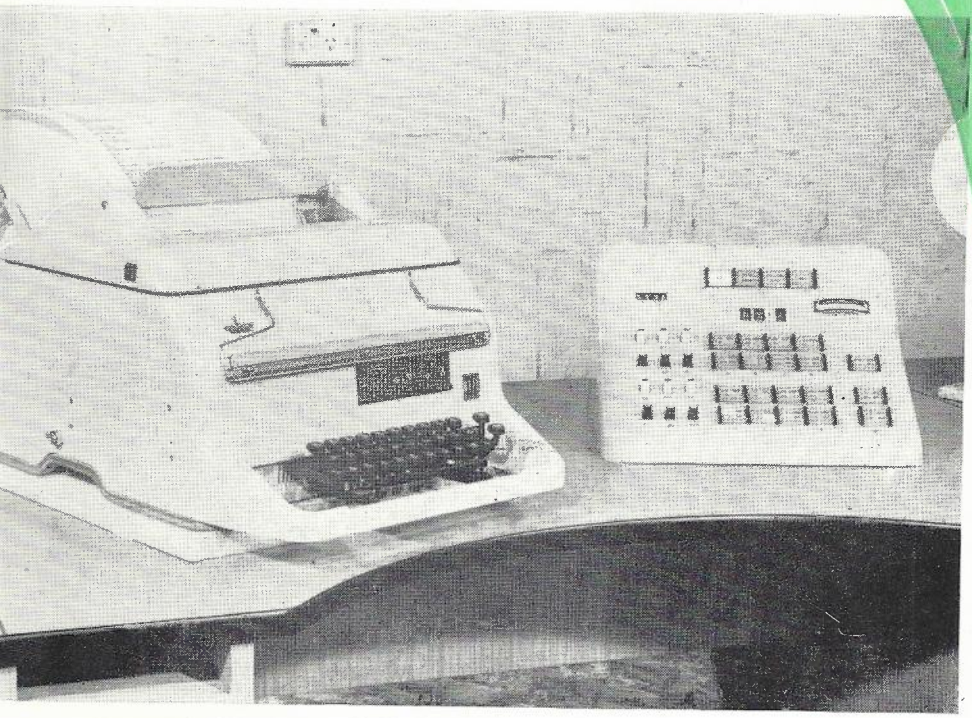
THE
Telecommunication Journal OF AUSTRALIA



A Semi-Automatic Switching Position for Service Assistance, Conference and Broadcasting Traffic in the Telex System.

IN THIS ISSUE

VOL. 16, No. 2 Registered at the General Post Office, Melbourne, for transmission by post as a periodical. JUNE, 1966

WHERE SOUNDS ARE RARELY HEARD

Water still seeps through limestone caves the world over patiently adding to the already spectacular scene, still ticking the years away largely unheard.

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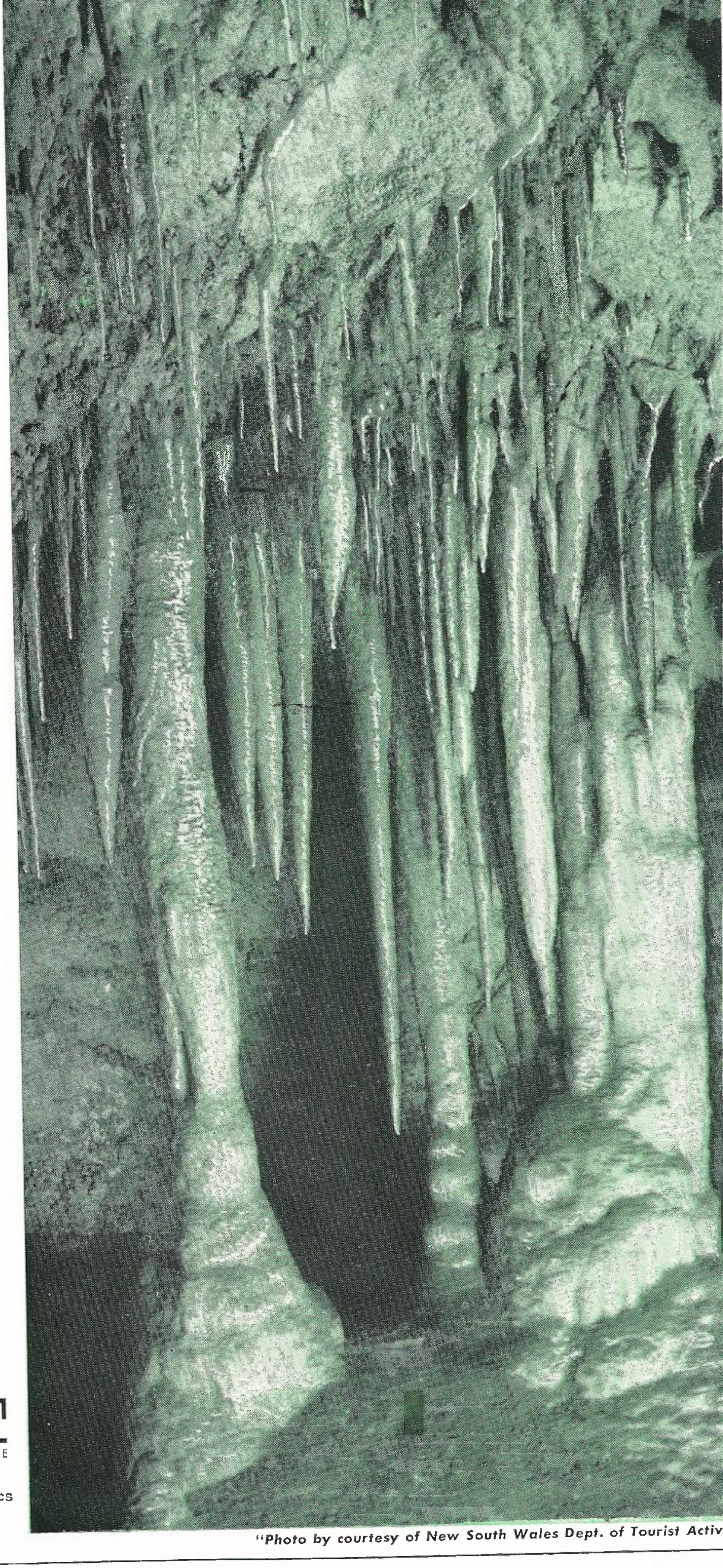

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The TELECOMMUNICATION JOURNAL *of Australia*

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The Journal is issued three times a year (in February, June and October) by the Telecommunication Society of Australia. Commencing with Volume 15, each volume comprises three numbers issued in one calendar year.

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*For addresses see page 191

C.C.I.T.T. TELEGRAPH AND PLAN COMMITTEE MEETINGS IN MELBOURNE - SEPTEMBER, OCTOBER, 1966

*R. D. KERR**

INTRODUCTION

From 7th September to 26th October, 1966, various units of the C.C.I.T.T. (International Telegraph and Telephone Consultative Committee) meet in Melbourne. The general description of the organisation of the C.C.I.T.T. was given in the October 1963 issue of the *Journal* (Ref. 1.) on the occasion of the meetings of the Telephone Switching Study Groups in Melbourne at that time. (See also Refs. 2 and 3.) In comment on this further series of meetings, it must be explained that the technical work of the C.C.I.T.T. falls essentially into four departments:—

- Telephone Switching and Signalling
- Telephone Transmission
- Miscellaneous Activities, including corrosion, protection, vocabulary and symbols
- Telegraphy

In the latter department there are six Study Groups dealing with questions concerning the techniques of telegraphy, namely:—

- Study Group I — Telegraph Operation and Tariffs
- Study Group VIII — Alphabetic Telegraph Apparatus
- Study Group IX — Telegraph Transmission
- Study Group X — Telegraph Switching
- Study Group XIV — Facsimile Telegraph Apparatus
- Study Group (Spec. A.) — Data Transmission

Of the foregoing, Study Groups I and X have meetings in Melbourne. As well as these Study Groups, there exist a number of Working Parties which deal with questions which cover a broad field of study impinging on both operating, switching and terminal equipment and which, in consequence, concern several of the regular Study Groups. Among these are Working Parties to study —

- Message Re-Transmission
- World-Wide Telex and Gentex
- Efficiency Factor in ARQ Systems

These also will hold meetings in Melbourne in conjunction with Study Groups I and X.

The method of operation of the Working Parties is to study very complex questions and to submit draft recommendations, in their areas of interest, to the responsible Study Groups. This arrangement might be criticized in theory on the grounds that it provides too many points at which review could take place, but, in practice, it has worked very well in the telegraph area because the Study Groups have been prepared to accept the Working Parties' reports on the questions under study. The alternative working method of studying a complex question in one Study Group, referring it with an opinion to another and continuing this process while all sides of the question are examined, is apt to prove much less satisfactory. During recent years Australia has taken an active part in the work of these Study Groups and Working Parties, and this is one reason why the invitation was issued, and accepted, at the 1964 Plenary Assembly in Geneva, to hold meetings in this field of study in this country.

In the recent development of inter-continental telephony, it is perhaps easy for it to pass unnoticed that intercontinental telegraphy has also developed rapidly; indeed, in the case of Australia the number of international Telex calls to and from Europe, the Americas, Africa and Asia total 238,000 for 1964-65, while the international telephone calls to and from these places total 237,000 in that year. In the Telex case these calls were connected to little more than 2,000 Telex subscribers, while the telephone calls were to some 2 million subscribers. The traditional international telegraph service has continued to grow and, as well as the Telex service, there has been a great increase in leased international telegraph private lines so that, in all, Australia's international Telecommunications Authority — the Overseas Telecommunications Commission — still receives the larger part of its earnings from telegraph sources.

As well as the Telegraph Study Group and Working Party meetings mentioned above, the Plan Committee for Asia and Oceania (Chairman — Mr. Vasudevan, India) meets at the same time. The work of the Plan Committees which exist on a regional basis within the C.C.I.T.T., and with representation from the C.C.I.R., is to review the requirements for international telegraph and telephone circuits to be provided, both by land-line, submarine cable and radio (including satellites), within the region concerned, so that all administrations are conversant with the regional plans for overall development of international telecommunications. As a matter of interest, Australia is now included in the Plan Committee (Asia and Oceania), and this came about at the 1964 Plenary Assembly in Geneva on the suggestion of one of the Vice-Chairmen, Mr. Vital of Mali, a suggestion with which Australia agreed.

Turning to the work of the Telegraph Study Groups and Working Parties, which meet in Melbourne, the following summarises the position:—

STUDY GROUP I — TELEGRAPH OPERATION AND TARIFFS

(Chairman — Mr. Vargues, France)

As the name indicates, this Study Group is primarily concerned with traffic and charging aspects of the international telegraph services, but as in all telecommunications activities the inter-play of what operational facilities are desired, what technical facilities are possible, and what these will cost and their practicability mean that most questions have many facets, technical, traffic, accounting and administrative.

Among the questions under study is a group dealing with the principles of charging for Telex calls. With calls transitting several countries, the distribution of charges among the various administrations has been determined, in the past, by agreed clerical procedures on manually-ticketed calls. However, the advent of automatic working has increased difficulties here as there are differences in the methods of metering or automatic ticketing in the various systems, while there are substantial investments in the plant already installed in the various national networks, and the established clerical procedures can no longer be simply applied.

A further group of questions relates to charging for telegrams, which has been traditionally based on wordage. This system does give considerable operating complications and does tend to place a high penalty, discouraging long telegrams, in comparison with short ones so that new possibilities are being explored. Yet another group of questions relates to phototelegraph services for which the established procedures and charging methods have been determined in the context of point-to-point operation. With improvements in phototelegraph equipment, and with the advent of inter-continental telephone cables it has now become possible to provide for complex multi-point phototelegraph transmissions. Within the Commonwealth system these have already been established for some years and agreed standards are required for general international working in this way. Other important questions which concern this Study Group are dealt with in more detail in connection with the working parties.

STUDY GROUP X — TELEGRAPH SWITCHING

(Chairman — Mr. A. Jansen, Netherlands)

This Study Group is concerned with switching and signalling techniques for the Telex and Gentex services. Although the Telex service is well known to Australian readers, the Gentex service is possibly not so well known. A number of countries, mostly in Europe, operate automatic direct switched networks which interconnect Post Offices and permit telegrams to be transmitted from the office of origin to office of destination. Technically these networks are similar to the Telex service, but there is no need for metering and some networks do incorporate special facilities such as "camp-on-busy" and automatic "spill-over" into positions in major telegraph centres if a required connection cannot be effected in a stipulated time. These systems have been interconnected internationally, and

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are known as the Gentex service. Some countries use separate networks for Telex and Gentex, while others actually use the Telex network for both services; although in these latter cases there is often some sort of barring of access between the two groups of terminal stations.

The basic standards of signalling for these systems have been established for some time but there is a constant need for revision and refinement of these standards to match the increasing complexities of world-wide operation of these services.

The particular problems of numbering and signalling over inter-continental circuits are being given special consideration in the Working Party on World-wide Telex and Gentex, while those for message relay working are with the Working Party on Message Re-transmission.

A new area of investigation for this Study Group is the extension of the Telex service to provide for speeds and codes other than the 50 baud, 5-unit code (international alphabet No. 2) which has been rigidly standardised hitherto. In particular, the possibility of operation at up to 200 bauds with the proposed new 7-unit information code is envisaged by a number of administrations.

WORKING PARTY ON MESSAGE RE-TRANSMISSION

(Chairman — Mr. Bonacci, Italy)

As in Australia, where the message relay system, TRESS has been introduced to eliminate manual operations in the Public Telegraph Service at intermediate telegraph offices so, in the international sphere, there has been an interest in introducing equivalent systems. These may take many forms ranging from simple torn-tape relay systems, such as have been widely used for leased networks within Australia, to electro-mechanical automatic switching systems with perforated tape storage, and to computer-based systems which function essentially as time division electronic switching systems with control by computer and magnetic storage of information.

Each of these systems has an economic place but their inter-connection in a world-wide network requires international acceptance of standardised routing codes and message formats. During recent years considerable progress has been made in this direction, but procedures in respect of special classes of traffic remain to be determined and there are substantial problems in inter-operation between domestic systems, particularly those using Gentex, and the international system. For the greatest advantages to be achieved, these problems cannot be treated only as a matter of national responsibility and this is generally accepted. Further studies are therefore being directed to the establishment of internationally standardised procedures which will facilitate the inter-connection of a wide variety of national systems. With the progress which has already been made, the Overseas Telecommunications Commission is currently considering the installation of a message relay switching system for Australia's international telegraph service.

It is interesting to note that although Gentex provides a technical alternative to message re-transmission for international working, and indeed several nations using Gentex did not see the need for any alternative, the advantages of message re-transmission systems, particularly over inter-continental circuits, are now generally acknowledged.

WORKING PARTY ON WORLD-WIDE TELEX AND GENTEX

(Chairman — Mr. Gosewinckel, Australia)

As originally determined, the standards for international Telex and Gentex were evolved in the context of the European system. When the ARQ multiplex, and later the inter-continental telephone cables, made possible the world-wide interconnection of these systems, a new series of technical problems had to be faced. This working party was formed to deal with these problems and has made a good deal of progress in the establishment of a global numbering plan. Because the operating and administrative arrangements for international telegraphy differ from those for telephony in many countries, the Telex numbering plan, although similar in concept to the telephone plan, must differ considerably from it in detail. Also, progress has been made in the evolution of a high-speed signalling system. Aspects which require further study are routing arrangements which retain the necessary technical and commercial flexibility in an automatic system as has been achieved with manual switching, the requirements of international accounting for charges, and the transmission characteristics of a world-wide network.

As all of Australia's international traffic is also inter-continental traffic, we have played an active part in this working party. This was recognised at the last Plenary Assembly when Mr. W. G. Gosewinckel, of the Overseas Telecommunications Commission (Australia), was appointed chairman of the Working Party to fill the vacancy which occurred when Mr. Vargues became chairman of Study Group I.

WORKING PARTY ON EFFICIENCY FACTOR

(Chairman — Mr. Wilcockson, Great Britain)

Firstly, it must be noted with regret, that the Chairman, Mr. Wilcockson, has recently deceased. Mr. Wilcockson had been associated with the development of automatic teleprinter switching in the British Post Office for some time, during which he had been a British delegate to many C.C.I.T.T. meetings, so that his wide knowledge, experience, and cheerful personality will be missed from the Telegraph Study Groups.

A great deal of the progress which has been made in the development of inter-continental Telex working may be attributed to the introduction of the ARQ multiplex. This system, using automatic conversion from 5-unit code start stop working on land line networks to 7-unit synchronous working with automatic detection of errors and their correction (ARQ) in transmission over H.F. radio telegraph circuits, was originally evolved by the Netherlands P.T.T. in association with Radio Corporation of America. It has achieved world-wide acceptance, but with the extension in its use, some inherent problems must be faced. Under bad radio conditions the error detection/correction cycle may operate so frequently as to seriously reduce the traffic-carrying capacity of the channel. Administrations are consequently faced with problems in deciding at what stage the channel should be considered unserviceable and "busied out", at what stage of unserviceably, established calls could be "broken down", and what adjustments should be made to charging when traffic capacity is reduced. The "efficiency factor" has been used to measure the performance of ARQ systems, and this is how the Working Party dealing with these questions gained its name.

CONCLUSION

No account of the work of the Telegraph Study Groups would be complete without a mention of the C.C.I.T.T. Secretariat. These international civil servants handle the documentation of the C.C.I.T.T.'s work, translation and interpretation facilities, and liaison between the various international authorities interested in communications. Apart from the other sections of the International Telecommunication Union, these include such diverse groups as the World Meteorological Organisation, International Civil Aviation Organisation, International Standards Organisation, and others. The Secretariat is quite small, totalling only about 30 persons, including all administrative and clerical personnel as well as engineering. Of these, Mr. Besseyre, Senior Counsellor, who has had a long association with the former C.C.I.T., as a French delegate, and as a member of the Secretariat, and latterly with the C.C.I.T.T., and his assistant, a Japanese engineer, Mr. Okabe, deal with the Telegraph Department's affairs.

REFERENCES

1. E. Sawkins, "C.C.I.T.T. Study Group Meetings in Melbourne, October, 1963"; Telecommunication Journal of Aust., October 1963, Vol. 14, No. 2, Page 87.
2. C. J. Griffiths, "The International Telecommunication Union in 1965"; Telecommunication Journal of Aust., October 1965, Vol. 15, No. 3, Page 167.
3. E. R. Banks, "The Technical Assistance Role of the Consultative Committees"; Telecommunication Journal of Aust., October 1965, Vol. 15, No. 3, Page 172.

Mr. R. D. Kerr of the Australian Post Office and Mr. W. G. Gosewinckel of the Overseas Telecommunications Commission (Australia) inspect a sub-assembly from an O.T.C. semi-automatic telex position.

Mr. E. STEWART

Four prominent personalities in Australian Telecommunications, E. Stewart (Headquarters Postmaster-General's Department) S. Jones (Standard Telephones and Cables, Sydney) T. Skelton (Postmaster-General's Department, N.S.W.) and H. Robertson (Postmaster-General's Department, Victoria) began their careers together when they qualified at an appointment examination for Junior Mechanics-in-Training, Postmaster-General's Department held in Victoria in September, 1921. Three are still active in telecommunications, but one, Mr. Stewart, retired recently from the Department, an occasion which the Board of Editors wishes to mark with this brief reference to an outstanding career.

After completing the Junior Mechanics course Mr. Stewart was appointed Cadet Engineer in 1925. He qualified as Engineer, Postmaster-General's Department at an "Open Engineers" examination and was appointed Engineer in 1927. He moved to Central Office in 1928 and spent 6 years in the Transmission Section before transferring to the Research Laboratories where he was promoted Divisional Engineer in 1935. At this time, he was associated with the design and installation of the 6WF radio broadcasting transmitter in Perth, Western Australia. In 1936 he was promoted Assistant Supervising Engineer in the Research Laboratories and during World War II, was associated with radar investigations in liaison with the Radio Physics group in C.S.I.R.O.

Mr. Stewart's career entered a new phase when in 1950 he was appointed to the newly created position of Supervising Engineer, Technical Planning (later Systems Planning) in Central Office. Co-ordination of planning activities in the various Plant Sections and provision of high level planning advice to the Engineer-in-Chief became major tasks. In addition, he conducted preliminary investigations into overall problems which rapid post-war growth were bringing to the Department, particularly in the Sydney and Melbourne networks. During the late 1950's as a member of the Radio Frequency Allocation Review Committee he was engaged on special assignments concerned with the re-allocation of radio and TV frequencies in Australia.

In 1961 Mr. Stewart was promoted Assistant Engineer-in-Chief, Plant, Central Office a position which became Senior Assistant Director-General Lines and Switching before his retirement from it on 31 December 1965.

Mr. Stewart represented Australia on many overseas missions, e.g. Cairo 1938 — first ITU Administrative Telephone and Telegraph Conference, and Atlantic City 1947 — ITU Plenipotentiary Conference. In 1959 he led the Australian Delegation to the ITU Extraordinary Administrative Radio Conference at

Geneva and in 1960 he became the first Australian representative to the ITU Administrative Council.

An unhurried, friendly manner, a calm, logical approach and a quiet, unassuming personality won Mr. Stewart many friends during his career in telecommunications. The Board of Editors on behalf of the Telecommunication Society of Australia is very pleased to join with readers of the *Journal* in wishing Mr. Stewart the very best in his well earned retirement.

DEVELOPMENTS IN TELEGRAPH MESSAGE SWITCHING SYSTEMS

K. B. CASEY, B.E., Grad.I.E. Aust.*

Editorial Note: This paper was presented at the 38th ANZAAS Congress, Hobart, on August 17th, 1965.

INTRODUCTION

For many years telegraph message switching systems in Australia have been quite simple in equipment provision, relying almost entirely on the ability of human operators to achieve a satisfactory service.

With the rapid expansion that has occurred in business and industrial circles in the last decade has come the need for fast reliable and flexible communications, and this has been reflected into message switching as well as other communication media. The ever increasing labour costs have also been reflected into this field, placing the emphasis on automatic operation in preference to manual working.

Message switching systems have found their application initially in the Postmaster-General's Department for handling the Public Telegram traffic, and subsequently in the Defence Departments, newspaper, airline and financial organisations, manufacturing industries and retail trading firms. Each organisation established an independent network, based on a central switching office with access to all out-stations or branch offices. The out-stations were equipped with a standard teleprinter and connected via P.M.G. land-lines or telegraph trunk channels to the switching centre.

Such systems provide rapid and safe transmission of operational administrative or accounting information with the advantage of reception in the form most suitable for the area's needs, i.e. paper tape or page copy.

The alternatives to such systems are:—

(i) The Postal System network; generally too slow for the transfer of operational information.

(ii) The Public Telephone Network; generally too expensive in view of the volume of traffic and distances to be covered.

(iii) The Public Telex Network; this network is quite satisfactory and is widely used where the traffic volumes are small, but becomes far too expensive for heavy traffic users. Further, the operating and message handling problems become prohibitive with heavy traffic densities and with priority and multi-address messages in this system.

Requirements of Message Switching Systems

In order to appreciate the relative advantages of the message switching systems to be discussed, it is firstly necessary to define the facilities which can be provided, and which are required of message switching systems. While all the principal facilities are listed below it should be borne in mind that all of these are not required with every installation and many successful systems have been operated with quite a limited number.

Requirements of message switching systems are:—

(i) The ability to reliably handle traffic on a continuous on-line basis.

(ii) To operate with minimum cross office switching delay.

(iii) To incorporate facilities for checking the incoming message sequence number to detect lost messages.

(iv) The ability to insert a sequence number on outgoing messages.

(v) The ability to cross reference the incoming message sequence number against the outgoing message sequence number for message tracing purposes. This is commonly known as first line monitoring.

(vi) The ability to generate check messages to be transmitted to line in low traffic periods in order to check the continuity of the line.

(vii) The ability to handle multi-address messages.

(viii) The ability to handle priority messages.

(ix) The ability, if required, to interrupt the passage of a low priority message to an outgoing line when an extremely urgent message is to be transmitted.

(x) The ability to store or file a history record of the messages as they pass through the system so that they can be retrieved and re-sent in the event of a lost or mutilated message.

(xi) The ability to handle different transmission speeds on different lines.

(xii) The ability to handle a number of message formats.

(xiii) The ability to perform message format or code conversion.

Message Format

Since a message is to be transmitted from an outstation into the system without any communication or confirmation with the receiving position at the switching centre or the destination station it is necessary for the originating station to clearly state the message address and other instructions and to sequentially number messages to avoid lost messages. In order to regularise these statements operating formats have been laid down. These formats vary from a very loose convention of start and end of message for manual tape relay, up to extremely complicated procedures requiring letter perfect transmission over approximately 20 characters. In general, it can be said that the more sophisticated the switching system the greater the complexity of message format required, the greater the responsibility placed on originating operators and the greater the chance of equipment interruptions disrupting the transit of the message.

Typically a message format is as follows:—

(i) Start of address indicator — from one to four telegraph characters (typically ZCZC).

(ii) Channel identification code and message sequence number.

(iii) Start of address indicator — one or two telegraph characters.

(iv) Message priority indicator — a two letter code.

(v) Message address or addresses. Each address being a two to seven letter code.

(vi) End of address indicator — one or two characters.

(vii) Message text, i.e. the main body of the message.

(viii) End of message indicator — from one to four telegraph characters (typically NNNN).

TYPES OF MESSAGE HANDLING SYSTEMS

Manual Systems

Fully Manual Torn Tape Relay: While it may not be strictly valid to refer to these systems as switching systems they do perform the functions of message transfer and are worthy of analysis in view of their simplicity and of the number installed. In Fig. 1 the principles of the systems are shown.

The receive lines from the outstations are terminated on tape reperforators. An operator tears off each message, sorts it in regard to priority and address and inserts it at the first opportunity into a tape transmitter fixed to the outgoing line. For multi-addressed messages, the operator must retrieve the tape from the first transmitter and re-insert it into subsequent transmitters.

A log of message numbering is achieved by manually checking each incoming message sequence number against a check sheet, and numbering on the outgoing side is achieved by tab (that is short sequentially numbered tapes inserted before each tape), or alternatively by automatic equipment. As an additional safeguard against lost messages a first line monitor can be connected to the transmitter so that incoming and outgoing number sequences are cross-referenced.

* Mr. Casey, at time of writing, was Engineer, Class 2, Subscribers Equipment, Telegraphs and Power, Headquarters.

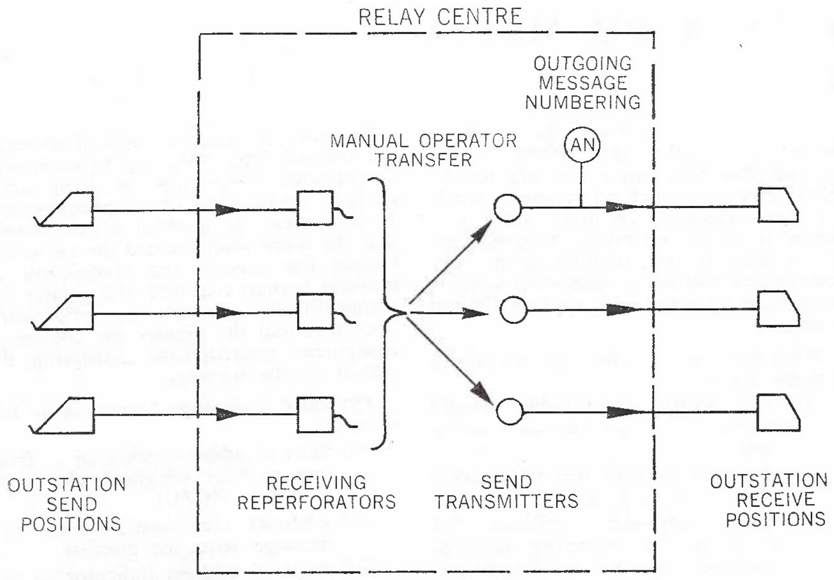

Fig. 1—Operating Principles of a Manual Relay Cenrte

Systems of the type shown in Fig. 1 have been quite popular in the past, undoubtedly because they can, so long as sufficient efficient operators are provided, satisfy all the requirements for switching systems set out above. However the physical problems of sorting, storing and transmitting become prohibitive as the number of lines in the system increases beyond 20, particularly if these lines are heavily loaded. In quite small systems of up to ten lines an operator could be expected to handle up to 200 messages an hour, depending on the amount of message logging required. In large systems this figure falls considerably, due to the physical distance to be covered and the need for each message to be handled by two operators, one removing the tapes from the incoming machine, sorting and storing them in an intermediate rack, and a sending operator who removes the tapes from the rack and inserts them into the transmitter.

Semi-automatic Line Selection Systems: In an endeavour to overcome the physical problems of handling a large number of torn tapes and to minimise the number of operators required, systems of the type shown in Fig. 2 were devised.

Instead of individual transmitters being fixed to each line, a transmitter position is associated with a push button panel and is able to select any of the outgoing lines. By arranging the receiving reperforators in tiers within arm's reach of the operator who is seated in front of the transmitter it is possible for one operator to handle from six to ten incoming lines, depending on traffic loading, together with three transmitters. In this way, provided the system is adequately dimensioned and with optimum grouping of reperforators and transmitters to facilitate traffic flow, it is possible for the operator to handle up to 300 messages per hour, thus achieving optimum utilisation of operating labour.

A distinct advantage of this system is that the time required to transmit multi-addressed messages is greatly reduced as the operator can select a combination of out-going lines by pressing a number of push buttons and simultaneous transmission can be made to each line from the one transmitter. The limitations on this type of system are physical, occurring when the operators can no longer reach the number of incoming reperforators or due to a reduction of operator efficiency as the transmitters encounter switching delays because of increased outgoing traffic loading.

This type of system achieves the most efficient use of manual operators and has been successfully operated up to 30 lines, although this would appear to be approaching the maximum efficient size.

A feature of manual systems which should be borne in mind when comparing them to automatic systems is the relative inability of the manual operator to cope with traffic peaks. While operators can sustain a rate of 300 messages per hour, i.e. 12 seconds per message, they are not capable, naturally enough of greatly reducing this handling time if a peak of traffic arrives, and the system then goes into delay, and cannot be cleared until a considerable time after the peak has passed. As will be shown later the switching time of the common equipment of an automatic system even with the slowest systems is around one second and thus while traffic peaks may put the system into delay, clearance is effected much quicker than with the manual working.

Automatic Systems

The obvious advantages to be gained by automatic systems are the elimination of human operators, which affords considerable savings in running costs particularly in large systems, a reduction in lost and mis-routed messages and a greatly decreased message switching delay. Further the physical limitations of system size and the congestion which occurs with heavy traffic peaks are eliminated. Since the human operator has been removed intelligence of the switching control must be placed in common control equipment which is of necessity complicated. The reliability of the system is therefore largely a function of the reliability of the common control equipment. Whereas with manual systems a circuit fault puts one line out of service, a fault in the common equipment of an automatic system can prevent operation of the entire system. It is therefore essential, in order to achieve system reliability to duplicate common equipment and this considerably

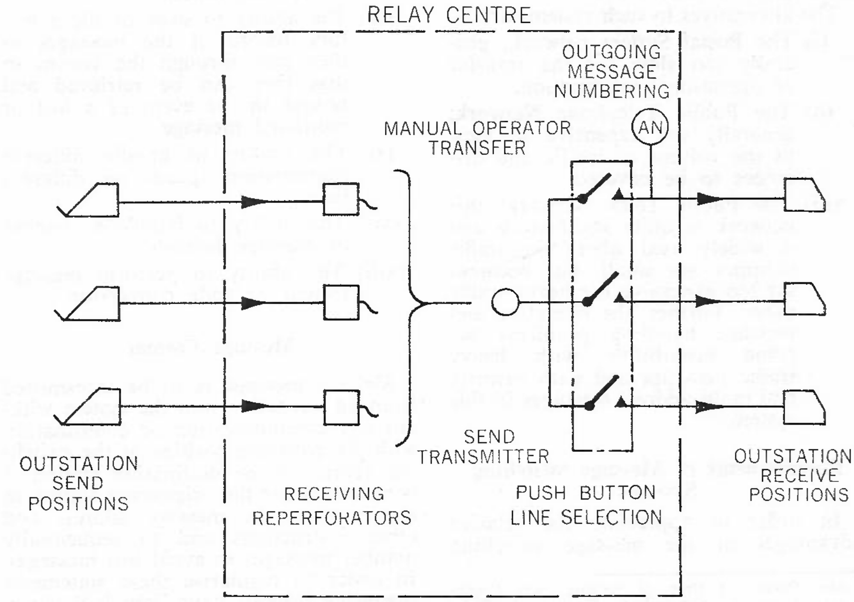

Fig. 2—Operating Principles of a Semi-Automatic System

increases the cost involved, particularly for the more sophisticated systems. In operating automatic systems, it must be observed from the outset, that, whereas with manual systems the message format can be quite unrestricted relying on the intelligence of the operator to interpret the address, with automatic systems the start and end of message and start and end of address indicators, together with the address and priority coding must adhere to a strict procedure. This places considerable responsibility on the originating teleprinter operator in order to ensure the transit of messages through the system. As a result more highly skilled operators must be employed at the outstations otherwise the advantages to be gained in automatic working are jeopardized by an excessive number of message re-runs. Alternatively, where skilled operators cannot be justified, format generating equipment can be associated with the outstation teleprinter so as to insert the start and end of message sequence on each message. The operator is therefore only required to type the message text. Such equipment is not cheap and could rarely be justified at all outstations.

Automatic systems fall into three basic types, classified by the method of message storage and logic control—

Sequential access storage.

Random access storage using fixed circuit logic.

Random access storage using programmed logic.

Sequential Access Storage: The storage medium in this type of system is either paper tape or magnetic tape or core storage of small capacity. The basic mode of operation of these systems is shown in Fig. 3.

As the message is received from the outstation and taken into the incoming store, incoming equipment scans the message for the incoming channel code and message sequence number to ensure that no messages have been lost. The output side of the store scans the message looking for the start of address indicator, then pauses for the common control equipment to be connected. This feature is particularly necessary when the cross office transmission speed is greater than line speed to ensure that the cross office connection is not held unnecessarily due to the read-out of the store catching up to the read-in.

When the common equipment is connected, the address of the message is read from the store into the common equipment where analysis and selection of the outgoing line takes place, and also into a small capacity store so that it will be available for re-transmission to the outgoing line.

Once connection has been made to the outgoing line, the common equipment is released and a test is made to determine whether the outgoing line is busy or free. If busy, the transmitter must "camp-on" the outgoing line, and continue to retest until the line becomes free. When free, the automatic numbering equipment associated with that line inserts the heading line of the message including an outgoing channel number. The address is sent from the address store, followed by transmission of the message text from the incoming store. On the end of message indicator the cross office connection is released.

Transmission of the message from the outgoing store to line can commence immediately the message starts to arrive at the input side as speed changing is usually from a higher speed of cross office to the lower line speed.

The sequential nature of the incoming store imposes the limitation that messages can only be taken from the store in the order of their arrival. Thus if a message at the head of the queue is waiting to switch, all other messages behind it in the store are in delay. This delay can be avoided if a pool of intermediate stores are provided such that instead of a message "camping-on" a busy line, it is diverted into an intermediate store thus allowing the next message in the queue to be switched. The provision of these intermediate stores is quite expensive and they are provided only with the more sophisticated systems.

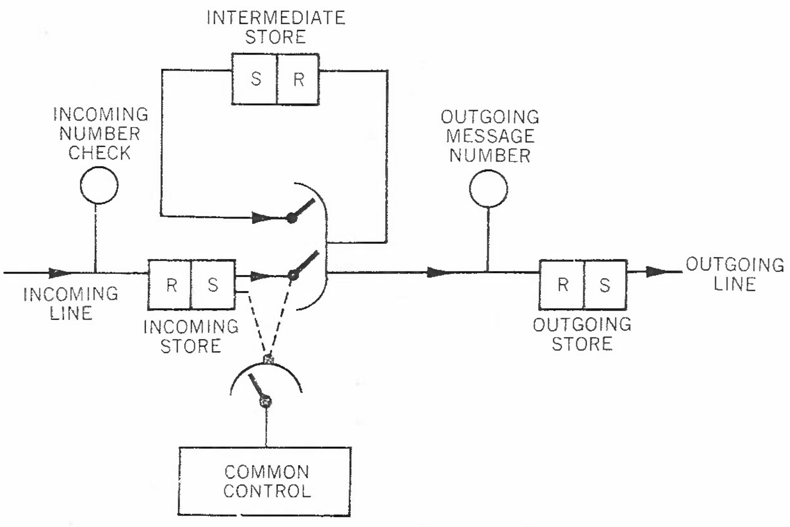

Fig. 3—Operating Principles of a Sequential Access System

Provided certain traffic loading conditions which are beyond the scope of this paper, are satisfied, systems of this type can efficiently handle large volumes of traffic with cross office delays of less than one or two times the message length, and can readily switch up to 3000 messages per hour.

In general sequential access storage systems do not lend themselves to handling priority or multi-address traffic Again because of the limitations of sequential accesses, a priority message arriving behind a number of low priority messages cannot receive attention until all the other messages ahead of it have been switched. Obviously this results in considerable delay to the priority message. However, once the priority message has reached the head of the incoming queue it is relatively easy to arrange for it to be given preference in gaining access to the outgoing line, or alternatively it can be switched via a special outlet which by-passes the outgoing store and be sent directly to line.

With multi-addressed traffic the limitation is imposed by the capacity of the address store to hold a number of addresses and for reasons of economy this is usually limited. This limitation can be avoided if reversible transmitters are employed. Such transmitters read the message header into the common control, and then reverse back to the start of address of that message, so that the address can subsequently be sent to line. Further, as a multi-addressed message has to switch to a number of lines, complications arise if on testing these lines not all are free. The message must wait until all are free simultaneously or alternatively if intermediate stores are provided, the messages can be sent to the idle lines as well as being held in the intermediate store until such time as the busy lines become free. While the first approach results in the most simple and economical solution, it is from a traffic handling standpoint far inferior to the second. With intermediate stores both the common control and the address store must be capable of recognising the lines to which the message was sent on the initial attempt, and deduct these from subsequent transmissions of that message. The equipment required to perform this operation is quite complicated and expensive.

First line monitoring equipment for logging the incoming message sequence number against the outgoing sequence number is possible with these systems, though is not always provided when tape stores are used, as these stores present a ready checking point for lost messages.

When considering sequential access magnetic stores it should be noticed that as they are usually of rather limited capacity (2000 characters being typical) it is not possible to keep a permanent record of one day's traffic as it is with tape storage, thus first line monitoring facilities are more applicable to these systems. This contributes to magnetic storage systems being generally higher in cost than tape systems.

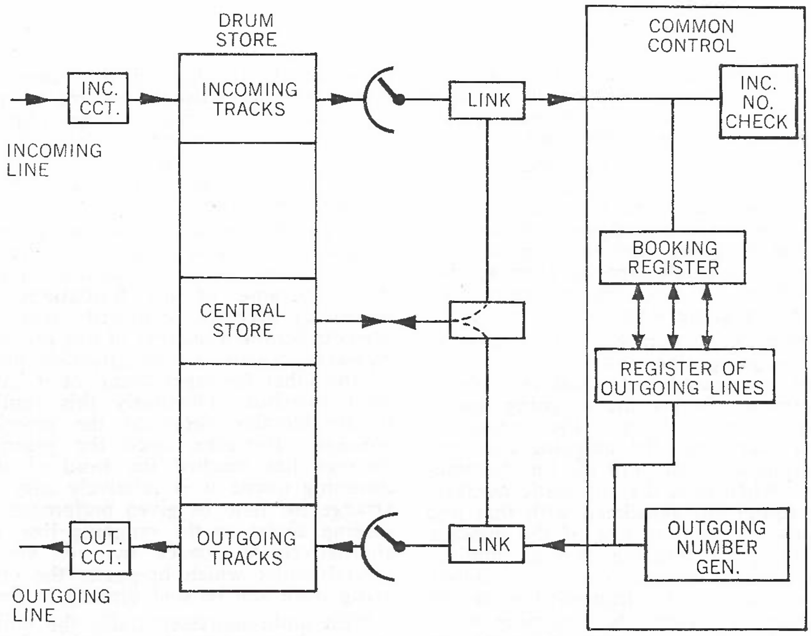

Fig. 4—Operating Principles of Random Access Fixed Circuit Logic Systems

Random Access With Fixed Circuit Logic: Random access is the term applied to storage devices, which permit a message to be removed from the store at any time after its arrival irrespective of its time of arrival or of other messages already in store.

This facility represents a considerable advance on the techniques of message handling and removes the limitations on priority and multi-address which were inherent in the previous systems. Random access storage gives in effect the same flexibility possible with the purely manual relay system, but with vastly improved handling speeds and reliability.

A common method of providing the large capacity random access storage is with a rotating magnetic drum. Typically a drum 5 ft. high with a 12 in. diameter and rotating at 1500 r.p.m. is capable of storing 250,000 telegraph characters and can be used at a speed of 50 kilobauds.

Fig. 4 shows a typical trunking diagram of the system.

Since the message is received at the incoming circuit at speeds of between 50 and 200 bauds, a scan is made to detect the start of message signal. Once detected, each character is taken into a one character line store and at the end of that character is transferred at 50 kilobauds to an incoming track on the rotating drum. The incoming line circuit meanwhile has been scanning for the end of message signal, and when received, the message is transferred from the incoming track via a group and link circuit to the central store. As it passes through the link circuit the message header is taken into the common control.

From the message header the incoming message number is checked and the priority and address analysed. This information is placed in a booking register.

The booking register is continually scanned and compared to a register of outgoing lines, and once it has been recognised that a message is waiting and that the outgoing line is free, the highest priority message is read from the store via the outgoing link circuit to the outgoing line track, an outgoing number being inserted in the message on the way.

From the outgoing track the message is transferred character by character at 50 kilobauds to a store in the outgoing line circuit and from there to line at the desired telegraph operating speed.

For multi-address messages, a mark is placed in the booking register for each of the required outgoing lines and thereafter the message is treated as a number of individual messages. This is possible because the read out of a message from the central store is non-destructive and the message is available there until it is replaced by another message being read-in, which is not allowed until the message has been cleared to all addresses.

Over-flow magnetic tape stores are provided in the event of the common store approaching its maximum capacity (due to failure of outgoing lines for example). Messages can be transferred from the common store to these tapes and retrieved later when the line is available.

Since the individual line circuits are extremely simple, containing virtually only a one character store, the remainder of the system being on a common basis, the need for circuit reliability is greatly increased. A failure in the common control or drum storage equipment will not only prevent switching, but will result in messages being lost as there are no individual line stores for holding the incoming traffic. This traffic will continue to arrive until such time as all outstations are contacted and asked to stop sending. This is in contrast to systems having individual line stores where a common control failure will stop switching but will not result in lost messages. It is therefore necessary to duplicate virtually the entire system to achieve reliability, and this of course greatly increases the cost.

Random Access with Programmed Logic: The distinguishing feature of this method of working is the use of a standard electronic computer programmed for message switching, working via interface equipment to telegraph lines or data links. The basic operating principles are shown in Fig 5.

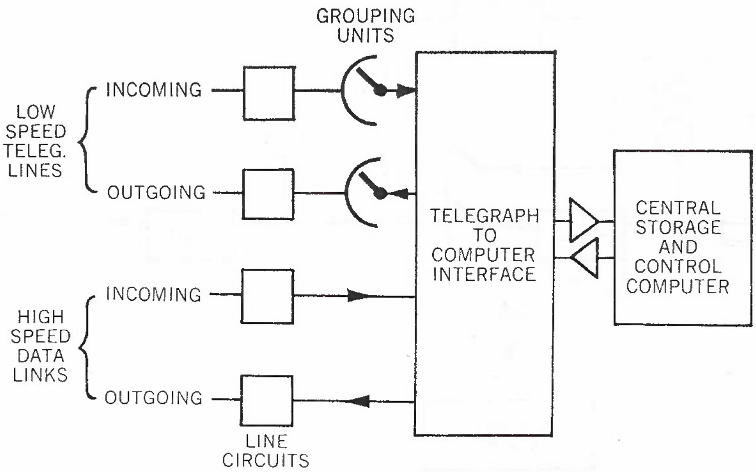

Fig. 5—Operating Principles of a Random Access Programmed Logic System

As a message switching system it can of course provide all the required features, at extremely high cross office speeds and with the utmost flexibility in address decoding and multi-access working and system trunking.

Since the message interpreting and address decoding equipment is not tied to fixed logic circuits it is possible to accommodate a wide range of telegraph operating speeds and to handle messages with different message formats or even with different code alphabets as code translation can be readily handled in the programmed control.

Further, since the control logic of the system is dictated by programme, it is possible by changing the control programme or portions of it to quickly alter the trunking, the operating speed of any line, etc. This enables the size and operating conditions of the network to be altered as the traffic varies with daily or seasonal requirements or when additional lines are added.

Many systems have the ability to perform error detecting or correcting functions on each received character, or in the event of a mutilated message, the computer can generate a request to the outstation to re-run messages.

The inclusion of large capacity magnetic tape or disc file stores enables history records of all messages to be retained and on a request for a re-run of a message from an outstation, the computer can retrieve this message and resend it without recourse to a manual operator.

Alternatively the mutilated message can be presented to an operator, on a television screen for example, where it can be corrected or edited by a simple keyboard operation.

Extending beyond the strict telegraph message switching field this system can also switch data traffic either independently of the low speed telegraph traffic or by grouping large volumes of telegraph traffic onto a broad band group (1,000 bauds or higher) for transmission. This feature can be used for large volume links to other switching centres or into a subsidiary computer for processing. The only computer based system scheduled for installation in Australia to date is for a major airline operator, and incorporates this facility in order to transfer messages from the switching computer into a seat reservation and booking computer. Information as to the seat details are then returned to the switching computer and sent as a telegraph message to confirm the booking to the outstation.

A further possibility claimed by most manufacturers is to time share the computer's capacity, which is not fully utilised particularly in light traffic periods so as to simultaneously run the switching programme with a routine data processing programme. In this way administrative or clerical data processing can be performed on the same computer without interfering with the message switching and this is obviously a most attractive feature from the user's viewpoint. The computer can also give regular reports and statistical data on the traffic being carried and on the performance of the system itself. The stringent reliability requirements imposed by real-time continuous on-line operation dictated the installation of a dual system. In order to avoid any interference to the traffic in event of a failure the two computers are operated in parallel, with each message actually being processed by them both, although only one is actively on line at a time. Line patching facilities are also offered which can automatically replace the line circuitry.

Typically a system with a storage capacity from 5 to 500 million bits could switch a 500 line system carrying 60,000 messages per hour, the cross office transmission time for each message being less than 60 milliseconds.

Such systems, at this stage appear to offer the ultimate in message and data handling, but as will be discussed, the cost is extremely high and a considerable effort must be deployed to organise the executive programmes. However, once installed the speed and flexibility and supplementary facilities are most attractive.

COST STRUCTURE

In order to obtain information on the cost of message switching systems an analysis was made of the systems already installed in Australia and general estimates were obtained from system manufacturers, particularly in relation to those systems of which there are no examples in this country. While the figures quoted could not be considered applicable to any particular system, due to the wide variety of facilities and manufacturing techniques employed, it is felt they are representative of the range of cost for each system type and of the relative cost relationships between types.

Fully manual systems range in cost from around £500 per line to £1,200 per line for systems fitted with automatic message numbering. Due to the absence of common control equipment the cost of these systems increases linearly with the number of lines, that is cost per line is independent of the number of lines.

With automatic selection systems the cost not only varies with facilities, but also with the type of equipment used. It is interesting to note that these systems can be cheaper than fully manual systems principally due to the reduction of the number of cross office transmitters. However, quite elaborate semi-automatic systems are available, which include intermediate stores for handling multi-address traffic. Such systems can cost up to £3,000 per line.

Automatic tape storage systems incorporating the minimum of facilities (particularly if facilities for multi-address and priority are excluded) can cost as little as £1,500 per line. When multi-address and priority facilities are included the cost for tape storage systems approaches £5,000 per line. Since the common equipment in these systems is not of great complexity and as the storages are provided on a per-line basis, the cost per line is again more or less independent of the number of lines.

With automatic magnetic storage systems the cost per line for equivalent facilities is up to twice that for a tape storage system being made up mainly of the difference in cost between the tape and magnetic storages. It is usual, however, for magnetic storage systems to be installed with a wider range of facilities than tape storage systems mainly as a result of the inherent advantages of magnetic storage, for example, higher cross office transmission speeds. Further, as the storage capacity of the magnetic stores is limited (up to 4,000 characters), such systems invariably incorporate intermediate stores. While this immediately results in distinct advantages in traffic handling the cost of such systems with intermediate storage can be as high as £8,000 per line.

A most important aspect of the cost structure of the systems so far discussed is that the cost per line is, particularly with the manual systems and to a lesser extent with the automatic sequential ac-

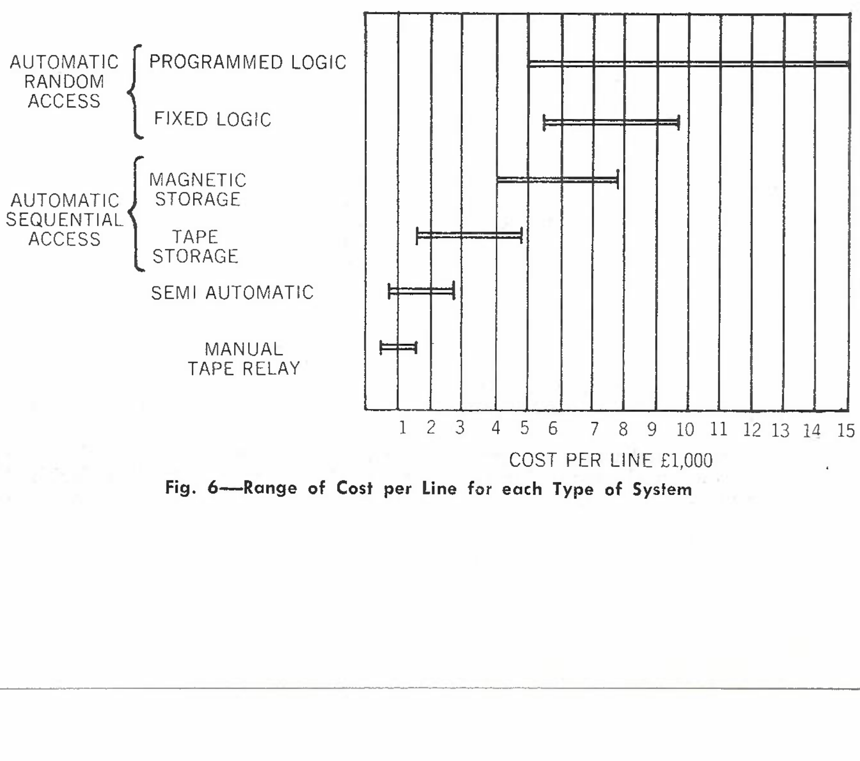

Fig. 6—Range of Cost per Line for each Type of System

cess systems, independent of the number of lines. Such systems are therefore applicable to small installations, and enable an operator to tailor both the size and facilities of his system to his limited capital, and to increase the size and facilities in subsequent years as more capital is available, or as traffic growth demands it.

This is in direct contrast to the random access systems, in which both the line storage and switching control is provided on a common basis. The initial capital outlay for such systems is in general mainly independent of the number of lines and thus for small systems the cost per line can be extremely high, of the order of £10,000 to £15,000 per line but can be quite competitive for large systems approaching £5,000 per line.

Typically the initial cost of a random access fixed logic system is of the order of £300,000 and range up from £800,000 for a programmed logic system. The lower cost of the fixed logic systems comes from the fact that these systems have been engineered particularly to the message switching application. By contrast, programmed logic systems employ a computer adapted from a general purpose design with a resulting redundancy of circuit provision. Further, storage must be provided in the programmed logic system to accommodate the executive programmes, and this is not required with fixed logic systems where the executive control is to a large extent hard wired. In general it can be said that when considered as a means of switching low speed (50 to 200 bauds) telegraph messages, the fixed logic systems represent the most economical method of realizing the facilities set out in the introduction. This is certainly true for small systems, but for large systems the programmed logic systems, even at today's prices can be competitive, and can be far more attractive if the data processing capabilities or the flexibility of these systems are utilised.

So far the capital investment involved in message switching systems has been discussed, but it should be noted that this does not necessarily represent the cost of the system to business, industrial or governmental department using the system. It is common practice throughout of the world for the communication administration or for major electrical manufacturers to provide and install such systems and to lease them for a smaller annual charge to the operator. This practice is adopted in Australia where the Department has for many years rented fully manual and semi-automatic selection systems, and will be applied shortly by a major computer manufacturer who is to lease a programmed logic system to a major airline operator.

The annual rentals charged vary between 20 to 40% of the installed capital, but it should be remembered that this charge also includes the cost of system maintenance, and an allowance for ultimate replacement.

EXISTING INSTALLATIONS IN AUSTRALIA

A survey of the message handling systems at present in Australia is summarised in Table I. In total there are approximately 50 systems, representing a capital investment of over two million pounds.

TABLE 1

Type	No. of Installations	Average No. of Lines	Average Capital Investment per Line
			£
Full Manual Relay	34	10	750
Semi-Automatic Line Selection	8	16	1,300
Automatic Sequential Access Storage	7	90	1,500
Automatic Random Access Storage. Fixed Circuit Logic.	2	40	6,500
Automatic Random Access Storage. Programmed Logic.	—	—	—

Of these systems 31 are owned and maintained by the P.M.G. Department but leased to private business, industrial or governmental organisations. All of these are of the manual or semi-automatic types.

Seven integrated automatic tape storage systems are operated by the Department to carry the public telegram traffic. Generally these are quite large systems, one being of 350 lines. The seven systems are interconnected in an Australia-wide network and for the last six years have carried approximately 20 million messages annually.

Approximately 12 systems are owned and maintained by operators outside the Department, principally by the armed forces.

FUTURE DEVELOPMENTS

Up until six years ago only manual systems were operating in Australia. Increasing operating costs and the need for greater efficiency and reduced handling times precipitated the installation of eight semi-automatic and nine automatic systems since then to replace existing manual systems. This trend is continuing, and at present a further three semi-automatic systems are being developed, and one automatic tape storage system is being installed.

It could be expected, that for smaller systems of up to 20 lines, this tendency of replacing manual with semi-automatic or sequential access systems will continue for a few years, but it is doubtful if this trend will result in the replacement of all manual systems. On the other hand many users, particularly in the Airline and Governmental fields are becoming interested in random access systems, and quite recently a major Airline company announced plans to install a computer based system (random access programmed logic) to replace their rather large manual system. This is the first of the programmed logic systems scheduled for Australia.

While many of the operators would like to follow this lead and avail themselves of the very attractive facilities offered by such systems the large capital outlay involved is a considerable deterrent. There is a tendency therefore to install the most economical semi-automatic or fully automatic systems for the present with a view to writing such systems off, if in a few years the sophisticated systems become more economical. There are two factors which could precipitate this. Firstly, as electronic computers become more widely used their cost would reasonably be expected to decrease with technological and manufacturing refinements. Secondly, as has already been discussed, these systems are quite competitive providing there is a need for a large number of lines. This suggests that a common carrier network could be established, possibly by the Department or another legally constituted body, consisting of inter-connected programmed logic systems in order to lease independent groups of lines to the smaller users.

The programmed logic, allowing flexibility in traffic, operating format etc., is ideally suited for this application. However the organisational and administrative problems associated with this approach should not be underestimated, and there is naturally considerable reluctance on the part of a user to allow his vital communications to be controlled from outside his organisation, and there is also the fear of loss of privacy particularly among competing organisations.

The above trend could result in manual semi-automatic or tape storage automatic systems being converted directly to the programmed logic systems and subsequently in very few installations being made in this country of complicated sequential storage systems of the magnetic variety or of fixed programme random access systems.

Another branch of development will undoubtedly come from the data transmission field as a result of computers being applied in organisations which to date have had no message switching requirements. This requirement will be inter-computer high speed traffic and also lower speed transmission from data collection points into a central computer for processing. While it is true that such traffic could be handled on direct private lines, and in all probability will be so handled initially, this traffic could be readily accommodated at high speed on a common carrier switching network with a considerable saving in trunk channel charges.

ARM 50 CROSSBAR TRANSIT EXCHANGE

*K. BARNES, B.Sc., Grad. I.E. Aust.**

INTRODUCTION

The L. M. Ericsson ARM 50 system is a common control group selector system designed for small and medium size telephone and telegraph transit switching centres. The system was first installed in Finland in 1954, and is now in use in a number of countries overseas. The pilot installation for the Australian Post Office will be the 80-line Automatic Telex exchange at Canberra (1), which is due to be placed in service some time in 1966.

It has been pointed out by Wright (2) that the ARM 50 exchange will find an application in the telephone network in some of the smaller centres, where there are four wire switching requirements and where the 20 year capacity of the trunk exchange is not likely to exceed three 200-line units.

The common control equipment of the ARM 50 system is generally similar to that of the ARM 20 system, the main difference being that no test blocks are provided in ARM 50, the test and selection of a free line on the required route being effected by a marker (M) after route determination has been carried out by a route marker (VM). The registers and line relay sets are the same as those used in ARM 20, the types provided depending on the method of signalling used. When the common control equipment is built out to its maximum capacity and the system is required to handle approximately 6000 calls per hour, call waiting times approach three seconds.

GENERAL DESCRIPTION

System ARM 50 is a group selector stage built up of crossbar switches and comprising initially two partial stages GVA and GVB, verticals of GVA being connected to verticals of GVB to form links. The system operates on the by-path principle, the switches being operated under the control of markers. The selector stage is one-way (from GVA to GVB), the incoming lines being connected to the GVA stage and the outgoing lines to the GVB stage. A both-way line, therefore, must be connected to both GVA and GVB partial stages.

The type of ARM 50 system selected by the A.P.O. is known as ARM 503/2, in which the crossbar switches are permanently wired to the rack. For the sake of simplicity, the term ARM 50 will be used in this article to refer specifically to the ARM 503/2 exchange.

Basic Switching Unit

The basic switching unit consists of two crossbar switches each with 10 verticals comprising the GVA stage, and two similar switches comprising the GVB stage, the outlets of each pair of switches being horizontally multipl ed.

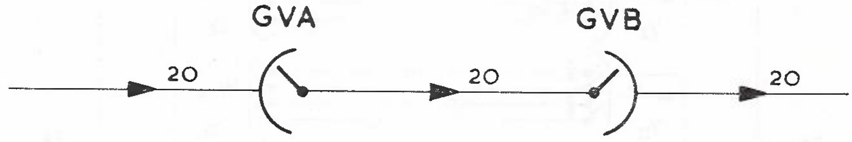

Fig. 1 — A 20-group.

This unit, called a 20-group, is shown in Fig. 1, and contains 20 inlets in GVA and 20 outlets in GVB, with 20 GVA-GVB links.

Two 20-groups can be accommodated in one GV rack, and due to this mechanical design the system has an initial capacity of 40 inlets and 40 outlets, or 40 both-way lines, with 40 GVA-GVB links. The 20 links from each GVA group are distributed over all GVB groups. In some cases, the 20 links can be equally distributed, for example where the GV equipment consists of one rack or two 20-groups, in which case each GVA group is connected by 10 links to each of the two GVB groups, as shown in Fig. 2.

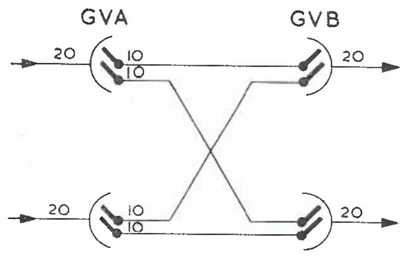

Fig. 2

However, in other cases the 20 links cannot be distributed equally over all GVB groups, for example where the GV equipment consists of three racks or six 20-groups, in which case each GVA group is connected by four links to two GVB groups and by three links to the other four GVB groups.

Internal Congestion

Internal congestion in ARM 50 means that no free link is available; that is, the selected outgoing line is connected to a GVB group which cannot be reached from the GVA group containing the incoming line because all links are busy. In such a case, the connection can be routed via an overflow link in another 20-group. An overflow link OFLR is a relay set interconnecting one GVA inlet and one GVB outlet in each 20-group, and the way in which a call is routed via an overflow link is shown schematically in Fig. 3. In this example, an incoming line in 20-group No. 1 may be routed to a free line located in the GVB multiple of the same 20-group if one of the 10 links from GVA to GVB in the same 20-group is free. If all these links are occupied, as indicated in the figure, test is made of an overflow link OFLR in 20-group No. 2. If this overflow link is free, connection is made from GVA of 20-group No. 1, over one of the free links to GVB of 20-group No. 2, via the overflow link OFLR to GVA of 20-group No. 2. If now there are free links from this GVA to GVB of 20-group No. 1, the connection is established as indicated in Fig. 3.

Since an overflow link is connected to one GVA inlet and one GVB outlet in each 20-group, the effective capacity of each 20-group is reduced to 19 inlets and 19 outlets.

Link Interconnections

As stated previously, all 20-groups are interconnected by means of links, the method of interconnecting depend-

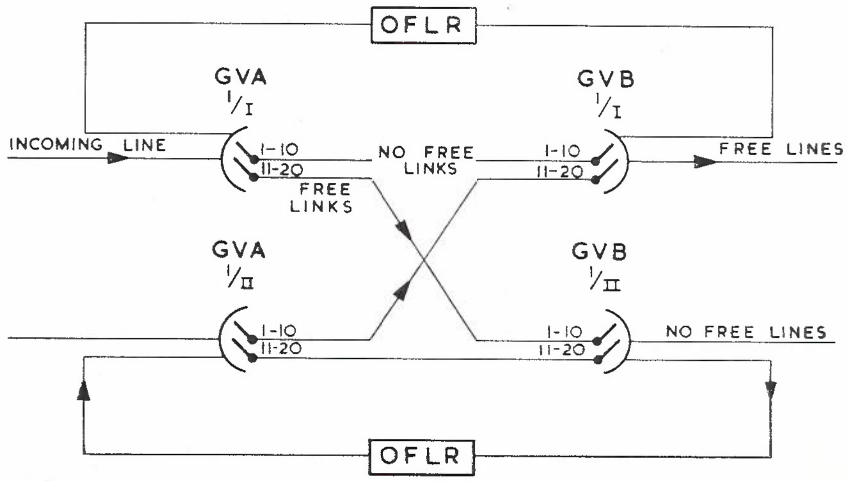

Fig. 3 — Routing of a Call via an Overflow Link.

* Mr. Barnes is Engineer, Class 2, Subscribers Equipment, Telegraph and Power, Headquarters.

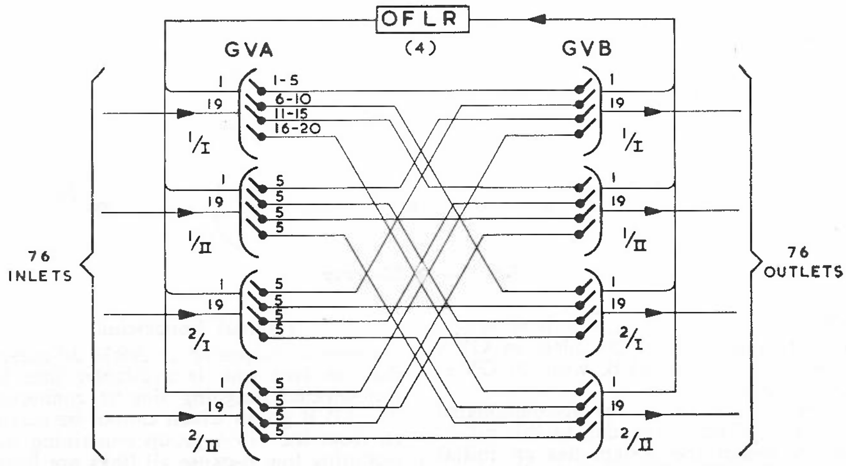

Fig. 4 — Link Interconnection Scheme for an Installation Having Two GV Racks.

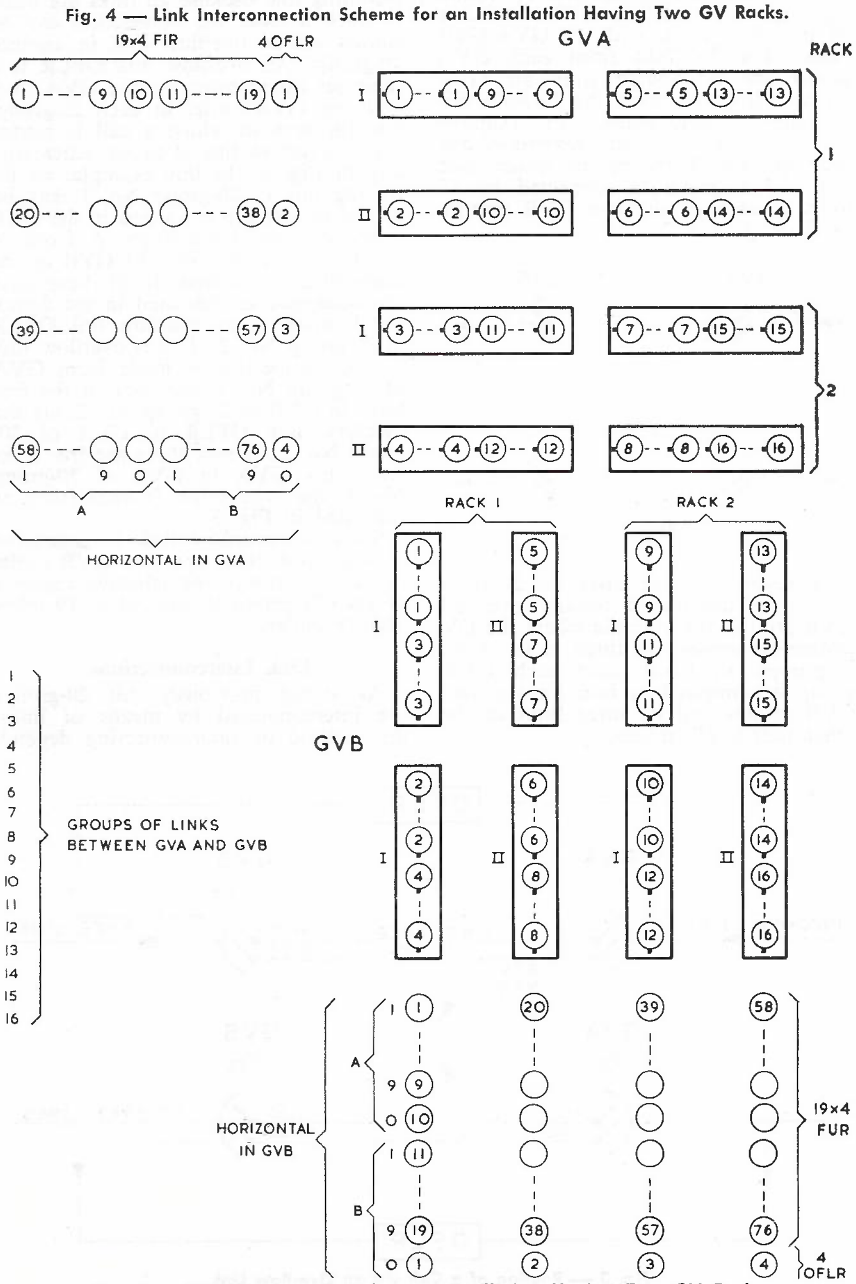

Fig. 5 — GV Grouping Plan for an Installation Having Two GV Racks.

ing on the number of GV racks installed. As an example, the link interconnection scheme used for an installation having two GV racks, or four 20-groups, is shown in Fig. 4, while the GV grouping plan for this exchange is shown in Fig. 5. It can be seen how the effective capacity of an exchange of this size is reduced to 76 inlets and 76 outlets, by the allocation of one inlet and one outlet in each 20-group for overflow links.

The incoming and outgoing lines on a route are equally distributed among all 20-groups, and because of the link distribution an incoming line in any GVA group can be connected to an outgoing line in any GVB group, as long as a link is available.

Exchange Capacities

The practical upper limit of a 2-stage ARM 50 exchange, imposed for traffic reasons, is 10 groups or 200 inlets and 200 outlets. The exchange is built up beyond this capacity by the addition of a third switching stage GVC, which allows the practical upper limit to be extended to three such 200-groups, or 600 inlets and 600 outlets. The GVC stage is common to all 200-groups, which in turn are interconnected via GVA-GVB overflow links, while the normal overflow links between 20-groups within the same 200-group are not provided. A number of GVB outlets are connected to GVC verticals to form GVB-GVC links. The outgoing lines of major routes are connected to remaining GVB outlets, while the lines of minor routes are connected to GVC outlets. The trunking arrangement used for 3-stage working is shown in Fig. 6.

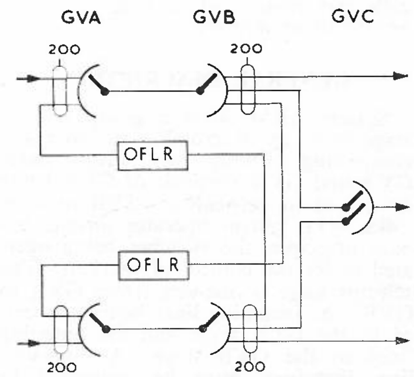

Fig. 6 — Trunking Arrangement for 3-Stage Working.

ARRANGEMENT AND FUNCTIONS OF EQUIPMENT

Fig. 7 shows the block diagram of a 2-stage ARM 50 transit exchange. The arrangement and functions of the various units of equipment shown in the diagram are described in the following sections.

Line Repeaters — FIR, FUR

The lines connected to the transit exchange may be of many types, and each type has its own repeater. For example, the lines include among others, inter-transit exchange trunks, junctions to the local terminal exchange and circuits to test and service positions. No further reference to types will be included in this article.

Register Finders, RS

A register finder provides access between incoming repeater and register. The type of register finder marker RSM used depends on the number of wires to be through-connected, being either the RSM-64 line, with capacity for 64 repeaters and 20 registers for a 10-point connection, or the RSM-64/20, with capacity for 64 repeaters and 20 registers for a 20-point connection with RS switches working in pairs.

Register, REG

A register directs and controls the connection to the called subscriber. It receives and stores information regarding the calling subscribers classification and tariff zone, and the called subscribers routing digits, and passes this information on to the route marker when connected. After the connection from incoming line to outgoing line is completed, the marker releases and the connection is held under the supervision of the register which transmits signals forward over the outgoing line so that a connection may be set up to the called subscriber. The register is released when the connection is completed, or when control of the connection has been taken over by another register in the subsequent exchange.

Call Distributor for Route Markers, RK/VM

RK/VM contains free marking relays and a call distributor, which distributes incoming calls so that route markers will be occupied consecutively.

Register to Route Marker Connector, RM

The connection between register and route marker is a 48-wire connection, which is completed by means of multi-coil relays in RM. The smallest RM unit consists of a relay set which connects eight registers (divided into two groups of four) to two route markers. Only one register in each group of four can be served at a time, and one route marker can in turn serve 10 RM units, which is the capacity of the RM rack; that is, one RM rack, fully equipped, can connect 40 registers to two route markers.

RK/VM and RM relay sets are mounted on the RM rack.

Route Marker VM

The marker functions of the system are divided between two units, route marker VM and marker M.

The route marker identifies the calling register, establishes connection with it via RM, and receives from it tariff and routing information. It analyses this information, selects the required route or part of a route in a direct or alternative route which has free lines, transmits back to the incoming line repeater the tariff rate appropriate for the connection, and connects itself to a marker. The marker then sets up the connection by selecting both a free line on the selected route, and a free path through the switching stages.

The route marker normally contains equipment for 20 routes, although the system is designed for a maximum of 55 routes. A route can consist of three line groups, each comprising a maximum of 40 lines distributed to two route parts each of 20 lines. This arrangement can be used, for example, for one direct route with two route parts, and two alternative routes each with two route parts. Thus if all three groups or six route parts are used for the direct route, the latter can contain a maximum of 120 lines.

The ARM 50 system at present being installed for the A.P.O. has a maximum capacity of two route markers, which are installed on the one VM rack. Each route marker contains the following relay sets:—

AK-REG Call chains for registers. The call chains can identify, in two stages, calls from 10 register groups each of four registers.

KM-S A relay set for the reception of digit and tariff information from the register. The relay set also receives information to determine to which marker the route marker is to be connected.

S A relay set for routing and tariff analysis and determination. A route marker can contain either one or two S-relay sets, depending on the degree of complexity of analysis required.

ZS A relay set containing rate setting relays which operate on a particular combination of originating tariff zone, subscribers classification and routing digit information, and return the appropriate tariff rate to the incoming repeater for metering purposes.

VVR A relay set for route marking, and for the test and selection of a route part. The relay set also contains relays which initiate the setting up of a call to an overflow link should internal congestion be encountered, as well as control relays for time supervision, fault registration and other special functions.

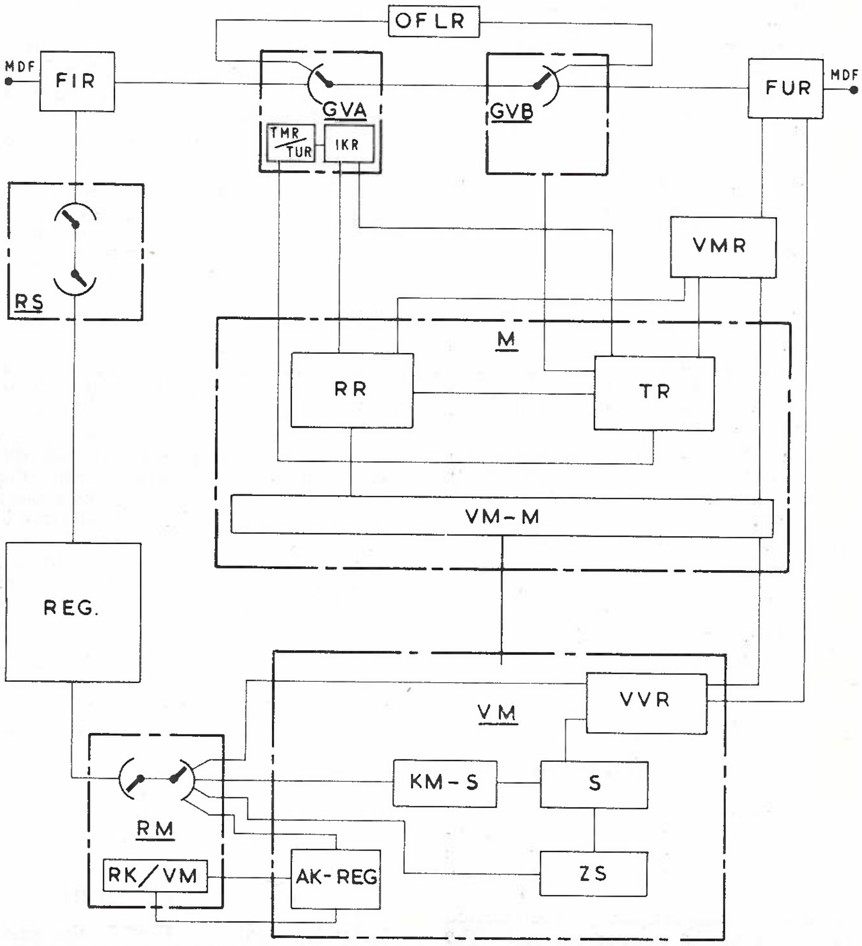

Fig. 7 — Block Diagram of a 2-Stage ARM 50 Transit Exchange.

Marker, M

The marker sets up the connection through the selector stages. It selects a free line on the required route, finds a free path through the selector stages from the incoming line to the selected outgoing line, and completes the connection by causing the appropriate horizontal and vertical magnets to operate.

The ARM 50 system has a maximum capacity of two markers, which are installed on the one M rack. In the 2-stage system, each marker contains the following relay sets.

VM-M A relay set for completing the 74-wire connection between marker and route marker.

RR A relay set for the indication and marking of idle GVA-GVB links. The relay set also contains relays which connect marker identification code to the route marker, to ensure that the correct marker-route marker connection is established.

TR A relay set for the test and selection of a free line on the required route, by the use of line test relays in series with cold cathode tubes. The same test circuits are used for test and selection of a free overflow link. The relay set also contains control relays for test supervision, as well as relays for the testing and operation of horizontal and vertical magnets in both selector stages.

Group Selector Equipment, GV

A GV rack comprises two 20-groups, and contains four GVA and four GVB switches wired to the rack and connected together by means of links as previously described. The GV rack also contains the following relay sets:

IKR A relay chain per 20-group permanently wired to the rack, for the identification and selection of the incoming repeater and the operation of GVA horizontal magnets corresponding to its position in the GVA multiple. The relay set also contains relays for the connection of the test and control wires of the marker to the GVA switch group.

TMR/TUR A relay set per 20-group for the test and selection of a marker.

OFLR One relay set per rack containing two overflow link circuits, each of which is wired to horizontal position 20 in the GVA and GVB multiple of the same 20-group.

Route Connector, VMR

The operation of a particular route marking and route test relay combination in the route marker causes the operation of a particular multicoil relay in the route connecting relay set VMR, which connects the lines on the selected route part to the marker for test. The relay set also contains relays which connect the OFLR links to the marker for test and selection of a free overflow link. A VMR relay set has a capacity of 10 route parts, each of 20 lines, and additional relay sets are wired to the VMR rack as required.

3-Stage Working

Additional units of equipment are required when a GVC stage is added. Briefly, these units are:

GVC The smallest GVC unit consists of a crossbar switch with 10 verticals for links to GVB outlets, and 20 outlets for connection to outgoing repeaters. When more links are required, additional switches are wired to the GVC rack.

IKR-C A relay set wired to the GVC rack and used to connect the test and control wires of the marker to the GVC switch group.

IKR-B A relay set used to connect test and selection wires to MLR relay set for the indication of idle GVB-GVC links.

MGR A relay set added to the marker for the purposes of marking the 200-group, for marking idle GVA-GVB links, and for controlling the operation of horizontal magnets in the GVC stage.

MLR A relay set added to the marker for the purposes of marking idle GVB-GVC links, and for the subsequent selection of a GVC vertical which can be reached via an idle GVA-GVB link.

VMR-C A relay set used to connect to the marker, for line test, those outgoing lines of a route part which are connected to the GVC stage.

Signalling

In the telephone case, dialled impulses are received and stored in the register, and transferred to the route marker in the form of a D.C. "2 out of 5" code for route and tariff determination. After switching is completed, the called number is forwarded from the register in the form of loop disconnect D.C. signalling to a step-by-step terminal exchange, or in the form of MFC compelled sequence signalling to an ARK terminal exchange or to the next crossbar transit exchange (2).

In the telegraph case, digits in the form of start-stop telegraph characters are received and stored in the register, and transferred to the route marker on a 5-wire basis for each character, earth representing space. After switching is completed the called number is forwarded as start stop telegraph characters to the telegraph terminal exchange, or to the next transit exchange (1).

SWITCHING PROCEDURE

Referring again to Fig. 7, the procedure for establishing a call through the ARM 50 2-stage exchange can follow one of two possible forms. These are:

(a) Normal connection, in which the call is switched on a free link from the GVA group containing the incoming line to the GVB group containing the selected outgoing line.

(b) Connection using OFLR, in which the call is switched via an overflow link relay set, as shown schematically in Fig. 3, owing to the unavailability of a free GVA-GVB link.

These two types of connections are described separately in the following sections.

Normal Connection

On an incoming call, the line repeater FIR is connected to a free register REG via a register finder RS. REG receives and stores information regarding the calling subscribers originating tariff zone and classification markings as well as the routing digits. Upon the receipt of sufficient digits for route determination, REG calls a free route marker VM, via a route marker connector, RM. (The VM to be used for this call was pre-selected by the VM call distributor RK/VM, which now selects and allots a VM to receive the next call.) The calling REG is identified in two stages in the AK-REG relay set in VM, after which connecting relays in RM operate to connect REG to VM.

Routing and tariff information are transferred from REG to the digit receiver KM-S in VM, and subsequently to the digit analyser S, where route and tariff are determined. The tariff is determined by an analysis of the calling subscriber's tariff zone and classification markings together with the routing digits, combinations of which operate particular relays in S which in turn operate the appropriate relays in the tariff transmitter ZS, to return the tariff rate to the incoming repeater. The route is determined by an analysis of the routing digits, combinations of which operate particular relays in S which in turn operate appropriate route relays in the route marking relay set VVR, to indicate whether or not a free line exists on either the direct route or any alternative route. The originating tariff zone and calling subscriber's classification markings may also be used to impose certain limitations of route choice; for example, in cases where subscribers from a particular tariff zone or having a particular classification are allowed access to certain routes and barred access to others.

When VM has established that a free line exists on the required route, the switching process commences. The incoming line is identified in the GVA group to which it is connected by the relay chain IKR. A free marker is selected by the marker test set TMR/TUR and connected through IKR to the GVA group. Idle links between the GVA group containing the incoming line and all GVB groups are indicated by relays in the link marking relay set RR. The marker now transmits a signal to KM-S in VM, to indicate to VM which M has been selected, after which VM completes the VM-M connection.

M now operates horizontals in GVA corresponding to the multiple position of the incoming line. VM then operates a relay in the route connector VMR to connect the outgoing lines on the selected route part to M for line test. Although the route part may contain free lines distributed over all GVB groups, only those lines are tested which can be reached via an idle GVA-GVB link. This is done by connecting test relays in the line test relay set TR to outgoing repeaters via contacts of link marking relays in RR. M selects a free line in a GVB group which can be reached via a GVA-GVB link.

The GVB group to which the selected line is connected is tested and busymarked from M, which now operates the GVB horizontals corresponding to the multiple position of the selected outlet. GVA and GVB verticals are now operated in series from M, and the through connection is completed from incoming line through the selector stages GVA and GVB to the outgoing line. After the through connection is checked, VM transmits an "end of selection" signal to REG, which takes over the holding of the connection and initiates the release of common equipment. REG remains in circuit if it is to control subsequent switching, and only FIR, FUR and verticals in GVA and GVB remain occupied during the call.

Connection Using OFLR

Assume that VMR has connected the lines of the selected route part to M for line test. Because the test of outgoing lines is carried out by relays in TR via RR relay contacts, the success of the test will depend on the availability of free links, as indicated in RR, from the GVA group containing the incoming line to some of the GVB groups containing free lines on the selected route. If the test now is unsuccessful, the reason may be that there are no free links available. A connection is now set up to an OFLR link.

First, VM operates a relay in VMR which connects OFLR links to M for test, in the same way as it connected outgoing lines for test. M now tests for and selects a free OFLR in a group other than the group containing the incoming line, in the same manner as it tested for a free outgoing line; that is, the OFLR test circuit has the same characteristics as the FUR test circuit. The GVB group containing the selected OFLR is tested and busymarked from M, which then operates GVB horizontals corresponding to the multiple position of the selected OFLR, hereafter called OFLR (B side). GVA and GVB verticals now operate in series, and the connection from incoming line to OFLR (B side) is completed. VM remains held, but M and relays in VMR now release.

VM carries out a route test again and selects a route part on the original route containing a free line. The OFLR selected is now identified in the GVA group to which it is connected by relays in IKR. Hereafter this side of the OFLR will be called OFLR (A side). TMR/TUR now tests for and selects a free marker, which is connected via IKR to the GVA group containing the OFLR (A side). Idle links from this GVA group to all GVB groups are then indicated in RR. M now transmits a signal to VM to indicate which M has been selected, after which VM completes the VM-M connection.

M now operates GVA horizontals corresponding to the multiple position of the OFLR (A side). VM then operates a relay to VMR to connect outgoing lines of the selected route part for line test, after which M tests for and selects a free line in a GVB group which can be reached via an idle link from the GVA group containing the OFLR (A side). The GVB group to which the selected line is connected is tested and busymarked from M, which then operates GVB horizontals corresponding to the multiple position of the selected line. M then operates GVA and GVB verticals to complete the connection from OFLR (A side) to outgoing line. Four verticals are now operated and the connection from incoming line, through the switching stages and OFLR to the outgoing line, as indicated schematically in Fig. 3, is completed. VM transmits the "end of selection" signal to REG as before, after which REG takes over the holding of the connection and initiates the release of common equipment.

CONCLUSION

This article has dealt primarily with the 2-stage ARM 50 exchange, the first installation for the A.P.O. being the Auto. Telex exchange at Canberra due for cutover in 1966, to be followed by telephone switching centre installations at Gladstone, Jamestown and Melrose in South Australia, and Bruce Rock in Western Australia. It is understood that at the present time there is no plan for the initial installation of a 3-stage ARM 50 exchange. In all probability, however, the addition of a GVC partial stage to one of the above 2-stage installations will receive serious consideration when these exchange capacities approach 200 lines.

REFERENCES

1. R. McKinnon, N. R. Crane and J. Krol, "Automatisation of the Australian Telex Network — Part 2"; Telecommunication Journal of Aust., Vol. 14, No. 3, Page 208.

2. L. M. Wright, "Crossbar Trunk Exchanges for the Australian Network — Part 1"; Telecommunication Journal of Australia, Vol. 14, No. 5/6, Page 356.

3. R. Bager, "Crossbar Systems ARM 201 and ARM 503 for Transit Exchanges"; Ericsson Review No. 2, 1960, Page 34.

SEACOM: NEW SOUTH WALES LAND SECTION

J. LIIV, A.M.I.E. Aust. and B. W. G. PENHALL, B.E.***

INTRODUCTION

The general planning aspects of and various details of the Brisbane-Cairns microwave radio system associated with the SEACOM Submarine Cable System have been described previously (Ref. 1, 2, 3, 4). This paper describes the general equipment features of the two main links, which comprise the SEACOM land section between Sydney and Brisbane, together with the short coaxial tails connecting the SEACOM Supergroup from Paddington O.T.C. to Redfern and inter-connecting the radio link to the coaxial cable system at Lismore. The main links are the Broadband Radio System between the Redfern (Sydney) and the Goonellabah (Lismore) Radiotelephone Terminals and a coaxial cable system between Lismore and Brisbane.

For the purposes of the SEACOM system, the overall transmission link between Sydney and Cairns will provide a through circuit for a basic super-group having a 240 Kc/s bandwidth in the frequency range 312 to 552 Kc/s. This supergroup is being provided in both directions of transmissions on a four-wire basis. The SEACOM supergroup is received from the O.T.C. Intercontinental Exchange at Paddington at the basic supergroup frequency and is transmitted to the City South Carrier Terminal over a short haul coaxial tail operating over two tubes of a 12 tube cable of 1.57 miles. At City South Carrier Terminal, the supergroup is translated into its nominated line frequency of 812 to 1,052 Kc/s (SG4) to be used between Sydney and Brisbane and is then combined with the other supergroups (up to a maximum of 15) before being transmitted to the Redfern Radio Terminal via another short haul coaxial tail of 2 miles. At Goonellabah Radio Terminal Station the 4 Mc/s telephony baseband is connected to coaxial tail equipment over a 3.5 mile section of 8 tube coaxial cable to Lismore. The telephony baseband is taken to the supergroup demodulating equipment in the Lismore Carrier Terminal and is translated into the 16 supergroups some of which, including the SEACOM supergroup (SG4), are connected via supergroup filters, in order to prevent cross-talk and noise between systems, to the supergroup modem equipment associated with the Lismore-Brisbane Coaxial Cable System.

The first part of this article deals with the Sydney-Lismore Broadband radio link and the second with the Lismore-Brisbane Coaxial Cable System and the shorthaul coaxial tails.

Overall supergroup regulation will be provided by means of a 408 Kc/s pilot which will be injected at the output of the O.T.C. modem equipment at both Paddington and Cairns. Regulation in the north bound direction will be carried out at Brisbane and Cairns Carrier Stations and in the south bound direction at Brisbane and City South Carrier Stations.

The pilot frequency will be monitored at City South and Lismore in the northerly direction, and at Cairns and Lismore in the southerly direction. Recorders and alarm facilities will be provided at City South, Lismore, Brisbane and Cairns.

The route details from Sydney to Tweed Heads are shown in Fig. 1.

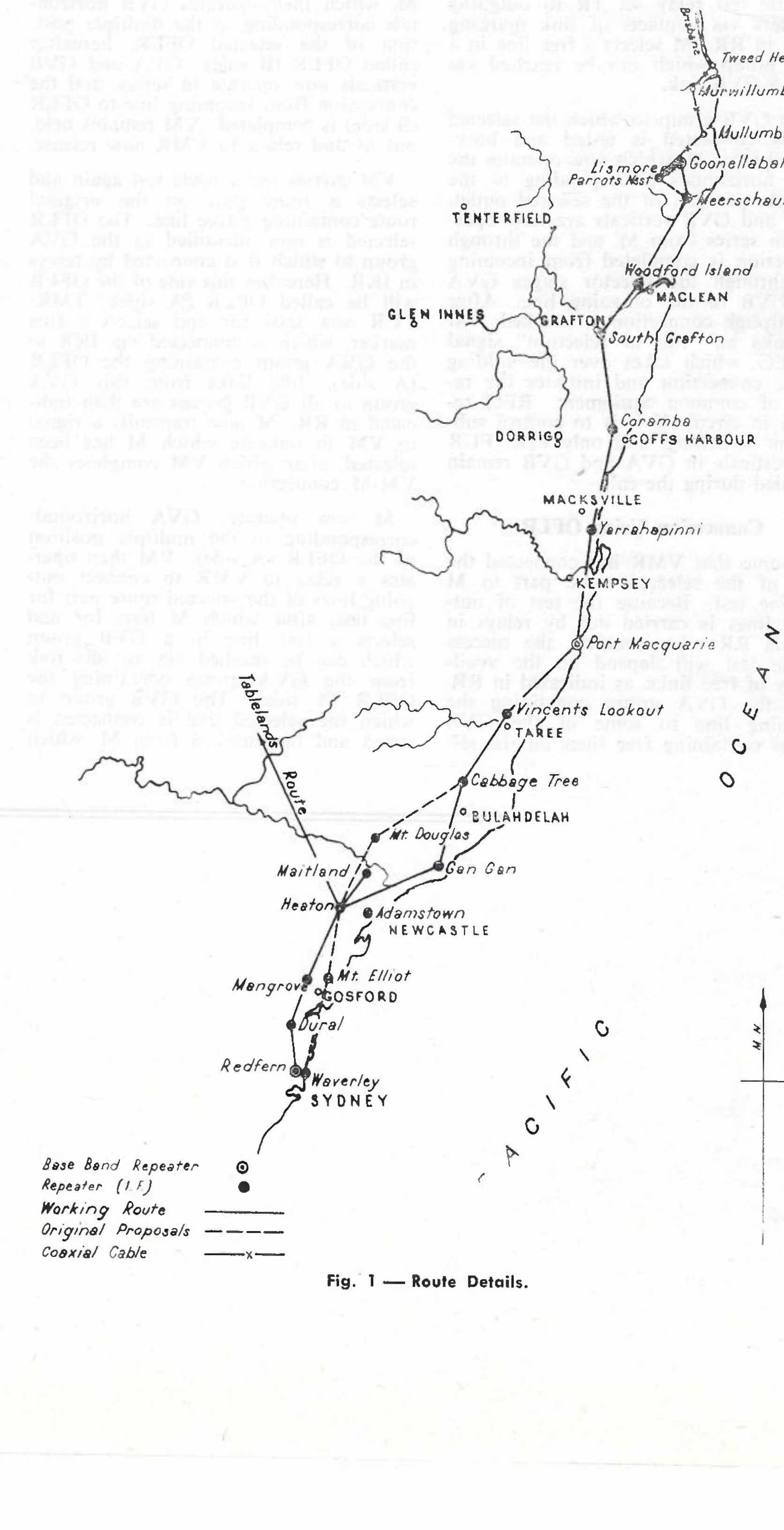

Fig. 1 — Route Details.

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SYDNEY-LISMORE RADIO SECTION

The main length of the N.S.W. section of the SEACOM route is via a 4,000 Mc/s broadband radio bearer which extends from the main Sydney radio terminal at Redfern to Goonellabah radio terminal near Lismore via twelve repeater sations.

This bearer will be described under the following broad headings:—

- History of the route.
- Description of the equipment.
- Description of a typical installation.
- Propagation behaviour of the various paths.
- C.C.I.R. Performance Standards applied to this route.
- Upgrading of the route and the estimation of its performance.

HISTORY OF THE ROUTE

The section of the route from Heaton to Meerschaum was selected prior to 1956 to form the backbone for a flood emergency network following the disruption of communications during the disastrous floods of 1949 and following years. To meet this need a 12 channel 450 Mc/s bearer was considered sufficient with auxiliary 4 channel 160 Mc/s bearers providing town to town communication along the same route. The addition of 2 Gc/s and 4 Gc/s bearers of larger capacity was considered a future possibility. With the above in mind a route with fairly long paths was chosen, five of the eleven paths being greater than 40 miles. The only apparent consideration of a suitable path was availability of line of sight with a 2,000 Mc/s first fresnel zone clear of obstructions assuming unit earth radius. Naturally ease of access and availability of commercial power were foremost in the selector's eye, nevertheless the provision of both of these services exceeded £10,000 at several sites.

Small brick buildings giving an equipment floor area of 300 sq. ft. and an emergency plant floor area of 150 sq. ft with 1,000 gallon water tanks and toilet facilities were erected along this route. Light duty B.I.C.C. masts to 120 ft were erected to carry VHF aerials, and future 450 Mc/s aerials. 10 kVA Petbow diesel alternator sets were installed to cater for the extended blackouts which occurred days at a time during floods. In all, a route was developed sufficient for the then planned needs.

The present route is shown in Fig. 1 with original paths not now in use shown in broken lines. A major change was the replacement of Mt. Douglas with Gan Gan to give an interconnecting point with the proposed North Coast Coaxial Cable at Gan Gan (Pt. Stephens). The route of the cable has since been changed and Port Macquarie is the point of possible interconnection. The Parrot's Nest repeater, which gave a four mile line-of-sight path to the roof of the Lismore Exchange, has now been changed to Goonellabah which is two miles east of the exchange, and connected to it by an eight tube coaxial cable link. This re-arrangement saves a frequency planning problem associated with extending the route north. Other than these two changes the route remains unaltered from that originally proposed for 12 to 60 channel bearers, although now it is required to cater for 960 channel high performance broadband radio bearers. Some short term propagation tests (4 weeks approximately) including height-gain tests were carried out by the P.M.G. Research Laboratories on paths which had possible troublesome ground reflections. These tests showed that the South Grafton-Woodford Island path was found to require space diversity for control of this possible source of deep fading.

The section of the route Sydney to Heaton has a different history. It was conceived as a medium capacity route and originally involved the two coastal paths, Waverley Exchange to Mt. Elliott, (near Gosford) then to Heaton, but following inspection in 1956 by visiting engineers from Standard Telephone and Cables Ltd. (London), the alternative paths, Redfern-Dural-Mangrove-Heaton were selected. During 1957/58 S.T.C. (Sydney and London) carried out short term propagation tests under contract and pronounced the paths clear of irregularities of propagation. The paths have actually shown only occasional mild fading.

A 600 channel S.T.C. system installed on the Sydney-Heaton section of the route, and extended into Maitland, was commissioned in 1960. This system included two 4 Gc/s bearers in each direction operated in parallel to provide automatic standby facilities. A larger brick building was erected on this section of the route providing 500 sq. ft of equipment floor space, 300 sq. ft for diesel alternator plant and 3,000 gallon water tanks. A 30 kVA diesel alternator was provided for emergency power and heavy duty towers to 200 ft in height erected each being capable of supporting about six 10 ft parabolic aerials.

During 1963 the Sydney-Heaton system was expanded by the commissioning of an S.T.C. 4 Gc/s TV Bearer Type RL4D while the original protection bearer was modified to allow it to carry 960 channels or a TV channel and switching facilities added to allow both the 600 channel bearer and the TV bearer access to the modified protection bearer. Also at this time an S.T.C. 960 channel system, type RL4D, comprising two parallel bearers, was installed between Heaton and Lismore with a back to back baseband repeater at Port Macquarie. This system did not use Goonellabah as the Lismore terminal but had a repeater at Parrot's Nest, and then terminated directly in the Lismore Exchange. This equipment was installed in the existing small brick repeater buildings with the exception of Gan

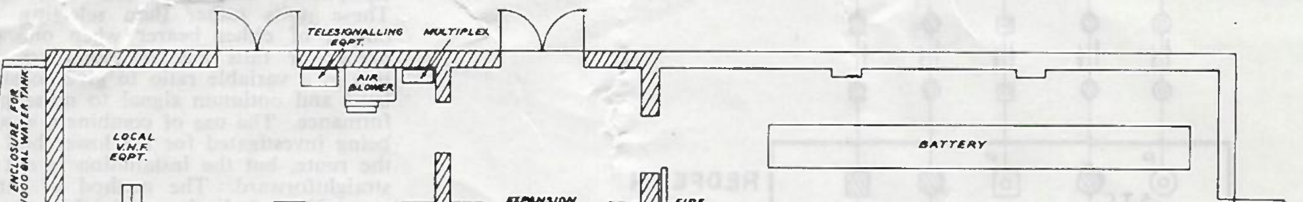

Fig. 2 — Typical Repeater Equipment Layout.

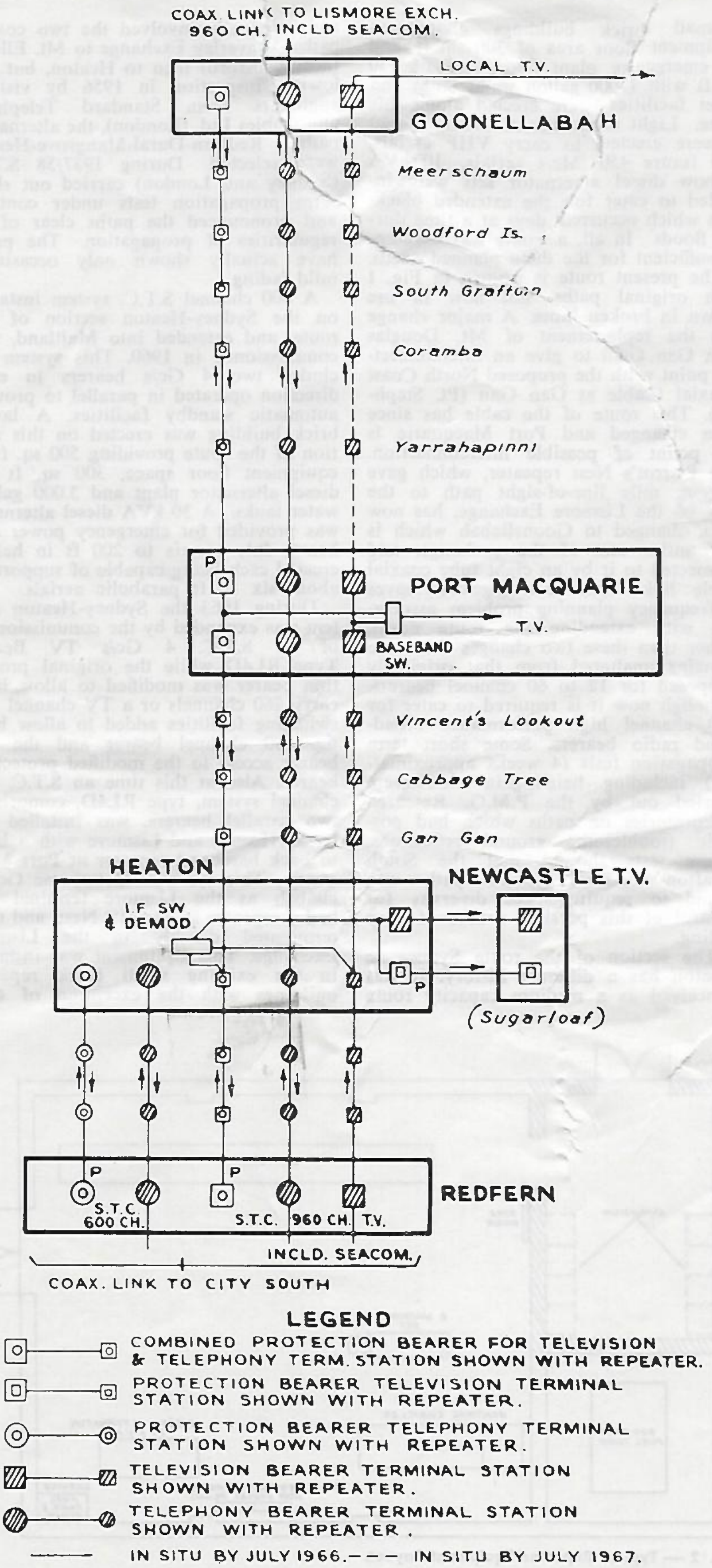

Fig. 3 — Route Diagram.

Gan and Port Macquarie at which larger buildings were specially provided, which included space for no-break power plant besides normal diesel alternator units. Again heavy duty self-suporting towers to 200 ft were provided at all stations to support 10 ft parabolic aerials fed by relatively high loss (type WG.12A, 1.8 db per 100 ft) S.T.C. wave-guide. Space diversity equipment using phase shift RF combiners was installed on the South Grafton-Woodford Island path to control the ground reflections as recommended by the P.M.G. Research Laboratories.

The early experience with the 600 channel system and the initial experience with the new 960 channel system confirmed the necessity to provide No-break Power Plant. This involved extending all buildings to provide an additional 525 sq. ft of floor space. In the case of the smaller brick buildings, (Cabbage Tree through to Meerschaum) this extension also catered for the new larger capacity diesel alternator power plant allowing the old power plant space to be used for projected system expansion. A typical building layout as it now exists is shown in Fig. 2.

In 1965 the Heaton-Port Macquarie section was expanded by the addition of an S.T.C. 4 Gc/s TV Bearer, type RL4E. This would normally involve only the addition of switching at Heaton and Port Macquarie to allow sharing of the protection bearer, but with the pending SEACOM traffic a complete re-arrangement was made requiring the addition of another bearer, also S.T.C. 4,000 Mc/s 960 channel equipment, type RL4G, between Redfern and Heaton, with through connecting at IF of the bearers at Heaton. The route as arranged in this manner was completed early in 1966. Also included in this work, preparatory to SEACOM traffic, was the installation of baseband combiners. The use of these units on the Port Macquarie-Lismore Section is straightforward by simply placing the baseband switching equipment with baseband combiners. These units rather than selecting the output of either bearer when one degrades or fails actually combines the two in a variable ratio to give constant level and optimum signal to noise performance. The use of combiners is also being investigated for the lower half of the route, but the installation is not so straightforward. The method of interconnection of the bearer in this case is shown in Fig. 3, which also shows the bearer arrangement for the whole route.

The use of baseband combiners in conjunction with normal baseband switching equipment has problems associated with reliability when interconnected in the simplest way shown in Fig. 4, as no automatic protection is provided if the combiner fails. Nevertheless, the use of combiners in this manner on a route intended to carry telegraph traffic and possibly data also would improve the automatic changeover times for 90% or more of the changeovers. This improvement is considered necessary because the S.T.C. equipment when operating in a shared protection scheme suffers 70 millisecond traffic breaks in case of sudden failure

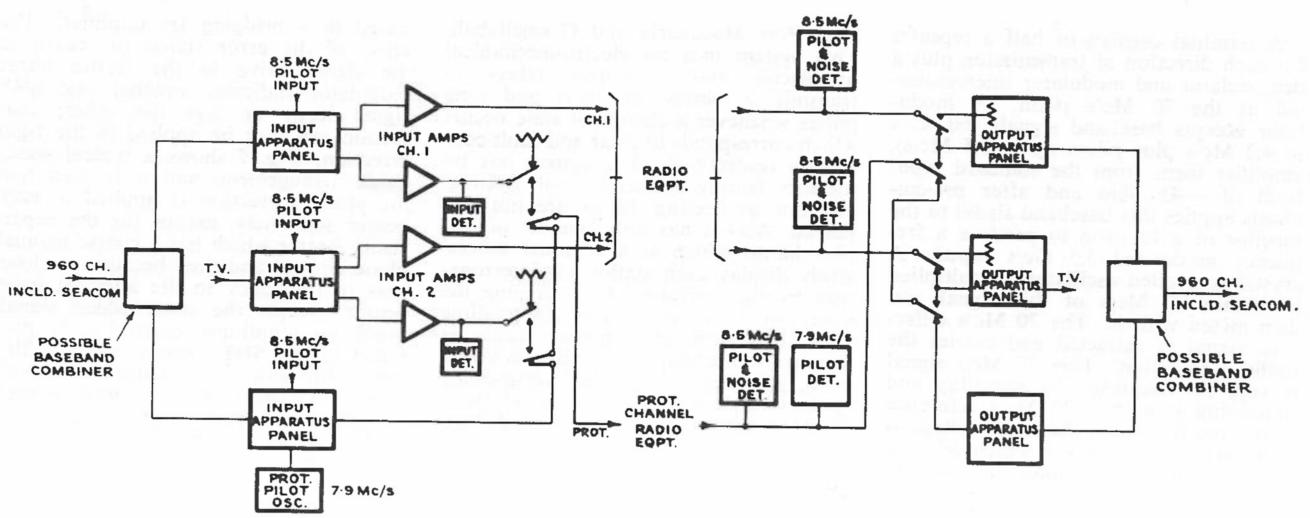

Fig. 4 — Baseband Switching.

of the working bearer. Since the protection bearer is free for 90% of the time when called upon to only protect two bearers then by interconnection as shown in Fig. 4, the normal changeover can be arranged so that when the protection bearer is not in use by the TV channel it is being used for telephony traffic via the baseband combiner, the switching time being then less than 1 millisecond if the normal telephony bearer fails.

Description of Equipment

The bearer equipment installed on this route was manufactured by S.T.C. London, and involves two basic types, RL4E and RL4G, both employing vacuum tubes, which were manufactured around 1963 and 1965 respectively. The equipment is capable of carrying 960 telephone channels or one TV channel to CCIR standards (using suitable paths) and has the following pertinent characteristics:—

- R.F. output : + 36dbm
- Output device : periodic magnetically focused travelling wave tube.
- Typical receiver noise factor : 13 db.
- Receiver threshold : — 76 dbm.
- Typical fixed equipment losses per path: 3db (CBF, filters, isolaters, etc.)
- Input level for 0 dbmo : — 45 dbm.
- Output level for 0 dbmo : — 20 dbm
- Modulation : CCIR pre-emphasised FM using 200 Kc/s RMS nominal deviation for 0 dbmo.
- Equipment basic and inter-modulation noise for 960 channel with white noise loading (+ 15 dbmo) per typical section (172 mls) assumed as follows (pWo weighted in a standard 4 Kc/s telephone channel).

	1002 Kc/s (SEACOM)	3886 Kc/s (Top Channel)
Modem, basic	50	20
Modem, Internal	25	20
Group Delay Distortion	55	65
Waveguide Internal for path	12	20
Aerial Interference	100	100

The frequency plan employs the recommended CCIR arrangement (recommendations 278 and 296, Los Angeles, 1959) using common transmit frequencies (and receive frequencies) at most stations. This fixes the route capacity in the 4 Gc/s band as six main bearers and the supervisory bearer as detailed in Fig. 5. The interlevel plan is used at some stations to reduce interference by over-shoot, unwanted antenna coupling, etc.; this involves a shift down in all frequencies of 14.5 Mc/s compared to the normal frequency plan shown in Fig. 5.

The diagram of a repeater appears in Fig. 6, showing the typical radio frequency filter arrangements. The wanted 4 Gc/s channel is extracted from the waveguide after reception by the aerial by a band stop filter, which directs the wanted channel via a band pass filter and isolator within the repeater bay to a crystal mixer. A crystal mixer then converts this signal into a 70 Mc/s signal which is amplified by a 27db fixed gain low noise pre-amplifier and then further amplified in the main ACC controlled IF amplifier to give a standard 70 Mc/s output level of half a volt rms for a range of inputs of —30 to —75 dbm. This signal is then further amplified by a limiter amplifier and then converted up in a balanced mixer to 4 Gc/s again, (213 Mc/s nominally removed from the incoming frequency) and then finally amplified by a travelling wave amplifier to + 36 dbm. The channel is then passed via isolators and a band stop filter to the outgoing waveguide system and aerial.

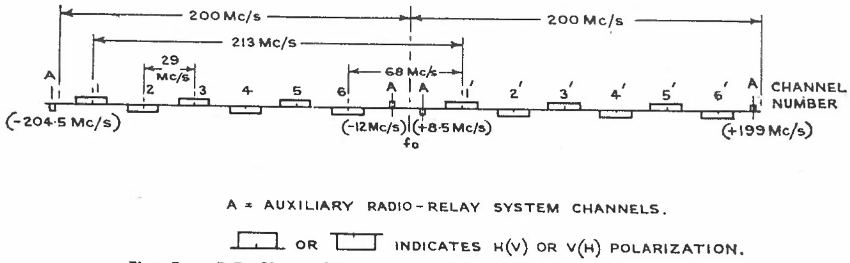

Fig. 5 — R.F. Channel Arrangement for 960 Channel Telephony.

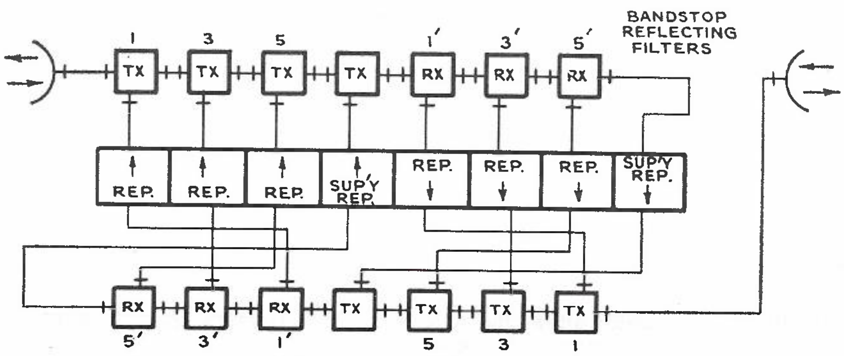

Fig. 6 — Repeater Waveguide.

A terminal consists of half a repeater for each direction of transmission plus a demodulator and modulator interconnected at the 70 Mc/s point. A modulator accepts baseband signals (60 Kc/s to 4.2 Mc/s plus pilots up to 8.5 Mc/s), amplifies them from the standard input level of —45 dbm and after pre-emphasis applies this baseband signal to the repellor of a klystron to produce a frequency modulated 3.5 Gc/s signal. A crystal controlled oscillator is multiplied to within 70 Mc/s of this signal and then mixed with it. The 70 Mc/s difference signal is extracted and carries the traffic modulation. This 70 Mc/s signal is kept on frequency by sampling and comparing it with a 70 Mc/s reference crystal oscillator and the error voltage is then fed to a servo motor which drives a tuning plunger in the modulated klystron cavity so correcting the frequency and completing the feed back loop. The demodulator accepts the 70 Mc/s modulated signal from the receiver, amplifies and limits it and via a discriminator extracts the traffic baseband information. This traffic information is then amplified, de-emphasised and again amplified to produce a standard output level of —20 dbmo. The pre-emphasis mentioned above applies a rising characteristic from about 100 Kc/s to help make the most efficient use of the radio frequency (4Gc/s) bandwidth available.

The traffic information from the demodulator and to the modulator is connected in accordance with Fig. 4. This scheme of interconnection allows the sharing of the protection bearer by up to 5 working bearers (2 only on this route at present) in case of failure of any one working bearer. On failure of a bearer, either causing loss of 8.5 Mc/s pilot or high noise level in the respective detectors, a tone is sent via the supervisory bearer to the transmit terminal. This tone causes a switch to parallel-connect the respective traffic information to the protection bearer. At the receive terminal the loss of 7.9 Mc/s pilot at the protection bearer pilot detector is noted and the switching sequence is then completed by operation of the receive changeover switch. The baseband switches remain interconnected in this mode until the normal bearer becomes operational again. The point of operation of the pilot and noise detectors is adjustable, the normal values being a 3db decrease in pilot level and 30db increase above unloaded basic noise. Recovery of 2db and 8db respectively is required before restoration.

Also on this route is a 4Gc/s supervisory bearer which is used for carrying various orderwires and telesignalling information along the route. This bearer is also capable of carrying 60 telephone channels over 3 tandem connected paths to CCIR requirements, but this capability has not yet been used since it is unprotected by a standby system. This bearer demodulates and re-modulates at each repeater station to allow full access to the order wires and telesignalling information. Along this route is a telesignalling system which allows the state of operation of each station to be supervised at the control terminals, i.e., Redfern, Port Macquarie and Goonellabah. This system uses an electro-mechanical uniselector and associated relays to transmit a series of short and long pulses whenever a change of state occurs which corresponds to clear and fault conditions respectively. The system has no memory feature and as a result fleeting, and not so fleeting, faults are not displayed. Also it has only one set of display lamps which at a terminal successively display each station on interrogation by the operator. To overcome the many shortcomings of this telesignalling system on such an important route as this, it is intended to install a continuously scanning solid state telesignalling system which will allow up to 32 items of information to be telesignalled back from all stations simultaneously within 2 seconds. Such a comprehensive telesignalling system is considered necessary with valve type equipment on important routes to allow accurate and speedy acion in time of fault. The present telesignalling system has been responsible for extended breaks because of its inability to accurately display the information simultaneously for all stations. In fact a printer coupled to the lamp display is really necessary if the history of events leading to a fault is to be known.

On four of the paths of this route space diversity is considered necessary because of the excessive fading involved. It is generally held that aerials spaced vertically 100 wave lengths apart (25 ft. at 4Gc/s) will have uncorrelated signal levels during deep fading due to atmospheric anomalies. In the automatic space diversity system used on this route two aerials are used and their outputs combined before being applied to the input of a single receiver. Automatic control circuits are provided to ensure that the two signals always combine in phase. The phase difference between the SHF signals from the two aerials is removed by the following method. The signal from one of the two aerials is phase modulated by a ferrite waveguide modulator at a frequency of 35c/s. When this signal combines with the signal coming directly from the other aerial amplitude modulation results at the frequency of the original phase modulation if the two signals are out of phase. If the two signals are in phase this amplitude modulation is zero. The amplitude modulation, magnitude and phase, represents an error signal which is detected in a bridging IF amplifier. The sense of the error signal in regard to the signal drive to the ferrite phase modulator indicates whether one SHF signal leads or lags the other; correction can thus be applied in the right direction. Fig. 7 shows a typical waveguide arrangement, and it is seen that the phase correction is applied to each bearer separately, except for the supervisory bearer which has a coarse manual phase control and then because of closeness in frequency to the adjacent main bearer accepts the same added signal. Since no amplitude correction is provided to the SHF signals before addition a 3db gain only results when both signals are equal. If one signal is 10db or more lower than the other then a loss of 3db results to a no diversity arrangement. This is why during severe interference type fading no improvement in the hourly median results, but under minor fading or no fading a 3db improvement is obtained. To date diversity equipment has been fitted on one path and the considerable improvements possible are shown in Table 1. On this path the diversity on one bearer was disabled completely and during the worst month 196 fades below 20db and 37 below 30db occurred. With diversity this was reduced to 13 and 2 respectively. Also an improvement in the hourly median depression results on this path because they are generally unaccompanied by deep interference type fading which are probably due to ground reflections. The critical aerial displacement used assures a strong signal in at least one aerial at any instant.

A Typical Repeater Station

As mentioned earlier, most of the repeater stations have been expanded from small units intended for low capacity route operation only. These buildings are brick and now consist of an equipment area, approximately 15 ft. by 30 ft. and a larger power room of 20 ft. by 30 ft., as shown in Fig. 3. These buildings are provided with 1,000 gallon water tanks and 500 gallon fuel storage tanks. They also are provided with toilet facilities. The equipment room is pressurised by fan units to keep dust ingress to a minimum. Each building is connected to a 3-phase commercial supply which suffers from numerous breaks in bad weather and in time of serious flood has been broken for several days at some sites. To assure con-

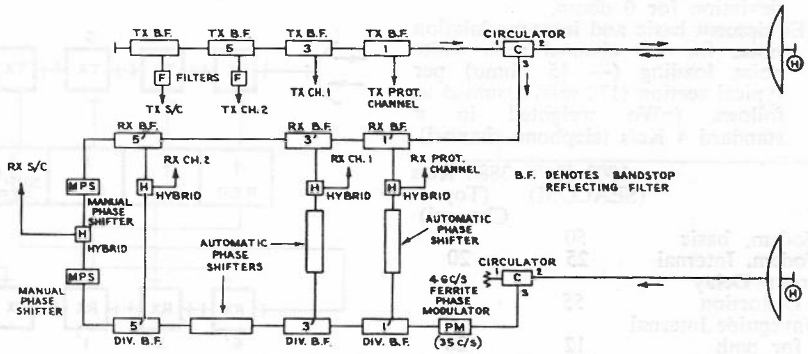

Fig. 7 — Diversity Waveguide

tinuity of power in these circumstances a 30 kVA diesel alternator set is provided and to cater for short breaks of up to 15 minutes a no-break system has been installed. This consists of two types. One type known as a "3 machine set" was installed at most stations and employs an a.c. motor continuously driving an a.c. alternator, which then supplies the station load. On the same shaft is a d.c. motor which in the event of power failure is driven from a bank of batteries (123 volts). These are planned to provide at least 3 hours of operation in case the diesel generator fails to start automatically and staff have to travel to the site. The newer no-break sets installed are termed "2 machine sets" and do not use an a.c. motor. Instead, a 3-phase rectifier supplies a d.c. motor driving an alternator to supply the station load continuously with the main battery bank floating on the line. In the event of mains failure the d.c. drive lasts for up to 3 hours as previously mentioned. It is current practice before servicing the no-break sets to run up the diesel alternator set and synchronise it with the no-break set before closing down the latter for routine maintenance. This assures absolute continuity of power to the equipment which experience has shown to be essential for minimum fault incidence operation and long valve life.

Propagation Characteristics of the Paths

The majority of the paths run in close proximity to the coast, as seen in Fig. 1, and as a result most paths suffer severe fading. The severity of the fading is aggravated by the long path lengths, many being over 40 miles. The prime cause of the fading appears to be atmospheric inverse temperature gradients which form primarily in the summer at various altitudes. These gradients also cause multi-path signals whose phase varies randomly; such random additions at a receiving aerial cause severe fading typically of 20 to 40db with possible durations of several seconds. This interference type fading is often superimposed upon median depressions typically of 5 to 20db, which are possibly caused by defocusing in the atmospheric inverse temperature gradient regions.

The paths on this route have been fitted with pen recorders (1 inch per hour paper speed) which are attached to the receivers and are capable of recording fades to approximately 40db below the normal free space signal. Some of these recorders have been operating for 12 months, and others for several months only. The degree of fading on each path is analysed in Table 1, which shows the number of hours, during the worst month for a particular path, of minor and severe fading. Also indicated for the same period are the number of occasions on which 20db and 30db fades were exceeded. The worst hour median fade for each path is also indicated. The fading results for the route were examined on a weekly basis, and the route worst month selected; the comparison of the minor and severe fades for each path during this period provides an interesting comparison to the path worst month hours, remembering that the CCITT/CCIR requirements apply to a route, not a path.

For the purpose of the analysis a minor fade is one which has a depressed hour median greater than 2db but no fades in excess of 20db during the hour, while a severe fade is a half hour in wh[illegible] one or more fades exceed 20db.

CCIR Performance Standards

The route to this date has formed part of the Australian Trunk Line Network, and as such is called upon to meet the performance standards of the CCITT and CCIR 2,500 km (1550 miles) reference circuit which is assumed to be composed of nine reference sections. These sections are assumed to be equal in length making each 172 miles long. It is also assumed that a demodulating point exists at the end of each reference section. The Sydney-Lismore route has two sec-

TABLE 1: SUMMARY OF FADING RECORDS

Path	Length (Miles)	Worst Hr. Median Fade (Note 1) (db)	Hrs. of Fading (Path) Worst Mth.		No. of Worst Month Fades Exceeding		Hrs. of Fading Route Worst Month after Upgrading (Note 2)		Period of Observation (Months)
			Minor	Severe	20db	30db	Minor	Severe	
Redfern-Dural	16	Records too short						—	1
Dural-Mangrove	30	12	19	7	7	13		5	13
Mangrove-Heaton	26	10	10	2.5	9	5	8.5	5	13
Heaton-Gan Gan	42	22	30	42	215	50	40	4	14
Gan Gan-Cabbage Tree	33	11	33	24	74	37	28	43	13
Cabbage Tree-Vincents LO	43	9	63	21	91	12	20	10	13
Vincents LO-Pt. Macquarie	31	8	22	5.5	35	5	17	9	13
Pt. Macq.-Yarrahapinni	43	14	36.5	42.5	346	65	45	4	13
Yarrahapinni-Coramba	42	14	15.5	38	140	5	60	4	13
Coramba-Sth. Grafton	35	13	12	2	32	1	23	20	4
Sth. Grafton-Woodford	24	10	90.5	35.5	196	37	—	—	12
Sth. Grafton-Woodford	With Diversity	4	1.5	1.5	13	2	0	0	12
Woodford-Meerschaum	41	20	53.5	9.5	118	38	5	5	12
Meerschaum-Goonellabah	10	No Records							

Note 1: Worst Hour Median Fade represents the reduction in signal level necessary to obtain a value for the Worst Hour above and below which equal time is spent by received signal.

Note 2: Severe fading reduced to 10% when diversity fitted as opposed to diversity not being fitted. Minor fading unchanged but includes previous severe fading.

Note 3: The "path' and "route" worst month are not always the same month.

tions, the total route length being 416 miles.

The relevant standards laid down by CCITT and CCIR for a reference circuit of 1550 miles may be summarised as follows, noting that the term pWo (or dbmo) refers to the power level so amplified at a test point that if test tone of 0dbm is established at the switchboard in a telephone channel then this level gives zero dbm at the same test point after this amplification.

(i) The psophometrically weighted mean minute noise should be less than 7,500 pWo (—51.2 dbmo) for at least 20% of the worst month, and that for shorter systems (down to 172 miles) the noise limit may be reduced proportionately to path length. The allowance for Sydney-Lismore would be 2000 pWo.

(ii) The psophometrically weighted mean noise should be less than 7,500 pWo for the worst hour, again reduced as in (i) making 2000 pWo for this route. This is the hardest requirement to meet since it corresponds to 0.15% of a month.

(iii) The psophometrically weighted mean minute noise should be less than 47,500 pWo (-43.2 dbmo) for 0.1% of the worst month (43 minutes); in this case the time is proportioned to path lengths as deep fades (approximately 30db on a typical path) are recognised as being non-coincident. The allowance for Sydney-Heaton would be 18 minutes.

(iv) The 5 milli-second mean noise should be less than 1,000,000 pWo (—30 dbmo) for 0.01% of the worst month (4.3 minutes) for telephony circuits of 0.001% for VF telegraphs and it again reduces as in (iii) above. CCITT gives the alternate limit that the 1 second mean noise should be less than 200,000 pWo (—37 dbmo) for 0.01% of any month. This time allowance reduces as in (iii), making 1.8 minutes for this route. The CCITT requirement is more closely related to radio bearer propagation interruptions. These allowances are also taken to include all unserviceability of the bearer from any cause whatsoever. This requirement is a hypothetical one and is therefore an aim, and not a design criterion.

It is worth noting that although the route has been in operation for 18 months or so measurements of system performance in terms of CCITT and CCIR requirements are not available. The statistical CCIR requirements require extensive instrumentation and long term observation and has not been attempted in Australia to date, nor in many other countries from information at hand. The only noise measurement regularly undertaken is that which is assumed to correspond to free-space propagation conditions on all paths and in practice agrees closely with the calculated value.

Upgrading of the Route and Estimates of Performance

The possibility of SEACOM traffic was known virtually before this route had carried any traffic and interruptions by severe fading were noted during line-up of the system early in 1964. Also, after only 5 months in traffic serious interruptions due to severe fading occurred during the summer months of the same year. Even without SEACOM traffic, improvements of the system performance would have been necessary, but when SEACOM traffic became a certainty a sense of urgency developed.

The upgrading route consists of:—

(i) Replacing many of the longer waveguide runs of the type WG. 12A (1.8 db per 100 ft) with Hackethal elliptical waveguide (1 db per 100 ft),

(ii) the use of 4 and 5 meter parabolic aerials in place of the 3 meter units on the longer paths,

(iii) the installation of space diversity equipment on three of the paths with the severest interference type fading, and

(iv) the installation of baseband combiners on both the Redfern-Port Macquarie and Port Macquarie-Goonellabah sections.

These improvements increase the received signal levels on the longer paths and coupled with diversity on the worst paths the present degrading effects of fading should be virtually eliminated.

The performance of the upgraded Sydney-Lismore section of the SEACOM land circuit is detailed in Appendix 1 and may be summarised by the statement that the various CCIR and CCITT limits specified above attributable to propagation problems will be bettered while short breaks due to deep fades should be non-existent.

The non-availability of the system for traffic due to equipment failure has been specified as 0.1% of any month maximum for the land section of the SEACOM route, 0.03% has been nominally allocated to the Sydney-Lismore radio bearers. This amounts to an outage time of 13 minutes; with the completion of no-break power plant facilities at all stations this should be achieved.

LISMORE-BRISBANE COAXIAL CABLE SYSTEM

General

The route between Lismore and Brisbane is served by a coaxial cable system of S.T.C. manufacture operating on 2 tubes of a standard size 4 tube coaxial cable of outer diameter 0.375 inches and using the interstice pairs for alarm and supervisory purposes. The cable is 143 miles long and is at a depth of 4 feet in rural districts and in conduits in city and urban areas. The cable between Lismore and Tweed Heads is located, as far as possible, in positions not subjected to wash-aways in order to provide the maximum reliability against flooding which occurs over about 20 miles of this section.

Engineering features of river crossings made between Tweed Heads and Brisbane have been described in a previous article. (Ref. 5). Maintenance patrols and a gas pressure alarm system are provided and are similar to those in use along the Sydney-Melbourne coaxial cable (Ref. 6).

One pair of tubes provides the bearer for the 6Mc/s carrier telephone system, to CCITT standards. This system was adopted by the Department at the time as it could provide cross patching between TV and Telephony bearers where these are provided, and having repeaters nominally spaced at 6-mile intervals. Details of the repeater sections along the route from Lismore to Brisbane are shown in Table 2.

The common terminal equipment installed initially at the two terminals at Brisbane and Lismore will provide for a telephony system comprising 16 supergroups (960 channels), but could be increased to 21 supergroups (1260 channels) by the addition of master group equipment, if required. The coaxial cable equipment was supplied by Standard Telephones and Cables Limited and is partly of Australian manufacture and partly of United Kingdom manufacture, the supergroup, carrier supply and line equipment being of United Kingdom manufacture. The equipment is of the BPO type 51 construction and is mounted on rack sides 10 ft 6 in. high in terminals and attended repeaters and on racks 6 ft high in the dependent or unattended repeaters.

High Frequency Line Equipment

The line equipment of the S.T.C. coaxial cable system provides the amplification and equalisation necessary to off-set the loss in transmission over the coaxial cable and comprises the outgoing and incoming terminal amplifying equipment and the amplifiers provided at regular intervals along the coaxial cable route. The equipment was designed for a nominal cable repeater section 6.03 miles long, at a mean buried cable temperature of 17°C estimated to be encountered along this route. The loss of repeater sections is built out to the nominal repeater length by means of line building-out networks.

Automatic pilot regulation is provided at every repeater station to cater accurately for variations in the cable attenuation due to temperature changes and a line pilot of 4142 Kc/s is used for this purpose. Other line pilots used in this system are at frequencies of 308 and 6142 Kc/s and these are discussed under pilot regulating equipment. All line amplifiers are provided in duplicate with manual and automatic changeover facilities to ensure that a working amplifier is replaced by a standby amplifier in cases of failure, or for maintenance reasons. The transmit line equipment at the terminal station raises the level of the signal output from the translating equipment to that suitable for transmission to line, applies pre-emphasis of the high frequencies to improve the signal to noise ratio and combines the telephone baseband and the 3 line pilots. The receiving line equipment provides the correct de-emphasis required to produce a flat level point and amplifies the signal to a level suitable for connection to the translating equipment.

TABLE 2

Station Name	Type of Repeater	Route Distance from Previous Station (miles)
LISMORE	Terminal	—
Wilsons Ridges	Dependent	5.61
McLeans Ridges East	Dependent	5.62
Brooklet South	Dependent	5.62
Bangalow	Dependent	4.97
Ewingsdale West	Dependent	4.97
MULLUMBIMBY	Minor	5.78
Billinudgel Nth.	Dependent	5.81
Burringbar Sth.	Dependent	5.85
Stokers Siding East	Dependent	5.65
MURWILLUMBAH	Main	5.64
Nth. Tumbulgum	Dependent	5.90
Terranora	Dependent	5.51
TWEED HEADS	Minor	5.70
Currumbin	Dependent	4.293
Burleigh Heads	Dependent	4.491
Surfers Paradise	Dependent	5.674
SOUTHPORT	Main	5.574
Coombabah	Dependent	5.798
Oxenford	Dependent	5.133
Pimpama	Dependent	5.115
Halfway Creek	Dependent	5.243
BEENLEIGH	Minor	4.732
Slacks Creek	Dependent	5.562
Eight Mile Plains	Dependent	5.886
Holland Park	Dependent	5.757
BRISBANE	Terminal	4.895

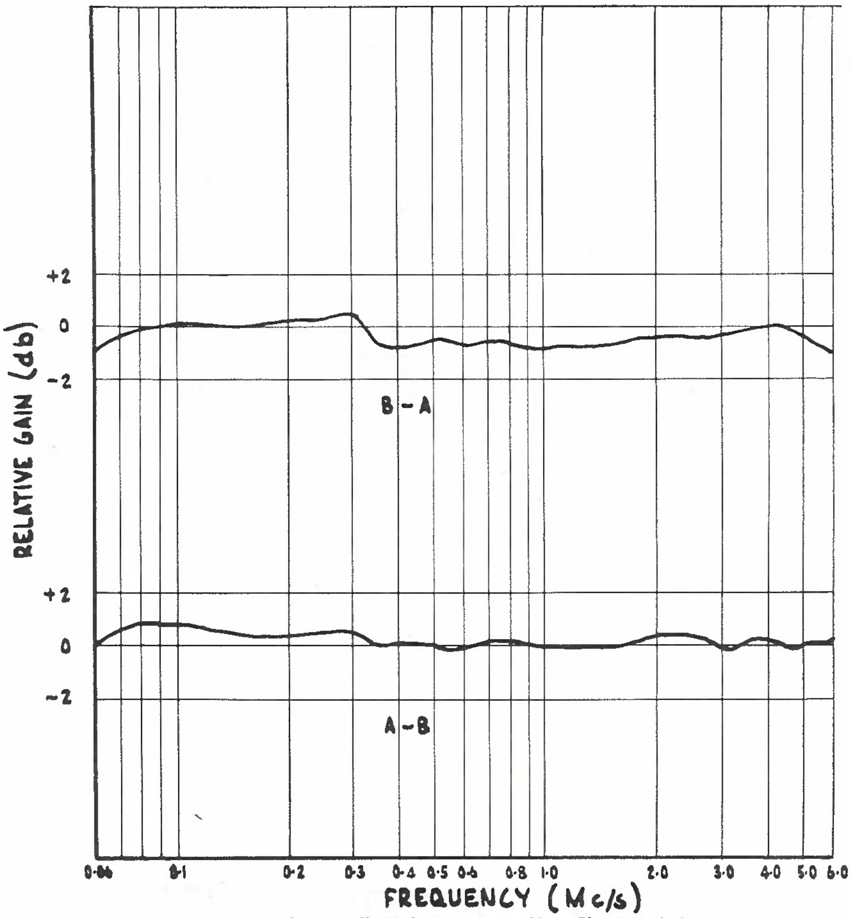

Fig. 8 — Typical Overall High Frequency Line Characteristics.

The overall gain/frequency characteristics of the high frequency line from Brisbane to Lismore, after recent re-equalisation is shown in Fig. 8.

There are three types of repeaters used in the system between the terminals and these are:—

Dependent — 4 wire repeater employing single pilot regulation (4142 Kc/s), to compensate for the cable losses in each direction of transmission.

Minor — Provided where it is desired to extract a small number of supergroups from the system, and provides power for dependent stations up to a maximum of 6 in. each direction.

Main — Provided where several supergroups are extracted and are provided so that not more than 12 repeaters are included between any two main or terminal stations. Comprise back to back terminal repeaters and supergroup dropping racks.

Minor repeaters are provided at Beenleigh (Queensland), Tweed Heads and Mullumbimby (N.S.W.) whilst main repeaters are located at Southport (Queensland) and Murwillumbah (N.S.W.). Dependent repeaters are not staffed, but all other repeaters are staffed during the day (usually 8 a.m. to 6 p.m.), with the exception of Brisbane, which is staffed continuously. Dependent repeaters are normally installed in pre-fabricated buildings with external dimensions of 14 ft by 12 ft and having an internal floor to ceiling height of 8 ft. These dependent buildings are similar to those used in the Sydney-Melbourne coaxial route, but a different layout of the repeater building is used and is shown in Fig. 9. Separate rack sides are used for each direction of transmission and a simplified block schematic diagram of a dependent repeater is shown in Fig. 10. Two mobile dependent repeater equipments are being provided to substitute for any working dependent repeater which is catastrophically damaged.

Power to operate the dependent repeaters is fed from the minor repeater stations, but on failure of the power feed, the dependent repeater is kept powered from the 240 volt a.c. commercial mains through a voltage regulator by means of an automatic power changeover circuit.

Line Amplifier

The line amplifier provides the gain and basic equalisation required to compensate for the cable loss over a repeater section. The line amplifier used in the dependent repeaters is the same as that in the terminals, minor and main repeaters. The nominal gain of the amplifier rises from 14.4 db at 300 Kc/s to approximately 60 db at 6.5 Mc/s, the gain/frequency characteristic being so arranged that in conjunction with the networks in the system the level of signals applied to the input of the following section of cable is similar to that at the input to the cable at the

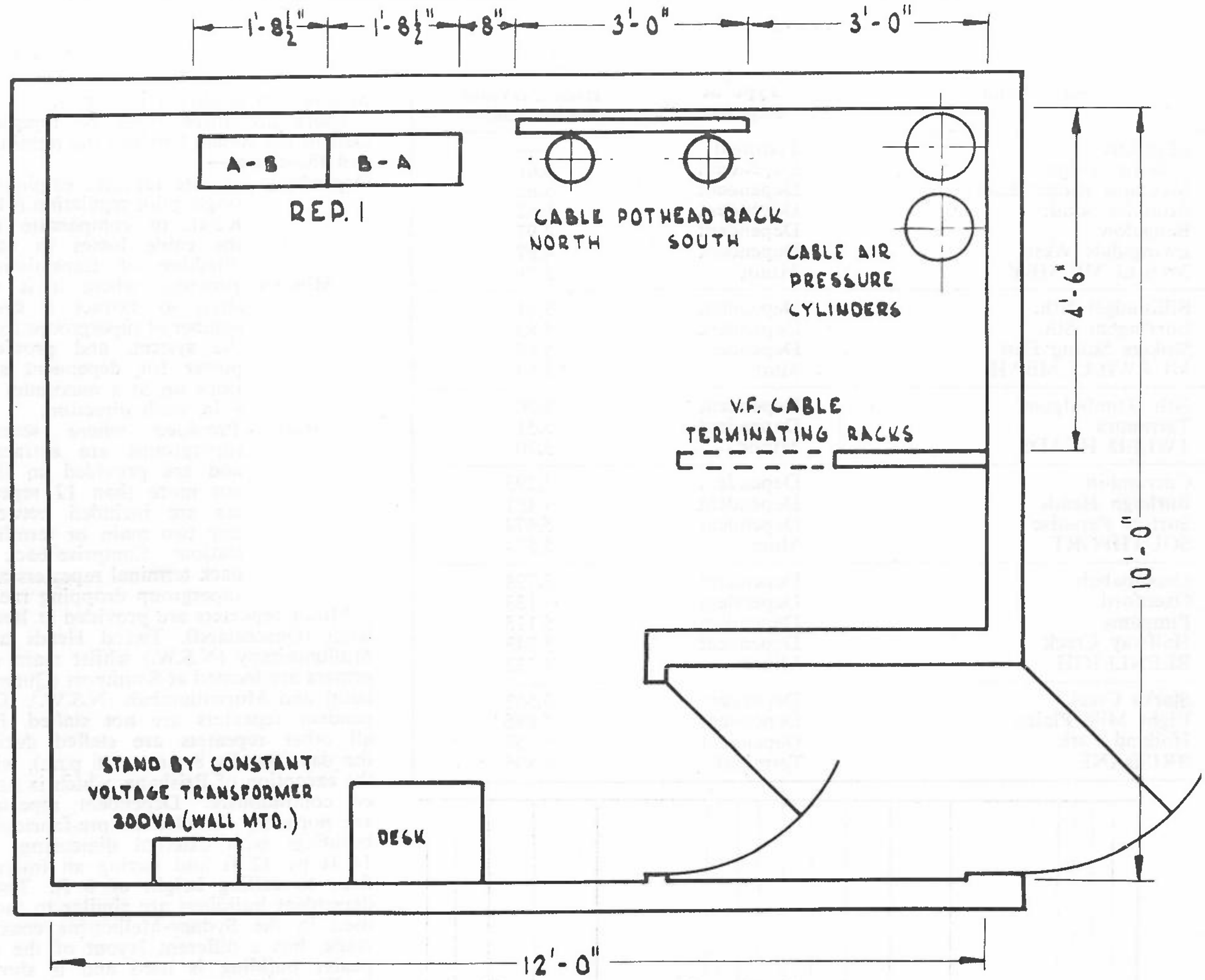

Fig. 9 — Typical Equipment Layout — Dependent Repeater.

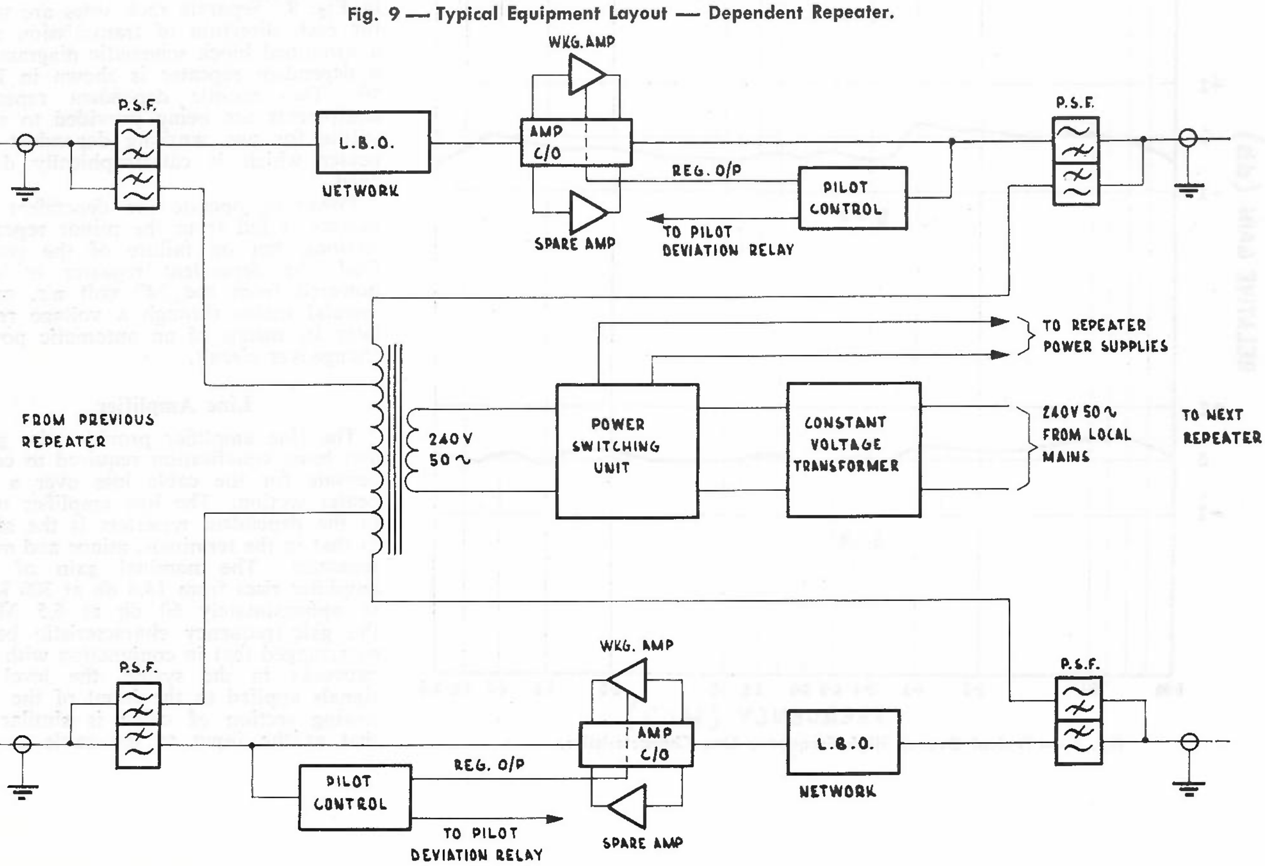

Fig. 10 — Dependent Repeater — Block Schematic.

transmitting terminal. The input and output transformer networks provide 75 ohm terminations for the coaxial cable.

The amplifier consists of 2 feedback triples connected in tandem. The gain/frequency characteristic of the amplifier is obtained from the combined effects of the input, output and interstage transformers and feedback networks. A Beta network is connected between each of the two feedback lines and earth, and is terminated in a thermistor for automatic control of the amplifier or in a series resistor for manual operation. The gain/frequency characteristic of the first Beta network and, therefore, the first triple, provides compensation for the effects of valve ageing and is controlled by appropriate setting of the terminating resistor, whilst the gain/frequency characteristic of the second triple is usually controlled automatically by the thermistor associated with the 4142 Kc/s pilot frequency in order to compensate for changes in line characteristic due to cable temperature variations.

Line amplifiers are mounted in pairs on a rack side and are connected into circuit by the action of the amplifier switching panel. Changeover from working to spare amplifier (which is adjusted manually to provide for similar gain to that of the working amplifier) occurs under valve fail alarm conditions. The line amplifier uses seven electron tubes type STC L5A170K, which are special tubes, manufactured for close tolerances on intermodulation figures and inter-electrode capacitances and are batch tested for long life. The overload point of the amplifier is at least +26 dbmo at the amplifier output.

Pilot Regulating Equipment

The pilot control and regulating circuits provided with the S.T.C. Coaxial Cable line equipment are designed to ensure that the overall gain/frequency response of the high frequency line can be maintained within acceptable limits from transmit to receive terminal of the system. There are 3 line pilot signals transmitted in each direction of transmission and these are:—

(i) The upper pilot frequency (6142 Kc/s) which is used to control regulating circuits provided to compensafe for the effects of valve ageing and changes in repeater temperatures.

(ii) The middle pilot frequency (4142 Kc/s) which is provided to control regulating circuits used to compensate for the effects of changes in cable temperature.

(iii) The lower pilot frequency (308 Kc/s) which is employed to control regulating circuits to compensate for the effects of changes in amplifier gain due to valve ageing and repeater ambient temperature variations. The 308 Kc/s and 6142 Kc/s regulators are inter-dependent.

The three pilot frequencies are generated at the transmit terminals for onward transmission to the receive terminal of the system. Normal and standby oscillators are provided with facilities for automatic changeover from working to spare oscillator in the event of deviation of the pilot level from nominal by ±2 db. The pilot frequencies are combined with the signals from the frequency translating equipment so that the correct ratio of pilot to signal level is maintained. At the receive terminal and at main repeaters, the broadband signals, including the pilots, are amplified and then taken to three gain control units, where the pilot frequency is selected by the appropriate filter for each control unit. Each frequency is amplified, rectified and fed into a computer circuit, which interprets changes in pilot level in such a way that the control signal applied to the thermistors in the equalising networks is varied only by the amount necessary to restore pilot levels to their nominal value. This is accomplished by taking the main transmission path through thermistor controlled networks, whose losses are governed by a 2 Kc/s oscillator output, which in turn is controlled by the received 308 and 6142 Kc/s pilot levels. The 308 and 6142 Kc/s pilots regulate only the receive line equipment at terminal and main repeater stations.

At minor stations the pilot control panels are similar to those at the main stations but are of simplified design and operate regulating circuits in the receive line amplifier on the middle pilot frequency (4142 Kc/s). Manually adjusted networks are provided to cater for level variations caused by ambient temperature changes and valve ageing.

At unattended stations the level of the middle pilot signal (4142 Kc/s) is selected from the line amplifier output by a pilot control panel which actuates a thermistor in the line amplifier second Beta network to control the gain/frequency characteristics.

Translating Equipment

General: As the SEACOM path is connected at the basic supergroup frequencies the description of the features of the translating equipment will be restricted to supergroup equipment and associated carrier supplies. The supergroup translating and carrier generating equipment used on the Lismore-Brisbane coaxial cable system is the same as that used to modulate and demodulate the SEACOM supergroup at City South and Lismore to its nominated line frequency (SG4) for transmissions over the radio link.

Supergroup Modem Equipment: The supergroup modem equipment translates each basic supergroup band 312 to 552 Kc/s to its required line frequencies in the range 60 to 4,028 Kc/s. A Supergroup Distribution Frame is used to cable the basic supergroups in each direction to and from the supergroup modem equipment. 16 Supergroups are modulated on 3 rack sides, and carrier frequencies ranging from 116 Kc/s at intervals of 248 Kc/s are used to modulate supergroups 3 to 16. The carrier supply (612 Kc/s) for supergroup 1 is derived from the group carrier supplies, whilst supergroup 2 is transmitted to line at the basic supergroup frequencies. The SEACOM supergroup (SG4) is modulated with a frequency of 1364 Kc/s to occupy the band 812 to 1052 Kc/s. In the reverse direction the Supergroup modem equipment translates the band of line frequencies back to the 16 basic supergroup frequencies (312-552 Kc/s).

Carrier Generating Equipment: Group and supergroup generating equipment is installed at the terminal main and minor repeater stations and are associated with supergroup carrier supply amplifiers and distribution racks. The essential supplies are duplicated with provision for automatic or manual changeover between working and spare equipment. The supergroup modulation frequencies are derived from the basic 124 Kc/s crystal master oscillator which is provided in duplicate and has a stability of 2 parts in 10^7 per month and feeds separate high gain 124 Kc/s amplifier. The 124 Kc/s frequency is applied to a harmonic generator which produces odd harmonics up to the 21st harmonic (i.e., 2604 Kc/s). These harmonics are then fed into a frequency doubler and 2604 Kc/s modulator to produce the other supergroup frequencies. A combination of amplifiers, filters, equalisers, etc., is used to select the various carrier frequencies and to provide the correct output levels. A simplified block schematic of the supergroup carrier generating equipment is shown in Fig. 11.

Power Plant and Supervisory Equipment

Power Plant: To provide an uninterrupted supply of 240 volts a.c. per phase to neutral and regulated within ± 1% in voltage and at a frequency of 50 cycles within the limits of +1% and —5%, 3 machine all electric no-break plants together with normally stationary diesel alternator sets have been installed at terminal, main and minor repeater stations as follows:—

(i) Brisbane — 40 kVA NB set and 100 kVA NS set to power the coaxial cable and other station equipment.

(ii) Beenleigh — 10 kVA NB set and 30 kVA NS set to supply power for the minor repeater equipment at Beenleigh and dependent repeaters beetween Brisbane and Southport.

(iii) Southport — 10 kVA NB set and 30 kVA NS set to supply power to the main repeater equipment at other a.c. operated long line plant at Southport.

(iv) Tweed Heads — 10 kVA NS set and 30 kVA NS set to supply power for the minor repeater equipment at Tweed Heads and for the dependent repeaters between Southport and Murwillumbah.

(v) Murwillumbah — 10 kVA NB set and 30 kVA NS set to supply power for the minor repeater equipment and other a.c. long line plant at Murwillumbah.

(vi) Mullumbimby — 10 kVA NB set and 30 kVA NS set to supply power for the minor repeater

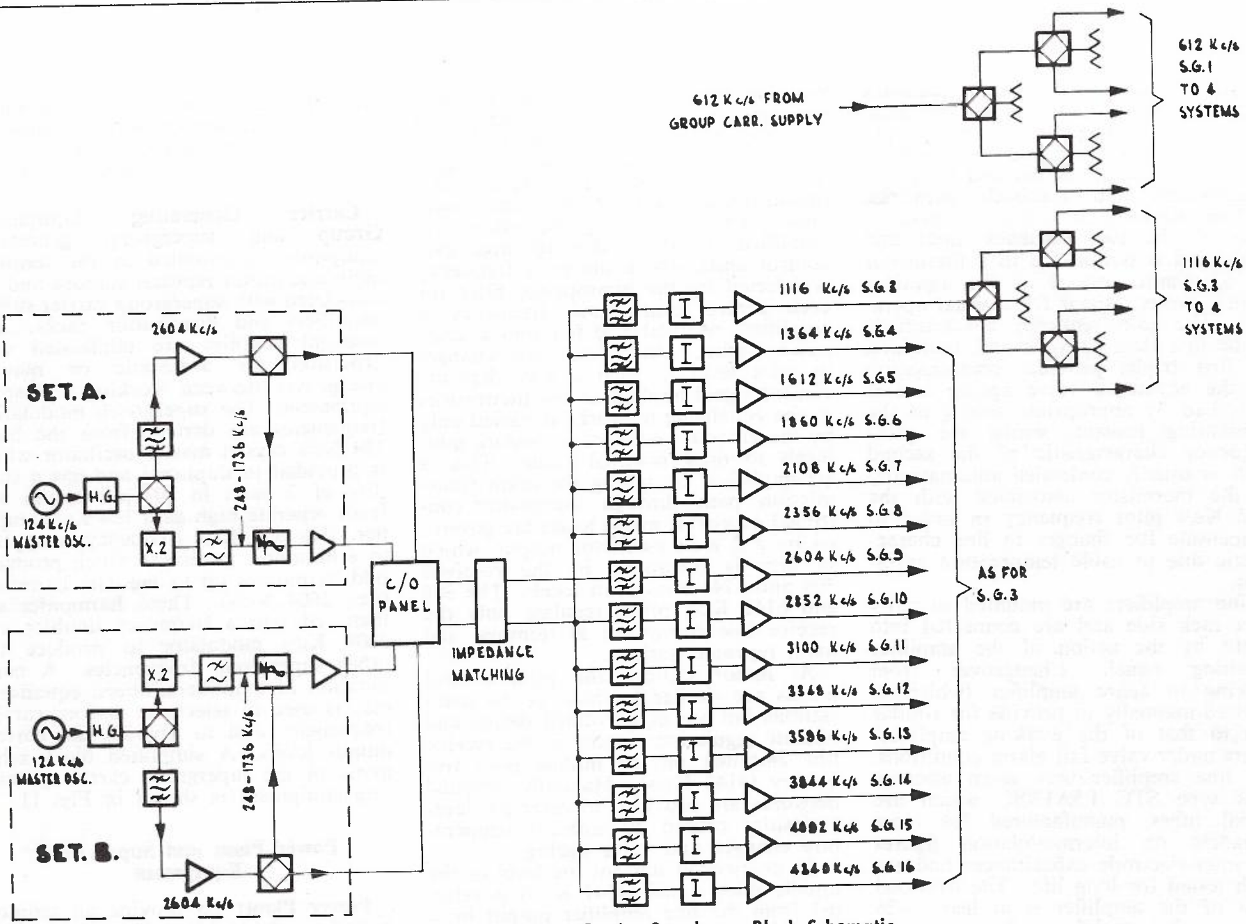

Fig. 11 — Supergroup Carrier Supply — Block Schematic.

equipment at Mullumbimby and for the dependent repeaters between Murwillumbah and Lismore.

(vii) Lismore — 30 kVA NB set and 136 kVA NS set to provide power for the terminal coaxial cable equipment and other a.c. operated long line equipment at Lismore.

All electric 3 machine No-Break equipment has been described previously (Ref. 7).

Power Feeding: The power required for the operation of the dependent repeaters is supplied over the centre conductors from the no-break equipment at the minor repeater stations. The regulated 240 volt a.c. no-break supply is wired to the supervisory rack sides at the minor stations where it is transformed to 750-0-750 volts a.c and is applied to the centre conductors of the first pair of coaxial tubes via power separating filters. A circuit breaker is connected in the 240 volt side of the power feeding circuit to provide overload and unbalance protection. At the dependent repeater the power feeding voltage is connected from the power separating filters to a transformer the secondary of which provides 240 volts for the operation of power packs in the repeater. The primary of the transformer is tapped to provide the 750-0-750 volts feed to the next dependent station and compensates for the voltage drop over the cable length. Automatic changeover facilities are provided to connect the repeater equipment to regulated a.c. main supply in the event of failure of the power feeding equipment.

Supervisory Equipment: The S.T.C. coaxial cable system provides simple and effective supervisory facilities which provide for local and remote indicators of various alarm conditions. The alarms are grouped into four categories; (a) deviations of pilot A to B, (b) B to A by more than ±2db, (c) power failure, and (d) high tension or valve failure in either the working or standing amplifiers (non-urgent). Other alarm indications have been provided by the Department for the supervision of the system and these include local power fail, door open, gas alarm cable and gas reservoir cylinder alarms. Order wire facilities are provided by means of a 4-wire telephony circuit connecting all stations. Voice frequency repeaters are provided at 12 mile intervals in each direction of transmission and facilities are provided to automatically bypass any repeater of the order wire circuit should an amplifier fail. D.C. signalling facilities are arranged by means of cailho circuits over the 4-wire speech circuit.

Coaxial Tail Equipment

General: This equipment is used between O.T.C. Paddington and City South, City South and Redfern and between Goonellabah Radio Terminal and the Lismore Carrier Station in N.S.W. The equipment is a simplified 6 Mc/s, standard 0.375 inch coaxial cable line system, suitable for operation over short distances usually less than 12 miles in length. Automatic line pilot regulation and remote supervisory facilities are not provided. The amplifiers are of Siemens and Halske manufacture and employ a flat 3 stage amplifier (G Amp.) and an equalising 4 stage amplifier (E Amp.) to provide the required high frequency line of 6 megacycle bandwidth to C.C.I.T.T. specifications. The amplifiers are of the valve type, the valves in each stage being duplicated and wired in parallel to guard against interruptions due to valve failure.

The equipment is a.c. operated from the no-break supply provided at Redfern, City South, Lismore and Goonellabah.

Transmitting Equipment: The equipment at the transmitting end comprises a G flat amplifier, station line equaliser, variable attenuator pads and a power separation filter. The amplifier has a fixed gain of 39.1 db. The signal is usually applied without pre-emphasis to the coaxial line through the power separation filter, at a level of —11.3 dbm out of the amplifier to achieve a satisfactory signal to noise ratio. The power separating filter is provided on eeach pair of tubes to protect against induced voltages. Where the length of the coaxial tail is short and is only transmitting supergroup frequencies as in the case of the O.T.C. Paddington to City South Carrier Terminal link, it is possible to provide a pre-equalising network to match the attenuation/frequency characteristic of the cable and so eliminate the receive amplifier.

Receive Equipment: The receive coaxial tail equipment is designed to provide equalisation and amplification necessary to compensate for the attenuation of the short haul coaxial cable over the frequency range of 60 Kc/s to 6.2 Mc/s. The receive equipment consists of a power separating filter, line building out network to build out the cable section to the full length of 5.75 miles and an equalising amplifier. The equalising E amplifier has a sloping gain/frequency characteristic with a gain of between 50.8 db and 58.6 db at 6.2 Mc/s. Alarm indications are provided from the transmit and receive racks back to the control station as well as being displayed locally in cases of failure of power supplies to and valves of the G and E amplifiers. A view of two racks of the Siemens and Halske Coaxial Cable Tail Equipment at City South Carrier Terminal is shown in Fig. 12.

REFERENCES

1. C. J. Griffiths, "SEACOM Submarine Cable System : Sydney-Cairns Land Section — Overall Planning Aspects"; Telecommunication Journal of Aust. Vol. 15, No. 1.
2. M. Strohfeldt, "Transmission Performance of the Brisbane-Cairns Microwave System"; Telecommunication Journal of Aust. Vol. 15, No. 2.
3. V. J. Griffin, "Survey and Selection of Brisbane-Cairns Microwave Radio Route"; Telecommunication Journal of Aust. Vol. 15, No. 2.
4. L. Clayton, "Design and Provision of Equipment for the Brisbane-Cairns Microwave System"; Telecommunication Journal of Aust. Vol. 15, No. 3.
5. J. H. Curtis, "Brisbane-Tweed Heads Coaxail Cable — River Crossings"; Telecommunication Journal of Aust. Vol. 13, No. 6.
6. F. J. Harding, "Sydney-Melbourne Coaxial Cable — The Gas Pressure Alarm System"; Telecommunication Journal of Aust. Vol. 13, No. 3.
7. A. Hannah, "Sydney-Melbourne Coaxial Cable — Power Plant"; Telecommunication Journal of Aust. Vol. 13, No. 3.

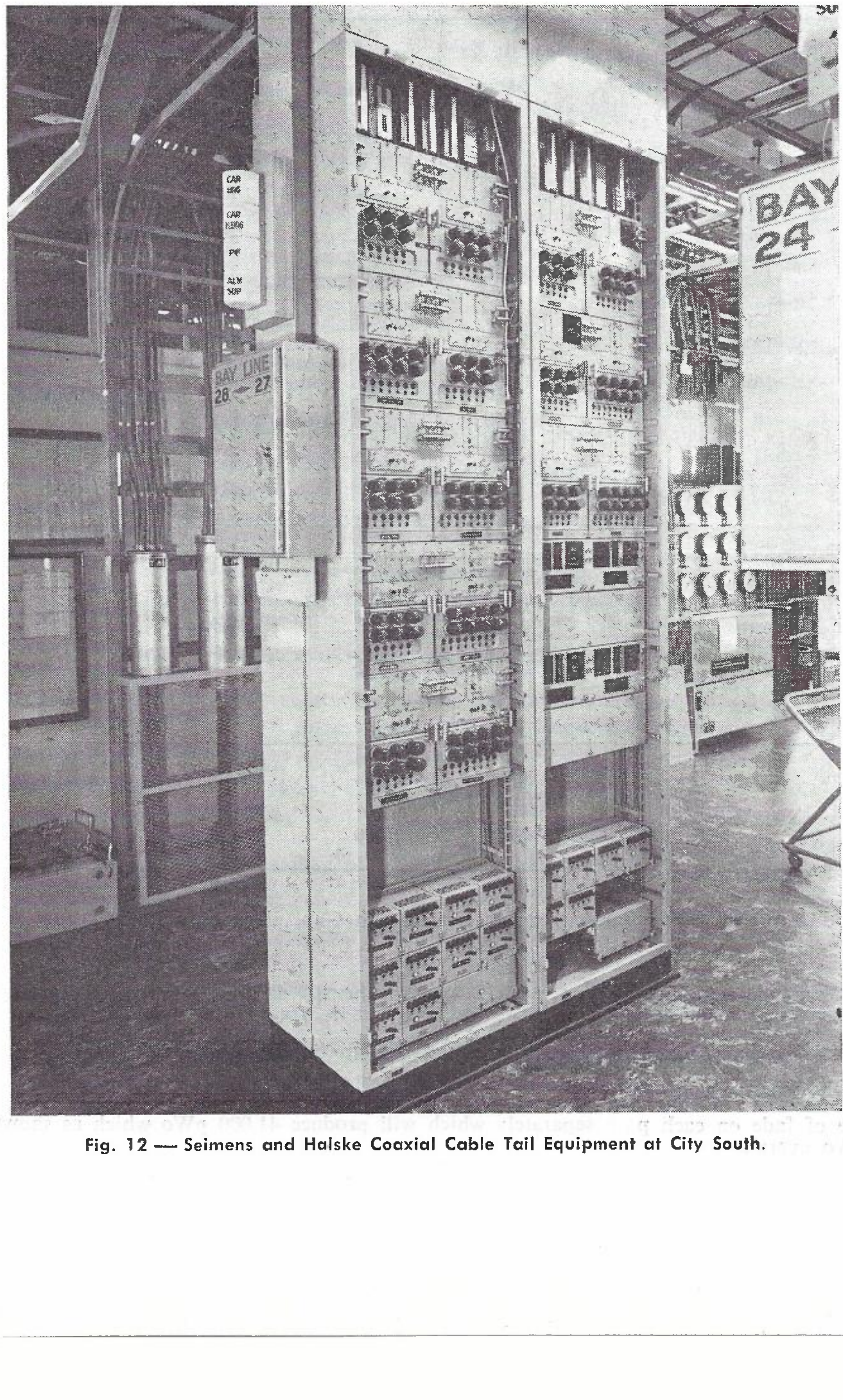

Fig. 12 — Seimens and Halske Coaxial Cable Tail Equipment at City South.

APPENDIX 1.

ESTIMATED PERFORMANCE OF UPGRADED SYDNEY-LISMORE RADIO SYSTEM

The estimated performance of this route is detailed in Table 3, and is explained in the following notes:

(i) The long term median noise (say over 12 months) virtually corresponds to that with free space path loss on all paths assuming no intermodulation noise is present, i.e. only several channels in use on the average compared with the system capacity of 960 channels. On these assumptions the upgraded system improvement is that due to net path loss reduction because of the lower loss waveguide and increased gain of the larger aerials. The use of diversity will improve the received signal (see main text), since each aerial can be assumed to be in an equal field strength region. Baseband combiners should give a net improvement of 2.5 db.

(ii) The busy hour noise under non-fading conditions corresponds to that normally measured when routine white noise measurements are performed. It consists of that in (i) above plus intermodulation effects due to equipment, waveguide and aerial coupling, a figure of 320 pWo being applicable to the top slot (960 ch) and 270 pWo for the SEACOM slot (1 Mc/s) per modulation section.

(iii) The worst hour noise is a little difficult to interpret; CCIR indicates that this allowance should be reduced according to system length from which it may be inferred that all tandem-connected systems suffer their worst hour condition simultaneously, on this basis only 2,000 pWo should be allocated to the Sydney-Lismore system. Propagation measurements on the various paths of this system indicate that the worst mean hour noise contribution per path due to severe median signal depressions plus Rayleigh type fading will be unique, i.e., one per year of this magnitude or approaching it, and unaccompanied by similar magnitude fading (i.e., 10 db less at least) on any other path. As the observations cover eleven paths in a coastal region where correlation could most be expected, this limit of 2,000 pWo could comfortably be extended to that of a complete CCIR reference circuit i.e., 7,500 pWo, less normal noise of the reference circuit due to fixed and busy hour effects for this route and this equipment (which could be considered representative). As shown in Table 4, the allowance for a single path in the top slot (960 channels) is then 3,360 pWo or 4,260 pWo for the SEACOM channels (1 Mc/s) for worst hour mean noise assuming the system is loaded with white noise to +15 dbmo. All upgrading action reducing net path loss will give improvement to the depressed median noise, but diversity will not help. The effect of the superimposed Rayleigh fading on the mean hour noise may be taken as 8.5 db assuming a 42 db fade limit; diversity should reduce this effect to 0 db. The baseband combiners will effectively reduce the depth of the fade; if they restrict the fade to 30 db (which seems possible), the mean hour effect of Rayleigh fading will be reduced to 7.5 db.

(iv) The minute mean noise for 20% of the worst month (i.e. 135 hours) should not exceed 2000 pWo for

TABLE 3: ESTIMATION OF PERFORMANCE OF SYDNEY-LISMORE BEARER IN SEACOM CHANNELS

(For understanding of this Table, Notes (i) to (vi) in the text of this Appendixshould be studied.)

Path	Long Term Median (Note 1) Before Upgrading (pWo)	Long Term Median (Note 1) After Upgrading (pWo)	Worst Hour Mean Fade (Note 3) (db)	Worst Hour Noise (pWo)	20% of Mth Minute Mean Noise (pWo) (Note 5)	Fade for 47500pWo Minute Mean Noise (Note 6) (db)	Time in Worst Mth 47500 pWo Exceeded (Minutes)
Redfern — Dural	3.7	3.7	4	9	7.4	40	0
Dural — Mangrove	15	15	20	1,500	30	34	0.3
Mangrove — Heaton	15	15	18	950	30	34	0.3
Heaton — Gan Gan	33	1.8	20	180	3.6	44	0
Gan Gan — Cabbage Tree	14	4.8	18	300	9.6	39	1
Cabbage Tree — Vincents LO	41	14	17	700	28	35	0.6
Vincents LO — Pt. Macquarie	19	19	16	750	38	33	0.8
Pt. Macq. — Yarrahapinni	33	12	11	150	24	35	0.2
Yarrahapinni — Coramba	26	13	11	165	26	35	0.2
Coramba — Sth. Grafton	16	16	20	1,600	32	34	1.2
Sth. Grafton — Woodford	8	8	7	40	16	37	0
Woodford — Meerschaum	31	31	23	6,200	310	31	0.6
Meerschaum — Goonellabah	1.7	1.7	—	—	34	44	0
Route Total	256	147		—	558	41,000 pWo	5.2
Fixed Noise		100		—	100	450 pWo	—
Intermod Noise		—		—	555	2,430 pWo	—
Baseband Combiner Improvement (Note 2)		2.5db		2.5db	2.5db	—	—
Final Route Performance		183		3,500 (Note 4)	960	47,500 pWo	5.2
CCIR Requirement		—		4,350	2,000	—	18

Notes:
1. Paths with diversity given a 3 db net path loss reduction except Heaton-Gan Gan, given only 1 db.
2. Applies to Route Total pWo only.
3. Includes the worst value of median fade actually observed over 12 months plus 8.5 db for the effect of Rayleigh fading if diversity not fitted less improvement for diversity of 3db included in Note 1.
4. This figure obtained by allowing Baseband Combiner improvement of 2.5 db on the worst path.
5. 3 db fade on all paths except the worst which assumes 10 db.
6. This fade represents the degree of fade on each path separately which will produce 41,000 pWo which as shown in the text produces 47,500 pWo overall.

this system. The propagation records show that in the system worst month 170 hours of fading existed in which fading exceeded 20 db in any hour in any path. When diversity is installed on the three additional paths, the corresponding number of hours should be reduced to 45 hours, assuming diversity action reduces the effect on these paths to 10% of the previous hours. The records also show that when upgraded, simultaneous periods of severe fading should only exist for 4 hours on 2 or more paths. The estimation of this performance criterion is rather complex and various writers use many approaches; the most applicable in this case appears to degrade each path by 3 db and the worst path (Woodford Island-Meerschaum) by 10 db. The analysis appears in Table 3 showing a result of 960 pWo being 3 db inside the allowance of 2,000 pWo.

(v) The minute mean noise of 47,500 pWo should not be exceeded for more than 0.03% of the worst month (i.e. 18 minutes) for this system. Because of the short duration (several seconds) of fades which contribute most of this noise they will be assumed to be non-simultaneous on the various paths. Examination of the fading records shows that deep median depressions are likely to exist on several paths and to simplify analysis all paths will be given a fade of 10 db in a full CCIR section (very conservative). It may be deduced from Table 4 that a total of 6,500 pWo obtains, leaving 41,000 pWo for the path undergoing the deep fade. The fade to produce this result is shown in Table 3. To obtain the time that this fade level is exceeded, it is increased by 4 db as recommended by CCIR (allows for shortness of fade duration compared to 1 minute), 10 db is then subtracted to allow for a typical depressed median and the resultant entered on a Rayleigh distribution curve to obtain the % of time this fade exceeded. By using the hours of severe fading shown in Table 1 the time per path may be then obtained; this is entered in Table 3, the estimate for the system being 5.2 minutes against the allowance of 18 minutes.

(vi) The one second mean noise of 200,000 pWo should not be exceeded for more than 0.003% of the worst month (i.e. 1.8 minutes) for this system. With the system upgraded it is thought that this limit will rarely be exceeded due to propagation difficulties since threshold for all paths is between 40 and 50 db below free space signal. Time between fades on normal and protection bearers (separated by 116 Mc/s in the 4 Gc/s band) of 40 db depth should allow correction by the baseband combiners.

TABLE 4: ANALYSIS OF CCIR REFERENCE SECTION (TYPICAL)

Section Length = 1550 miles, Modulation Sections = 9
Length of Paths = 29 miles, No. of Paths = 54

Typical Thermal Noise per Path	=	20 pWo (6 8)
Typical Basic Noise per Mod. Section	=	20 pWo (50)
Typical Internal Noise per Mod. Section	=	320 pWo (270)
Typical Total Noise per Mod. Section	=	460 pWo (361)
CCIR Total Noise per Mod. Section	=	833 pWo
Noise for Fading per Mod. Section	=	373 pWo (472)
Typical Thermal Noise for Section	=	1080 pWo (360)
Typical Basic Noise for Section	=	180 pWo (450)
Typical Internal Noise for Section	=	2880 pWo (2430)
Typical Total Noise for Section	=	4140 pWo (3240)
CCIR Total Noise for Section	=	7500 pWo
Noise for Fading for Section	=	3360 pWo (4260)

Note: Figures in brackets for SEACOM channels (1Mc/s), others for top channel in 960 channels (4Mc/s).

TECHNICAL NEWS ITEM

IMPROVEMENTS TO RURAL SUBSCRIBERS SERVICES

The problem of providing improved service to the rural subscriber is of considerable interest. A large majority of telephone subscribers who are remote from local townships are at present provided with magneto telephone services over long earth-return galvanised-iron lines, some of which are as long as one hundred and fifty miles. Usually the larger portion of each such line is provided, and maintained by the subscriber (P.P.E. line). Inherently, these lines have high attenuation and high noise levels, the noise is particularly high during poor atmospheric conditions. Furthermore, on routes on which a number of subscribers services are provided, the lines may run parallel to each other for many miles and the crosstalk between circuits is quite high. The transmission performance of these lines is further deteriorated by lack of maintenance: many fault situations, such as sagging spans, fallen branches on the line, and so on, can be readily detected and remedied by the subscriber; however high resistance joints and corrosion are not so evident visually, but they have a considerable effect upon performance. The transmission on some lines is so poor during adverse conditions that makeshift calling procedures become necessary; for example, the subscriber may be forced to crank his generator several times during a conversation in attempts to break down high resistance joints, or if transmission is so poor that signalling is impossible the operator may come across the line at locally agreed times to enquire whether the subscriber wishes to make a call (it is often possible to speak but not to ring).

There appear to be three approaches to the problem of effecting an improvement, and these are being studied by the Postmaster-General's Department at this time. Firstly the possibility exists of improving the transmission performance of the existing lines; it seems beyond doubt that a satisfactory method of jointing can be found (if not already existing) which together with DC-wetting would provide a reliable and stable transmission medium based on P.P.E. G.I. lines. Secondly improvement may be obtained with the use of special equipments. Typical examples under consideration include the provision of telephones with improved microphone circuits, press-to-talk amplified telephones, voice switched telephones, subscribers carrier systems and line concentrators. Signalling can be improved by the use of high sensitivity bells or by signalling at voice frequencies. Some of these devices are already undergoing field trials.

Third approach is the provision of a different transmission medium, for example VHF radio, drop wire and plastic cables. (drop wire is probably the cheapest form of metallic pair and can be used in a similar line construc tion to earth return G.I. wire).

EXECUTIVE - SECRETARIAL TELEPHONE SYSTEMS

*R. B. CULLEN, B.E.**

INTRODUCTION

There exists a growing demand for modern telephone facilities designed specifically to meet the requirements of executive-secretarial situations. There are two factors which appear to stimulate this growth:—

(i) The telephone is a major means of communication within most business organizations. A wider appreciation of the critical nature of this communication function has led to an examination of telephone systems and a growing demand for methods of improving their effectiveness.

(ii) Australian executives have become increasingly aware of the high grade telephone facilities available to their counterparts overseas.

The general telephone requirements of an organization are provided using a variety of equipment ranging from PABX installations to the straightforward Intercom systems. Such systems can be described as "basic" telephone systems and they provide telephone facilities for a wide coverage of people within an organization. Executives faced with a more critical communications function, require more sophisticated facilities than those available from most basic telephone systems.

To provide these specialized requirements the Australian Post Office offers a range of equipment which supplements the facilities available from basic telephone systems and this equipment will be discussed in detail. Replacements being developed for the older items of equipment will also be outlined. Although the major usage of the A5 or A10 Intercom Telephone and the Cordless Switchboards were properly described above as providing a basic system for small organizations they are sometimes used to to supplement PABX or larger PMBX systems to provide executive-secretarial facilities. The Intermediate Telephone is another item of standard equipment which is widely used. These standard items of equipment were not designed for executive-secretarial situations and their major facility deficiencies for these situations will be discussed.

This growing demand for facilities which could not be provided using standard items of equipment led, in 1963, to special investigations in the Victorian Administration of the Postmaster-General's Department; the outcome was the development of the Multifone range of equipment. The Multifone which introduced many new and sophisticated facilities is a flexible system readily tailored to particular requirements. It is discussed in detail for the following reasons:—

(i) Unlike the items of standard equipment the Multifone was developed specifically for use in the executive-secretarial field and incorporates many of the special facility requirements to be discussed.

(ii) Multifones became available in limited quantities to Victorian executives in November 1964 and these installations represent one of the few real sources of information on facility requirements in this field.

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FACILITY REQUIREMENTS

The broad facility requirements of executive-secretarial situations are briefly reviewed below.

Intercom between executive and secretary is an almost universal requirement. Some executives require rapid high priority intercom to other executives. In many cases the basic telephone system can meet this requirement; where this proves inadequate, special devices are superimposed upon the basic system to provide these facilities.

Incoming Calls: Either the executive or the secretary can require to answer incoming calls. Lines on which the executive answers calls are termed direct lines. Lines on which the secretary answers calls for the executive are termed filtered lines. In the latter case the secretary answers the call, identifies it, and offers it to the executive using an Intercom facility. The executive may then take the call if desired.

Transfer of Incoming Calls: The facility to transfer incoming calls from their normal point of answer is aimed at minimizing unanswered calls and is of fundamental importance. Transfer of direct lines involves the diversion of incoming calls to the secretary when the executive is not available. This requirement is widespread. The majority of filtered line users also require a transfer facility. This involves diversion of the normally filtered call direct to the executive when the secretary is unavailable.

Outgoing Calls: At times the secretary will be required to make outgoing calls for the executive, but many executives consider it more polite to make their own outgoing calls and require access to the line for this purpose. This access should not necessitate contacting the secretary.

Privacy of Line Connection: Where both the executive and the secretary can gain access to a line, most executives wish to ensure the privacy of their conversation. To achieve this it is necessary for the secretary to be excluded from the line while the executive is connected.

STANDARD ITEMS OF EQUIPMENT

The standard items of equipment most frequently used to provide executive-secretarial facilities are now considered in some detail.

Two Line Telephone

The Two Line Telephone which is illustrated in Fig. 1 enables either of two lines to be connected by the operation of a line key. A hold key allows a call to be held, while the other line is in use.

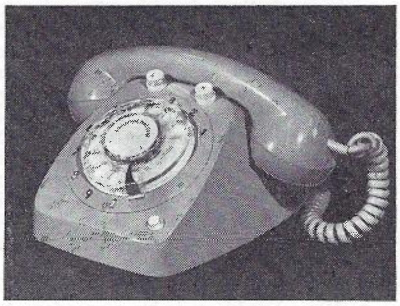

Fig. 1 — The Two Line Telephone.

Intermediate Telephone

The Intermediate Telephone, illustrated in Fig. 2, soon to be replaced by the Intercom System 1/3, is widely used. In the usual application a secretary is provided with the Intermediate Telephone to filter calls to an executive who has a special telephone with a call button.

Fig. 2 — The Intermediate Telephone.

The facility to switch one line to either of two extension points leads to a wider usage of the Intermediate Telephone as a line switching device than the CB Extension switch which it replaced.

Executive Access to the Line: To obtain access to the line it is necessary for the executive to contact the secretary. As discussed earlier most executives require a more direct form of access.

Transfer of Incoming Calls Direct to the Executive: Most executives require to take incoming calls direct when the secretary is not available. This is accomplished in an Intermediate Telephone Installation by a physical switching operation at the secretary's position. The superiority of the Automatic Trans-

Fig. 3 — A Typical Multiple Intermediate Telephone Installation.

fer facility incorporated in the Multifone over manual switching methods will be discussed later.

Executive's Line Connection: The executive is limited to one line. However, the Two Line Telephone is easily adapted to connect into an Intermediate Telephone system to provide the executive with a direct line. Executives with two lines usually take calls on the second line direct. When the executive is not available a means of transferring such calls to the secretary is often required. This is provided using a transfer key and an additional telephone at the secretary's position.

Secretary's Line Connection: The secretary is restricted to one line and this constitutes a major limitation to the use of this device. The secretary usually requires a personal line in addition to the line "filtered" to the executive. This can only be provided by installing an additional handset at the secretary's position.

The secretary may be required to filter calls on a number of lines to a number of executives. This requirement is sometimes met by installing a number of Intermediate Telephones at the secretary's position, or by constructing a special unit.

These requirements have led to a significant number of multiple instrument installations of the type shown in Fig. 3. The inability of these installations to meet requirements did much to stimulate the development of the Type 2 Multifone Installation which will be discussed later.

Intercom Sytems Designed to Replace the Intermediate Telephone

Two new devices have been developed by the Central Administration to replace the Intermediate Telephone. These devices should become available to subscribers in the near future.

Intercom System 1/2: This system provides the executive and the secretary with telephones which are both physically similar to the Two Line Telephone discussed earlier. One line position at each telephone terminates the filtered line and the other is used to provide an intercom facility between executive and secretary. Manual transfer is retained but the executive gains direct access to the filtered line, a significant improvement over the Intermediate Telephone facility.

Intercom System 1/3: Although this system incorporates some new facilities such as monitoring for the secretary and direct intercommunication between extensions, it provides facilities similar to those of the Intermediate Telephone. The executive is provided with a telephone or a Two Line Telephone while the secretary remains limited to one line.

The secretary's unit is of modern design and is illustrated in Fig. 4.

Use of Intercom Systems 1/2 and 1/3 in the Executive-Secretarial Field: From the executive - secretarial facility point of view, Intercom System 1/2 is the more attractive one since it provides for direct access to the line by the executive. Executives requiring one line will be provided with this system. Executives requiring two lines cannot be accommodated with System 1/2 and would be provided with System 1/3 and a Two Line Telephone.

The data on executive line requirements extracted from Multifone Installations and detailed later suggests that executives with individual secretarial assistance are fairly evenly divided between a one and a two line requirement. For this reason it seems probable that a considerable usage of both these systems will be experienced.

Both these new systems restrict the secretary to one line. Victorian experience is that a large percentage of secretaries require two or more lines.

There appears to be a large demand for a one executive system provided with:—

(i) Direct access for the executive to one or two lines as required.

(ii) Two or three lines for the secretary, one of which can be filtered to the executive.

(iii) Some form of automatic transfer as described later for the Multifone range of equipment.

Fig. 4 — The Secretary's Unit of Intercom. System 1/3.

Fig. 5 — A 3 + 12 PMBX (Cordless Switchboard) in a Modern Secretarial Situation.

Cordless Switchboard

The recently introduced range of Cordless Switchboards has reduced the size and improved the appearance of this type of equipment. These devices are designed to provide basic telephone system for small organizations but fall short of requirements in many executive-secretarial situations where they are sometimes used in Victoria. The major deficiencies of switchboards when used in these situations are as follows:—

Ratio of Lines to Extensions: Currently available switchboards include 2 + 6, and 3 + 12 sizes. A typical 3 + 12 installation is shown in Fig. 5. In executive-secretarial situations the ratio of lines to extensions tends to be equal to or greater than unity. Where cordless switchboards are installed in this field a large proportion of the extensions is unused which leads to an unnecessarily large unit at the secretary's position.

Experience with Multifone and Intermediate Telephone installations indicates that a great many executives are associated with a particular line and calls on that line are not usually required to be switched to other executives.

Where calls on a line are required to be switched to a number of executives the Cordless Switchboard represents an economical method of providing the facility but even in this case the ratio of lines to extensions seems too low for most requirements.

Executive Access to the Line: To obtain access to the line the executive must contact the secretary. As with the Intermediate Telephone this falls short of the facility required.

Transfer of Incoming Calls: Incoming calls signal at the switchboard and there is no satisfactory means of transferring them to signal direct to the executive.

Intercom Telephone (A5 and A10)

The Intercom Telephone is illustrated in Fig. 6. These units are provided for the secretary and for all executives connected to the system. A pushbutton

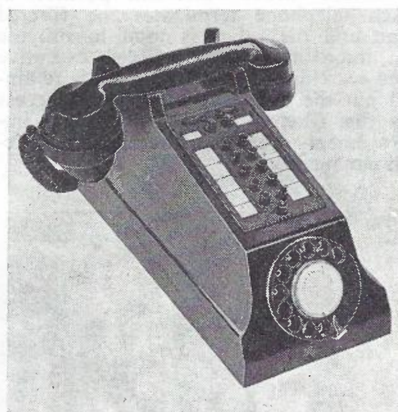

Fig. 6 — The A10 Intercom. Telephone.

Intercom facility is provided between all points connected to the system. One or two lines connect to the A5 or A10 systems respectively and these lines appear on pushbuttons at each unit connected to the system.

As the A5 and A10 systems are designed to provide intercommunication facilities between a number of speaking points with direct exchange line access their usefulness in the executive-secretarial field is limited. The deficiencies for executive use are:—

Ratio of Lines: The A5 and A10 systems are 1 + 6 and a 2 + 11 facilities and as in the case of cordless switchboards the ratio of lines to extensions is too low. A modification to the A10 system which affords some relief to this situation is to disconnect an incoming line from the multiple connection and connect it exclusively to one executive. Even with this modification the secretary remains restricted to two lines.

Pushbutton Intercom: The intercom fails to indicate the calling party to the called party and also is non-secret. As mentioned previously, some executives require secrecy.

Transfer of Incoming Calls: A weakness of the A5 and A10 systems is that the units are not able to signal an incoming call except by the addition of a "transfer unit" usually at the secretary's position. If the executive requires to answer calls direct either all the time or via some transfer facility when the secretary is unavailable, a special modification can be performed to provide incoming signalling at the executive's position. This modification together with arrangements of transfer keys meets most requirements but the solutions are complex and leave much to be desired.

Intercom Systems Designed to Replace the Intercom Telephone

The Australian Post Office is developing two systems to be known as Intercom Systems 2/7 and 3/11 to replace the A5 and A10 systems but they will not be suitable for executive-secretarial use. However, this deficiency will be rectified by new executive-secretarial systems also in the design stage.

THE MULTIFONE

Having outlined the reasons why standard items of equipment do not represent a complete answer to equipment provision in executive-secretarial situations it becomes appropriate to consider in some detail the Victorian Multifone development. This will afford an opportunity to discuss some of the more refined facility requirements found in this field.

The Multifone aims to satisfy those areas of demand where standard equipment proves unsuitable and is designed to complement the facilities available from standard equipment. It enables a telephone to connect to one of a number of lines by the operation of a Key Unit, and provides flexible facilities for a wide range of executive-secretarial situations.

Physical Construction

Each Multifone contains a Key Unit located at the user's desk and an associated Rack which houses the the required equipment. The separation of equipment from the Key Unit led to a minimum sized Key Unit, removing from the design many problems of miniaturization which would have been associated with the development of an integrated unit. To facilitate testing and maintenance, each Key Unit can be connected direct to the Rack via plug and socket terminations.

Key Units

The Key Unit contains a key for each line together with common control keys;

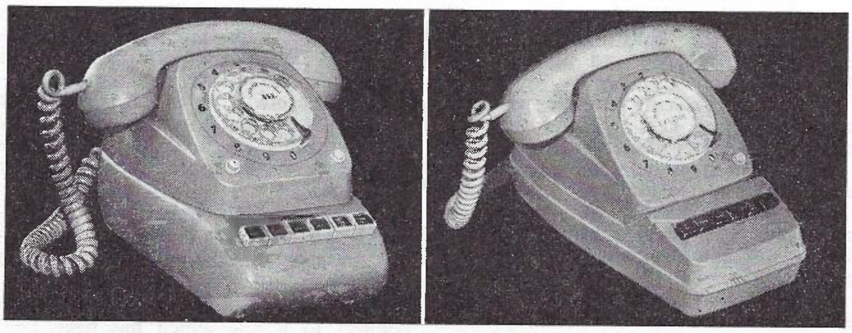

Fig. 7 — Multifone Plinth Key Unit. Left: Fibre Glass. Right: Injection Moulded.

a lamp in each key provides visual signalling. The main requirements of a Key Unit are attractive appearance and ease of operation. To meet requirements three types were developed.

The Plinth Key Unit: This key unit contains six keys. The initial Plinth Units (See Fig. 7) were produced in fibre glass a material which proved unsuitable for quantity production. The new Plinth Unit which features a two-part injection moulded plinth and improved key accessibility, is now in full production.

The Drawer Key Unit: This Key Unit illustrated in Fig. 8 was produced in a range of sizes. Production difficulties of fitting drawers to desks together with a difficulty in seeing visual signals led to the development of a Console Unit to replace the Drawer Unit.

The Console Key Unit: The Console has a moulded case, is easier to use, install, and maintain, than the Drawer Unit (See Fig. 9).

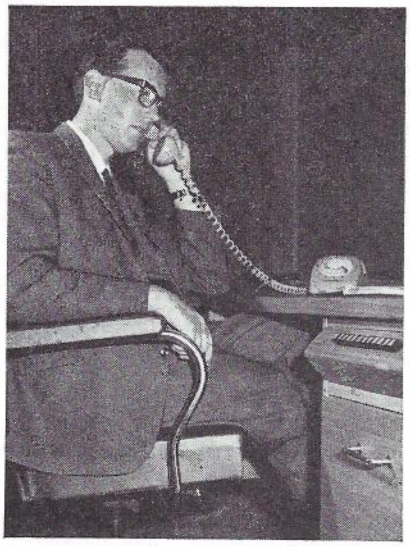

Fig. 8 — The Multifone Drawer Key Unit.

Fig. 9 — The Multifone Console Key Unit.

The Equipment Rack

The Rack 25 in. x 18 in. x 8 in., is sometimes located in the secretarial area but more often in a PABX room or some separate area set aside on a particular floor of a building. (See Fig. 10). The assembly of the various components within the rack will be discussed later.

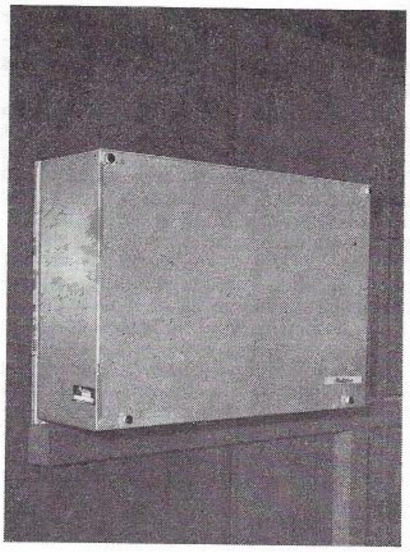

Fig. 10 — The Multifone Equipment Rack.

MULTIFONE FACILITIES

A wide range of facilities can be provided using one of three relay modules, known as Line Modules, for each line connected to the Multifone. The particular facilities required are provided by strappings on each module. A five digit code identifies and standardises the particular line module strappings required. Some strappings are still designed for each Multifone, notably those involving the position of components within the Rack assembly and those determining the order in which lines appear on keys in the Key Unit.

This method of facility provision has the advantage that many facilities are easily altered after installation. Experience with Multifones has been that executives are primarily concerned with the basic elements of their requirements before installation. Efforts to specify further refinements, for example the types of audible signalling described below, are only partially successful. Once the installation is in use however these minor details become more significant and the choices available are better appreciated.

Line Connection: The operation of a non-locking line key connects the Multifone to that particular line. A steady lamp in the line key indicates which line is connected.

Types of Lines: A Multifone can accommodate exchange, PABX, PMBX. and Intercom lines. The PMBX line features lock up signalling which causes a sustained signal at the Multifone in response to an incoming burst of ring from a switchboard. This signal automatically cancels if not answered within 60-90 seconds.

A Multifone can be interconnected with other items of equipment including a single telephone, Two Line Telephone, Three Line Telephone, or another Multifone to produce the various types of filtered and direct line facilities required.

Incoming Calls: An interrupted buzzer together with a flashing lamp in the particular line key indicate an incoming call.

Audible Signal: Multifone subscribers demand a range of buzzer signals for use on different types of line. Each Multifone can be readily adjusted to suit particular requirements using one of the following three types of audible alarm on each line.

Type 1: Direct Buzzer: The buzzer operates whenever an incoming call occurs even when the handset is removed. This facility is used to draw attention to important lines.

Type 2: Handset Cut-off: Lifting the handset cuts off the buzzer signal. This ensures that incoming calls do not intrude audibly on a call in progress. A flashing line lamp is the sole indication of an incoming call when the handset is lifted.

Type 3: Special Cut-off Feature: This is essentially the Type 2 facility with an additional facility which enables the buzzer to be cut-off with the handset in the normal position. This facility together with the Automatic Transfer facility detailed below, can be usefully employed by executives who require to silence selected lines when, for example, they are in conference.

Automatic Transfer of Incoming Signalling: The requirement to transfer incoming signalling between the executive and the secretary has already been outlined. The basis of provision of this facility in the Multifone is an automatic transfer if the call is not answered within a preset delay period. The delay period is readily adjustable between 10 and 30 seconds and most executives select a delay of the order of 12 seconds.

Key operation was rejected as the primary method of achieving transfer because past experience indicated that inevitably there is a failure to operate or restore keys which leads to misdirected calls. Many subscribers provided with Key Transfer facilities have expressed dissatisfaction with them. The delayed automatic transfer appears to be a most effective method of minimizing lost calls and has been the subject of much favourable subscriber comment.

Key Transfer of Incoming Signalling: The disadvantage of delay methods of transfer is the additional length of time which the caller must wait before receiving an answer. Optional Key Transfer facilities are available on the Multifone which eliminate this delay and effect immediate transfer under certain conditions. These facilities supplement rather than replace the Automatic Transfer feature discussed above.

Temporary Transfer can be provided using a non-locking key at the executive's position which, when operated, effects immediate transfer of any call signalling on the Multifone. Subsequent calls are not affected and signal in the normal manner.

Permanent Transfer can be provided using a locking key at either the executive's or the secretary's positions which, when operated, permanently operates the transfer facility.

This type of facility can be usefully employed if either executive or secretary are absent from the office for long periods.

Hold: This feature enables calls to be held while calls on other lines are dealt with. Any number of lines can be held in this manner and reconnected to the Multifone as required. A single common hold key provides this feature and a fast pulsing line lamp draws attention to held lines.

Unit Line: One line on the Multifone, designated the Unit Line, can if required be arranged to connect to the Multifone by lifting the handset. No key operation is required to connect to this line and in effect the Multifone behaves like a simple telephone connected to the Unit Line. The selection of a line on which there is a high incoming or outgoing traffic as the Unit Line can lead to a considerable reduction in operator effort. To connect to some other line when the Multifone is not in use it is necessary to preselect by operating the required line key and then lifting the handset. This avoids any unnecessary connections to the Unit Line.

The Unit Line facility is widely used and has proved extremely popular with Multifone subscribers.

Power Fail: If the power to the Multifone should fail one selected line can be arranged to connect automatically to the Multifone to provide a limited service.

Automatic Release: Ease of operation is a major requirement of units designed for modern executive-secretarial situations. Automatic release of facilities has been used in the Multifone to effect large reductions in the number of operations required of the Multifone user. Some examples of this are as follows:—

Release of Line Connection: The operation of a second line key automatically releases an existing line connection and effects the new connection.

Release of Hold Condition: To reconnect to a line which has been held the line key is operated. This effects the connection and automatically releases the Hold condition.

Handset Release: All line connections and held lines are automatically released when the handset is restored.

Release of Preselected Lines: A line which is accidentally pre-selected is automatically released after about 60 seconds if the handset is not lifted.

TYPICAL MULTIPHONE INSTALLATIONS

Three representative types of installation will be considered:—

Type 1: Lines Shared Between a Number of Executives: This group deals with the installations where calls on a particular line are required to be switched to a number of executives.

Type 2 and 3: Lines Used Exclusively by Particular Executives: This group deals with installations where calls on a particular line are only required to be switched to one particular executive. *Type 2* is for situations where the executive requires up to two lines, and *Type 3* for those where the executive requires more than two lines.

Fig. 11 — Type 2 Multifone Installation — A Secretary provided with a Plinth Unit.

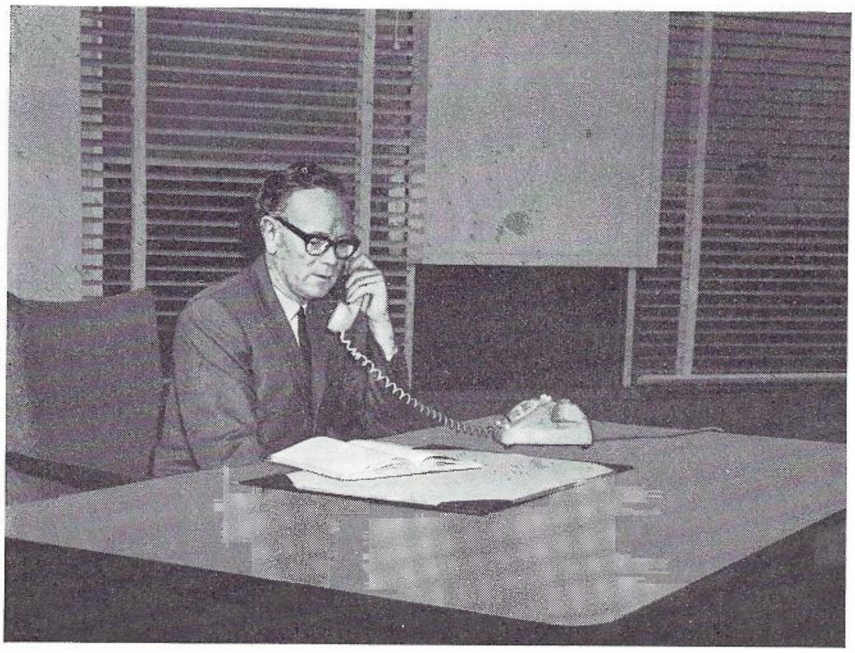

Fig. 12 — Type 2 Multifone Installation — an Executive provided with a Two Line Telephone (modified).

Type 1 Installation

This type of Multifone is still in the developmental stages. Although three prototype units have been installed little information is available concerning the demand for this device. It is mentioned here because it represents a logical extension of the Multifone into an area where standard equipment appears inadequate.

This type of installation involves the operation of a number of Key Units in multiple. Other Multifone features such as Automatic Transfer Unit Line and Common Hold are also provided on this device. A simple single channel, dial activated intercom system has been developed to link the points on this system.

Type 2 Installation

Equipment: Executives connected to this type of Multifone can be provided with a telephone or Two Line Telephone which is modified by the addition of a pushbutton and lamp to terminate a filtered line (Line B or C below). The "Modified Telephone" and the "Modified Two Line Telephone" mentioned later refer to these devices. This equipment combined with a Multifone for the secretary provides a most comprehensive range of telephone facilities for this class of executive.

A typical executive-secretarial situation of this type is shown in Figs. 11 and 12, both these items of equipment blend effectively into the modern office setting.

Types of Line: All types of line available are illustrated in Fig. 13. In actual installations the secretary's Multifone can contain any number and any combination of the line types illustrated.

Line A: This is a direct line to the Executive with automatic transfer of calls to the secretary when the executive is unavailable. The temporary transfer facility discussed earlier is often provided.

Line B: This line enables the secretary to filter calls to an executive. The facility provided is similar to the Intermediate Telephone which was discussed earlier with the followng significant differences:—

(i) The executive can gain access to the line by lifting the handset. It is not necessary to contact the secretary as is the case with the Intermediate Telephone.

(ii) Simultaneous connection to the line by executive and secretary is not possible with the Multifone. Whichever point is connected to the line is given priority and guard lamps indicate that the line is unavailable to the other point. The Intermediate Telephone can be strapped to either provide simultaneous connection or to ensure that it cannot occur.

(iii) The Multifone automatic transfer facility enables calls unanswered by

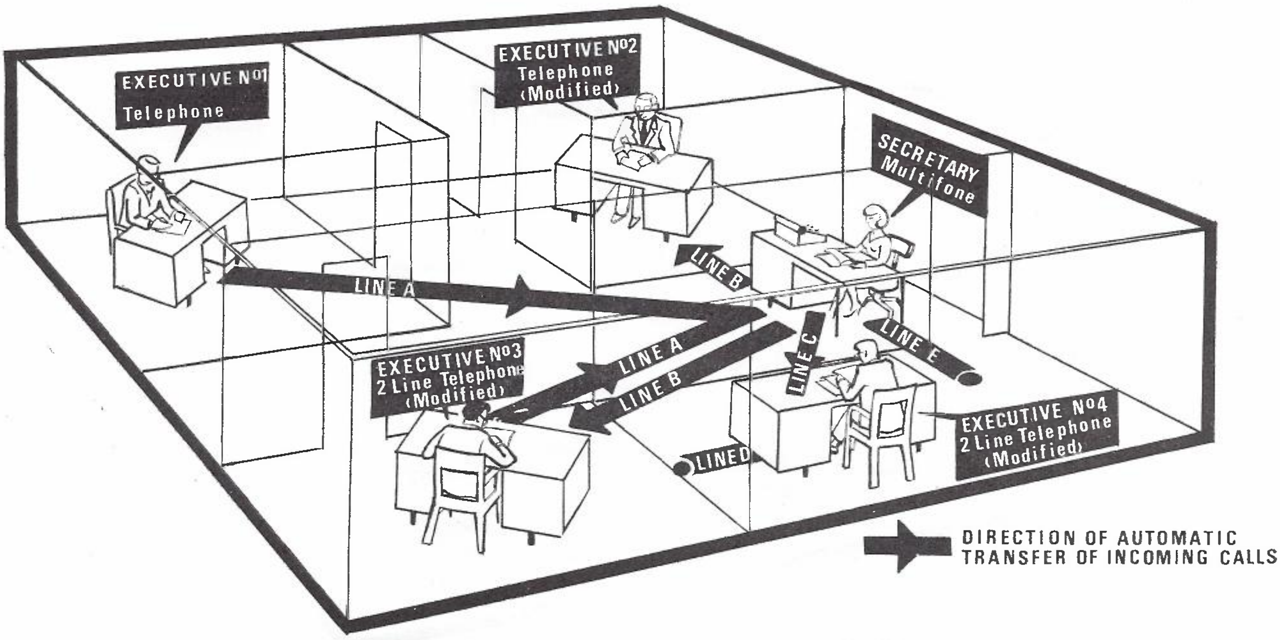

Fig. 13 — Type 2 Multifone Installation — Typical Facilities.

the secretary to transfer to the executive. A manual switching operation is required to accomplish this with the Intermediate Telephone.

(iv) The secretary with an Intermediate Telephone is limited to one line termination. No such limitation exists with the Multifone, and in a typical installation the secretary requires a personal line and in addition filters calls on three lines to three executives.

Line C: This is similar to Line B. The transfer facility is modified in this case by the addition of an optional filter facility. A key at the executive's unit controls both the first point of signal and the direction of Automatic Transfer of incoming calls.

From the point of view of incoming signalling this line behaves as Line A in one position and Line B in the other position of the key. In either arrangement the Intercom facility incorporated in Line B is available.

Line D: This is a direct line to the executive with no transfer facility to the secretary. Either this line is used only for outgoing calls or interception of incoming calls by the secretary when the executive is unavailable is not required.

Line E: This is a direct line to the secretary. This is usually the Unit Line on the Multifone.

Type 3 Installation

Equipment: The executive and in most cases the secretary are provided with a Multifone. The Console or Drawer type of Key Unit is most frequently used in this type of installation. (See Fig. 14.)

Types of Line: All types of line available are illustrated in Fig. 15. Actual installations can contain any number and any combination of the line types illustrated.

Fig. 14 — Type 3 Multifone Installation — an Executive provided with a Console Key Unit.

Line E: This is the secretary's Direct line, and is usually the Unit line of the secretary's Multifone or Three Line Telephone.

Lines F and G: These can be Exchange, PABX or PMBX lines. Calls on Line F are answered by the secretary and filtered to the executive. Line G is a direct line to the executive. These lines appear at both the executive's and the secretary's positions and Automatic Transfer operates in the direction indicated by the arrows. If required, privacy of line connection is provided by giving the executve priority over the line. Guard lamps in the appropriate line keys indicate lines in use on the other unit.

A line connected to one unit can be transferred to the other by holding it and contacting the other unit using the executive-secretary Intercom line (Line H). The line is taken at the second unit by the operation of the appropriate line key. The Hold condition on the first

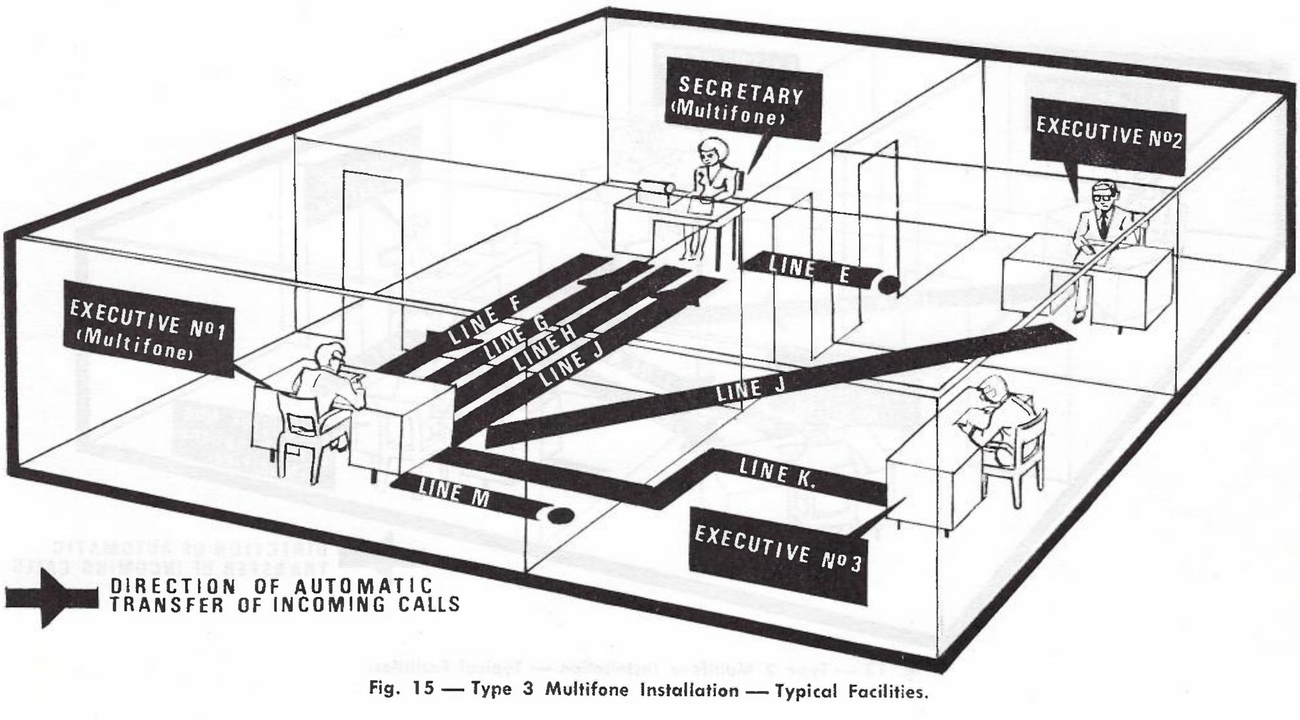

Fig. 15 — Type 3 Multifone Installation — Typical Facilities.

unit is automatically released by this operation.

Line H: This is an Intercom line between executive and secretary.

Line J: This is an Intercom line to Executive No. 2. Multifone intercom lines can terminate at the distant end on a wide range of devices including Two Line Telephones, Three Line Telephones, Multifones and many other special types of units.

Calls from Executive No. 2 are automatically transferred to the secretary if Executive No. 1 is unavailable. Where Executive No. 2 directs the activities of Executive No. 1 it is common for Executive No. 2 to require some answer on the intercom line irrespective of the availability of Executive No. 1.

Line K: This is an Intercom line to Executive No. 3. Unlike Line J, calls on this line cannot be taken by the secretary. Either Executive No. 3 does not warrent an answer when Executive No. 1 is unavailable or Executive No. 3 is unable to call Executive No. 1 on this line. This restriction to "one-way" signalling is often employed by executives who require to restrict incoming traffic, but require intercom facilities giving direct access down to various areas under their control.

Line M: This is a direct line to the executive which does not appear at the secretary's unit. Either this line is used for outgoing calls only or incoming calls do not warrent interception by the secretary when the executive is unavailable.

MULTIPHONE PRODUCTION

The Multifone development had two essential objectives:—

(i) To provide a unit with sufficient flexibility to cover a wide range of subscriber requirements.

(ii) To devise a method of construction which would minimize special production and design effort and lead to minimum production delays.

In order to achieve (ii) above, a modular form of construction was adopted which incorporated a minimum number of basic units which combine to produce a Multifone. These basic units include Key Units, Rack, and Relay Modules, and can all be manufactured using reasonable production runs and held in stock without any knowledge of specific subscriber requirements. On receipt of an actual order, these basic units are assembled to produce the required Multifone. This approach to production removes most of the critical delay factors to the period prior to the placement of an order by the subscriber. Experience to date indicates that the assembly and testing functions can be performed within five weeks of receiving an order. This represents a considerable improvement over the 6-12 month design and production delays experienced with earlier custom built units which aimed to satisfy similar requirements.

Relay Modules

Multifone facilities are provided by relay modules which mount on the Rack. The main types of module are as follows:—

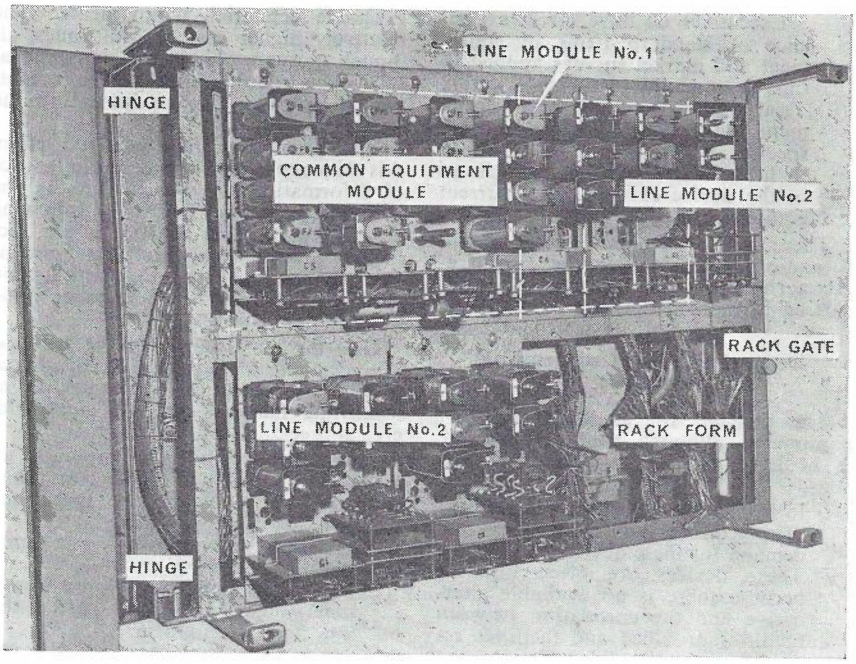

Fig. 16 — The Multifone Equipment Rack — showing the mounting of various Modules,

Common Equipment Module: This module provides facilities common to groups of lines. One common equipment module is provided on each rack in the position shown in Fig 16. Typical facilities which involve this module are, Intercom, Automatic Transfer, Hold, Unit Line, Power Fail, and the provision of fast and slow pulsing lamp signals.

Line Modules: One line module is provided for each line. Three types of line modules are used in the Multifone.

Line Module 1: Provides a general purpose line termination which can handle all types of line (except lines B or C outlined for Type 2 Installations).

Line Module 2: Provides the Filtered Line facility; lines B or C outlined for Type 2 Installations.

Line Module 3: Provides three intercom lines.

Most of the flexibility of the Multifone is achieved by individual strapping on each line module. This is performed on the lower terminal block at the rear of the module.

A Line Module 1 is illustrated in Fig. 17. Plug and socket connection of Line Modules is a recent refinement to facilitate maintenance and testing procedures.

The various Relay Modules mount on the Equipment Rack, a typical assembly is illustrated in Fig. 16. The modules terminate on the Rack "wiring form" and mount on a "gate" which swings open to gain access to the line terminations and the plug and socket connection to the Key Unit.

MEASUREMENT OF DEMAND

Information on the demand for executive-secretarial equipment is required to establish overall production figures and also to facilitate both the physcial and facility aspects of the design of new equipment.

Two techniques can be used to measure this type of demand situation:—

(i) Some form of "Market Survey" of executive-secretarial situations. The difficulty with this technique is that executives often do not posses direct experience of the facilities to be discussed. For this reason it is difficult to assess more than an outline of facility requirements.

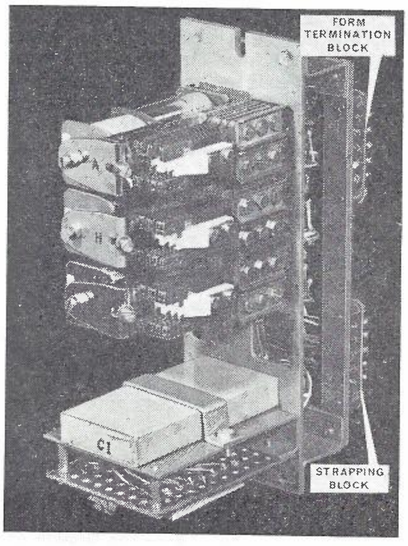

Fig. 17 — The Multifone Line Module.

Executives do have direct experience of standard items of equipment and market surveys applied in this area would yield more detail.

(ii) Trial installations of new equipment and facilities can lead to more specific information and is useful in fields where no close substitutes to the device exist amongst current equipment.

There are two main sources of information on demand in the executive-secretarial field and these are now considered in more detail:—

Demand For Standard Items of Equipment

The demand for standard items of equipment, although well documented, is of little use for the following reasons:—

(i) It is difficult to separate executive-secretarial demand from the total demand for these devices.

(ii) These devices are often installed because there is no available alternative and the correlation between facilities provided and facilities required is poor. For example the high demand for Intermedate Telephones cannot be interpreted to mean that:—

(a) Executives do not require better transfer facilities and more direct access to the line.

(b) Secretaries are satisfied with three or four instruments on their desks.

Demand For Multifones

This is an example of the trial installation technique discussed above, where the flexibility of the Multifone leads to a good correlation between facilities provided and actual requirements.

The difficulty in using Multifone data is that executives selected are unlikely to be representative of the whole executive-secretarial field. It is not proved necessary to "sell" Multifones to subscribers at this stage. All available production has been absorbed by subscribers on their own initiative requesting improved facilities or by subscribers obtaining new PABX units reviewing their executive-secretarial requirements. The relatively higher cost of Multifones, although not an observable deterrent at this stage, would inhibit some executives from using this equipment in the long run.

Notwithstanding the above restriction, this data represents a most useful source of information on requirements in the executive-secretarial field. The following details represent an analysis of the facilities provided using Multifone systems over the period from the introduction of the Multifone in September 1964 until March, 1966.

Growth of Orders for Multifones: The demand for Multifones, illustrated in Fig. 18, appears to be expanding as Multifone facilities become more widely appreciated by executives.

Costs: The flexibility incorporated in the Multifone leads to higher costs when compared with the more specialised standard items of equipment.

The Multifone subscriber is required to meet the following costs:—

(i) The installation costs of the Multifone system, but not the cost of the Multifone equipment.

(ii) An annual rental based on the type and number of lines connected to the system.

The rising demand for Multifones indicates that at least a significant portion of executives are less concerned with the cost of telephone equipment than with obtaining sophisticated facilities tailored to their specific requirements. The high value attached to executive time means that a telephone system capable of achieving reasonable savings in time and efficiency can command high rentals.

Executive Line Requirements: The Exchange PABX and PMBX line requirements of executives are often significant when assessing the usefulness of various items of equipment in this field. The relative usefulness of Intercom Systems 1/2 and 1/3 described earlier is an example. This information has been extracted for all executives connected to Multifone systems and is shown in Fig. 19. Executives are fairly evenly divided between a one line and a two line requirement.

The recent advent of a presentable two line device in the form of the Two Line Telephone would tend to release a suppressed demand for two lines but probably has not had sufficient time to achieve this yet.

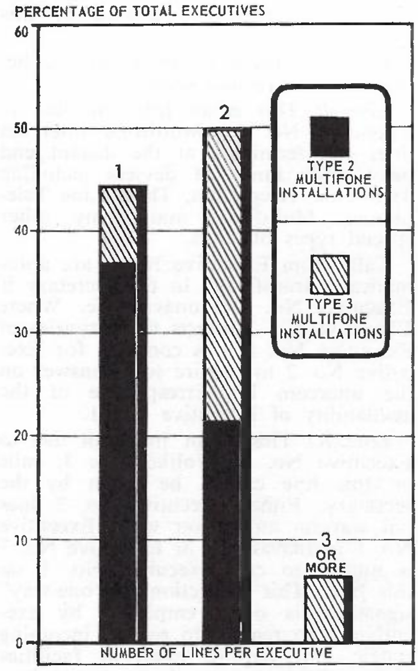

Fig. 19 — Executive Line Requirements — the Exchange, PABX, or PMBX, line requirements of Executives connected to Multifone systems.

Executive-Secretarial Situations:— The number of executives per secretary in all executive-secretarial situations provided with Multifone systems is analysed in Fig. 20. The typical Type 2

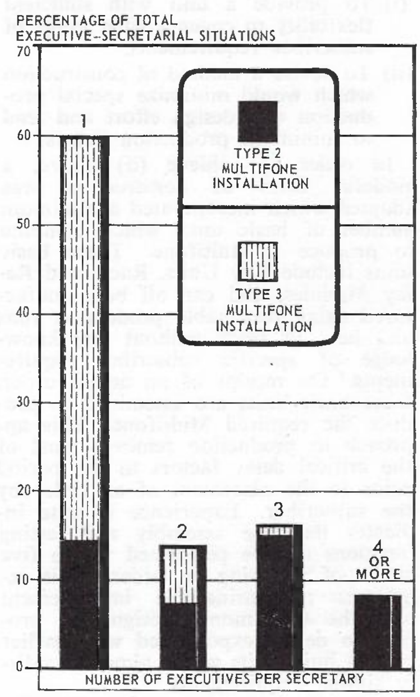

Fig. 20 — The Number of Executives per Secretary in Multifone Executive-Secretarial Situations.

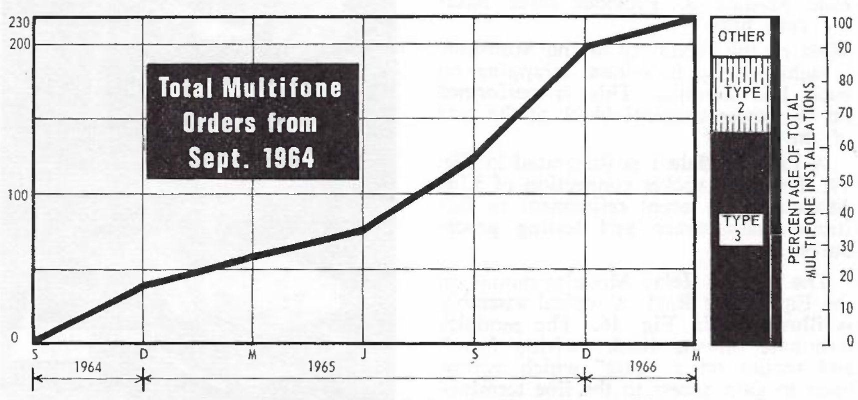

Fig. 18 — The Growth of Orders for Multifone Installation. the Rack form and the Rack gate.

installation involved three executives. This is in line with a trend discernible in a number of organisations towards the sharing of secretarial services among executives.

FACILITY SELECTION

The design of substation telephone equipment entails a selection of facilities to be provided in a particular device. Certain "basic" facilities will be easily selected but the number of additional or marginal facilities to be added to the basic requirements is often difficult to establish.

In general, the addition of a marginal facility will:

(i) **Increase** the user satisfaction of those who judge the new facility to be worth the additional costs involved.

(ii) **Decrease** the user satisfaction of those who do not require the facility or feel it to be too costly. Where the facility provision remains optional and the costs are directed at those who use the facility, this decrease in satisfaction will not occur.

A net increase in satisfaction would seem to justify the inclusion of the facility. In general, the maximization of user satisfaction seems the most logical design approach for adoption in a public utility.

The measurement of user satisfaction is complex and refined market techniques are required to make facility selections in this manner. Lack of such information leads to a reluctance to incorporate additional facilities which involve significant cost increases. Marginal facilities rejected because they involve significant cost increases may well be justified if net user satisfaction were considered since the satisfaction created by the facility may exceed the dissatisfaction associated with the increased costs.

Lack of detailed market information can lead to a minimum cost approach to facility design which results in non-optimum facility provision. This effect is most marked where the effect of cost on user satisfaction is small. Although costs may dominate facility selection in other fields, experience with Multifone installations suggests that costs may not be the major factor in the executive-secretarial field. There are strong grounds for believing that the user satisfaction generated by a number of items of standard equipment used in the executive-secretarial field could be improved by the addition of some new facilities.

CONCLUSION

Although the demand for telephone equipment in the executive-secretarial field is relatively small and varied, it represents a significant and largely unsatisfied demand by an important class of subscriber. Many items of standard equipment are being modernized but none is intended to meet executive-secretarial requirements. Two different but complementary approaches are required to meet this type of demand.

(i) To develop specific items of equipment to meet the high demand requirements.

(ii) To develop a flexible unit capable of meeting a wide range of demands.

The A.P.O. has commenced the development of an Executive System designed specifically for the executive-secretarial field and the new Intercom System 1/2 is the first of these.

In the meantime the Multifone, developed and used in Victoria provides a useful interim solution.

ACKNOWLEDGMENTS

Various staff of the Substation Installation Section, Melbourne, in particular, Mr. R. Jones, Supervising Technician, made valuable contributions to the Victorian equipment developments outlined. The quality of these devices is a tribute to the abilities of the Melbourne Postal Workshops, which produced the units, and assisted in the design, in particular, in the mechanical field. The co-operation of the Subscribers Equipment Section, Central Administration, in supplying details of new equipment developments is greatly appreciated. Lastly, the author wishes to recognize the considerable contribution to these developments made by Mr. N. A. Cameron, Engineer, Class 3, Substation Installation, and to thank him for his advice on the preparation of this article.

TECHNICAL NEWS ITEM

THE AUTOMATIC TELEPHONE TRAFFIC RECORDING SYSTEM

The Australian telephone network is in the midst of a phase of rapid expansion in size and complexity. At present, there are approximately 2 million subscribers services connected to some 7,000 exchanges, and growth is such that the number of subscribers will double over the next 10-12 years. Trunk line traffic is growing at an even faster rate and the Department's trunk line network will need to be duplicated over the next 7-8 years.

At the same time, the complexity of the network is rapidly increasing as departmental objectives of nation-wide automatic service are progressively implemented. The use of a common control crossbar switching system for both local and trunk automatic services offers great flexibility in network design but demands a new range of comprehensive traffic information if these networks are to be designed to optimise traffic dispersal and thereby minimize the enormous costs in meeting the growth ahead.

Until recently, traffic information for service surveillance and future planning has been obtained from small samples of data collected and processed manually; but this is no longer adequate. Larger samples are needed and because of the high cost and shortage of labour, automatic data processing is the only feasible method. The Australian Post Office has consequently embarked upon a project to develop a fully automatic traffic data collection and processing system. The system will record a sample of some 5,000 calls per hour during the busy period of an exchange. The data, which will be recorded in computer legible form, will consist of the destination exchange code, the route taken by the call, and the call duration. The data will be processed, using an electronic computer to produce traffic occupancy and traffic dispersion measurements.

Two methods of recording are under consideration — paper tape and incremental magnetic tape. Paper tape is a considerably slower computer input medium and has the additional disadvantage that the recording medium cannot be re-used. Incremental magnetic tape recording is initially more expensive but running costs are lower since magnetic tapes can be re-used. In addition, they have a higher recording speed — a great advantage when data sources are being queued to use the recorder.

System design is at an advanced stage and prototype recording units have been developed for use with local crossbar exchanges. When completed, the system will provide an efficient basis for network traffic surveillance and for production of the basic planning information which is essential to ensure the efficient and orderly growth of the Australian telephone network.

SERVICE ASSESSMENT FOR CROSSBAR EXCHANGES

*J. W. SPRATT, B.E.**

INTRODUCTION

In a large automatic telephone network, it is essential for the telephone administration to be able to assess the quality of service being given to subscribers. The most direct method of doing this is to sample what is in effect the finished product of the telephone switching machine, that is, the ability of subscribers to correctly establish calls and conduct conversations that are satisfactory from the transmission view point. This assessment is best made by the use of trained operators carrying out service assessments on live telephone calls. This method is the most fundamental indicator of service quality because it checks overall performance as seen by the user. It also takes into account the incidence of defects such as cut-offs, poor transmission and wrong numbers, due to faults in subscribers' equipment and internal and external plant equipment. This particular technique is used by most major telephone administrations throughout the world.

There are other indicators of service quality used by the Australian Post Office and other telephone administrations, for example, traffic route testing which is used a great deal now by the A.P.O. However, whilst the percentage failure of test calls generated by traffic route testers provides a very useful indicator of the performance of a particular traffic route, it does not necessarily reflect the precise service experience of the subscriber. Another indicator of service quality is the incidence of trouble reports received from subscribers concerning the telephone servce. The A.P.O. analyses subscriber trouble reports to determine and locate network defects and is investigating the use of trouble report statistics to determine subscriber satisfaction with the service. Because of the subjective nature of such statistics they can never be regarded as a replacement for service assessment results, but rather as another complementary indicator of service performance.

Looking more closely at the question of performing service assessments by operators it is necessary to determine what information is required, and how it is to be obtained. Information on the following items is required:—

(i) That the caller waits for and receives dial tone.
(ii) That the caller dials an actual number.
(iii) That the caller hears ring tone.
(iv) That the call matures effectively.
(v) That correct metering of the call takes place, particularly on subscriber dialled calls.
(vi) That the call is free from noise and interference.
(vii) That congestion or malfunctions are not present.
(viii) That telephone directory instructions are clear and precise, and that the subscribers are aware of these instructions.

Equipment supplying the operator with this information, should possess the following features:—

(i) Have a negligible effect on the signalling and supervisory conditions of the call being assessed.
(ii) Provide access to all local calls and calls via all important switching devices.
(iii) Provide access to calls being switched to all destinations accessible to subscribers.

To do this a service assessment system requires three basic parts:—

(i) Sampling equipment to connect a call to,
(ii) junction signalling equipment which conveys the required information over a junction to,
(iii) display equipment.

The fundamental conception and principle of service assessment equipment has not changed over recent years, in that basically the operator is given high impedance access to live traffic with the facility of having displayed on a digit display, information such as, number being called, metering signal, time of call, etc. The display equipment itself has been modernised and improved with the introduction of a more direct reading read-out device, also there have been improvements to the access circuits as outlined in the next paragraph. It has also been necessary to make improvements to the repetition of impulsing signals from the originating exchange to the assessment centre. This latter requirement has been met by the use of high impedance transistorised access circuits which repeat the dialled impulses over a junction employing single commutation direct current signalling or other suitable techniques.

Formerly sampling was effected at the subscribers' line equipment, but because of the difficulty in obtaining suffcient traffic for the operator, and the need for frequent re-jumpering, this method was later changed to sampling step by step group selectors. Initially one selector was associated with each sampling circuit; a later extension provided for an access switch to be associated with each sampling circuit, thus giving each sampling circuit access to a large number of selectors.

THE DISPLAY UNIT

Essentially the display unit reproduces in audible and visual form the various electrical control signals. As a first requirement the display must reproduce the signals accurately, and secondly, the display should be convenient. In this regard the visual indicators and keys should be grouped together in the direct line of sight of the operator. The in-line numerical display is favoured, and the keys are arranged in a corresponding manner.

The choice of the numerical indicating device to be used should be carefully considered. The one chosen will depend on the following factors:—

Ease of read-out
Ease of mounting
Space available for mounting
Operating voltage
Maintenance.

Many such devices are now available. A projection type indicator uses 12 lamps each throwing a narrow beam of light through a transparent number, to project a number on a translucent screen and is suitable for operation by normal exchange voltages. A cold cathode indicator uses ten numerals as cathodes, and application of negative potential to a particular cathode causes a glow discharge to emanate from the corresponding numeral. These tubes require a typical operating voltage of 180 volts D.C. Other types include an edge lit projection tube, and those using the new and important technique known as electroluminescence. Electro-mechanical type read-out devices are also available.

The display unit is fitted to a suitable desk, so as to permit ease of working by the operator. A photograph of a typical 2-position service assessment suite with control panel and structural details is shown in Fig. 1.

SERVICE ASSESSMENTS AT THE SR RELAY SET

When the L. M. Ericsson Crossbar system was introduced to Australia, service assessment equipment of L.M.E. design usually referred to as RKR or Reg. (Register) K observation, was installed and tried in the early installations. However, this equipment does not meet all the A.P.O.'s requirements. Firstly, only calls handled by a pre-determined register are sampled, as the register is a key item of equipment, more reliable service assessment would result if calls on all registers could be sampled. Secondly, the RKR equipment gives no metering indications. The A.P.O. has always depended on service assessment equipment to check that the metering system is basically reliable and this is most important, particularly on S.T.D. sampling. For these and other reasons, steps were taken to develop suitable service assessment equipment for the crossbar system. Accordingly, it was decided that service assessments at the SR relay set should meet the needs of the A.P.O. On this basis a prototype SR service assessment installation was planned for the then proposed new Goulburn crossbar exchange.

Sampling Arrangements

The criteria for determining the correct sampling arrangements are that the rate at which calls are sampled is a maximum, and that all subscribers and

* Mr. Spratt is Engineer, Class 2, Long Line and Country Installation, New South Wales.

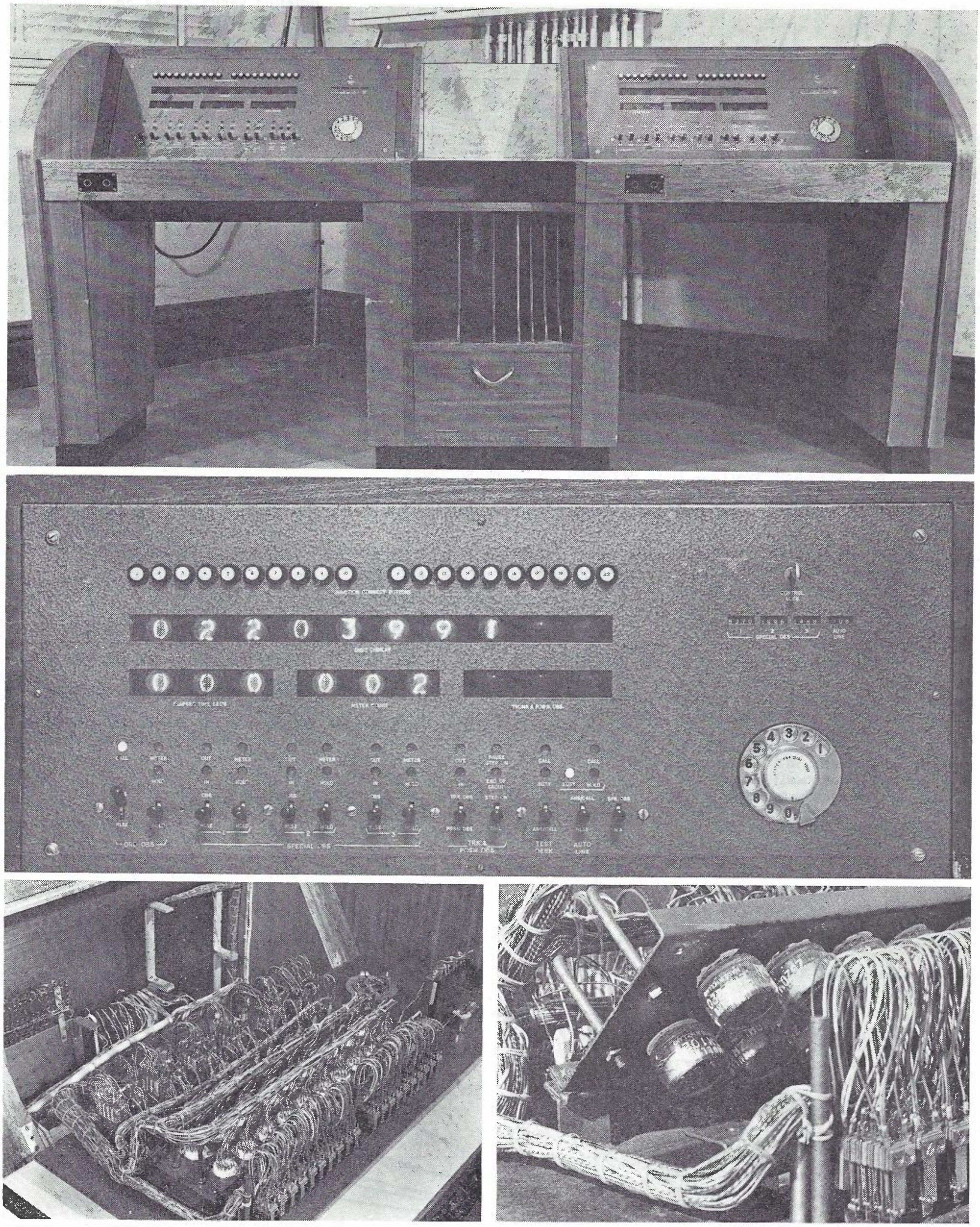

Fig. 1 — The Display Unit. Top: 2 Position Service Assessment Suite. Centre: Service Assessment Desk Control Panel. Bottom Left: Mounting Details for Cold Cathode Numerical Indicator Tubes. Bottom Right: Rear View of Control Panel.

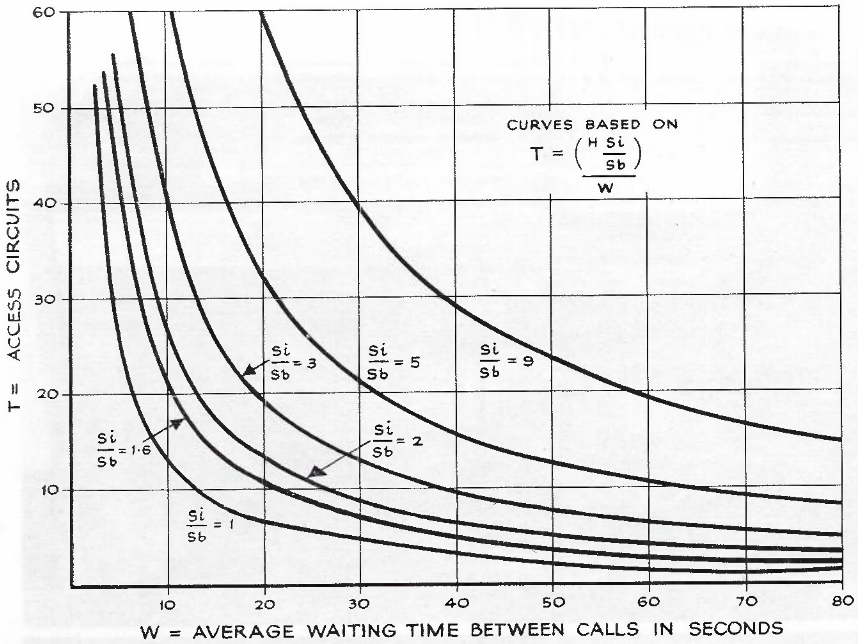

Fig. 2 — Curves Showing Relationship Between Number of Access Circuits and Operator Waiting Time Between Calls.

registers are sampled. These criteria are dependent on several factors, namely:—

(i) The correct SR's are selected for sampling.

(ii) A sufficient number of sampling circuits are provided.

(iii) The SR's carry sufficient traffic.

With regard to (i) three SR's in any thousand line group can be selected which give access to all thousand numbers, although five SR's are the minimum number which will give balanced access. In addition, the fifth SR in each row (the 5th SLB vertical) is not used as it is a last choice device, and hence would lower the sampling rate. Considering (ii), it is found that the rate of increase at which SR's are sampled suffers an exponential decline as the number of sampling circuits increases. (See Fig. 3.) Finally considering (iii) it is apparent that the greater the traffic carried by the SR's the greater will be the sampling rate.

Service Assessment Dimensioning Diagrams

From formulae derived in Appendix I, various service assessment dimensioning diagrams have been prepared.

Fig. 2 shows the relationship between the number of access circuits and the operator waiting time between calls. for various values of the ratio idle SR's to busy SR's (Si/Sb) hereinafter referred to as the "SR Ratio". For Fig. 2, a figure of 130 seconds for average SR holding time is assumed. The number of access circuits shown are the number that are free. In other words, if access equipment other than pre-selector type is being considered, then allowance has to be made for the number of access circuits associated with busy SR's. Curves for relay type access circuits can be similarly prepared. These curves clearly show how the improvement in operator waiting time falls off as the number of access circuits is increased. This points to an upper limit for the number of access circuits to be provided in those cases where the SR Ratio to be expected during service assessments is known. The smaller the SR Ratio the smaller is the waiting time; the waiting time of the operator is also reduced as the SR holding time is reduced.

Fig. 3 shows the relationship between the number of access circuits and the number of calls sampled per hour for differing values of the SR Ratio and a given set of parameters. These are:—

Average holding time effective calls He = 130 secs.

Average service assessment holding time of calls sampled to maturity Hm = 24 secs.

Average service assessment holding time of all ineffective calls Hi = 25 secs.

In addition, it has been assumed that every 10th call is sampled to completion, and that 20% of all calls are ineffective for various reasons.

For example, from the diagram it can be seen that with 30 access circuits and an SR Ratio of 2 to 1, 79 calls could be campled per hour. Or putting it another way, if 10 access circuits yielded 57 calls per hour then by increasing the access circuits to 30, the sampling could be increased to 79 per hour.

In practice other factors can determine the number of access circuits used, such as the number of access circuits pre-wired on a relay set base. However, it is important that a compromise be obtained between:—

(i) The minimum number of access circuits—as this limits installation effort, jumpering and re-arrangement effort, and

(ii) effective utilisation of operators.

OUTLINE OF SYSTEM

This service assessment system consists of three main parts, the access equipment at the sampled exchange, the junction equipment linking the sampled exchange with the sampling exchange, and the sampling exchange equipment associated with the service assessment

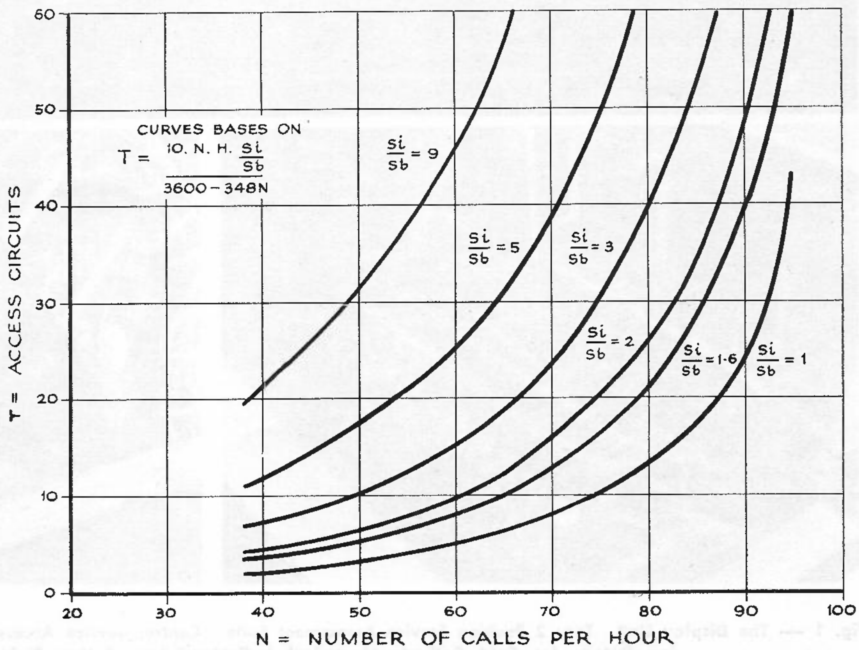

Fig. 3 — Curves Showing Relationship Between Number of Access Circuits and Number of Calls, Sampled per Hour.

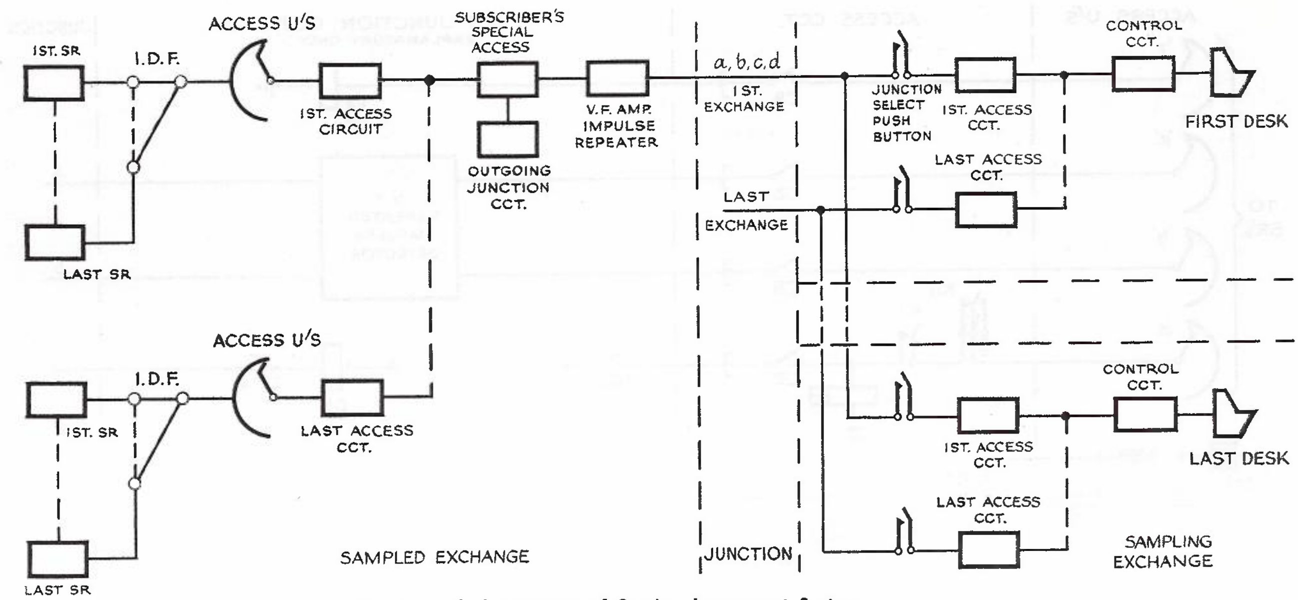

Fig. 4 — Block Diagram of Service Assessment System.

desk. The following description applies to the block diagram in Fig. 4.

In this system a crossbar, or step by step exchange, or a combination of both, can be sampled simultaneously. The service assessment suite can consist of any number of desks. The junctions incoming from the distant exchanges can be connected to any desk or multipled over any combination of desks. As all incoming junctions terminate on access circuits on each desk any operator is able to sit on any combination of junctions that appear on the desk.

To commence sampling the operator pushes on the buttons of the exchanges to be sampled. These buttons have an inbuilt lamp, and this lamp glows steadily in the buttons multipled on other desks to warn the other operators not to use the junction. The push button sets the associated desk access circuits in a "ready to receive call" condition, and also sends a start signal over the junction to commence operation of the access circuits at the sampled exchange.

The access circuit for both step by step and crossbar exchanges employs the same principle, but only the crossbar case will be discussed here. A number of access circuits* can be provided, each consisting of an access uniselector and controlling relays. The uniselectors normally stand on a free SR, and when an access circuit is picked up by an SR becoming busy, the remaining access circuits are put into a pre-selecting condition, during which they will step off busy SR's and continually select free SR's. When an access circuit is engaged a pick-up signal is sent to the service assessment desk, where the access circuit associated with that junction is engaged and the desk is readied to receive a call. As soon as this desk access circuit operates it prevents all other access circuits on that desk from receiving calls.

* Access uniselectors have been dispensed with, in newly developed relay type tapping circuits.

At this stage a common call lamp lights, and the lamp in the push button flashes telling the operator which junction is calling.

At the sampled exchange a transistorised impulse repeater and speech amplifier relays the appropriate information over the junction to the desk. A visual display indicates elapsed time in seconds from the commencement of the call, the number of meter pulses received and the digits dialled. The combination of elapsed time and meter counter is a big improvement over earlier designs, as it facilitates meter checking on S.T.D. calls.

Release by the operator can be effected during or after a call. If release is effected during a call the access uniselector steps on and the complete circuit is free for further use. If the caller clears first then the connection to his line circuit is retained, and all his follow-on calls can be sampled until the circuit is released by the operator. In addition, a "caller hung up" lamp on the desk indicates to the operator that the caller has hung up as distinct from the lock-out condition.

The system also provides for special subscribers' service sampling. At the sampled exchange a subscriber's access circuit is used which shares the junction with the SR access equipment. At the sampling exchange a number of special subscriber's position circuits are provided on each desk, and the junction can be connected to any position circuit. The special subscriber's service assessment circuit always takes precedence over an SR sampling call, and should a call originate from a special subscriber under service assessment then the SR access circuit at that exchange is released, the junction to the desk is re-seized and the display on the desk is immediately cleared so as to prepare for the receipt of the special subscriber's signals. The facilities for the display and release of the call are identical with those for SR service assessments.

CIRCUIT DESCRIPTION

This circuit description has been divided into three main parts namely, the access equipment, the junction equipment and the desk equipment. The circuit operation of each part is described independently of the other, except where a knowledge of the circuit operation in another part is desirable.

The Access Circuit (Fig. 5)

Assuming that all access uni-selectors are standing on free SR relay sets, and that the desk is free, the ground on the 'd' wire of an SR causes pick-up to occur. Relay C operates to ground on the 'd' wire and contact C1 operates CA on its ab winding via contact CNA 3 normally operated to 200 ohm battery. Relay CA operates CB (not shown) to switch 4 wires to the outgoing junction circuit, and operates relay DC at contact CA2. Contact DC6 open circuits the operate winding of relay CA and completes a holding circuit for relay CA via coil de. The holding circuit of relay CA is via a CA3 contact tree, and this ensures that only one CA relay can hold, by disconnecting the operating battery at contact DC6, thus eliminating coupling of SR's due to simultaneous seizures. Contact DC4 sends a pick-up signal to the service assessment desk.

Whilst one access circuit is in use the remaining access uni-selectors will step off busy SR's. Relay C operates on pick-up and the uniselector gets drive from ground at contact C1, CA5 normal (CA cannot operate due to CNA3 released), drive magnet to battery at DM.

Release by the operator is effected during the call by the operation of relay DN. Relay DN releases relay DC, which in turn releases relay CA at contact DC6, and the drive circuit for the switch is completed to cause the switch to drive to the next free outlet. This drive does not occur when release by the oper-

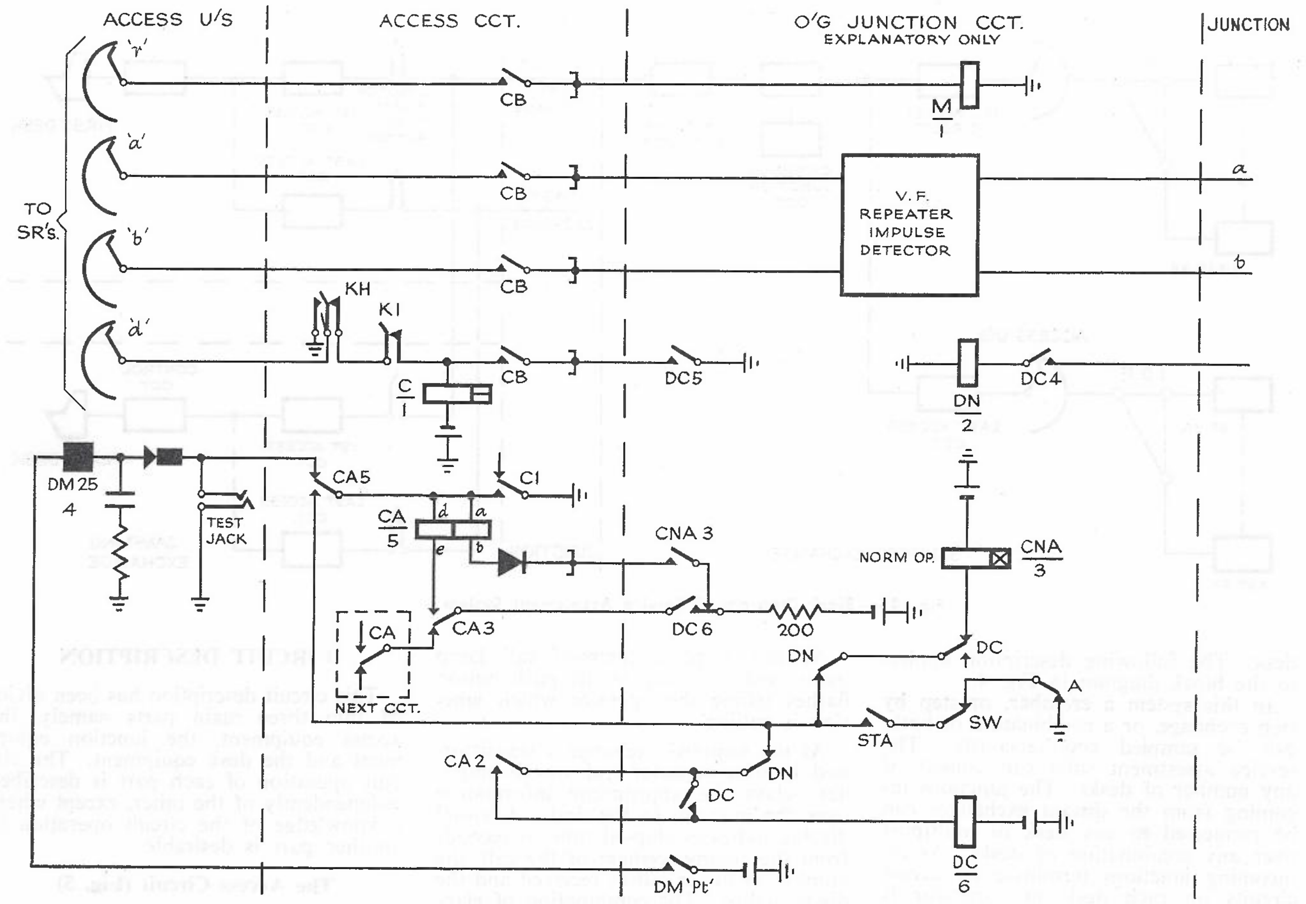

Fig. 5 — SR Sampling Circuit.

ator occurs after the caller has hung up.

Call count meters (circuitry not shown) associated with each access circuit record the number of effective pick-ups in each access circuit.

Once a call has been sampled ground at contact DC5 holds the connection on the SLB 'd' wire back to the caller, and thus no particular action is required by the operator to hold a call for tracing. This feature allows the original caller to make follow-on calls on other SR relay sets without interference, but because the crossbar switch verticals are held all these follow-on calls can be sampled. The original SR seized is guarded by the earth applied to the 'd' wire from contact DC5. In the present design sampling of these follow-on calls provides for speech, "caller hung up" indication and metering. Dialled digits are displayed on any indicator tubes still free after the first call.

Although the circuit, as originally installed, provided a separate operator holding facility in accordance with long standing practice this feature is not used. This is because the operation of the holding key by the operator places earth on the GVA 'd' wire, and this action completely disables the called subscriber's service.

Modification to the SR Relay Set

The ground which is applied to the SLB 'd' wire of normal calls to hold the connection back to the caller, will under line lock-out conditions prevent the caller from releasing until the operator releases the connection. This occurs if the line lock-out condition is brought about while the register is still held. Normally the holding for the register and register finder, is disconnected by the register and although this still takes place, the ground returned on the 'd' wire from the service assessment equipment prevents the register finder releasing. Consequently, the caller's line relays, and the register occupation relay (R1) hold in series on the 'c' wire, and no further action can take place until the operator releases the call. This difficulty is overcome by inserting a diode in the 'd' wire in the SR in such a way as to block the ground at DC5.

Detecting the Subscribers' Meter Pulses

The detection of the calling subscribers' meter pulses poses a major design problem. This is due to the desire to retain the RKR test for negative battery* on the 'r' wire. The solution involves either a single meter pulse to occur at the service assessment desk when a call from a sampled public telephone is answered, or the installation of a positive 48V battery supply at the sampled exchange. The following description applies to the former case.

A drawing showing the relevant circuitry of the meter wire (r) is shown in Figure 6. To the left of the drawing are shown the two possible connections, namely the 500 ohm ground of the meter of a normal subscriber, and the combination of ground and negative battery present in the P.T. auxiliary relay set. In the middle, are the elements of the SR relay set, which for this purpose are the thousand ohm ground applied permanently to the 'r' wire on answer, and the 200 ohm negative battery applied to the 'r' wire at each meter pulse. At the right of the circuit is the service assessment circuitry to detect the meter pulses.

It is not intended to discuss the operation of the P.T. auxiliary line circut here, but the operation insofar as it affects the operation of the service assessment equipment can be stated as follows:—

On pick-up by a public telephone, 500 ohm ground is applied to the 'r' wire for approximately ½ to 1 second. Then the R2 relay is applied

* This negative battery test has been dispensed with as a result of a recent policy decision.

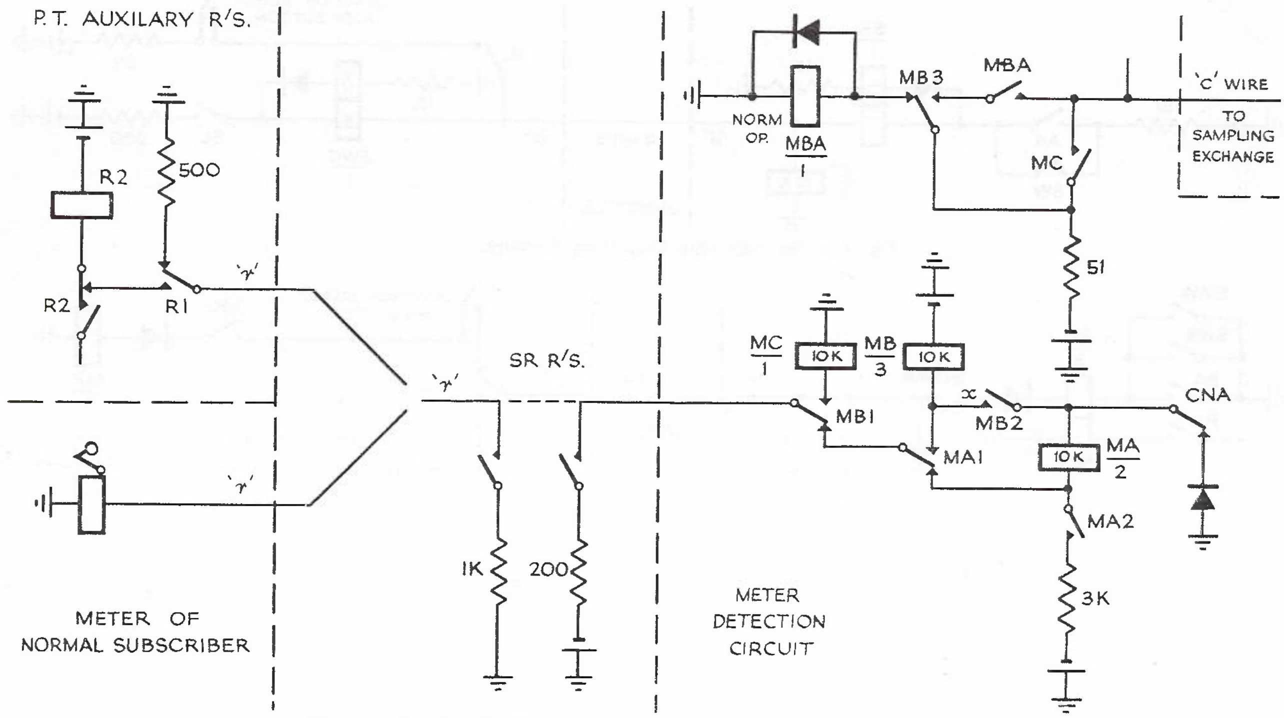

Fig. 6 — Circuitry for Meter Pulse Detection on the "r" Wire.

to the 'r' wire and operates on answer to the 1,000 ohm ground in the SR. After this, the 'r' wire, in the P.T. auxiliary relay set remains open circuit.

As the 500 ohm ground for the subscriber's meter of a non P.T. call is applied to the 'r' wire for the full duration of the call, the problem can be stated in the following way:—

The detector in the service assessment equipment must not respond to 500 ohm ground in the P.T. or subscribers' line circuits; must not respond to 500 ohm negative battery in the P.T. line circuit; must not respond to 1,000 ohm ground from the SR, but must respond to 200 ohm negative battery from the SR. At first sight a solution does not appear possible, but use can be made of the fact that the meter pulse occurs only after the R2 relay in the P.T. auxiliary circuit has gone open circuit.

The circuit operation will now be described.

Relay CNA is normally operated and releases when a call is sampled. For a P.T. call relay MA is shunted down by 500 ohm ground from the P.T. auxiliary circuit. When relay R2 is applied to the 'r' wire relay MA operates. Contact MA1 prepares for the operation of relay MB. When answer signal (reversal) is received relays R2 and MB operate to 1,000 ohm ground from the SR. Relay R2 locks and open circuits the 'r' wire.

Relay MB locks via an 'x' contact and disconnects its own operating path to contact relay MC to the 'r' wire. Relay MB also applies a negative pulse to the junction 'c' wire during the slow release of MBA. This pulse causes a meter indication to be given on the service assessment desk. Any meter pulse which occurs after answer operates relay MC which in turn repeats it on the junction 'c' wire. For normal subscribers, relay MA remains shunted down until the first meter pulse is received. Relay MA then operates, and applies MB to the 'r' wire. When the meter pulse ceases the 500 ohm ground of the meter in parallel with the 1,000 ohm ground from the SR operates relay MB, and the first meter pulse is repeated on the junction 'c' wire, as already described. From there on, relay MC responds to the meter pulses and repeats them on the 'c' wire.

Junction Signalling

"a" and "b" Wires: The "a" and "b" wires convey speech and dialling impulses, and a reversal sent back from the sampling exchange is used for holding purposes. Impulsing is of the loop disconnect type, and if warranted standard single commutation dial relay sets can be interposed in the junction.

"c" and "d" Wires: The "c" and "d" wires are used for controlling signals. (See Table 1). The signalling polarities are so arranged that a positive battery supply is not required at the observed exchange. The maximum allowable resistance of each wire is 1,000 ohms.

"d" wire (See Fig. 7): When the button on the service assessment desk is pushed on, 2,000 ohm positive battery is applied on the "d" wire to operate the start relay ST at the sampled exchange.

Relay ST prepares the access circuit. The circuit for the start relay is designed not to interfere with the operation of the SK or SWC relays. These two latter relays operate on the telegraph (duplex) principle, that is, a negative potential applied at one end of the 'd' wire operates a relay at the other end, and vice versa. The relay at the end at which battery is applied will not operate due to the differential connection of its windings. If battery is applied at both ends, both relays operate. To "speak on service assessment" relay SL (not shown) is operated by the "speak on service assessment" key and relay SL applies negative battery to the SWC relay, whereupon relay SK operates to provide for the by-passing of the buffer amplifier at the sampled exchange.

'c' Wire (See Fig. 8): When an access circuit takes a call, relay DC operates, as previously explained, and applies 1,000 ohm ground via relay DN to the 'c' wire, to operate relay L in the desk

TABLE 1: FUNCTIONS OF THE "c" AND "d" WIRES

	"c" and "d" Wire Controlling Signals	
	"c"	"d"
SR Service Assessments	Pick-up Metering Release	Start Speak on Obs.
Spec. Subs. Service Assessments	Metering Release O/C Indication	Speak on Obs. Pick-up I/C Indication

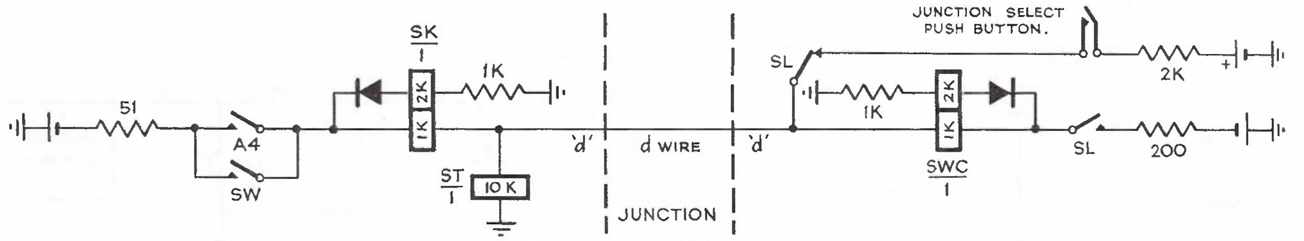

Fig. 7 — The "d" Wire Controlling Circuitry.

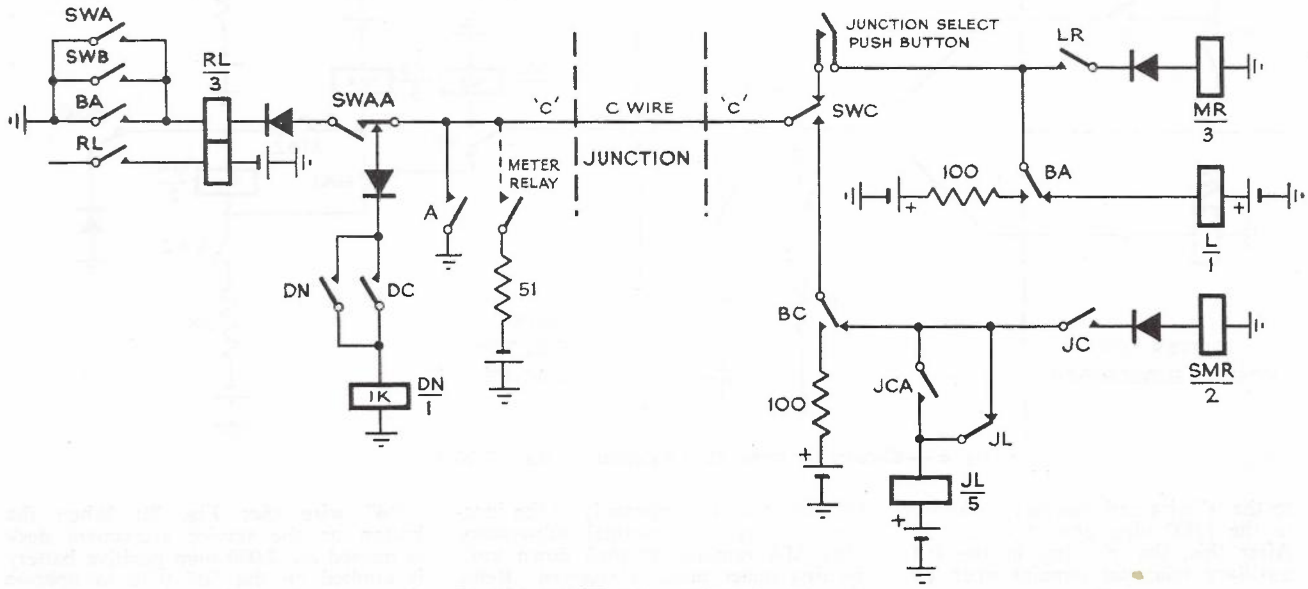

Fig. 8 — The "c" Wire Controlling Circuitry.

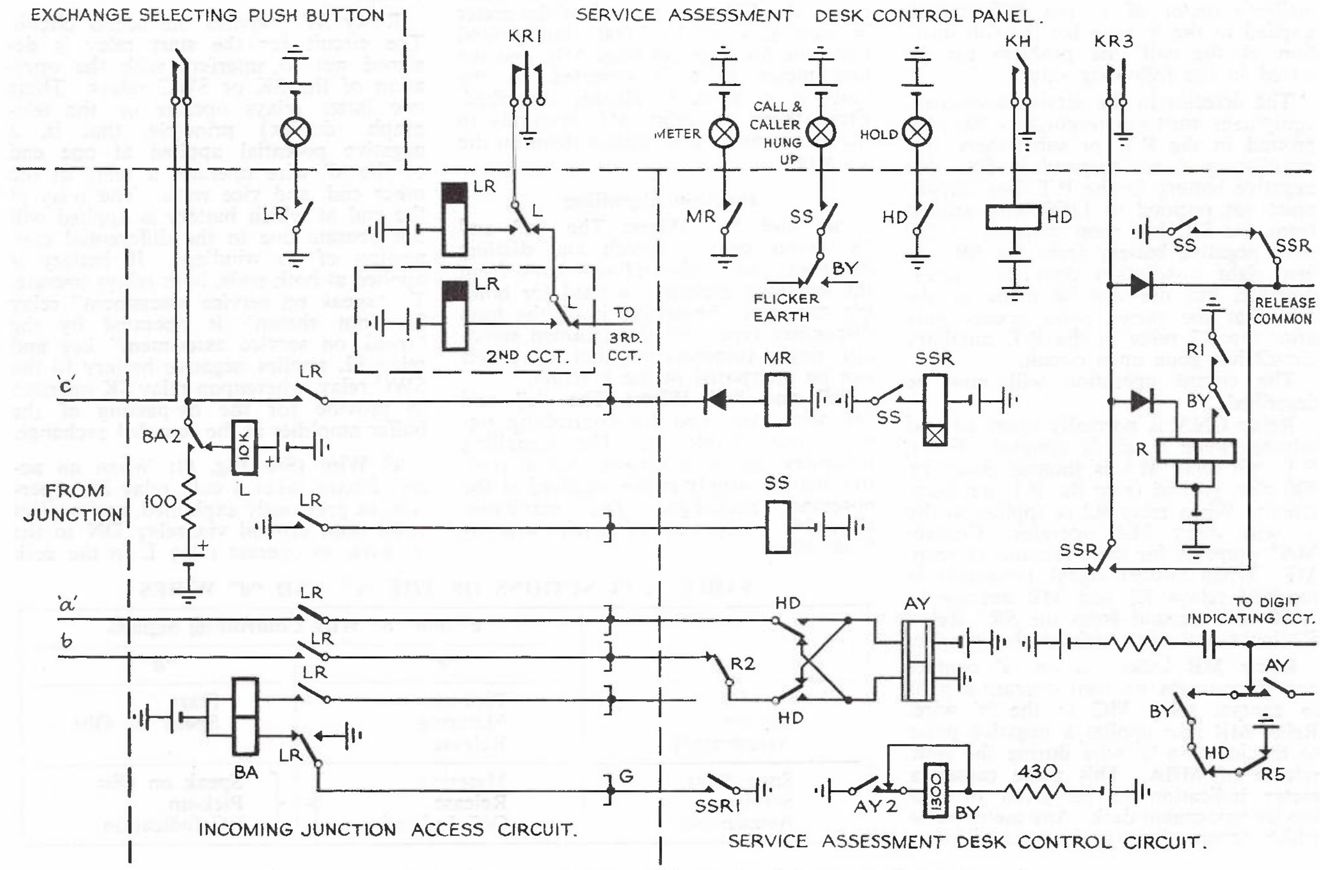

Fig. 9 — Simplified Access and Controlling Circuit at Sampling Exchange.

circuit. Relay DN will not operate in series with relay L. Relay L operates relay LR (Fig. 9) to switch the "a", "b" and "c" wires through to the common desk circuitry. Impulses are now repeated on the "a" and "b" wires, and metering impulses are relayed over the 'c' wire by pulses of negative battery to operate relay MR in the desk circuitry. The call is released by the operation of the release key which in turn operates relay BA (Fig. 9) in the desk access circuit. Relay BA returns 100 ohm positive battery to operate relay DN. Relay DN operates and locks, and releases the distant access circuit.

The remainder of the circuitry shown associated with the "c" and "d" wires is used on special subscribers' service assessment calls.

Service Assessment Desk Controlling Circuitry (Fig. 9)

This description applies to calls both from crossbar and step by step exchanges, but does not include special subscribers' service assessments.

On receipt of 1,000 ohm ground via relay DN from the sampled exchange, relay L operates, and in turn operates relay LR. Relay L contacts are arranged in a chain to prevent more than one LR relay operating, thus avoiding coupling. Relay LR in operating through connects the "a", "b" and "c" wires and operates the SS relay. Relay LR also operates the BA relay of all other access circuits over the "G" common and applies earth to the lamp in the push button to signal the calling exchange to the operator. The BA relay of other access circuits in operating, causes 100 ohm positive battery to be sent to the other exchanges being sampled and so prevents them from sampling calls.

Relay SS in operating lights a common call lamp, energises the release circuit of all counting relays during the operate lag of relay SSR and operates relay SSR. The operation of relay SSR starts the elapsed time counter.

The operation of the elapsed time counter, shown in Fig. 10, will now be described. As soon as relay SS operates the elapsed time counter displays "000", through normally made contacts of the counting relays UW, DW and CW. Relay TA responds to one second pulses and on the first pulse contact TA1 operates the first armature of counting relay UW and the counter shows "001". On the 10th pulse the 10th armature of UW operates. The contact on the 10th armature UW.11 operates relay W to ground at contact TA2. Relay W in operating energises the release winding of relay UW via contacts W4 and TA1 and relay W locks itself independent of contact UW.11. Contact W3 energises the 10's counting relay DW so that the indicator now shows "010". At the end of the tenth one second pulse relays TA and W release. Relay DW continues to be pulsed every 10 seconds until at 100 seconds contact DW.11 operates relay X and contact X3 energises the first armature of the hundred's counting relay CW, whereupon the counter shows "100". At the 1,000th pulse the counter re-starts at "000".

When relay LR switches the "a" and "b" wires relay AY operates and contact AY2 operates relay BY and the circuit is ready to receive impulses. The dialled impulses are repeated to the digit indicating circuit where they are stored on the digit relays. Metering pulses are received by the MR relay and contacts of MR cause the meter counter to record meter pulses in the same way, as described above for the elapsed time counter.

When the caller hangs up, relay AY releases followed by relay BY and the common call lamp flashes. The entire circuit remains held, however, from the SLA/B switches and access circuit at the sampled exchange to the relays and visual display at the sampling exchange. When the operator throws the release key the access circuit and service assessment junction are released, and the service assessment desk circuitry and visual display are restored to normal.

The circuit operation on release by the operator is as follows:

The release key (KRI) releases Relay LR. Relay LR releases relays SS and SSR, but during the release of SSR, relay BA is energised from contact SSRI. Contact BA2 returns positive battery on the "c" wire to operate relay DN at the sampled exchange, and so initiate release there.

When relay SSR releases, BA releases and the incoming junction access circuit is at normal. The release key contact KR3 applies ground to the release common for all counting relays, and also operates relay R. Contact R5 provides for early removal of the energisation path to the counting relays, to ensure that the release pulse will be effective. Contact R3, not shown, ensures satisfactory release of the digit steering reley RCS in the event that the release key is operated during impulsing. Contact R2, not shown, ensures the early restoring of the circuit to normal when a special subscriber's call overrides an ordinary service assessment call. Contact R1 keeps relay R locked dependent on relay BY to ensure that the impulsing lead will not generate a false impulse in the event of the operator restoring the release key before relay BY has released. Contact R1, by locking R until relay BY releases, also inhibits false impulses in the event of the call being overridden by a special service assessment call.

The elapse time counter circuit is released as follows, see Figure 11. When the release earth pulse from key KR3 is applied to the "R" common, relays W, X and Y operate. Contacts of these relays energise the release windings of the corresponding counting relays UW, DW

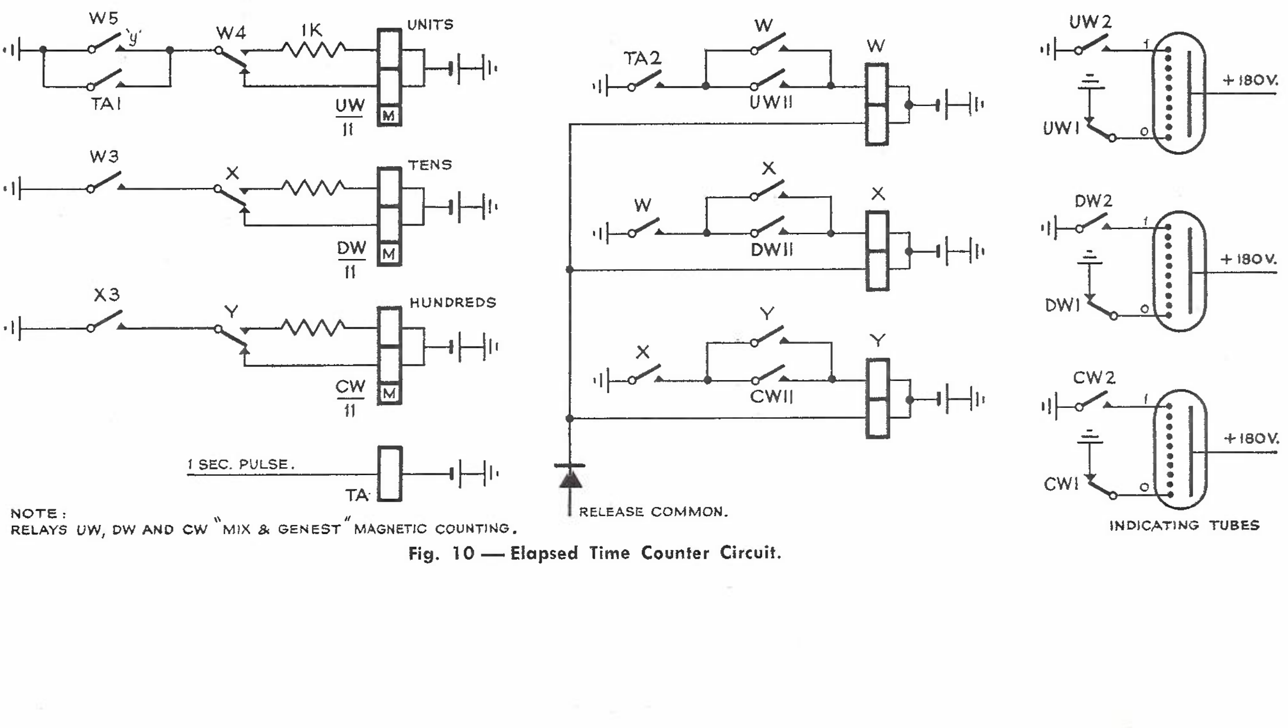

Fig. 10 — Elapsed Time Counter Circuit.

and CW. At the end of the release pulse relay W releases followed by X and then Y. Releasing of relays W, X and Y in sequence ensures that the counting relays are not energised. Contact W5 is an early break (on release) to ensure that relay RCW is not pulsed during the release of relay W. The meter counter releases similarly.

The circuit is now released, and is in a condition to receive further calls. It will be noted that a release pulse is applied to the counting relays, both at the beginning and end of every call.

EQUIPMENT PERFORMANCE

On 17th June, 1964, a two position SR service assessment suite was placed in service concurrently with the establishment of the new Goulburn 3400 line crossbar exchange.

The monthly quota of 200 local and 200 STD calls is filled with about 50 hours of operator's time on the 10 existing access circuits, and local calls are sampled at an approximate rate of 40 an hour in the busy hour.

After the initial settling in period, good results are obtainable. Intense activity on the MDF, such as occurs following most cutovers, causes a large number of intermittent short circuits to occur across subscribers' lines. In each of these cases, an SR is seized and a large number of pick-ups with the digit 1 only displayed will interfere with the normal service assessments.

Long waiting times can be experienced by the operator if dry joints develop in the pick-up wires. Under this condition the access uniselectors, once they have found the offending outlet, cannot step off, and thus the total number of effective access circuits is reduced. Call count meters associated with each access circuit permit the detection of faults such as these. Occasionally too, a call already in progress will be sampled. This fault is caused by intermittent dry joints.

The cutover of magneto subscribers to automatic, causes apparent faults associated with subscribers' habits to occur. These include first digit mutilation caused by pre-dial tone dialling, and new calls being superimposed on existing calls, caused by the caller not waiting for dial tone before re-dialling.

Some difficulty may be experienced, with the RKR leakage test failing on a call which is under service assessment. This is due to the relatively low input resistance of the outgoing junction repeater.

It is apparent, that as the dialling impulses are detected at the input to the local register, then the digit display will not necessarily reproduce the digits that are stored in the register. This is due to the disparity that exists between the impulse storage performance of the register and the service assessment equipment. Generally the register, being more sensitive in this regard, will satisfactorily store a wider range of impulses than the digit display. In fact, dials in bad adjustment can be detected in this way. However, this shows that the performance of the impulse detection and storage circuitry of the service assessment equipment should approximate as nearly as possible to that of the local register. Future design could well be directed towards this goal.

ACKNOWLEDGMENTS

The author acknowledges the help given by the District Telephone Manager and staff at Goulburn, N.S.W., and by Supervising Technician Mr. Regan and staff during the execution of the work.

GENERAL REFERENCES

(1) K. R. Richardson, "Special Service and Observation Facilities for the Launceston Telephone Network", Telecommunication Journal of Aust., June, 1957, Vol. 11, No. 1, page 10.

(2) J. J. Perkins, "Telephone Service Observations", POEE Paper No. 186, 1945.

(3) P. J. Barnard and E. H. A. Beck, "The New Centralised Service Observation System", POEE Journal, Vol. 49, Part 2, July 1956, page 81.

(4) G. Moot, "Maintenance of Telephone Networks Comprising Crossbar and Step by Step Equipment", Telecommunication Journal, June 1964, Vol. 14, No. 4, page 267.

(5) G. Moot, "Some Developments in Qualitative Maintenance", Telecommunication Journal, October 1959, Vol. 12, No. 2, page 77.

APPENDIX I

DATA FOR SERVICE ASSESSMENT DIMENSIONING DIAGRAMS

To Determine Number of Access Circuits Required

let T = Number of access circuits with associated idle SR's.

let Si = Total idle SR's.

let Sb = Total busy SR's.

let W = Average operator waiting time between calls in secs.

let H = Average holding time of SR's in secs.

Now SR's are engaged on the average, at intervals of $\frac{H}{Sb}$ secs..

∴ A particular SR is engaged on the average, at intervals of $H \times \frac{Si}{Sb}$ secs.

In a group of T SR's, SR's are engaged on the average at intervals of $H \times \frac{Si}{Sb} \times \frac{1}{T}$ secs.

In other words the average time between calls $W = H \times \frac{Si}{Sb} \times \frac{1}{T}$ secs.

$$\therefore \quad T = \frac{H.Si}{W.Sb} \qquad \ldots\ldots (1)$$

To Determine the Number of Calls Handled in Unit Time

let N = Number of calls sampled per hour.

let He = Average holding time of effective calls = 130 secs.

let Hm = Average service assessment holding time of calls sampled to maturity = 24 secs.

let Hi = Average service assessment holding time of ineffective calls = 25 secs.

It is assumed that every 10th call is sampled to completion, and that 20% of all calls are ineffective for various reasons, including D.A. Then total duration of all calls and waiting times, in an hour =

$$NW + \frac{N}{5} Hi + \frac{N}{10} He + \frac{7}{10} N\, Hm = 3{,}600 \text{ (all in secs.)}$$

Transposing

$$N = \frac{36{,}000}{10W + 2Hi + Hc + 7Hm}$$

Substituting for Hi, Hc and Hm

$$N = \frac{36{,}000}{10W + 348} \qquad \ldots\ldots (2)$$

From equations (1) and (2) the service assessment dimensioning curves are derived.

AN EXPERIMENTAL ALARM SYSTEM FOR ARK EXCHANGES

*R. S. RAVEN, A.M.I.E. Aust.**

INTRODUCTION

A fundamental requirement of unattended exchange operation is a means of advising the maintenance control centre of specific alarm conditions. This may be achieved by an automatic signalling device or regular interrogation calls to the remote exchange, or a combination of both. In metropolitan areas circuits can often be allocated exclusively for alarm signalling, but in rural areas trunks are rarely in excess of traffic requirements and either regular interrogation or signalling over normal traffic channels is necessary.

A typical RAX seizes a nominated junction and applies tone when an urgent alarm occurs. This is recognised by an operator and interrogation is used to determine the actual fault. Minor alarms are detected by calling the interrogation unit regularly.

The recent trend towards automation of rural parent exchanges finds this arrangement wanting, and the philosophy of alarm extension has been reviewed. One result is this experimental alarm system for ARK exchanges. Its main features are as follows:

(i) It signals 9 distinct alarms automatically.

(ii) The circuit designated for alarm transmission is available for normal traffic.

(iii) It detects an excessive percentage of call failures.

(iv) It incorporates interrogation facilities.

GENERAL FEATURES

The 5 basic units of the ARK alarm relay set are shown in Fig. 1.

Alarm relays are provided for 9 fault conditions, enabling ancillary equipment alarms to be segregated from those of the ARK equipment. Locking facilities are included for those relays operated by a pulse. Each alarm relay lights the display lamp appropriate to the fault and provides a marking earth for the data transmitter. Where there are several spare pairs to the parent exchange the marking earths are thereby extended and operate the parent alarm relays directly. The alarm relays also connect either "urgent" or "semi-urgent" alarm tone for transmission over the junction during the "alarm call". This tone enables an operator at a manual parent exchange to recognise an alarm and no parent-end alarm relay set is required. A fault tone representing the most urgent alarm is also selected. This is used by the interrogation unit.

The data transmitter uses loop signalling and so is suitable for derived circuits. When the designated channel is free the transmitter seizes it and advises the parent there is an alarm. It then awaits 12 metering signals from the parent and during these it advises which of the 9 alarm relays is/are operated. The alarms are remembered at the parent on 9 alarm relays. These recreate the ARK exchange lamp display and activate the parent exchange alarm system. The junction is then returned to normal traffic. The operation of the data transmitter and receiver is monitored and mis-operation causes a "system fail" alarm at the parent.

Provision is made to select which alarms require the recall of a technician after hours. This selection is easily changed from day to day without attending the ARK exchange. Subscriber traffic on the channel does not produce false "clear" signals.

The transmitter controller monitors the exchange alarms. When an important change occurs, including a "clear", it has the data transmitter recall the parent and send the new alarm state. This revises the alarm and lamp display at the parent.

A service alarm counts time-outs as a percentage of calls and provides an alarm at 2 levels: one urgent, the other semi-urgent. Up to 11 time-outs can be counted, the actual number for each alarm being determined by straps. The count is reset automatically after a predetermined number of calls or by remote control at any stage.

The interrogation unit is connected to the technician's line and can be called from any telephone. After a few seconds of ring tone and silence the fault tone is connected. No new tones have been introduced and the standard ringing machine is retained. Its seven tones produce an "all clear" and 9 alarm signals as shown in Table 1. The remote reset facility built into the interrogation unit enables the two alarms using the same tone to be distinguished. When reset occurs any locking alarm restores and discontinues its alarm tone. A change in the tone means the alarm relay when locking was operated. If reset does not change the alarm tone the alternative alarm relay is operated.

TABLE 1: THE ALARM GROUPS

Category	Tone	Alarm Condition
All clear	N.U. Tone	No alarm
Urgent	P.T. Tone	General Urgent alarm or Urgent Service alarm*
	900 c/s	Voltage alarm
Semi-urgent	Dial tone C.R. Tone	General Semi-urgent alarm Channel Fail alarm or SR alarm*
Non-urgent	I.R. tone Busy tone	Charge Fail alarm or Semi-urgent Service alarm* P.G. alarm

* locking

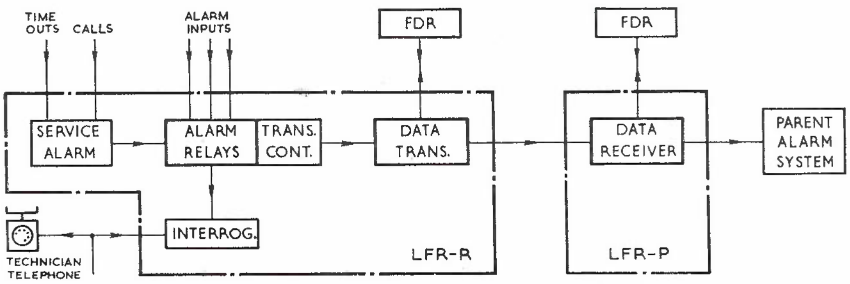

Fig. 1 — Block Diagram.

TRUNKING

Wherever possible the alarm relay set should be connected directly to the

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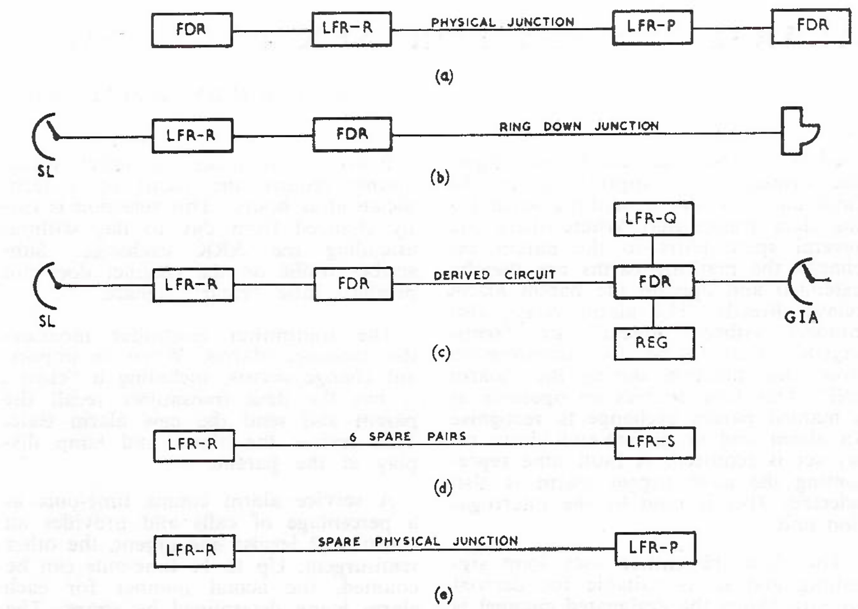

Fig. 2 — Typical Trunking.

junction (see Fig. 2). This minimises the risk of a faulty repeater suppressing an "alarm call". Only the use of spare pairs as in arrangements d and e eliminates this risk. When a derived circuit is used and for some manual parents the data transmitter must be connected "before" the repeater.

BASIC CIRCUIT OPERATION

The Service Alarm

It is normal for some time-outs to occur and an alarm is required only when the number is excessive. It is necessary, therefore, to automatically reset the count after a predetermined number of calls or at regular intervals. The former is preferred as it produces a "grade of service" or "percentage-type" alarm. Counting is done on B.P.O. No. 4 (miniature) uniselectors. Each time-out places an earth pulse on the TIME-OUT INPUT lead (see Fig. 3). This operates the TIME-OUT COUNT uniselector magnet USA. After the pulse, it releases and advances the wipers one step, counting the time-outs. Each earth pulse on the CALL COUNT INPUT lead operates the CALLS relay S2 which in turn operates the CALL COUNT uniselector magnet USB. When they release after the pulse the wipers advance one step. This counts the calls. To increase the counting capacity of the CALL COUNT uniselector USB, its wipers have been modified by cutting one wiper from each arc. This makes it electronically identical to a single bank 36 outlet switch. When used in conjunction with the ARK521 allotter or the 511 marker relay set 35 x 15 = 525 or 35 x 2 = 70 calls are counted before reset occurs. Experience to date suggests this number is adequate, but it can be increased without difficulty.

When few time-outs occur the CALL COUNT uniselector USB reaches its 35th outlet before the SERVICE ALARM relay CA3 has operated. The next earth pulse on the CALL COUNT INPUT lead operates the CALLS relay S2, which operates the RESET relay S3 and the CALL COUNT uniselector magnet USB. The RESET relay S3 locks and releases the CALLS relay S2. As the uniselector interrupters are open, the CALL COUNT uniselector magnet USB releases and advances the wipers to the "home" position. This extends the earth to the TIME-OUT uniselector wipers USA/W3, which connect it through the "homing" bank and the interrupters to the TIME-OUT COUNT uniselector magnet USA: whereupon it steps. When it reaches its "home" position the wipers break the drive circuit and apply the earth to the RESET relay S3. As its locking winding is now short-circuited it releases. Both uniselectors are now "home" and a new percentage measurement commences.

When an abnormal number of time-outs occurs, the TIME-OUT COUNT uniselector USA reaches the outlet strapped to the SEMI-URGENT SERVICE ALARM relay D4 before being reset. The alarm relay operates and locks and a "semi-urgent" alarm occurs. The call and time-out count continue. If the CALL COUNT uniselector USB reaches its 35th outlet both uniselectors are reset as usual but the alarm relay remains locked and the alarm persists. Alternatively, if the TIME-OUT COUNT uniselector USA reaches its "urgent alarm" outlet it operates the SERVICE ALARM relay CA3. This relay suspends further counting, thereby locking itself and an "urgent" alarm occurs. The time-out percentage which caused the alarm is stored on the uniselectors. The service alarm can be set to disregard time-outs of less than:

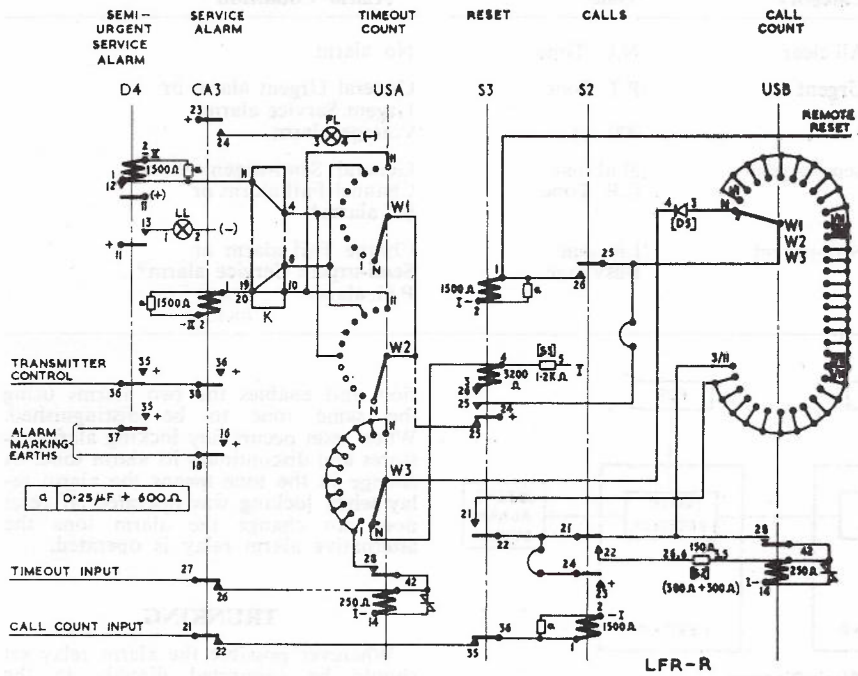

Fig. 3 — The Service Alarm.

	521	511
Semi-urgent	0.4%-7%	3%-8%
Urgent	1.0%-10%	4%-10%

The Alarm Relays

The alarms are divided into 9 groups for advice to the maintenance control centre (see Table 1). For 10-18 separate groups an extension relay set is re-

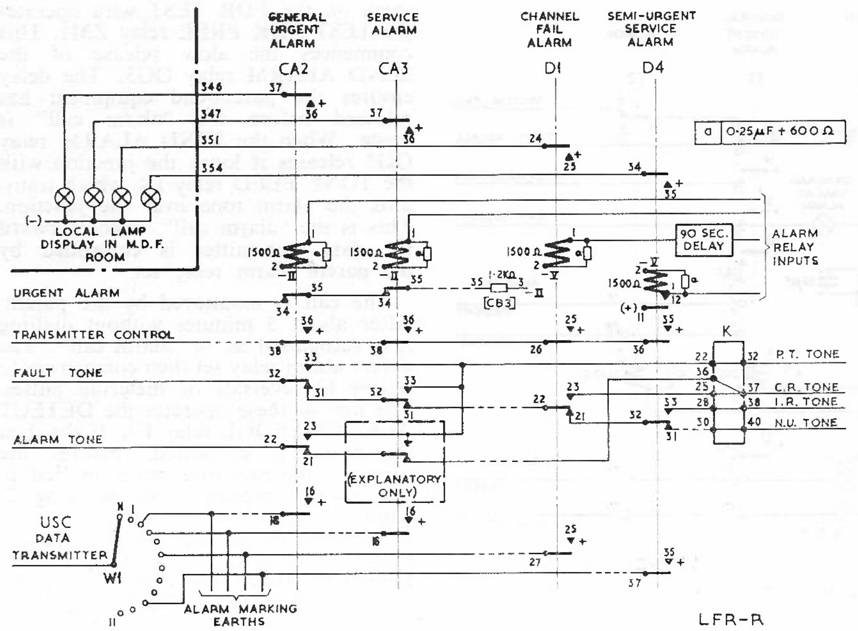

Fig. 4 — The Alarm Relays.

quired. Earth on an alarm lead operates the appropriate alarm relay, for example a fault classified as "general urgent" operates the GENERAL URGENT ALARM relay CA2 (see Figure 4). This activates the data transmitter and marks the actual alarm on the DATA TRANSMITTER uniselector bank USC/1. It also lights the display lamp in the MDF room. The GENERAL URGENT ALARM relay CA2 also switches the FAULT TONE and ALARM TONE leads to P.T. tone. These tones are used by the interrogation unit and transmitted during the "alarm call" respectively. For a manual parent exchange the operator recognises the alarm and no parent relay set or power is required (see Fig. 2b). To avoid confusing non-technical staff only two tones are used for the "alarm call" —P.T. tone for "urgent" alarms and C.R. tone for "semi-urgent" alarms. In comparison the interrogation unit uses 7 tones.

Locking facilities are included for relays operated by a pulse, such as the SEMI-URGENT SERVICE ALARM relay D4 which locks to a reset earth. The CHANNEL FAIL ALARM relay D1 operates through a 90 second delay to suppress spurious pulses.

The Interrogation Unit

When the automatic answering device is called it "reports" the most urgent fault in the exchange. This simple unit exploits the physical properties of a thermal relay for counting and timing. It is connected across the technician's line (see Fig. 5). When a call is received the 200 ohm earth applied to the c-wire operates the C-WIRE relay L1 and commences the slow heating of the INTERROGATION TIMING thermal relay TL1. After about 15 seconds it operates the RING TRIP relay L2 which loops the a and b-wires, tripping the ring. In exchanges not equipped for "terminating class of service" this will cause metering; in which case the ring may be tripped through a diode. It also connects the fault tone to the TONE FEED relay L4. The thermal relay continues heating and after a further 15 seconds it operates the START OF TONE relay L3 which locks and connects the tone to the caller. This tone has been selected by the alarm relays from the 7 tones available from the standard ringer relay set and signifies the most urgent alarm condition as listed previously. The START OF TONE relay L3 also disconnects the thermal relay which commences its slow cooling.

After cooling for 30 seconds the thermal relay releases the RING TRIP relay L2, which disconnects the alarm tone to warn that reset is impending unless the call is released. If the call has not cleared when the thermal restores about 30 seconds later, it operates the RESET relay S3. This locks (see Fig. 3) and releases those relays holding to a reset earth. The RESET relay S3 also disconnects the earth from the TIME-OUT COUNT uniselector wipers USA/W1 and USA/W2 to release any operated service alarm relay. It also operates the CALL COUNT uniselector magnet USB through its "homing common" and interrupters, causing it to step. When it reaches its "home" position the wipers disconnect its stepping circuit and extend the earth to the TIME-OUT COUNT uniselector wipers USA/W3. The earth now causes the TIME-OUT COUNT uniselector USA to step. When it reaches its "home" position too, it disconnects its drive circuit and short-circuits the locking winding of the RESET relay S3, making it slow to release. However, it is held operated by the interrogation unit (see Fig 5). The RESET relay S3 also short-circuits the blocking capacitor so that the TONE FEED relay L4 loops the line and operates. This reoperates the RING TRIP relay L2 which locks and releases the RESET relay S3, which in turn releases the TONE FEED relay L4. Opening the loop commences "called party clear" time supervision to force-release the call in 90 seconds. Meanwhile the RING TRIP relay L2 has restored fault tone to the caller to advise "reset" has occurred. Since all locking alarms were reset, any fault tone indicates an alarm condition still exists, whilst a change of tone indicates a locking alarm relay was previously operated. This resolves the ambiguity between two alarm conditions "sharing" the same tone. These paired alarm conditions are of similar urgency with the lesser being the locking alarm.

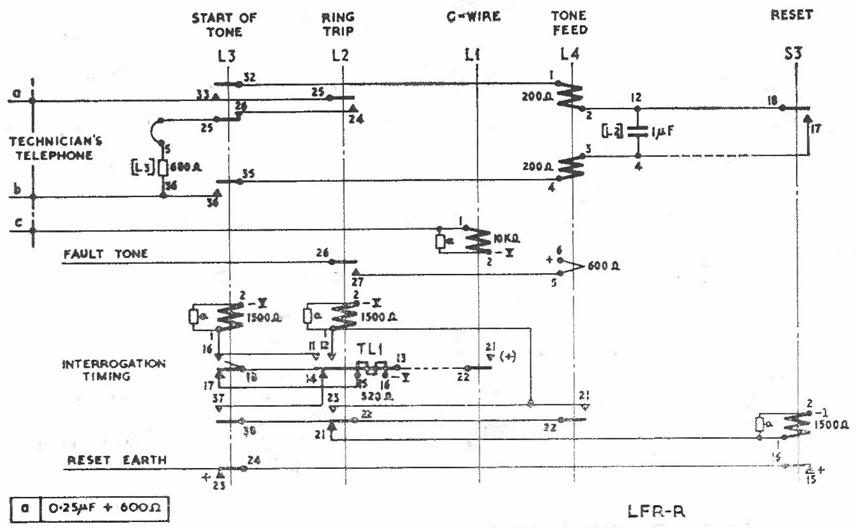

Fig. 5 — The Interrogation Unit.

Signalling Over Spare Pairs

Where six spare pairs to the parent are available, a single parent relay set

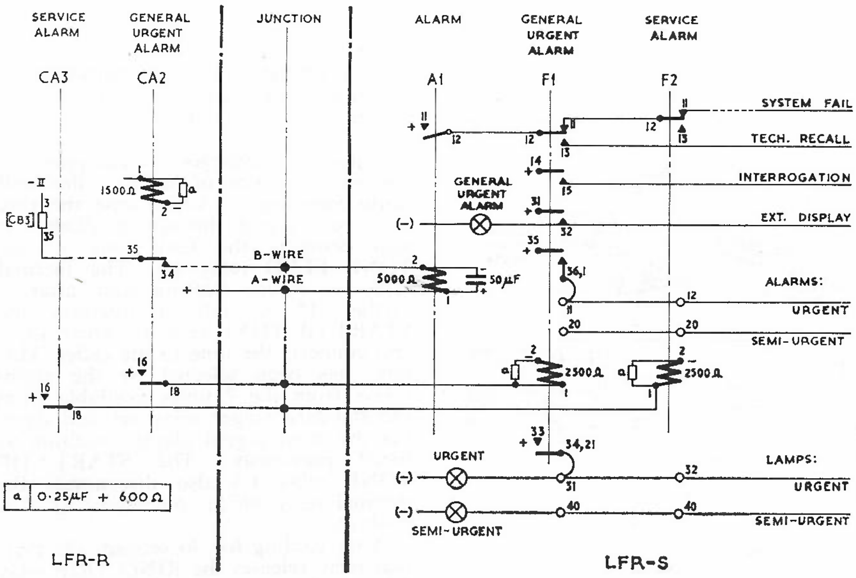

Fig. 6 — The Alarm Receivers.

suffices to receive alarms. Each alarm marking earth is then connected to one wire so that each ARK alarm relay operates its counterpart in the parent directly (see Fig. 6). An alarm relay classified as "urgent' also releases the ALARM relay A1: this gives a "system fail" alarm if an "urgent" alarm relay does not operate. Most junction failures should cause an urgent alarm.

If two alarms suffice, one spare pair can be employed to signal an "urgent" alarm on the b-wire and a "semi-urgent" alarm on the a-wire. The circuit is similar to that just described.

The Data Transmitter

As multimetering channels are becoming prevalent, an elementary data transmitter using metering pulses can signal several alarms and "clear" over one circuit. This avoids equipping several pairs with alarm detectors. The data transmitter is seized when an alarm relay earths the TRANSMITTER CONTROL lead and operates the ALARM relay OG1 (see Fig. 7). This connects the test wire from the repeater to the TEST FDR FREE relay ZM1 and busies the repeater by opening the e-wire. When the repeater becomes free, earth on the FDR TEST wire operates the TEST FDR FREE relay ZM1. This commences the slow release of the SEND ALARM relay OG3. The delay ensures the parent-end equipment has released before the "alarm call" is made. When the SEND ALARM relay OG3 releases it loops the junction with the TONE FEED relay L4, which transmits the alarm tone over the junction. This is the "alarm call". Henceforward the data transmitter is controlled by the parent alarm relay set.

The call is monitored by the parent. After about 3 minutes without dialling it is recognised as an "alarm call". The parent alarm relay set then commences to return 12 reversals or metering pulses. The first of these operates the DETECT ACKNOWLEDGE relay F4. If the data transmitter is connected "before" the repeater, the metering pulse applied to the c-wire operates it on winding 2; whilst if the data transmitter is connected directly to the junction the reversal operates it on winding 1. The DETECT ACKNOWLEDGE relay F4 operates the DATA TRANSMITTER uniselector magnet USC. After the metering pulse the DETECT ACKNOWLEDGE relay F4 releases, thereby releasing the DATA TRANSMITTER uniselector magnet USC which steps the wipers to the first outlet. This locks the ALARM relay OG1 and operates the SIGNAL PARENT relay F3 through the uniselector interrupters and coil, the uniselector receiving insufficient current to operate. The SIGNAL PARENT relay F3 momentarily opens the junction loop. This has no effect. The next metering pulse reoperates the uniselector magnet which releases the SIGNAL PARENT relay F3 so it can send another "open". After the pulse the magnet again releases and steps the wipers to

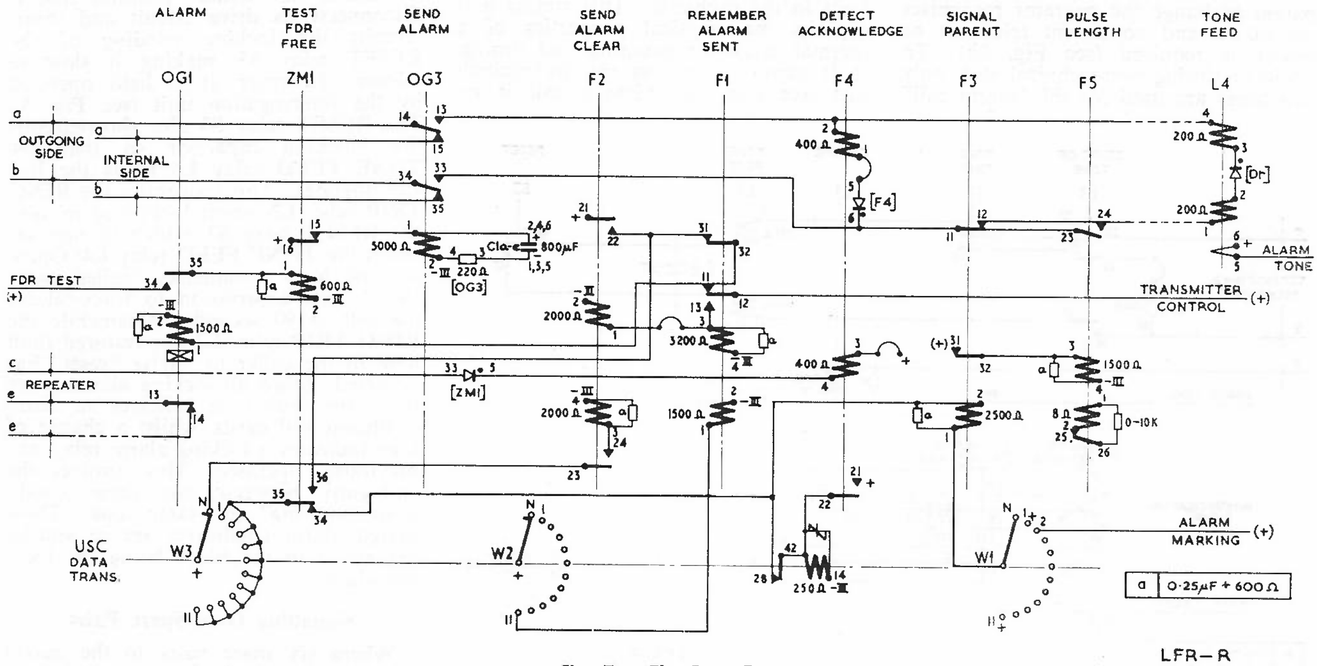

Fig. 7 — The Data Transmitter.

the second outlet. When the GENERAL URGENT ALARM relay CA2 is operated, its alarm marking earth reoperates the SIGNAL PARENT relay F3. This breaks the junction loop and disconnects the PULSE LENGTH relay F5 which releases slowly to restore the loop. The parent interprets this break as an alarm on the first alarm relay Accordingly it operates and locks the parent GENERAL URGENT ALARM relay H1 to remember this alarm (see Fig. 10). The metering pulses continue, each advancing the uniselector one outlet: meanwhile, each alarm marking earth is signalled to the parent where it is remembered. When the DATA TRANSMITTER uniselector USC reaches its 11th outlet the SIGNAL PARENT relay F3 reoperates and releases the junction. If the DATA RECEIVER uniselector USD is also on its 11th outlet the parent alarm relay set releases itself. Meanwhile, the DATA TRANSMITTER uniselector USC operates the REMEMBER ALARM SENT relay F1, which locks to the earth on the TRANSMITTER CONTROL lead, thereby releasing the ALARM relay OG1 and operating the SEND ALARM CLEAR relay F2. The ALARM relay OG1 releases the TEST FDR FREE relay ZM1 and reconnects the e-wire circuit, making the repeater available for another call. The TEST FDR FREE relay ZM1 reoperates the SEND ALARM relay OG3, reconnecting the junction to the repeater. It also operates the DATA TRANSMITTER uniselector magnet USC through its "homing arc" and interrupters. It steps "home". The SEND ALARM CLEAR relay F2 now locks to the uniselector. This relay and the REMEMBER ALARM SENT relay F1 hold while an alarm relay is operated.

Should the fault conditions clear, the alarm relays release. This releases the REMEMBER ALARM SENT relay F1 which operates the ALARM relay OG1 to make another "alarm call". When the junction is clear the call is made. The parent monitors the call and after about 3 minutes it commences sending the 12 reversals. The first operates and then releases the DETECT ACKNOWLEDGE relay F4. This steps the DATA TRANSMITTER uniselector USC to the first outlet, whereupon the SIGNAL PARENT relay F3 operates and opens the junction loop until the PULSE LENGTH relay F5 restores. The parent interprets this as a "clear" and releases all operated alarm relays in preparation for a new transmission of the ARK alarm state. The remaining metering pulses step the DATA TRANSMITTER uniselector USC as before. When no alarms remain the SIGNAL PARENT relay F3 will not reoperate until the uniselector reaches its 11th outlet, whereat it releases the parent equipment as before and operates the REMEMBER ALARM SENT relay F1. This time, with no earth on the TRANSMITTER CONTROL lead, the SEND ALARM CLEAR relay F2 does not operate. The ALARM relay OG1 releases, followed by the TEST FDR FREE relay ZM1. The uniselector steps "home", the REMEMBER ALARM SENT relay F1 releases, and the SEND ALARM relay OG3 reoperates, reconnecting the junction to the repeater. This relay is normally held operated so that failure of the ARK exchange battery "permanently loops" the junction. All other relays are released and the junction is available for normal traffic.

The data transmitter can respond to earth pulses from carrier signalling systems and send tone pulses where signalling with short breaks is unsuitable. No "clear" call is made to a manual parent exchange.

The Transmitter Controller

To keep the parent information current without generating traffic with regular "alarm calls", any important change in the ARK alarm state must be detected and a new "alarm call" made to inform the parent—particularly when an "urgent" alarm occurs after a "semi-urgent" alarm has been sent. For example, should the GENERAL URGENT ALARM relay CA2 operate after a "semi-urgent service" alarm has been "reported", it breaks the earth holding the REMEMBER ALARM SENT relay F1, which restores and operates the SEND STATE A relay CA1 and the slow-operate ALARM relay OG1 (see Fig. 8). This causes another "alarm call". The SEND STATE A relay CA1 locks to the GENERAL URGENT ALARM relay CA2 and reconnects earth to the TRANSMITTER CONTROL lead. During the new "alarm call" the SIGNAL PARENT relay F3 is operated by alarm marking earths twice; firstly from the GENERAL URGENT ALARM relay CA2 and later from the SEMI-URGENT SERVICE ALARM relay D4. Twice it breaks the junction loop and twice the parent relay set operates an alarm relay storing a "general urgent" alarm and a "semi-urgent service" alarm. The data transmitter always advises every alarm existent at the time of the "alarm call".

The parent must also be notified when an "urgent" alarm clears. When the GENERAL URGENT ALARM relay CA2 restores, it releases the REMEMBER ALARM SENT relay F1. The SEND STATE A relay CA1 holds until the REMEMBER ALARM SENT relay F1 restores, keeping it disconnected to ensure its release. The ALARM relay OG1 operates and makes a new "alarm call". The parent releases all its operated alarm relays as usual and reoperates those still appropriate. This time, as the junction remained looped during the period for sending a "general urgent" alarm, the GENERAL URGENT ALARM relay H1 was not reoperated, and in effect has been released (see Fig. 10). The revised ARK alarm state is now recorded at the parent.

The parent will generally be advised of changes and its alarm lamp display updated. For this purpose the 9 ARK alarms are divided into 4 groups:

A General Urgent and Urgent Service alarms

B Voltage and General Semi-urgent alarms

C Channel Fail, SR, Charge Fail and Semi-urgent Service alarms

D P.G. alarm.

An alarm in group D is transmitted with other alarms, but cannot originate an "alarm call" itself. After an alarm in group C has been sent, any alarm in group A or B will cause a new "alarm call". When an alarm in group A (or B) has been sent, a subsequent alarm in group B (or A) will also be sent, but a subsequent alarm in group C will not initiate another call. When both alarms in group A or B clear, the parent is advised irrespectively of alarms existing in any other group. Additional "send state" relays would allow more groups and hence a finer advice of alarm changes. However, all alarms are automatically retransmitted every time the service alarm resets itself, as the RESET relay S3 temporarily opens the TRANSMITTER CONTROL wire and releases the REMEMBER ALARM SENT relay F1 if it is operated (see Fig. 8).

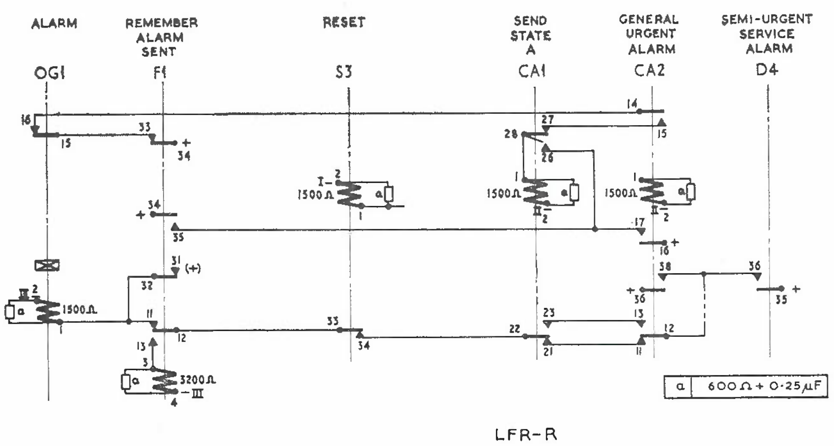

Fig. 8 — The Transmitter Controller.

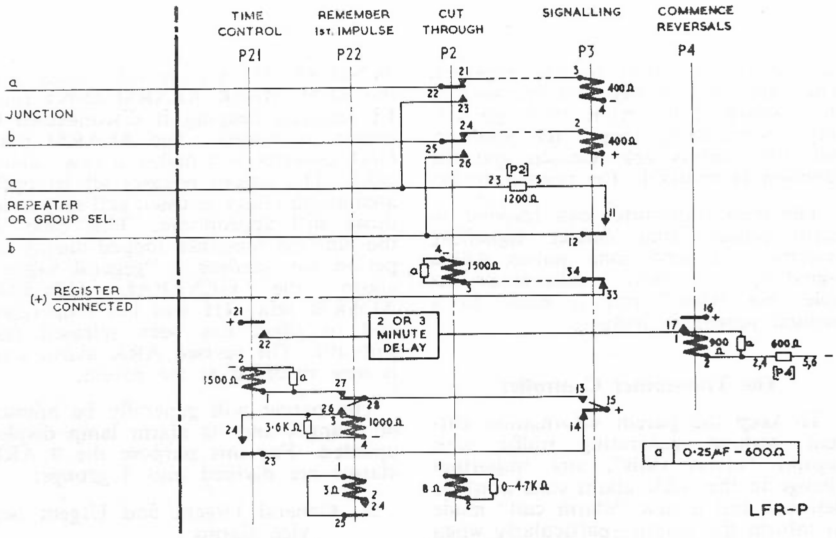

Fig. 9 — The "Alarm Call" Detector.

The "Alarm Call" Detector

A device to distinguish between "alarm calls" and subscriber calls on loop disconnect signalling junctions to step-by-step and ARF parent exchanges is shown in Fig. 9. An ARK subscriber calling operates the SIGNALLING relay P3. This relay seizes a group selector (step-by-step) or a repeater (ARF) and operates the TIME CONTROL relay P21 which activates the 2-3 minute delay circuit. On the first dial break the SIGNALLING relay P3 releases and operates the REMEMBER 1ST IMPULSE relay P22. In step-by-step exchanges and if the repeater has obtained a register, the CUT THROUGH relay P2 also operates and switches the junction to the repeater for the remainder of the call. It is trimmed to cancel first impulse distortion. The SIGNALLING relay P3 does not reoperate. If a register is not connected the SIGNALLING relay P3 receives the impulses. In either case the TIME CONTROL relay P21 releases and disconnects the delay circuit. The call is identified as from a subscriber.

An "alarm call" persits without "dialling," consequently after 2-3 minutes it is identified as an "alarm call" and the COMMENCE REVERSALS relay P4 is operated. It locks and the data transmission process commences. As the register force-releases subscribers who do not complete dialling within 90 seconds they are protected from the 12 multimetering pulses the data receiver sends.

In ARM exchanges and with carrier working the "alarm call" may be detected differently. It is likely that the repeater will seize a register and after 90 seconds (possibly without "dialling") a force-release signal will be returned. This would release a subscriber but not an "alarm call" which is consequently recognised and the data receiver connected through the repeater (see Fig. 2c).

The Data Receiver

A receiver to translate the data transmitter's signals back into specific alarms is shown in Fig. 10. When the data transmitter loops the junction it operates the SIGNALLING relay P3, which seizes a device and activates the 2-3 minute delay circuit. The "alarm call" is recognised after 2-3 minutes and the COMMENCE REVERSALS relay P4 operated. It locks and connects the REVERSAL relay P6 to the INTERRUPTED EARTH lead. The first earth operates the REVERSAL relay P6, which reverses the junction polarity and operates the DATA RECEIVER uniselector magnet USD. In the ARK exchange the DATA TRANSMITTER uniselector magnet USC also operates. After the pulse the REVERSAL relay P6 releases, restoring normal polarity to the junction and releasing the DATA RECEIVER uniselector magnet USD which steps to the first outlet. The uniselector in the ARK also steps to its first outlet and the junction loop is momentarily broken, releasing the SIGNALLING relay P3. The CLEAR relay P9 operates and opens the locking circuit of the alarm relays. Those operated release — this "cleans the slate" in preparation for the new data transmission. When the SIGNALLING relay P3 reoperates, the CLEAR relay P9 releases and restores the locking circuit.

The 2nd interrupted earth pulse recycles the REVERSAL relay P6, and both uniselectors step to their 2nd outlets. When the ARK GENERAL URGENT ALARM relay CA2 is operated, the SIGNAL PARENT relay F3 momentarily breaks the junction loop, releasing the SIGNALLING relay P3 and thereby operating the GENERAL URGENT ALARM relay H1 at the parent. It locks to remember the alarm.

The interrupted earth continues to pulse the REVERSAL relay P6, each pulse advancing both uniselectors one step. Whenever the DATA TRANSMITTER uniselector USC reaches an alarm marking earth the junction loop is momentarily opened, the SIGNALLING relay P3 pulses and the alarm relay connected by the DATA RECEIVER uniselector USD at that particular time operates and locks. When its uniselector reaches the 11th outlet, the data transmitter opens the junction and initiates its own release. In the parent exchange, when the loop is broken with the DATA RECEIVER uniselector USD on its 11th outlet, the SIGNALLING relay P3 short-circuits the COMMENCE REVERSALS relay P4 and it releases. This is the only way it can release. All relays other than the alarm relays release and the uniselector steps "home". The ARK alarm display has been recreated at the parent exchange.

The parent alarm system is actuated through the straps in the data receiver. Alarms classified as "urgent" earth the "urgent" alarm wire and light the "urgent" alarm lamp. The remaining

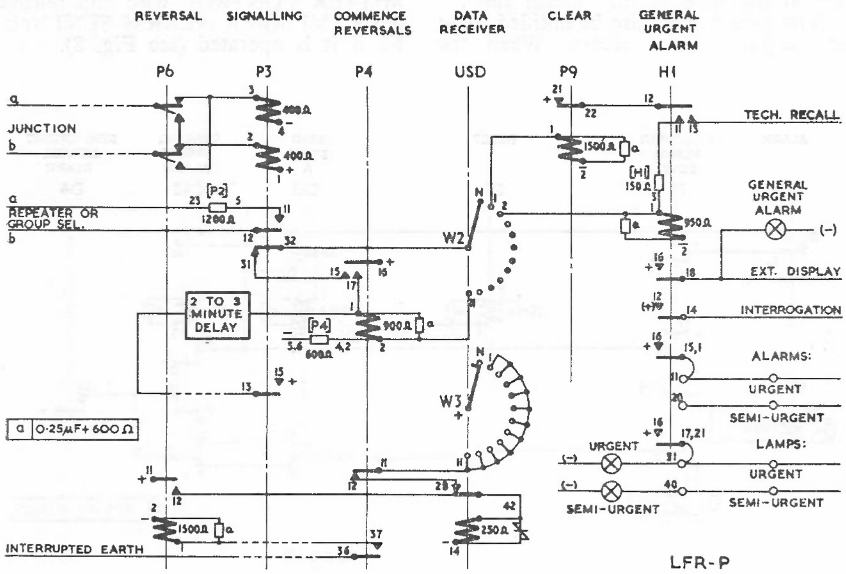

Fig. 10 — The Data Receiver.

alarm relays earth the "semi-urgent" alarm wire and light the "semi-urgent" alarm lamp. Each operated alarm relay also lights its individual lamp and extends an earth to the "recall" strapping block. Here each fault at each ARK exchange required to recall a technician after-hours is strapped to a common with a diode for extension as desired.

Each operated alarm relay also marks the parent interrogation device or the parent after-hours alarm transmitter. When the parent is not staffed and its alarm system is extended, the ARK exchange and its alarm are determined by calling the parent interrogation unit. This device sends a series of pips, one for every possible alarm condition. Between the read-outs for each ARK exchange a distinctive pip is inserted. When an alarm relay is operated a long pulse replaces the particular pip. All alarms at all ARK exchanges connected to that parent can be determined with one call.

Whilst the COMMENCE REVERSALS relay P4 is operated and the DATA RECEIVER uniselector USD is stepping, the thermal relay in the delay circuit cools. If it restores before BOTH uniselectors reach their 11th outlets and release the COMMENCE REVERSALS relay P4, a "system fail" alarm is actuated at the parent. This alarm represents a failure of the alarm equipment or the ARK exchange.

RACK MOUNTING

The alarm relay sets for ARK511 and 521 are similar but not interchangeable. Using L.M.E. relays, they fit on "3 bar" bases and mount on the basic rack (511) or the SNR-FDR rack (521).

TECHNICAL NEWS ITEMS

DATA TRANSMISSION SERVICE

Since the inception of the Telecommunication system in Australia The Australian Post Office has had the responsibility of providing all telegraph equipment and services. Over recent years there has emerged the requirement for the provision of ancillary telegraph-like services, broadly known under the general title of Data Transmission.

In the early years of this development when there was no basis on which to estimate future demand, the Post Office did not wish to inhibit the growth by setting technical standards. The policy of the Post Office was set out in a brochure entitled "Facilities for Data Transmission". Broadly speaking, the users were required to provide their own data modem (modulation-demodulation) units, the only stipulation being that they must have them approved before being allowed to connect them to Post Office lines.

In the light of the rapid expansion of computer services and the experience both in Australia and overseas, the Post Office has now adopted a new policy designed to foster and to guide the orderly growth of data services. The Post Office will define standards for speeds up to 1200 bauds and mode of transmission of data and will become the supplier of standard data sets (modems) for use on switched networks or leased lines. In doing this, it is using the procedure followed in most of the advanced countries of the world. Modems not provided by the Post Office will be permitted when the standard units cannot provide all the facilities required.

There are important technical and administrative advantages stemming from the Post Office assuming responsibility for the provision and maintenance of data transmission services. Standardisation of transmission and the provision and maintenance of modems, will enable the Post Office to assume the same measure of responsibility for data transmission as applies to the public telephone and telegraph networks. A survey of data equipment manufacturers and major users showed that the great majority are in favour of the Post Office taking this responsibility.

Uniform transmission mode prepares the way for the possible future operation of a switched data network. In this field standardisation is essential. Other factors that influenced the decision were that the incompatibility between the data transmission systems and existing communication systems would be avoided; the designer of data equipment is provided with a standard form of reproducible signals at the interface, thus enabling frequencies, levels, wave shaping and other transmission parameters to be optimised in respect to the diverse and variable characteristics of the telephone network. Testing of the equipment is also facilitated.

Choice of Standard

A detailed technical evaluation of the different modulation techniques in use for data transmision has been made and in general frequency modulation (FM) and phase modulation (Ph.M) are preferred. Both methods are competitive and each has advantages under special conditions. The C.C.I.T.T. has recommended adoption of FM for 200 baud and 600/1200 baud transmission for the telephone network. This is the predominant trend overseas, and while the Post Office is predisposed to accept C.C.I.T.T. recommendations, a final decision will not be made until the purchasing stage.

It is confidently expected that the new approach to the provision of data transmission services in Australia will enable the currently stimulated demand to be most readily catered for. It is envisaged that initially there will be two classes of modems—a 200 baud bothway unit and a unidirectional modem capable of operation either at 600 or 1200 baud.

HIGH DENSITY LINE TRANSMISSION EQUIPMENT USED IN AUSTRALIAN POST OFFICE

After years of trial and experiment the Australian Post Office is adopting high density packaging of electronic equipment employing semi-conductor devices and printed circuitry for all types of carrier equipment.

All line transmission equipment including coaxial repeaters is available now with transistor amplifiers to the exclusion of vacuum tubes. In addition most electromechanical relays, for example, in voice frequency telegraph systems, can be replaced by semi-conductor switches.

Within the last twelve months a series of specifications setting out general objectives to be met by this equipment has been issued. Specifications peculiar to various types of equipment are issued as required prior to purchasing action.

Over the last ten years the space occupied by carrier equipment has been reduced by a factor of five. This has required new approaches to the provision of access for testing and monitoring and the plug-in replacement of units which might fail.

Most of this equipment is manufactured in Australia, either to local designs, or overseas designs adapted to meet the requirements of local specifications.

A REMOTELY CONTROLLED MAGNETO EXCHANGE

R. M. TORKINGTON, B.E., A.M.I.E. Aust. and E. MOREN***

INTRODUCTION

One of the most difficult problems faced by communications administrations in all countries of the world, is the provision of telephone service at a reasonable cost to the sparsely settled areas of their countries. Up to date in Australia, the main solution to this problem has been the small manual magneto switchboard to which are connected long multi-party lines. This type of service has the major disadvantages that it is not continuous depending as it does on the willingness of one of the residents of the area concerned to act as the operator of the exchange, and in most cases, the transmission quality over the long party lines is extremely poor.

With the rapid and spectacular developments in automatic world-wide communications between heavily populated areas of the world, and in particular, the imminent use of satellite communications links, pressure has increased to improve the standard of service provided to subscribers still relying on the earliest form of communications system — the magneto manual exchange. The important requirements for service in isolated country areas can be summarised as reliable continuous operation which is not easily disturbed by floods or bush fires. The line work must be capable of being cheaply constructed so as to use earth return multi party lines where necessary.

A considerable amount of investigation and development work is going on in this field, both in Australia and overseas, as a matter of urgency in order to improve the quality of service provided in outback areas. Several solutions have been tried, notable amongst which were the L. M. Ericsson A.L.L. series of exchanges and a design development by the late Mr. L. Kennedy of Roma, Queensland.

This paper describes the design and development of a remotely controlled magneto exchange which has been developed to meet the requirements described above.

DESIGN PRINCIPLES

As every existing design had fundamental deficiencies in facilities and employed both obsolete and not readily available components, it was decided to redesign from basic principles.

A basic planning study indicated a capacity of 20 lines, as distinct from parties, would be adequate for almost all areas. It appeared that before the development to twenty lines eventuated, two overriding alternative factors would shift the economic balance. Either the area was becoming populated to a density sufficient to warrant conversion to automatic or the area covered had expanded beyond the capabilities of one copper centre, and a second exchange was indicated.

The obvious advantages of using components currently in production caused the design to be centred on an L.M.E. 30 point crossbar switch and ARK rack, which allowed 20 outlets to be allocated to subscribers, leaving 10 outlets for ancillary functions. Relays of the 3000 type were chosen in preference to RAF type because of the availability of design data, but conversion of the circuits into different relay types would be easy.

Using one crossbar switch, with ten verticals, would allow a maximum of five calls if one vertical were reserved for finding the originating party and one for the terminating party on a local or incoming call. If an alternative trunking arrangement as in the ARK system were used, then four verticals could be used for calls to or from the parent, and three pairs for local calls. This would involve greater complexity in the marking and call establishing sequence, which was not warranted as a total capacity of five calls was considered adequate. It was taken as axiomatic that the unit must be capable of local switching, and not be just a concentrator, and also provide queueing of calls for high junction usage efficiency.

TECHNICAL DETAILS

Various methods had been proposed to give satisfactory signalling performance on subscribers' lines. Direct current from the unit is unsuitable as the leakage current on a bad line could be higher than the loop current. Direct current from the telephone or amplified lines with tone signalling are feasible, but expensive, and power supply is a problem at the subscribers' premises. Stacked carrier working over a common bearer, and radiotelephone systems are all prohibitively expensive at the present state of the art.

Magneto signalling with local battery feed is the acceptable answer to this problem. Unfortunately this restricts signalling to only one electrical pattern. This can be coded in Morse fashion for ringing from the exchange to a particular party, or between parties on one line, but is not feasible for coded information between the subscribers and the exchange. Therefore the setting up of the call must be remotely controlled by a distant operator, hence the name Remotely Controlled Magneto Exchange (RCMX).

The junction repeaters were necessarily required to be capable of reverting a call for local connection without the use of a second junction, or the situation is embarrassing when all junctions but one are engaged. Line signals on the junction were chosen to be a constant mark for parent seizure, 67 mS space for dialled impulses and 300 mS for ring from the parent, and 300 mS minimum from the RCMX for repetition of subscriber ring. This basic sequence made the RCMX junctions comparable for physical, out-of-band signalling carrier, and rural carrier systems. Physical signalling in cailho fashion, giving no resultant loop current was necessary as a calling subscriber would be connected to the line while the operator sends reverted signals back to the RCMX.

From this point, the technical necessities for satisfactory signalling on the subscribers lines were clear. Full repetition of all signals at the RCMX indicated a local ring generator. Operator coding of ring in similar circumstances had proved unsatisfactory, so an automatic code generator was prescribed. The need for informing the generator of the code desired was met by allocating each party a three digit code. The first two digits would indicate the line and the third the ring code for the individual party. Code "1," two shorts, similar to automatic ring was allocated for exclusive services and recall on multiparty lines where the caller is unknown.

Immunity from "ghost" calls caused by lightning surges was achieved with a nominal delay of 300 mS before tripping on exclusive lines. Party lines were designed to reject all but a minimum of five seconds of continuous ring, so that interparty ringing was possible without calling the RCMX. The required current sensitivity was known from experience to be 5 ma maximum, so a test operate current of 3 ma was ued in the multiparty line relay set design. Full contact wetting is employed.

Automatic metering was precluded by the absence of electrical identification of individual parties on a multiparty line, and the lack of called party supervision. A docketing system at the parent sufficed as verbal identification is trustworthy in these areas.

CALL SEQUENCES

Only one signal originates from the subscriber, which can be for calling, recalling, or terminating the call. A common usage of the hand generator, that of burning in corroded joints in privately erected lines if voice transmission fades is now not permissible as the action taken by the RCMX on receipt of ring must depend on previous events. The possible sequences of a call were mapped and examined for ambiguities. The most critical decision for

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the RCMX to make is when to place two subscribers into local connection and shed operator control.

Fig. 1 illustrates a simple call from subscriber 'A' through the parent to elsewhere in the network. The possible deviations in the pattern demonstrate the necessity for the two unusual tones used to complement the normal tones in the exchange. It is unusual to supply

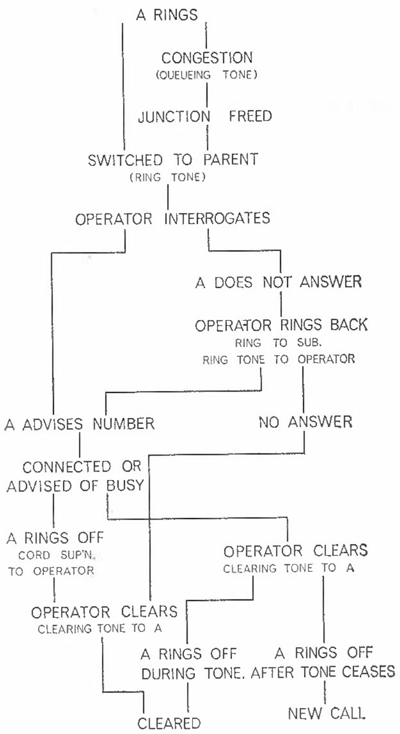

Fig. 1 — Subscriber Through Parent Call.

tones in a magneto network, but queueing tone, one pip of 400 c/s every three seconds, the inverse of CN tone, is valuable to the subscriber to indicate that his call is acknowledged, that there will be a delay until a junction becomes free, and he may hang up and wait for the operator to ring back.

Clearing tone, continuous 400 c/s, indicating the call is being terminated, is quite unusual. It was decided that after a call was answered, it must remain the prerogative of the operator to terminate it. Otherwise the RCMX would slowly be congested by false traffic if the callers failed to ring off. If the operator clears before or during subscriber ringoff, then a timeout period is necessary during which the RCMX recognises ring as clearing and not origination of a new call. By having 400 c/s present on the line during timeout, the subscriber knows that the operator has terminated the call, and to wait until tone ceases before ringing for another call. The period was made 3 to 4 seconds for a call to or from the parent, and 7 to 10 seconds for a locally connected call as two parties will normally be ringing off.

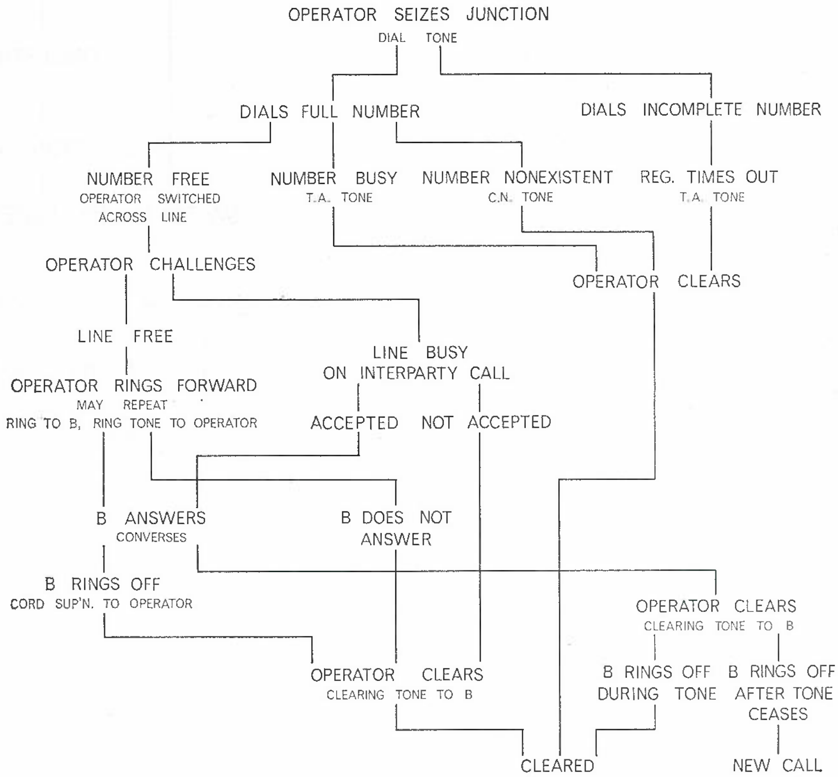

Fig. 2 — Parent to Subscriber Call.

Fig. 2 illustrates the variations in a call from the parent to an RCMX subscriber 'B'. Tones indicate lack of success to the controlling operator, while silence indicates that the call is switched to the required line. Privacy is ensured on a call through the RCMX, but not on interparty calls which the RCMX has not established. Consequently automatic ring forward is undesirable and the preferred procedure is for the operator to challenge a line before manually ringing forward. The ring code generator having been preset for the correct code by the last digit dialled, it sends three complete codes of ring out to line each time the operator depresses the

Fig. 3 illustrates the many more variations possible in establishing a local call. The critical event which presets the RCMX to remaining in local connection instead of clearing when the operator disconnects is the ringing out on the called line. This is cancelled by either party ringing off before the operator clears, and is re-established by the operator ringing again, ad infinitum.

When a tone denoting an ineffective call is encountered, the operator must advise the calling subscriber of its significance, even though the caller hears the tone. The facility was designed into the RCMX that the operator can clear tone from the line by momentarily operating the ring forward key. Clear conversation is then once more possible.

One slight defect in the pattern is an ambiguity the RCMX cannot detect. If the called party is rung but does not answer, then the operator must cancel this by ensuring that the calling party rings off, or the RCMX will presume that a local connection is desired when the operator clears.

TRUNKING

Two trunking schemes are practicable with exchanges of this type. One is as used in the L.M.E. ARK system, where a parent call is established by an FDR, and transferred to different switch verticals wired to an SNR for local calls. This method results in a very complex marker and does not permit a three way connection of operator, calling and called parties.

By using a link and junction line repeater system, it was found to be possible to reduce the marker functions to simple preference rotation and sequencing. Marking and switching of a called party is performed directly by the line relay contacts in a chain, and called party switching directly by the register. The trunking is shown in Fig. 4. There are 20 line relay circuits, five links, and three junctions. All other relay sets are one only. The memory functions, such as whether the register analysed the number as unobtainable, busy, or free, the steering of the digits to the register and ring code generator, and the line signal repetition are concentrated in the junction repeaters because of their small number.

The sequencing functions for timeout and presetting for local call connection are retained in the links, as also is a secondary transmission bridge

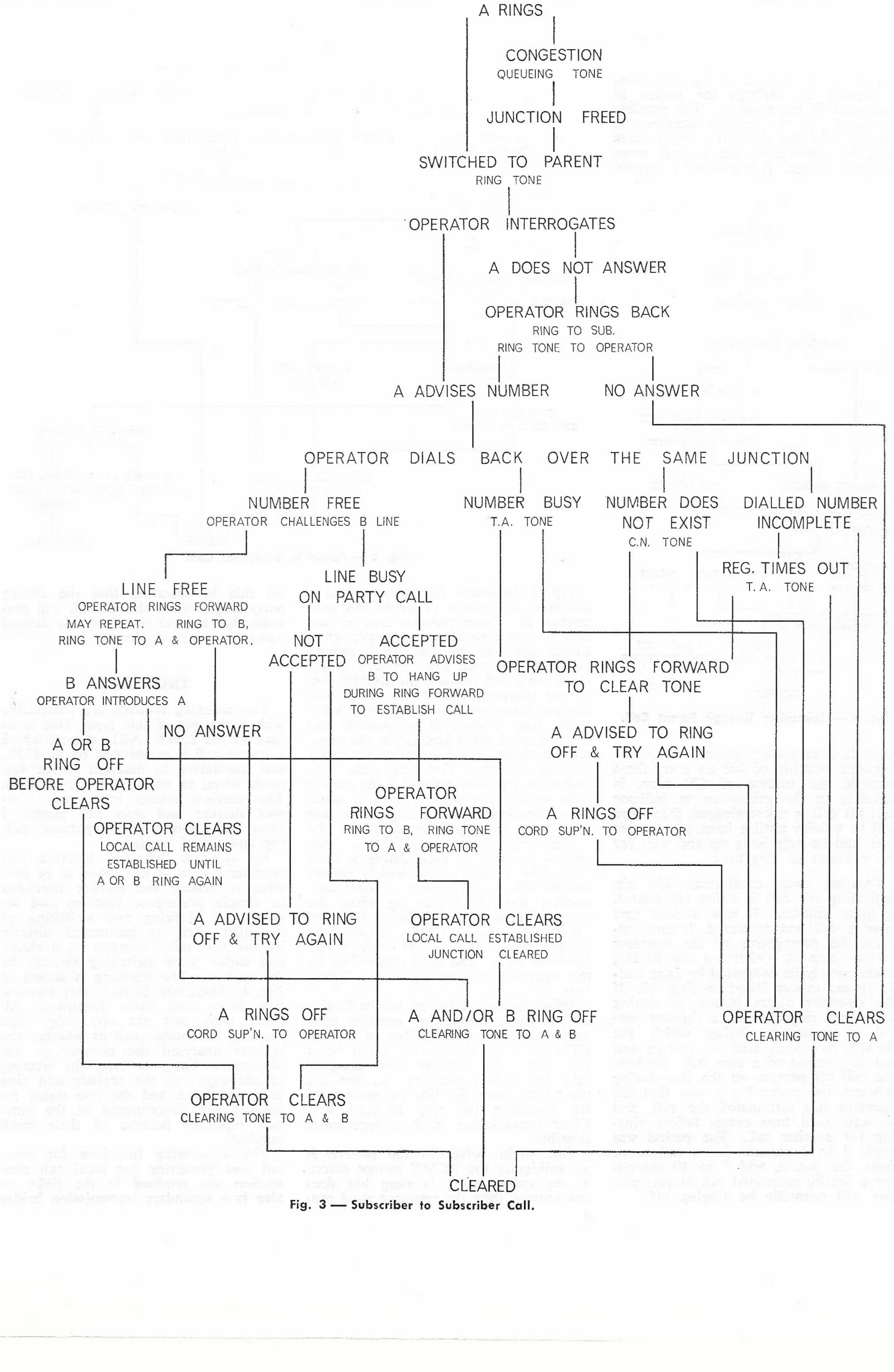

Fig. 3 — Subscriber to Subscriber Call.

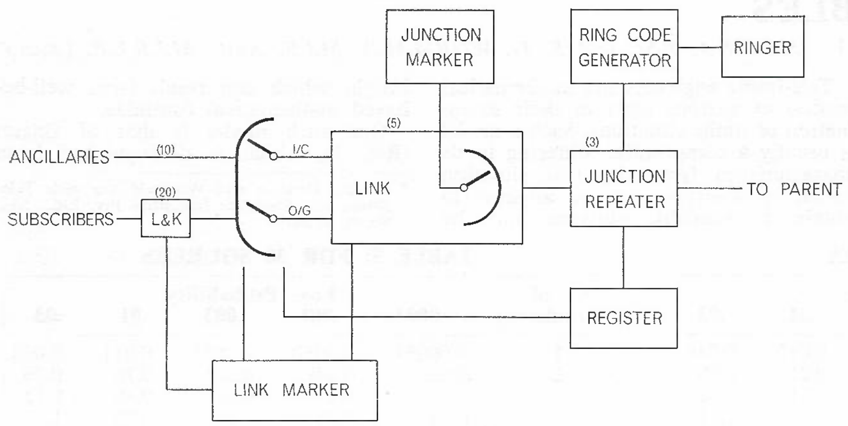

Fig. 4 — Trunking.

for detecting local connection ringoff and supplying clearing tone.

The ring code generator required three banks, one coupled to each junction as coded ring can be required at any time during a call, and possibly coincidentally with ringing on another junction.

The use of two markers, performing different operations, is unusual. However, their functions are so discrete that no direct connection exists between them. On a call from a subscriber, the link marker selects and activates a link, connecting it to the subscriber. The link calls the junction marker which selects and connects a junction repeater to the activated link. Both markers then release.

On a call from the parent, the junction marker connects a link to the repeater. When the digits have been dialled, the register calls the link marker to switch the link onto the subscriber it has selected. If the number were disconnected, or unobtainable, the strappings in the register would cause it to pass a suitable signal to the junction repeater and the marker would not be called.

The numbering scheme was chosen to extend from 201 to 390 for 20 subscribers lines, and the technician's line is 481. Five of the remaining nine outlets were allocated for direct access to the links, one for extended alarms, and one for remotely controlling the diesel generator. The two spare outlets of course could be used for subscribers if L. and K. relays were provided, just as the junctions could be increased by adding more relays to the links and junction marker, and the capacity of the unit doubled or trebled by adding more switches; but these trends have no limits, and the essential simplicity of the unit is lost in the process.

PLANNING CONSIDERATIONS

The RCMX equipment was not designed to be cheap. Before the design was commenced, it was decided that a cheap unit would be an economic liability, a point which has been amply illustrated in the past. On the contrary, every possible facility having an influence on the quality of service was included. The installed equipment costs appear to be about three-quarters of an equivalent automatic unit.

The economic advantage derives from the lack of linework costs. No upgrading of Departmental or private sections of lines or change of instruments is necessary, which results in savings exceeding the cost of the equipment, and considerable goodwill from the subscribers.

In case it should appear that all engineering effort should be devoted to automation of the network instead of the perpetuation of magneto lines, it must be asserted that judicious use of an RCMX leads the way to full automatic service in a controlled and economic manner.

An RCMX establishes and stabilises the copper centre, as well as the site, hut, and power supply, but avoids the heavy expense of linework. Then when opportune, the linework can be upgraded in sections to automatic standard. Finally the instruments can be changed, the RCMX rack interchanged for automatic equipment which is of the same construction, and the area is automatic. The recovered RCMX rack would then be used elsewhere. In the meantime the subscribers would have had a good service, and the area would have its own directory entry.

In general, there are many instances where installation of an RCMX would be sound practice. The provision of new services at low cost in outlying areas is the most apparent application. New settlers taking up land in an agricultural development scheme would not have the time or money for erection of long private lines, but all would desire a telephone service.

A similar situation exists where a large property is being subdivided, and the few lines to the property could be used for junctions to an RCMX. Similar economic principles would apply to an area served by long pole routes which are in disrepair. It may be cheaper to partially dismantle the routes and install an RCMX than rebuild the route.

Sometimes exigent factors override the economic balance. Operators of magneto switchboards in isolated private properties quite often resign, become unreliable, or unable to continue the service. The pressure exerted by the subscribers for restoration of their service could well be relieved by the installation of an RCMX even though it might be otherwise marginally uneconomic. Alternatively, service could be restored by removing the switchboard to another property, but the cost in linework alterations of one or two shifts could result in a greater final expenditure than for an initial RCMX at the optimum location.

Many other factors cannot be economically evaluated but affect any comparison of an RCMX with a manually attended switchboard. The service is continuous, secret except on party lines, and more reliable than one which depends on a private operator to be within earshot and co-operative. The operator's salary is evaluable, but the administrative overhead can only be averaged. The improvement in speech transmission and saving to the subscribers in the length of privately erected lines are goodwill features, but may induce subscribers to make an "Unconditional Contribution" to the cost of an RCMX.

PROTOTYPE INSTALLATION

The prototype was constructed in the Brisbane Workshops, and tested in the Queensland Telephone Equipment Laboratory. The time taken for preparation of the exchange for installation was much longer than normal because the motivation was primarily to develop an optimum design for future production and only secondarily to provide a service to a group of subscribers. Large sections were rebuilt where normally a deficiency could be eliminated in a more expedient but less artful manner. When laboratory tests were complete, the prototype was taken to Bogandilla, a property 35 miles from Miles, its parent exchange.

On the 28th October 1965, the RCMX was cut into service with eight exclusive and two party line services. A subscriber education campaign was carried out by Telecommunications Division Officers using tape recorders to illustrate the tones. After cutover there was the normal anxiety, even though hundreds of test calls had been made, until the first public call was handled successfully. None were forthcoming. After a while, the school bus passed, and half and hour later the exchange came to life. The natural enthusiasm of the children provided a steady stream of calls, and the success of the design project was finally established.

ACKNOWLEDGMENTS

Our thanks are due to Mr. B. J. McKinley, within whose subsection, Switching Systems Design, the project was sponsored; to our many colleagues in the Telecommunications Division who gave invaluable advice and assistance; and to the Divisional Engineer and Staff of Roma Division who worked untiringly to make the prototype installation a success.

ENGSET TRAFFIC TABLES

*V. V. DRIKSNA, B.Sc. and E. G. WORMALD, M.I.E. Aust., M.I.R.E.E. (Aust.)**

A computer programme has been written to calculate traffic tables in accordance with the postulates of Engset. As such tables appear not readily available, some of the results are published for their potential interest of usefulness in traffic engineering.

Tele-traffic engineers use mathematical models of various sorts in their examination of traffic situations. Such a model is usually a compromise, differing in its characteristics from the real situation which it describes, in an attempt to obtain a calculable outcome and the insight which can result from well-behaved mathematical formulae.

One such model is that of Engset (Ref. 1), which is distinguished from

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TABLE 1: FOR 5 SOURCES

No. of Trunks	Loss Probability .0003	.001	.003	.01	.03
1	0.00037	0.0013	0.0038	0.013	0.038
2	0.036	0.065	0.11	0.21	0.38
3	0.21	0.32	0.47	0.71	1.07
4	0.66	0.89	1.17	1.58	2.11

TABLE 2: FOR 10 SOURCES

No. of Trunks	Loss Probability .0003	.001	.003	.01	.03
1	0.0003	0.0011	0.0033	0.011	0.034
2	0.029	0.054	0.094	0.18	0.32
3	0.16	0.24	0.35	0.55	0.85
4	0.41	0.57	0.77	1.09	1.53
5	0.80	1.04	1.34	1.77	2.34
6	1.33	1.65	2.03	2.58	3.27
7	2.00	2.42	2.89	3.52	4.30
8	2.86	3.37	3.91	4.63	5.48
9	4.06	4.64	5.24	6.03	6.90

TABLE 3: FOR 15 SOURCES

No. of Trunks	Loss Probability .0003	.001	.003	.01	.03
1	0.00032	0.0011	0.0032	0.011	0.033
2	0.028	0.051	0.089	0.17	0.31
3	0.15	0.22	0.33	0.51	0.80
4	0.37	0.52	0.70	1.00	1.43
5	0.71	0.92	1.19	1.60	2.15
6	1.13	1.43	1.77	2.29	2.96
7	1.65	2.02	2.44	3.05	3.83
8	2.26	2.70	3.19	3.89	4.75
9	2.96	3.46	4.02	4.80	5.75
10	3.74	4.31	4.93	5.78	6.79
11	4.65	5.27	5.94	6.83	7.90
12	5.68	6.35	7.07	8.01	9.10
13	6.88	7.60	8.36	9.30	10.4
14	8.39	9.16	9.92	10.9	12.0

TABLE 4: FOR 20 SOURCES

No. of Trunks	Loss Probability .0003	.001	.003	.01	.03
1	0.00032	0.0011	0.0032	0.011	0.033
2	0.027	0.049	0.087	0.16	0.30
3	0.14	0.21	0.32	0.50	0.78
4	0.36	0.49	0.68	0.97	1.38
5	0.67	0.88	1.13	1.53	2.07
6	1.06	1.34	1.68	2.18	2.84
7	1.53	1.88	2.29	2.89	3.65
8	2.07	2.49	2.96	3.65	4.52
9	2.67	3.15	3.70	4.46	5.42
10	3.33	3.88	4.49	5.32	6.36
11	4.07	4.66	5.32	6.22	7.33
12	4.85	5.50	6.22	7.18	8.35
13	5.71	6.42	7.16	8.17	9.40
14	6.63	7.37	8.17	9.23	10.5
15	7.63	8.43	9.25	10.3	11.6
16	8.72	9.54	10.4	11.5	12.8
17	9.94	10.8	11.7	12.8	14.1
18	11.3	12.2	13.1	14.2	15.4
19	13.1	13.9	14.7	15.8	17.1

TABLE 5: FOR 30 SOURCES

No. of Trunks	Loss Probability .0003	.001	.003	.01	.03
1	0.00031	0.0010	0.0031	0.011	0.032
2	0.026	0.048	0.085	0.16	0.29
3	0.14	0.21	0.31	0.48	0.75
4	0.34	0.48	0.65	0.93	1.33
5	0.63	0.83	1.08	1.47	2.00
6	1.00	1.27	1.59	2.08	2.73
7	1.43	1.76	2.16	2.74	3.50
8	1.92	2.32	2.78	3.45	4.31
9	2.46	2.91	3.44	4.20	5.16
10	3.04	3.56	4.14	4.97	6.03
11	3.67	4.24	4.89	5.79	6.92
12	4.33	4.96	5.66	6.63	7.84
13	5.03	5.72	6.47	7.51	8.80
14	5.78	6.50	7.30	8.39	9.74
15	6.56	7.32	8.16	9.30	10.7
16	7.37	8.19	9.07	10.3	11.7
17	8.22	9.07	9.98	11.2	12.8
18	9.10	9.98	10.9	12.2	13.8
19	10.0	10.9	11.9	13.2	14.9
20	11.0	11.9	12.9	14.3	15.9
21	12.0	12.9	14.0	15.3	17.0
22	13.0	14.0	15.0	16.4	18.1
23	14.1	15.1	16.2	17.5	19.2
24	15.3	16.3	17.4	18.7	20.4
25	16.4	17.5	18.5	20.0	21.7
26	17.8	18.8	19.9	21.2	22.9
27	19.2	20.2	21.2	22.6	24.2
28	20.8	21.8	22.8	24.1	25.6
29	22.7	23.6	24.6	25.8	27.3

TABLE 6: FOR 40 SOURCES

No. of Trunks	Loss Probability .0003	.001	.003	.01	.03
1	0.00031	0.0010	0.0031	0.010	0.032
2	0.026	0.048	0.084	0.16	0.29
3	0.13	0.20	0.30	0.48	0.74
4	0.34	0.47	0.64	0.91	1.32
5	0.62	0.81	1.06	1.44	1.97
6	0.97	1.23	1.55	2.03	2.68
7	1.39	1.71	2.10	2.67	3.43
8	1.85	2.24	2.69	3.35	4.22
9	2.37	2.82	3.33	4.08	5.05
10	2.92	3.42	4.00	4.83	5.89
11	3.50	4.07	4.70	5.62	6.75
12	4.13	4.74	5.44	6.42	7.65
13	4.78	5.44	6.20	7.24	8.54
14	5.46	6.18	6.98	8.08	9.46
15	6.16	6.94	7.78	8.94	10.4
16	6.90	7.72	8.60	9.82	11.3
17	7.67	8.53	9.44	10.7	12.3
18	8.45	9.35	10.3	11.6	13.3
19	9.27	10.2	11.2	12.6	14.3
20	10.1	11.1	12.1	13.6	15.3
21	11.0	11.9	13.0	14.5	16.3
22	11.8	12.9	14.0	15.4	17.3
23	12.7	13.8	14.9	16.4	18.3
24	13.7	14.7	15.9	17.4	19.4
25	14.6	15.7	16.9	18.5	20.4
26	15.6	16.7	17.9	19.5	21.4
27	16.6	17.8	19.0	20.6	22.5
28	17.6	18.8	20.0	21.6	23.6
29	18.7	19.9	21.1	22.7	24.7
30	19.8	21.0	22.2	23.9	25.9

TABLE 7: FOR 50 SOURCES

No. of Trunks	Loss Probability .0003	.001	.003	.01	.03
1	0.00031	0.0010	0.0031	0.010	0.032
2	0.026	0.047	0.083	0.16	0.29
3	0.13	0.20	0.30	0.47	0.74
4	0.33	0.46	0.63	0.90	1.30
5	0.61	0.80	1.05	1.42	1.95
6	0.96	1.22	1.53	2.01	2.65
7	1.36	1.68	2.07	2.63	3.39
8	1.82	2.20	2.65	3.30	4.17
9	2.32	2.76	3.27	4.01	4.97
10	2.85	3.35	3.92	4.74	5.80
11	3.41	3.97	4.61	5.51	6.65
12	4.01	4.62	5.32	6.29	7.53
13	4.64	5 30	6.05	7.09	8.41
14	5.29	6.01	6.80	7.92	9.31
15	5.98	6.73	7.58	8.75	10.2
16	6.68	7.48	8.36	9.61	11.1
17	7.39	8.24	9.17	10.5	12.1
18	8.14	9.02	10.0	11.3	13.0
19	8.90	9.83	10.9	12.2	14.0
20	9.68	10.7	11.7	13.2	15.0
21	10.5	11.5	12.6	14.1	16.0
22	11.3	12.3	13.5	15.0	17.0
23	12.1	13.2	14.4	15.9	17.9
24	13.0	14.1	15.3	16.9	18.9
25	13.8	15.0	16.2	17.8	20.0
26	14.7	15.9	17.1	18.8	20.9
27	15.6	16.8	18.1	19.8	21.9
28	15.5	17.7	19.1	20.8	23.0
29	17.5	18.7	20.0	21.8	24.0
30	18.4	19.7	21.0	22.8	25.0

TABLE 8: FOR 100 SOURCES

No. of Trunks	Loss Probability .0003	.001	.003	.01	.03
1	0.00030	0.0010	0.0030	0.010	0.031
2	0.025	0.046	0.081	0.16	0.29
3	0.13	0.20	0.29	0.46	0.73
4	0.32	0.50	0.62	0.89	1.28
5	0.59	0.78	1.02	1.39	1.91
6	0.93	1.18	1.48	1.96	2.60
7	1.32	1.63	2.01	2.57	3.31
8	1.75	2.12	2.56	3.22	4.07
9	2.22	2.65	3.16	3.89	4.86
10	2.73	3.22	3.78	4.60	5.66
11	3.25	3.80	4.43	5.33	6.48
12	3.81	4.41	5.10	6.07	7.34
13	4.40	5.05	5.79	6.82	8.19
14	5.01	5.71	6.51	7.60	9.05
15	5.63	6.38	7.21	8.41	9.92
16	6.26	7.07	7.95	9.22	10.8
17	6.92	7.78	8.70	10.0	11.7
18	7.60	8.48	9.48	10.9	12.6
19	8.29	9.22	10.2	11.7	13.5
20	9.00	9.97	11.0	12.5	14.4
21	9.70	10.7	11.8	13.4	15.4
22	10.4	11.5	12.6	14.2	16.3
23	11.2	12.3	13.2	15.1	17.2
24	11.9	13.1	14.3	16.0	18.1
25	12.7	13.8	15.1	16.9	9.1
26	13.2	14.6	15.9	17.7	20.0
27	14.2	15.5	16.8	18.7	21.0
28	15.0	16.3	17.7	19.6	21.9
29	15.8	17.1	18.5	20.5	22.9
30	16.6	17.9	19.4	21.4	23.9

the well-known Erlang model by its limited number of sources, which becomes a parameter adding an extra dimension to the traffic table.

When the authors attended a programming course (in "Usercode") for the KDF9 computer at Sydney University, the compilation of Engset tables was undertaken as a useful practical excercise. The resultant computer programme has been used to calculate tables around useful ranges of the basic parameters. See Tables 1 to 8. No other numerical tabulation of Engset tables is known, and the graphical results available in the Philips Telecommunication Review (Ref. 2) are neither convenient to use nor do they cover the range we desire.

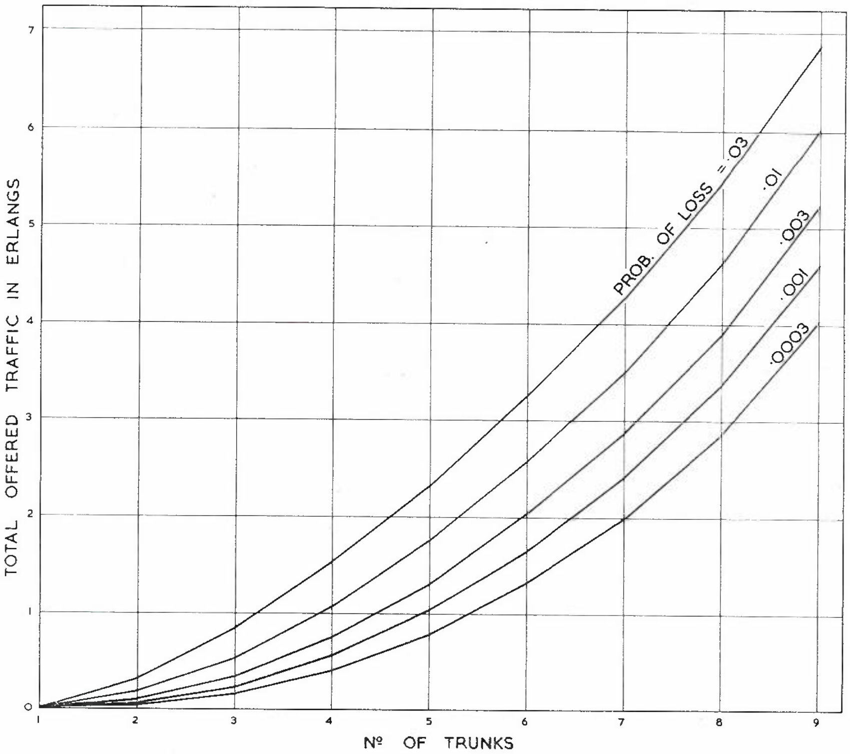

Fig. 1 — For 10 Sources.

The results have also been graphed in two ways — with curves for each grade of service applied to a fixed number of sources (for example see Fig. 1), or with curves for each number of sources applied to a fixed grade of service (for example see Fig. 2). Copies of the full set of graphs (11 sheets) may be obtained from the authors by readers who have some use for them.

The accuracy of the tables has been checked where possible by comparison with the Philips graphs and by comparison with the standard Erlang tables to which the Engset results are asymptotic as the number of sources increases without limit.

Appendix 1 describes the mathematical basis of the tables. The postulated conditions are fairly realistic in application to small groups of lines connected to a simple crossbar line switching stage or to a simple relay matrix line switching stage, although the calculated congestion will usually be higher than in a real system because the source traffics are not identical in a real system, but distributed over a range; and for other reasons.

It is understood that the Australian Post Office does not use the Engset formula except in special cases. They have some interest in developing a traffic table for very small exchanges; which would be more akin to the Engset than the Erlang model, but likely to

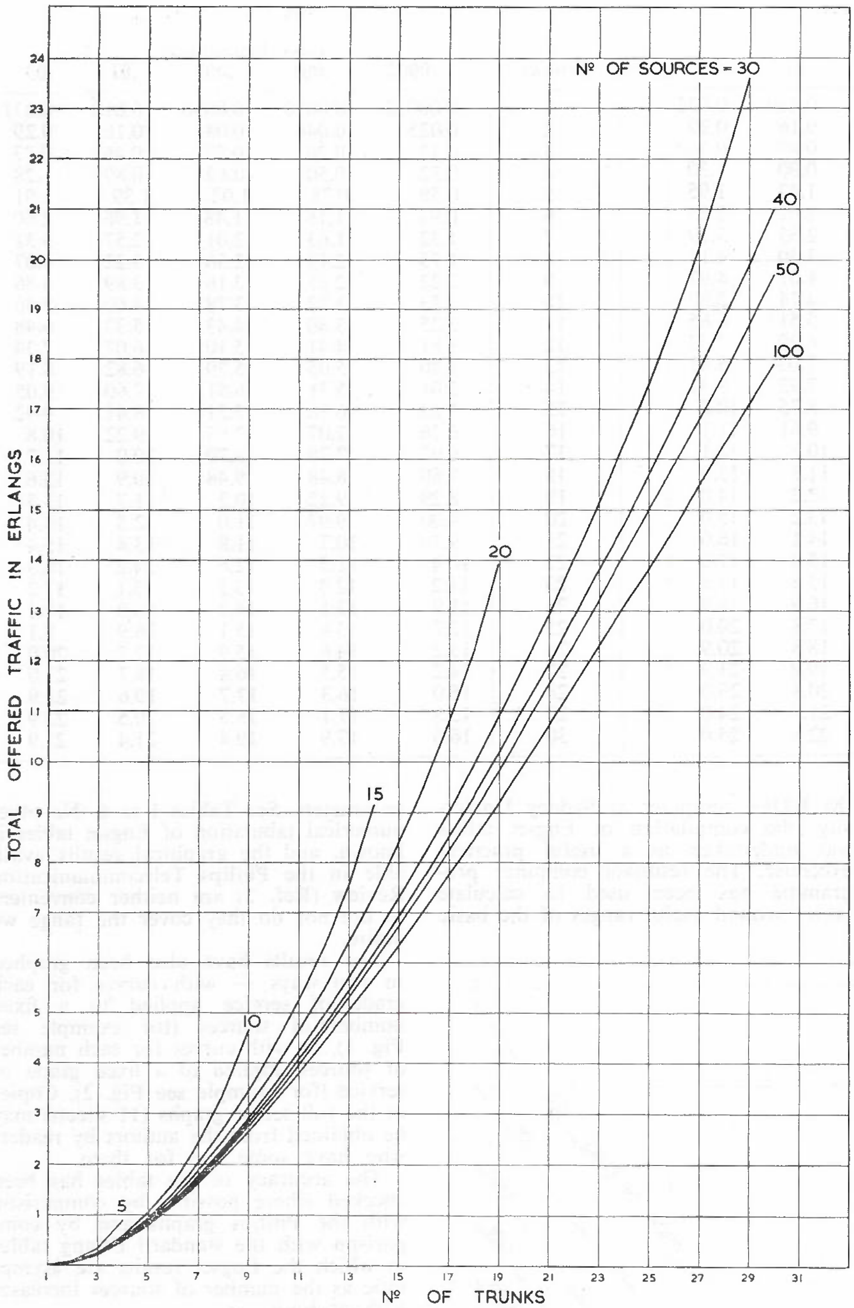

Fig. 2 —. For Probability of Loss = 0.001.

include allowances for non-uniformity of traffic sources, for the effect of the number of free sources being reduced by two for each local call and for the effect of repeated attempts. It appears that on the American scene, when dealing with traffic from limited sources either the Engset or binomial distribution may be used but entered with half the actual number of sources to account for these effects. This empirical arangement appears to work satisfactorily.

It is desired to acknowledge the assistance of the Basser Computing Department of Sydney University, and helpful discussions with various Post Office engineers. The permission of the Managing Director, Telephone & Electrical Industries Pty. Ltd., for publication of this paper is also gratefully acknowledged.

REFERENCES

1. T. Engset, "Die Wahrscheinlichkeitsrechnung zur Bestimmung der Wahleranzahl in automatischen Fernsprechaemtern;" E.T.Z. 1918. Vol. 31, Page 304.

2. M. M. Jung, "Loss probability charts calculated with the formula of Engset;" Philips Telecommunication Review, 1962, Vol. 23, No. 4, Page 186.

APPENDIX I

MATHEMATICAL BASIS OF THE TABLES

Engset's formula is concerned with traffic offered to a group of trunks by a finite number of sources. It is applicable under the following conditions:

1. The sources are independent of each other, i.e. the chance that a certain source will originate a call is independent of the state of the other sources.
2. All sources have the same traffic intensity.
3. The inter arrival time distribution of the sources are not subject to any requirements other than implicit in condition 1.
4. The holding time distributions are not subject to any requirements.

The Engset loss formula is:

$$B = \frac{\binom{S-1}{N}\left\{\frac{a}{1-a\,(1-B)}\right\}^{N}}{\sum_{x=0}^{N}\binom{S-1}{x}\left\{\frac{a}{1-a(1-B)}\right\}^{x}}$$

where: A = total offered traffic
S = number of sources
N = number of trunks
B = probability of loss

$a = \frac{A}{S}$ = traffic offered per source

The values of a satisfying this formula are obtained by an iterative method. For fixed values of the parameters B, S, N, the right hand side of the equation is computed using a trial value of a, giving a calculated probability of loss Bc. This is then subtracted from the fixed value B, the sign of B-Bc determining whether the value of a used was too large or too small. Accordingly, a new trial value of a is obtained by adding or subtracting an increment δa to or from the last used value of a, and the computation carried out again. The technique of binary 'chopping' is employed to ensure that the successive trial values of a rapidly converge on the actual value of a. If the sequence of trial values of a used is

$----, a_{n-1}, a_n, a_{n+1}, ----,$

then $a_{n+1} = a_n \pm \delta a$

where $\delta a = \frac{1}{2}|a_n - a_{n-1}|$

The computations are carried on until $\delta a \leqslant C$, where C is a variable that is adjusted by the programme so that the desired degree of accuracy is obtained. This adjustment is carried out by another parameter of the programme, namely the required order of accuracy. When this stage is reached, the computation is terminated, the last used value of a is multiplied by S to give the total traffic, and the result printed. The programme parameters are then adjusted suitably, and the computations again carried out until all desired combinations of the parameters have been tabulated.

TRANSMISSION OF POWER WITH MICROWAVES

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INTRODUCTION

The concept of transmission of electric power by means of radio waves dates back to the turn of this century with the first unsuccessful attempts by the famous inventor Nikola Tesla (Ref. 1). Three decades later H. Noble (Ref. 1) of the Westinghouse Laboratory succeeded in transmitting several hundred watts over a distance of 25 ft. using dipole aerials during the World Fair at Chicago. Recent renewed and serious interest coincided with the advent of satellites in the late 1950's and with the evolution of new microwave power techniques. To the earlier aim of transmission of power through space has been added that of transmission of power through or along wave guides.

The progress of the most recent achievement (July-October 1964) over earlier ones is seen in the successful flight, to a height of 50 feet, of a helicopter propelled by rectified microwave power intercepted by its aerial. The power fed to the transmitting aerial was 5 kW cw. (Ref. 2).

Future scope is indicated by the fact that already 400 kW cw can be generated in the Amplitron tube (Ref. 3) and that 1,000 kW cw were expected to be developed in a new klystron under development during 1964.

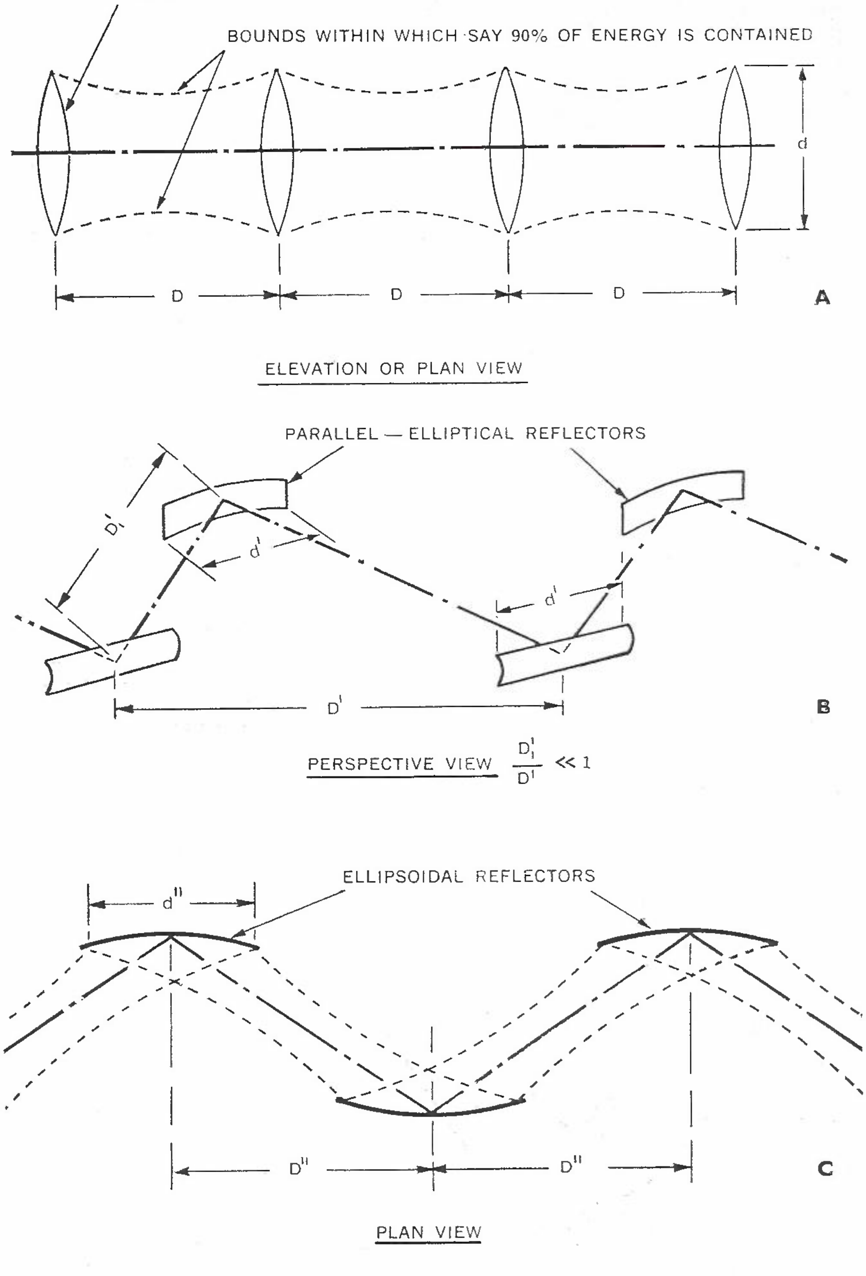
The first symposium in this new field, held by the I.E.E.E., U.S.A., in May 1964, showed that a new technology is emerging. A condensed version of this Symposium (Ref. 2) is reviewed below, following an outline of the problems involved.

THE PROBLEMS INVOLVED

In radio communications the radio frequency energy transmitted may be regarded as incidental because it is only the carrier of the desired information, the latter being conveyed by it in an encoded form. As long as a minimum power level of the carrier above the noise level (signal to noise ratio) is maintained, so that the encoded information can be transmitted and received with adequate fidelity, nothing is gained by increasing the power of the transmitted signal.

In this new field, however, it is the actual power received which is the operational system criterion. A high level cw signal has to be generated, transmitted, received and converted or rectified with a minimum of losses. Distortions of the transmitted "Signal", so important in communications, because of the high fidelity demanded, are unimportant.

Conventional power transmission at 50 c/s in three phase systems is very efficient, the losses amounting to 0.001 db per kilometer (km). Any new form of power transmission must compete with this low attenuation as well as being comparable in terms of overall capital and maintenance cost per kW. However, there are unique applications for radiated power where conventional techniques cannot be used, for example, the transmission of power upwards through space to a hovering platform and horizontally across certain types of terrain which are impassable by the conventional method. In these cases higher losses than 0.001 db/km and higher costs could well be tolerable.



IF λ = 0.11 m, d' AND D' COULD TYPICALLY BE 11 m and 330 m RESPECTIVELY

Fig. 1 — Three Types of Beam Waveguide.

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The power levels being transmitted over high voltage transmission lines today are hundreds of megawatts and more, the latest development by the conventional method being a 700 kV line which will transmit 4 GW over two three-phase circuits in parallel. For comparison the 132 kV and 220 kV lines between Yallourn and Melbourne can transmit on the average 100 MW and 250 MW respectively on each three phase circuit of which there are at present four at 132 kV and four at 220 kV totalling to some 1,400 MW for average loading. For short term peak loading they could probably carry twice as much power i.e. 28 GW.

Before the development of microwave power tubes capable of generating 200 kW and 400 kW (and by now possibly 1,000 kW) in one tube, there was no real incentive to investigate low loss transmission and high efficiency RF conversion to lower frequencies or rectification to DC. Now that high power tubes are a reality, research in these two fields has already resulted in new ideas and devices. It is stated that progress in the high power field is necessarily slow because of the high cost of the devices and experiments involved.

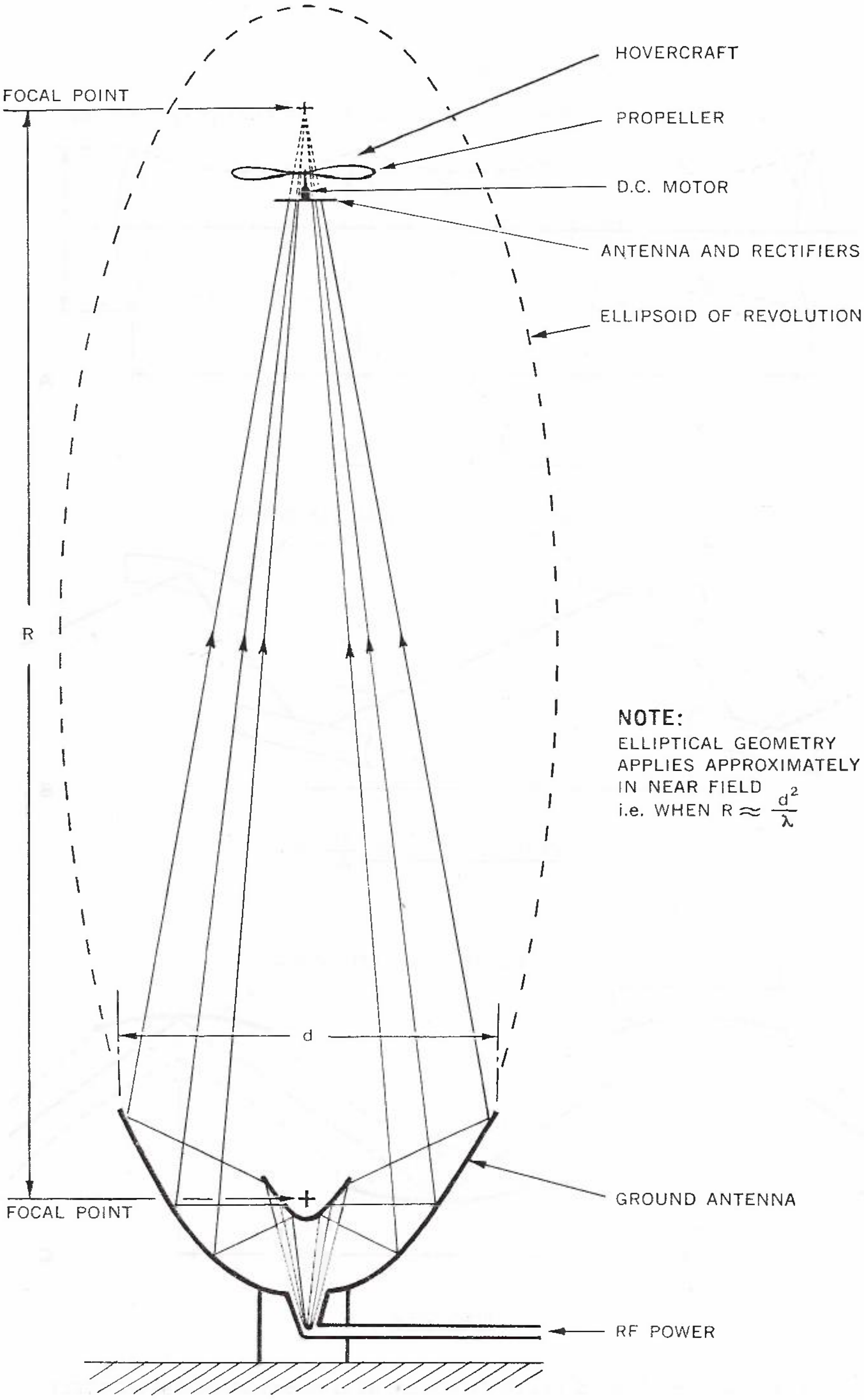

Fig. 2 — Schematic of the Hovercraft Experiment.

The main difficulties with high power tubes are the life of the cathode, the DC to RF conversion efficiency and the transfer of the developed power from within the tube to the guide outside through an "output window".

Transmitting the generated microwave power can be accomplished by wave-guides, surface wave lines and by free space radiation. In wave-guides the fundamental modes are too lossy while in the oversize, overmoded wave-guide, where the theoretical losses are of the same order as those for power transmission lines at 50 c/s, there is a serious difficulty in the conversion of energy at guide imperfections and bends from the low loss TE_{01} mode to others which are more lossy. From the point of view of power carrying capacity, wave guides present no major problems. Surface wave lines would need considerable reduction of losses before becoming competitive. In the radiated form all long distance transmission involving the far field has to contend with the inverse square law. A number of proposals to overcome this, beam wave guides, are reported below (Fig. 1). For beam guide launching and receiving aerials the aperture distribution will have to be Gaussian in order to confine the radiated beam to as small a diameter as possible. Providing the antenna separation is not too great, transmitting antennas directing power to hovering craft could have an elliptical reflector rather than a paraboloidal one in order to concentrate the radiated energy to the smallest possible volume near the second focal point of the ellipsoid (Fig. 2), thereby allowing the receiving aerial to be made small and thus light in weight.

Direct rectification of RF energy to DC is another new field to microwave engineering. The presently achieved efficiency with conventional devices of 50% will have to be improved upon. Existing devices can only handle low levels of power. Completely new devices have to be developed to handle medium and large power levels.

Another problem to be overcome is the serious interference potential to existing and future communications circuits of any practical application of microwave power transmission. Routes along which power would "flow" would have to be planned with this in mind, particularly if the form of transmission chosen is one or other of the beam guides. In this respect wave guides which form enclosed metal ducts that could even be placed below ground level, would reduce the interference problem very substantially. A further advantage of such an underground system would be its protection from accidental or intentional damage.

A further consequence of the immense interference potential would require the allocation of one or several frequency bands specifically for power transmission.

Last but not least the high levels of radiated and or guided powers involved will present a serious hazard to human and animal life.

PRESENT STATE OF DEVELOPMENT

High Power Microwave Generators

The power output at frequencies suitable for microwave power transmission (300 to 10,000 Mc/s) has increased by a factor of 25 over the last five years with the development of two types of microwave tubes: for S band frequencies (2.4-3.1 Gc/s) the Amplitron and for X band frequencies (8.2-12.0 Gc/s) the klystron. The operation of the Amplitron is based upon the continuous-cathode crossed-field interaction principle (Refs. 3, 4, 5, 6) which is also used in the more well known magnetron. It is basically an amplifier. The highest cw output powers achieved to date are 400 kW at 3.0 Gc/s with an efficiency of 70%. With higher voltages and magnetic fields, higher output powers at efficiencies up to 80% are expected. Important features of the design are a non-thermionic, secondary-emission, all-platinum cathode which should have extremely long life, a very efficient high velocity liquid cooling method dissipating several kW/sq. cm. of anode area and a novel form of output window which will eliminate both the conventional output window problem and the problems of handling large amounts of power in conventional wave-guides. The importance of efficiency is demonstrated by the following comparison. Given the same anode dissipation as in the above quoted case of 70% efficiency and 400 kW output, a tube of 80% efficiency would develop 700 kW and a tube with 90% efficiency would develop 1,500 kW. Such efficiencies have already been produced on special lower power Amplitrons. The 400 kW was obtained with a gain of 10 db; for the higher efficiencies this would rise correspondingly to 12.5 db and 16 db respectively.

The input power to the Amplitron, being 40 kW cw, can be supplied by conventional off-the-shelf klystrons for instance.

The more familiar klystron has been perfected and scaled up with less revolutionary design changes to produce 200 kW cw power at 10 Gc/s (Refs. 7, 25). Klystron gain per tube is in the vicinity of 50-60 db but overall efficiency is barely 45%. Taking an optimistic view this may perhaps be increased to 60-70%. As stated earlier a new tube expected to produce 1,000 kW was forecast for the end of 1964 but no information as to whether this was in fact achieved has been sighted to date.

A new technique using multiple beam klystrons mounted in the same vacuum envelope and employing a common cathode promises higher efficiency. Output powers equal to that of conventional tubes have already been produced (Ref. 2).

A feature of klystrons is that several can be operated in parallel. This has not been claimed for the Amplitron.

The power requirements for microwave power transmission to be competitive with conventional techniques are so great that, despite the tremendous increases of power levels of microwave tubes in recent years, new device approaches must be developed. One proposed device is an electromagnetic amplifying lens which handles input and output power in a quasi-optical fashion (Ref. 8).

Transmission Guides

There are three classes of guides:—

(i) wave-guides where the entire field is within the guide walls;

(ii) surface wave-guides, where the field is essentially on the outside of the guiding structure;

(iii) beam wave-guides where the field is in a wave beam of special field configuration which is guided by repeating the cross-sectional field distribution at periodic intervals.

Wave-guides: A rectangular wave-guide 1 m. x 0.5 m. in cross section can transmit a power of 2.5 GW in the fundamental TE_{10} mode at near breakdown field strength of dry air; a circular guide of 1 m. diameter could similarly transmit 4 GW in its dominant, the TE_{11} mode. Pressurised, both guides could transmit considerably more power. This compares favourably with the latest development of a 50 c/s 700 kV dual circuit three phase line. However, in both wave-guides the losses would be of the order of 0.3 db per km. for the lowest range of frequencies carried, i.e., aproximately 300 Mc/s and more at higher frequencies in the fundamental mode. This means that over a distance of 10 km. (6 miles) 50% of the energy is lost. Such a loss is some two orders of magnitude too high. Hope for a brighter prospect for wave-guides is the claim that the attenuation of most modes, even those in rectangular guides, theoretically decreases with frequency if the frequencies are sufficiently high (Ref. 9).

The circular guide TE'_{on} modes in oversized guides have theoretical losses of about 0.01 db per km., but the suppression of mode conversion is a formidable problem. Although the mode conversion in the TE_{01} mode has been overcome for communications purposes, experts are careful in their prediction that "the outlook is not encouraging".

For a re-entrant oversized wave-guide less than 1.5 m. diameter at theoretical loss of 0.001 db per km. at 10 Gc/s has been stated (Ref. 2). To achieve this the suppression of mode conversion along the entire length of the guide is needed. Here too the prospects are not yet bright (Refs. 11, 12).

Surface Wave-guides: This type of guide has launcher and collector losses; conductivity and dielectric losses, as well as radiation losses where the line changes direction (Refs. 13, 14, 15). For a 1 cm. diameter conductor with 1 mm. cover of dielectric all losses would amount to 2.35 db per km. at a frequency of 300 Mc/s. Being open the line is affected by weather conditions, particularly ice, sleet and above 1000 Mc/s also by rain. However, its construction is cheap compared with say a 1 m. diameter wave-guide and hence it may have special applications over limited distances. One possibility as yet not stated is its application to the hovering vehicle.

Beam Wave-guides: These are relatively recent inventions whose object it is to constrain a beam of radiated energy within a volume of constant diameter in order to overcome the inverse square law (Refs. 16, 17, 18). This is achieved at the cost of providing at regular intervals lens-shaped "phase transformers" (Fig. 1A), or, using reflective techniques, a pair of straight elliptical reflectors (Fig. 1B) or one ellipsoidal reflector per interval (Fig. 1C). Assuming a frequency of 3Gc/s, a double reflector arrangement as in Fig. 1B, the beam cross section d' being 10 m. x 10 m. and reflectors spaced 300 m. apart, the theoretical reflector losses using copper would be 0.003 db per km. while diffraction losses are negligible. The spacings and the losses are comparable with those of conventional power lines. The power carrying capacity would be 170 GW (Ref. 2.).

Reflector dimensions for higher frequencies would be smaller but then rain and fog would increase the transmission losses. Experiments have been made but results are not directly comparable with this relatively optimistic picture. Nevertheless, the experiments brought out the need for more efficient launchers and collectors. No information is available yet comparing the cost of such reflectors or lenses to the towers of conventional transmission lines. The interference potential of such a guide was not discussed but it is certain to be enormous and possibly insuperable except in the most remote locations.

Free Space Transmission

Under this title transmission of power to a hovering small helicopter 18 ft. up is reported in which the transmission efficiency from RF power into transmitting aerial, to RF delivered by receiving aerial (52%) is broken up in detail (Ref. 2). The conversion of received RF power to DC was 51% efficient employing close spaced thermionic diode rectifiers. The separation of both aerials is such that near field conditions apply. The distance is also sufficiently small so that the transmitting reflector can be made elliptical to advantage, rather than parabolic as illustrated in Fig. 2.

Improvement in transmission efficiency is predicted up to 90% within a few years and present RF to DC rectification efficiency of 70% with semiconductor diodes is forecast to rise to a possible 90%.

The experiment described is then scaled up to what could be achieved in range if present day maximum power tubes were used. A factor of 1,000 for the distance is given but this appears over-optimistic as it takes no account of the changed aerodynamic environment at a height of 18,000 ft. nor of the required aerial diameter which, scaled up, would have to be some 90 ft. in diameter.

Flying a model six-foot helicopter on guide wires to a height of 50 ft. was demonstrated on 28th October, 1964, at Raytheon's Spencer Laboratory where the demonstration described above also took place. Beside the fact that 5 kW were supplied to the aerial and that thousands of tiny diodes were used in a special "rectifying antenna" little other information is available about this experiment. It is stated that it is quite feasible to cause the vehicle to automatically hover over the radiated beam (beam riding). The prediction that with a 400 kW Amplitron a helicopter could be flown to a height of 50,000 ft. should again be treated with caution for similar reasons to those stated above.

Amongst the applications of this new technique are listed television transmission, missile detection, aviation beacons, navigational and weather aids, surveillance, and last but not least hovering platforms of laser communications systems above the turbulence of the atmosphere.

Against this it is interesting to note one author's scepticism: "Contingent upon finding suitable applications, the growth of this new technology could be most rapid."

RECTIFICATION OF MICROWAVE POWER

Direct conversion of microwave energy into DC power is a new development, probably because there was no need for it until its desirability emerged in connection with microwave power transmission.

Both thermionic and solid state diodes have been used so far. Their characteristics are compared in Table 1.

The low impedance property allows a DC motor to be driven directly between anode and cathode, although with semiconductor diodes a bridge rectifying circuit is usually used. Series connection of many diodes in the bridge circuit results in higher impedance source.

In hover craft the potential aerospace applications require a non-directional antenna. This makes it desirable to break up the total antenna aperture into a large number of separately terminated small-aperture functions. Hence the term rectifying antenna or "rectenna" (Ref. 19). A plane reflector plate is mounted a quarter wave length behind the small dipoles to increase the efficiency.

For the rectification of power levels in the order of MW or GW the need for radically new methods was immediately obvious. One of the first steps forward recognised the reversibility of the DC to RF conversion in the magnetron. This proposal is, however, not a success because of the difficulty of freeing electrons against the opposing DC field (cathode positive, anode negative).

This difficulty is avoided in injected beam crossed-field devices such as klystrons and travelling wave tubes (Ref. 20). A particular form of the latter, a backward wave oscillator, has been run as an RF to DC converter and was quite successful. Efficiency was 40% giving out 160 W. Along similar lines a klystron RF to DC converter has been proposed with a computed efficiency of 60-80% (Refs. 21, 22). In another proposed form of klystron rectifier, RF energy is used in three inputs to provide heater power, launcher power and acceleration power. No efficiencies are stated, nor is it evident if this idea has been tried out.

A "multipactor" (for multiple electron impact) rectifier utilises secondary emission on the perforated electrode surfaces in the RF field where an electron cloud is made to oscillate between and impact on the electrodes, thereby generating secondary electrons which constitute the discharge DC current (Ref. 23, 24). Half wave and full wave rectification is possible. Efficiencies around 59% are indicated if losses in the re-entrant RF cavity can be neglected. Adding an axial DC magnetic field and an RF phase shifter for a second cavity the efficiency is expected theoretically to rise to 92% neglecting cavity and waveguide losses. The idea of phase changing may eventually lead to polyphase rectifiers. The multipactor appears to be a promising new rectifier having both high peak and high average power capability (MW and kW respectively).

The obvious conclusion is that high power rectifying devices are still in the early stages of development.

TABLE 1

Characteristic	Close-spaced Thermionic Diode	Point-contact Semiconductor Diode
Internal impedance	low	low
Upper frequency limit	≈ 3 Gc/s	> 3 Gc/s
RF to DC efficiency	≈ 40-50%	> 50% up to 70%
Power handling capacity	good (900 W. from one) (QR 1222)	low (several mW)

CONCLUSION

Of the three main fields: generation, transmission and rectification of microwave power the first named is presently the most advanced and the other two follow in the order stated.

Microwave tubes developing 400 kW exist and 1,000 kW tubes are "around the corner". Research work is being done to produce yet higher power tubes.

Power transmission with wave-guides offers high capacity circuits but in the fundamental and dominant mode their attenuation is too high whereas in oversized over-moded guides, although the attenuation becomes acceptable, another serious problem, that of mode conversion, is still unsolved. Power transmission by surface wave lines is so lossy that it has application only for very short distances and then only when weather conditions permit. Power transmission with beam wave-guides offers theoretically an optimistic picture as far as losses and power carrying capacity is concerned but costs are probably rather high. Much further experimental work is needed to confirm the theory.

Power transmission by radiation through space to a hovering craft does not have to be so competitively efficient as the guided transmission of power along the earth. An overall DC to DC efficiency of 20% over distances up to 50 ft. has been achieved. This is the field which is likely to see the first applications of the new technique. The prediction of helicopters being flown to a height of 50,000 ft. with presently available components appear over-optimistic extrapolations of the small scale experiment using guide wires.

Direction rectification of microwave power being logically the latest field to be investigated is in fact the least advanced at the present moment. The close-spaced thermionic diode and semiconductor rectifiers appear to be able to cater for the demands of power for hovering craft with efficiencies between 50-70%. For high power rectification, however, there is no device as yet but a range of new ideas and devices is under very active development. The most promising from the point of view of efficiency and power handling capacity is the electrostatically focused klystron and the multipactor.

In the high power device field the rate of progress is not likely to be very rapid because of the large costs involved.

So far little attention has been given in the literature to the potential interference to existing and future communications facilities by high power microwave transmission.

REFERENCES

1. W. C. Brown, "History of Microwave Power Transmission and the Microwave-Powered Helicopter", Wire and Radio Communications, Nov. 1964, pp. 76-89.
2. E. C. Okress et. al., "Microwave Power Engineering"; I.E.E.E. Spectrum, Oct. 1964, pp. 76-100.
3. W. C. Brown and G. Perloff, "High Power CW X-Band Amplitron", 1960 IRE International Conv. Record, Vol. VIII, pt. 3, pp. 52-55.
4. W. C. Brown, "The Amplitron, A Super Power Microwave Generator", Electronic Progress, Raytheon Co., Burlington, Mass., July-August, 1960.
5. G. E. Dombrowski, "Theory of the Amplitron," IRE Trans. on Electronic Devices, Vol. ED-6, October, 1959, pp. 419-428.
6. W. A. Smith and F. A. Zawada, "A 3-Megawatt, 15-Kilowatt S-Band Amplitron", Microwave J., Vol. 2, Oct. 1959.
7. R. B. Nelson and F. O. Johnson, "Klystron CW Power Generation," Proc. Special Symp. on Electron. Power, IEEE Region III Annual Meeting and Technical Conference, Clearwater, Fla., May 2-6, 1964.
8. W. C. Brown and G. E. Dombrowski, "Analysis of a New Crossed Field Amplifier, the EAL or Electromagnetic Amplifying Lens," IRE Trans. on Electron Devices, Vol. ED-9, Mar. 1962, pp. 221-228.
9. A. E. Karbowiak, "Guided Wave Propagation in Submilli-metric Region"; Proc. IRE, Vol. 46, Oct. 1958, pp. 1706-1711.
10. N. Marcuvitz, Waveguide Handbook, Radiation Laboratory Series, Vol. 10. New York; Mc-Graw-Hill Book Co., Inc., 1951.
11. G. Goubau, "Limitations of High Power Waveguide Transmission"; Proc. Special Symp. on Electron, Power, op. cit.; see also ref. 44.
12. H. M. Barlow, "The Relative Power Carrying Capacity of High-Frequency Waveguides"; Proc. IEE (London), Vol. 99, pt. III, Jan. 1952, pp. 21-27; Sept. 1952, pp. 323; see also ref. 13.
13. G. Goubau, "Surface Waves and their Application to Transmission Lines"; J. Appl. Phys., Vol. 21, pp. 1119-1128.
14. G. Goubau, "Designing Surface-Wave Transmission Lines"; Electron, Vol. 27, April, 1954, pp. 180-184.
15. G. Goubau and C. E. Sharp, "Investigations with a Model Surface Wave Transmission Line for Long Distance Transmission"; IRE Trans. on Antennas and Propagation, Vol. AP-5 April 1957, pp. 222-227.
16. G. Goubau and F. Schwering, "On the Guided Propagation of Electromagnetic Wave Beams"; Ibid., Vol. AP-9, May, 1961, pp. 248-256.
17. J. R. Christian and G. Goubau, "Experimental Studies on a Beam Waveguide for Millimeter Waves"; Ibid., pp. 256-263.
18. J. Degenford, W. Sirkis and W. Steier, "The Reflecting Beam Waveguide"; 1964 IEEE International Conv. Record, Vol. XII, pt. 2, pp. 132-142.
19. R. H. George, "Solid State Microwave Rectification"; Proc. Special Symp. on Electron. Power," op. cit.
20. "Microwave Rectifier Tube," Electron. Design, Aug. 3, 1960, pp. 58-99.
21. S. P. Yu, "Electrostatically Focused Microwave Klystron Rectifier"; Proc. Special Symp. on Electron. Power, op. cit.
22. E. M. Sabbagh et al., "Microwave Energy Conversion"; WADD Tech. Rept. No. 61-48, pt. I, ASTIA, New York, N.Y., April 1961.
23. P. P. Keenan, "A High Level Microwave Rectifier"; Proc. Special Symp. on Electron. Power, op. cit.
24. M. P. Forrer and C. Milazzo, "Duplexing and Switching with Multipactor Discharges"; Proc. IRE, Vol. 50, Apr. 1962, pp. 442-450.
25. T. Moreno, "High-Power Axial-Beam Tubes"; in Advances in Electronics and Electron Physics, L. Marton, ed. New York: Academic Press Inc., Vol. XIV, 1961.

DIMENSIONING OF THE QUEUE FOR THE MELBOURNE CENTRALIZED COMPLAINTS CENTRE

*B. J. McMAHON, B.E.**

INTRODUCTION

In the classical description of queueing processes, the queue is formed as a result of the congestion which occurs at a service point when the number of customers requiring service exceeds the number of available servers. In order that a mathematical model of this queueing process can be formed, three distinct features of the service must be defined. These are the input and service mechanisms, and the queue discipline.

The simplest mathematical model which can be defined is useful both in a range of direct applications, and as a starting point in the development of models for more complex processes. The properties which define this model will be discussed and some results quoted. The modifications necessary to extend the simple model to one which describes the queue which occurs at a telephone complaints centre will then be discussed. The method of application of this theory to the dimensioning of the Complaints queue is then discussed, and an appraisal of the performance of this queue is made. The design and operational aspects of the Complaints queue are the subject of a companion paper (Ref. 1).

SIMPLE QUEUE MODEL

The model is defined by specification of the input and service mechanisms, and the queue discipline. It is based on service from only one point, with all inputs to this point coming from one population of customers.

The Input Mechanism: The pattern of arrivals is assumed to be completely random. This assumption leads to a simple mathematical solution, and it is commonly found to be a close approximation to the actual pattern of arrivals. The fundamental property associated with completely random arrivals is that the probability of an arrival occurring during an interval of time is dependent solely on the length of that interval, and the average rate of arrivals. It will not be influenced by the sequence of arrivals which has occurred prior to the interval being considered. If the average rate of arrivals is λ per unit time, then the probability of one arrival between the times t and $t + \delta t$ will be $\lambda\delta t$, independent of t.

The Service Mechanism: The queue has already been postulated to have only one server. The service mechanism is fully defined by allowing this server no rest if there is any customer in the system, and by defining the service time for each customer. This service time is also assumed to be completely random, so that the probability of a customer leaving the system during an interval δt will be $\mu\delta t$, where μ is the average number of customers leaving the system in unit time.

The Queue Discipline: In the simplest queue, the discipline is that the customers will be served in order of arrival, and that no customer may leave the queue.

COMPLETELY RANDOM PROCESSES

Having defined broadly the arrival and service patterns, it will be instructive to consider the properties of the assumed distributions, before discussing the behaviour of the queue.

Since the probability of one arrival in the interval δt is $\lambda\delta t$, and the probability of more than one arrival in this interval is negligible, being of the order of $(\lambda\delta t)^2$, then the probability of no arrival occurring in the interval δt is $1 - \lambda\delta t$. From this, the probability distribution of the number of arrivals during a finite interval t_o may be found, as illustrated in Fig. 1, by dividing the interval into elements of δt, and summing the probabilities as $\delta t \rightarrow 0$. It is found that the arrival pattern for completely random arrivals follows the Poisson distribution. Thus the probability of there being r arrivals in an interval t_o is given by

$$\omega_r = (e^{-\lambda t_o}(\lambda t_o)^r)/r!$$

Since λ is the average number of arrivals in unit time, this distribution will have a mean value of λt_o, and it is discrete, having meaning only when r is zero or positive and integral.

An alternative way of considering this arrival pattern is in terms of the distribution of inter-arrival times. This will be a continuous distribution and its characteristics can be evaluated from the assumptions already made. The probability of an inter-arrival time x is given by the negative exponential distribution

$$\varepsilon(x) = \lambda e^{-\lambda x}.$$

Since arrivals occur at an average rate of λ, the mean interval between arrivals is $1/\lambda$, and this is the mean value of the distribution $\varepsilon(x)$. The maximum value of the distribution will occur when $x = 0$, and decreases exponentially with increasing x. Thus the short intervals will be relatively frequent, and there will be a tendency for arrivals to occur as groups in which the individuals are separated by fairly short intervals.

A further property of the random arrival pattern which is often useful in the distribution of intervals from one arrival to the k^{th} succeeding arrival. This is found to be the distribution $\theta(x)$, where

$$\theta(x) = (\lambda(\lambda x)^{k-1}e^{-\lambda x})/(k-1)!$$

The equivalence between the two distinct views of the random process, resulting in the Poisson and negative exponential distributions, should be emphasised. In many cases the characteristics of a service mechanism are more readily expressed in terms of required service times, and if these are found to have an exponential distribution with mean $1/\mu$, then the probability of completion of service in an interval δt is $\mu\delta t$. The service can therefore be treated as a completely random operation.

PROPERTIES OF THE SIMPLE QUEUE

A number of important properties of the queue which has been defined in the previous sections will now be quoted. For convenience, a term which is related to the average service and arrival times will be introduced; this is the traffic intensity, ρ, defined by
ρ = (Mean service time of a single customer)/(Mean inter-arrival time between successive customers) $= \lambda/\mu$.

The traffic intensity is a dimensionless quantity, the units of which are called erlangs (Ref. 2).

The results which are obtained by an application of queueing theory are related to an equilibrium situation which exists an infinite time after the system began operation. In general, the properties of this equilibrium condition are closely approximated by the properties measured at time t after operation has commenced, for fairly large values of t. In addition, it also provides a basis for accurate assessment of the relative pro-

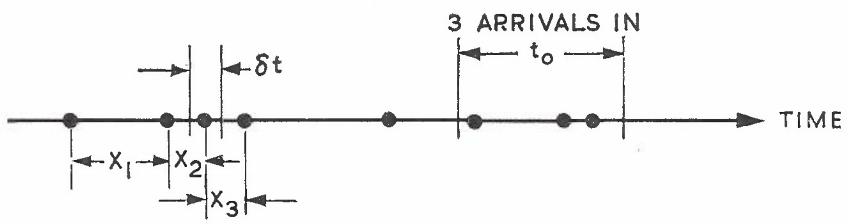

Fig. 1 — Random Arrivals.

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portions of time which the system spends in its various states.

The most important result of this theory for the single-server queue is the probability of finding the system in state A_n, in which n customers are in the system; one will be receiving service, and n — 1 will form the queue. This probability is written P_n, where

$$P_n = (1 - \rho)\rho^n.$$

When n = 0, this reduces to

$$P_o = 1 - \rho.$$

Thus, the proportion of time during which there are no customers in the system is $1 - \rho$, which will be a measure of the free time available to the server.

Additional properties which may be derived for this queue are:

1. Average number of customers in system $= \rho/(1 - \rho)$.
2. Average number of customers in the queue $= \rho^2/(1 - \rho)$.
3. Probability of more than n customers in the queue $= \rho^{n+2}$.
4. Average waiting time in the queue $= \rho/(\mu - \lambda)$.

It may be seen by substitution of particular values of ρ into these formulae, that with low values of traffic intensity, long queues are extremely unlikely. Since this situation results in having a server spending a large part of his time idle, some compromise must be made between efficient use of the server and reduction in delays to the customers.

EXTENSION OF SIMPLE MODEL TO THE COMPLAINTS QUEUE

At the Melbourne Centralised Complaints Centres, a number of operators are used to handle the incoming traffic. This number will vary, depending on the expected traffic, but at all times of interest there will be more than one operator at the Centre, and so the queue model must incorporate a number of servers. In addition, the queue length will be limited, firstly to allow for economic construction of the queueing apparatus, but also to provide better system operation. This limitation on the queue length means that some calls offered will not gain a place in the queue, but will be lost to the system. Such a system is often referred to as a loss-delay system (Ref. 3).

The inputs to the queue are provided by a large number of telephone subscribers and to a first approximation they will be acting independently. This approximation may not be justified when a significant proportion of the complaints calls results from a major fault in the network. However, the inputs can be considered to conform to the pattern of completely random arrivals assumed for the simple queue model.

The service time which must be specified for the queue is dependent on the time that it takes the operator to handle the call. Most of the Complaints traffic can be described in two categories, service and assistance calls, and these must be examined to find the overall service or holding time. A limited investigation of the holding times of complaints calls has been made, some of the results being plotted in Fig. 2. When compared with the negative exponential curve which has been drawn for the average holding time of the same calls, it can be seen that this limited sample indicates that the distribution of holding times is usefully approximated by the exponential law.

The queue model previously considered did not allow any customer to leave the queue once he had arrived. At a Complaints centre, this condition cannot be enforced, since a subscriber may occupy a place in the queue and then hang up. When the operator answers this call, it will have zero service time, and the next call will be taken immediately. In not making any allowance for this situation, it is assumed that the waiting time in the queue will be small enough to encourage the subscribers to wait for service, so that few errors will be introduced by neglecting this occurrence.

As shown in Fig. 3, the system has R operators, and Q available positions, so that a total of R + Q subscribers can be accommodated by the system before a call will be lost. The analysis of the model of this queue should result in a technique such that the values of

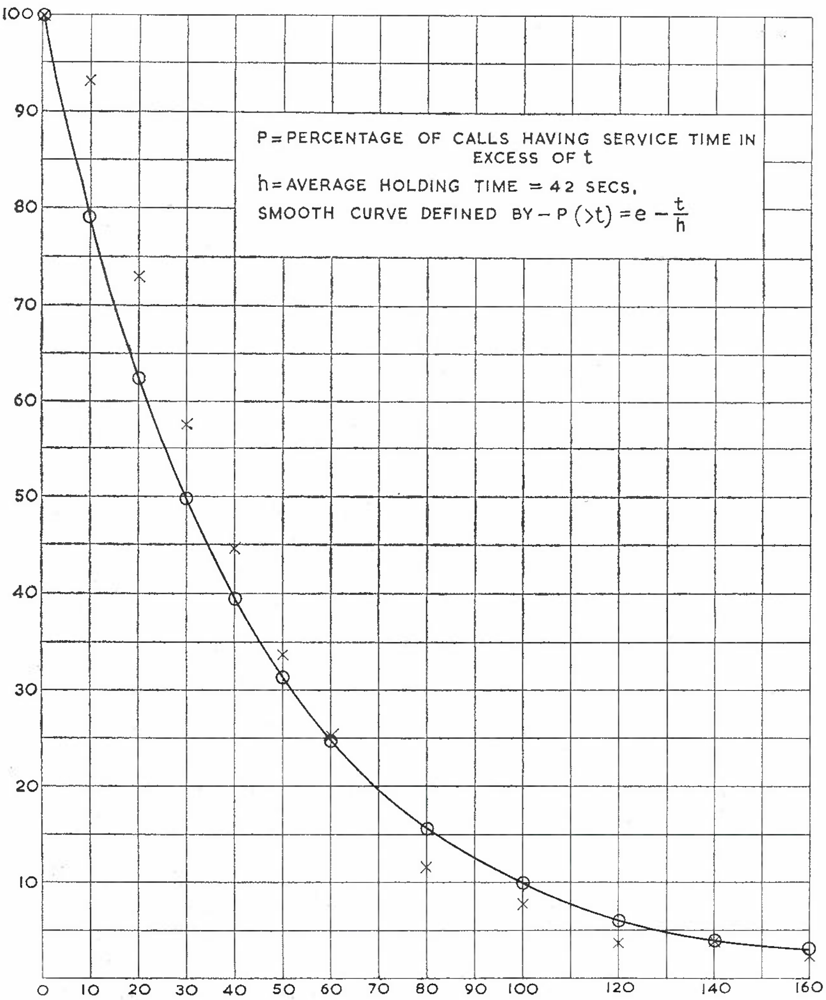

Fig. 2 — Distribution of Complaints Holding Times.

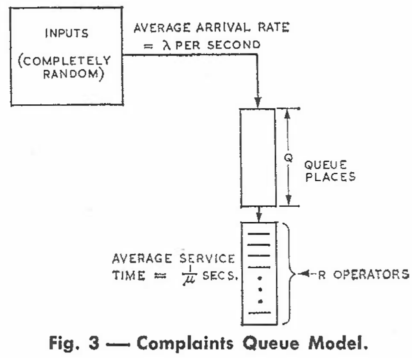

Fig. 3 — Complaints Queue Model.

R and Q can be nominated to handle an input traffic intensity ρ in some satisfactory manner. The next section will examine the basis for definition of a satisfactory standard of service.

SERVICE STANDARD OF THE COMPLAINTS QUEUE

It is usual in telephone traffic service to provide sufficient apparatus to ensure that no more than a certain proportion of the offered traffic will be lost during the "busy hour" of service. This loss is the first parameter used to define the service standard, and has been chosen as 0.002. Thus, on an average, 1 in 500 calls which arrive during the busy hour will be lost because the system is fully occupied.

The second parameter which is used to specify the service standard is related to the delay which is encountered by a call when it is taken into the queue. This may be specified as an allowable average delay, but for the Complaints Queue it has been specified by allowing only 2 per cent. of the calls to have a waiting time in excess of 12 seconds. This figure has been chosen to provide a standard of service which would obviate the need for "speed-of-answer" practice. Selection of a figure of 2 per cent. would ensure that only this proportion of calls would be delayed in excess of 12 seconds during the period for which traffic existed at the assumed level. The overall figure would be less than 2 per cent. by a factor dependent upon the ratio of the traffic in the non-busy period to that occurring in the "busy-hour".

PROPERTIES OF COMPLAINTS QUEUE MODEL

A summary of the terms and symbols used for this model is listed here for convenience.

ρ = Traffic Intensity offered to system (Erlangs).

λ = Average number of calls per second during busy hour.

$1/\mu$ = Average holding time of calls (seconds).

R = Number of operators serving the queue.

Q = Number of queue positions.

L = Proportion of calls lost to the system.

W(t) = Probability that if a call were offered, it would be delayed by a time $\geqslant$ t.

P(n) = The probability that there are n calls in the system.

A = ρ/R = Traffic Intensity per operator.

As with the simple single-server queue, the basic property of this queue is the probability of n customers being in the system, P(n). The method by which the distribution of P(n) is found will be outlined, and the useful results derived from this distribution will be quoted. It has been seen that the queue has two modes of operation, and the mathematical solution is based on consideration of these modes.

(i) When some servers are idle; that is, when $n < R$.

The probability of there being n customers in the system at time $t + \delta t$ is related to the condition of the system at time t in the following way:

$P(n, t + \delta t)$ = Joint probability of $n - 1$ customers at time t, one arrival and no departures in δt

+ Joint probability of n customers at time t, no arrival and no departures in δt

+ Joint probability of $n + 1$ customers at time t, no arrival and one departure in δt

$$= P(n-1, t)\lambda\delta t(1 - n\mu\delta t)$$
$$+ P(n, t)(1 - \lambda\delta t)(1 - n\mu\delta t)$$
$$+ P(n+1, t)(1 - \lambda\delta t)(n+1)\mu\delta t.$$

In this analysis, all terms involving $(\delta t)^2$ are considered negligible, which allows us to neglect terms involving more than one arrival or departure in the interval δt.

Collecting terms and proceeding to a limit as $\delta t \rightarrow 0$

$$\frac{dP(n, t)}{dt} = P(n-1, t)\lambda - P(n, t)(\lambda + n\mu) + P(n+1, t)(n+1)\mu.$$

The situation under consideration is assumed to be a steady state, so that this derivative must be zero, that is, the state probabilities will be independent of time t. Thus,

$$0 = \lambda P(n-1) - (\lambda + n\mu)P(n) + \mu(n+1)\ P(n+1) \ \ldots \ (1)$$

(ii) When all servers are busy; $R \leqslant n$.

In this case, the basic relationship remains the same, but since the customers waiting in the queue are not allowed to leave the system, the probability of a departure will be related to the number of customers being served R, rather than the general number of customers n.

Thus,

$$P(n, t + \delta t) = P(n-1, t)\lambda\delta t(1 - \mu R\delta t) + P(n, t)(1 - \lambda\delta t)(1 - \mu R\delta t) + P(n+1, t)(1 - \lambda\delta t)\mu R\delta t.$$

Again, by collecting terms, proceeding to the limit, and equating the time derivative to zero, the following relationship is found,

$$0 = \lambda P(n-1) - (\lambda + \mu R)P(n) + \mu R P(n+1) \ \ldots\ldots\ldots \ (2)$$

The equations (1) and (2) describe the relationship between the state probabilities in the two operating modes of the queue. However, since $P(n-1)$ has no meaning when $n = 0$ and $P(n+1)$ has no meaning when $n = R + Q$, since the system cannot have less than zero or more than $R + Q$ customers, two additional equations must be obtained for a satisfactory description of the end states. These are developed in exactly the same way as the basic equations, and are found to be

$$0 = \lambda P(0) - \mu P(1) \ \ldots\ldots\ldots\ldots\ldots \ (3)$$
$$0 = \lambda P(R + Q - 1) - \mu R P(R + Q) \ \ (4)$$

Since the system under consideration is real, it must always exist in one of the possible states; thus,

$$\sum_{n=0}^{R+Q} P_n = 1 \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (5)$$

The method of solution of the equations (1) to (5) is to find P(1) in terms of P(0) from equation (3) and substitute this in equation (1) for successive values of n. This gives a solution for P(n) in terms of P(0), and the normalising condition (equation (5)) is then used to find the actual values. The results are more useful, however, in terms of P(R), and this form will be used here. Thus

$$P(n) = (R!/n!)\rho^{n-R}P(R)$$
$$0 \leqslant n < R \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (6)$$
$$P(R + n) = A^n P(R)$$
$$0 < n < Q \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (7)$$

where $P(R) = 1/[1/E_R(\rho) + A(1 - A^Q)/(1 - A)]$ .... (8)

and $E_R(\rho) = \rho^R/[R!(1 + \rho + \rho^2/2! + \ldots + \rho^R/R!)]$ .... (9)

Equation (9) defines the Erlang Loss Formula.

From this solution of the state probabilities of the system, the two useful properties of the model can be derived.

Probability of Loss, L: The probability of a call being lost will be equal to the probability that all places in the system are full. Thus, from equation (7),

$$L = P(R + Q) = A^Q P(R). \ \ldots. \ (10)$$

Probability of Excess Waiting Time, W(t): The exact solution for W(t) consists of a summation of the joint probability of having K calls in the queue with K or fewer calls receiving service in time t. Thus

$$W(t) = P(R)\sum_{K=0}^{Q-1} A^K(1/K!)\int_{\mu tR}^{\infty} x^K e^{-x}dx.. \ (11)$$

An approximate solution for W(t), which is sufficiently accurate for low values of loss L, is given by

$$W(t) = P(R)e^{-(1-A)\mu tR}/(1 - A) \ \ldots \ (12)$$

DIMENSIONING OF THE COMPLAINTS QUEUE

The Service Standard which has been chosen for the Complaints queue can now be used to select appropriate values of Q and R for various levels of traffic intensity ρ.

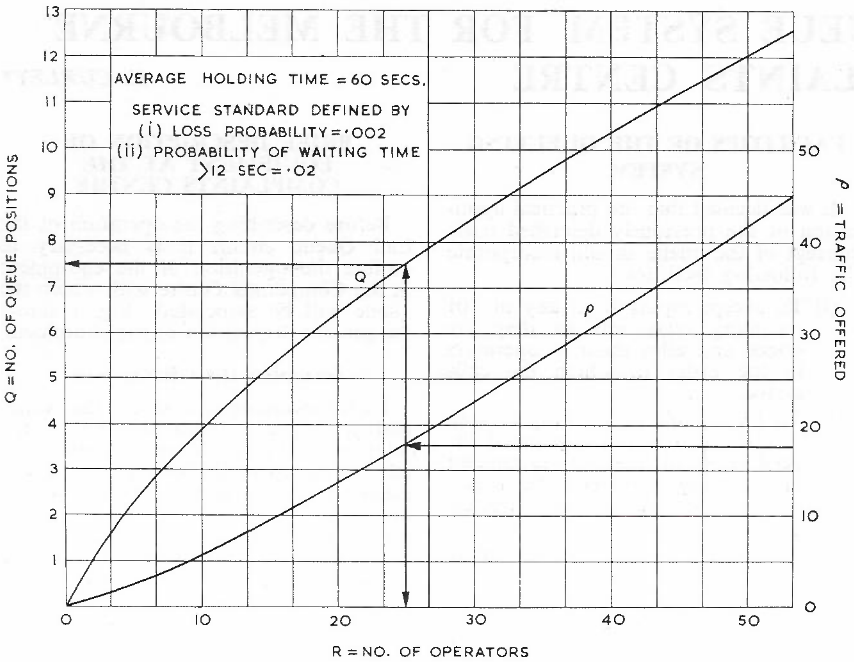

Fig. 4 — Queue Design Parameters.

It may be seen from equation (10) that if the loss probability L is to be 0.002, then extending the queue length Q would allow a larger value of A to be tolerated, since this will have a second order effect on P(R). However, this would result in an increase of W(t). Since W(t) must be made equal to 0.02, there will be a unique pair of values of Q and R which will satisfy equations (10) and (12) simultaneously. These have been calculated for traffic levels from 0 to 45 erlangs, and the results are plotted in Fig. 4. This figure can be used by entering on the Traffic ordinate at the required level, and drawing a horizontal line to meet the ρ curve. A vertical line is then drawn through this point to cut the R ordinate and the Q curve. The values of Q and R appropriate to this traffic level ρ are then read directly from the ordinate scales.

PERFORMANCE APPRAISAL

In this section an examination is made of the differences between the ideal queueing device assumed in the model, and the actual device which has been used (Ref. 1). The effect of these differences on the standard of service realised by the queue can then be predicted.

It may be seen from the description of the operation of the queue that it will take a finite time for a call to be given a position in the queue, and also for an operator to obtain a call from the queue. This processing time may lead to incorrect placement of calls in the queue, and can be assumed to have an average value of approximately 0.85 seconds. To determine the effect of this departure from the ideal models, a specific traffic level must be assumed, together with a queue designed for this traffic. Suppose the traffic offered is 18 Erlangs, and the average holding time is 60 seconds. From Fig. 4, the required values for R and Q will be $R = 25$ and $Q = 8$.

The random traffic input will, as noted above, provide a Poisson distribution of the number of calls arriving in time t_0. When t_0 is given the value of 0.85 seconds, it is found that:

- the probability of 2 calls arriving in an interval $t_0 = 0.0251$,
- the probability of 3 calls arriving in an interval $t_0 = 0.0021$,
- the probability of 4 calls arriving in an interval $t_0 = 0.0001$.

Since the inputs are assumed to be derived from pure chance traffic, then these calls under consideration must be assumed to be dispersed among all the levels of traffic which can occur about the assumed average level. Thus the calls given the wrong queue position by one, two, or three places, will not be seriously affected when there is no queue length but all operators are busy. Consideration of the probability of finite queue lengths will then indicate whether the probabilities listed above are likely to seriously degrade the service.

The probability of a call arriving when there is a finite queue length may be found from equation (7). It is found that the chosen service standard results in a queue which has calls waiting for about 6 per cent. of the time. Thus the joint probability of incorrect queue placement with a substantial queue length will be very small. The degradation of service due to the finite processing time will therefore be small for this assumed traffic.

The restriction of queue length in a properly dimensioned queue is also important in determination of the waiting time of delayed calls. When Q and R have the correct design values, the terms in the summation of equation (11) have low values when $K \rightarrow Q - 1$ compared with the total sum. Thus the addition of further terms to this summation, which must be done to account for an increase in the queue length, will have only a minor effect on W(t).

However, when the system is changed by an increase in traffic, without any change in the number of operators, the change in the characteristics of the delay will be dependent on the queue length provided.

Referring to the waiting time equation (11), it can be seen that the probability of excess waiting time is directly proportional to P(R), the probability of all operators being busy with no calls waiting. To a first approximation, equation (8) may be written

$$P(R) \simeq E_R(\rho).$$

In the situation being considered. P(R) will increase since ρ has increased and R has been kept constant. With this increase in traffic. the sum of terms in equation (11) will also increase, due to the influence of A^K. In addition, the terms for $K \geqslant Q$ would now constitute an important part of the total. All these factors will tend to increase W(t), and a specific example will illustrate the relative importance of these factors.

For any traffic level, the design figure of 0.02 for W(t) is made up of $P(R) \simeq 0.025$, and the summation of equation (11) which is approximately 0.8. If the traffic A now increases by 10 per cent., P(R) will approach 0.05. For 25 operators and a queue length of 8, this would cause W(t) to be 0.05. If, however, the queue length was allowed to become 25, the summation term would then more than double its original value and be 1.8, causing $W(t) \simeq 0.09$. Thus, with this excessive queue length, a 10 per cent. increase in traffic causes 4.5 times the desired proportion of calls to encounter a waiting time in excess of 12 seconds.

CONCLUSION

A procedure for the dimensioning of a multiple-service queue with a known service time, randomly distributed, has been found. The mathematical model on which this method is based is an accurate representation of the queue at a Telephone Complaints centre, and is representative of a number of queueing situations found in telephone systems.

ACKNOWLEDGMENT

The results which are plotted in Fig. 2 are based on traffic studies conducted by W. D. Eccleston of the P.M.G. Victorian Engineering Division. This study also provided the basis for selection of the service standard for the queue.

REFERENCES

1. K. A. Curley, "The Electronic Queue System for the Melbourne Centralised Complaints Centre; Telecommunication Journal of Aust., Vol. 16, No. 2, June 1966.
2. Cox and Smith, "Queues"; Methuen Monograph Series.
3. Smith and Smith, "Loss and Delay in Telephone Call Queueing Systems"; A.T.E. Journal, Vol. 18, No. 1, January 1962.

THE ELECTRONIC QUEUE SYSTEM FOR THE MELBOURNE CENTRALIZED COMPLAINTS CENTRE

*K. CURLEY**

INTRODUCTION

The centralization of the Complaints services for the Melbourne network created a need for an efficient, reliable, and inexpensive system for queueing of the input calls to provide the most satisfactory switching of these inputs to the available operators. The system described in this paper fulfils these requirements, and has been operating satisfactorily since May, 1963. Although it has been designed specifically for the Complaints service, the queueing system could be readily adapted for use wherever a queueing function of this type is required.

The Centralized Complaints system allows any metropolitan subscriber to call a Complaints centre by dialling 1100. Depending on the caller's location the call is directed to one of three centres situated at the Russell, Windsor and Hawthorn telephone exchanges. The largest installation is at Russell where there are 24 operator positions serving 90 incoming trunks and handling assistance and repair requests from approximately 278,000 telephones (Ref. 1).

The basic concept of the queue, which was designed in the P.M.G. Research Laboratories, is to allot a permanent sequential code to each of the incoming relay sets, and as the relay sets are seized, to write their unique code into a slot (or position) within a memory. As operators become free, the codes are extracted from the memory in order of their time of arrival and decoded to mark the incoming relay set which is next to be served. The operator's finder then searches for the mark and connects the operator to the allotted Incoming Relay Set.

The decision to use electronic digital techniques rather than a more conventional wholly electromechanical approach to the queueing function was based on the following considerations:

(i) With either system an information store is required. The ferrite core is a cheap, reliable and space saving component that lends itself to this application.

(ii) There was a need to gain practical experience with the design of the interface between electromechanical equipment and high speed electronic switching circuits. From this aspect, much of that learned during the design of the queue has since been used in the design of other equipment where this type of interface exists.

(iii) There was also a need to introduce electronic digital techniques into field usage to familarise staff with the philosophy of this type of equipment of which much more will probably be seen in the future.

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FACILITIES OF THE QUEUEING SYSTEM

It was decided that the practical application of the previously described basic concept of the queue should incorporate the following facilities:

(i) To accept inputs from any of 101 incoming relay sets as they are seized and allot them to operators in the order in which the calls arrive.

(ii) To be capable of working in conjunction with another queue if the need arises to increase the number of incoming relay sets. 202 inputs can be catered for by this arrangement.

(iii) To provide queue positions for up to 25 calls awaiting the attention of an operator. If necessary, a shorter queue length can be arranged.

(iv) To cause busy tone to be transmitted to other callers when all queue positions are filled. Under these conditions the waiting time to other callers would be excessive if they were allowed to wait for a queue position.

(v) To be capable of working in conjunction with another queue with one queue on standby. It had been decided that two queues should be installed at Russell so that in the event of breakdown there would be no prolonged degrading of service. At the other centres where the traffic is comparatively light, the incoming calls could be answered at random for the duration of a breakdown without degrading the overall service too severely.

(vi) To arrange automatically for the queue to be removed from service and allow the operators to answer the calls in random order in the event of the following faults occurring:

- (a) Fuse operated.
- (b) Failure of the control uniselectors to drive.
- (c) Failure of the memory "writing" circuit.
- (d) Failure of the memory "reading" circuit.
- (e) Failure of the electronic power supply.

(vii) To provide a start signal to a circuit (Call Acceptance Allotter) that will allot only one operator to an incoming call when there have been no calls awaiting. This feature prevents many operators' switches from hunting for the one call simultaneously during the slack period.

(viii) To provide facilities to routine test the full operation of the queue circuit.

BRIEF DESCRIPTION OF EQUIPMENT AT THE COMPLAINTS CENTRE

Before describing the operation of the Call Queue circuit it is necessary to outline the operation of the equipment in the Complaints Centre with which the queue will be associated. Fig. 1 shows the general disposition of the equipment.

Incoming (I/C) Relay Sets

Each incoming trunk to the Complaints Centre is terminated on an I/C relay set. The queue in its basic form can handle up to 101 I/C relay sets. The function of the relay set in relation to the queue is:

(a) To extend a mark to the queue control start circuit on the common queue call (QC) lead. To prevent feedback, the relay sets are isolated from each other by diodes at the queue input.

(b) To extend a mark on the QM lead to the MUQ motor uniselector bank in the queue control circuit. The outlets of two levels of the MUQ selector are wired to the QM leads of the I/C relay sets, thus making provision for 104 relay sets, however, in practice 101 relay sets will be the maximum number wired.

(c) To receive a signal when the queue is congested and busy the relay set to further incoming traffic.

(d) To switch to a condition whereby the operators will answer the looped relay set at random, if the queue is out of service.

Finder (FDR) Relay Set

Each of the operators positions are equipped with two FDR relay sets with provision made for a third circuit in the future. Each relay set is associated with a 16 level motor uniselector (FDR). The outlets from two levels of the FDR are multipled over the same levels on all other FDR's and connected to I/C relay sets making it possible for any FDR to connect to any of the I/C relay sets. Two other levels of the FDR are multipled to the same levels on all other FDR's and connected in multiple to two levels (11 and 12) of the queue decoding motor uniselector MUM.

The functions of the FDR circuit in relation to the queue are:

(a) To accept a call waiting signal from the queue control and start the FDR selector searching for the waiting mark that appears on one of the outlets in the levels that are tied to the queue decoding selector MUM.

(b) To provide an earth on the "queue looking" (QL) lead to prevent calls being taken into the queue until the FDR has found the marked outlet. In this way preference is given to an operator answering before the acceptance of an I/C call.

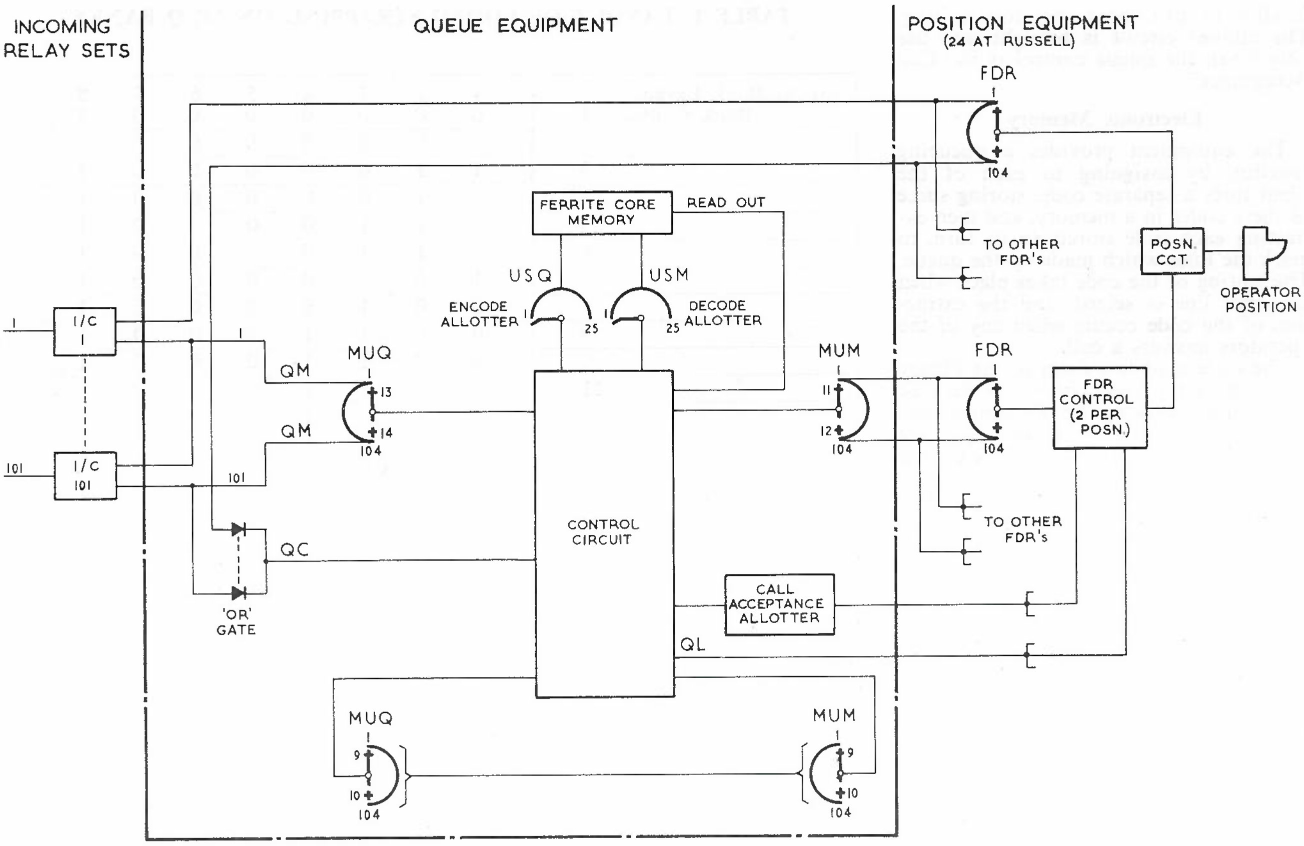

Fig. 1 — Block Schematic — Centralised Complaints.

When the FDR locates the mark on the MUM bank, the wipers of other FDR levels will be lodged on an outlet associated with the calling I/C relay set. Switching takes place in the I/C relay set to extend the calling subscriber to the operator. A lamp flashes on the operator's position to indicate that a call has been found. The FDR remains switched to the I/C relay set for the duration of the call.

Operators Position Circuit

The number of operators positions provided will depend on the amount of traffic to be handled. It is anticipated that enough operators will be provided to keep the speed of answer to a maximum of 12 seconds for 98% of the calls.

The position circuit has no function that directly affects the queue control circuit. A call waiting lamp is provided but this is lit from the queue Display and Delay circuit.

When a call waiting lamp is lit, the operator operates one of the answer keys. The FDR relay set is now prepared to accept a call waiting earth from the queue control, find the call allotted by the MUM selector and switch it to the operator.

OPERATION OF THE CALL QUEUE CIRCUIT

A detailed circuit description will not be attempted in this article. In the following sections, however, a general outline of the main functions will be made while referring to Fig. 1, and the less familiar aspects such as coding, storage, etc. will be considered in some detail.

General Description of Operation

The queueing system has two distinct modes of operation. When the traffic is light, such that there are sufficient operators available to handle each call as it arrives, the memory facility is bypassed, and an input line is switched directly to provide a marked outlet. This condition is known as "Call Acceptance" and the process of direct switching continues until all operators are busy. Any further inputs are then stored as a series of codes in the memory, and are decoded in turn to provide marked outlets as operators become available to handle the traffic.

All the input lines are commoned through a diode OR gate to provide a start signal to the control circuit when any one input is earthed. The control circuit then causes the input line finder MUQ to search for and locate the earthed input. If the system is in Call Acceptance the output line corresponding to this input will be marked directly by a second motor uniselector MUM. If the call is to be allotted a queue position, however, the code corresponding to the input line must be written into the memory. The input line finder is then released to await further calls, and the control circuit is also available to decode the stored calls under control of the operator. The signal to decode the next call from the queue is given to the control circuit when an operator seizes the marked outlet which has already been set up by the queue control

The function of the USQ uniselector is to allot the next memory position to the encoding section of the control circuit each time a memory position is encoded. The function of the USM uniselector is to allot the next memory position to the decoding section of the control circuit each time a memory position is decoded. Therefore the USM switch will always be behind the USQ switch by a number of steps that is equivalent at any time to the number of calls that are in the queue awaiting an answer. When there are no calls in the queue the uniselectors will be on the same numbered outlet and the control circuit is returned to the "Call Acceptance" condition.

When there are no calls awaiting an answer, it is usual that all free operators wait with an answer key already operated. When this condition exists, the first I/C call would cause all finders associated with operated answer keys to hunt simultaneously for the one call. To overcome this, an allotter circuit is used to allot, in turn, those operators waiting. The allotter circuit is brought into use only when the queue control is in "Call Acceptance".

Electronic Memory

The equipment provides a queueing function by assigning to each of the input lines a separate code, storing some of these codes in a memory, and then extracting each code stored, in its turn, to mark the lines which made up the queue. The storing of the code takes place when an input line is seized, and the extraction of the code occurs when any of the operators answers a call.

The code used is a form of the binary code (the Gray code) in which each of seven digits making up a number can have only one of two values which are designated '0' and '1'. To provide coding for up to 128 different lines, it is necessary to use 7 digits; each code then consists of one of the 128 possible arrangements of '0''s and '1''s.

In this application, the order of the codes used has been chosen so that each successive code differs from the preceding in only one digit, as may be seen from the table of code equivalents in Table 1. The code used here is not the conventional binary code, which is unsuitable.

The memory is made up of toroidal cores of a magnetic ferrite, there being one of these cores to store one digit of a number. Thus, in this particular queue, the storage of 25 7-digit numbers requires a memory made up of 175 individual cores. These consist of material which can be magnetised in one of two directions by a current flowing in the appropriate direction along a wire threading the core. In the normal condition, the core is magnetised in the direction corresponding to a '0' being stored as shown in **Fig. 2a.**

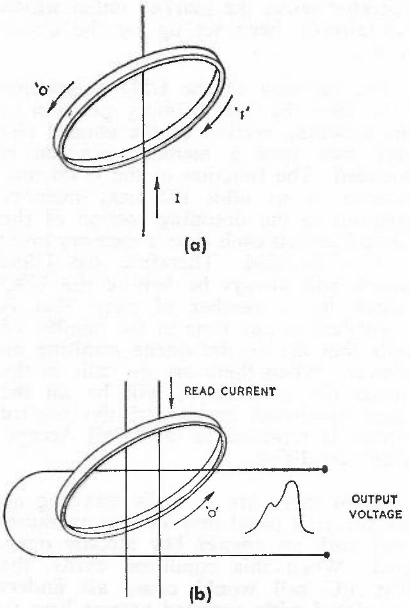

Fig. 2 — Ferrite Core Storage
(a) Core Setting.
(b) Core Reading.

TABLE 1: LAYOUT OF CODED STRAPPING ON MUQ BANKS

MUQ Bank Levels / Bank Contact	1	2	3	4	5	6	7	8
1	0	0	0	0	0	0	0	1
2	1	0	0	0	0	0	0	1
3	1	1	0	0	0	0	0	1
4	0	1	0	0	0	0	0	1
5	0	1	1	0	0	0	0	1
6	1	1	1	0	0	0	0	1
7	1	0	1	0	0	0	0	1
8	0	0	1	0	0	0	0	1
9	0	0	1	1	0	0	0	1
10	1	0	1	1	0	0	0	1
11	1	1	1	1	0	0	0	1
12	0	1	1	1	0	0	0	1
13	0	1	0	1	0	0	0	1
14	1	1	0	1	0	0	0	1
15	1	0	0	1	0	0	0	1
16	0	0	0	1	0	0	0	1
17	0	0	0	1	1	0	0	1
18	1	0	0	1	1	0	0	1
19	1	1	0	1	1	0	0	1
20	0	1	0	1	1	0	0	1
21	0	1	1	1	1	0	0	1
22	1	1	1	1	1	0	0	1
23	1	0	1	1	1	0	0	1
24	0	0	1	1	1	0	0	1
25	0	0	1	0	1	0	0	1
26	1	0	1	0	1	0	0	1
27	1	1	1	0	1	0	0	1
28	0	1	1	0	1	0	0	1
29	0	1	0	0	1	0	0	1
30	1	1	0	0	1	0	0	1
31	1	0	0	0	1	0	0	1
32	0	0	0	0	1	0	0	1
33	0	0	0	0	1	1	0	1
34	1	0	0	0	1	1	0	1
35	1	1	0	0	1	1	0	1
36	0	1	0	0	1	1	0	1
37	0	1	1	0	1	1	0	1
38	1	1	1	0	1	1	0	1
39	1	0	1	0	1	1	0	1
40	0	0	1	0	1	1	0	1
41	0	0	1	1	1	1	0	1
42	1	0	1	1	1	1	0	1
43	1	1	1	1	1	1	0	1
44	0	1	1	1	1	1	0	1
45	0	1	0	1	1	1	0	1
46	1	1	0	1	1	1	0	1
47	1	0	0	1	1	1	0	1
48	0	0	0	1	1	1	0	1
49	0	0	0	1	0	1	0	1
50	1	0	0	1	0	1	0	1
51	1	1	0	1	0	1	0	1
52	0	0	0	0	0	1	0	0

Notes: (1) The '0' signifies that the code strapping is not connected to the contact; the '1' signifies that this strapping is connected to the contact in question.

(2) Bank contacts 2-51 Black are allotted to I/C Relay sets 1-50; contacts 1-51 Red are allotted to I/C Relay sets 51-101. Bank contacts 1 and 52 Black, and 52 Red are used only for routing.

If a current of sufficient magnitude, about 500 mA, is then passed through the wire in the appropriate direction, the magnetisation of the core can be changed to the direction '1'. This core will then remain in its '1' state until a further current pulse in the opposite direction occurs during the decoding process, on another wire threading the core. This read current pulse switches the core back to the '0' magnetised state; as the core switches, an output voltage pulse is induced on the output loop which threads the core (see Fig. 2b).

The interface between electronic and electromechanical circuitry assumes most importance in relation to the memory function, and so will be considered in some detail for this part of the equipment.

The output pulse from the cores is of the order of 50mV, with a duration of about .005ms. Such pulses must provide a marked outlet on a motor uniselector, which involves the problem of using the low-amplitude outputs from the cores in association with relay circuitry in which transient voltages well in excess of 50 volts may occur. In addition, the read and write currents are of the order of 500mA, with a fast rise-time in the case of read current, so that care must be taken to prevent direct coupling between the read current wires and the output wires.

The pulse output from the cores is not of sufficient duration to allow mechanical searching by the motor uniselector so the pulse must be converted to a steady condition which can later be reset after the searching process is completed. To provide this function, the core output after being amplified is used to switch a transistorised bistable multivibrator, or binary, with a high speed relay as load in one collector circuit. This is illustrated in Fig. 3.

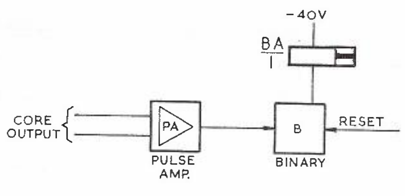

Fig. 3 — Converting the Core output to a Steady D.C. State (1 per Memory Level).

Construction of Memory and Code Circuitry

The memory is made up of 25 groups of cores, each group containing seven levels, as shown in Figs. 4 and 5. Each group is permanently associated with a position of the uniselectors USQ and USM. Each level of the memory is associated with one level of USQ, so that seven levels of USQ are used. Only one level of USM is used by the memory, since USM is associated with complete groups, and not individual memory levels of a group.

The allocation of the codes corresponding to given I/C relay sets is achieved via a strapping on the banks of MUQ (See Table 1). The write wires to levels 1-7 of the memory are connected to coded strapping on the seven MUQ banks 1-6 and 8. Current flow (or its absence) through any write wire is then determined by whether the coded strapping on the MUQ banks is connected to the MUQ bank contact, or not. Thus if a '1' is required in level 3 of the memory, this write wire must be connected via the strapping on MUQ3 to the wiper on this level.

This is illustrated in Fig. 4, by considering the writing of the code for the relay set assigned to MUQ bank position 23, when USQ is on contact 13. The code to be written is 0011101, in which the left-hand digit will appear in level 7 of the memory, and the right-hand digit in level 1. For each of the memory levels, 1, 3, 4 and 5 the circuit will consist of: earth behind high-current switch CAW, USQ wipers common, contacts 13 of USQ level, through cores and along write wires to MUQ coded strapping, contacts 23 of MUQ, MUQ wipers, 68 ohm resistors to battery. For the remaining memory levels, however, the coded strapping does not go to contact 23 of the associated MUQ levels and so no current can flow in these cores when the switch CAW is on.

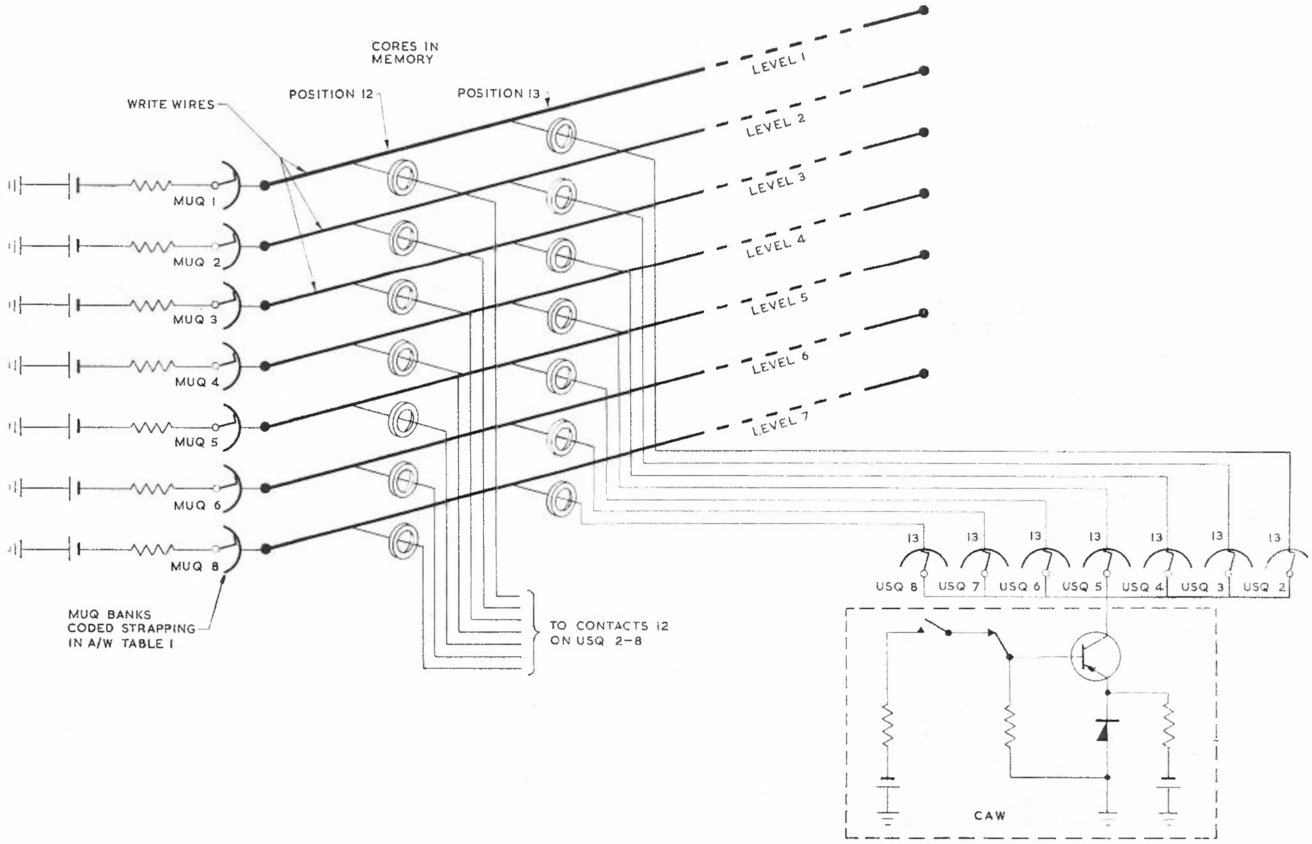

Fig. 4 — Ferrite Memory Writing.

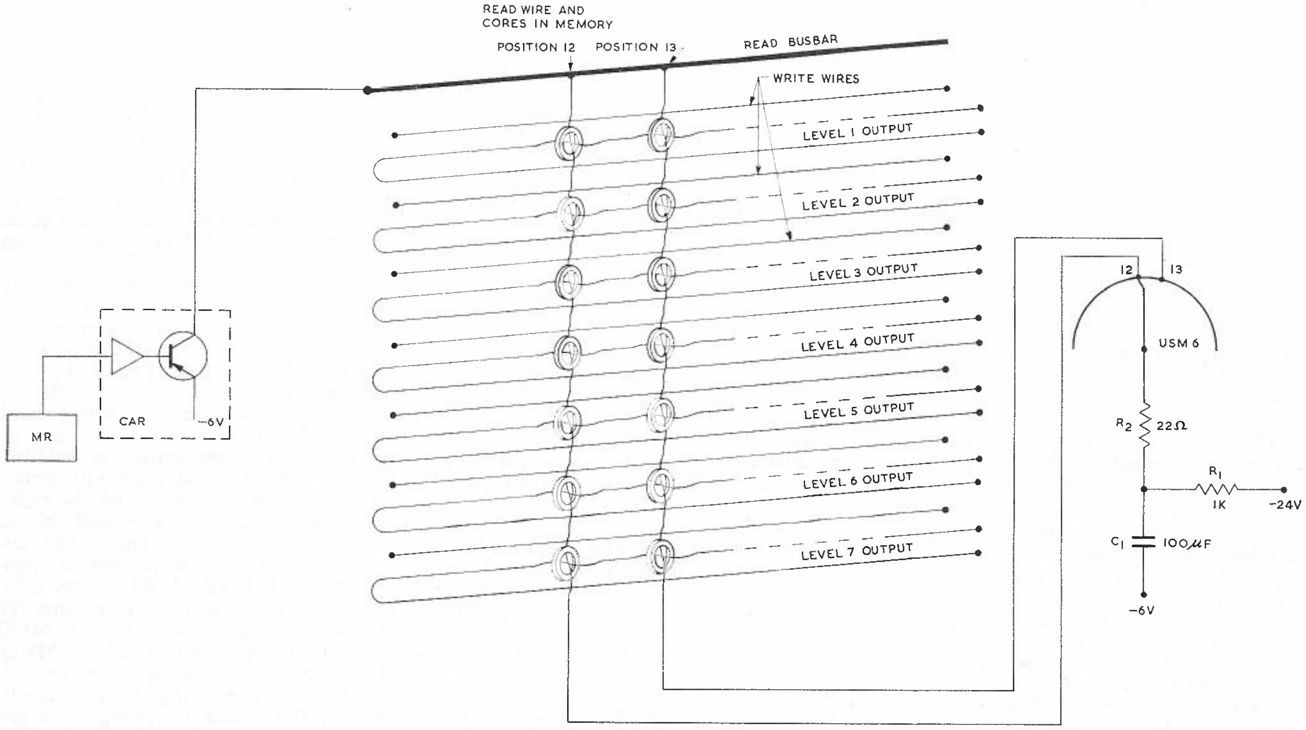

Fig. 5 — Ferrite Memory Reading.

The first step in the decoding of a stored call is the reading of the code stored in the memory, which is achieved under the control of USM. For each memory group, a read wire threading all cores in that position is connected to the appropriate contact on bank 6 of USM, as shown in Fig. 5.

Thus, when the information in position 13 of the memory is to be read, the circuit for the read current will consist of: Earth behind Read Current switch CAR, read wire in position 13 of memory, contact 13 on level 6 of USM, USM6 wiper, to 24 volts supply via 22 ohm load resistors. When this read current occurs, all cores in position 13 which had been storing a '1' will be switched to the '0' state, and on the corresponding output wires a pulse will occur. The remaining cores will stay in the '0' state, and will produce no output pulse.

The output pulses from the memory are used to operate the binaries and their associated relays, and it will now be shown how the code set up in this series of relays is used to provide the correct marked outlet.

Consider a similar system having 8 input lines, requiring 3 digit working, with the MUM banks wired to the contacts of relays BA, BB and BC as shown in Fig. 6.

It can be seen that for any combination of BA, BB and BC, there is only one position of MUM which will operate the relay TM. For example, if the code set up is BA normal, BB operated, and BC normal, TM can be operated only when the wipers are on contact 4.

An extension of this system using seven relays BA-BG could provide unique location of 128 codes. However, the banks of MUM are limited to a maximum of 52 contacts. By using single-ended wipers which search alternately over two banks of contacts, it would be possible to locate up to 104 unique codes. In practice, three of these are used only for routining, restricting the input of the queue to 101 lines.

Electronic Circuit Design and Assembly

The design of the electronic circuits is based upon the use of voltage supply lines derived from the negative 50 volt exchange battery. No use is made of the positive battery supply. The logic circuitry is operated from voltage levels derived with Zener diodes from the 50 volt supply.

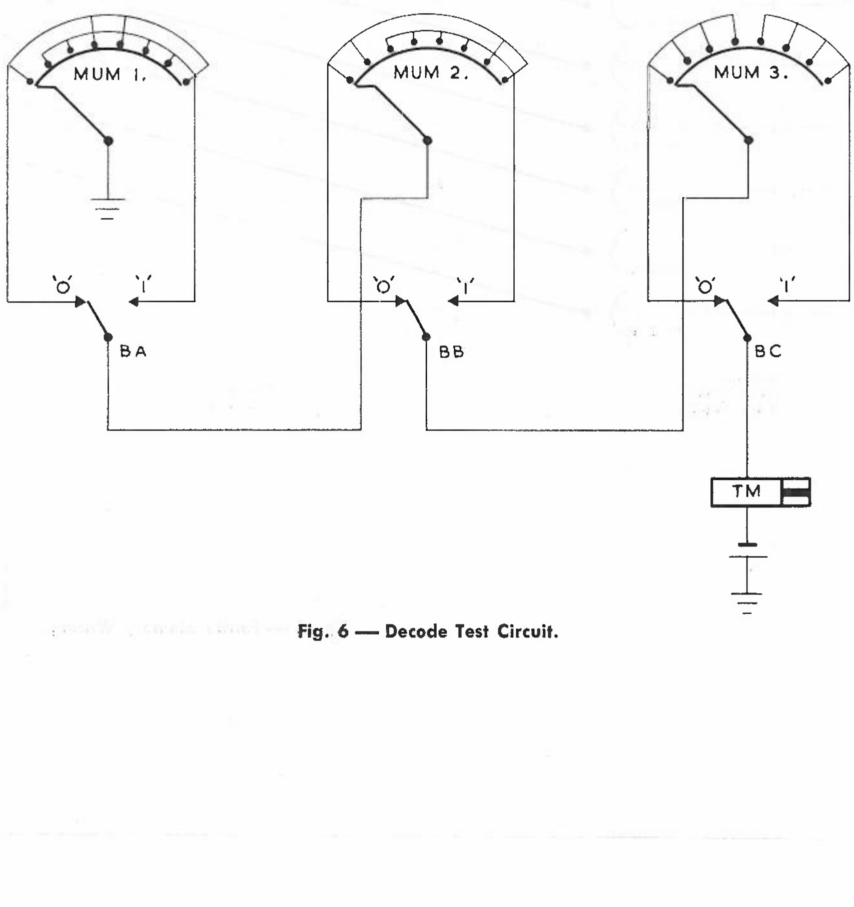

Fig. 6 — Decode Test Circuit.

The multivibrator circuits used are quite straightforward in design, apart from a modification to the binary circuits to reduce their sensitivity. Cross-coupling capacitors are not necessary to provide reliable triggering, and use of these capacitors would result in making the circuits more sensitive to supply transients.

The major difficulty in the design of the memory current-drive circuits is the provision of suitable load resistance. The write circuit consists of seven paths which may draw 700mA, and are under the control of relay contacts through a high-current transistor. Although under normal operating conditions the average dissipation in each load resistor is not very large, the load has to be capable of withstanding fault conditions. This requirement has been satisfied by using 12 watt resistors for each writing level, and these are mounted in a separate relay base.

The duty cycle of the read current pulse can be accurately determined in advance, since the **on** period is under the control of the monostable multivibrator MR. The load circuit for the read amplifier, shown in Fig. 5, allows the 600mA pulse to discharge capacitor C_1 without providing a severe load on the power supply. There is then sufficient time to recharge C_1 through R_1 before another read pulse can occur; R_1 also reduces the circuit dissipation problems. The function of MR in the circuit is to ensure that the read pulse generated by the current amplifier, CAR, is applied to the ferrite core read wires in one step. If the CAR is operated directly from relay contacts the read pulse would be affected by contact bounce and the amplitude of the core output pulse may be reduced. Once MR is triggered it will deliver a continuous output for 15 milliseconds irrespective of the state of the relay contacts.

Since the design of the queue uses both core and transistor circuitry, it is necessary to provide a method of mounting these circuits in a way suitable for wiring to the associated relay circuits and compatible with exchange rack mounting. A number of techniques were considered and the problem is treated in two ways.

The magnetic core circuits require special wiring techniques with particular emphasis on accuracy of assembly. In addition, the fine wiring must be provided with protective covers which are unlikely to require removal after initial installation and testing. A third consideration of importance here is that the wiring to the pulse amplifiers should be kept as short as practicable.

A solution to these problems is found by enclosing the entire memory in a clear perspex case. The fine wire threading the cores terminates on pins within this case. These pins are also used to terminate the memory access wiring which is taken out of the case in a bound loom. Thus the memory can be built up and its protective cover attached before it is wired in with the rest of the circuitry. (See Fig. 7.)

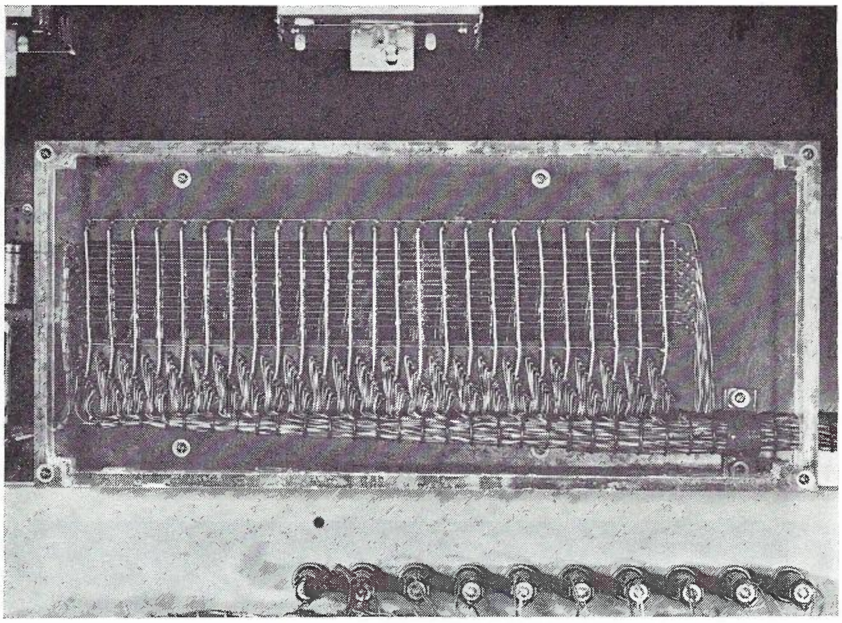

Fig. 7 — Ferrite Core Memory.

The sense wires are brought out of the memory case in a separate loom and terminate on a plug. The pulse amplifier circuits are connected via a socket to this plug and mount on a circuit board which can be fixed to the memory panel. However, since the circuit board is external to the perspex case, testing and replacement of the pulse amplifiers can be achieved without disturbing the memory wiring.

The binary circuits have associated with them, as a collector load, a high speed relay. With these circuits it is of particular advantage to mount them in a standard relay base. This mounting technique is also applied to the rest of the transistor circuitry.

ROUTINING AND MAINTENANCE

An integral part of the design is the Routiner circuit which is intended to provide testing of the complete circuit, from incoming line finder to outgoing line marker, including the memory facility.

This is achieved by replacing the function of incoming lines by a selected number of test keys, and the function of the operators by a single answer key. Since it is likely that some of the maintenance staff will have little experience with transistor circuitry, a fault-finding procedure has been developed which is intended to isolate a fault to a particular plug-in card.

In discussing faults which may occur with the circuit, it is important to distinguish between two distinct types, regular and intermittent faults. The fault-finding procedure depends for its usefulness on isolation of a faulty card by interchanging with spare cards. This procedure will not be applicable to intermittent faults, but when correctly applied it will be very useful in locating regular faults.

In addition to the detection of faults during routining, the behaviour of the queue during service can also provide evidence regarding certain types of fault. This depends on the provision of three alarm conditions, namely:—

(i) When any call is decoded with a '0' in each digit, the MUM switch will test in to the contact on position "Black 1".
(ii) When the line finder circuit is started, but MUQ is unable to find a mark.
(iii) When MUM is unable to locate a code set up by the series of relay contacts.

These alarm conditions will occur during routining if they are caused by a regular fault, and can be located in the usual manner. However, when they occur intermittently, their detection may require the use of complex test equipment by experienced operators. The fact that the queue behaviour can give a guide to the type of fault is dependent upon the coding scheme used, and this will now be considered.

The coding used is, in effect, a seven digit code. Since the motor uniselectors are limited to 104 positions, then some of the 128 available numbers are not used, as explained previously. When the decoding process results in the establishment of one of these unavailable codes, MUM will provide an alarm failure as listed in (iii) above. After such a failure, inspection of the queue will indicate that the alarm was caused by a fault of type (ii) or (iii), rather than type (i). It should not prove difficult to check if the alarm was caused by an MUQ fault.

Now consider the possible faults and the service errors which they introduce.

An intermittent fault in any of the memory drive circuits will always cause the 'Black 1' service error. Intermittent faults which provide a '0' output instead of a '1' in a particular level may be caused by failure to write a '1' in that level, or failure to obtain a '1' in the binary sensing the output of that level. Since the faults under consideration are of low probability, it may be assumed that this will occur only on one level at a particular time. When this fault does occur, the resulting code will be in one of the following classes:—

(i) Incorrect code, but available on an MUM outlet — probability 0.46.
(ii) Incorrect, unavailable code — probability 0.042.
(iii) 'Black 1' decoded — probability 0.012.
(iv) Correct code; '0' stored in faulty level — probability 0.486.

These error probabilities assume that all incoming lines have the same probability of usage.

The importance of these results is that a significant proportion about 5% (the sum of (i) and (iii)) of all coded calls affected by this error will lead to an alarm condition during service. This fraction is small, but gives a good indication of the occurence of a repeated failure.

These figures also indicate that the presence of the 'Black 1' system fault during service, without the occurrence of the 'Unavailable Code' fault, is very unlikely to be caused by this type of coding error. It would almost certainly be caused by complete lack of the writing or reading function.

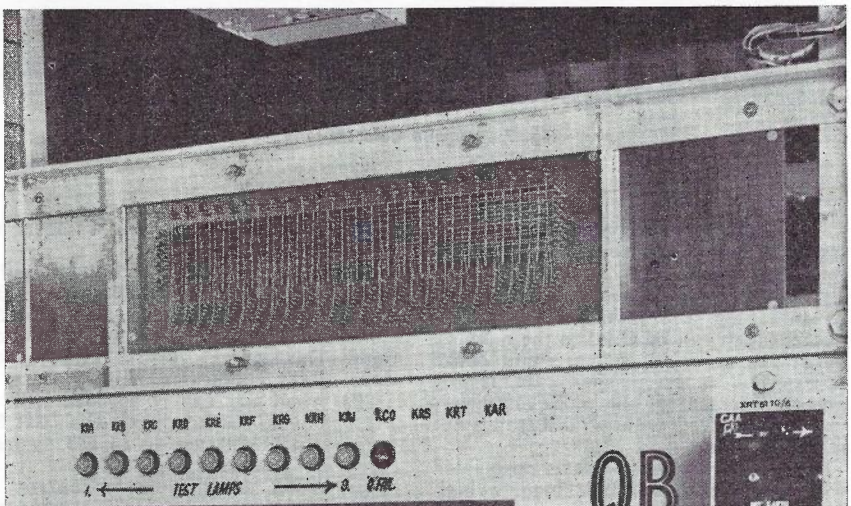

Fig. 8 — Control Panel and Uniselectors.

CONSTRUCTION OF QUEUE EQUIPMENT

The queue equipment is built on a sub-rack which is mounted on a standard 4 ft. 6 in. rack. Figs. 8 and 9 are photographs of the equipment. The equipment consists of:

(i) A control relay set using 17 relays.
(ii) Two 16 level Siemens Motor Uniselectors (1400 Type).
(iii) Two 8 level 25 outlet B.P.O. uniselectors.
(iv) A panel on which is mounted a 25 position seven digit ferrite core memory, with seven associated pulse amplifiers.
(v) A 22 point and a 10 point relay base into which the electronic circuits are plug-mounted.
(vi) A miscellaneous relay set using eight relays that is only used when two queues are working in parallel.
(vii) A panel of keys and lamps for routing facilities, etc.
(viii) A 10 point relay base in which are mounted certain resistors that are required to operate at maximum dissipation under fault conditions.

The transistorised Pulse Amplifiers are assembled on a card mounted on the memory panel so that the wiring from the memory output can be kept to a minimum length. This arrangement reduces stray pick-up in the inputs of the amplifiers. The inputs and outputs, etc., of the pulse amplifiers are connected via a plug and socket to allow a quick replacement of the card in the event of a fault occurring.

The wiring of the control and miscellaneous relay sets is arranged so that no alteration to the circuit is necessary if another queue is installed. An alteration to the strapping on the terminal blocks will arrange for both queues to operate in parallel.

When two queues are operating in parallel some functions of each control set are necessarily interlinked. The "U" jacks of the relay sets are arranged so that if a control relay set is removed from the rack for service, certain "U" jacks bridge to allow the other control circuit to remain in service.

CONCLUSION

In May, 1963, three queue systems were installed, two at Russell and one at Windsor. Until the time of writing this article in November 1965, the Windsor installation has not experienced a single fault in the queue or its immediate control circuitry. At Russell, where the traffic is much heavier the faults that have occurred in the electronic section of the queue have been one open capacitor (faulty manufacture), one broken wire on the pulse amplifier card, two short circuited diodes in the control circuit start OR gate and one dry joint. In addition an intermittent fault in the memory read circuit persisted for some time. This was finally tracked down to a dirty USM uniselector bank.

The faults that have occurred in the electromechanical section have been confined to the type of fault expected in hard worked motor uniselectors. The average number of calls received by the Russell equipment is approximately 6000 calls daily and the record number of calls received for any one day stands at 10,796.

When consideration was given to the size of the queue that would give a satisfactory speed of answer there were some design parameters that were not then known and a 25 position queue was selected from convenience. However, McMahon (Ref. 2) discusses the theory of queueing and indicates that a lesser number of queue positions would be more suitable. If necessary, the field equipment can easily be modified to shorten the queue length.

ACKNOWLEDGEMENTS

The use of ferrite cores as means of storing a digital information is well known and there is no need to mention all the literature relating to the subject. The particular application of these circuits, as used in the Electronic Call Queue, was devised by Mr. H. S. Wragge, Sectional Engineer, Switching Systems Sub-Section, Research Laboratories.

The prototype equipment was designed, constructed and tested by staff of the Electronic Switching Division, Research under the control of Mr. B. J. McMahon, Group Engineer in that Division who also has contributed greatly to the material in this article.

The field equipment was manufactured by the Victorian Postal Workshops and installed by the Victorian Installation staff.

REFERENCES

1. M. D. Zilko, "Analysis of Subscribers Trouble Reports"; Telecommunication Journal of Aust., Vol. 15, No. 1, Feb. 1965, page 23.
2. B. J. McMahon, "Dimensioning of the Queue for the Melbourne Centralized Complaints Centre"; Telecommunication Journal of Aust., Vol. 16, No. 2, June 1966.

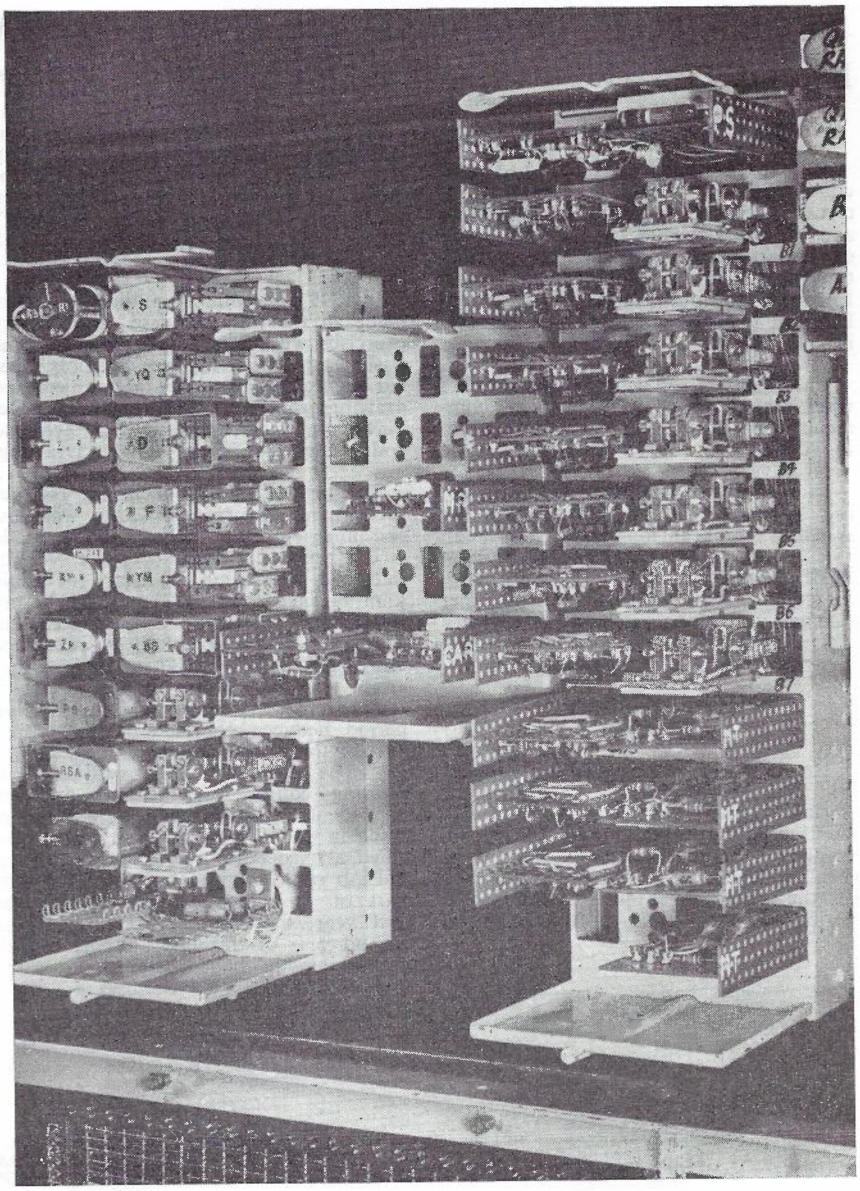

Fig. 9 — Logic Cards and Relays.

TECHNICAL TRAINING IN THE AUSTRALIAN POST OFFICE PART II

*V. J. WHITE, B.A., B.Sc., A.M.I.E.Aust., M.A.P.S.**

TRAINING OF LINEMEN

Prior to 1938, lines training had been conducted primarily on-the-job. The increasing demand for cable jointing skills and the trend toward more precise standards particularly in aerial line construction led to the development of formal Lineman Training Courses and the establishment of Lineman's Training Schools in each State.

The first courses were taught in 1938 when small groups of trainees commenced an 18 month lineman-in-training course.

In contrast to the technician-in-training course the lineman-in-training syllabus has been relatively stable. In 1965 a new syllabus was introduced and this has been the first major change since the courses began in 1938. In this paper lineman-in-training syllabuses will be discussed under two headings, Past Courses and the 1965 Revision.

Past Courses

The 1938 course provided Departmental training in the four subjects of Aerial, Conduits, Cable Laying and Cable Jointing, with general theory instruction being provided concurrently at technical colleges. The instruction in each of the practical subjects comprised a period of school training followed by a period of on the job training. In addition instruction was given in Telephony (at the Technicians' School) in Motor Transport and periods were spent in an Engineer's Store and in an Engineer's Office. The course was completed in 18 months.

In 1949 some minor modifications were made to the initial course. Preliminary exercises were introduced to give some basic instruction in use of tools, first aid was taught as a separate subject and drawing principles were covered by Departmental lectures in lieu of technical college instruction in Trade Drawing.

The use of outside technical colleges for general theory instruction was discontinued in 1952. Other changes made at this time were division of the syllabus into two parts and provision for cable jointing instruction to be given before instruction in aerial or conduits and cables. A new job condition prevented trainees under age of 18 from undertaking aerial training so that it was necessary for them to work as jointers' mates in the period between completion of the first part of the course and attainment of age 18. The difficulty of co-ordinating a training course with overall duration dependent on age of trainees, was recognised in the 1956 amendment which provided a fixed period of 26 weeks for on the job cable jointing training. The first part of the course then occupied the first year, the second part became the second year of training, and the overall course length then became two years. The 1952 and 1956 syllabuses are illustrated in Fig. 4.

The 1965 Revision

The lineman-in-training scheme since its inception in 1938 aimed to provide training in all the major lineman functions, even though one of these, cable jointing, was a Lineman Grade 2 function. Graduates from the scheme were advanced as Lineman Grade 1; their training in cable jointing was justified by the shortage of qualified staff and the fact that most graduates from the scheme were employed immediately as cable jointers. In subsequent years it was claimed that in most States the training scheme was producing more cable jointers than could be employed effectively, and it was suggested that training of all linemen-in-training in cable jointing was becoming unnecessary. In addition changes in cable design often involved modification in cable jointing techniques which should be taught in the schools at a time as close as possible to their application on the job. It was decided, therefore, to eliminate the development of cable jointing skills from the basic syllabus, retaining only sufficient basic instruction on the topic to enable trainees to perform Lineman Grade 1 functions on graduation.

At the same time, the opportunity was taken to amend the syllabus content of all subjects so that the new syllabus reflected modern work requirements. The effect of the overall revision was to shorten the course to one year.

The new syllabus is shown in Fig. 5. Details of the allocation of periods to each topic in the various subjects are

* Mr. White is Engineer, Class 4, Training, Headquarters. See Vol. 16, No. 1, page 88.

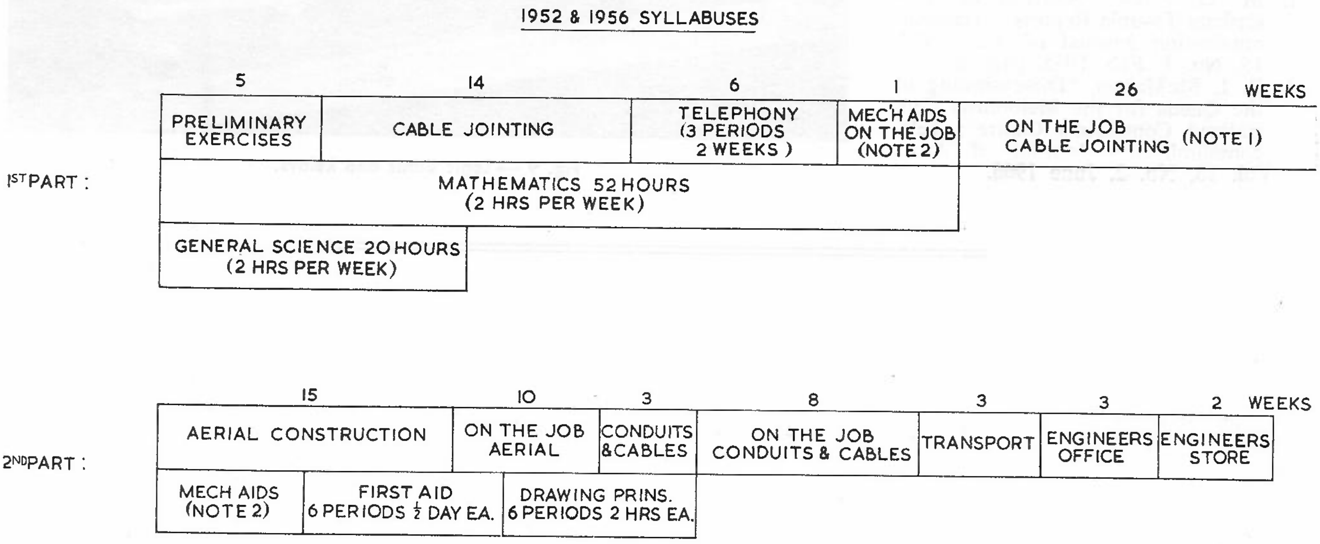

Fig. 4 — The 1952 and 1956 Lineman-in-training Courses.

Notes: 1. In the 1952 syllabus trainees spent between 12 and 52 weeks in the field as cable jointers' mates in between the first and second parts of the course. The actual length of the course was determined by the condition that Part 2 should be commenced as soon as possible after trainee attained age 18 years. In the 1956 syllabus trainees spent a fixed period of 22 weeks on-the-job cable jointing. Each part of the course then occupied one year.

2. In the 1956 syllabus the 2 weeks on mechanical aids was done wholly in the 2nd year.

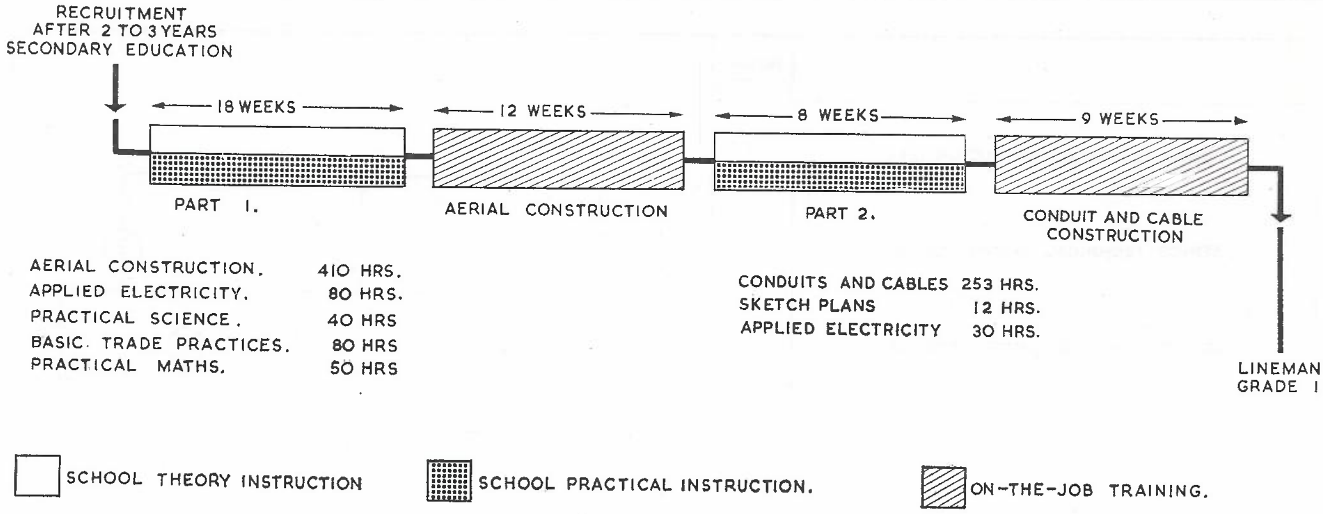

Fig. 5 — The 1965 Lineman-in-training Course.

Note: Before appointment as Lineman Gr. I, trainees return to the school for one week final revision and review of the whole course.

TABLE 10: COMPARISON OF 1956 AND 1965 LINEMAN-IN-TRAINING SCHOOL SYLLABUSES WITH ELECTRICAL TRADES COURSE.

Type of Instruction	Lineman-in-Training Course		Trades Course (hours)
	1956 Syllabus (hours)	1965 Syllabus (hours)	
Total length of school training	1,720	990	1,296
Practical instruction	1,037	540	648
General theory instruction.	90	150	216
Specialised theory instruction	593	300	432
Total theory instruction.	683	450	648

given in Appendix 4. In Table 10, the overall amounts of practical and theory instruction in the new syllabus have been compared with those in the previous syllabus and in an electrical trades course.

Secondary Lines Courses

As with technician training, an important part of lineman training is the provision of special courses to give existing staff conversion type training in new skills. Under the new lineman-in-training syllabus, instruction in cable jointing skills is provided as a secondary course; other courses include:—

- Loading and Balancing
- Cable Protection
- Coaxial Cables
- Cable Recording
- Explosives
- Pole Inspection
- Human Kinetics
- Artificial Respiration
- Lines Estimating Procedures
- Storekeeping Procedures
- Supervision

Secondary courses in elements of the basic lineman-in-training syllabus are also provided for existing staff who have not been lineman-in-training.

SCHOOL STAFFING

School instructional staff are recruited from qualified field staff (Senior Technician or Lineman Grade 2) and given an internal instructor training course, comprising an initial course of 60 hours instruction supplemented by on the job training and further instruction (37 hours) spread over two years.

School staffing is controlled by a loading scheme which is based on principles developed from a joint Public Service Board-Departmental investigation known as the Eltham Committee. These principles are:—

(i) A school year of 42 weeks

(ii) Instructors' weekly hours of attendance 38¾ hours

(iii) Trainees' weekly hours of attendance 36¾ hours

(iv) 24 hours (technician) or 26 hours (lines) lecturing per instructor per week

(v) Provision for extra curricular manhours required for such activities as travelling, development of new courses, proving new equipment or techniques, field supervision, instructor training, preparation and marking of correspondence lessons, etc.

(vi) Ratios of trainees to instructors as follows:—

(a) Technician Schools

Type of Group	No. of Trainees per Instructor
Lesson	Maximum of 30
Laboratory	Maximum of 16
Practical	Average of 12
Advanced Practical	Average of 8
Unit Course	8-16 depending on type of course.

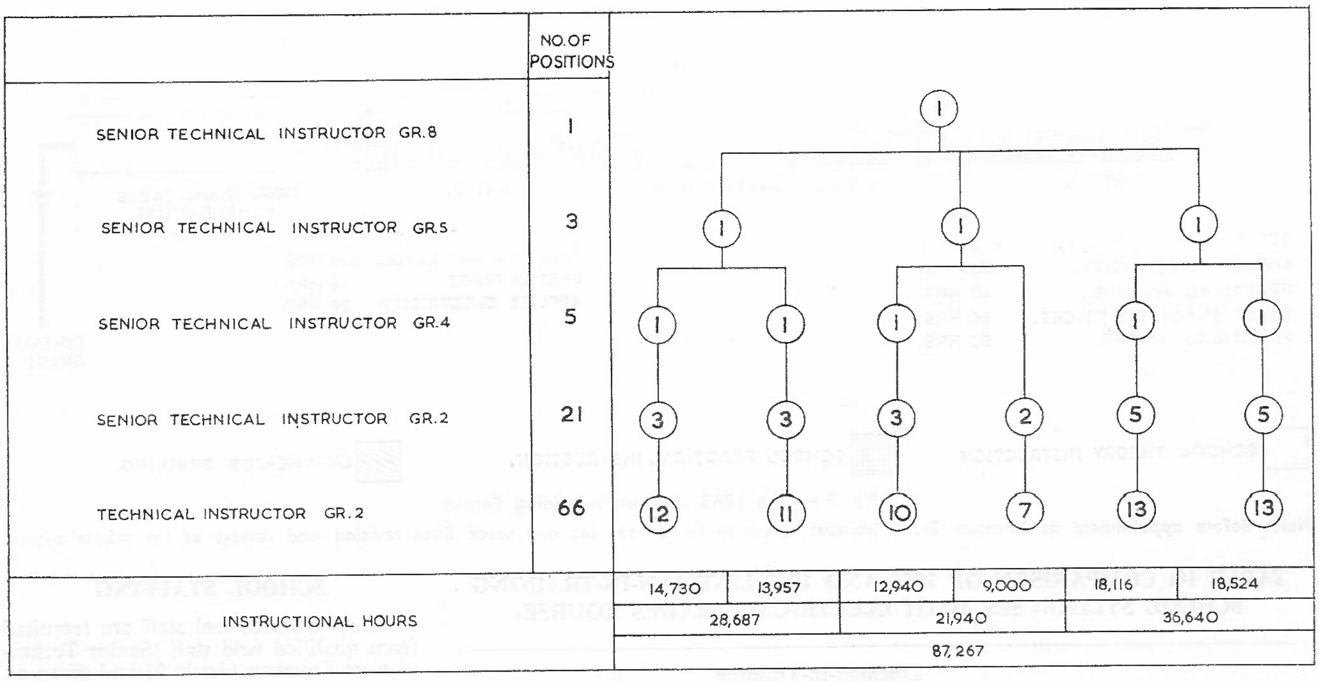

Fig. 6 — A Large School Organization. Designations shown refer to a classification structure which has since been amended.

(b) Lineman Schools: Maximum group sizes are 12 or 8 depending on the subject to be taught.

Having determined the total instructional load, the school organisation is developed with appropriate provision for supervisory positions. An organisation for technician technical instructors spread over three schools each in charge of a higher grade Senior Technical Instructor, is shown in Fig. 6.

COURSE DESIGN ASPECTS

Training may be regarded as the bridge between the recruitment situation and the work situation. Determination of training requirements involves a close analysis of the recruitment situation on the one hand and the work requirements on the other. As each of these situations may be continually changing it follows that the training course linking them should also be reviewed from time to time. The beginning phase of any training course should be kept as close as possible to the current level of knowledge and skill of the new recruit; the level of knowledge and skill to which the trainee is taken by the course should match as closely as possible that required by the work situation. The path between the initial and final phases of the training course should be direct and efficient.

Perhaps it is the need to take a recruit as quickly and as directly as possible toward a specific work situation that identifies an industrial training course from its counterpart in technical education. In education, diversions from the main path are often deliberately encouraged, course objectives are defined in general terms only, and there is usually greater concern with the teaching of general principles.

The steps taken in the A.P.O. to design and develop technical training syllabuses are described elsewhere (Ref. 4). In course design the aim is to meet the following general criteria:—

(i) The course is based on a detailed statement of objectives which accurately reflect the work requirements and there is a close relationship between what is taught on course and what is required on the job.

(ii) School training is followed as closely as possible by opportunity to apply in actual work operations what has been learnt in the school.

(iii) Teaching of theoretical principles is followed closely by laboratory projects and/or practical exercises to facilitate adequate understanding and reinforcement of basic concepts.

(iv) The treatment of topics in each subject is sequenced to ensure a logical development and to provide for co-ordination with related topics in other subjects.

(v) Ample opportunity is provided to revise and review fundamental principles as the course develops.

(vi) There is provision for frequent testing and evaluation of trainees and each trainee is kept regularly informed of his progress.

(vii) Trainees who will be unable to cope with the course are identified as early as possible.

(viii) Content of courses is frequently reviewed to ensure compatibility both with the educational system from which recruits are drawn, and with the changing needs of the work situation.

PROGRAMMED INSTRUCTION

Programmed instruction is a method of presenting material to be learnt in which:

(i) The material is broken down into a series of very small steps or frames which are presented one at a time.

(ii) Usually each frame contains a unit of information and a question seeking a response from the trainee.

(iii) The trainee is required to respond to each frame before proceeding to the next. When he does, the correct response to the previous frame is revealed.

One source of the development of this technique lies in the work of the experimental psychologist, Skinner, who demonstrated that complex behaviour patterns could be established in birds and animals by arranging for small movements in the required direction to be rewarded immediately after they occurred. The other source of this technique came from education itself, where Plessey discovered that new learning occurred when students used a mechanical device which recorded the number of correct answers to a test and which incidentally gave the students an immediate indication of whether they were right or wrong.

It is claimed that programmed instruction improves learning efficiency because:

(i) trainees proceed in small steps and make a minimum of errors so that incorrect responses do not have to be "unlearned."

(ii) trainees are kept active as they work through the material.

(iii) responses made are immediately checked against the correct response.

(iv) immediate knowledge that a response is correct tends to reinforce the learning.

(v) trainees may work through the material at their own pace; fast learners do not have to wait for slow learners and slow learners are saved the embarrassment of publicly making wrong responses.

(vi) the effectiveness of the programmed material can be experimentally verified before it is used on a wider scale.

Favourable experience with the technique overseas has encouraged Australian education authorities to make some initial uses of it. In the Department a trial conducted with 1st year technicians-in-training in Sydney using a basic maths course specially prepared by the Commonwealth Office of Education has confirmed the advantages of this form of instruction. In this trial one group of trainees used the programmed course during formal lesson periods and did no homework, whilst a second group received conventional instruction involving homework assignments and revision tests. Before the trial the performance of both groups on a common test was statistically similar; after the trial both groups were tested again and on this occasion the programmed instruction group's performance was statistically superior to that of the conventional instruction group. A detailed report on this trial will be found in Ref. 3.

Some programmed sequences in practical science are also being used in the new lineman-in-training course. The programmed instruction is given as part of a conventional lesson, and it appears that initial experience with this approach has also been favourable.

The main problem in extending the use of programmed instruction is the availability of the programmed material. Programmed sequences should preferably be tailor-made to meet the needs of particular situations and particular groups, so that only limited use can be made of commercially available programmes. Even when trained staff is available, the effort required to produce a programme with well defined objectives and with proven effectiveness is considerable. The practical approach is to programme small units of each course so that these can be used as part of conventional lesson sessions. This will reduce the task of preparing programmed material to manageable proportions and will allow the technique to be introduced without having to wait for whole courses to be available in programmed form.

CONCLUSION

This paper has traced the history of technical training courses in the A.P.O. and has described in detail new course revisions introduced in 1965. Some comments have been made about school staffing and course design aspects, and initial experience with programmed instruction techniques has been described.

Judged by the criterion of the quality of its graduates, the Department's technical training courses successfully achieve their objectives. The qualified technician or lineman coming out of the Training Schools is highly regarded and during his on the job training periods he quickly becomes an effective unit in the work force.

It is considered that the 1965 syllabus revisions will further improve the effectiveness of technical training in the Australian Post Office. In the case of technician training, the Department now has a highly flexible course capable of meeting existing requirements both for the generalist with a broad training in a variety of equipment and for the specialist with training in depth in a particular field. This flexibility is provided through the unit course concept which is not only capable of meeting present day complexities but has the potential of being able quickly to meet new requirements caused by further technical change.

ACKNOWLEDGMENT

The 1965 syllabus revision required considerable planning over a long period by a large number of training people both at Headquarters and in the States. The author wishes to acknowledge the work done by these people, as well as the efforts of school staffs in resolving the many problems associated with the implementation of the new syllabuses.

REFERENCES

3. V. J. White, "Effectiveness of Programmed Instruction for Teaching of Maths to Technicians-in-Training in the Australian Post Office"; Programmed Instruction Bulletin, June 1966, Vol. 1. No. 2.

4. V. J. White, "Syllabus Construction in the Australian Post Office"; Personnel Practice Bulletin, June, 1966.

ERRATA

Tables 3 and 4, in Part I of this article, on page 73, Vol. 16 No. 1 are reprinted below to correct errors in the printed versions:—

TABLE 3: CHANGES IN AMOUNT AND PROPORTION OF THEORY INSTRUCTION IN TECHNICIAN-IN-TRAINING SYLLABUSES

YEAR	No. of Hours of Theory Instruction	% of Total Syllabus Hours
1942	1,170	40%
1948	1,368	44%
1954	650	21%
1958	1,110	45%
1965	1,425*	58%*

*This figure varies according to Unit Courses undertaken.

TABLE 4: TRENDS IN AMOUNTS OF GENERAL THEORY AND APPLIED THEORY IN TECHNICIAN-IN-TRAINING SYLLABUSES

YEAR	Amount of General Theory (Hours) (1)	Amount of Applied Theory (Hours) (2)	Ratio (1) : (2)
1926	798	546	1.5
1948	588	780	0.8
1954	210	440	0.5
1958	300	810	0.4
1965	688	737*	0.9*

* These figures vary according to the Unit Courses undertaken.

APPENDIX 4.

ALLOCATION OF PERIODS TO TOPICS IN EACH SUBJECT IN THE 1965 LINEMAN-IN-TRAINING SYLLABUS

PRACTICAL MATHEMATICS

Topic	No. of Periods (55 mins.)
Basic Maths.— Add, subtract, multiply, divide, fractions, decimals, percentages	14
Angles	4
Areas	6
Surface areas and volumes	7
Formulae	7
Ohm's Law	7
Calculations required in special situations	4
Estimating material requirements	6
Total:	55

PRACTICAL SCIENCE

Topic	No. of Periods (55 mins.)
Matter	3
Simple machines	4
Force	4
Measurements	3
Heat	3
Friction	3
Hydraulics	6
Petrol engines	9
Diesel engines	2
Strength of materials	7
Total:	44

APPLIED ELECTRICITY

Topic	No. of Periods (55 mins.)
How a telephone works	2
Conductors and insulators	5
Electric currents and circuits	16
Special circuits	8
Sound	3
Electrical energy	6
Ohm's Law	6
Magnetism	5
Inductance and capacitance	7
Electrolysis	2
Crosstalk	8
Transmitters and receivers, bells and generators	8
Telephone instrument	8
Testing	10
M.D.F.s	3
Protection devices	4
Switchboards	3
Carrier systems	2
Electrical conditions of Subs. circuits	6
Miscellaneous topics	8
Total:	120

BASIC TRADE PRACTICE

Topic	No. of Periods (55 mins.)
Introduction	8
Safety precautions	4
Marking out job	13
Use of metalwork tools	6
Soldering	4
Bending and threading pipes	8
Drilling, tapping and threading	8
Bolts, washers, screws, nails	3
Paints and painting	6
Saws and chisels	8
Braces and wood drills	4
Axe and adze	4
Drilling holes in masonry and glazed surfaces	8
Tests	4
Total:	88

CONDUITS AND CABLES

Topic	No. of Periods (55 mins.)
Safety precautions	4
Timbering trenches	8
Excavating and backfilling	24
Mechanical aids	42
Conduits	16
Iron and plastic pipes	8
Jointing pits	8
PIQL and PIUT cables	20
Plastic cables	16
Labelling, tagging and identifying cable pairs	16
Acetylene and propane gas equipment	4
Concrete	8
Manhole construction	36
Installing and housing cables	21
Pillars and cabinets	14
Gas pressure alarm system	3
Main distributing frames	4
Subscribers' lead-ins	5
Miscellaneous topics	15
Examinations	4
Total:	276

AERIAL CONSTRUCTION

Topic	No. of Periods (55 mins.)
Introduction	4
Equipment and aerial line material	8
Timbers and poles	4
Loading and handling poles	12
Ropes, knots and tackles	12
Pole fitting	26
Pole erecting	20
Stays and staying	24
Safety precautions	8
Wires, wire jointing, erecting and dismantling	42
Cable terminal boxes, pillars and cabinets	15
Isolated cable terminal poles	32
Subscribers' leads, and re-arranging Subs. wires	40
Telephone order, Stores and material procedure	16
Transpositions	23
Mechanical aids	28
Maintenance Inspections, Power crossings, faults	28
Replacing and shoring poles	18
Transformer boxes	4
Aerial cables	26
Oxy-acetylene equipment	16
First Aid	14
Miscellaneous topics	11
Examinations	14
Total:	445

A PORTABLE TEST SET FOR LINEMEN

G. F. CARBOON, A.M.I.E., Aust.*

INTRODUCTION

With the introduction of underground cables of very large capacity, there is an increasing demand that deterioration be discovered before rain or flooding puts a large number of circuits out of action simultaneously. Preventive maintenance on line plant is highly important, because line faults are liable to cause a complete breakdown of a subscriber's service or of an important trunk route. It is therefore the aim in external plant maintenance to detect as many faults as possible in the incipient stages, thus providing subscribers with a service that rarely fails. This aim is being achieved by the complementary aids of:

- (i) Pressurising subscribers' cables fitted with appropriate "upon-failure" alarms—
- (ii) providing automatic P.G. alarms in exchanges —
- (iii) testing periodically with automatic line insulation routiners —
- (iv) and more recently, by the use in crossbar exchanges of the "K" Register. This register, which is available to all subscribers in the exchange, makes an insulation and foreign battery test when seized by the subscriber. If the particular line is faulty a suitable alarm is raised.

This article describes a simple test set for use by linemen to test continuity, insulation resistance and foreign potential on telephone lines. Up to the present time, Detectors Nos. 2 and 4 and Insulation and Continuity Testers have been used, on a somewhat restricted distribution, for this purpose. The aim in developing this set has been to produce a unit that meets the majority of testing requirements, is convenient to use, gives direct reading in volts and megohms, is sufficiently robust for field use, and is cheap enough to allow a liberal distribution.

DESCRIPTION

The test set contains a moving coil voltmeter with a full scale deflection of 100 microamps. A switch changes the voltmeter to an ohmmeter using a 30-volt battery as the current source. The voltage scale is calibrated in steps of one volt from 0 to 80 whilst the ohms scale is calibrated in megohms and decimals of megohms at significant values that are explained in the instruction notes appearing on the inside of the leather carrying case lid. The meter case has the same dimensions as the A.P.O. Multimeter Meter No. 2A and can therefore be housed in the standard leather Meter Carrying Case (Serial 399-Item 20),

Historical Development

The new set was developed following extensive field trials on a test set called "Pandora", which originated in N.S.W., and which consisted of a voltmeter mounted in a wooden case with a press type switch to change from voltmeter to ohmmeter. The meter scale had 40 divisions, from 0 to 80. The testing voltage for the ohmmeter condition was 80 volts derived from a 90-volt dry cell battery. The unit was designed to give test readings as close as practicable to the exchange desk meter. Following extensive field tests with "Pandora" and several subsequent sets with various modifications, the set shown in Fig. 1, known as a Lines Test Set No. 1 (Serial 140, Item 85), was developed.

DESIGN ASPECTS

Some of the design considerations that led to the development of the Lines Test No. 1, are as follows:

Meghoms Scale

Initially, it was thought desirable with this set, for direct comparison purposes, to have the exchange test desk meter and the field test meter read identically when measuring resistance. However, the test desk operator, when taking resistance measurements on the test desk voltmeter, must convert these into ohms or megohms, by referring to a conversion table. By placing a suitably chosen megohms scale on the meter the testing lineman does not need to convert but reads the resistance directly from the meter. He may still compare results with the test desk if desired as the test set also has the volts scale which gives readings similar to the test desk meter, whether resistance or foreign battery is being measured.

Testing Voltage

When water enters a lead covered paper insulated cable a fault condition exists. The fault resistance is usually low, owing to the paper absorbing the moisture and providing a large area of contact between conductors and the earthed cable sheath. Such fault conditions normally raise P.G. (permanent glow) alarms and the faults are located readily by established location methods. However, when moisture enters a plastic sheathed plastic insulated cable it is necessary for one or more conductors to be in contact with the moisture for a fault condition to exist. Because of the absence of a surrounding earthed metallic sheath the fault resistance is high and variable with foreign battery frequently encountered on the faulty lines. Usually, the surface area of conductors (electrodes) exposed to the moisture (electrolyte) is small and, in such circumstances, "electrolytic polarisation" has a marked effect on the fault resistance; the fault resistance exhibiting a dynamic characteristic rather than a true ohmic characteristic. (See Appendix for definition of terms.)

Numerous field tests on plastic cable faults indicated that with an 80-volt testing battery polarisation was too rapid, causing the dynamic insulation resistance to rise to a high and often acceptable value in a matter of seconds. The same resistance measured on a test

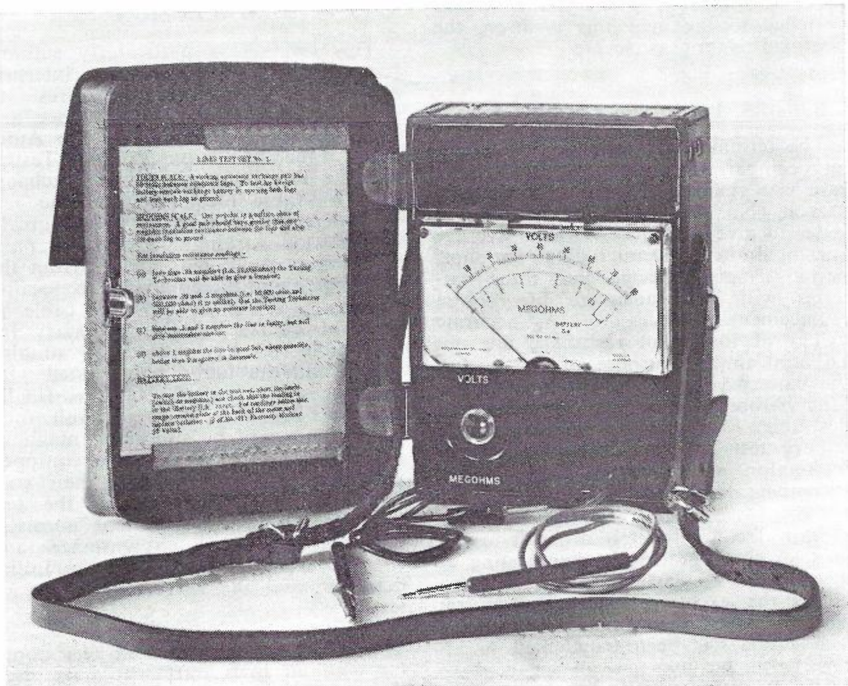

Fig. 1 — Lines Test Set No. 1.

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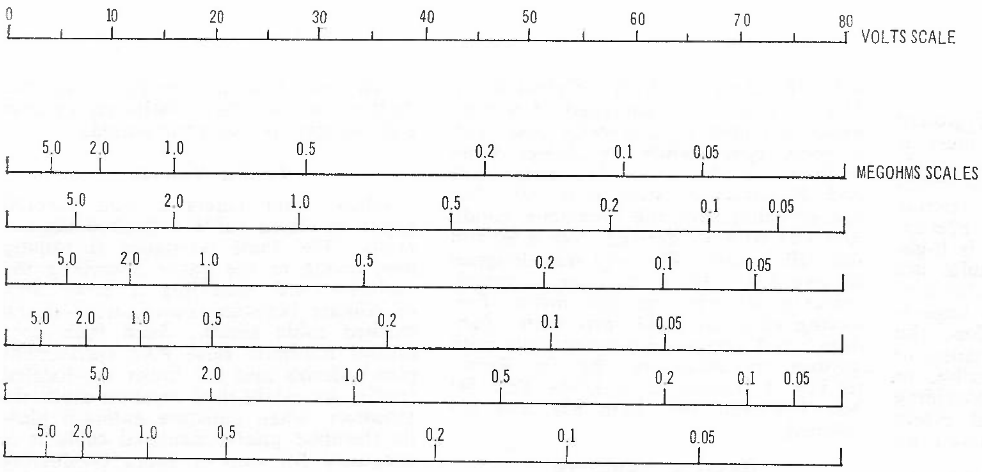


FULL SCALE DEFLECTION (MICROAMPS)	METER RESISTANCE (MEG OHMS)	BATTERY VOLTAGE (VOLTS)
400	*0.225	90
100	0.45	45
100(50)	0.30	30(15)
100	0.15	15
50	0.60	30
50	0.18	9

* 0.025 MΩ VOLTAGE DROPPING RESISTANCE

Fig. 2 — Megohm Scales for Variations in Meter Sensitivity and Battery Voltage.

set using a lower testing battery voltage indicated a much slower rise in dynamic resistance, giving a positive introduction of a fault condition. After a study of the effects of reducing the testing voltage with changes in the sensitivity of the movement (refer Fig. 2) it was decided to adopt a 30-volt testing battery and a 100 microamps full-scale deflection voltmeter. These values give a megohms scale with the graduations conveniently spaced at both ends of the scale. The 100 microamps with 30-volt combination rather than the 50 microamps with 15 volts, was chosen for two minor reasons. The 100 microamps movement is cheaper, more robust and, in the event of 50 volts being encountered when testing whilst switched to the megohms position, the overload is not as severe.

Batteries, Leads, and Carrying Case

The terminal arrangement in the battery compartment of the standard meter case was changed slightly to house two 15-volt (No. 411) minimax batteries in series to give 30 volts. With an average current drain of 50 microamps for short periods, it is expected that these batteries will have adequate life before replacement is necessary. As accurate values of insulation resistance are not essential to the purpose of this meter, the battery voltage could fall by 10 per cent before replacement is considered desirable. With this in mind, a simple battery test has been included on the instruction sheet, rather than include a compensating rheostat.

Quite frequently, it is difficult to obtain an earth potential when testing at a joint in a plastic distribution area unless the exchange earth appears on working pairs; accordingly, the positive lead probe has been lengthened to allow it to be used as an earth stake where required; also, when testing pillar and cabinet tags, crocodile clips can be slipped readily onto the probes to facilitate this operation.

The standard leather meter carrying case has been altered to allow the extended strap ends to pivot freely about positions above the centre of balance of the unit. This enables the operator to suspend the unit around his neck with the meter resting conveniently against his chest in a safe workable position, leaving both hands free to test and record results. Such a method of supporting the meter was found to be essential when testing pairs at a cable box from a ladder, and to be desirable when testing pairs at a cabinet or pillar.

CONCLUSION

This test set is particularly suitable for assisting lines staff detect, interpret and take corrective measures to eliminate low insulation resistance and foreign battery recorded by the Automatic Line Insulation Routine Testers and the Reg. "K" in crossbar exchanges. On fault location work the test set will enable a lineman to test quickly all non-working distribution pairs that cannot be tested directly from the exchange, and thereby help to localise the fault without opening the cable. It may, of course, become necessary for the cable to be opened at suitable points and the faulty pairs tested with the test set before the fault is finally located. In times of high fault incidence there will be substanial manhour savings when all jointers are equipped with test sets to carry out their own line tests. This will relieve the test desk of the heavy load that normally develops under such circumstances and confine exchange testing to the initial detection and the final fault clearance test.

The test sets have proved very popular with all lines staff who have used them and, at a cost of $22 (including the leather carrying case) it is expected that, with intelligent application, each set will quickly save more than its purchase price.

APPENDIX

Terminology

Electrolytic Polarisation or Overpotential: The departure of the e.m.f. of a cell or of an electrode potential, from its reversible value upon passage of a current, and phenomena directly connected with this departure, are called "polarisation", and the electrodes or cells are said to be polarised. A more specific term of similar meaning to that of polarisation, is "overpotential" (or overvoltage). Various types of overpotential may be distinguished.

Ohmic Overpotential: In some electrode processes a film of oxide, or some other substance forms on the electrode surface and sets up a resistance to the passage of current accross it. If the current strength is I and the resistance of the electrode surface is R ohms, this ohmic overpotential is given by IR. The ohmic overpotential at an electrode can reach considerable values, e.g. several hundred volts.

Concentration Overpotential: Concentration Overpotential is caused by the existence of a difference in concentration of the ions between the electrode solution interface and the bulk of the solution.

Activation Overpotential: Activation Overpotential is concerned with the reaction occurring upon electrolytic deposition of ions or evolution of gases.

In most electrode processes it is found that, after making allowance for the ohmic and concentration overpotentials, the electrode still exhibits some overpotential, which is particularly marked, for example, in the evolution of hydrogen and oxygen.

ALUMINIUM DISTRIBUTION CABINETS — RESISTANCE TO RIFLE FIRE

*T. N. PIMM, Grad.I.E. Aust.**

INTRODUCTION

Distribution cabinets and pillars are used in Metropolitan areas to provide flexibility in the use of pairs in main subscribers cables and to provide cross connection facilities from main to distribution cables. The units are made of cast aluminium (BS 1490 alloy LM 6) and are available in three sizes, 300 pair, 900 pair, and 1800 pair. (See Fig. 1). The principal dimensions are given in Table 1.

* Mr. Pimm is Engineer Class 2, Lines Section, Headquarters. See Vol. 16, No. 1, Page 87.

TABLE 1: DIMENSIONS OF PILLAR AND CABINETS

	300 pr.	900 pr.	1800 pr.
Overall Height	3 ft. ¼ in.	3 ft. 1½ in.	4 ft. 6 in.
Overall Diameter	6⅛ in.	11⅛ in.	11⅛ in.
Thickness of Cover	5/32 in.	7/32 in.	7/32 in.

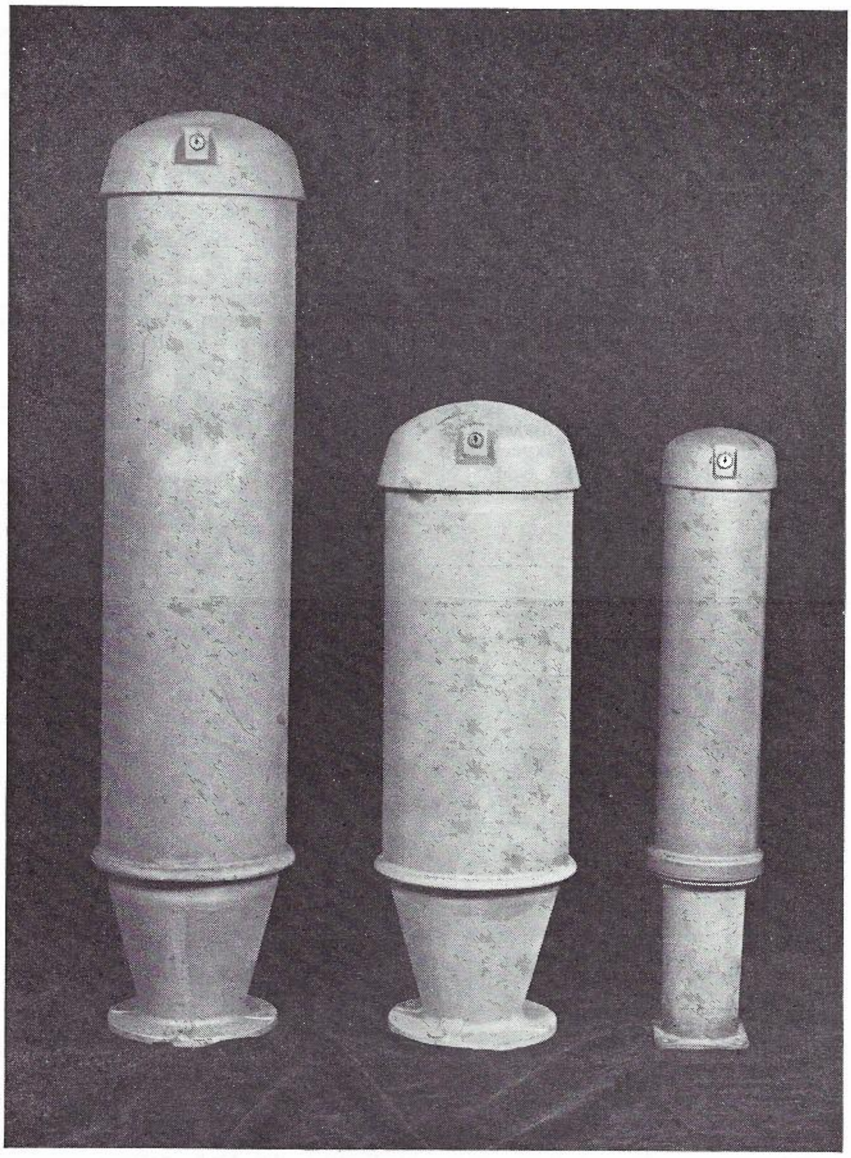


Fig. 1 — Aluminium Distribution Cabinets and Pillar. Left to Right: 1800 pair cabinet, 900 pair cabinet, 300 pair pillar.

Up to the present time they are not in general use in rural areas and the need to investigate their resistance to vandalistic shooting has not arisen. With the advent of solid state amplifiers and their important characteristic of low power consumption, developments are under way for their application to rural carrier frequency balanced pair cables. Due to the small size of the equipment, buildings are no longer necessary and either buried or above ground enclosures are suitable for housing line amplifiers. In the application to rural carrier cables there are many advantages in selecting an above ground housing which is easily accessible for maintenance purposes and largely free from water entry and corrosion problems, which are inescapable when underground installations are adopted. The existing cabinets have the advantage of proven design, ready availability and low cost, and line amplifiers to suit them are now being developed for 12 channel and 60 channel balanced pair operation.

To those familiar with the installation of equipment in the country, the problems of vandalism by rifle fire are well known. Peppered and damaged road signs, buildings, insulators and even vital water tanks are a familiar sight in rural areas. Therefore a cautious approach is being adopted on the introduction into such an environment of another probable target. For this reason, it was decided to carry out tests on the cabinets to obtain information on their susceptibility to damage from 0.22 in. and 0.303 in. bullets at various ranges.

BALLISTIC TESTING

The ranges for the 0.22 in. calibre were chosen on the basis of maximum and minimum probable firing distances. A shooter of the kind considered is unlikely to choose a target at a distance greater than 100 yards owing to the reduced chances of gaining a hit. That is, the vandal is not in the class of the keen and accurate shooter, but is in effect a casual shot who will choose an object because of its proximity and attractiveness. At the short range, the vandal is expected to have either sufficient common sense or hard earned experience to realise the danger of ricochet. A lower limit of 20 yards was therefore considered reasonable and 40 yards was chosen for an intermediate range. The cartridges used for the test were "Civic" high velocity, long rifle type (Fig. 2) with an average muzzle velocity of approximately 1,350 feet per second.

The ranges chosen for 0.303 in. ammunition were based on the sure knowledge of their greater damage potential at much greater distances than 0.22 in. calibre. Distances of 100 yards and 200 yards were chosen, with greater distance being unwarranted as already

Fig. 2 — Cartridges used in Tests and Examples of Deformer Bullets after Testing.

considered. In order to obtain a high accuracy during the 0.303 in. tests it was decided to use a short range (30 yards) and to vary the charge to simulate longer shots. This then allowed accurate placing of rounds in two or three positions from full face to glancing shots. The calculated velocities were 2,230 feet per second at 100 yards and 2,030 feet per second at 200 yards (Fig. 3).

The tests were carried out at the Army Inspection Staff Proving Ranges at Footscray, Victoria under the guidance of Mr. J. Cook, the Senior Inspector for Small Arms Ammunition. The velocity of the 0.303 in. cartridges was determined by a Photo-Electric Counter Chronometer (PCC) over a 100 ft. base with an instrumental midpoint at 90 ft from the muzzle. The recording of the velocity of the 0.22 in. cartridges was by PCC equipment over a 50 ft. base with an instrumental midpoint at 30 ft from the muzzle. The 0.22 in. cartridge velocity was not recorded during the testing at 100 yards. Testing was restricted to the 300 pair and 900 pair covers as the 1800 pair, having the same thickness of metal as the 900 pair, was expected to sustain similar damage. The results of the tests are given in Tables 2 and 3.

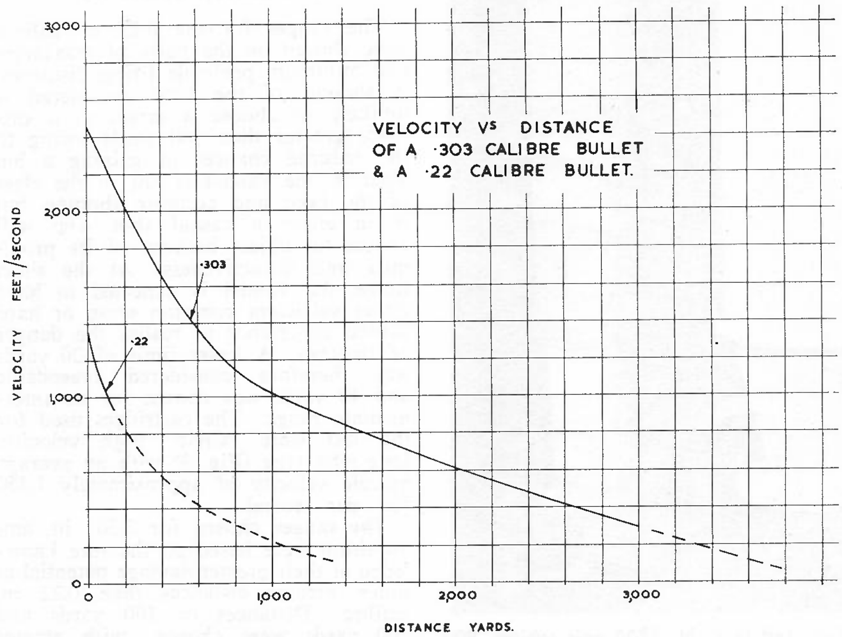


Fig. 3 — Velocity/Distance Curves for 0.303 in. and 0.22 in. Calibre Bullets.

CONCLUSION

From the foregoing results it can be seen that the 300 pair pillar is vulnerable to damage from 0.22 in. calibre high velocity bullets at least up to 40 yards range and probably to 60 yards. However, it is apparent that, having passed through one thickness of aluminium, the remaining energy in the bullet was insufficient to cause any further damage to the inner surface on the opposite side. Furthermore the target width for penetration is only about 2 in. and as accuracy is not expected to be high under these conditions a relatively small amount of damage may be expected on any one unit.

However, considering the large number of shooters using 0.22 in. rifles it would be inadvisable to install the 300 pair unit in large numbers throughout the country areas unless some extra protection was arranged. As this unit will only hold two or three repeaters, its usage in any case would be small and since carrying out these tests it has been decided to concentrate equipment design effort on the 900 pair and 1800 pair sizes.

It will be seen that even at 20 yards range the large casing was not fully penetrated by a 0.22 in. calibre bullet. The maximum penetration was approximately 3/16 in. with some associated deformation of the casing. The inside surface of the casing had, in several cases, star shaped cracks associated with the deformation of the metal (Fig. 6), and these small cracks would allow leakage of air from a pressurised container.

Some examples of the deformed bullets which caused this damage are shown in Fig. 2.

Neither the 300 pair nor the 900 pair casing offered much resistance to 0.303 in. calibre bullets at ranges of 100 and 200 yards (velocities of 2179 and 1998 feet per second). It is of interest however, to consider the range at which a 0.303 in. bullet will just fail to penetrate the 900 pair cabinet. A first approximation may be obtained by assuming that equal energy contained in either a 0.22 in. or 0.303 in. bullet will cause equal penetration. (Strictly this is incorrect owing to differences in both material and shape).

The 0.22 in. calibre long rifle bullet has a weight of 40 grains and a 0.303 in. a weight of 174 grains. Equating the energy of a 0.303 in. calibre bullet to that of the 0.22 in. at 20 yards, we have:

$$E = \tfrac{1}{2} M_1 V_1^2 = \tfrac{1}{2} M_2 V_2^2$$

$$\text{Then } V_2 = \sqrt{\frac{M_1}{M_2}}\, V_1$$

and taking $V_1 = 1250$ feet per second

$V_2 = 600$ feet per second.

A 0.303 in. calibre bullet has this velocity at about 2,000 yards (Fig. 3) indicating the high damage potential of these bullets.

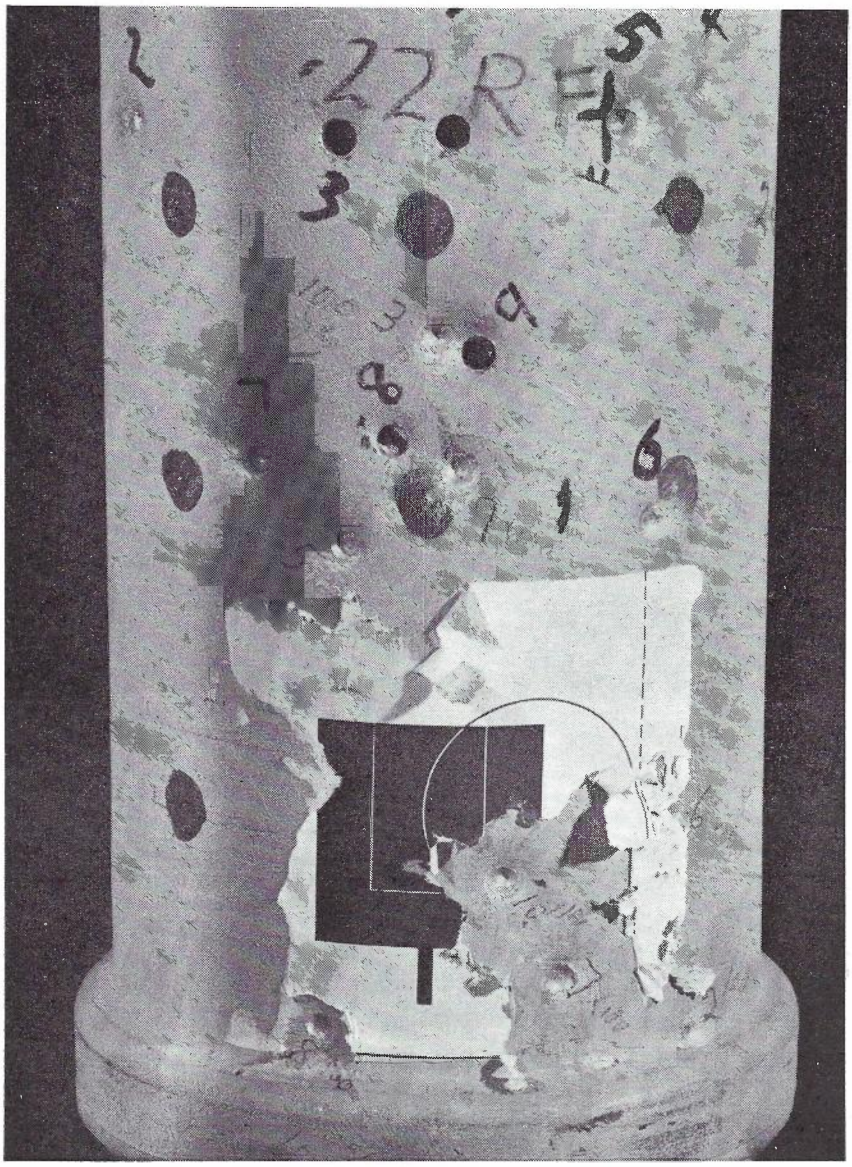


Fig. 4 — Penetration of 0.22 in Calibre Bullets on 300 Pair Cover at 20, 40 and 100 yd. Ranges. (See Table 2).

TABLE 2: TEST RESULTS — 300 PAIR COVER

	Circumferential Distance from centre line (inches)	Velocity at 30 ft. (ft. per sec.)	Striking Velocity (ft. per sec.)	Depth of Penetration (inches)	Remarks
0.22 in. calibre, 20 yards Fig. 4 Top row	$\frac{1}{4}$	1223	1194	Full	Hit centre column
	1	1241	1212	Full	No damage to inside surface on rear of pillar.
	$1\frac{3}{4}$	1243	1214	1/8	Star shaped crack inside surface.
	$2\frac{3}{4}$	1251	1222	1/32	
	$3\frac{1}{2}$	Not Rec'd.	NR	1/32	
0.22 in. calibre, 40 yards Fig. 4 Centre row	1/4	1218	1131	Full	Penetration just complete
	1/2	1284	1197	Full	
	$1\frac{1}{2}$	1215	1128	1/8	Fine tear in metal at bottom of hole. Star shaped crack inside.
	$2\frac{1}{8}$	1145	1058	Negligible	
0.22 in. calibre, 100 yards Fig. 4 Lower shots					Maximum penetration of 7 shots was 1/16 in. with star shaped cracks at inside surface in 4 cases.
0.33 in. calibre 200 yards	Central		1998	Full, front only	Hit centre column
	$3\frac{1}{4}$		1998	Full, front and rear	Large section torn out at rear.

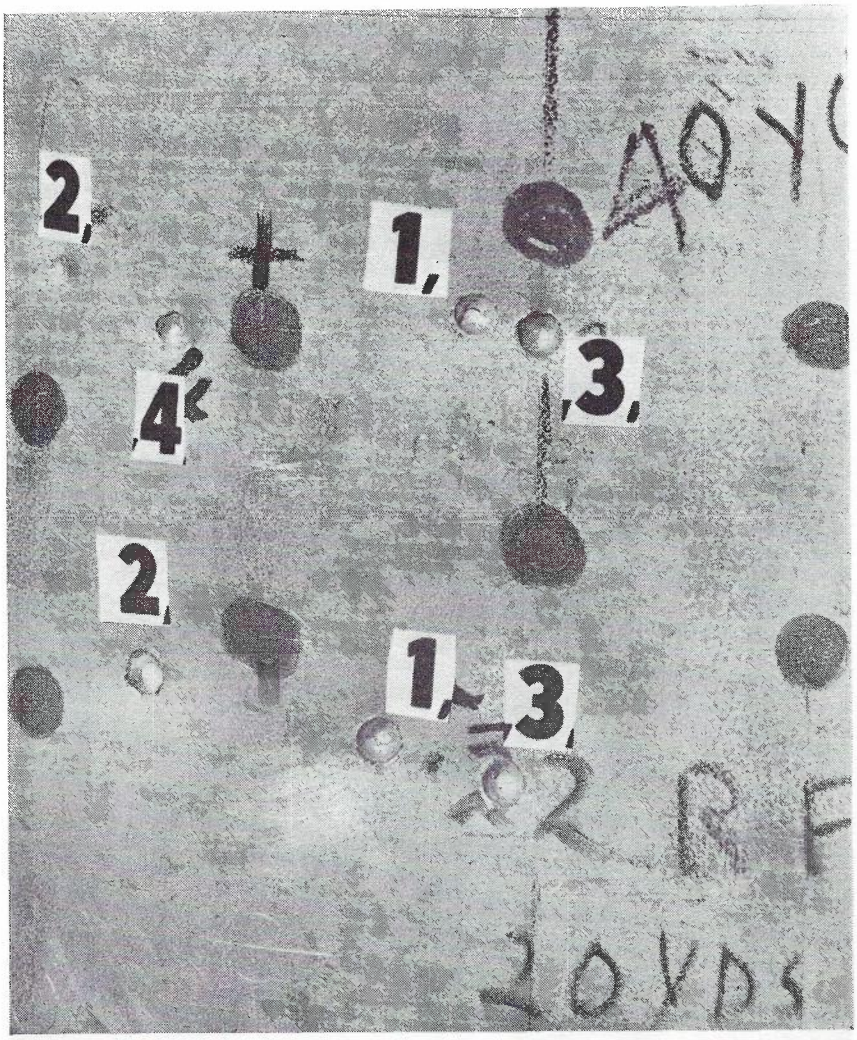


Fig. 5 — Penetration of 0.22 in. Calibre Bullets on 900 Pair Cover at 20 and 40 yd. Ranges. (See Table 3).

TABLE 3: TEST RESULTS — 900 PAIR COVER

	Circumferential Distance from Centre Line	Velocity at 30 ft. (ft. per sec.)	Striking Velocity (ft per sec.)	Depth of Penetration (inches)	Remarks
0.22 in. calibre, 20 yards, Fig. 5 Lower row	1/4	1197	1168	5/32	Local deformation, star shaped crack inside surface.
	1	1232	1203	3/16	Slight local deformation, fine tear in metal at bottom of hole. Star shaped crack inside surface.
	3	1315	1286	3/16	Slight local deformation. Star shaped crack inside surface.
0.22 in. calibre, 40 yards, Fig. 5 Upper row	0	1236	1149	1/8	Local deformation to ⅛ in. between these two adjacent holes. Star shaped cracks inside surface.
	1/2	1241	1154	5/32	
	2¾	1212	1125	1/16	negligible deformation
	3¾	1225	1138	1/32	negligible deformation
0.303 in. calibre, 100 yards	2		2179	Full Front and rear	No denting of surface surrounding bullet entry except for side shots. Severe tearing on rear face of cabinet.
	3¾		2179		
	4½		2179		
0.303 in. calibre, 200 yards.	1¼		1998	Full Front and rear	No denting of surface surrounding bullet entry except for side shots. Severe tearing on rear face of cabinet.
	2		1998		
	4		1998		
	4½		1998	Incomplete Penetration at rear.	

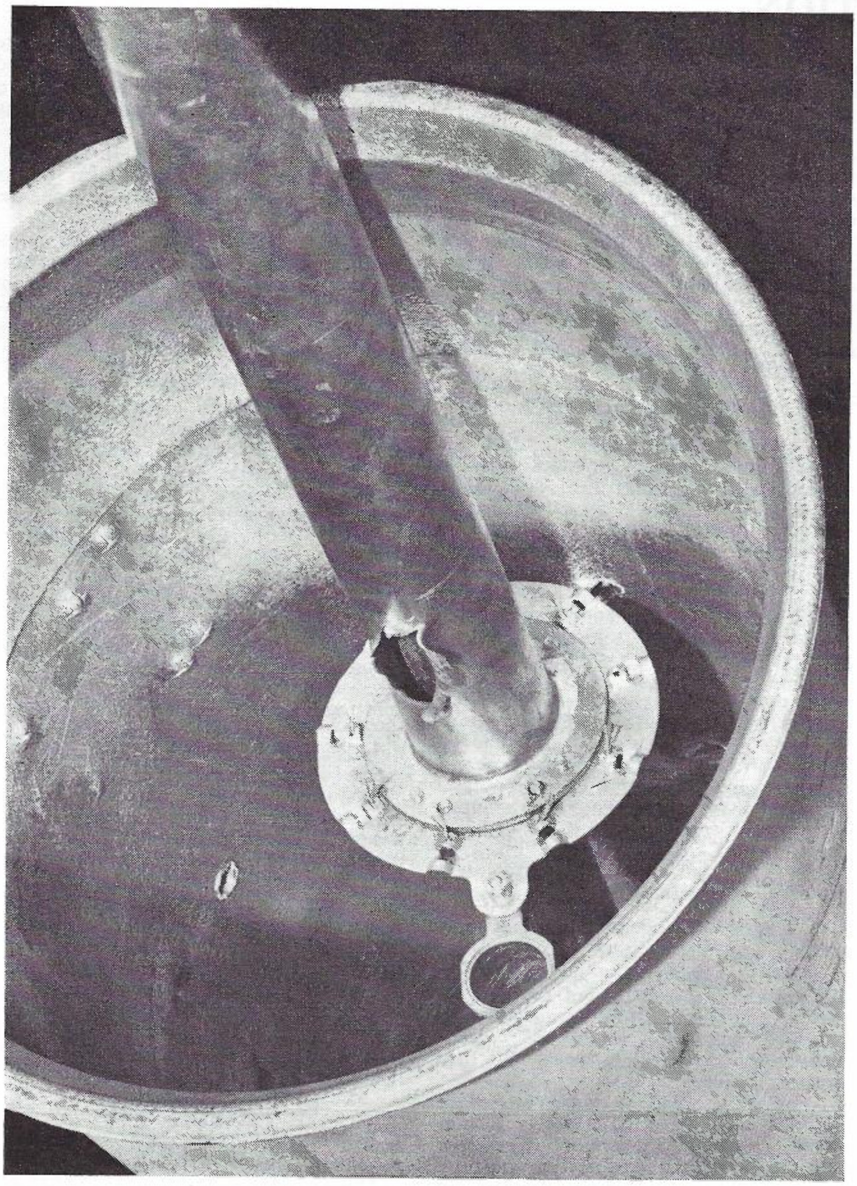


Fig. 6 — Inside Surface of a 900 Pair Cover, showing Star Shaped Cracks from Bullet Penetration.

Consideration may be given to extra protection of the cabinets in order to avoid damage even from 0.303 in. bullets. Such protection however, would need to be of the order of $1\frac{1}{2}$ in. of concrete or $\frac{3}{8}$ in. steel. The cost and weight of this protection severely limits its practical use when compared to installation of a container in a manhole. If, however, the local probability of such damage could not be tolerated and manhole installation was inadvisable for other reasons, a possible method of protection is indicated in Fig. 7 where access is relatively easy and construction cost is not excessive.

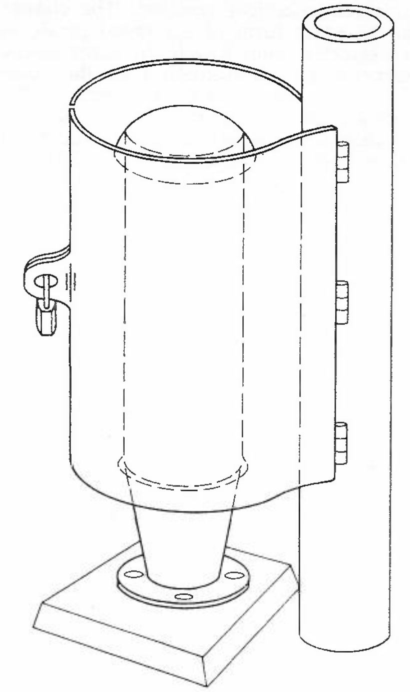


Fig. 7 — A Possible Method of Providing Additional Protection.

ACKNOWLEDGMENT

The Author wishes to thank the Department of the Army for their valuable assistance in making staff and facilities available for the ballistic testing.

CORROSION PREVENTION

Editorial Note: This article is an extract from the papers and subsequent discussion on the general subject of "Corrosion", presented at the meeting of the Equipment Design Study Group, P.M.G. Research Laboratories, by Mr. J. Der, B.Sc., Mr. J. L. McKay, A.R.M.I.T., and Mr. A. H. Baddeley, B.Mech.E., B.E.E., A.M.I.E. Aust.

THE MECHANISM OF CORROSION

Corrosion involves a re-arrangement of the atomic state of metals and conversion into an ionic form by chemical or electrochemical reaction. The change to the ionic form of the metal produces a protective film which, in many cases, prevents any continuation of the reaction. Whether or not this happens depends upon the volume of the corrosion product with respect to that of the metal from which it was formed. A corrosion product of smaller volume yields a porous film, and corrosion proceeds further.

Surface deterioration may occur primarily as a result of mechanical abrasion, sometimes called "erosion", but the most dangerous aspect of corrosion is a combination of corrosion and erosion referred to as "fretting corrosion."

In general, corrosion is accelerated by the presence of a ready supply of oxygen, by the presence of water, especially water containing dissolved salts, by large changes in temperature and by the presence of ultraviolet and/or infrared radiation.

Referring to the acceleration of corrosion in the presence of water containing dissolved salts, we come to the special case of "galvanic corrosion" which occurs when two dissimilar metals are in contact in an electrolyte. The two metals will assume positive and negative electric potentials with respect to one another. Whether this will result in corrosion or not, and which metal becomes the anode, depends upon the particular system of materials.

Several criteria for determining what will happen in the case of galvanic corrosion have been based upon measurements of the standard electrode potentials of the various metals. (Standard Electrode Potential is defined as "The potential of a chemical element dipping into a solution containing its ions at unit activity, referred to that of hydrogen under a pressure of one atmosphere.) These criteria and similar ones based on potentials measured in sea-water will give adequate guidance only if the potential differences are large, which is not often the case. The cases where only small differences in potential are set up must be treated separately on an experimental basis in compiling reliable indications of the acceptability of metal combinations.

PROTECTIVE FINISHES

Metals may be protected against corrosion by means of an applied coating which may be either a chemical treatment or a dipped or electroplated metal finish. The choice of coating is determined in each case by the nature of the task assigned to the metal part.

For example, an unseen component could be given a tenacious chemical treatment which would be unsuited, by its apperance, to visibly exposed locations.

Protective coatings may be of the envelope type (e.g. nickel on steel) or the sacrificial type (e.g. zinc on steel). Chemical treatment finishes are of the envelope type. They are usually very thin and evenly distributed and are either oxides of the base metal or an adherent salt with oxygen in the acid radical.

These and other types of protective coatings will now be described in greater detail.

CHEMICAL FINISHES

Aluminium

Aluminium has its own natural oxide coating which is very thin and fairly adherent, thus giving it a reasonable degree of protection except in the case of fretting corrosion where the oxide film is continually scraped off by abrasion. The oxide coating can be improved by anodising. The anodising process basically consists of making the component the anode in a sulphuric, oxalic or chromic acid bath. The gelantinous aluminium oxide is capable of absorbing dyes during the sealing action in boiling water; thus, the component may be made more attractive in appearance and at the same time the corrosion and abrasion resistance is improved. Aluminium alloys may be similarly treated, but they are usually grey to black in colour after anodising. The treatment provides a suitable key for paints.

Oxides on Ferrous Materials

When ferrous materials are heated in air to a temperature of 200°-350°C., they produce thin adherent oxide films varying in colour from straw through blue to almost black. These colours may result by accident from the heat treatment given.

Another way to produce an oxide coating on ferrous materials is to immerse the component in a hot alkaline bath of potassium and sodium nitrates for 10-15 minutes. These finishes, in themselves, are not very resistant to corrosion because of their porosity. The porosity is useful for absorbing and retaining oil or lanoline or as a key for paint.

Oxide coatings may also be formed on copper, magnesium and zinc by chemical means or by atmospheric corrosion. These are very porous and do not offer much in the way of protection except as a key for painting.

In the case of stainless steel, the protection is provided by a film of chromium oxide derived from the chromium added as an alloying element. The chromium oxide tends to break down in chloride solution and where there is a limited supply of atmospheric oxygen. For instance, stainless steel will corrode if moisture is present and if some adjacent part is clamped over the stainless steel in such a way as to exclude oxygen.

Phosphate Coatings

Phosphoric acid is used, particularly in the automotive industry, for producing a protective ferrous phosphate coating by chemical action on iron and steel components. The phosphate is a thin, clear and somewhat porous coating which should never be used without sealing with oil or wax. In most instances, it is used as a key for paints and will withstand stoving enamel temperatures.

When used without subsequent painting, but with oil or wax sealing, phosphate coatings will protect internal plant for periods of 5 to 10 years. For external plant, painting is essential to provide adequate protection.

Chromate Passivation

Zinc or cadmium electroplated coatings, as used extensively in the telecommunications equipment field, can be improved remarkably by subsequent chromating. The surface layer of zinc or cadmium is converted to the insoluble chromate, with some soluble chromate present as well. The soluble chromate bleeds out if the surface is damaged by abrasion to form more insoluble chromate on the freshly exposed surfaces. The colour, bronze to olive green, of the chromate depends on the bath temperature, composition, duration of treatment and the brightness of the plated surface. The coating is impervious to liquids and is even slightly repellent to water. It also provides a good key for paints.

Zinc base die castings are often treated in a chromate bath and may be used in the chromated condition alone or subsequently painted.

There are baths available to chromate brass and copper. Tests of chromated brass and copper in the humidity chamber indicate satisfactory performance in comparison with electro-tinned materials. Inspection difficulties could arise from the fact that little or no colour change occurs when brass or copper is chromated.

ELECTRODEPOSITED COATINGS

Sacrificial Types

The two main sacrificial coatings are zinc and cadmium, deposited to thicknesses of 0.0004 in. to 0.001 in.

Cadmium has been popular for many years, having a better appearance than zinc. It has good throwing power, so will cover the bottoms of fairly large depressions, The corrosion products of cadmium are not as unsightly and voluminous as in the case of zinc. Chromating improves the corrosion resistance and can give a pleasing brass-coloured finish.

Zinc plating can be substituted for cadmium in many cases where its lower cost can be advantageous. Zinc plating in industrial atmosphere gives better protection than does cadmium but, in marine and salt spray tests, cadmium is superior. Chromating of the zinc plating reduces the volume of white rusting and improves the corrosion resistance.

Envelope Types

Electro-deposited coatings of the envelope type are those which form an envelope of deposited metal totally enclosing the base metal. In practice, this is difficult to achieve because porosity is always present.

Copper: Copper is not used on its own except for other applications than corrosion prevention, such as electrical contacts.

When zinc base die castings are to be nickel plated, a minimum thickness of 0.0004 in. of copper must be deposited first to prevent staining of the nickel during plating.

During the nickel shortage of the 1950's copper was used as a practical substitute for nickel as a plating metal on steel. When copper is used as an undercoat for nickel, the corrosion resistance of the nickel is decreased because the electropotential difference between nickel and copper is greater than that between nickel and iron. The same comment applies to chromium plating over copper.

The main reason why copper underlayers are used, particularly in the automotive field, is because the copper plating is more easily buffed than is the underlying steel.

Nickel: Nickel is probably the most commonly used electroplating material of the type which produces an envelope coating. The most common of the nickel electroplated finishes is bright nickel. Brighteners such as cobalt and complex organic sulphur compounds are added. The envelopes are high in residual stress and tend to be brittle and may crack. The coatings also tend to trap some of the sulphur of the bath and the sulphides change the electropotential.

To overcome these defects, the semi-bright bath was developed. The deposit is ductile, low in stress and has good levelling properties. The latest trend in nickel baths is to use a duplex nickel deposit. The semi-bright nickel is plated on the base metal to approximately half the required thickness and then the remaining thickness is built up by means of a bright nickel layer. The two layers may be distinguished under the microscope by mounting and etching. The semi-bright bath results in large columnar grains whereas the bright nickel bath gives a banded fine-grained deposit.

Chromium: Bright chromium has been used for many years as a deposit over nickel although it may be used over bare steel. The latter is not a suitable coating. The thickness is usually of the order of 0.00002 in. Where continuous, chromium plate is very resistant to abrasion and corrosion. Most conventional plating has a few hairline cracks, since there is a high residual stress and the plating is brittle. These cracks allow corrosion to proceed due to the galvanic cell formed between the chromium and the base metal, be it nickel or steel. Since there are comparatively few cracks, there is a high current density and as a result, unsightly pits develop fairly rapidly.

A recent development has been micro cracked chromium plating. This means that the plating, as it comes from the bath, has 1000-1500 cracks per linear inch. This exposes a good deal more of the corroding medium, thus dropping the current density. The appearance of such finishes is very similar to the normal bright chrome.

Tin: Tin is a suitable plating metal for ferrous materials to be used in dry conditions and gives generally satisfactory protection on copper base alloys such as brass and bronze. Tin plating is sometimes applied to components which must be soldered later, although the coating gives a more acceptable surface if the deposited tin is melted after plating. The melting reduces porosity. Tin can be deposited on aluminium solution to form a thin adherent coating.

HOT-DIPPED COATINGS

Three metals are commonly applied as protective coatings by a hot-dipping bath. These are zinc (as in hot-dip galvanising), lead and tin (or tin alloys).

Hot-dip galvanising gives excellent protection for outdoor equipment but it has disadvantages for accurately fitting components, since the coatings of zinc are quite thick in parts and a smooth surface is not easily obtained. Also it is not unusual for the parts being dipped to distort under the thermal shock.

Dipped lead coatings are preferable to electro-deposited lead because they are less porous. Lead coatings have special application in and around battery rooms.

They give better protection than zinc in heavy industrial areas, although toxicity problems can arise.

Dipped tin or tin alloy coatings are useful as soldering aid finishes for items such as metallic eyelets, tags and printed wiring.

METAL SPRAYED COATINGS

Sprayed metals are produced by melting a metal in a flame and blasting the molten metal on to the surface to be coated.

Sprayed zinc and aluminium are often used as a corrosion protection on large frames which are first cleaned by pickling or by sand-blasting. These latter processes provide a key for the sprayed metal. The surface of the sprayed metal is porous and rough and so provides a good key for paint.

PAINT-LIKE COATINGS

Zinc-rich bonded sodium silicate finishes have been approved by the P.M.G.'s Department for repairing damaged areas of equipment. This finish would suit, for example, some types of pole-mounted equipment although for the more

	GOLD, PLATINUM GOLD-PLATINUM ALLOYS.	RHODIUM, PALLADIUM, GRAPHITE.	SILVER, HIGH SILVER ALLOYS.	TITANIUM.	NICKEL, MONEL, COBALT, HIGH-NICKEL & HIGH COBALT ALLOYS.	NICKEL-COPPER ALLOYS.	18/8 STAINLESS STEELS.	COPPER, BRONZE, COPPER ALLOYS, SILVER SOLDER.	COMERCIAL YELLOW BRASS & BRONZE.	LEADED BRASS, NAVAL BRASS, LEADED BRONZE.	HIGH CHROMIUM LOW NICKEL STEELS (18/2).	CHROMIUM, TUNGSTEN, MOLYBDENUM.	12% CHROMIUM STEEL.	TIN, INDIUM, TIN-LEAD SOLDER.	LEAD, LEAD-TIN SOLDER.	DURALUMIN. *	STEEL (EXCEPT CORROSION RESISTANT TYPES)*	ALUMINIUM.	CADMIUM & ZINC PLATE, GALV. STEEL, BERYLLIUM, CLAD ALUMINIUM.	MAGNESIUM. *
GOLD, PLATINUM GOLD-PLATINUM ALLOYS.					X	X	X	X	X	X	X		X	X	X	F	F	X	X	F
RHODIUM, PALLADIUM, GRAPHITE.									X	X	X		X	X	X	F	F	X	X	F
SILVER, HIGH SILVER ALLOYS.										X	X		X	X	X	F	F	X	X	F
TITANIUM.																F	F			F
NICKEL, MONEL, COBALT, HIGH-NICKEL AND HIGH-COBALT ALLOYS.	X												P	P	X	F	F	P	X	F
NICKEL-COPPER ALLOYS.	X												X	X	X	F	F	X	X	F
18/8 STAINLESS STEELS.	X													P	X	F	F	P	P	F
COPPER, BRONZE, COPPER ALLOYS, SILVER SOLDER.	X													X	X	F	F	X	X	F
COMERCIAL YELLOW BRASS & BRONZE.	X	X													X	F	F	X	X	F
LEADED BRASS, NAVAL BRASS, LEADED BRONZE.	X	X	X													F	F	X	X	F
HIGH CHROMIUM LOW NICKEL STEELS (18/2.)	X	X	X													F	F	P	X	F
CHROMIUM, TUNGSTEN, MOLYBDENUM.																F	F		P	F
12% CHROMIUM STEEL.	X	X	X		P	X										F	F	X	X	F
TIN, INDIUM, TIN-LEAD SOLDER.	X	X	X		P	X	P	X								F	F		P	F
LEAD, LEAD-TIN SOLDER.	X	X	X		X	X	X	X	X							F	F			F
DURALUMIN. *	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F
STEEL (EXCEPT CORROSION RESISTANT TYPES)*	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F		F	F	F
ALUMINIUM.	X	X	X		P	X	P	X	X	X	P		X			F	F			F
CADMIUM & ZINC PLATE, GALV. STEEL, BERYLLIUM, CLAD ALUMINIUM.	X	X	X		X	X	P	X	X	X	X	P	X	P		F	F			F
MAGNESIUM. *	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	

[ ] COMPATIBLE.

[X] NOT COMPATIBLE.

[P] COMPATIBLE IF NOT EXPOSED WITHIN 2 MILES OF A BODY OF SEA WATER.

[F] COMPATIBLE ONLY WHEN FINISHED WITH AT LEAST ONE COAT OF PRIMER. (EG. ZINC CHROMATE, EPOXY OR SYNTHETIC ALKYD IRON OXIDE)

TABLE 1: METALS COMPATIBILITY CHART

NOTES: Anodised aluminium is compatible with all other metals.

Anodised magnesium is not sufficiently protected and, if not primed should be separated from other metals by a vinyl or mylar tape.

Metals indicated by * must be finished with at least one coat of primer.

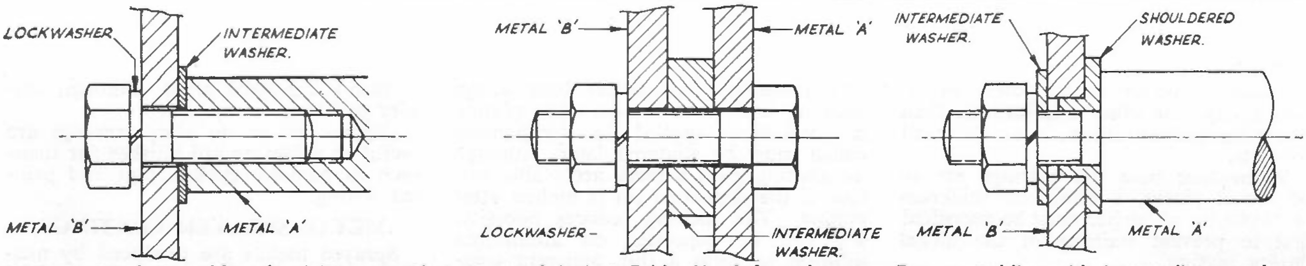


Fig. 1. Typical assemblies for joining metal A to metal B (see Table 2). Left and centre: Two assemblies with intermediate washers. Right: Typical assembly with shouldered and intermediate washers.

important working articles, it should not be regarded as an adequate substitute for hot-dip galvanising.

Lead-tin alloy paint has similar properties to lead plating. It is readily solderable but, unfortunately, is porous. It is useful for electrical connectors but, from a corrosion resistance viewpoint, it cannot be recommended.

ELECTRODELESS NICKEL

This chemical treatment uses a 7% phosphorus alloy of nickel and promises to be of value in the telecommunication field. It has properties similar to those of electro-deposited nickel with the following advantages:—

(i) even thickness
(ii) heat treatable to 600 Diamond hardness
(iii) very little porosity
(iv) excellent corrosion resistance
(v) similar speed of application to that of electrodeposited nickel.
(vi) no limit on thickness (as distinct from electrodeless gold and tin coatings). Nickel keeps coming out of solution in what is termed an auto-catalytic self-regenerative process.

At present, the process is expensive (around $2.50 per square foot) but an increase in the number of operating plants in Australia and an increase in the volume of parts to be coated may reduce the price to a more competitive figure.

METAL 'A'		METAL 'B'		SCREW AND/OR NUT.	LOCK WASHER	SHOULDERED AND / OR INTERMEDIATE WASHER.
MATERIAL	PROTECTION	MATERIAL	PROTECTION			
BRASS	SILV. PL OR NOT	BRASS	SILV. PL OR NOT	STAIN. STEEL	Ni PL. BRONZE	NIL
"	SILV. PL.	LIGHT ALLOY	COPPER THEN SILVER	CHROME PL. STEEL	"	"
"	CHROME PL. CAD. PL OR NOT	"	ANODISED OR NOT	"	CAD. PL. STEEL ●	"
"	SILV. PL.	"	"	"	" ●	CHROME PL. STEEL
"	SILV. PL. OR NOT	STAIN. STEEL	NIL	STAIN STEEL	Ni PL. BRONZE	NIL
"	SILV. PL.	STEEL ●●	CAD. PL. CAD. PL. & PASSIVATE OR NOT	CHROME PL. STEEL	CHROME PL. STEEL	CHROME PL. STEEL
"	CHROME PL. CAD. PL. OR NOT	" ●●	"	" ●	"	NIL
LIGHT ALLOY	ANODISED OR NOT	LIGHT ALLOY	ANODISED OR NOT	CAD. PL. STEEL ●	CAD. PL. STEEL ●	"
"	"	BRASS	SILV. PL.	CHROME PL. STEEL	Ni PL. BRONZE	CHROME PL. STEEL
"	"	"	CHROME PL. CAD. PL. OR NOT	" ●	CHROME PL. STEEL	NIL
"	"	STEEL ●●	CAD. PL. CAD. PL. & PASSIVATE OR NOT	CAD. PL. STEEL ●	CAD. PL. STEEL ●	"
"	"	STAIN. STEEL	NIL	CHROME PL. STEEL	Ni PL. BRONZE	CHROME PL. STEEL
STEEL ●●	CAD. PL. CAD. PL. & PASSIVATE OR NOT	BRASS	SILV. PL.	"	"	"
" ●●	"	"	CHROME PL. CAD. PL. OR NOT	CHROME PL. STEEL ●	CHROME PL. STEEL	NIL
" ●●	"	STAIN. STEEL	NIL	CHROME PL. STEEL	Ni PL. BRONZE	CHROME PL. STEEL
" ●●	"	LIGHT ALLOY	ANODISED OR NOT	CAD. PL. STEEL ●	CAD. PL. STEEL ●	NIL
STAIN. STEEL	NIL	BRASS	SILV. PL. OR NOT	STAIN. STEEL	Ni PL. BRONZE	"
"	"	LIGHT ALLOY	ANODISED OR NOT	CHROME PL. STEEL	CHROME PL. STEEL	CHROME PL. STEEL
"	"	STEEL ●●	CAD. PL. CAD. PL. & PASSIVATE OR NOT	"	"	"

● FOR EXTERIOR PARTS & FRONT PANELS, REPLACE CAD. PLATED STEEL BY CHROMIUM PLATED STEEL

●● ALL STEELS & CAST IRONS EXCEPT AUSTENITIC STAINLESS STEELS & STEEL OF HIGH CHROMIUM CONTENT ≥ 12%

TABLE 2: HETEROGENEOUS ASSEMBLY CHART (SEE FIG. 1).

ASSEMBLY OF DISSIMILAR METALS

The question of galvanic corrosion has already been mentioned and the limitations of existing methods of predicting the behaviour of the various metal combinations have been indicated.

Nevertheless, for the practising designer, some sort of guide in the selection of suitable metal pairs and in the protection of metals which must be mounted close together is essential. These are, in effect, two distinct problems. The first one requires a chart or table showing which pairs of metals may be safely left in contact and those which must not be permitted to remain in contact. Such a chart is reproduced in Table 1. This chart is an adaptation of one reported by Littlefield and Groshart of the Boeing Company in "Machine Design" of 9th May, 1963.

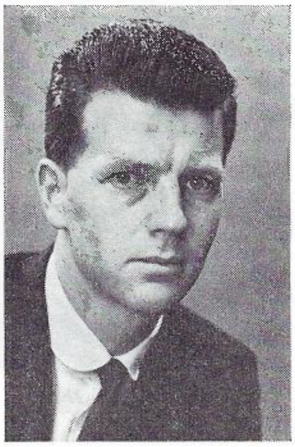
In it, the compatibility of each pair of metals is indicated by the symbol lying in the square located at the intersection of the two relevant rows at right angles to one another. Notice the special requirements of duralumin, steel and magnesium, irrespective of the metal with which they are in contact.

There are times when incompatible materials must be bolted together and we then come to the second basic problem, namely, what to do to prevent galvanic corrosion. In most cases it is possible, by judicious selection of the screw or nut material and by interposition of a suitable spacing washer, to reduce the electropotential differences between all mating surfaces to reasonably safe values. Fig. 1 shows typical assemblies in which a metal "A" must be joined to another metal "B" by means of a screwed connection.

In Table 2, the most commonly used combinations of metals are listed in the columns for metals "A" and "B". The other columns contain recommended specifications of the metals to be used for the screw (or nut), for the lockwasher and for the intermediate washer where one is necessary. The information contained in Table 2 has been obtained from the design handbook of a commercial manufacturer — Le Materiel Telephonique Paris and its origin is hereby gratefully acknowledged.

OUR CONTRIBUTORS

K. B. CASEY



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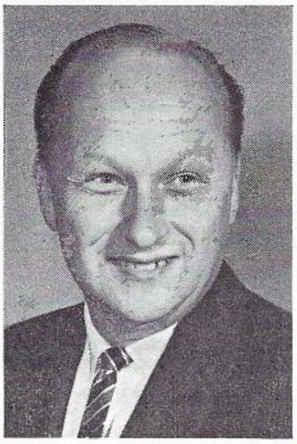

J. LIIV

R. B. CULLEN

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J. LIIV, co-author of the article "Seacom Cable System — New South Wales Land Section", joined the Postmaster-General's Department N.S.W. as a Cadet Engineer in 1940. After qualifying as an Engineer in 1943 he served in the Telephone Equipment and Metropolitan Lines Sections in Sydney before taking up duty in the country engineering division with headquarters in Canberra. In 1950 Mr. Liiv was appointed Divisional Engineer and after a total of seven years' service in charge of various divisions in the Telephone Planning, Metropolitan Exchange Installations and Primary Works Sections in Sydney transferred to the Trunk Service and Telegraphs Section in 1957 where he, at present, occupies the position of Divisional Engineer, Trunk Service No. 1. In this position Mr. Liiv is responsible for the overall maintenance and operation of the N.S.W. portions of the Sydney-Melbourne and Lismore-Brisbane coaxial cable systems and of all broadband carrier systems associated with radio bearers in N.S.W. He has been closely associated with recent developments in the Trunk Service field such as quality control of long line equipment, switching of television relays, trunk line aspects of STD facilities and true four-wire trunk switching. Mr. Liiv is an Associate Member of the Institution of Engineers, Australia.

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R. B. CULLEN, author of the article "Executive-Secretarial Telephone Systems", commenced with the Postmaster-General's Department as a Cadet Engineer in 1957. He graduated as Bachelor of Engineering at the University of Melbourne in 1962 and was appointed Engineer Class 1, Substation Installation Division (Western), Melbourne. Mr. Cullen has been involved in investigations of many subscriber requests for special facilities, and in the development of substation equipment to meet these requirements. This included an investigation of executive-secretarial requirements in the Melbourne area and the development of the Multifone and its associated items of equipment. Mr. Cullen is at present acting Engineer Class 2 in the Substation Installation Section, Melbourne.

O. F. LOBERT, author of the article "Transmission of Power with Microwaves", joined the staff of the P.M.G. Research Laboratories in December, 1950, on completion of the Honours Course in Electrical Engineering at Melbourne University. In the Radio Systems Division he was in the team which developed a 900 Mc/s 120 channel radio telephone system before transferring to the Propagation Division. In 1956 he was awarded a Public Service Board Post-Graduate Scholarship to attend the post-graduate course for the Diploma of the Imperial College at the University of London. On his return he rejoined the Propagation Division of the Research Laboratories until 1961. Since then he has been Engineer Class 3, first in the Radio Systems Division where he was mainly concerned with design and research into aerials and since 1963 in the Microwave Techniques Division where his research activities covered circulators, parametric amplifiers and lately a close association with the laser research programme. Mr. Lobert is an Associate Member of the Institution of Engineers, Australia and a Graduate Member of the Institution of Electrical Engineers.

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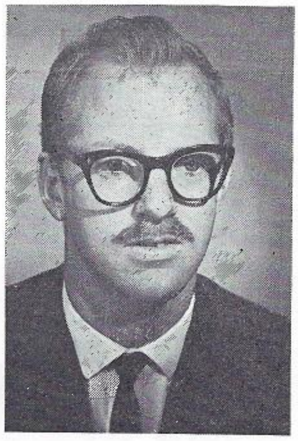

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E. G. WORMALD, co-author of the article "Engset Traffic Tables", joined the Australian Post Office in 1939 as Junior Mechanic-in-Training. Promoted to Cadet Engineer in 1943 and Divisional Engineer in 1950, his work included PABX installation, internal plant planning and special duties as N.S.W. representative on the (Engineering) Multi-metering Committee. After the design and introduction phases of the Traffic Distribution Recording project, he had charge of a Traffic and Trunking Division until his resignation in 1960. His work in control of A.W.A.'s Teleprinter and Data Systems Circuit Laboratory included development of the 'DATABLOC' system of potted logic and a range of devices (such as a regenerative telegraph repeater) using it. Since 1964 he has led the Systems Design Group of Telephone and Electrical Industries Pty. Ltd., a member of the Plessey Telecommunications Group.

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G. F. CARBOON, author of the article "article "A Portable Test Set for Linemen" joined the Department as a Telegraph Messenger in 1942. He completed the Mechanic-in-Training course in 1946 and was appointed as Technician A.B.C. Studios. Upon completion of a cadetship in 1953 he was appointed as Engineer Grade 1, Metropolitan District Works, followed by promotion to Group Engineer Lines Section, Central Office, in 1955. In his present position of Engineer Class 2, District Works, he has shown particular interest in plastic cable jointing, cable fault location and joint-use construction. He was responsible for the erection on S.E.C. poles of the first S.E.C. aerial supervisory cable ten miles cross-country from Thomastown to Keilor (Melbourne), using the Telsta Mobile Work Platform. Mr. Carboon is an Associate Member of the Institution of Engineers, Australia.

B. J. McMAHON, author of the article "Dimensioning of the Queue for the Melbourne Centralised Complaints Centre", joined the Postmaster-General's Department as a Cadet Engineer in 1956, and obtained the Bachelor of Engineering Degree with Second Class Honours from the University of Queensland. During 1960 and 1961 he was attached to the Queensland Engineering Division as Engineer Class 1, and transferred to the Research Laboratories in November, 1961. His main activities have been in the development of electronic equipment for use in conjunction with electro-mechanical equipment, including Call Counters and the Automatic Traffic Recorder in addition to the Queueing Equipment. He is at present with the Electronic Switching Division of the Laboratories as Engineer Class 2.

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B. W. G. PENHALL, co-author of the article "Seacom Cable System — New South Wales Land Section", joined the Postmaster-General's Department, New South Wales as a Cadet Engineer in 1951. After completion of his Bachelor of Engineering Degree at the University of New South Wales he was attached to the Radio Section and as an Engineer in the Radio-telephone Installation Division was responsible for the design, installation and testing of VHF Radio-telephone systems. Since the introduction of broadband radio bearers he has been primarily engaged on the installation and commissioning of this type of equipment. During 1964 he was detached from this work to act as Divisional Engineer, Studios. With the transfer of Studio activities to the A.B.C. he returned to the broadband field to carry out special work associated with system design and upgrading. In this position he was closely associated with the investigation into the performance and upgrading of the Heaton-Lismore broadband system.

K. A. BARNES, author of the article "ARM 50 Crossbar Transit Exchange", is Engineer Class 1, Queensland, currently on temporary transfer as Engineer Class 2, Telegraphs Design and Installation Section, Headquarters. He joined the Postmaster-General's Department in 1949 as Technician-in-Training and after qualifying spent some time on Country Equipment Installations as Technician, and then Senior Technician. In 1955 he was transferred as Technical Instructor and later spent several years as acting Engineer, first in technical training and later in material supplies. He qualified as Trainee Engineer in 1959, completed the Bachelor of Science Degree (Physics) at the University of Queensland in 1961, and qualified as an Engineer in 1962 at the examinations of the Institution of Engineers. From 1963 to 1964, he was Engineer, Technical Training, and since his transfer to Headquarters in February 1965, he has been working on the Automatic Telex Project. He is a Graduate Member of the Institution of Engineers, Australia.

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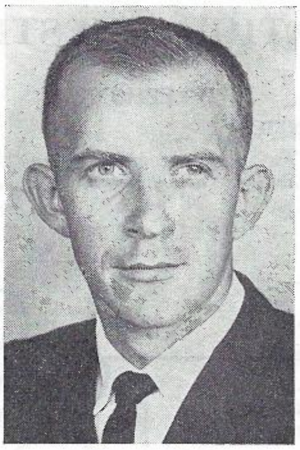

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K. A. CURLEY, author of the article "The Electronic Queue System for the Melbourne Centralised Complaints Centre", joined the Department in 1946 as a Technician's Assistant. He qualified as Technician in 1948 and Senior Technician in 1950. He worked initially on telephone installation and exchange maintenance in Melbourne and in 1953 joined the staff of the Circuit Laboratory, Telephone Equipment Section, Central Office. He was appointed as Supervising Technician Grade 3 in charge of the Laboratory Technical Staff and for some time was Acting Group Engineer in the Laboratory. In 1962 he transferred to the Research Laboratories as Senior Technical Officer Grade 2 in the Electronic Switching Division.

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E. MOREN, co-author of the article "Design of a Remotely Controlled Magneto Exchange", joined the Postmaster-General's Department in 1955 as a Technician-in-Training at Brisbane. He was engaged on maintenance of Telephone Equipment at Rockhampton and Townsville until promoted to Senior Technician at Roma in 1963. From that time, he has been largely occupied with the development, installation, and maintenance of S.A.X.'s and the R.C.M.X.

V. V. DRIKSNA, co-author of the article "Engset Traffic Tables", graduated from the University of N.S.W. in 1963 as a Bachelor of Science, majoring in Physics. Since that time he has been employed in the Systems Design Group at Telephone and Electrical Industries Pty. Ltd. (a member of the Plessey Telecommunications Group) investigating aspects of telephone traffic and trunking. At present he is engaged in developing simulation programmes relating to these problems, utilizing the KDF9 computer at Sydney University.

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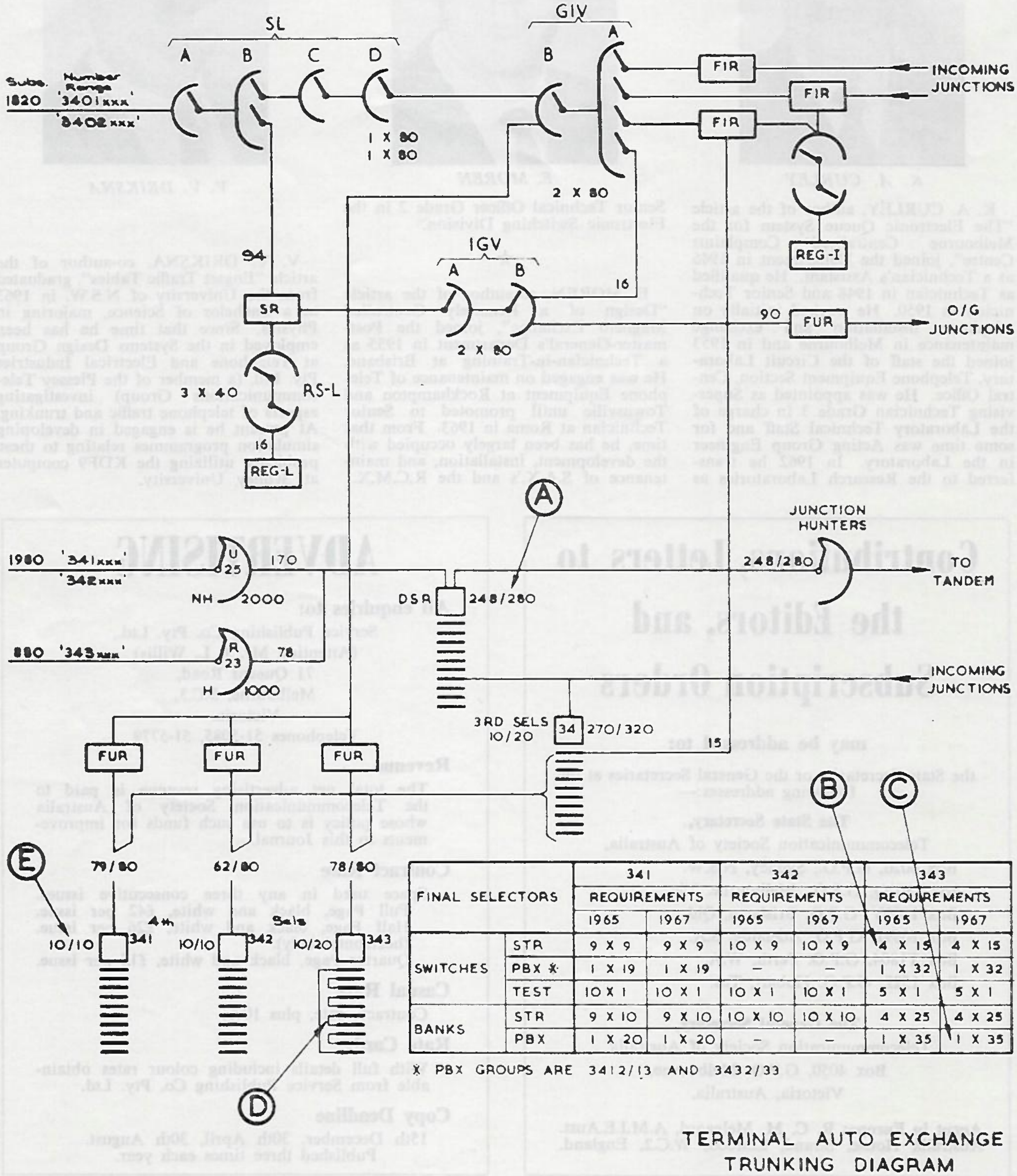
ANSWERS TO EXAMINATION QUESTIONS

Examination No. 5364—3rd July 1965 and subsequent dates to gain part qualification for promotion as Senior Technician (Telecommunications), Postmaster-General's Department.

TELEPHONY

QUESTION 1

(a) *Test and plugging-up line circuit facilities are available on an exchange test desk for the use of a testing officer. List three types of faults on subscribers' lines which can be catered for by using this equipment.*



FINAL SELECTORS		341 REQUIREMENTS 1965	341 REQUIREMENTS 1967	342 REQUIREMENTS 1965	342 REQUIREMENTS 1967	343 REQUIREMENTS 1965	343 REQUIREMENTS 1967
SWITCHES	STR	9 X 9	9 X 9	10 X 9	10 X 9	4 X 15	4 X 15
	PBX *	1 X 19	1 X 19	—	—	1 X 32	1 X 32
	TEST	10 X 1	10 X 1	10 X 1	10 X 1	5 X 1	5 X 1
BANKS	STR	9 X 10	9 X 10	10 X 10	10 X 10	4 X 25	4 X 25
	PBX	1 X 20	1 X 20	—	—	1 X 35	1 X 35

Fig. 1

(b) Explain the purpose of a test and plugging-up line circuit.

(c) In the space provided below, sketch a simplified diagram which illustrates the circuit test condition in a test desk for a low resistance test (low scale) on a subscriber's line.

(d) Why is the low scale facility provided on a test desk?

ANSWER 1

(a) Three of the following:—

Earth on "B" line.
Battery on "A" line.
Earth on "A" line.
Battery on "B" line.
Short circuit line.
Open circuit line.

(b) Refer to Course of Technical Instruction, Telephony 4, Paper 8, Para. 4.1.

(c) Refer to Course of Technical Instruction, Telephony 4, Paper 8, Fig. 16b.

(d) To obtain a greater degree of accuracy in measuring resistances below 500 ohms.

QUESTION 2

(a) Briefly explain the meaning of any THREE of the following terms when used with crossbar automatic exchange equipment and circuits.

(i) S.L. stage.
(ii) Semi-detached circuit drawings.
(iii) Multi-coil relay.
(iv) M.F.C.
(v) ARK equipment.
(vi) Conditional selection.

(b) Part of the trunking diagram in Fig. 1 shows trunking requirements for ARF 102 crossbar automatic exchange equipment.

Which device on the trunking diagram provides transmission battery for each of the following calls

(i) Subscriber No. 340 1011 to subscriber No. 56 8012?

(ii) Subscriber No. 56 8012 to subscriber No. 340 1011?

(c) The diagram in Fig. 2 is used in grouping plans for ARF 102 crossbar automatic exchange equipment.

(i) What does symbol A represent?

(ii) What does symbol B represent?

(iii) What does symbol C represent?

(d) ARF 102 crossbar automatic exchange equipment uses a multi-frequency code for compelled sequence signalling.

(i) How many frequencies are provided for signalling from registers to markers?

(ii) How many frequencies are provided for signalling from marker to registers?

(iii) Explain briefly what is meant by the term "compelled sequence signalling".

ANSWER 2

(a) Three of the following

(i) S.L. stage is the term given to the switching stage directly associated with groups of subscribers lines in an ARF or ARK type exchange.

(ii) Semi-detached circuit drawings are those in which the contacts of a relay are shown associated with the relay but not necessarily in the same order in which they are mounted on the relay. A broken line links together the contacts and associated relay coils.

(iii) A multi-coil relay consists of a contact field of ten springsets under the control of ten armatures and relay coils all mounted on a common yoke.

(iv) The term M.F.C. refers to the method of signalling known as Multi-Frequency Code signalling. A code for a signal consists of two V.F. tones simultaneously applied to a circuit.

(v) ARK equipment is the term used for small country exchanges using L.M.E. crossbar equipment.

(vi) Conditional selection is the term used to indicate the method of selection in which the following conditions must be fulfilled:—

(i) A free outlet must be available in a desired route.

(ii) A free link circuit between partial stages must have access to the free outlet, and must be accessible to the calling inlet.

(b) (i) SR relay set.
(ii) FIR relay set.

(c) (i) A crossbar switch.
(ii) Vertical Unit No. 2 of the crossbar switch.
(iii) The first of 20 outlets from the verticals of the crossbar switch.

(d) (i) Six.
(ii) A maximum of six frequencies can be provided. Five frequencies are usually provided for signalling from the GV markers and four frequencies from the SL markers.
(iii) Compelled sequence signalling means that the duration of any signal is not determined by any timing arrangements but is controlled by signals in the opposite direction. Both the commencement and termination of a signal are determined either by the arrival or by the disappearance of a signal sent from the other end of the connection.

QUESTION 3

(a) What is meant by the term "closed numbering scheme" when applied to switching and numbering plans?

(b) A typical national number dialled to reach a subscriber may be 0582-32516.

(i) What part of this number is termed the area code?

(ii) Which digit in the above number is referred to as the C digit?

(c) Name the five types of switching centres in the trunk line network proposed for the nationwide subscribers' dialling plan.

(d) What is the backbone or final route when used in trunking and switching terminology?

(e) Sketch in the space provided below the circuit principles used in true 4-wire switching of trunk line circuits.

ANSWER 3

(a) A "closed numbering scheme" is one in which each subscriber's service is identified by a unique telephone number which is dialled irrespective of the point of origin of the call.

(b) (i) 0582. The access code "0" is incorporated in the area code (0ABC).
(ii) 2.

(c) Main, Primary, Secondary, Minor, Terminal.

(d) One for which no later choice alternate route is provided.

(e) Refer to Course of Technical Instruction, Telephony 5, Paper 6, Fig. 34.

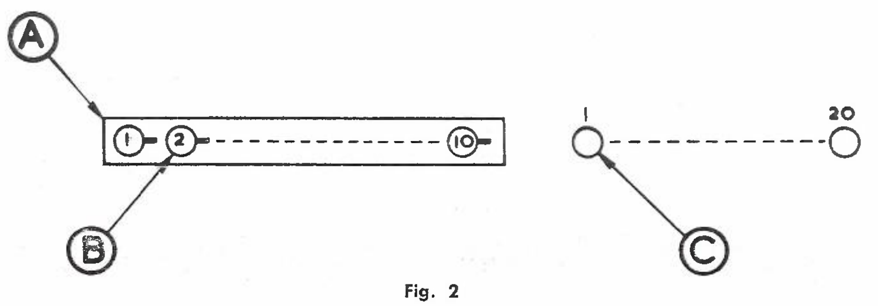


Fig. 2

QUESTION 4

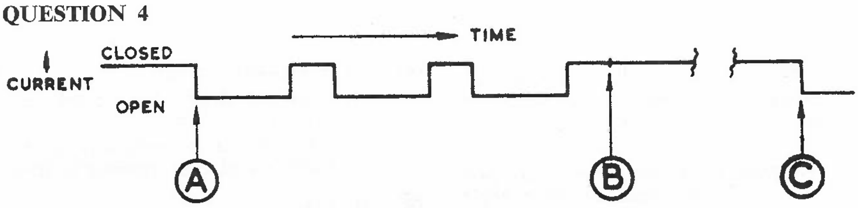


Fig. 3

(a) *Fig. 3 represents the values of current flow with respect to time in a subscriber's impulsing circuit from an automatic telephone.*
  (i) *How many impulses are there in the pulse train as shown between points A and B?*
  (ii) *What is the ideal time for a complete impulse?*
  (iii) *What is the period called, between points B and C and what is the approximate minimum time for this period?*
  (iv) *How is the time interval mentioned in (iii) above, obtained?*

(b) *What is a "tie line" when used in conjunction with subscribers P.B.X.'s?*

(c) *What does the term "restricted access" mean when applied to a tie line?*

ANSWER 4

(a) (i) Three.
  (ii) 100 mS (66.6 mS break, 33.3 mS make).
  (iii) The interdigital pause. The approximate minimum time of the interdigital pause is 400-500 mS.
  (iv) About half of the interdigital pause time is taken up by the subscriber turning the dial, and the dial pulsing mechanism is mechanically arranged to introduce a lost motion period of about 200 mS before each train of pulses.

(b) A "tie line" (Plan 26) is a circuit between two switchboards which provides intercommunication between the extensions connected to each switchboard.

(c) "Restricted access" means that subscribers extensions from one P.B.X. or P.A.B.X. cannot be connected via the tie line to an exchange line.

QUESTION 5

(a) *State the switch or relay set capacity of the following Automatic Exchange equipment racks, bays or trunk boards—*
  (i) *2000 type group selector rack for 200 outlet switches.*
  (ii) *2000 type discriminating selector repeater.*
  (iii) *Pre-2000 type switching (discriminating) selector repeater bay with no junction hunters.*
  (iv) *Pre-2000 type group selector trunk board.*
  (v) *2000 type uniselector rack.*
  (vi) *2000 type auto-auto repeater rack (with uniselector routiner access).*

(b) *On the trunking diagram (Fig. 1) there are arrows pointing to features referred to in the following questions. What is the meaning of—*
  (i) *the two figures marked "A" 248/280?*
  (ii) *the two figures marked "B" 4 x 15?*
  (iii) *the two figures marked "C" 1 x 35?*
  (iv) *the symbol marked "D"?*
  (v) *the two figures marked "E" 10/10?*

(c) *List the switches used in a call from subscriber 34 3014 to subscriber 34 1232 (assume no congestion on the DSR local route).*

(d) *If there was congestion on the DSR local route, how would the call mentioned in 5 (c) above be trunked?*

ANSWER 5

(a) (i) 80.
  (ii) 40.
  (iii) 100.
  (iv) 240.
  (v) 300.
  (vi) 110.

(b) (i) 248 D.S.R.'s are installed, with positions and cabling for an ultimate of 280.
  (ii) 4 groups of straight line final selectors, each group containing 15 switches.
  (iii) 1 group of 35 P.B.X. final selector switch banks.
  (iv) The 4th and 5th levels are interconnected.
  (v) The 4th selector has a capacity of 100 outlets (10 levels with 10 outlets per level).

(c) Homing type U/S associated with sub. 34-3014, D.S.R., (Junction Hunter during setting up) "34" third selector, "341" fourth selector, "3412" P.B.X. final selector (not shown).

(d) Via D.S.R., Junction Hunter, first and second selectors and R.S.R. at the tandem exchange, incoming "34" third selector at the originating exchange, fourth selector, and P.B.X. final selector.

QUESTION 6

(a) *On what classes of 3000 type relay would you expect to use the three types of armature shown in Fig. 4?*

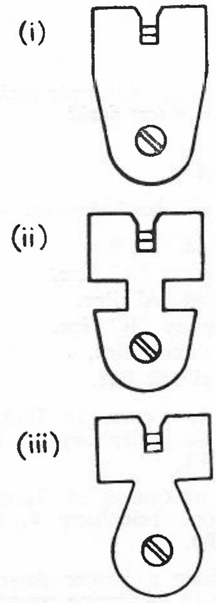


Fig. 4

  (iv) *What would happen to the operate and release currents of a relay if armature type (ii) is used when type (iii) should normally be provided on that particular relay?*

(b) *Relays are slugged to slow down their operate or release times whilst nickel iron CORES are used to speed up these times. Explain briefly how this occurs and give an example of the use of each in telephony.*

(c) *From your reasoning above, briefly explain why nickel iron CORES are not used for impulsing relays.*

ANSWER 6

(a) (i) General purpose relay.
  (ii) Impulsing relays having 200/200 ohm coils.
  (iii) Impulsing relays having 50/50 ohm coils.
  (iv) Operate and release currents would increase.

(b) Slugs on relays provide a low resistance path for eddy currents which oppose the rise and decay of magnetic flux. This causes the relay to be slow to operate or release.

Nickel Iron cores have a high resistance to eddy currents and hence the rise and decay of magnetic flux is not affected to the same degree.

Examples.

N.I. core — HA and HB relays in 2000 type group selectors. These relays must release quickly during the outlet testing time.

Slugged Relays — B relays in some impulsing circuits are slugged to enable them to hold while impulsing is in progress.

(c) The high resistance to eddy currents alters the electrical damping of the circuit to such an extent that oscillations or "ringing" may occur with sufficient energy to prematurely operate or release the relay. This would cause faulty impulsing.

QUESTION 7

(a) In the circuit of a DISCRIMINATING Selector Repeater what is the meaning of the symbols shown in Fig. 5?

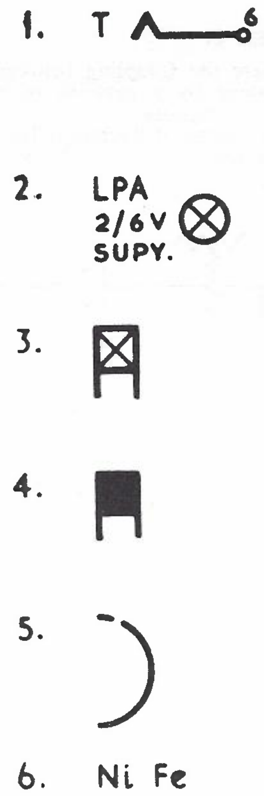


Fig. 5

(b) What is the principal function of each of the following relays in the circuit of the Discriminating Selector Repeater.

(i) Relay DA?

(ii) Relay LT?

(iii) Relay LD?

(iv) Relay JG?

(c) Explain briefly the operation of the Discriminating Selector Repeater when the first and second digits dialled are '66'.

(In the examination candidates were given a circuit of a Discriminating Selector Repeater.)

ANSWER 7

(a) (i) Test Jack point No. 6.

(ii) A 6V lamp, type No. 2, used for supervisory purposes. The first designated lamp in a circuit.

(iii) Slow operate relay (armature end slug).

(iv) Slow release relay (heel and slug).

(v) Homing arc of Junction Hunter.

(vi) Nickel iron core fitted to relay H.

(b) (i) Digit absorbing. Releases the switch if the local group first digit is dialled.

(ii) Branch discriminaton.

(iii) Local discrimination.

(iv) Provides an additional guard period on the junction to the main exchange when LD operates.

(c) Sub. loops. D.S.R. steps to the first level. Sub. dials first digit; wipers stepped on to 6th contact in first level. DA relay operates and releases switch to normal. Relay OA operates, releases DA and changes the impulsing circuit from the rotary magnet to the vertical magnet.

Second digit dialled. Wipers stepped to level 6. Wipers cut in to 6th level and JD operates.

The switch functions as a repeater for the remainder of the call.

QUESTION 8

(a) Fig. 6 shows one possible configuration for Standard Telephone Facilities Plan 3. What should be done if the loop resistance of the exchange line is 176 ohms?

(b) Why is a 2 mf capacitor connected to terminals 5 and 6 of the last socket?

(c) The subscriber requires a 6 inch extension bell near one of the intermediate sockets. How should this be connected?

(d) The subscriber requires the bells in both telephones to be silent. Explain briefly how this would be done.

(e) How many sockets are permitted on a Plan No. 3 installation (Portable Service)?

ANSWER 8

(a) A 300 ohm, 3 watt wire wound resistor must be wired in series with the L2 (—) exchange line connection.

(b) Only one line capacitor should be left in circuit or impulse distortion will occur on outgoing calls from the 400 type telephone. As either telephone may be unplugged, the capacitors in both telephones are disconnected and the 2mf capacitor connected to the permanent socket wiring.

(c) The bell should be connected in series with the red bell conductor e.g. this wire could be removed from socket terminal 3 and connected to one side of the bell. The other side of the bell is connected to terminal 3.

(d) To silence the bell in the 400 type telephone, connect the intrument with a three conductor line cord and insert a link between tags 3 and 4 in the plug. To silence the bell in the 800 type telephone, insert a link between telephone terminals P1 and GS 25.

(e) Six.

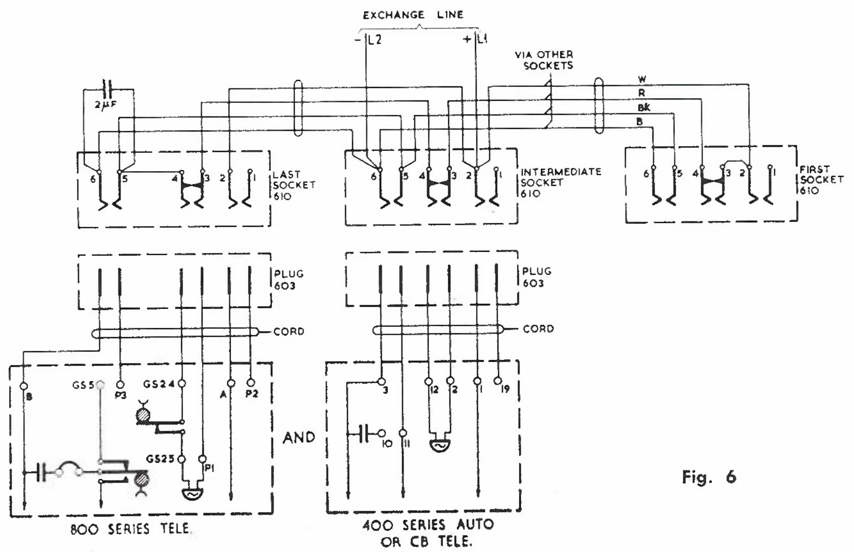


Fig. 6

Examination No. 5372 — 24th July, 1965 and subsequent dates, for appointment, promotion or transfer as Technician (Telecommunications) Postmaster-General's Department.

SECTION C

LONG LINE EQUIPMENT

QUESTION 10

(a) *The following table of figures represents the results of a series of measurements made to determine the Characteristic Curve of a thermionic Triode Valve.*

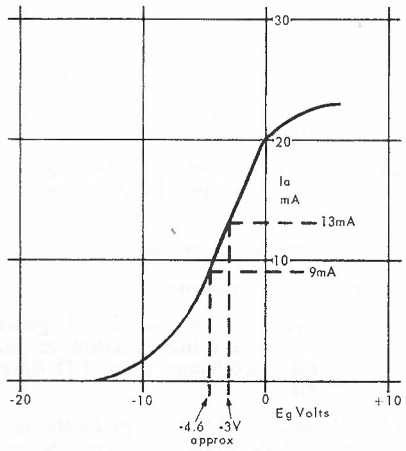
Anode Current (Ia)	*Grid Bias (Eg)*
0 mA	*—14V*
0.5 mA	*—12V*
1.0 mA	*—11V*
1.7 mA	*—10V*
3.4 mA	*— 8V*
6.0 mA	*— 6V*
10.6 mA	*— 4V*
20.0 mA	*0V*
21.7 mA	*+ 2V*
22.5 mA	*+ 4V*
23.0 mA	*+ 6V*

Choose suitable scales and draw the graph of the operating characteristic of the Triode Valve on the graph paper (MG019) supplied.

(b) *Use the graph you have drawn to determine what grid bias values are required to produce Anode Currents of 9 mA and 13 mA.*

ANSWER 10

(a) and (b) See Fig. A.



QUESTION 11

(a) *State what is meant by "Resistance-Capacity Coupling" of audio frequency voltage amplifiers.*

(b) *Draw a simple schematic circuit of a resistance-capacity coupled amplifier.*

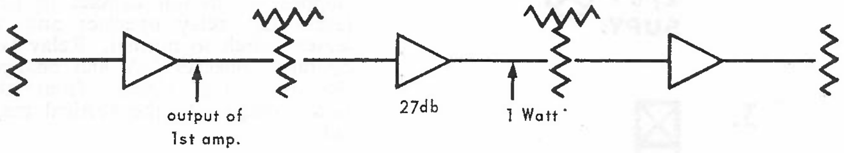
(c) *In a three-stage amplifier, the second stage amplifier has a power gain of 27 db and provides 1 watt of power to the third stage. Calculate the output power of the first amplifier (Antilog 0.7 = 5).*

ANSWER 11

(a) Where the Coupling between stages is done by a network of resistors and capacitors.

(b) See Course of Technical Instruction, Applied Electricity 2, Paper 10, Fig. 7.

(c)



$$\text{db} = 10 \log \frac{P1}{P2}$$

$$27 = 10 \log \frac{1000 \text{ mW}}{P2}$$

$$2.7 = \log \frac{1000}{P2}$$

$$\text{Antilog } 2.7 = \frac{1000}{P2}$$

Antilog 0.7 = 5

Antilog 2.7 = 500

$$500 = \frac{1000}{P2}$$

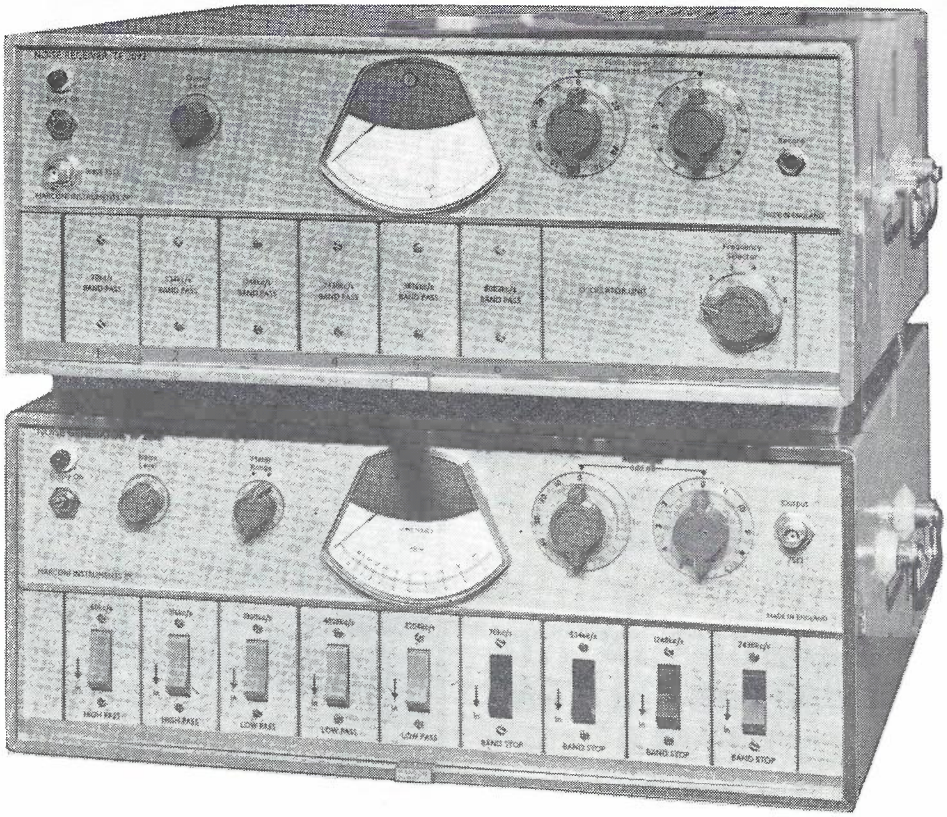
$$P2 = \frac{1000}{500}$$

$$P2 = 2 \text{ mW}$$

Marconi Instruments

WHITE NOISE

Test Set Type OA 2090



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* Performance meets C.C.I.R. recommendations.
* Filters at out-of-band frequencies allow maintenance measurements in actual traffic.
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Please write for full technical information about this instrument.
Address your enquiries to

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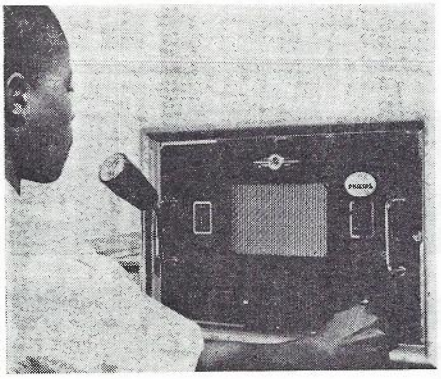
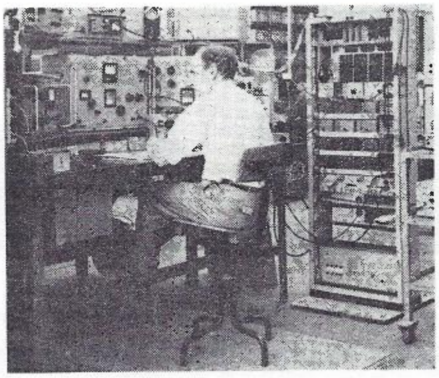
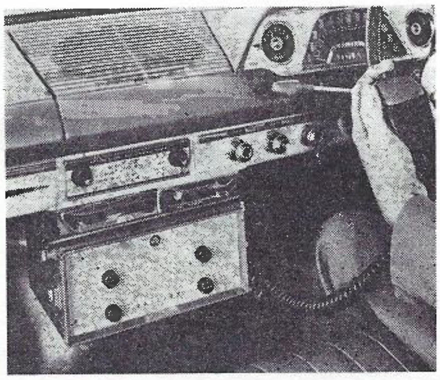
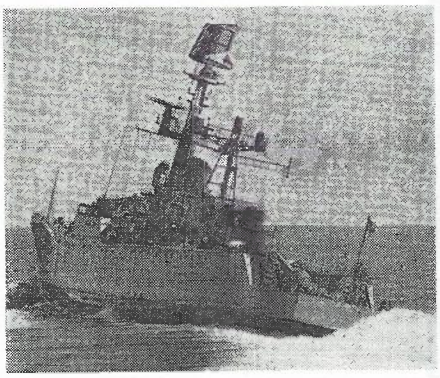
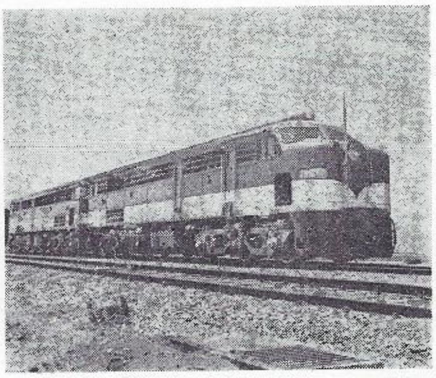
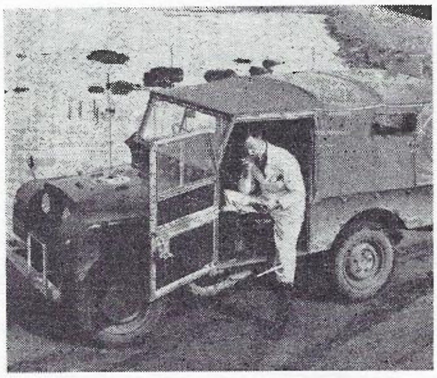
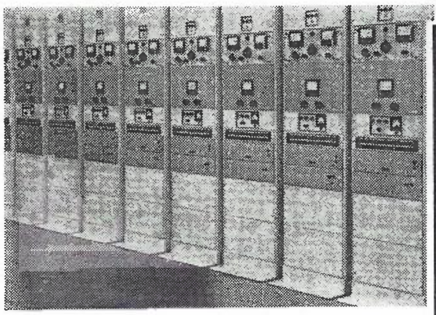
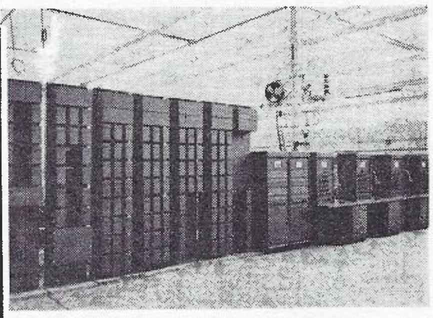
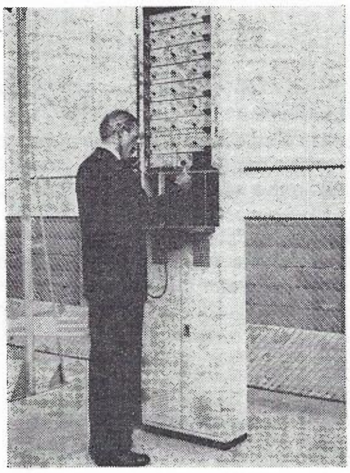
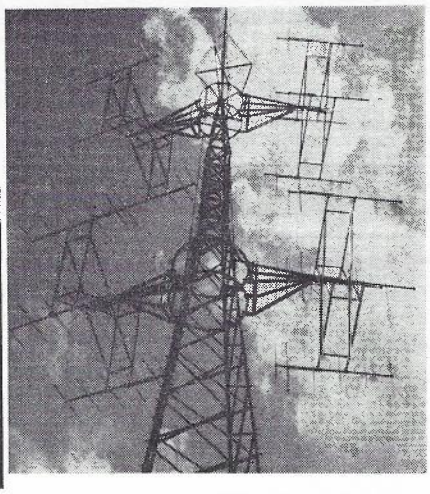








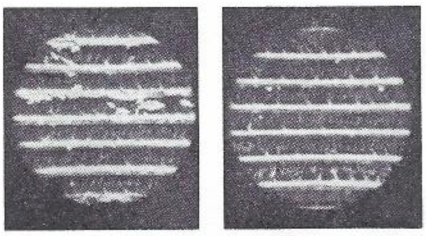




Some plain talk from Kodak about tape:

Slitting accuracy and skew angle

Tape is made in wide rolls which are slit to width — ¼" for most audio tapes. There are three main considerations in this process: cleanliness, dimensional accuracy and trueness of cut. Cleanliness cannot be given too much consideration. When the tape is slit, particles of the oxide and the base can flake off. This condition arises from poor oxide adhesion and poor quality-control standards on slitters. Slitting dirt is virtually non-existent in Kodak tapes because of our "R-type" binder and our unique slitting techniques.

Tape dirt clogs the recording gap and prevents the tape from making intimate contact with the head, thus causing "dropouts" and high-frequency losses. Oxide dirt can also cause a phenomenon known as re-deposit. During a normal tape transport operation, gummy oxide dirt can actually re-deposit on the magnetic layer and fuse in position. Just imagine a highway strewn with giant boulders. Well, that's the way re-deposits appear to your recorder heads. Pleasant thought, isn't it?

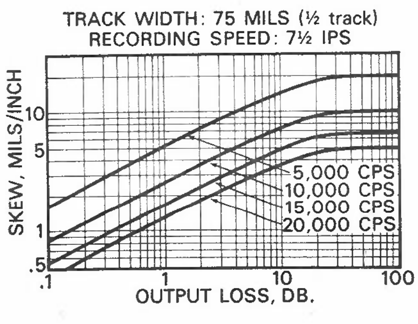


It's like splitting hairs, only more critical

To get some idea about how Kodak tape slitting compares to ordinary slitting, take a look at these two photomicrographs. The dirt you see between the turns on the left is oxide dirt. Compare it to the virtually spotless edges of Kodak Sound Recording Tape on the right.

From our 42-inch-wide master web, we have to cut 160 quarter-inch ribbons of tape—each almost two miles long. That's a lot of total mileage, especially when you think how straight and true those edges must be to assure optimum tracking on your recorder. The standard specification for slitting accuracy calls for a tolerance on width of ±.0020 inches. We decided that that was just about double what it really should be, so we hold ours to ±.0010 inches.

But the really critical part of slitting is a bad guy known as weave.



When a tape weaves, it passes the head at a continuously changing skew angle. Look at the graph.

Note how losses pile up as skew angle increases. And as you would guess, the losses are in proportion to the frequency. Higher frequencies, higher losses. Same principle, really, as an azimuth loss.

The patterns of tension set up within the roll when the tape is wound are quite interesting. Normally, the tension at the outside of the roll will decrease until it reaches a point of zero tension about ⅓ of the way from the core. Beyond this point the tension increases, but the direction of that force is reversed. Near the core the tape is in a state of compression. It's just the opposite with the outer layers. They're clockspringed.

Proper tape tension is also important if you want to prevent "stepping." Stepping usually takes place at the point of zero tension. You can visualize it as a lateral shearing of a roadway during an earthquake. This sets up stresses which cause fluted edges and prevent proper head contact. From winding billions of feet of motion picture film, Kodak has developed some pretty specialized tension-control techniques. The end result, of course, is that when you get Kodak tape on a roll, you know it's wound properly: not too loose, not too tight. Just right. Our Thread-Easy Reel is part of the story, too. Because it is dynamically balanced, we get a good wind right off the bat, and you get a good rewind, too, when you run it on your tape deck.

Kodak Sound Recording Tape in a complete variety of lengths and types is available at your nearest Kodak Branch. Please contact: Magnetic Products Sales Division, KODAK (Australasia) PTY. LTD. KM1124

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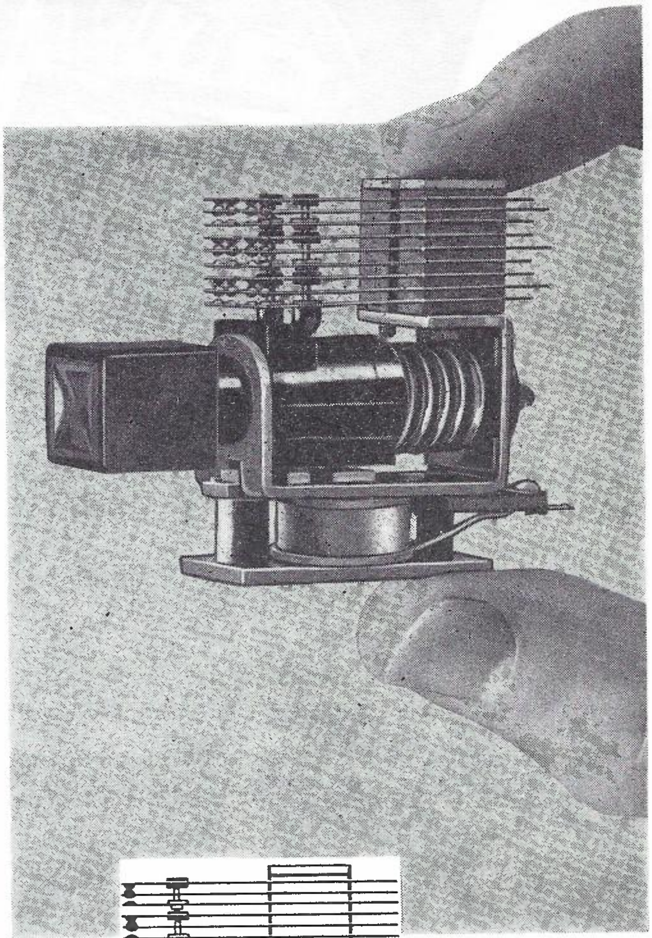

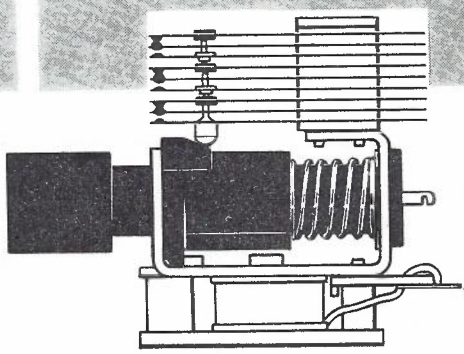

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Suitable for all types of national, regional and local Toll Switching centres, CATT handles all DDD routing functions and works with any Register/Translator equipment where operator or toll dialling facilities already exist.
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ANI is an inexpensive high speed system using DC to avoid interference with telephone exchange operation. Self-checking and fault printout facilities are included and the system is fully protected against misoperation by outside agencies. No special power or tone sources are required and MF or DC loop outpulsing can be arranged to suit all destination signalling conditions. (Individual sets of transistor oscillators are supplied in each ANI Register.)

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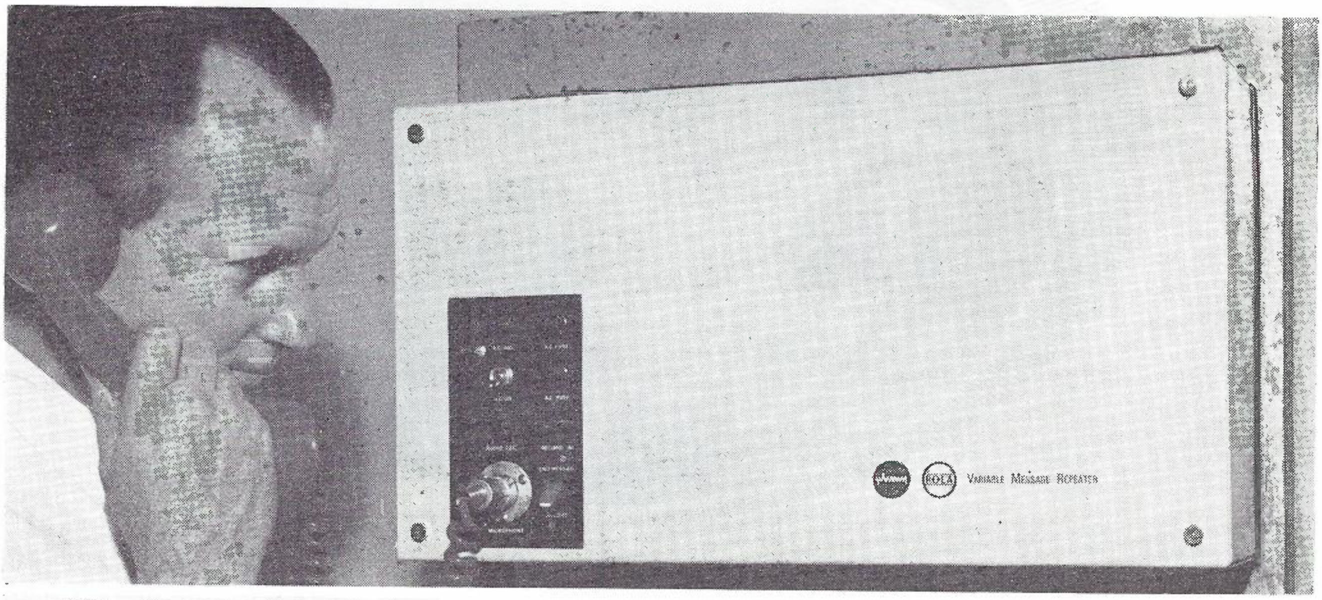
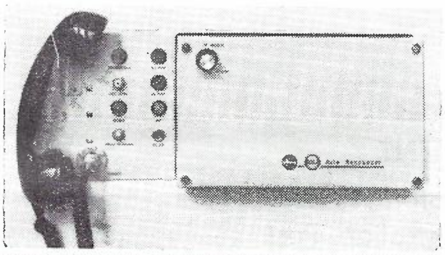
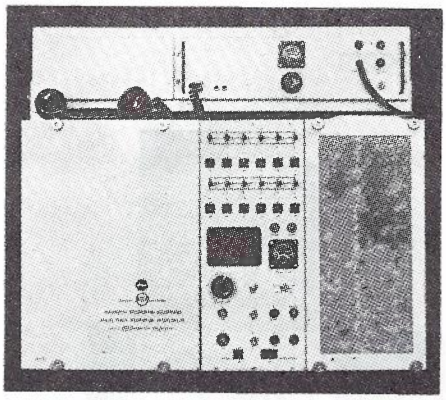
Drum announcement equipment







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The Rola model Variable Message Repeater offers automatic announcement facilities of up to 3 minutes duration over the telephone system. The equipment, designed for heavy duty operation, recycles at the end of each message. Many types of information services can utilize the V.M.R. News, weather, sporting and stock exchange information are equally adaptable to this flexible equipment.

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The Rola model Auto Announcer is a simplified voice announcement unit offering extreme reliability and economy. Dependent on the application models are available with up to 10 channels provided. The equipment is ideal for area identification, announcement of fault conditions and other short messages. For specialized applications the Auto Announcer may be modified. Contact Rola for details.

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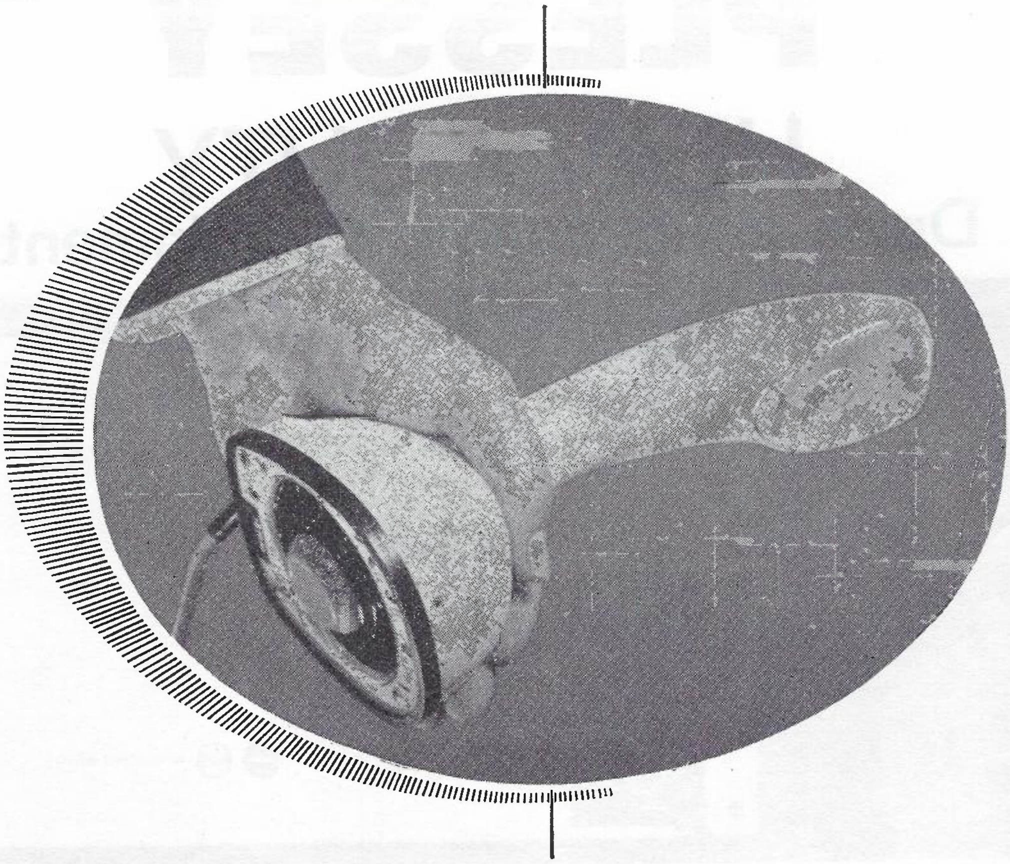

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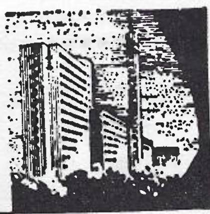

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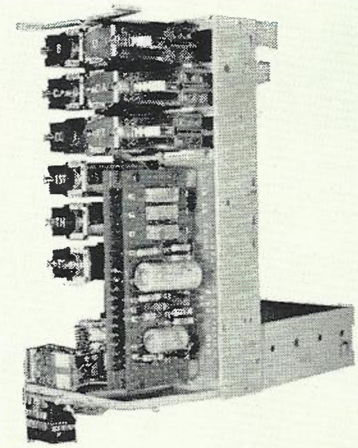
For Metropolitan Exchange networks there is a centralised data transmission system which automatically operates testing circuits at distant Exchanges. For Rural Automatic Exchanges there is an automatic diagnostic tester which can be connected from the Exchange to the required line by dialling.

Both systems greatly reduce the problems of cost and availability of maintenance staff by making testing as fully automatic as practicable. The systems soon pay for themselves in reduced costs and, in addition, they improve efficiency and reliability of the telephone system.

The advanced design concepts used in the Metropolitan Exchange system have been partly derived from the Company's related activities in the design and manufacture of other TELSCAN systems. These are sophisticated digital systems for remote supervisory control and telemetry of utilities and industrial plant as well as remote exchange testing.

The latest techniques have been applied by engineering staff widely experienced in telephone systems, and this has made available modern and comprehensive test systems and equipment.



E.C.E. RAX Test Set

Remote Exchange Testing System

The E.C.E. system of Remote Exchange testing for Metropolitan areas enables comprehensive substation and subscribers' line tests to be carried out throughout each Automatic Exchange area from a Test Desk normally situated at a large Exchange in the area.

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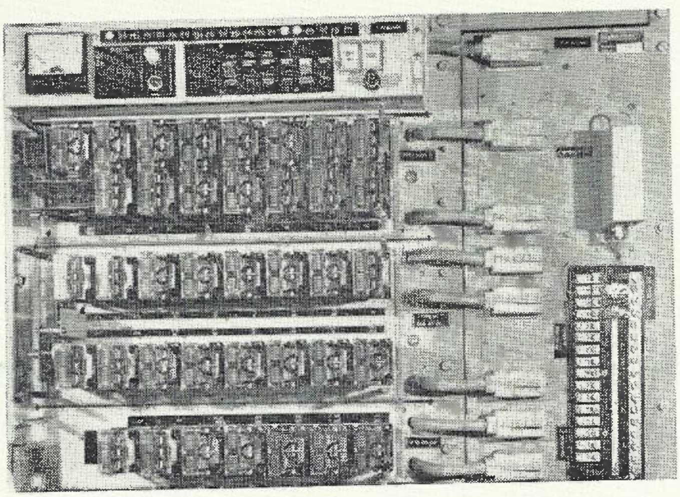

Remote Exchange Testing Equipment showing **TELSCAN** Relay Sets

Rural Exchange Test Set

This automatic test set for RAX use has been designed and produced by E.C.E. to enable Engineering staff to remotely test RAX exclusive and two-party subscribers' lines in rural automatic exchanges. It may also be used in conventional automatic exchanges where special access is available to the final selector.

An automatic test cycle is initiated when the Testing Officer dials the test level followed by the subscriber's number. Then test pulses of 1500 c.p.s. tone will be heard at three-second intervals, allowing time for identification and recording on a check list.

Pulse Length Monitor

The E.C.E. Pulse Length Monitor uses solid-state electronic timing circuits to check the length of make and break pulses on subscriber telephone dials more accurately than the conventional impulse speed, weight and counts tests.

The Pulse Length Monitor is incorporated in the E.C.E. Remote Exchange Testing equipment and is also available as a separate item for local exchange use.

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