known as long haul systems. These systems although similar in performance to the long haul are much less complex, and less expensive. As they are designed for operation over short distances generally on a single or two hop circuit, the performance of the terminal radio equipment need not be up to the very high standard of that designed for long paths particularly in frequency stability and perhaps linearity.

In general, these systems are suitable for hops of up to 30 miles, and three such hops are a maximum for one system. The repeaters are normally demodulating, as will be seen later in a description of one type of equipment. These systems are extremely useful for spur routes branching from main routes for either telephony or television, and also for short independent hops for telephony junction work in large cities, or telephony trunk work between smaller provincial centres not served by a long haul system. In general either 300, 600 or 960 telephone channels or one television channel may be carried by a bearer depending on the equipment and the path lengths, and a fully equipped system would comprise two such bearers plus a protection bearer in each direction.

The operation of one particular type of equipment will be discussed and it will be shown where economies have been effected to make the system attractive for short haul operation.

TYPICAL SHORT HAUL EQUIPMENT

Several manufacturers have available short haul equipment as a special type (not merely one hop of a long haul system) and the Postmaster-General's

* Mr. Longfoot at time of writing was Engineer Class 1, Radio Section, N.S.W.

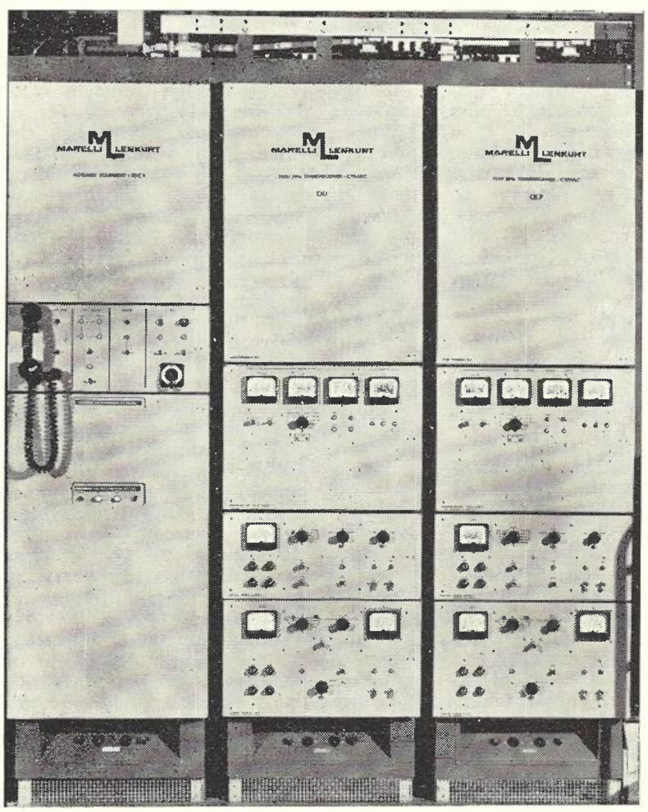


Fig. 1. (a).—Typical Short Haul Radio Broadband Bearer Terminal Equipment installed in three 7 ft. bays.

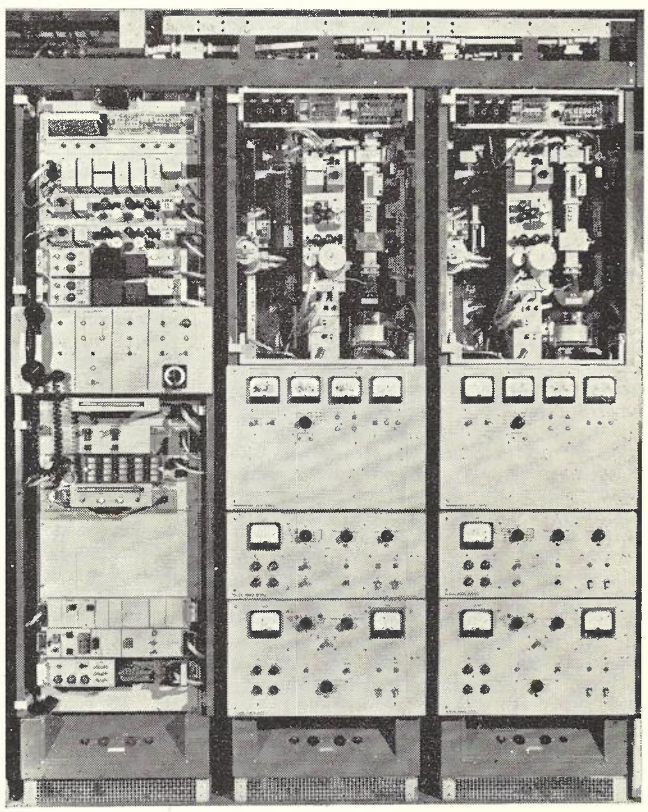


Fig. 1. (b).—Typical Short Haul Radio Broadband Bearer Terminal Equipment showing:—
Left: Combined circuit supervisory and equipment switching bay.
Centre: Main channel radio bay of transmitter, receiver, power supplies and amplifiers.
Right: Protection channel radio bay as for main channel.
Top: Waveguide circuitry and components.

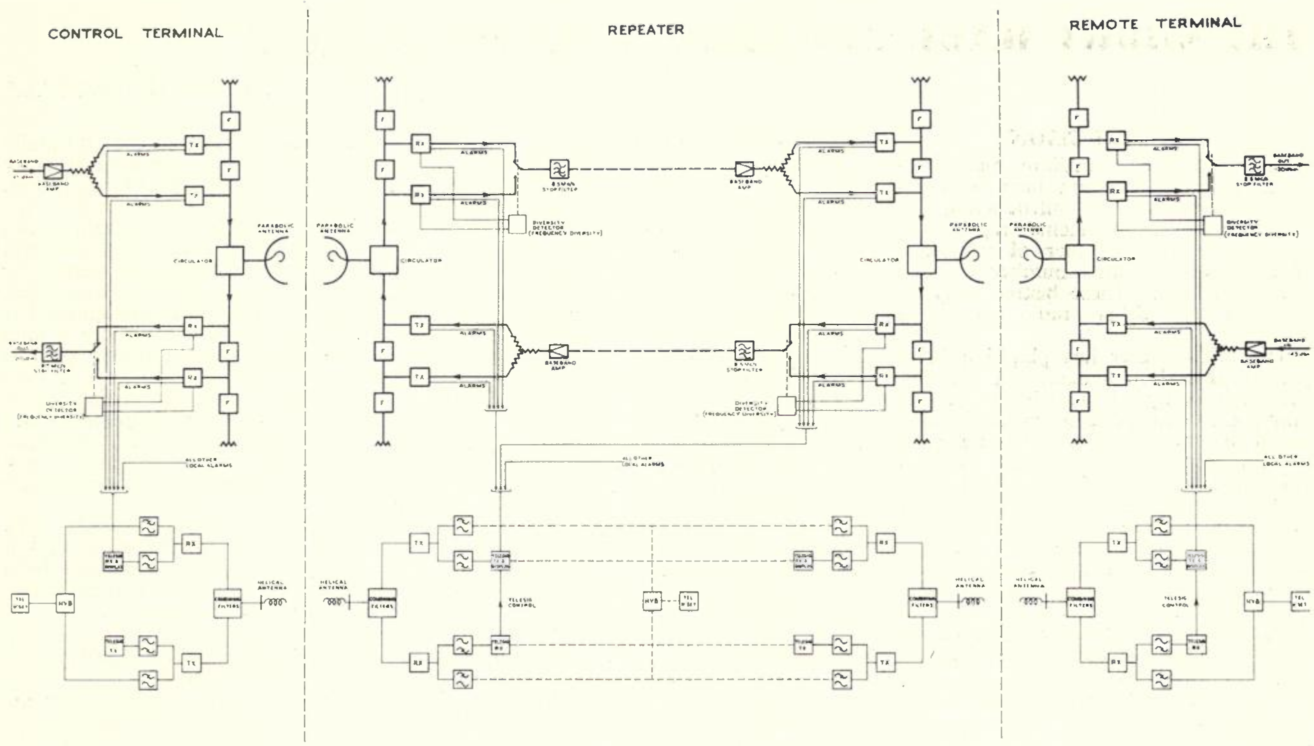


Fig. 2.—Schematic Diagram of Typical Two Hop Short Haul Radio Broadband Bearer Circuit.

Department has chosen the FV8 system manufactured by the Marelli Lenkurt Company of Italy, to fulfil the initial requirements. Already a 600-channel telephony system has been installed between Sydney and Dural to carry telephony junctions, and many short one-way television systems have been installed in several States to supply the regional transmitters of the National Television Service with programmes.

An FV8 terminal may comprise some or all of the following: up to three radio bays with waveguide filters; waveguide feeder and parabolic antenna; a switching bay to check and switch the radio bearers; a supervisory bay to transmit and receive alarm and channel condition signals; and a supervisory bearer bay to carry the supervisory signals and technicians order wire. The switching, supervisory, and supervisory bearer bays take various forms and where simplified forms are adequate several of these functions may be included in the one bay. A front view of the Sydney terminal of the Sydney to Dural system is shown in Fig. 1; two radio bays and one combined switching and supervisory bay are installed.

A repeater is essentially two terminals placed back to back and it is only the supervisory equipment which may differ from that used at a terminal. Back to back repeaters make the system more versatile, as broadband telephony or television signals may be inserted or withdrawn as required. A block schematic of a typical one repeater system is shown in Fig. 2.

The FV8 radio bays, feeders and aerials are the crucial elements of the system and it is in these, that the short haul system differs from the long. This R.F. equipment is the only part of a short haul system, peculiar to such a system, so it is the only part which will be described in detail, the supervisory and switching equipment consist of conventional circuitry used in similar form in both long haul radio and coaxial cable systems.

The R.F. equipment consists of transmitters, receivers, waveguide components and antennas. Briefly, the transmitter accepts the incoming television or telephony baseband signal and after frequency modulation transmits the modulated carrier at an output power of about one half watt in the 7000 Mc/s band. This carrier is propagated through the waveguide to the antenna where it is radiated; at the other end of the circuit a portion of the radiated power is picked up by the receive antenna and reaches the receiver through the waveguide. The receiver amplifies and frequency demodulates the carrier, and the baseband telephony or television is processed and routed to the switching bay.

Transmitter

The input to the transmitter from the switching bay is applied to the telephony or television input whichever is appropriate. These signals will occupy all or part of the frequency band 30 c/s to 5 Mc/s. The signal is amplified after passing through a pre-emphasis network and the output of the amplifier applied directly to the repeller electrode of a reflex klystron. A reflex klystron with a tuned cavity has the property of being an oscillator, in this case in the 7000 Mc/s region. Given fixed mechanical dimensions the frequency of oscillation is dependent on the electrode voltages and is particularly sensitive to change in repeller voltage, hence if the signal is applied to the repeller, superimposed on the d.c. supply the resulting microwave oscillation will be frequency modulated. This type of modulator is simple, but has one serious drawback; the input signal level is not linearly related to the resulting change in frequency over a reasonable bandwidth. For transmission of television and more particularly multiplex telephony signals, good modulation linearity is essential and so methods have been evolved to overcome this non-linearity. In long haul systems low power specially designed klystrons are used with loading in the output waveguide. Using this arrangement it is not too difficult to obtain good linearity, however, quite a large amount of complex equipment (oscillators, A.F.C. circuits, mixers, and travelling wave amplifier) is required after modulation which if used in a short haul system would defeat the advantage of simplicity.

The modulating klystron in a short haul system is the actual power producing unit and power klystrons are usually non-linear. The problem has been overcome by the use of a special klystron with very heavy loading of the cavity, achieved by reflecting screws and a phase shifter in the output waveguide. This arrangement proves satisfactory if the mechanical construction of the whole klystron and waveguide assembly is extremely rigid, and temperature and d.c. electrode voltages remain very constant. The electrode voltages are held to very close tolerances by the use of highly regulated power supplies, and the temperature of the oscillator assembly held to within 1°C. by the use of a variable speed cooling fan controlled from a temperature feedback circuit. A diagram of the microwave section of a terminal is shown in Fig. 3.

The linearised modulated output from the klystron is fed through an isolator, a directional coupler and another isolator to the transmit waveguide filters. An isolator is a ferromagnetic waveguide device having a high attenuation to energy travelling in one direction and low attenuation to energy travelling in the other. The first isolator after the klystron prevents any variation in the output loading affecting the klystron loading and hence its linearity, the second gives extra protection in this regard and absorbs standing waves due to any filter mismatch. A directional coupler is a waveguide device which picks off a part of the power in the through waveguide travelling in one direction, but ignores any power propagating in reverse (See Fig. 3). It is used in this case to pick off a part of the output power for testing and alarm purposes; the transmitter alarm, and power meter are operated from a diode detector fed from the directional coupler.

Filters, Waveguide and Antenna

All transmitter outputs (up to three) are combined in waveguide channel branching filters and proceed by a common waveguide to a receiver and transmitter circulator. As there is only one antenna and main waveguide run, the output of the transmit filters must be fed through sort type of directional device to the main waveguide. The device must also be capable of accepting the receive signal and channelling it to the receive filters, without any power going to the transmit filters. In other words it must perform a function akin to the familiar 2 wire, 4 wire hybrid encountered in telephony. Such a device is termed a circulator, being descriptive of its electro-magnetic operation.

The common waveguide to the aerial has the internal dimensions of 3.48 cm. by 1.58 cm. and will transmit powers in the 7000 Mc/s band with 0.6 db attentuation per 10 meters, an average length waveguide run of 40 meters would hence give an attenuation of 2.4 db. To transmit telephony signals with low intermodulation distortion, and television with minimum waveform distortion, the waveguide should reflect very little power. To achieve this the internal walls of the straight and bend sections should be very smooth and of constant size, and the joints between sections should be such that a minimum discontinuity ensues. In practice small reflections will occur at joints, and to ensure that these are sufficiently small every waveguide run is tested after installation for standing wave ratio over the range of frequencies of the transmitters and receivers; this also ensures no damaged waveguide, or foreign matter in the guide goes undetected.

The short haul system invariably uses parabolic dish antennas due to their lower cost combined with high gain. The dishes are centre fed from a waveguide swan neck and horn. The antennas supplied by Marelli Lenkurt are three meter diameter parabolic dishes with a gain of 44 db over a short dipole, and the resultant beam of radiated energy is highly directive. For example, if such a dish is disaligned 1° from the true alignment in either the vertical or horizontal plane, the received signal strength will drop approximately 15 db.

The maximum path length possible is governed by the transmitted power, receiver noise factor, and the allowable maximum noise in either a telephone channel or on a television signal. Allowing a reasonable system margin, 30 miles would be the order of the maximum for a 600-channel telephony system or a 625-line television system.

Receiver

After passing through the circulator and receive channel branching filters the received signal proceeds into the receiver

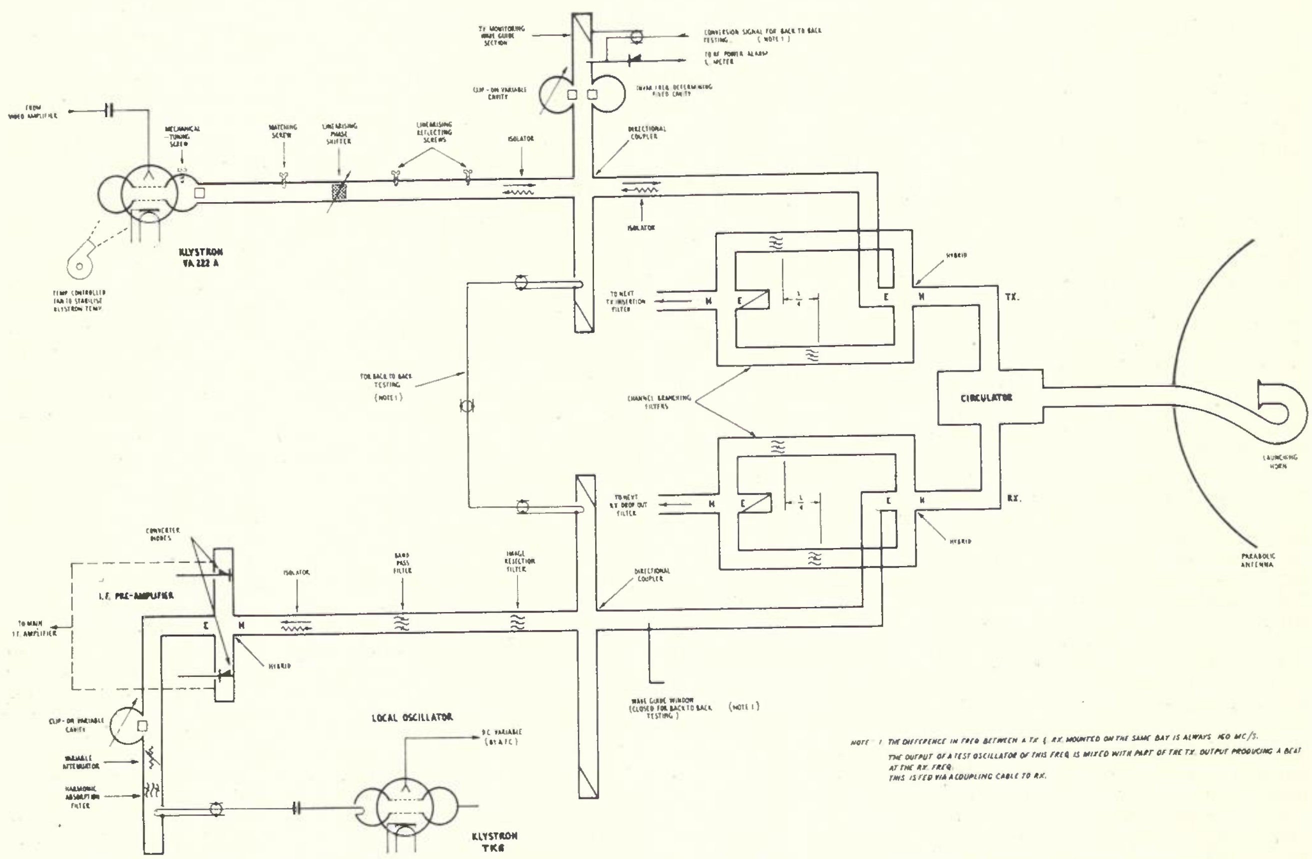


Fig. 3.—Schematic Diagram of Typical Microwave Circuitry for Short Haul Radio Broadband Bearer Terminal Equipment.

via a directional coupler for injecting test signals, an image frequency rejection filter, a channel band pass filter and an isolator. The signal then proceeds into a special piece of waveguide circuitry which functions as a hybrid network at microwave frequencies. It comprises a waveguide junction having four arms. The input microwave signal is fed into one arm, the local oscillator signal (70 Mc/s away from the carrier) is injected into the second arm and mixing occurs in balanced crystals situated in the third and fourth arms. The local oscillator consists of another reflex klystron coupled into the hybrid via a variable waveguide attenuator. The frequency of oscillation is governed by the klystron repeller voltage and this is used to control the local oscillator frequency via the Automatic Frequency Control (A.F.C.) loop. The A.F.C. keeps the intermediate frequency on 70 Mc/s by varying the local oscillator frequency to compensate for any changes in the distant transmitter frequency.

The output of the mixer crystals will be the frequency modulated signal centred around a carrier of 70 Mc/s. The I.F. preamplifier is a low noise 70 Mc/s amplifier which brings this signal up to a level where further amplification can take place without the need for subsequent low noise stages. The preamplifier has a fixed gain of 15 db and this remains constant within 0.1 db over the frequency range from 60 Mc/s to 80 Mc/s. The signal passes from the preamplifier through an amplitude and phase equaliser to the main I.F. amplifier. The main I.F. amplifier brings the signal up to a level suitable for demodulation and has a variable gain from 15 db to 65 db controlled by the input signal level by A.G.C. action to give a constant main I.F. output level of + 7 dbm. This is constant within 0.1 db over the frequency range 60 Mc/s to 80 Mc/s. There are three outputs from the main I.F. amplifier, the main output through which the signal passes, a sampled secondary output taking a signal to the A.F.C. panel, and a d.c. output with a value proportional to signal level. This d.c. output is amplified and used to control the signal fail and muting relay, and to control the gain of the main I.F. amplifier by altering the grid bias and hence the gain, of the valves used in each stage.

The secondary sampled output is taken to the A.F.C. panel where it passes through several narrow band limiter stages to a frequency discriminator. The d.c. output from the discriminator is proportional to frequency and is fed to the local oscillator repeller power supply; here it is used to directly control the repeller voltage. The polarities are arranged so that the local oscillator frequency changes to bring the intermediate frequency closer to 70 Mc/s.

The main output from the I.F. amplifier proceeds to the limiter discriminator panel where it passes through three limiter stages and to a wide band linear discriminator. The demodulated output signal should be similar to the pre-emphasised input signal, provided no significant distortions have been introduced. The discriminator output is de-emphasised and amplified in the receiver video amplifier to yield outputs of the required level.

TESTING

After installation of a broadband system the equipment must be thoroughly tested and set up to ensure optimum operation. Tests must be conducted on the transmitters, receivers, waveguide, filters and antennas.

Waveguide, Components and Antenna

The waveguide and antennas must be tested for standing wave ratio (S.W.R.), and the filters for S.W.R. and pass or stop frequency band. In a waveguide device the S.W.R. is an indication of the power reflected from a poor termination, or discontinuity. Several methods exist for measuring the ratio of forward to reflected power (related to S.W.R.), which differ in their method of execution but are similar in principle. The same pattern of apparatus is used for all these tests and usually consists of a microwave sweep oscillator, which will sweep over one or all of the channels; a means of launching the test signal into the waveguide, usually a coaxial to waveguide adaptor, crystal detectors, precision waveguide attenuators, directional couplers, a waveguide "magic tee", a precision wavemeter and various other minor waveguide components.

To measure the S.W.R., a swept signal is launched into the guide so that a measured amount proceeds to the section under test (Fig. 4). If the waveguide or antenna or whatever is being measured, presents a perfect termination over the entire swept band of frequencies, no power will be reflected: however, if a mismatch is present a reflection will occur and travel back to the launching point. This returned power is measured and compared with the forward power and the result displayed on an oscilloscope, the vertical axis giving the ratio of forward to reflected power and the horizontal axis, frequency. Variable, precision cavity absorption wavemeters are usually used to check the calibration of the horizontal frequency scale. Two devices commonly used for detecting the reflected power are the directional coupler (already described) and the waveguide hybrid which is also used in conjunction with launching the wave.

Transmitter

The transmitter must be tested for correct frequency, output power, linearity and deviation. To measure frequency the monitor output waveguide stub in the transmitter is used (see Fig. 3). This has an inbuilt invar cavity, tuned in the factory for resonance at the particular transmitter operating frequency; the cavity is not permanently coupled to the waveguide but can be brought into play by opening a small coupling window. The transmitter is tuned by adjusting the klystron repeller voltage or cavity and watching the power output meter for a dip, when this occurs the cavity is at resonance absorbing some of the monitor power. The frequency may be checked at any time during normal operation by simply opening the cavity "Window" and checking the dip in output. The output power can only be accurately checked by breaking the waveguide at a suitable point and inserting a power measuring termination; this usually consists of a waveguide termination with a small thermistor mounted near the end, the transmitter power heats the thermistor and changes its resistance, and this change is measured in a bridge circuit. Direct reading instruments of this type are commercially available.

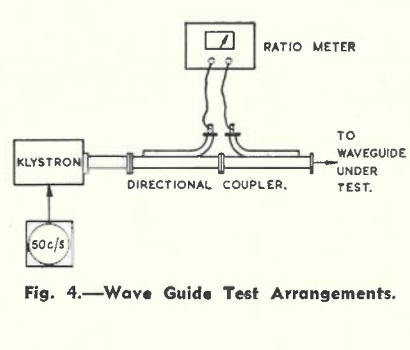


Fig. 4.—Wave Guide Test Arrangements.

The frequency deviation is set using the Bessel carrier null method. It is a well known fact that the frequency modulation sideband and carrier amplitudes are described by Bessel functions. As the modulating signal level changes, so does the amplitude of the carrier and the sidebands, and the relationship between these amplitudes is governed by Bessel functions of various orders depending on the sideband.

The carrier is described by a Bessel function of zero order and this first becomes zero, i.e., the carrier amplitude becomes zero when the ratio of peak deviation to modulating frequency is 2.4. The deviation is set by feeding the transmitter with a signal of calculated amplitude and frequency, displaying the sideband distribution on an oscilloscope screen and adjusting the deviation sensitivity until the first carrier null is observed. This sideband display is obtained by coupling the transmitter output into a receiver of the same frequency and sweeping the receiver local oscillator and hence the intermediate frequency up and down in frequency together with the oscilloscope horizontal trace. The I.F. output is mixed with a fixed 70 Mc/s signal and fed to an A.M. detector and low pass filter so that every time a carrier or sideband passes through 70 Mc/s, a small beat occurs. If the output of the above arrangement is fed to the vertical plates of the oscilloscope, each carrier and sideband is seen as a perturbation on the screen.

The linearity of frequency deviation with change of input signal is vitally important if good intermodulation characteristics are to be maintained; this quantity is measured as follows. A 50 c/s mains derived large amplitude signal is applied directly to the repeller of the transmitter klystron in such a way that the normal video signal can be superimposed (Fig. 5). The amplitude of the large signal is adjusted to sweep the klystron ± 7 Mc/s about the centre frequency. A small video signal of

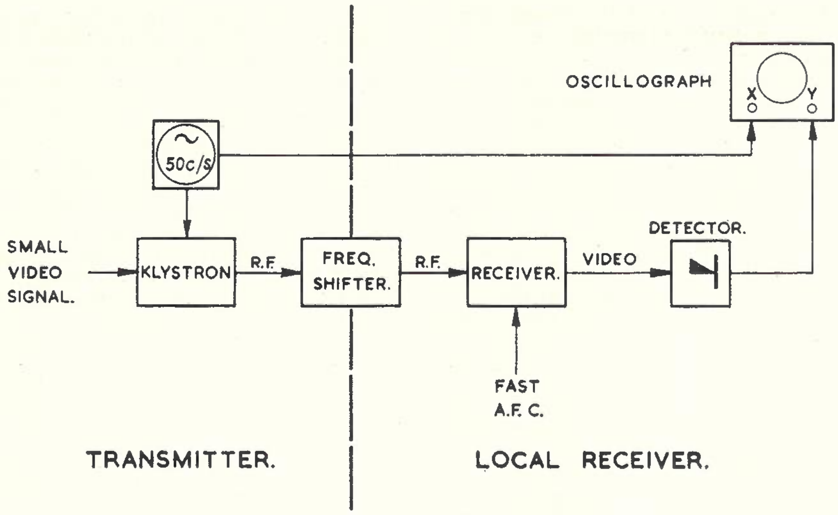


Fig. 5.—Transmitter Linearity Test.

constant amplitude and frequency is fed into the video circuits in the normal way. The transmitter output is propagated to the remote receiver of the same frequency, or is frequency shifted and coupled to a local receiver (see Fig. 3 for illustration of this mechanism). Now the change in deviation of the small constant video signal as the klystron is swept over its range, will represent changes in klystron linearity. If this is F.M. detected in the receiver, without the receiver discriminator affecting the linearity then the rectified output will represent transmitter linearity. However, the incoming receiver I.F. frequency will be sweeping up and down 7 Mc/s about 70 Mc/s and hence any non-linearity in the demodulating characteristics will also show up. To eliminate this, the long time constant is removed from the receiver automatic frequency control circuits, allowing the local oscillator frequency to follow the 50 c/s sweep thus keeping the I.F. on 70 Mc/s with only the small video signal sidebands appearing. This only uses a small and consequently linear part of the discriminator characteristic. The demodulated receiver output is displayed vertically on an oscilloscope swept horizontally at the same rate as the transmitter klystron thus linearity is read directly. The overall linearity is checked using this arrangement but not allowing the local oscillator to sweep with the transmitter, and the receiver linearity by sweeping the receiver klystron instead of the transmitter.

The transmitter baseband amplifier must be tested for a flat amplitude vs. frequency characteristic from 30 c/s to 5 Mc/s and this is usually done by spot frequency checks in the usual way.

Receiver

The receiver must be tested for correct I.F. frequency on incoming signal, noise factor, linearity, frequency and phase performance of I.F. circuits, baseband amplifier frequency response and output level. The I.F. is set to the correct frequency by feeding a crystal oscillator derived 70 Mc/s signal into the A.F.C. circuit, and adjusting the A.F.C. discriminator for zero d.c. output; sensitivity of the A.F.C. circuit is tested by feeding in signals a few Mc/s either side of 70 Mc/s and checking the amplitude and polarity of the A.F.C. discriminator output. When this is satisfactory, the A.F.C. will always keep the receiver tuned to the incoming transmitter, provided the local oscillator klystron remains within its normal operating range.

The receiver noise factor may be measured by detecting the I.F. signal with no receiver input and then feeding microwave noise into the receiver with an amplitude just sufficient to increase the I.F. output by 3 db. The externally generated noise is then substantially equal to the noise generated within the receiver. Microwave noise sources usually consist of argon or neon tubes introduced into the waveguide. The noise generated is a function of the current through the tube and the temperature, and each tube is supplied with a formula for computing receiver noise factor as a function of these quantities. The measurement of receiver discriminator linearity has already been described in the transmitter testing section.

The frequency vs. amplitude and frequency vs. phase response of the intermediate frequency circuits are measured by sweep methods. To test the frequency vs. amplitude response the output of a sweep generator sweeping linearly from 60 to 80 Mc/s is introduced at the input to the circuit and the A.M. detected output is fed to the vertical plates of an oscilloscope swept horizontally with the sweep generator. This yields the required response directly. The frequency vs. phase response is measured by injecting the sweep generator into the circuit exactly as for the amplitude response but with a small constant video signal modulated onto the main sweep. At the output of the section under test the signal is fed into a discriminator yielding a small video output of varying phase. The phase of this signal is compared with the video input in a phase comparator and a signal proportional to phase difference displayed on an oscilloscope in the same way as the amplitude response.

The baseband amplifier frequency vs. amplitude response is measured in the usual way and the equivalent is set by feeding line up signal into the transmitter (already adjusted for correct deviation) and adjusting the receiver baseband attenuator for line up level at the output.

Overall Testing

Certain overall tests must be carried out; baseband frequency vs. amplitude response, linearity, and white noise. The overall frequency response is usually measured by point to point or swept frequency methods and the system should be substantially flat from 30 c/s to 5 Mc/s, the degree of departure allowed depending on the length of the system. The overall linearity test has already been described, and to yield a good intermodulation figure the linearity should be better than 2% for 600-channel operation.

The white noise test gives the intermodulation and thermal noise performance of telephone channels when the system is fully loaded. White noise consists ideally of a signal having a uniform level at all frequencies in the band considered, and this is supposed to represent a band fully occupied by frequency multiplexed telephony traffic. To measure the intermodulation in one telephone channel due to all the others, the white noise is sent over the system with the output eliminated over a band of frequencies equivalent to one channel. At the output the signal introduced by the various items of equipment into this narrow band is measured with a selective level measuring set. Any signal present is either due to thermal noise or intermodulation. A great deal can be learned about the system performance to telephony by varying the noise input level, and the position of the eliminated channel.

The tests described may be considered as being the more basic tests carried out on a short haul bearer; there are many tests performed on a bearer to determine its performance for a particular application, e.g., television waveform tests, which have not been described. It is considered that those which are dealt with, test the more fundamental properties of the system. Although it could quite rightly be argued that transient tests in the time domain are just as applicable as frequency vs. amplitude and phase tests, these are not yet commonly used, except where the system is to carry television, and even then frequency domain tests are still carried out.

CONCLUSION

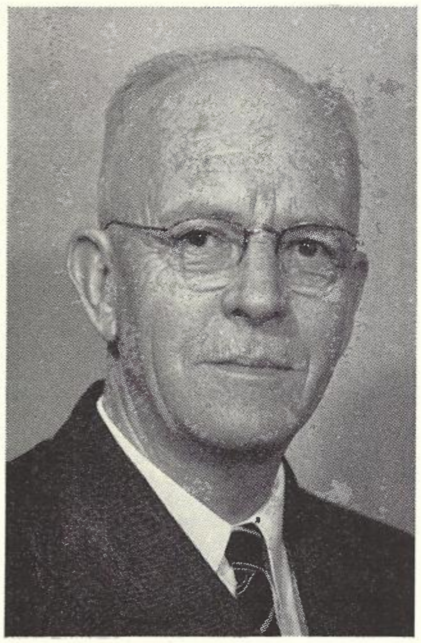
The passage of a signal has been traced through one hop of a short haul system in an approximate way to give an idea of the functions of each section of the equipment. From this it can be seen how simple some sections are, particularly the transmitter and the local oscillator of the receiver.

The points where the performance of

a short haul system is inferior to the long are in the transmitter linearity, stability of transmitter linearity, transmitter frequency stability and transmitter power. The poorer transmitter linearity and stability of linearity result in fewer telephony channels for a given intermodulation noise limit, but does not affect television markedly unless the stability is very poor. The frequency stability of a long haul system is crucial, as any drift in frequencies is additive and is transmitted throughout the link. In the limit the R.F. frequencies could approach the skirts of the waveguide filters giving reflections of the outer sidebands and consequent intermodulation in the baseband output. This is not such a problem in the short haul system and so a free running transmitter with an A.F.C. controlled receiver can be used providing a great simplification. The lower transmitted power results in poorer thermal or fluctuation noise in a channel, and repeater spacings must be adjusted accordingly. None of these limitations become serious unless the system has a large number of hops and, of course, it is then no longer a short haul circuit.

The major use for the short haul type of system at present is short single or multiple hops, either between centres or as a spur from a long haul system, so supplementing the other radio bearers. At present radio systems are somewhat limited in the capacity to provide a bearer capable of a long run with a large number of drop outs; where this situation is encountered, coaxial cable would still appear to be the logical solution. Research in the extraction and insertion of channels from non-demodulating repeaters of radio bearers is advancing and it is likely this will be the next major breakthrough in this field. When this occurs and the majority of equipment is transistorised it is likely that radio will be the appropriate bearer for all major routes.

CHANGE IN VICTORIAN ENGINEERING DIVISION MANAGEMENT



MR. E. D. CURTIS, M.I.E.Aust.

On 10th December, 1963, Mr. E. D. Curtis, M.I.E.Aust., retired from his position as Assistant Director, Engineering, Victoria, after a total period of 48 years' service. He commenced in the Department as a Telegraph Messenger in Victoria in 1916, became a Draftsman-in-Training in 1922 and qualified as Engineer in 1925. Following experience as an Engineer in internal plant work he was promoted as Assistant Supervising Engineer, Telegraph Service; Supervising Engineer, Radio and Telegraphs (1950); Superintending Engineer, Planning Branch (1955); and Assistant Director, Engineering (1960). His wise leadership in a time of rapid technical change and spectacular growth leaves the State in a strong position for the future.

Mr. Curtis actively supported the Society throughout his service and was President of the Victorian Division in 1960. The Board of Editors is pleased to record their appreciation for the contribution he made to the Society's growth and development in Victoria and takes this opportunity of wishing him, on behalf of the Society, a long and happy retirement.

Mr. I. M. Gunn, M.B.E., previously Assistant Engineer-in-Chief, Services at Headquarters, succeeds Mr. Curtis.

Mr. Gunn brings to his new appointment a broad background of engineering experience both in the States and at Central Office. Following appointment as Cadet Engineer in 1928, his initial service as Engineer was in a Country Division; as Divisional Engineer in 1940 he supervised the installation of the Melbourne-Seymour Trunk Cable. His subsequent State engineering experience included periods as Divisional Engineer, Transmission Measurements, Divisional Engineer, Ararat, Supervising Engineer, Country, Deputy Superintending Engineer, Metropolitan, and Superintending Engineer, Services. In 1957 he transferred to Central Office as Supervising Engineer, Lines, and in 1959 was appointed Assistant Engineer-in-Chief, Services.

Mr. Gunn received the M.B.E. award for the excellent past he played in the provision of communications for the 1956 Melbourne Olympic Games.

The Board of Editors and the Society have pleasure in congratulating Mr. Gunn on his new appointment and offer him best wishes and full support in his new sphere of activity.

MR. I. M. GUNN, M.B.E.

AUTOMATIC LINE INSULATION ROUTINERS

*B. DRAYSON**

INTRODUCTION

Moisture is one of the most frequent causes of service impairment in subscriber lines, but the effects of such faults are often intermittent; they appear in wet weather and disappear in dry weather. These transitory faults are usually, but not always, of the minor type causing slight interference to service such as noise or reduced transmission level. Lead cable sheaths that have developed fine cracks or sheath openings admit moisture during periods of rain or excessive dampness, and the insulation properties of the paper covered wires decrease. Leaks may appear at cable terminals or on interior wiring in the presence of excessive moisture.

However, in the case of plastic cable, plastic insulation is waterproof and failure of service only occurs if water has access to wires which are exposed through the insulation. Entry of water can be through pin holes occurring during manufacture or through faulty joints.

One danger with plastic cable is that water that has obtained access will travel along the cable and enter a joining lead covered paper insulated cable and cause failure. Water can flow along a level plastic cable at the rate of seven yards or more per hour, whereas in paper insulated cables with a more tightly packed core the paper insulation swells when wet preventing ingress of moisture. Water also causes corrosion of the copper conductors and if pinholes in adjoining conductor insulations are of the order of 1 foot apart, corrosion can occur in a few days.

Due to the lack of a conducting sheath, fault currents in plastic cables flow from the positive to the negative wires, thus causing foreign battery to be more prevalent in plastic than in paper insulated cables.

All of these types of cable faults can cause serious disruption to telephone services as was illustrated on Monday, 28th January, 1963, when over five inches of rain fell in Melbourne causing failure of several thousand metropolitan services. Of course, rain of this magnitude after a dry spell is unusual but any measures which could be taken to prevent such cable faults occurring thus preventing disruption to subscribers' services and saving the Department considerable expense and effort in locating these faults, would be well worth while.

One method of cable fault prevention at present being extended to subscriber cables is gas pressurisation. This feature is, of course, in general use on junction cables because their freedom from fault is of greater importance than subscriber cables; they are easier to deal with, too, because they are sealed at each end and are rarely disturbed.

Efforts to detect incipient cable faults so that they may be cleared before they cause serious trouble are possible by the use of Automatic Line Insulation Routiners, two of which are now in use in the Melbourne Telephone zone, one located at South Yarra Exchange and the other at Malvern Exchange.

The routiner is used to detect faults on subscribers' lines and is normally operated at night. The reason for this is to ensure that the greatest number of lines is available to be tested. The machine steps over busy lines which means that during a busy period of traffic, tests on large numbers of subs. lines would be omitted. Another reason for night testing is that this is the most effective time of day when air in cables is at its lowest temperature and the ensuing contraction has drawn additional air and moisture through any break in cable sheaths.

With large numbers of subscriber cables underground and the introduction of greater capacity cables, deterioration must be discovered before rain or flooding puts large numbers of circuits out of action. Preventive maintenance on line plant may be considered more important than on switching equipment, because line faults are more liable to cause a complete breakdown of a subscribers' service.

The aim is to discover cable faults during dry weather and with the aid of the Automatic Line Insulation Routiner, we have been able to detect and prevent large numbers of incipient cable faults from causing loss of service to many subscribers with the advent of wetter weather conditions.

EQUIPMENT

The routiner is designed to operate with conventional step-by-step exchange equipment. It can test line insulation either in a single exchange or several exchanges in sequence, obtaining access to subscribers' lines via a test distributor and test final selector. The routiner runs uninterruptedly finding line insulation faults that are below a pre-selected minimum level. Upon finding a fault, the routiner stops and prints out on a tape the subscriber's number, the sensitivity level (below which the fault was detected), and the type of fault located. Depending on whether the camp-on-fault feature is used, the routiner either stops on a fault and causes an alarm lamp to glow and a buzzer to operate, or proceeds to the next line and continues the automatic routining until the last line is tested.

Capacity: The routiner is designed for unattended operation, and can furnish a printed record of faulty line conditions for a maximum of nine exchanges (10,000 lines each) at a maximum rate of about 90 tests per minute (30 lines per minute), depending on sensitivity. The routiner normally tests at about 800 lines/hour.

The inter-exchange junction loop resistance should not exceed 1000 ohms, to ensure good impulsing characteristics. The junctions are four-wire circuits preferably with high insulation resistance to reduce the possibility of introducing an insulation leak between exchanges. One pair is used for operating the Test Distributor and the other pair for testing.

Features: A highly-sensitive D.C. amplifier and thyratron detector circuit is employed to accomplish line fault detection, the increased fault-circuit sensitivity makes possible earlier detection of battery, ground and loop faults. Controls and a lamp are provided to calibrate the fault circuit.

A test panel, housing keys and lamps, is mounted on the routiner rack. The keys are used to select the camp-on-fault feature and the initial start of testing function (or the restart of testing after a fault is detected with the camp-on-fault feature in use). The lamps on the test panel indicate routining progress, types of faults detected, busy lines and completion of routining.

DETAILED DESCRIPTION

Mounting: A steel rack (Fig. 1) provides mounting facilities for all equipment associated with the routiner. The rack measures 19½ inches wide and is 9 feet high. The routiner equipment

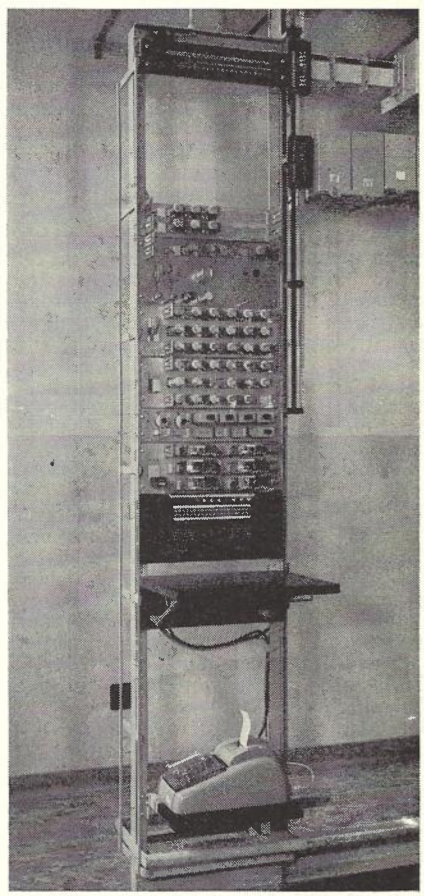


Fig. 1.—Front view of Automatic Line Insulation Routiner.

* Mr. Drayson is Engineer, Class 2, Metro. Service, Victoria. See page 333.

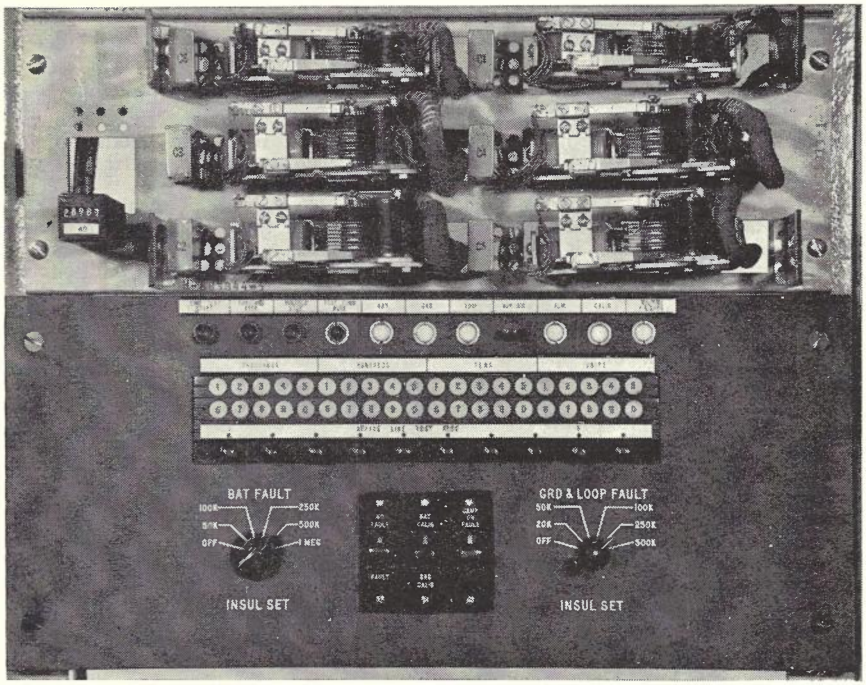


Fig. 2.—Test Control Panel.

is unit-mounted and the individual unit wiring terminates at terminal blocks at the rear of the assembly mounting strips. On the rack is mounted the fuse panel, auxiliary signal equipment, routiner equipment, common test equipment, test panel, a writing shelf and a readout printer; these components are described in subsequent paragraphs.

The fuse panel, mounted at the top of the rack, extends fused power distribution circuits to the equipment assemblies, and incorporates a lamp "FA", which, when lit, indicates a fuse has blown.

Auxiliary Signal Equipment: The auxiliary signal equipment consists of an alarm lamp (ALM), an auxiliary signal level key (AUG SIG), a relay and a buzzer. The AUX SIG key and the ALM lamp are mounted on the routiner test panel; the relay designated "C" and buzzer are mounted on the fuse panel.

With the AUX SIG and CAMP-ON-FAULT lever keys operated, a line fault causes the common test equipment to apply a ground on one side of the CAMP-ON-FAULT key thus completing a circuit through lamp ALM and relay C. Lamp ALM glows and the buzzer sounds from an earth via the operated contacts of relay C.

Test Panel: The test panel (Fig. 2) is installed at a convenient working height just below the common test equipment. All lamps and controls are mounted on the front of the test panel. The wiring at the rear of the panel is terminated at two terminal blocks to which connections are made to the routining equipment units, common test equipment, auxiliary signal circuit, and the fuse panel.

From this test panel, the operator can select any desired hundred or thousand group at which to start the test cycle. The camp-on-fault feature (and alarm, if desired) can also be selected along with the desired sensitivity range for insulation testing. These lamps and controls are described in the following paragraphs.

(i) Line Number, Thousands, Hundreds, Tens, Units (white). Ten lamps numbered 1 to 0 are mounted in each of the four groups. At any one time, only one lamp in the Thousands, one lamp in the Hundreds, one lamp in the Tens, and one lamp in the Units group will be lit indicating the line under test.

(ii) ALM lamp (white) glows whenever a fault is encountered. This lamp also comes on to indicate that the routiner itself is malfunctioning.

(iii) Fault, BAT, GRD, LOOP lamps (white) come on individually to indicate the type of line insulation fault encountered; foreign battery, L.I.R. to ground, or L.I.R. between.

(iv) TEST CONN BUSY lamp (red) indicates (when lit) that the test final selector accessed is busy. When the selector becomes idle, this lamp is extinguished. A busy test final can be jumped by pressing the start button.

(v) ROUTINE FINISHED lamp (green) comes on to indicate that the last line in the exchange has been tested.

(vi) CALIB lamp (white) is used in calibrating the sensitivity of the fault detection circuit.

Test Panel Controls: (i) Line Test Start push-button key operation causes the routiner to start functioning.

(ii) Camp-on-Fault (locking) lever key operation causes the routiner to stop when a line fault is detected, and causes the ALM lamp to be lit.

(iii) GRD CALIB/BAT. CALIB (locking) lever key is used to select either the ground and loop or the battery fault detection circuits for calibration.

(iv) THOUSAND STEP AND HUNDRED STEP push-button keys are used when it is desired to start the test cycle at a group other than the first hundred line group within an exchange. Momentary operation of these keys steps the corresponding rotary switch RS2 (thousands) or

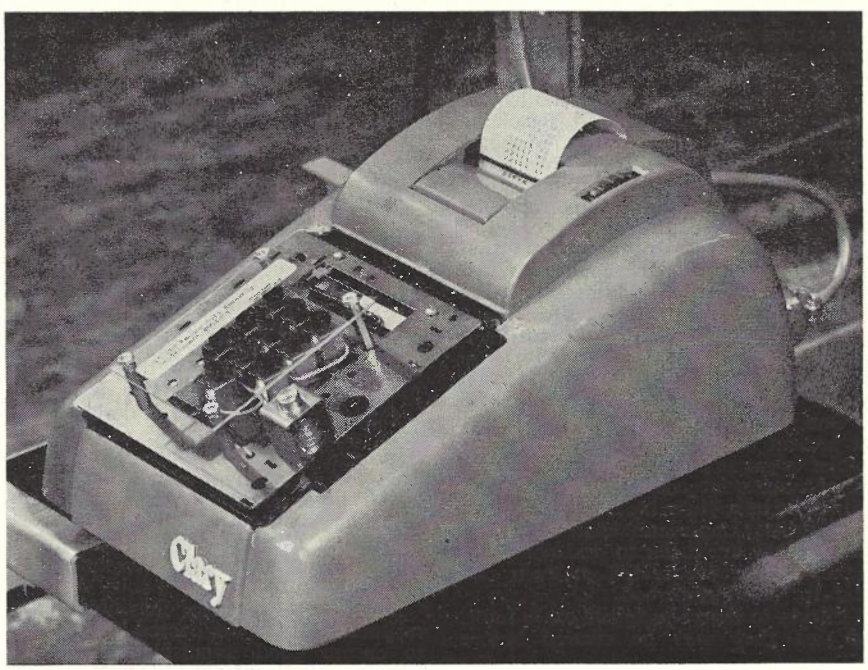


Fig. 3.—Clary Readout Printer.

RS3 (hundreds) once with each operation.

(v) BATT FAULT selector switch is a two level, five position switch. This switch selects one of five available sensitivity ranges for detecting battery line insulation faults (foreign battery). The selector switch resistance values corresponding to positions 1 to 5 are listed below:
Position 1— 50,000 ohms.
Position 2—100,000 ohms.
Position 3—250,000 ohms.
Position 4—500,000 ohms.
Position 5—1 megohm.
Setting of the selector switch to a desired position sets the minimum acceptable value of insulation resistance. For instance, to have the routiner record insulation faults of 100,000 ohms. or less, the BATT FAULT switch is set on position 2.

(vi) GRD AND LOOP FAULT selector switch is a two-level, five position switch. This switch selects one of five available sensitivity ranges for detecting ground and loop line insulation faults. The selector switch resistance values corresponding to positions 1 to 5 are listed below:
Position 1— 20,000 ohms.
Position 2— 50,000 ohms.
Position 3—100,000 ohms.
Position 4—250,000 ohms.
Position 5—500,000 ohms.

(vii) BAT CALIB AND GRD AND LOOP CALIB potentiometers are provided to calibrate the battery, and ground and loop fault detection circuit sensitivity.

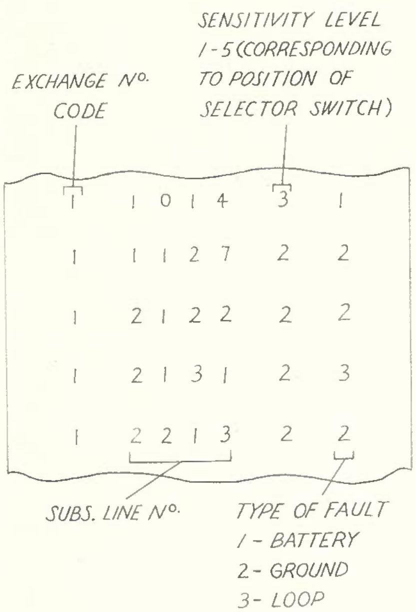


Fig. 4.—Section of Tape showing Fault Information.

Printer: The automatic line insulation routiner is equipped with a Clary Readout Printer (Fig. 3) which is mounted on a shelf similar to and below the test attendant's writing shelf. The readout printer prints out on tape, information regarding each line fault encountered. Thus a running and permanent record is kept of all line faults. A sample tape is shown in Fig. 4. The printer motor is powered by a 115V AC motor. The printer solenoids are connected to the Exchange battery and the common test equipment via a 27-way plug.

CONCLUSION

Although the line insulation testers have only been in service for a limited time they have illustrated the need for more such devices, and two more have been ordered to adequately cover the Melbourne telephone zone.

With the aid of this equipment it is possible to correct the greater part of insulation defects on a preventive maintenance basis which results in a reduction of subscriber reports. Service to the subscribers is thereby improved, maintenance effort reduced and repairs on an emergency basis involving the expenditure of overtime are required less frequently.

Obviously such equipment would not assist in detection of all cable faults unless operated continuously. Unless run continuously, a cable fault could occur after a line tester run and remain undetected until picked up by some other means, such as, for example, by P.G. alarms or gas pressure alarms. A combination of cable pressurisation with gas, automatic P.G. or cable fault alarms, together with planned use of the automatic line insulation routiner, gives every indication that a big improvement to the service rendered to subscribers under all conditions of weather will result, at an over-all economy in effort and cost expended.

ARTICLES BY P.M.G.'s DEPARTMENT STAFF APPEARING IN OTHER JOURNALS

An Application of Digital Computers in Telecommunication Network Planning.* By A. H. Freeman, A.M.I.E.Aust., and A. Gravell, B.Sc.

This paper reports an investigation being carried out by the Postmaster-General's Department into the network switching changes needed to make best use of a common control system in the Sydney telephone network. It describes the procedures involved in determining the junction circuit arrangement for optimum disposal of the network telephone traffic for any given arrangement of tandem switching points in the network and the methods used to calculate the cost of providing switching equipment and junction circuits to cater for the traffic distribution. The use of the Sydney University electronic computer, SILLIAC, to carry out the large volume of complex calculations is described, and the method of determining the optimum tandem layout for a large telephone network employing common control equipment is discussed.

Some Co-ordination Problems of Power and Telecommunication Lines.* By B. C. Todd, B.A., B.Sc., A.M.I.E.Aust. and R. Buring, B.Sc., B.E.

Recent developments in electric power practice are giving rise to particular difficulties in the operation of communication systems. Power and communication systems in Australia have been co-ordinated through the co-operation of engineers on field problems and through the working of the State and Central Joint Committees for Power Co-ordination. The paper broadly discusses a variety of power co-ordination problems and refers to aspects of recent interest to power and communication engineers in Australia. It outlines the difficulties arising from large fault currents and from unbalanced and earth return power systems. The effects of longitudinal induction are illustrated by reference to a severe exposure between Kiandra and Cabramurra in the Snowy Mountains. The effects of ground potential rise are discussed with particular reference to the provision of devices such as neutralizing transformers to protect telephone installations in power stations. A survey is given of the work to introduce economical forms of rural power distribution and to develop agreements and codes to control interference from rural power lines. The experimental isolated single-wire earth return system in the Mid-Lachlan County District is briefly described.

*These are abstracts of articles appearing in the Nov., 1963, issue of the Electrical and Mechanical Engineering Transactions of the Institution of Engineers, Australia.

THE USE OF TRANSISTORS WITH 3000 TYPE RELAYS

*A. MIDGLEY**

The application of transistors to the operation of 3000 type relays has to date been relatively limited. The high inductance of the 3000 type relay gives rise to a high back EMF on release, necessitating the use of some form of surge limiting in order to protect the transistor. This in turn causes the release time of the relay to be greatly increased and in many applications this can not be tolerated. Furthermore, the designer, confronted with the necessity of back EMF limiting, is usually not aware of the actual release time involved and being reluctant to carry out lengthy experiments on the subject, usually discards the original idea of using a transistor.

The aim of this article is to suggest a simplified design procedure, and to describe a method of reducing the release time of the relay. Included is a Table, giving measured release times of a range of coils under differing spring loads and residual air gaps.

TRANSISTOR TYPES

As the standard exchange 50V battery has the positive pole earthed, the PNP type transistor is most suitable for general use and is the only type considered herein. Although a large range of PNP transistors is now available, the majority have a voltage rating (Vce max or Vcb max) of 25 volts or less. For use on exchange supplies of —50V a rating of 60V or better is required and the range of types then becomes extremely limited. The type commonly used to date has been the OC77 which has a rating of 60V with base shorted to emitter (Vces). In some designs, however, it is required to have an appreciable resistance between base and emitter which necessitates a reduction in Vce, making the design marginal.

The type recommended as most suitable is the 2N398A, which has a voltage rating Vces of 105V and a maximum collector current (Ic max.) of 200 mA. The 2N398A is mounted in a standard Jedec T05 case and is a germanium PNP alloy type.

THE TRANSISTOR AS A SWITCH

The transistor used as a switch can be regarded as equivalent to a relay with one contact. It has two stable conditions:—

1. Cut off.
2. Bottomed or current saturated.

Condition 1 is easily achieved and no intricate design problems are involved. Referring to Fig. 1, TR1 is cut off when SW1 is in position 1 and no current will flow in RL except that due to inherent collector leakage current (Ices). For the 2N398A, Ices is approximately 50 micro-amps over the temperature range likely to be encountered in telephone exchanges.

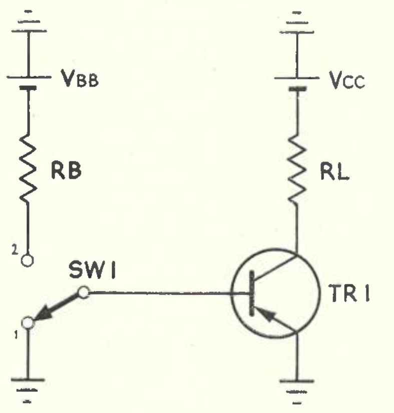


Fig. 1.—Basic Transistor Switching Circuit.

This current is so small, compared to those required for relay operation, that for most cases it can be ignored.

Condition 2 is achieved when an increase in base current causes no increase in collector current. In the general case, with a load in the collector circuit, this is achieved when virtually all the available supply voltage is dropped across the load resistor. There is a very small voltage drop across the transistor known as the knee or saturation voltage, (Vce sat) which in the case of the 2N398A is 350 millivolts (approx.). This value is very small compared to the usual supply voltages and this too can be ignored in most applications. Referring to Fig. 1, with SW1 in position 2, TR1 will be bottomed when the collector current (Ic) reaches a value which causes the supply voltage Vcc to appear across RL. In the practical application it is necessary to ensure that Ic in this condition is within the capability of the transistor. For the 2N398A it is required that $Ic < 200mA$.

The base current (Ib) required to bottom the transistor is governed by the required collector current and the DC current transfer ratio (β) of the transistor.

In a practical case, the necessary calculations become a simple application of Ohms Law. Referring again to Fig. 1:—

$$Ic = \frac{Vcc}{RL}$$

$$Ib = \frac{Ic}{\beta}$$

The published figures of β for a 2N398A are 60 average, 20 minimum. In order to allow for production spreads the minimum figure should be used in design calculations so that sufficient base current will flow to bottom all transistors likely to be encountered.

The voltage between base and emitter, Vbe (sat.), in the bottomed condition is quoted as 400 millivolts maximum for the 2N398A. As this figure is small compared to the usual base supply voltage (Vbb) it can be ignored in the calculation of the value of RB. In Fig. 1, the value of RB for a 2N398A is then:—

$$RB = \frac{Vbb}{Ib} = \frac{Vbb \times \beta}{Ic} = \frac{Vbb \times 20}{Ic}$$

DESIGN EXAMPLE

A typical design example is illustrated in Fig. 2. It is required that relay X should operate when the uniselector moves off its home contact. It is also required that in the idle condition (i.e., uniselector on home contact) the current drain should be a minimum. A further self evident requirement is that the cost of the final design should be as low as possible.

Figs. 2 (a) and (b) illustrate typical approaches to the problem, examples of which are numerous in telephony. In Fig. 2 (a) it is obvious that the idle current drain must be greater than the working current drain and infringes the standby requirement. Fig. 2 (b) involves the use of a slave relay with its cost penalty and the need for additional maintenance. Fig. 2 (c) represents an approach using a transistor. In the idle condition TR1 is off and the only current drain is that due to R1, i.e., 2mA. (approx.) therefore, this design is better than Fig. 2 (a). This design is also better than Fig. 2 (b) as the cost is lower than that of an additional relay and there is no additional contact to maintain.

The design steps involved for Fig. 2 (c) are simple. A suitable relay coil is selected, e.g., 4/SCO/441, 2000 ohms, 14,000 turns. When TR1 is bottomed the current through relay X (Ic) $= \frac{Vcc}{R1} = \frac{50}{2000} = 25mA$. This current is well below Ic max for a 2N398A. At this current there are 350 ampere/turns available which is adequate to operate 8 X 14 mil contact units with a 4 mil residual air gap.

The base current required is:—

$$Ib = \frac{Ic}{\beta}$$

$$Ib = \frac{25}{20} \text{ mA.}$$

$$= 1.25 \text{ mA.}$$

The value of R1 is given by:—

$$R1 = \frac{Vbb}{Ib} = \frac{50 \times 1000}{1.25}$$

$= 40,000$ ohms.

$= 39$ k-ohms nearest standard value.

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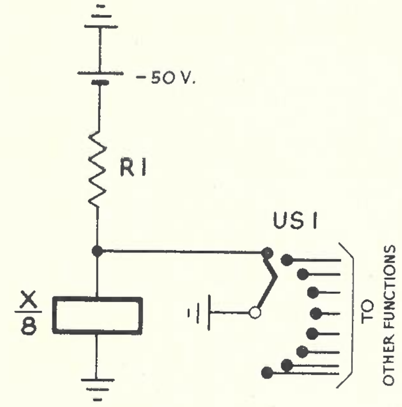
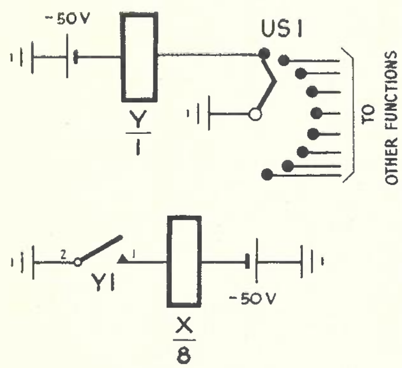
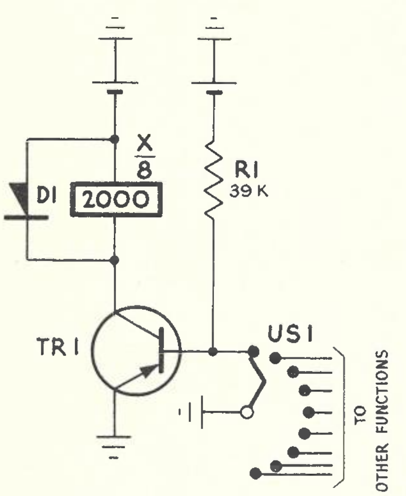
* Mr. Midgley is Supervising Technician, Overseas Radio Terminal, Sydney. See page 334.



(a) Shunt Method.



(b) Slave Relay Method.



(c) Transistor Method.

Fig. 2.—Three Approaches to a Switching Problem.

PROTECTION OF TRANSISTOR AT SWITCH OFF

In Fig. 2 (c), when TR1 is switched off by the uniselector returning home, the high inductance of the relay coil causes a high back EMF to appear across the coil, this potential being effectively in series with the supply voltage. The magnitude of this back EMF was checked experimentally on a number of coils by means of an oscilloscope, and it was found that even with coils with only sufficient ampere/turns for one or two springsets, back EMF's of the order of 1000 volts were produced. This high peak voltage was only present for a few microseconds, but would be quite capable of destroying the transistor. A simple and commonly used method of protection is to shunt the relay coil with a diode as in Fig. 2 (c). This prevents the voltage at the collector from rising above the supply voltage and effectively protects the transistor. The disadvantage of the method is that the diode, commonly referred to as a clamping or catching diode, has a slugging effect on the relay, making it slow to release. In the circuit of Fig. 2 (c) using a 4/SCO/441 coil and a 4 mil residual air gap, the release time was found to be 37 milliseconds. When the coil was changed to a 1/SCO/441, 2000 ohms and 22,000 turns, the release time was 135 milliseconds for the same residual air gap, and 90 milliseconds and 50 milliseconds respectively with air gaps of 12 and 20 mils.

It is possible to use a capacitor in lieu of a diode for protection, but this method also increases the release time of the relay and has a further disadvantage that at "switch on" a high charging current flows resulting in high peak collector dissipation in the transistor.

A method of reducing the release time of the relay, when a catching diode is used, has been suggested by C. F. Hill, of the Mullard Valve Co. (1). The basis of the method is that the catching diode is returned to a low impedance source, the voltage of which is higher than the collector supply voltage and yet lower than Vce (max) for the particular transistor. It is essential that the potential chosen for the catching diode return should be less than the avalanche voltage of the transistor at the collector current existing at switch off (2).

This method has been investigated with particular reference to its application to Departmental requirements and as a result a basic design as in Fig. 3 has been evolved.

When compared with a shunt diode the method offers a substantial decrease in release time, a typical example being 70 milliseconds with shunt diode reduced to 10 milliseconds, the circuit arrangement being as in Fig. 3, and the coil being 28/SCO/439, 8 × 14 mil spring units and a 4 mil residual air gap.

The choice of 12 volts as the collector supply was governed largely by the range of standard relay coils available. The use of a 200 ohm coil and a 12 V supply results in a collector current of 60 mA which is well within the capabilities of the 2N398A and the range of standard 200 ohms coils is such that any standard spring loading can be accommodated at 60 mA coil current. A further factor is that the ratio of collector supply voltage to catching voltage is high thus allowing the collector voltage at switch off to rise considerably above Vcc before the catching diode conducts, thereby greatly reducing the relay release lag.

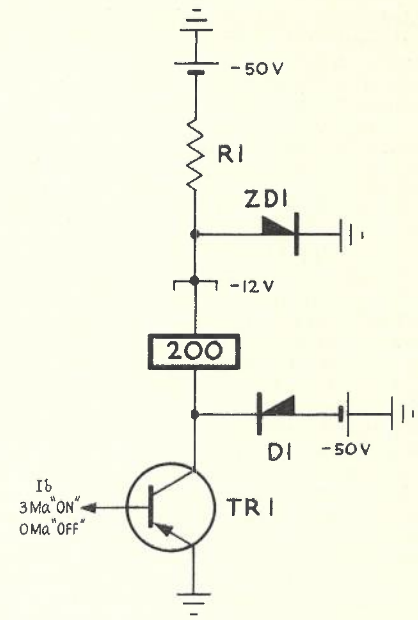


Fig. 3.—Basic Circuit for Reducing Release Lag of Transistor Operated Relay.

A 12 V supply is readily available from the standard 50 V exchange supply by utilizing a zener diode, suitable diodes in 1, 3 and 10 Watt ratings being readily available. Where a 12 V supply is derived in this manner, it is, of course, necessary to ensure that a standing current flows in the zener diode, even under maximum load conditions, to ensure satisfactory regulation.

AVALANCHE BREAKDOWN

The maximum voltage ratings for transistors as quoted by the manufacturer refer to the cut off condition. As collector current increases the voltage rating of a transistor falls. With a resistive load in the collector circuit, the voltage drop across this load causes the collector-emitter voltage to fall and the transistor remains in a safe operating region. However, with an inductive load, when "switch off" occurs, the collector-emitter voltage rises immediately to the reference voltage of the catching diode, while the collector current is still decreasing. A possibility of avalanche breakdown then exists if the catching voltage is higher than the the avalanche voltage, at the collector current then existing. Transistor manufacturers are usually not specific on this point, and voltage ratings for high collector currents are not generally available. However, it would appear that the danger of avalanche breakdown with inductive collector loads is mainly confined to power transistors with collector currents of the order of amperes. The operating conditions chosen for the basic design of Fig. 3 are, therefore, such that avalanche breakdown is not likely to occur.

POWER DISSIPATION

The power dissipation in a transistor in the "on" condition is the sum of the powers dissipated in the collector-emitter and base-emitter circuits. Provided that the transistor is fully bottomed this power dissipation is usually quite small. Considering the case of a 2N398A at Ic max and fully bottomed, the total power dissipated, P. Tot., is:—

$$P.\ Tot = Pce + Pbe$$
$$= Vce\ (sat.)\ Ic + Vbe\ (sat.)\ Ib$$
$$= 0.35 \times 0.2 + 0.4 \times \frac{0.2}{20}$$
$$(\text{Taking } \beta = 20)$$
$$= .07 + .004\ W$$
$$= 74\ mW.$$

The quoted figure for maximum power dissipation for the 2N398A is 90 mW at an ambient temperature of 55°C. so that it can be seen that power dissipation is not a problem where ON—OFF saturated switching is employed even at maximum IC. During the transition period from "ON" to "OFF", however, high peak dissipation can occur with inductive collector loads (1, 2, 3) and requires to be considered for each individual case. For the particular applications considered herein, this dissipation is not excessive, provided that the maximum switching rate is of the order of 10-15 per second. At higher switching rates the cumulative effect of each dissipation peak can give rise to destructive heating of the collector-base junction.

CHOICE OF CATCHING DIODE

The choice of a catching diode is dictated by the required reverse voltage ratings and peak diode current, in the particular application. A reverse voltage rating in excess of 50V is required for a 50 V battery supply and is suitable for all applications considered, but the peak current rating requires to be calculated for the individual case.

This peak current is the current flowing in the relay immediately prior to "switch-off". While these requirements can generally be met by a germanium point contact diode, it has been found that these types tend to be unreliable in this class of service and it is therefore recommended that a silicon junction diode be used, suitable types being 1N2860, OA620, etc.

RELAY RELEASE TIMES

In order to further simplify design procedures, a test circuit as in Fig. 3 was set up and the release times of the useable range of 200 ohm coils were measured. These measurements were made with the catching diode returned to both —12V and —50V. The results are set out in Table 1. It will be seen that the shortest release times are obtained when the design ampere/turns for a given spring load and residual air gap are approximately equal to the available ampere/turns.

An example of the use of this table is given in Fig. 4. Relay X and Y are both transistor operated and are released by a common function elsewhere in the relay set. It is required that on the release of Y a pulse be generated with a minimum pulse length of 50 milliseconds. It is also required that the release action of X and Y be completed in less than 100 milliseconds. The pulse is generated by the overlap action of X1 and Y1 contact groups. As X1 and 2 contacts are required to be made for the pulse to exist, X relay must have the longer release time. A 1/SCO/439 coil with seven contacts and four mil residual will, from the chart, result in a release time of 75 milliseconds with the catching diode returned to —12V. This will satisfy the requirement of release action less than 100 milliseconds. If a 34/SCO/471 coil with 12 mil residual is chosen for relay Y and the catching diode is returned to —50V a release time of 10 milliseconds will result. This in turn gives a release overlap of 65 milliseconds and satisfies the requirement of minimum pulse length 50 milliseconds. The margins between the timing requirements and the figures derived from the table are such that with normal coil manufacturing tolerances and relay adjustment tolerances, timing requirements would still be met.

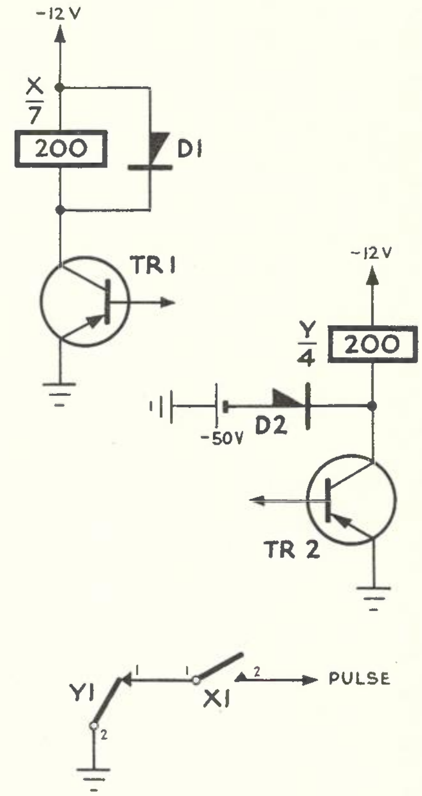


Fig. 4.—Example of Use of Table 1 to Develop 50 M/Sec. Pulse from Transistor Operated Relays.

WHEN TO USE A TRANSISTOR

Possibly the main advantage of operating a relay by means of a transistor is the operating sensitivity so obtained. Where the operating current drawn by a relay is within the capability of the operating source it would generally be better practice to operate the relay direct. However, many cases

TABLE 1—RELEASE TIME OF 200 OHM 3000 TYPE RELAYS

Coil Part No.	No. of Turns	Available Amp./Turns	4 Mils. Residual				12 Mils. Residual				20 Mils. Residual			
			No. of Contact Units	Design Operate Amp./Turns	Release Time in M/Secs. Condition 1	Release Time in M/Secs. Condition 2	No. of Contact Units	Design Operate Amp./Turns	Release Time in M/Secs. Condition 1	Release Time in M/Secs. Condition 2	No. of Contact Units	Design Operate Amp./Turns	Release Time in M/Secs. Condition 1	Release Time in M/Secs. Condition 2
20 SCO 439	3600	216	4	220	25	12	2	190	26	13	1	190	25	13
21 SCO 439	4200	252	5	240	37	15	3	230	28	12	2	230	24	12
34 SCO 471	4550	273	6	270	40	15	4	270	22	10	2	230	26	12
42 SCO 471	5000	300	7	290	32	12	5	300	26	11	3	290	19	9
28 SCO 439	5400	324	8	320	48	13	6	330	34	12	4	330	20	9
1 SCO 439	7000	420	8	320	70	14	8	380	49	11	6	410	30	12
"	"	"	7	290	75	16	7	350	48	12	5	370	35	13
"	"	"	6	270	88	19	6	330	49	14	4	330	37	13
"	"	"	5	240	100	19	5	300	58	15	3	290	45	14
"	"	"	4	220	110	22	4	270	66	15	2	230	68	19
"	"	"	3	190	125	28	3	230	81	17	1	190	97	26
"	"	"	2	150	196	46	2	190	103	25				
"	"	"	1	110	360	78	1	140	141	35				

Test Circuit as for Fig. 3. Condition 1—Diode returned to —12V Condition 2—Diode returned to —50V arise where such loading is not permissible and the current gain of a transistor can then be used to advantage.

Such a case is in test and supervisory equipment where it is often required that test and supervisory functions be performed on working circuits with a minimum of disturbance to the circuit concerned. In these cases it is often possible to utilize the low circuit loading factor of a transistor and avoid the use of a high resistance relay. Reduced cost and improved reliability can be obtained with a transistor approach, as high resistance relays are expensive to manufacture because of the fine gauge wire used and the liability to failure of such a coil is high, again because of the fine wire gauge.

The functions required to be performed by modern switching equipment are so diverse that possible applications of transistor switching are too numerous to be mentioned here. However, individual circuit designers will no doubt be aware of the possibilities in their own sphere of operations.

CONCLUSION

The impact of semi-conductors on the electronic industry in general has been remarkable, but to date the telephone switching field has seen only limited use of these devices. As device parameters improve and circuit designers become more familiar with their capabilities, the use of semi-conductors in the telephone field will inevitably increase. It is, therefore, hoped that the information contained herein will help to simplify detailed circuit design work in this field.

REFERENCES

1. Mullard Technical Communication, No. 19, July, 1956, pages 284-288.
2. Mullard Reference Manual of Transistor Circuits, page 254.
3. G. E. Transistor Manual, Chapter 6.

Contributions and Letters to the Editors

may be addressed to:

the State Secretaries or the General Secretary at the following addresses:—

The State Secretary,
Telecommunication Society of Australia,
Box 6026, G.P.O., Sydney, N.S.W.
Box 1802Q, Elizabeth St. P.O., Melbourne, Vic.
Box 1489V, G.P.O. Brisbane, Qld.
Box 1069J, G.P.O. Adelaide, S.A.
Box T1804, G.P.O., Perth, W.A.
Box 246C, G.P.O. Hobart, Tas.

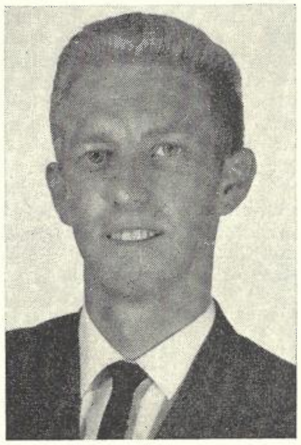
The General Secretary,
Telecommunication Society of Australia,
Box 4050, G.P.O. Melbourne,
Victoria, Australia.

Agent in New Zealand: E. C. Cheyne, c/o Engineer-in-Chief, G.P.O., Welllington, C.1.

Agent in Europe: P. S. Bethell, B.Sc., Dip.P.A. Australia House, Strand, London, W.C.2, England.

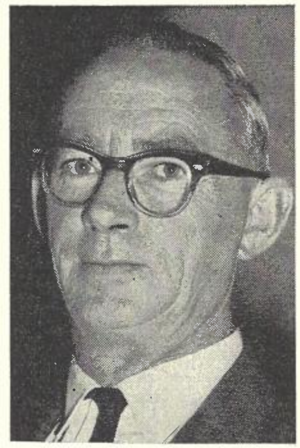
OUR CONTRIBUTORS

K. M. BARTSCH



B. R. KLOSE

G. MOOT



A. D. PETTERSSON

K. M. BARTSCH, co-author of the article "Pilot Installation of ARK Crossbar Exchanges", joined the Postmaster-General's Department in Adelaide in 1947 as a Technician-in-training. After completing this course he became a Type B Cadet Engineer. He graduated as Bachelor of Engineering at the University of Adelaide in 1957 and was appointed Engineer, Grade 1, Equipment Installation, in 1957. In 1958 he was engaged on circuit design as assistant to the Circuit Liaison Officer. Since 1959, when he was promoted to Group Engineer, Mr. Bartsch has been attached to the Long Line and Country Installation Division. He has been associated with the installations of Carrier equipment including the Alice Springs-Darwin 12-channel system which uses transistorised pole mounted minor repeaters between the regular repeater stations, as well as R.A.X.s and 2,000 type automatic exchanges. Since the beginning of 1963 he has been associated with the installations of ARK 511 and ARK 521 exchanges in South Australia.

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B. R. KLOSE, co-author of the article, "Pilot Installation of ARK Crossbar Exchanges", commenced with the Postmaster-General's Department as a Cadet Engineer in Adelaide in 1959. He graduated as Bachelor of Engineering at the University of Adelaide in 1962 and was appointed Engineer, Class 1, to the Long Line and Telegraphs Section in 1963. Mr. Klose is attached to the Long Line and Country Installation Division and has been associated with ARK 511 and ARK 521 crossbar exchanges since their introduction to South Australia.

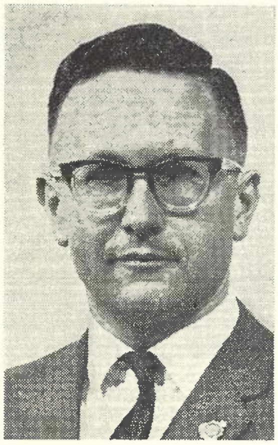
Mr. G. MOOT, author of the article, "Maintenance of Telephone Networks Comprising Crossbar and Step-by-Step Equipment", commenced in the Department in 1944 as a Technician-in-training. He completed the Cadet Engineer course in New South Wales in 1952 and served for a short period in a Metropolitan Service Division in Sydney. From 1954 to 1957 he served as an Engineer Class 2 in the N.S.W. Trunk Service Section, where his duties included control of the Sydney trunk exchanges and test room and the investigation and supervision of trunk switching and signalling maintenance practices throughout New South Wales. In June, 1957, Mr. Moot was appointed Engineer, Class 3, Telephone Equipment Maintenance, Headquarters, and represented this Administration at an international maintenance conference in Stockholm arranged by L M Ericsson. Mr. Moot has been engaged in the development of policy and practices for exchange equipment maintenance, with particular emphasis on qualitative maintenance techniques. He was promoted Engineer, Class 4, in late 1963 and is now Sectional Engineer, Exchange Installation and Service Standards. He is an Associate Member of the Institution of Engineers, Australia.

★

A. D. PETTERSSON, author of the article, "Maintenance of ARF 102 Crossbar Exchanges," is Divisional Engineer in charge of the Toowoomba Division, Queensland. He joined the Postmaster-General's Department in 1938 and, after training as a Cadet Engineer, was promoted as Engineer in 1948. Mr. Pettersson has been stationed at Toowoomba since 1954, and was closely associated with the first ARF 10 Crossbar installation in Australia. He has been attached to the Telephone Equipment Section at Headquarters since 1963, employed on the development of the supervisory practices for ARF 102 equipment described in his article, and the preparation of Engineering Instructions. He recently visited all Australian States giving staff training and guidance on the maintenance of Crossbar equipment and in 1963, visited Thailand for three months to provide technical assistance and training for the Telephone Organisation of Thailand. Mr. Pettersson is an Associate Member of the Institution of Engineers, Australia, and of the Institution of Radio and Electronic Engineers, Australia.

★

W. R. DEDRICK, author of the article, "Materials and Components in Crossbar", joined the Postmaster-General's Department in 1937 as a Clerk and was promoted Cadet Engineer in 1942 whilst on War Service with the A.I.F. In 1946 he commenced training, graduating B.Sc. (Melbourne) in 1948 and qualifying as Engineer in 1950. After experience in the Victorian Administration as Engineer and Group Engineer on Metropolitan Service, and Divisional Engineer, Subscribers' Installation, he was promoted Divisional Engineer, Training, at Headquarters, in 1953. He acted as Sectional Engineer, Training, from 1956-60. Whilst on training he was associated with all aspects of Engineering Division training, including the review of the A.P.O. Engineering Instruction system in 1955, the Trainee Engineer scheme introduced in 1956 and the 1958 revi-



W. R. DEDRICK

R. LANGEVAD

A. HOLDERNESS

S. J. MOFFAT

sion of the Technician-in-Training scheme. He transferred to the Telephone Equipment Section in 1960 as acting Sectional Engineer, Exchange Equipment Design, and was promoted to that position in 1962. In this capacity he is responsible for preparing drawings and other documents, for reviewing standards and specifications and for liaison with manufacturers on technical aspects of exchange equipment. Mr. Dedrick is an Associate Member of the Institution of Engineers, Australia.

★

R. LANGEVAD, author of the article, "Quality Assurance of Crossbar Equipment Manufactured in Australia", joined the Postmaster-General's Department as an Engineer in 1948. He enlisted in the Royal Australian Navy in 1942 as a Radio Mechanic and after discharge in 1945 completed a Bachelor degree course in Mechanical and Electrical Engineering at the University of Sydney. Since joining the Department, Mr. Langevad has had eight years' experience in Primary Works and Districts Works Divisions in Sydney and in 1955 was transferred to the new position of Divisional Engineer, Material Testing, to which he was appointed in 1956. From 1956 to 1963, in conjunction with T. & E. I. Pty. Ltd. and S.T.C. Pty Ltd., he was associated with the development of scientific method as applied to the inspection of the Department's engineering equipment, including statistical sampling and quality control. Mr. Langevad was appointed Supervising Engineer, Supplies and Training, N.S.W. in 1963. He is an Associate Member of the Institution of Engineers, Australia.

A. HOLDERNESS, author of the article, "Ring and Service Tone Equipment for Crossbar Exchanges," served four years with the Australian Electrical & Mechanical Engineers before completing a Diploma of Electrical Engineering (Footscray Technical School). He then joined the State Electricity Commission and later the Department of Supply. In 1958 he joined the Postmaster-General's Department, entering the Telephone Equipment Section, where he carried out the design and development of power plants. He recently joined the newly-formed power group in the Telegraphs, Power and Subscribers' Equipment Section of Central Office as Engineer, Class 3. He is an Associate Member of the Institution of Engineers, Australia.

★

B. R. DRAYSON

S. J. MOFFAT, author of the article, "Plug Terminating at Petersham Exchange," joined the Postmaster-General's Department as Telegraph Messenger in New South Wales, in 1937. After service with the Second A.I.F., he transferred to the Engineering Branch in 1947, and qualified as Technician in 1952 and as Senior Technician in 1959. Since 1952, he has been engaged on exchange installation works throughout the Sydney metropolitan area with Metropolitan Exchange Installation Division No. 3. Mr. Moffat attended a crossbar training course at Toowoomba (Qld.) in 1960. He acted as Supervising Technician, Grade 1, assisting the controlling Supervising Technician at Petersham Crossbar Installation and is at present acting as Supervising Technician, Grade 1, at Sefton Crossbar Installation.

★

B. R. DRAYSON, author of the article, "Automatic Line Insulation Routines", came to Australia from England in 1953. After a period in Western Australia, he joined the Government Aircraft Factory, Fisherman's Bend, Melbourne, as an Engineer, Grade 1, engaged on work connected with the Jindivic pilotless plane. He commenced with the Postmaster-General's Department in 1958 and after six months Induction Course, joined the P.A.B.X. Installation Division, Melbourne, as an Engineer, Grade 1. Following a period of 18 months with the P.A.B.X. Division, he was transferred to the Metro. Service Section, Melbourne, and acted as Group Engineer with the South Eastern Division. In 1961 he was transferred to the position he now occupies; Engineer, Class 2, Metro. Service, Eastern Division.

G. FEIGE

R. J. MUIR

F. HERBSTREIT

A. MIDGLEY

G. FEIGE, author of the article, "Quality Control During Assembly of Teleprinter Model 100", commenced as a Development Engineer in the Central Laboratories of Siemens & Halske AG, Berlin, in 1947, after completing his studies. Among other tasks, he was in charge of testing and further development of sub-assemblies of Teleprinter Model 100. Following this occupation he was charged with working out and making available test equipment for the assembly and final testing of teleprinters. Since 1959 he has been the Head of the Technical Department for teleprinter equipment in Berlin.

★

R. J. MUIR, co-author of the article, "Power Co-ordination in the Snowy Mountains Area", is a Divisional Engineer in the Transmission Planning Section in Sydney. He has the dual responsibilities of power co-ordination and radio-telephone planning. After war service with the R.A.A.F., he joined the Department in 1949 as an Undergraduate Cadet Engineer, while studying for the degree of Bachelor of Mechanical and Electrical Engineering at Sydney University, where he subsequently graduated with honours. He served in Metropolitan District Works and Lines Planning Sections in Sydney before being promoted as Divisional Engineer in charge of the Country Division of Bathurst. He transferred to his present position in 1962.

★

F. HERBSTREIT, author of the article "Epoxy Resin Based Joint for Large Size Cable", joined the Department in Victoria as a Cable Jointer's Assistant in 1951 and subsequently qualified as a Jointer and after several years' experience became a Cable Balancing Officer. In 1959 he transferred to Methods and Training Section, Central Office, to assist with a work study project on cable jointing. During this period he attended a Work Simplification Course, T.W.I. Jobs Method Course, and a Teacher Training Course. In 1961 he was transferred to the Lines Section, Central Office, where he assisted with writing Engineering Instructions on the improved method of cable jointing, and trained instructors in all States with this new method. Recently he has been engaged on a preliminary work study on cable hauling practices and the development of a suitable seal for large size plastic sheathed cable.

★

A. MIDGLEY, author of the article, "The Use of Transistors with 3,000 Type Relays", joined the Engineering Division, P.M.G.'s Department in 1940 as a Technician-in-training. He enlisted in the R.A.A.F. in 1942 and served in the South Pacific area as a Radar Technician. Following his discharge he resumed training as a technician and was appointed Technician and Senior Technician in 1948. After a brief stay in Metropolitan Service (Northern Division), he transferred to Country Service Section, where he worked as a Senior Technician in the Sydney Trunk Test Room and Overseas Radio Terminal. From 1953 to 1956 he was acting Supervising Technician (Inspection) in Trunk Service No. 2 engaged on maintenance oversight of the open wire system in country districts. Since 1956 Mr. Midgley has been working in the Overseas Radio Terminal, G.P.O., where he is appointed Supervising Technician, Grade 3.

ANSWERS TO EXAMINATION QUESTIONS

Senior Technician (Telecommunications) Telephone, Telegraphs, Radio and Research—July, 1962.
Telecommunication Principles — Paper No. 1. (Continued from Vol. 13, No. 6).

QUESTION 12.

(a) Briefly explain the principle of the vacuum tube voltmeter.

(b) A 600 ohm balanced attenuator has a nominal attenuation of 40 db at 10 Kc/s. The maximum permissible input power to the attenuator is 1 milliwatt. Describe with the aid of diagrams how you would check the loss of the attenuator.

ANSWER 12 (E. CULPH).

(a) Vacuum tube voltmeters are designed to achieve increased input impedance and/or increased sensitivity of the meter.

A meter can be connected between the cathodes of two identical triodes. Fig. 1.

The circuit is that of a Wheatstone bridge V1, V2, R1 and R2 comprising the arms.

When a voltage is applied to the input the grid potential of V1 changes causing an unbalance of the bridge which results in a current through the meter.

The deflection of the meter is dependent on the input voltage.

For A.C. operation a rectifying circuit is added to the input circuit.

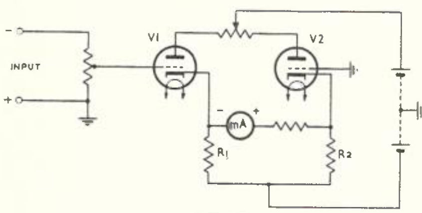


Fig. 1

This circuit does not give a great increase in sensitivity as the valves are operating as cathode followers.

For increased sensitivity a meter is used in conjunction with an amplifier. Because of the difficulty in providing D.C. amplification, large increases in sensitivity are only practical for measurement of A.C. voltage. The basic arrangement includes an A.C. coupled amplifier followed by a rectifier meter (Fig. 2).

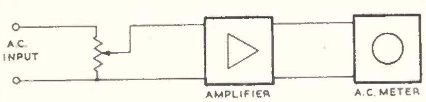


Fig. 2

A typical example of the type is the Transmission Measuring Set used with Long Line Equipment.

(b) Equipment required—

Oscillator Audio with 600 ohm output, 10 Kc/s.

Calibrated attenuator.

Switch.

VTVM calibrated in dbm across 600 ohms covering a range from 0 to less than –40 dbm.

600 ohm termination.

(i) Adjust output of oscillator to 1 mW or less (Fig. 3).

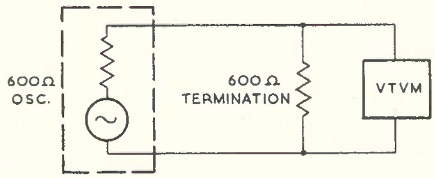


Fig. 3

(ii) Connect attenuator in circuit (Fig. 4). Note reading on VTVM.

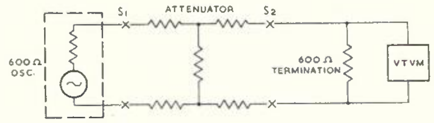


Fig. 4

(iii) Replace attenuator with calibrated attenuator and adjust for same reading (Fig. 5). Loss of calibrated attenuator = loss of attenuator.

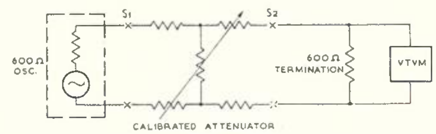


Fig. 5

Examination No. 5147, etc., 6th July, 1963, and subsequent dates. To Gain Part of the Qualifications for Promotion or Transfer as Senior Technician (Telecommunications) Telephone, Telegraphs, Radio and Research Postmaster-General's Department

TELECOMMUNICATION PRINCIPLES

Answers by *K. F. CODY*

QUESTION 2.

(*a*) *Two capacitors having capitances of 1.0 µF and 2.0 µF respectively and negligible leakage, are each connected to a 300 volt D.C. supply. The capacitors are then disconnected from the D.C. supply. What is the charge held by each capacitor?*

(*b*) *A variable capacitor having a capacitance of 1000 µµF and negligible leakage is charged from a 100 volt D.C. supply.*
After disconnecting the D.C. supply the capacitance is reduced to 250 µµF.
What change would you expect in —

(*i*) *the charge held by the capacitor?*

(*ii*) *the P.D. across the terminals?*

ANSWER 2

(a) The charge or quantity of electricity stored by a capacitor is calculated from —

$$Q = CE$$

Where Q = charge in coulombs.
C = capacity in farads.
E = P.D. across plates.

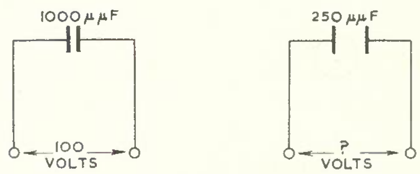
$$\therefore \quad Q = \frac{1.0 \times 300}{10^6}$$

$$= 300\ \mu \text{ coulombs} \ldots \text{(i)}$$

$$\text{and} \quad Q = \frac{2.0 \times 300}{10^6}$$

$$= 600\ \mu \text{ coulombs} \ldots \text{(ii)}$$

(b)



(i) Since there is no leakage, the charge after the change should remain the same as before.

(ii) Let C_1 be the initial capacity and E_1 be the initial P.D., then C_2 be the new capacity and E_2 the new P.D.

$$Q = C_1E_1 = E_2C_2$$

$$\therefore \quad \frac{1000 \times 100}{10^{12}} = \frac{250 \times E_2}{10^{12}}$$

$$\text{then} \quad 1000 \times 100 = 250 \times E_2.$$

$$\frac{1000 \times 100}{250} = E_2.$$

$$400 = E_2.$$

$\therefore$ The P.D. will rise to 400 volts.

EXAMINERS' COMMENTS

2(b) Many candidates were confused on the fundamental fact that the charge on the capacitor remains constant, and some were unaware that charge Q is measured in COULOMBS.

QUESTION 3.

(*a*) *What do you understand by the term TRUE POWER in an A.C. circuit?*

(*b*) *A parallel combination of pure inductance and pure capacitance is connected to an alternating voltage the frequency of which is variable from zero frequency to a frequency above resonance.*
Sketch the graphs of —

(*i*) *The variation of current in the inductive branch;*

(*ii*) *The variation of current in the capacitive branch;*

(*iii*) *The variation in the total circuit current*

What would be the impedance of this parallel circuit at resonance? Give brief reasons for your answer.

ANSWER 3.

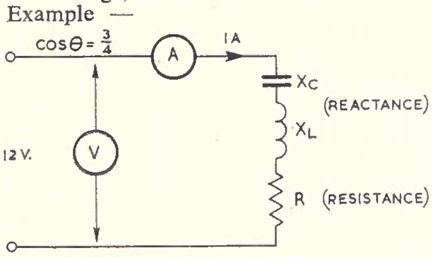
(a) The TRUE POWER of a circuit is the actual rate at which it dissipates power. It differs from the APPARENT POWER, in a partly reactive circuit, by reason of the PHASE DIFFERENCE existing between the applied voltage and the current flowing. The relationship between TRUE and APPARENT power is expressed in the following formula.

TRUE POWER = APPARENT POWER × COS θ

where

APPARENT POWER is the product of E and I using simple instruments, and COS θ is the cosine of the phase angle existing between the applied voltage, E and the current I.

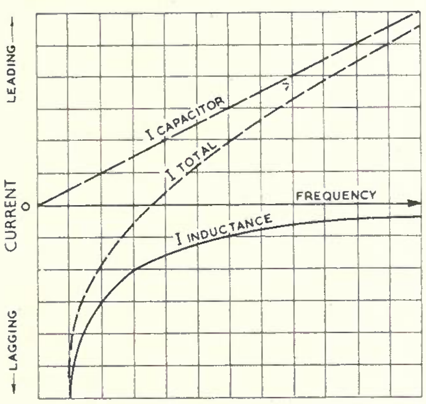
Example —



APPARENT POWER $= EI$
$= 12 \times 1$
$= 12$ watts.

TRUE POWER $= EI \cos \theta$
$= 12 \times 1 \times \frac{3}{4}$
$= 9$ watts.

(b)



(i) The reactance of a capacitor is calculated from

from $X_c = \dfrac{1}{2\pi fC}$

and since $I_c = \dfrac{E_c}{X_c}$

hence $I_c = E_c . 2\pi fC$

that is I_c is directly proportional to f.

(ii) The reactance of an inductor is calculated from $X_L = 2\pi fL$

and as $I_L = \dfrac{E_L}{X_L}$

hence $I_L = \dfrac{E_L}{2\pi fL}$

that is I_L is inversely proportional to f.

(iii) Since the capacitive branch passes a 90° leading current, and the inductive branch passes a 90° lagging current, the total current will be the difference between them.

The impedance at resonance can be calculated from —

$$Z = \frac{E}{I}$$

where Z is the magnitude of the impedance,
E is the applied voltage,
and I the current.

However, from the graph it can be seen that at resonance —

$I = 0$

hence $Z = \dfrac{E}{0}$

$=$ infinity.

Since the components are purely reactive they do not dissipate power. At resonance the current in the capacitor is supplied by the inductor and vice-versa, hence no current is drawn from the supply.

EXAMINERS' COMMENTS

3(a) Marks were deducted where the answers did not give a clear indication that TRUE POWER is the actual energy consumed in the circuit.

3(b) Graphs were poorly executed and marks were lost because of lack of identification of the various curves or failure to indicate any form of scale.

QUESTION 5.

(*a*) *A transmission line, 20 miles long has an attenuation constant of 0.3 dB per mile and a characteristic impedance of 600 ohms. When the line is correctly terminated the received voltage across the load is 2.0 volts.*
What is the input voltage to the line?
(Log 2 = 0.3)

(*b*) *A transformer, having three identical windings, is to be used for impedance matching of BALANCED lines. What impedance RATIOS can be obtained with the transformer?*
Illustrate each answer with a sketch.

ANSWER 5.

(a) Attenuation of line = attenuation constant × length.

∴ Line Loss $= 0.3 \times 20$
$= 6$ db.

The loss in decibels may be calculated using voltage ratios, providing the impedances involved are the same.

In this case —

$Z_{in} = Z_{out} = Z$ characteristic $= Z$ load

hence if $\text{db} = 20 \log \dfrac{E_{in}}{E_{out}}$

then $6 = 20 \log \dfrac{E_{in}}{E_{out}}$

i.e., $0.3 = \log \dfrac{E_{in}}{E_{out}}$

But we are given $0.3 = \log 2$.

so $\dfrac{E_{in}}{E_{out}} = 2.$

but E_{out} is 2 volts

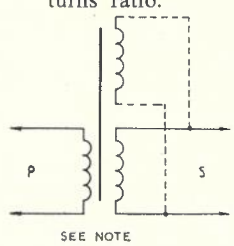
so $E_{in} = 2 \times 2$
$= 4$ volts.

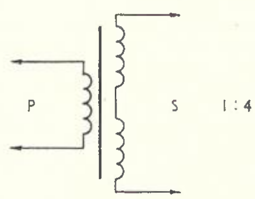
The input voltage is 4 volts.

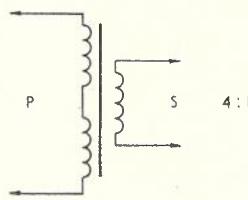
(b) From theory of transformers —

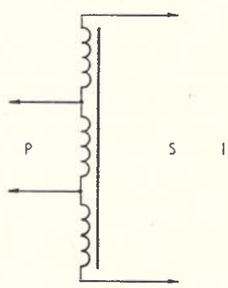
$$\frac{Z_s}{Z_p} = T^2$$

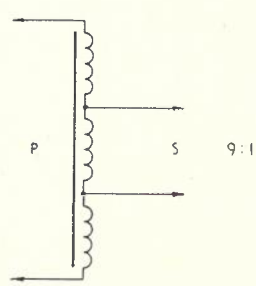
i.e., The impedance ratio is proportional to square of the turns ratio.











Note: The unused winding of the transformer in the case 1 : 1 could be connected across either the primary or secondary winding without affecting the ratio.

EXAMINERS' COMMENTS

5(a) Candidates lost themselves in lengthy calculations and misused log tables. The tables were not required as all the information necessary was included in the question including log 2 = 0.3.

5(b) Few candidates appreciated the fact that Impedance Ratio is proportional to the square of the turns ratio.

QUESTION 6.

(*a*) *Give four reasons why D.C. power supplies in Telephone and Long Line Stations always have one pole earthed.*

(*b*) *At a combined Telephone and Long Line Station having 24 volt, 50 volt and 130 volt battery supplies each battery has one pole earthed.*
State which pole is earthed in each case and briefly explain.

ANSWER 6.

(a) (i) The primary reason for earthing equipment and power supplies is to prevent them from accumulating dangerous or unpredictable voltages by leakage or induction from external sources. (See Fig. 1.)

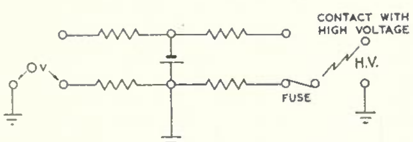


FIG. 1 EARTHED BATTERY.

(ii) At low levels, foreign currents or voltages give rise to crosstalk and noise. Earthing reduces the effects of these currents by providing them with a low impedance or balanced path to earth. (see Fig. 2a and b.)

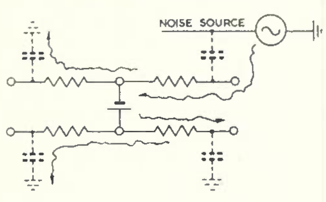


FIG. 2(a) NOISE IN UNEARTHED SYSTEM.

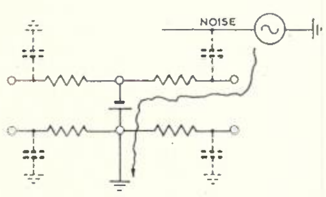


FIG. 2(b) "QUIET" EARTHED SYSTEM

(iii) As a considerable amount of equipment both local and remote from the station is in physical proximity to the earth, a reference point is available for the measurement of potentials, the identification of wires and the indication of faults. (See Fig. 3.)

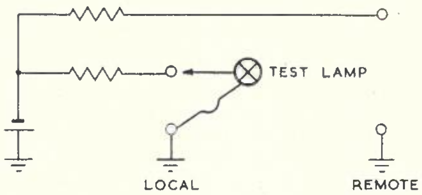


FIG. 3 TESTING, IDENTIFICATION.

(iv) The number of fuses, switch poles, etc., required to protect and distribute power is halved. (See Fig. 4.)

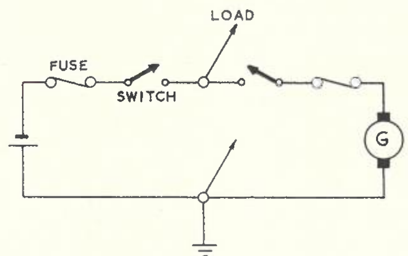


FIG. 4 PROTECTION & SWITCHING.

(v) The earth provides a return path for currents in power leads and certain signalling arrangements. As each exchange is similarly earthed, the voltages involved are definite and predictable. Examples include telegraph signalling, duplex services, S.C.D.C. repeaters and "Recall" in PMBX and PABX.

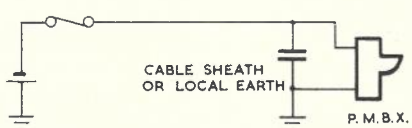


FIG. 5 POWER LEAD, EARTH RETURN.

(vi) The earthed terminal of a power supply provides a common point for the interconnection of various potentials which may be used in combination:— + 50 volts, — 50 volts, — 24 volts, + 130 volts, Ring current and tones. (See Fig. 6.)

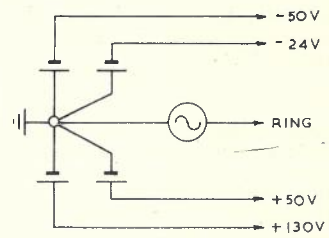


FIG. 6 COMMON.

(b) The poles of batteries at a combined station are earthed as follows:

24 volt — Positive earthed.
50 volt — Positive earthed.

Note: This refers to the main battery for the operation of automatic, CB or trunk exchanges. The metering battery (or supply) is referred to as Positive battery and has its Negative pole earthed.

130 volt — Negative earthed.

The reasons for earthing particular poles of each battery are:

24 VOLT

The use of 24 volts in Long Line Stations dates from the introduction of Long Line equipment into existing C.B. exchange buildings. The positive pole of the telephone exchange was earthed so that all of the equipment connected to the battery was maintained at a negative potential to earth, as it can be shown that this polarity reduces the corrosive effects of electrolysis. This corrosion would otherwise be disastrous on the fine windings of relays and transformers in the presence of moisture. In addition, this polarity is found to reduce the "sealing up" of partial earth faults.

50 VOLT

The main 50 volt battery of an exchange is earthed at the positive pole for the same reasons as in the 24 volt case.

50 VOLT (Positive)

If a second 50 volt battery exists at a station but has its negative pole earthed it may be used in association with the main battery for metering purposes, and as a reverse polarity for double current telegraph signalling.

130 VOLT

The 130 volt supply is earthed at the negative pole to provide a positive potential for the anodes of electron tubes in long line equipment. (The use of 130 volts negative for telegraph signalling has been discontinued in favour of 50 volts negative and positive available in automatic telephone exchanges.)

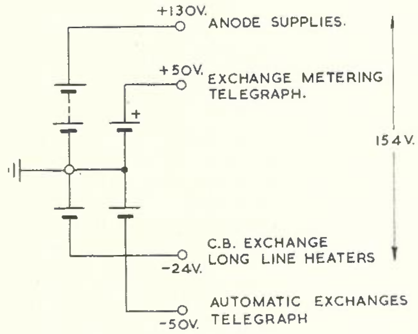
The common earth enables various voltages to be combined to provide additional potential. For example, an anode supply of

154 volts is provided effectively between negative 24 volts and positive 130 volts.

EXAMINERS' COMMENTS

6(a) Some candidates gave reasons for earthing of the positive poles only. They did not refer to supplies having their negative poles earthed.

6(b) Most marks were lost in reference to the positive 130 volt supply.



QUESTION 7.

When 5.0 volts D.C. is applied across a certain circuit, a current of 0.1 amps flows.

When the same circuit is connected across an A.C. supply of 50 c/s it is found that 10 volts are required to cause a current of 0.1 amps to flow.

(a) Calculate (i) the D.C. resistance of the circuit; (ii) the power absorbed under the D.C. conditions; (iii) the impedance of the circuit at 50 c/s.
Why is double the voltage required in the A.C. case?

(b) If the power absorbed by the circuit in the A.C. case is 0.6 watts calculate (i) the power factor of the circuit; (ii) the A.C. resistance of the circuit at 50 c/s. What factors would account for the A.C. resistance being greater than the D.C. resistance?

ANSWER 7.

(a)

(i) $R = \frac{E}{I}$

$= \frac{5.0}{0.1}$

$= 50$ ohms D.C. resistance

(ii) $P = EI$

$= 5.0 \times 0.1$

$= 0.5$ watts (D.C.)

(iii) $Z = \frac{E}{I}$

$= \frac{10}{0.1}$

$= 100$ ohms impedance

Double the voltage is required in the A.C. case since the impedance of the circuit at 50 cycles is double the D.C. resistance of the circuit.

(b) (i) Apparent (A.C.) power

$= E \times I$

$= 10 \times 0.1$

$= 1$ watt

True Power

$= 0.6$ watts

$$\text{Power Factor} = \frac{\text{True Power}}{\text{Apparent Power}}$$

$$= \frac{0.6}{1.0}$$

$$= 0.6$$

(ii) The term A.C. RESISTANCE implies that the effective resistance to A.C. of a practical circuit differs from the value measured by D.C. means. It is that value of resistance which would dissipate all the power used or lost in the circuit, for example by dielectric losses in capacitors, or eddy currents and hysteresis in inductors.

$$R = \frac{\text{Power}}{I^2}$$

$$= \frac{0.6}{0.1 \times 0.1}$$

$$= 60 \text{ ohms}$$

The A.C. (or effective) resistance is 60 ohms.

The A.C. resistance differs from the D.C. value in practice because it takes losses which occur into account. In this example the reactive device is probably an inductor, since the impedance increased with frequency. Losses in inductors include skin effect in the conductors, eddy currents and hysteresis.

EXAMINERS' COMMENTS

7(b) Very few candidates scored good marks in this question because they confined A.C. resistance with A.C. impedance.

QUESTION 10.

(a) What are the functions of the non-magnetic former as used in a moving coil meter?

(b) Complete the sketch below to show the basic electrical and magnetic construction of a moving coil meter, suitably labelling the principal parts.

Detail of mechanical parts such as pivots, springs, balance weights and zero adjusters are not required.

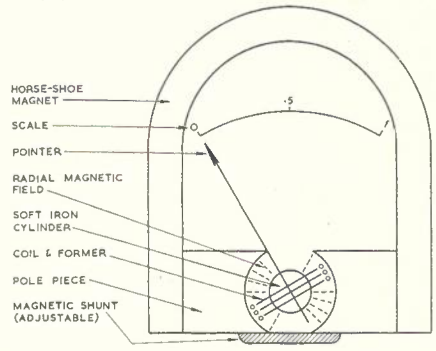
ANSWER 10.

(a) (i) The obvious purpose of the former is to provide support for the coil and for the attachment of pivots, etc.

(ii) The former behaves as a short circuited turn and provides damping of the needle swing through the action of eddy currents induced in it. These currents oppose the motion which produces them (Lenz's Law).

The former is non-magnetic so that it does not distort the magnetic field existing between the core and the poles, and to prevent it being acted upon by that field.

(b)



EXAMINERS' COMMENTS

10(a) Most lost marks were due to candidates missing the important factor of the former acting as a short circuited turn and providing the damping action (Lenz's Law).

10(b) Too many candidates lost marks for showing mechanical detail and for showing the coils wound on the pole pieces.

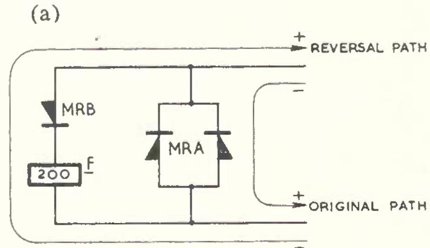
QUESTION 12.

(a) Draw a circuit showing how a standard relay can be made to behave as a polarized relay by using two metal rectifiers.

(b) Explain the operation of the above circuit and, in particular, the reasons for using two metal rectifiers.

ANSWER 12.

(a)



(b) The most usual application of the circuit shown is to respond to the reversal of polarity transmitted back from a final selector when the called subscriber answers.
The original current path is through the rectifier(s) MRA, shunting current from the "F" relay, which will not operate. The rectifier MRB is provided as additional opposition to the entry of current into the "F" relay circuit from the voltage drop occurring across the internal resistance of rectifier MRA. In some circuits MRA is doubled to further reduce this possibility on short junctions. After reversal MRB conducts

current to the "F" relay, while MRA becomes blocking (high resistance) due to the reversed potential developed across its terminals.

MRB is not a double unit, as the inclusion of the additional resistance of the "F" relay after reversal reduces the line current to some extent.

APPLICATIONS

As long as the reversal of line polarity is used to indicate the off-hook condition of the called telephone this circuit will be utilized in some form. Various versions of the circuit exist in the following variety of equipment.

Public telephones: In the variable tariff PT, the transmitter replaces the relay.

Repeaters: Auto-Auto, Manual to Auto.

Repeating Selectors: DSR, RAX links, 2 VF trunk selectors.

Test Sets: Routiners, Traffic Route Testers.

Operator Services: Interception and Complaints.

Crossbar Exchanges: Some types of FIR, FUR, FDR, SR, REG-L, REG-I and ULR.

EXAMINERS' COMMENTS

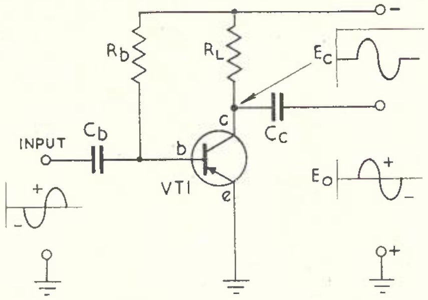
12(b) Although candidates knew the circuit they generally did not know the principles of its operation. A few candidates confused the term "polarised" and explained the circuit as one which would work on A.C. and not D.C.

QUESTION 14.

Draw the circuit of a simple single stage PNP common emitter transistor amplifier and explain how the collector current varies on

(*i*) *the negative half cycle of the input signal, and*

(*ii*) *the positive half cycle of the input signal.*



C_b BLOCKING CAPACITOR TO BASE.

R_b BASE BIAS RESISTOR.

R_L LOAD RESISTOR.

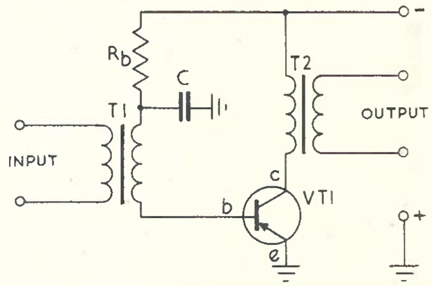
C_c BLOCKING CAPACITOR-COUPLING.

ANSWER 14.

Without an applied signal, there will be a steady current from the emitter to collector mainly determined by the bias current, and the current gain of the transistor.

(i) On the application of the negative half cycle of the input signal, the increase of electrons injected into the base-emitter junction stimulates the movement of holes in greater amounts from emitter to collector. The increased hole flow in turn permits more electron flow from collector to emitter. In the R/C coupled stage the increased current reduces the potential at the collector, making the collector less negative. The polarity of the output appearing after the coupling capacitor is a positive half cycle.

(ii) On the application of the positive half cycle of the signal, the number of electrons injected into the base-emitter junction is reduced, the hole flow is reduced and as a consequence the electron flow between collector and emitter is reduced. The potential drop across the load resistor falls, and the collector becomes more negative. The polarity of the output following the coupling capacitor is a negative half cycle.



R_b BASE BIAS RESISTOR.

C BYPASS CAPACITOR.

T1 INPUT TRANSFORMER.

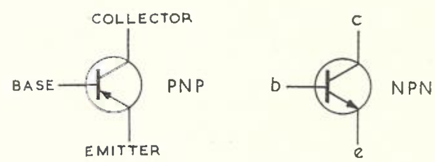
T2 OUTPUT TRANSFORMER.

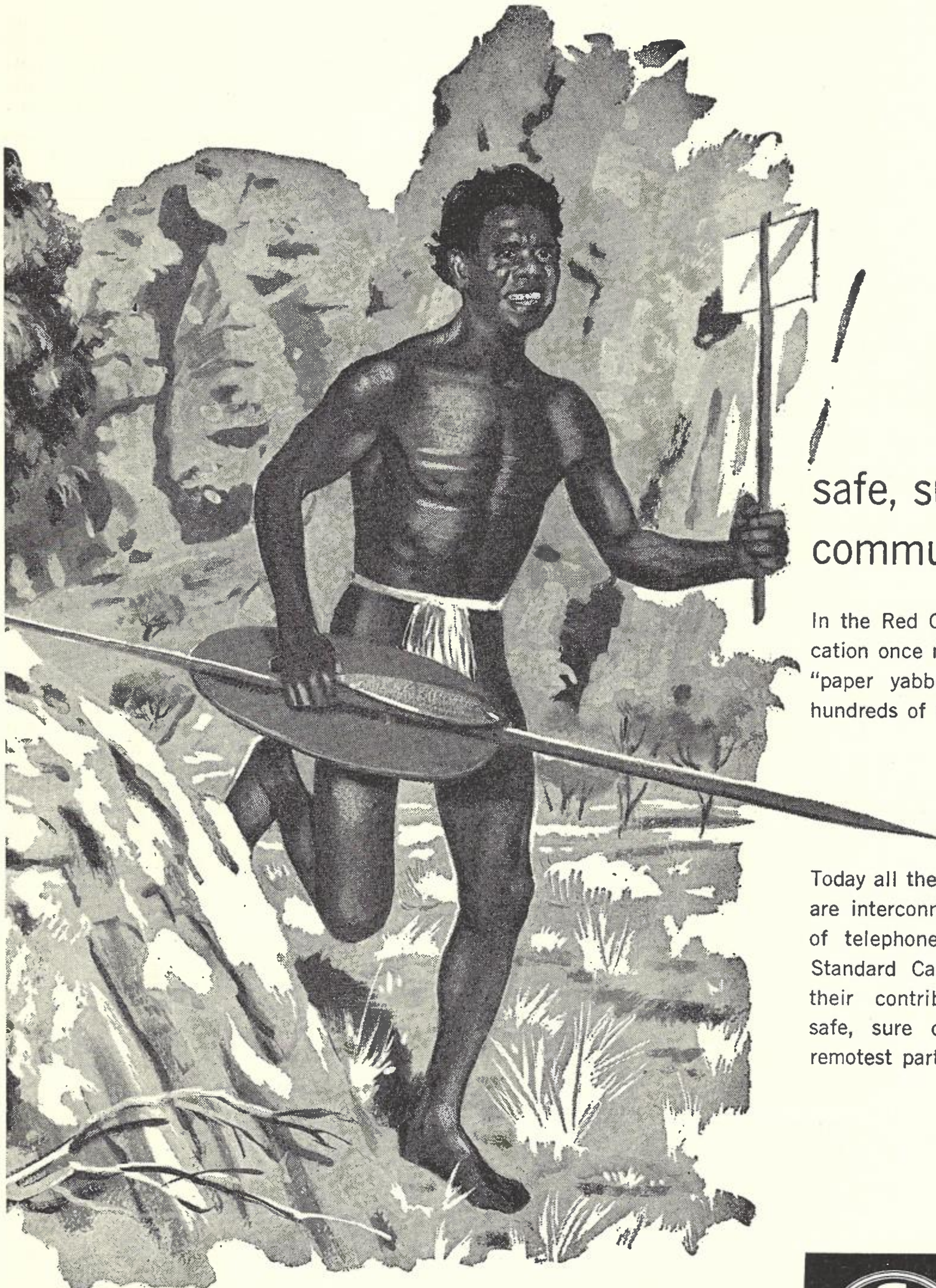
In the case of the transformer-coupled stage the currents in the circuit rise during the negative half cycle and fall during the positive half cycle.

Note: The functions of Cb and Cc could be performed by a single capacitor between stages or alternatively by one transformer.

EXAMINERS' COMMENTS

14. Low marks were scored by most candidates on this question. The circuits given were not good and candidates often could not correctly draw the symbols. The explanations of the working of the circuit showed a lack of knowledge of transistor principles.





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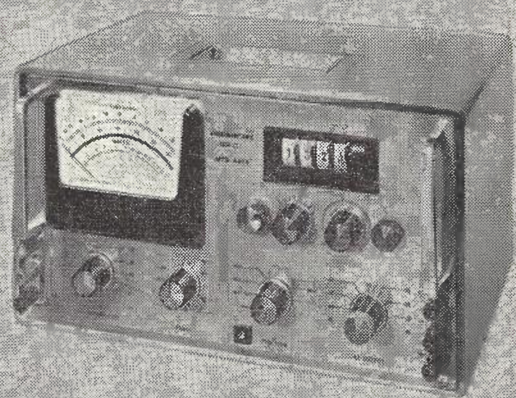

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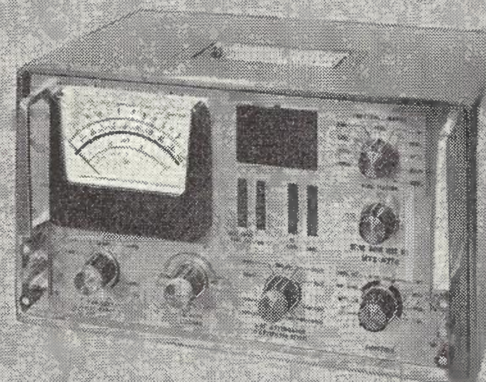

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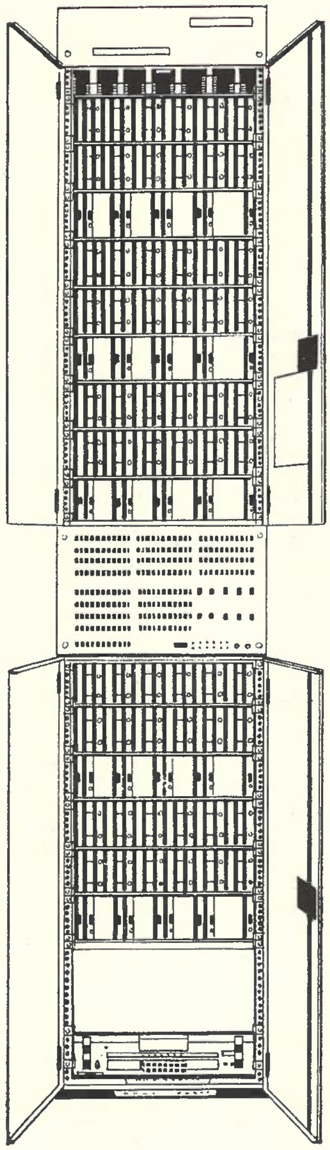

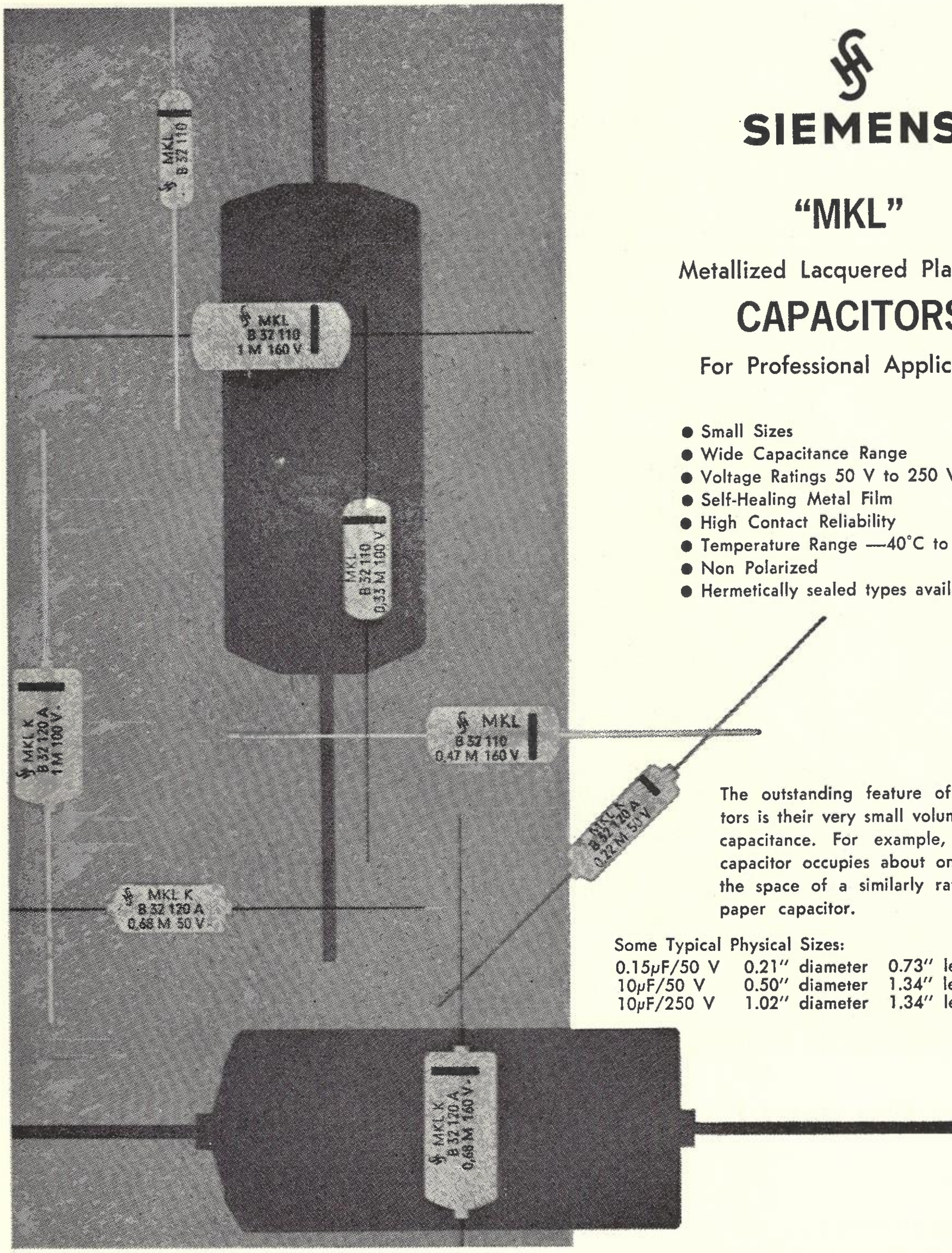

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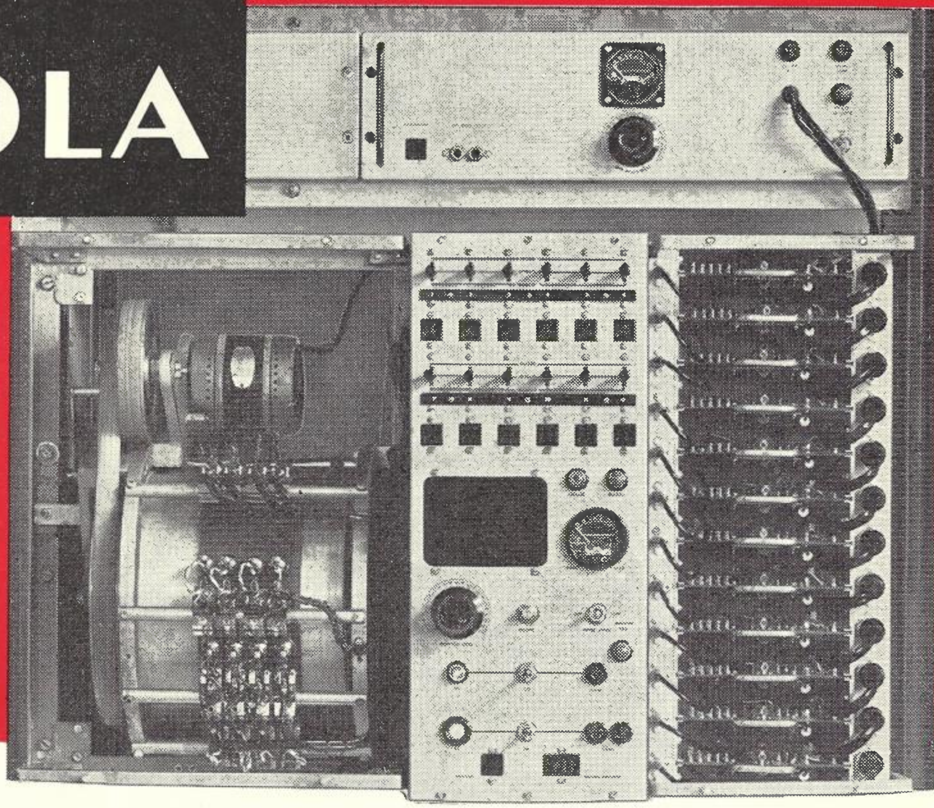

EXCHANGE INTERCEPT EQUIPMENT

The Rola Company Exchange Intercept Equipment, now standardised for service by the Australian Post Office, is a fully professional machine engineered to the highest standards required by telephone authorities and capable of recording and playing back messages into a telephone network.

The equipment is so designed that full actuation can be provided by normal telephone exchange equipment, with up to 12 tracks available, i.e., up to 12 messages may be recorded and played back as selected.

In a busy telephone exchange the Rola Exchange Intercept Equipment can provide weather forecast data for telephone subscribers. This forecast may be modified as often as is found necessary. Incorrect or obsolete directory numbers when called can be routed to the equipment where an automatic announcement giving the corrected information can be made to the caller.

A potential service that may be offered by the telephone authority is the hiring of recorded tracks for short periods. For example, a medical practitioner may leave a recorded message regarding his whereabouts to be routed to anyone calling his number.

Technical Description

The Rola Exchange Intercept Equipment comprises three main units: the Magnetic Drum unit, the Amplifier Section and the Switching Panel. They are mounted in a frame suitable for a standard Post Office 33" rack.

The 12 four-stage transistorised amplifiers have an output rating of approximately 500 mW. The switching panel permits monitoring and the change from the "Record" to the "Play" mode on any channel.

Further Information from:

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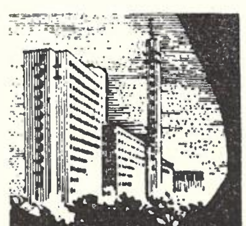

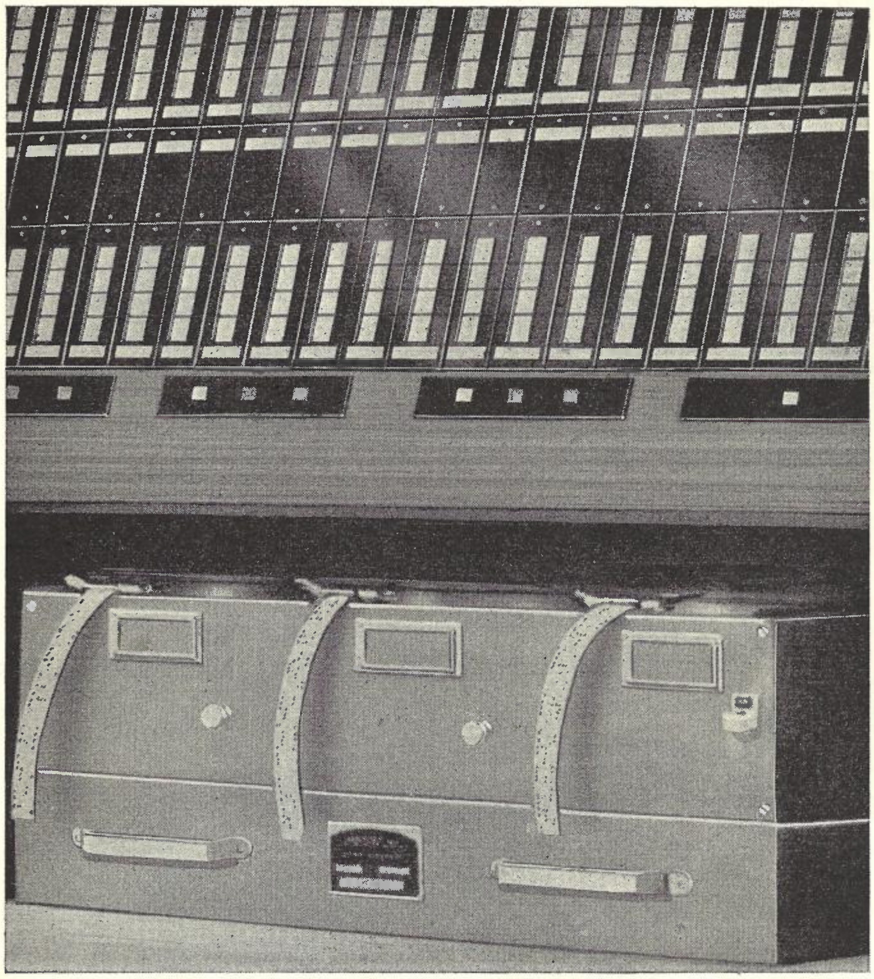

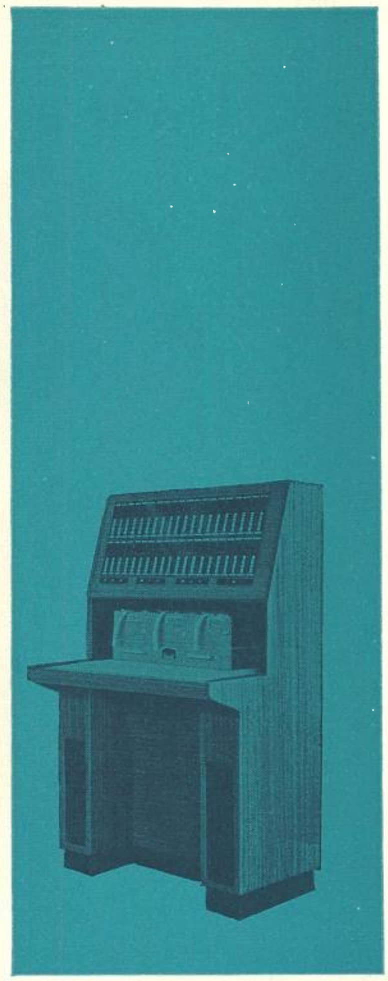

Semi-automatic torn-tape relay telegraph system

For moderately loaded message switching systems, the use of complicated and expensive equipment is not economic. The STC Semi-Automatic Torn-Tape Relay Telegraph system provides a limited amount of automatic control and, compared with manual transfer systems, uses the services of operating personnel more efficiently. Amongst the facilities offered are:

1. Torn-Tape working with automatic selection of outgoing route (or routes) by push button operation.
2. Automatic insertion of a heading line including outgoing message serial number by semi-electronic means.
3. Rapid and efficient message handling, one operator routing up to 150 messages per hour.
4. Simultaneous transmission of up to three different messages from each operating position.
5. Single transmission for multi-address messages.
6. Two degrees of priority, ensuring that priority messages have precedence over normal messages.
7. Visual indication at the operating positions of engaged outgoing routes.
8. Display at operating position of serial number of outgoing transmission(s).
9. Simple equipment requiring the minimum of maintenance.
10. Employment of well proven telegraph machines and switching equipment approved by the British Post Office and other administrations.
11. Suitable lamp indication during selection of outgoing circuits.
12. Cancellation of the selection in the event of a routing error.
13. Switching circuitry ineffective until the transmitter head is loaded with tape.
14. Release of connexion on completion of transmission i.e. when length of tape has passed through the transmitter head.

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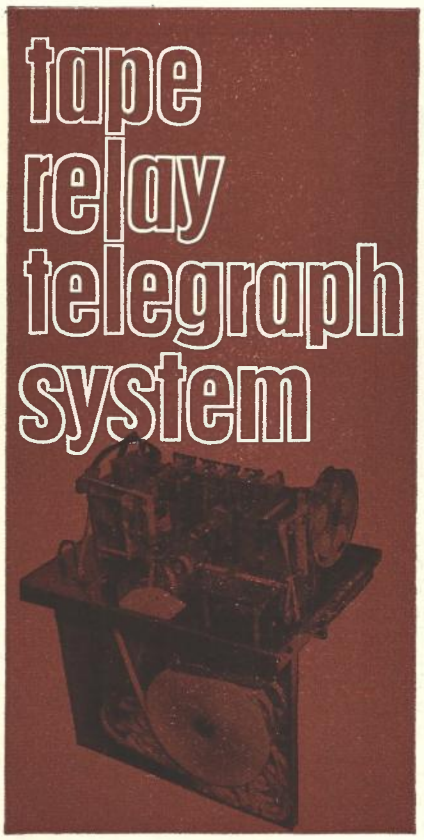

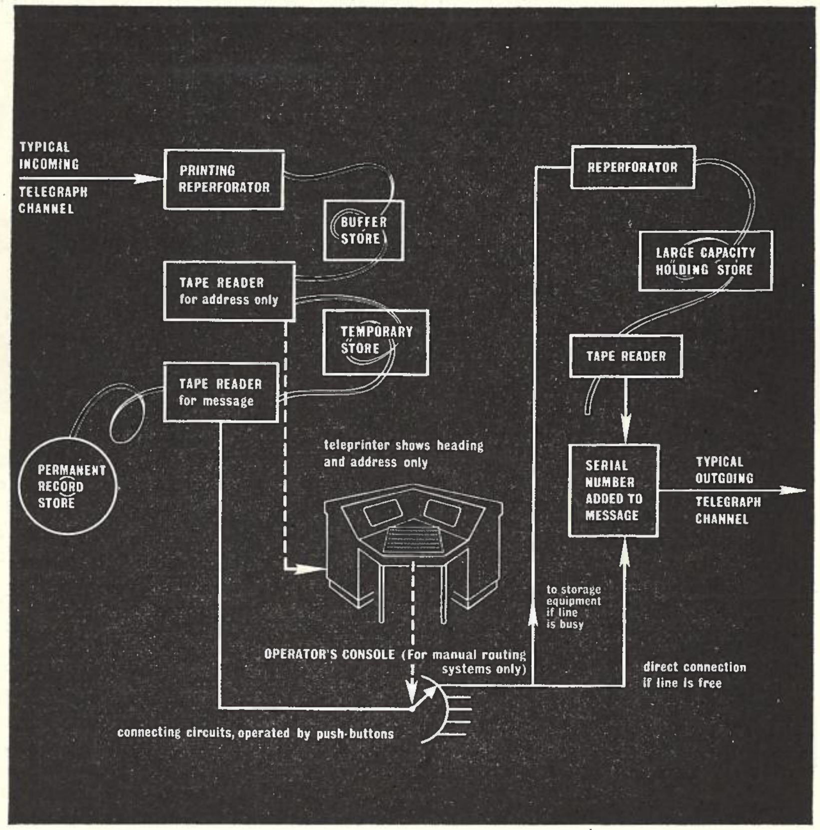

AMATI—Advanced Manual Automatic Tape Interconnector, the new STC/Creed Tape Relay Telegraph System, compatible with all-electronic systems, is designed for use in locations where the expense of more sophisticated telegraph systems cannot be justified. STC Switching Techniques and Creed Telegraph Machines combine to give efficient and high-speed routing of telegraph messages. Facilities offered include: High-Speed Cross-Office Transfer □ Universal Operation (mixed if required) i.e. **(a)** Torn tape—semi-automatic routing. **(b)** Continuous tape—semi-automatic routing. **(c)** Continuous tape—automatic routing □ Centralized Operating Position for Manual Routing Systems resulting in high operating efficiency □ Mixed Receiving and Transmission Speeds—depending on the speeds of the particular circuits concerned □ Electronic Circuitry combined with simple electro-mechanical switching □ Automatic Checking of incoming serial number □ Automatic Generation of message heading e.g. serial numbering, date and time transmission □ Permanent Record of messages □ Individual Storage of Incoming Duplex Lines on continuous tape systems □ Common Pool Outgoing Storage (each store catering for at least 36 000 characters) □ Write, 'phone or Telex, Standard Telephones and Cables Limited, Telephone Switching Division, Oakleigh Road, New Southgate, N.11, England. Australian Associates: STC Pty., Ltd., 252 Botany Road, Alexandria, SYDNEY. Cnr. Wilson and Boundary Streets, West End, BRISBANE. 174 King Street, MELBOURNE. 39 Empire Circuit, CANBERRA.

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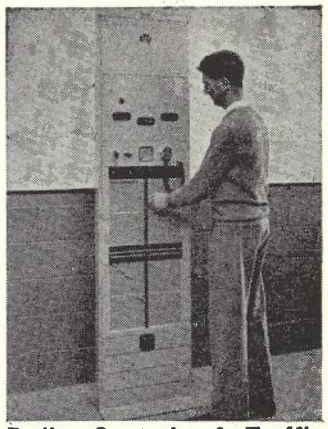
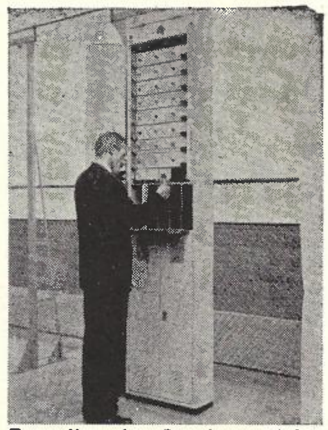
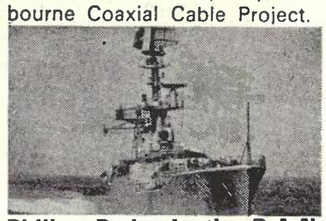
wide range of equipment manufactured by T.C.A.



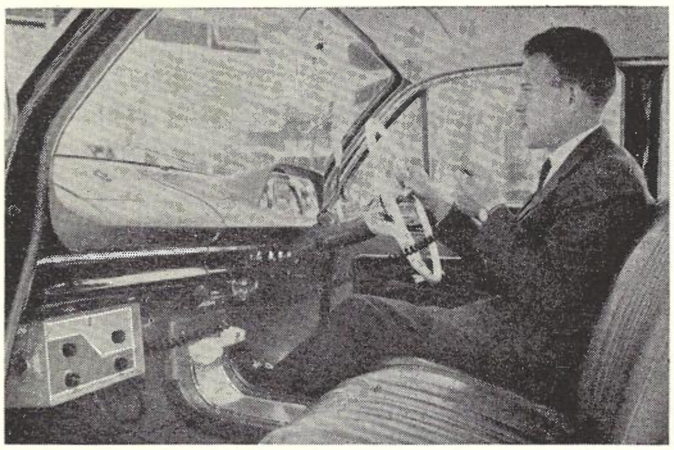
Radio Control of Traffic Lights. The Melbourne City Council ordered TCA Series 1857B equipment for nine King Street intersections. This equipment has been designed to enable the entire traffic light system of the city to be controlled, over a single VHF link, from a central point and includes the facility for voice communication to maintenance personnel. Eventually the system will embrace the whole of the central business district and finally to the extremities of the city.



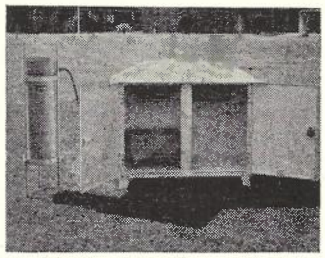
Broadband Carrier Telephone Equipment. This 48 channel modulation bay is being prepared for shipment to the Postmaster General's Department. The bay is identical to those previously supplied to the P.M.G. for the Sydney-Melbourne Coaxial Cable Project.



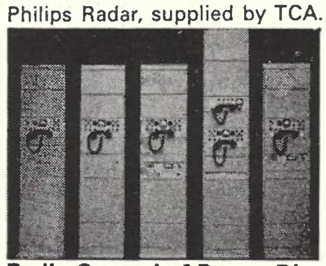
Philips Radar in the R.A.N. The anti - submarine frigates "Parramatta", and "Stuart" and the aircraft carrier "Melbourne" are all fitted with Philips Radar, supplied by TCA.



First to Transistorise Mobile Radiophones. In 1957 TCA led the world by replacing the vibrator power unit of its FM mobile radiophone unit with a transistorised DC/DC converter. The immediate acceptance and success of this venture inspired further development in transistorisation with the result that, in December, 1961, TCA commenced marketing a mobile unit with a fully transistorised receiver and DC/DC converter, and a transmitter that was transistorised to the extent that only three electron tubes remained. This unit is now the most field-proven unit available in Australia; already several thousand are in use throughout Australia and overseas countries by government and commercial organisations. For both recent Royal tours TCA mobile and base equipment was employed exclusively. The P.M.G. has approved the equipment for use throughout the Commonwealth.



Radio Reporting Rain Gauge System for the Commonwealth Bureau of Meteorology. To overcome the problem of obtaining regular details of rainfall in remote areas the Bureau has ordered from TCA a special Radio Reporting Rain Gauge System. The equipment operates at VHF and will automatically provide Bureau personnel, at the recording centre, with details of rainfall throughout their area. The facility for voice communication to maintenance personnel is also included. The Macleay River Valley will be the testing ground for the first system, where it is hoped it will aid the Bureau in providing a flood warning service to the many settlers in that area.



Radio Control of Power Distribution Networks. The Townsville and Mackay Regional Electricity Boards have taken delivery of a special electronic supervisory and control system designed and manufactured by TCA. The system provides a VHF duplex radio repeater link network connecting Townsville and Mackay with facilities for speech traffic, supervisory control of circuit breakers and tap changing regulators, and the telemetering of power flow indications.

TCA

TELECOMMUNICATION COMPANY OF AUSTRALIA PTY. LIMITED

A DIVISION OF PHILIPS ELECTRICAL INDUSTRIES PTY. LIMITED

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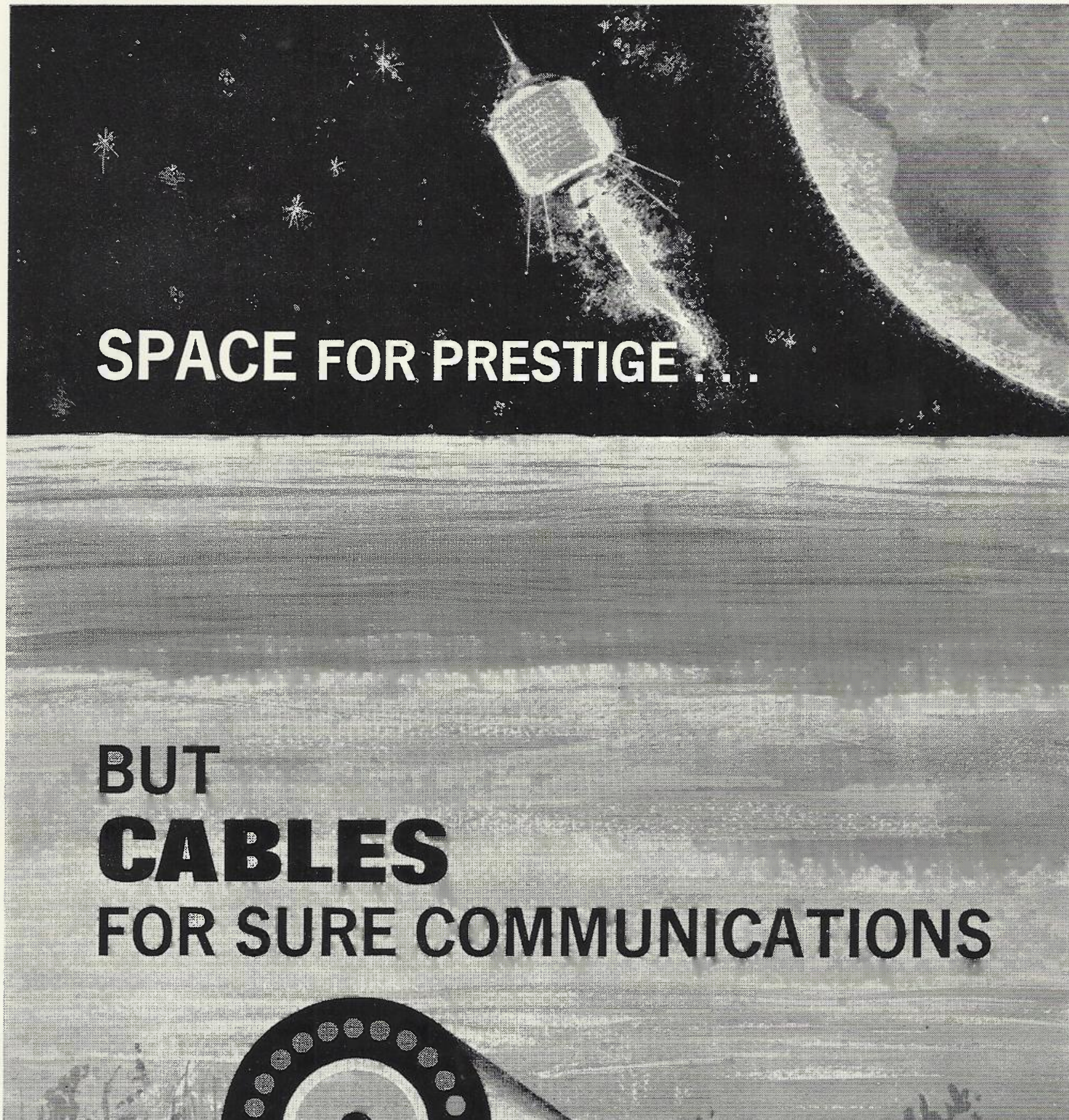
PHILIPS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FOR SURE COMMUNICATIONS

NEW

A silicon rectifier that **protects itself** against voltage transients

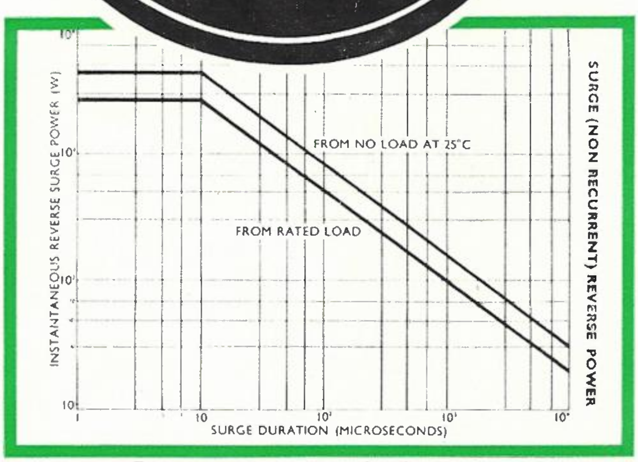
NEW

Permits reverse power **surges 50 times greater** than conventional silicon rectifiers

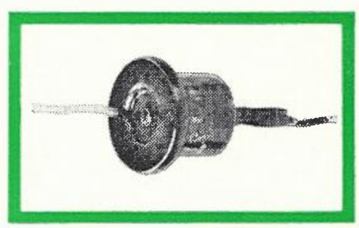
NEW

Can be **series connected** without voltage equalising resistors and, in many applications, without equalizing capacitors

SILICON AVALANCHE RECTIFIERS

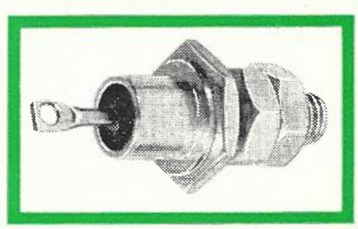


Typical example of avalanche characteristics
Surge (non recurrent) reverse power



TYPE RAS 310 AF

Rated Forward Current (At 25°C)	1.25 A
Rated Crest Working Reverse Voltage	1000V
Minimum Reverse Avalanche Voltage	1250V
Rated Maximum Reverse Surge Power	4kW
Rated Maximum Temperature	140°C
Standard Outline VASCA SO-16, JEDEC DO1, IEC 1-101	



TYPE RAS 508 AF

800V.
1000 A.V.V. 5A

(Illustrations twice actual size. Data sheets for each type available.)

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