THE

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Changes For Readers And Authors

The Council of Control of the Telecommunication Society of Australia is examining proposals to make the Telecommunication Journal of Australia more interesting and useful to its readers. It receives advice and assistance from State Committees of the Society from time to time, and the changes now being considered flow to a large extent from suggestions received from members of the Society throughout Australia. The main proposals are summarised below.

NEW LAYOUT

The Journal could be made more attractive by employing a new layout, a new approach to typesetting, and probably the use of colour in diagrams and elsewhere.

SHORTER, BRIGHTER ARTICLES

Perhaps more importantly, articles generally could be shorter and more concise, thus making them more attractive and valuable to our wide range of readers. Authors would be encouraged to emphasise the 'why' of their articles, and discouraged from describing details of the 'how'.

LESS 'FORMAL' INFORMATION

At present standing instruction to authors reads: "(The Journal) is not a suitable medium for formal information which would normally be obtained from (Australian Post Office) Engineering Instructions and other officially-published material." A close observance of this instruction, particularly as applied to supporting detailed information in articles, would be an improvement.

MAKING COMMUNICATIONS WORK

It is evident that no amount of improvement in the layout of the Journal will compensate for an article of turgid style and turbid thought. Most of our authors are engineers, and it is one responsibility of an engineer to communicate the results of his professional work to his fellows and others. But it is significant that most of our engineer-authors are specialists — communications engineers. We can reasonably expect such persons to be exemplars of the art of maximizing 'signal' and minimizing 'noise' in whatever they put their hand to : they are in the business of making communications work. The Council is confident that authors will respond to this plea on behalf of our readers. And this is an improvement which can be implemented forthwith.

NOTE: Intending authors may obtain 'notes on preparation of papers' from any of the Editors listed elsewhere in this issue.

R. G. Kitchenn,

General Secretary

THE TELECOMMUNICATION JOURNAL OF AUSTRALIA

VOL. 22, No. 1
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COVER
Joint Use
of Trenches

The TELECOMMUNICATION JOURNAL of Australia

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 has comprised three numbers issued in one calendar year.

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SOME ORGANISATION CHANGES IN THE AUSTRALIAN POST OFFICE TELECOMMUNICATION ACTIVITIES

One important function of this Journal is to provide a historical record of the significant developments in telecommunications technology in the Australian Post Office. The technology influences the style of organisation of a telephone administration, and hence no apology is needed for devoting space in this issue of the Journal to recording some of the significant changes being made to the organisation of telecommunications activities within the Australian Post Office. The following outline is an extract and summary of recent publicity issued by the Post Office concerning the changes.

The changes can be described under two headings:

- The Area Management Concept.
- Engineer Organisation Restructuring.

AREA MANAGEMENT CONCEPT

The present organisation of a typical state is shown in Fig. 1. The important feature of this organisation in the context of the changes to be made is the fact that the state Director is the only level which has final authority for activities at the work face i.e. both the Engineering Division and the Telecommunications Division are involved in field activities in any geographic area.

THE NEW CONCEPT OF AREA MANAGEMENT

What is Area Management?

Area Management is essentially:

- the grouping together of all activities which make up the telecomcommunications service in a particular area (customer sales and services, engineering installation and maintenance, finance and administration);
- into relatively self-contained and autonomous business units;
- with all necessary administrative support staff;
- under the control of an Area Manager;
- who is a senior business manager directly responsible to the State Director for the total telecommunication service in his Area and accountable to the Director for results.

There will be thirty-two areas, each constituting a business and service unit of manageable proportions. Area Managers will have a great deal of

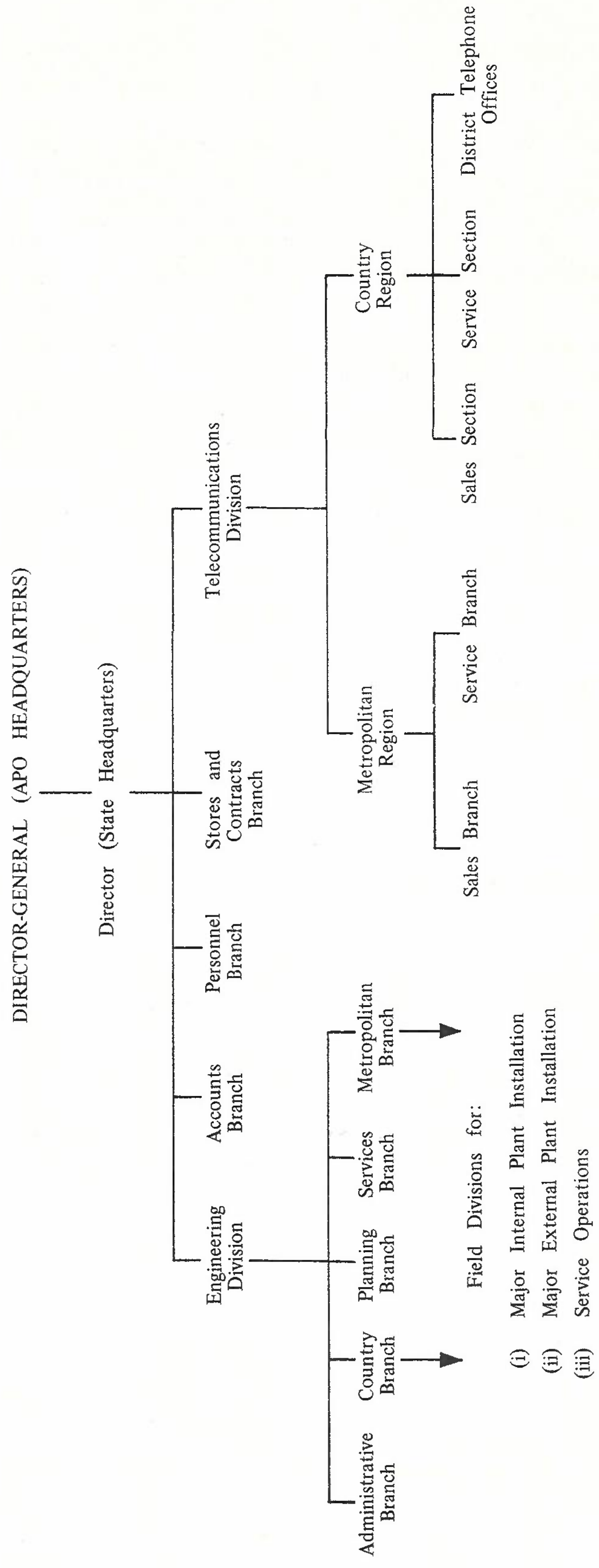
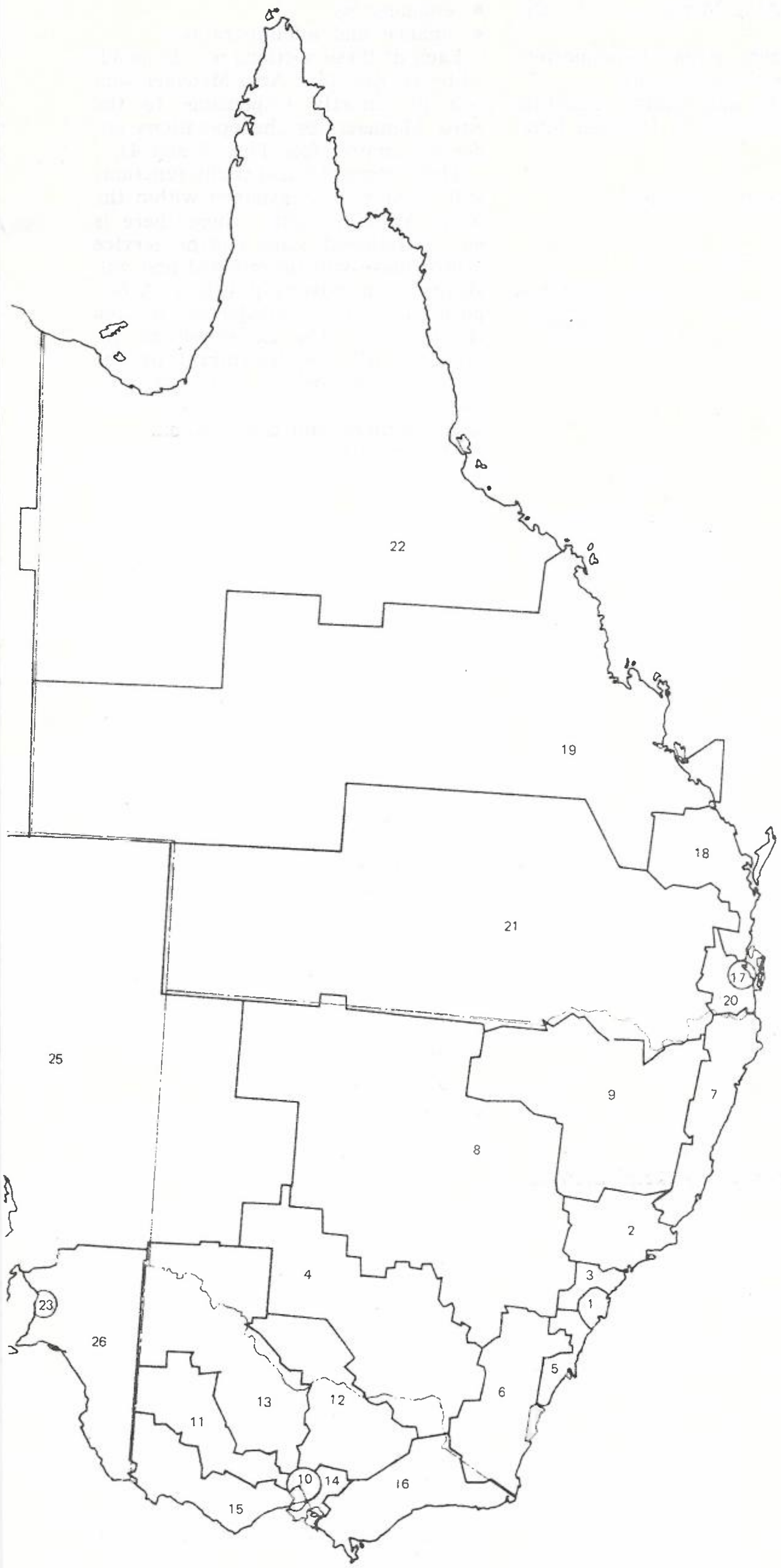


Fig. 1. — Present Typical State Organisation.

Fig. 2. — Telecommunication Area Boundaries.



TENTATIVE AREA CENTRE LOCATIONS

STATE	CODE NO.	AREA
New South Wales	1	Sydney
	2	Newcastle
	3	Gosford-Nepean (Parramatta)
	4	Wagga Wagga
	5	Wollongong
	6	Canberra
	7	Grafton
	8	Bathurst
	9	Tamworth
Victoria	10	Melbourne
	11	Ballarat
	12	Benalla
	13	Bendigo
	14	Dandenong
	15	Geelong
	16	Sale
Queensland	17	Brisbane
	18	Maryborough
	19	Rockhampton
	20	Southport
	21	Toowoomba
	22	Townsville
South Australia	23	Adelaide
	24	Darwin
	25	Kadina
	26	Murray Bridge
Western Australia	27	Perth
	28	Bunbury
	29	Central (Perth)
	30	North West (Perth)
Tasmania	31	Hobart
	32	Launceston

autonomy within guidelines laid down by State Headquarters which will reflect Commonwealth Headquarters policy.

Areas for the whole Commonwealth are shown in Fig. 2.

How will Area Management be Organised?

Within each Area Headquarters there will be three sections:

- commercial and traffic (existing Telecommunications Division functions);

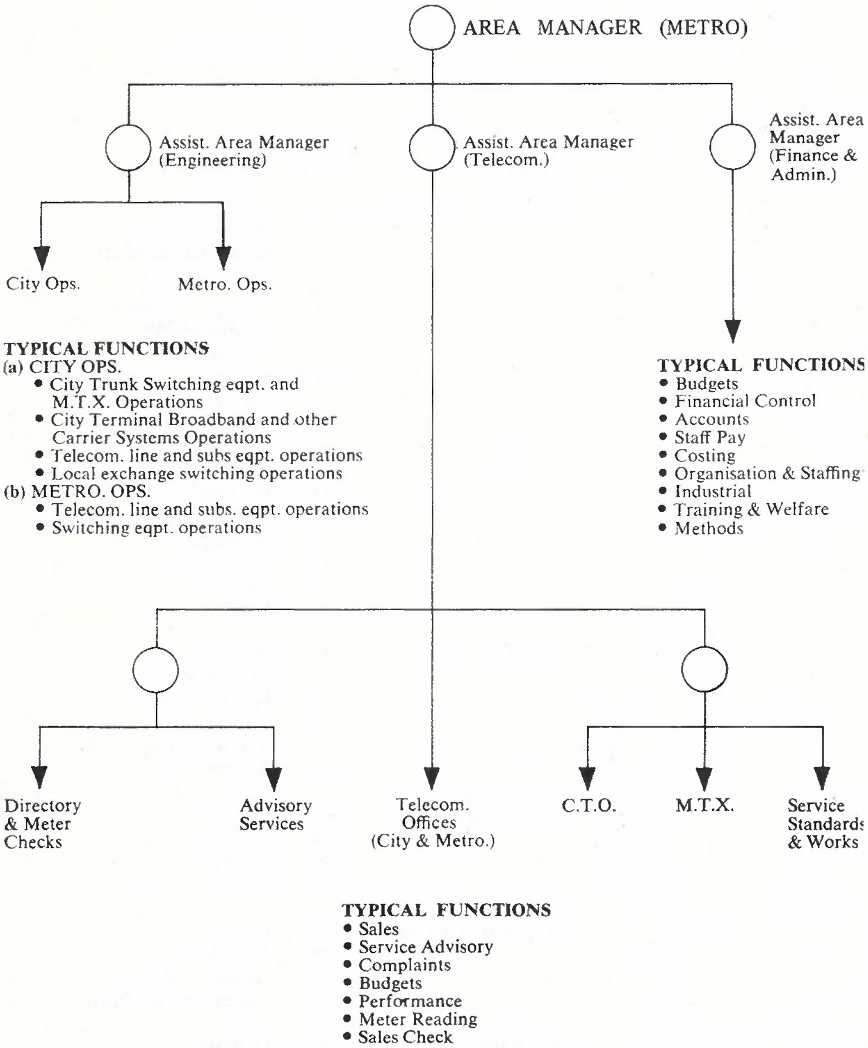


Fig. 3. — Typical Metropolitan Area Management (Telecommunications) Branch.

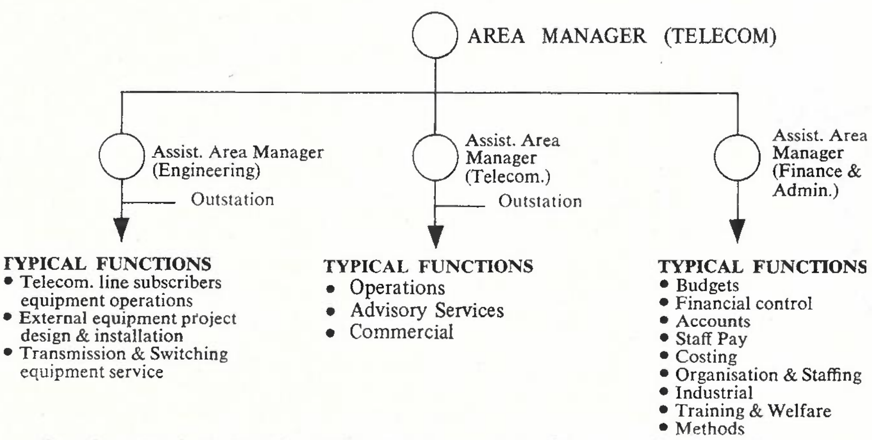


Fig. 4. — Typical Country Area Management (Telecommunications) Branch.

- engineering;
- finance and administration.

Each of these sections will be headed by an Assistant Area Manager who will be directly responsible to the Area Manager for the operations under his control (see Figs. 3 and 4).

The commercial and traffic functions will be partially regrouped within the Area. At each centre where there is an outstationed sales and/or service centre these will be retained and will absorb most existing positions. A few positions will be transferred to Area Headquarters. The extent of the regrouping will be determined by the findings of a working party currently reviewing Telecommunications Division functions and organisation.

The organisation of the engineering section will be based on the restructuring which was adopted following the investigation of the Engineering Review team established by the Public Service Board. Under this restructuring an outstationed engineering office will be retained at existing District Headquarters which do not become the centre for Area Headquarters. The outstationed office will be approximately two-thirds the size of existing Divisional Engineer Offices. Other positions will be regrouped at Area Headquarters as opportunity offers. The finance and administration section will be composed of:

- the administrative staff of the engineering office already stationed at the centre which becomes the Area Headquarters, plus
- some administrative elements transferred from District Telephone Offices and outstationed engineering offices, and
- other elements decentralised to Areas from State Headquarters.

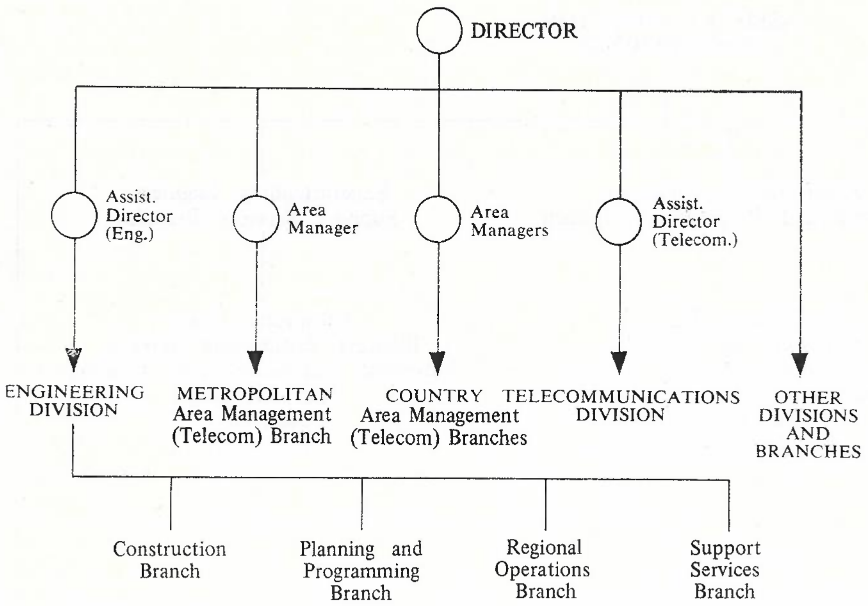
An Area will consist of:

- a Headquarters group consisting of the Manager and his three Assistant Managers with their supporting staff;
- outstationed engineering offices concerned with the provision and maintenance of service;
- sales and service units at larger district centres within the Area staffed by members of the Telecommunications Division as we know it now;
- exchanges, manual assistance centres, technician districts and line depots which will remain in their present locations.

The new State Headquarters organisation is shown in Fig. 5.

Area Management has three main objectives:

First, it is designed to improve the quality of service to customers. By placing managers closer to the cust-



NOTE: (a) Formal Lines of control are shown on this set of charts. However, Area Managers and their staffs would receive technical direction and advice from the Assistant Director (Engineering), the Assistant Director (Telecommunications) and their respective Head Office staffs and, as necessary from the Chief Accountant and Superintendent (Personnel).
(b) Placement of the functions on the same line does not indicate that they are all similarly classified.

Fig. 5. — Typical State Organisation under Area Management.

omers, they will be in a better position to gauge customer needs. By giving Area Managers appropriate authority and responsibility, they will be better equipped to meet these needs economically and effectively.

Second, Area Management will improve the economic performance of the telecommunications business. With clear responsibility for the business performance of each area, shorter lines of control and adoption of modern management and business techniques in relatively small areas, the new organisation present many advantages over the present arrangement.

Third, Area Management will improve staff working relationships by bringing senior managers closer to the field staff. Area staff will have clear lines of responsibility; many will exercise greater authority and will enjoy better career prospects.

ENGINEER ORGANISATION RESTRUCTURING

Engineering Section as the New Management Unit.

Restructuring of the A.P.O. Enginerring Organisation (those parts of the above organisation charts marked "Engineering") was undertaken by the P.M.G.'s Department following completion of investigations by an Engineer Review Team into the employment of engineers in the Commonwealth Public Service. The prime objective was to re-arrange the present organisation based on small managerial units, Divisions (i.e. Sub-sections), comprising generally 4 to 5 engineers, to somewhat larger managerial units corresponding to the basic Section unit described in the Public Service Board's Position Classification Standards.

The existing Division is considered to be too small and inflexible to meet current and anticipated future Post Office needs with optimum efficiency. It contains so few engineers, and these are so committed to their functional or regional duties that the absence of even one engineer is of serious consequence. Larger units, known as Sections consisting of an average of 7 or 8 engineers, have greater capacity to meet varying load conditions and withstand the effect of temporary absences.

The larger "Section" unit should enable better use to be made of technical and clerical officers with special skills, and also provide scope for use of engineers on specialist functions.

The next unit of organization is the Engineering Branch which encompasses a number of Sections, followed by a Division which encompasses a number of Branches. Fig. 6 shows a typical Engineering Division organization.

In the past, each Engineering Division (sub-section) was kept down to the traditional size of 4 engineers, or 5 or 6 on overload, by geographical sub-division or by divesting functions. As a result, the Division has rather limited authority and insufficient capacity to fully initiate, direct and finalise the work arising in its territory.

The small Divisional unit also loads the organisation with a co-ordination problem. This requires the provision in the organisational hierarchy of a level of co-ordinators who, because of their co-ordinating role and their physical separation from the work face, can seldom make much personal engineering contribution to the work in the Division under their control. To some extent this does not fully utilise the engineering talents of these officers.

The Postmaster-General's Department organisation was dissimilar to that of any other Commonwealth Public Service Department and it was inappropriate to apply new C.P.S.-wide Position Classification Standards to engineer positions in the existing A.P.O. organisation. A regrouping of Engineers based on the larger management unit (Section) was required because there would have been little significance in trying to apply the new Standards to the old organisation.

In summary, the restructuring of the Engineering organisation will:—

- enlarge the basic management unit
- provide greater flexibility in staffing;
- form new Branches with high level engineering management on specified functions;
- permit more effective utilisation of resources;
- allow greater technical specialisation within the management unit;
- minimise the need for inter-section co-ordination;
- shorten lines of control;
- orient organisational endeavour more closely towards corporate objectives;
- serve customers better;
- pave the way for the introduction of Area Management; and
- provide better career prospects for engineers.

Classes of Engineer

Engineers Class 1, Class 2 and Class 3 are for the most part performers of engineer work in ascending order of importance, complexity etc. Engineer management responsibilities will generally be carried at Engineer Class 4 level.

An Engineer Class 1 carries out engineering work of a Section under the Technical supervision of an Engineer of higher class. The closeness of this supervision progressively de-

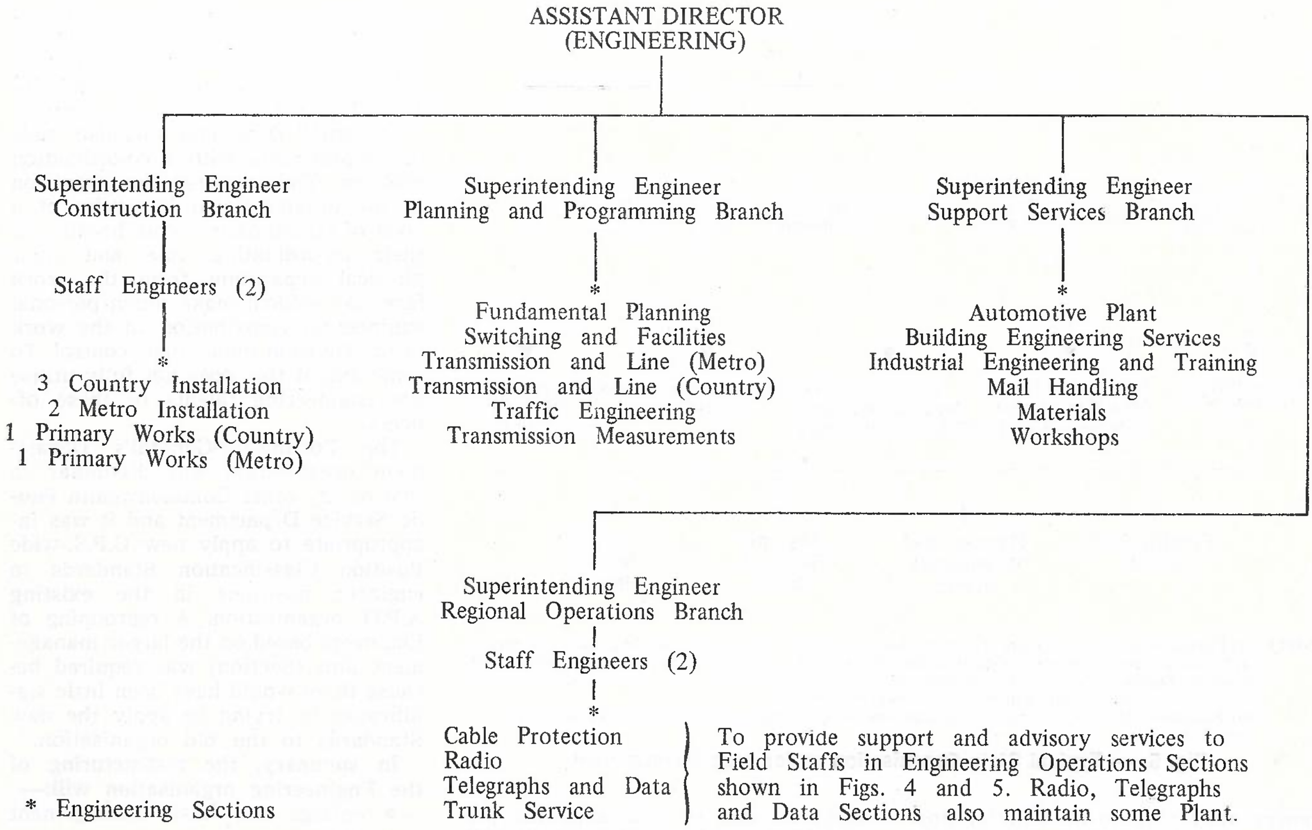


Fig. 6. — Organisation of Typical Engineering Division.

creases as the Engineer Class 1 gains experience.

A "new" Engineer Class 2 carries out the usual work of an Engineering Section without supervision, and the novel, complex and critical work with technical supervision by an Engineer of higher class. There will be proportionately less Engineers Class 2 in the new organisation compared to the old organisation.

A "new" Engineer Class 3 carries out the novel, complex and critical work, and generally provides the necessary technical supervision of Class 1 and Class 2 Engineers.

The application of these new definitions does not represent a radical change in the nature of work that Engineers Class 1 and 2 are doing now, but it does mean that in the future the Engineers Class 3 will be oriented more towards technical performance and technical specialisation and less towards administrative matters. This will require, in certain circumstances, that Engineers Class 3 control field staff directly rather than through a Class 2 Engineer as is generally the case at present.

In the new organisation, Staff Engineers have been provided in Branches with many Sections or in Divisions with many Branches. In these cases the Branch or Division Head, together with his Staff Engineers will form an engineering management team. In performing their allotted functional duties, Staff Engineers will exercise the same delegated authority as the Branch or Division Head. Operating in this way, Staff Engineers will greatly assist the Branch or Division Head. Staff Engineers will usually deal to finality on matters relating to their functions. They will not act merely as a "series check point" and pass matters on to their Head for decision.

The evolutionary trend in future organisation growth will be guided towards progressive decentralisation — from Central Office to State Headquarters at one level, and from State Headquarters to Area Management Headquarters at another level. This would include activities such as planning and programming, construction, and specialist maintenance activities.

THE EFFECT OF COMMON EQUIPMENT FAULTS ON SWITCHING SYSTEMS

*J. BUDDEN, B.E., B.Ec., M.Sc.**

INTRODUCTION

When an item of common equipment in a telephone system develops a fault condition, service to the subscriber suffers until that fault is detected and the item withdrawn from service. The extent to which service is impaired is a complex function of the technical characteristics of that system and the aggregate response by the subscriber to the unsuccessful calls. A model of this system is developed and explored. The most general expression for the relationship between the physical and environmental parameters and the resultant quality of service is derived. Examples of the application of these results to design and maintenance strategies in automatic telephony are given. The results of the model are shown to be relevant to the "art of maintenance" and suggest a review of some current practices.

RATIONALE

From the early days of automatic telephony considerable attention has been paid to the quantitative characteristics of telephone traffic and extremely sophisticated models of this stochastic process have been developed. These models are successfully applied to network design and specifications of plant layouts where the economics of effective utilization are considerable.

Networks are growing and becoming technically more complex while subscribers are demanding improvements in the quality of service. As we increase the power of our maintenance techniques attention is focused on the relationship between maintenance effort and system performance. Maintenance effort impacts on system performance in two ways:

(i) By improving the quality of equipment we reduce the probability of its failing — preventive maintenance.

(ii) By detecting faults faster, and removing them from service or fixing them, we reduce the number of calls which can be affected by that fault — corrective maintenance.

While we can measure the relationship between maintenance effort and equipment quality or fault life, we have no measure of the actual service to the subscriber — the proportion of calls which do not mature — as a direct result of a fault condition.

In a typical network from 0.001% to 1% of the units in the system could be faulty (and not blocked to traffic) at any one time. In these same networks however we can expect that the proportion of calls lost as a result of these faults vary from 0.1% to 10%. In part the reason for this lies in the considerably shorter holding time of an unsuccessful call. Whereas a normal call averages between 120 to 200 seconds the faulty call may be only held for 5 to 30 seconds. Thus, while the traffic carrying capacity of this unit may be similar in the faulty condition, it can handle considerably more calls (all of them unsuccessful) than in the operating condition.

APPROACH

We are interested in the disruption to service, caused by a faulty item in the system, for a variety of tactical and strategic decisions:

(i) At the grading level. We wish to apply quality control techniques.

(ii) At the exchange level. We wish to estimate the staff required to provide a given level of service and to exercise control over the activities of this staff to achieve that service.

(iii) At the network level. We wish to plan our staffing requirements and allocate what staff we have at present in an optimum manner.

It is at the first level to which the classical models of Erlang et alia relate. It is appropriate that this model should also be developed at that level as the data available can be most readily used at the lowest form of aggregation.

The approach adopted by the author involved a computer simulation of a model of the switching system. While it may be possible to develop a purely analytic approach to the relationship between faults and grade of service, the assumptions necessary to provide a tractable solution are too extensive. Hence a computer simulation, which allowed flexible structure, supported by some empirical experiments on subscribers habits, proved a valid model.

Simulation models are expensive if one wishes to map an entire results surface (rather than just seeking an optimum) hence the results of a limited number of experiments is used to derive the most general form of the relationship.

MODEL

Telephone traffic problems are characterised by large numbers of variables either under the control of the designer, or environmental, and complex interactions between them. Hence, first, to understand the process and, second, to make any meaningful analysis of the relationships, an early phase of the project must include some reduction of this complexity.

At the faulty unit in question there is essentially a single server highly impatient queue and the two variables which interact to yield the overall behaviour are:

(a) the way in which calls are offered the faulty unit and

(b) what the faulty unit does with the calls which it accepts.

Fig. 1 demonstrates the phenomenon. We see, for example, that at time zero

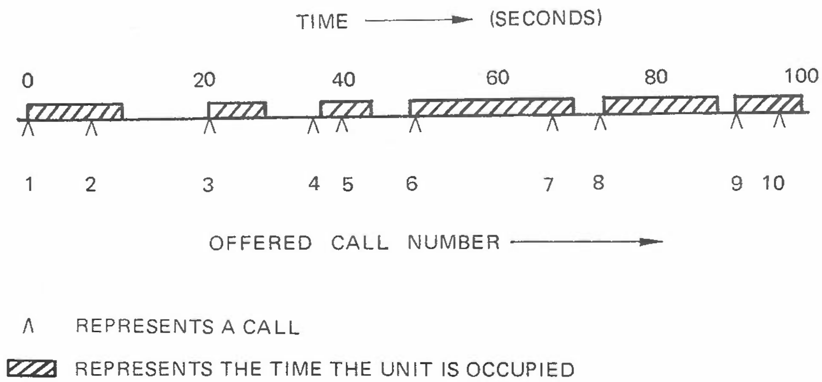


Fig. 1 — Simple Example of Phenomenon.

* Mr. Budden was Engineer, Class 2, Trunk Service. He is at present seconded to the Office of the Economic Adviser, Public Service of Papua and New Guinea.

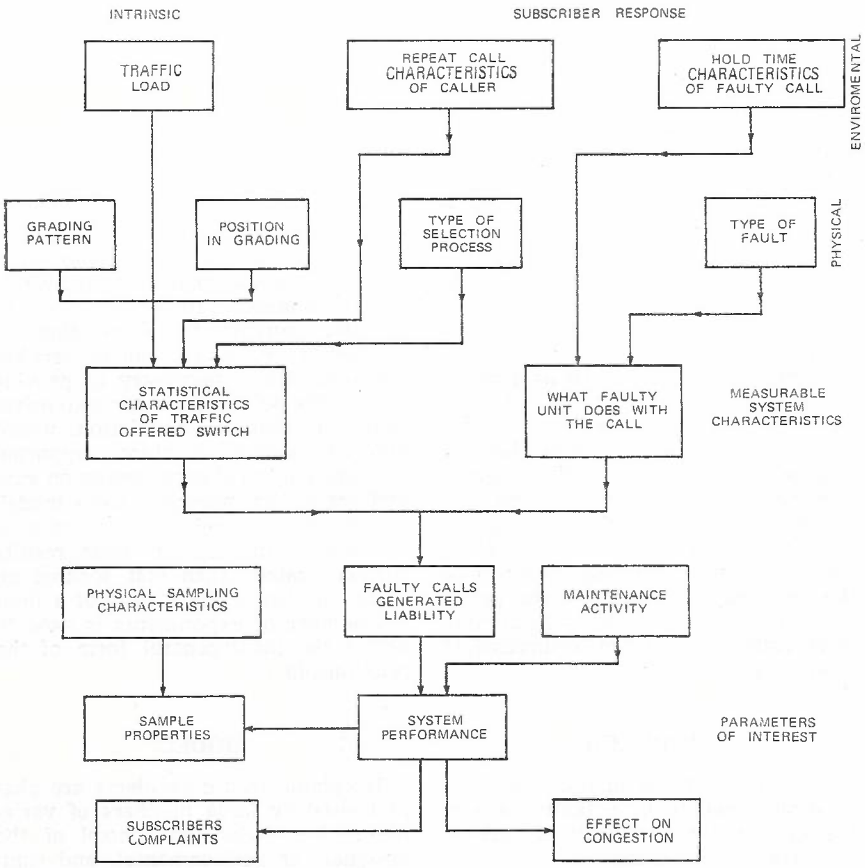


Fig. 2 — Diagrammatic Representation of Relationships.

a call was offered and accepted. Eight seconds later call number two was offered but not accepted because the first call was still held. The first call released at twelve seconds. At twenty-four seconds call number three was offered and accepted, and so on.

From Fig. 2 we see that (a) above, the offered call characteristics, are the result of the combination of:

(i) traffic
(ii) grading pattern
(iii) position in grading
(iv) type of selection process
(v) the response of subscribers to the fault condition

while (b), the way in which the unit handles calls, is dependent on:

(i) holding time of the caller who suffers the fault and
(ii) type of the fault — intermittency etc.

The following sections proceed to define and analyse these "basic" variables under the headings of environmental and physical.

Environmental Variables.

These variables include the rate at which subscribers are generating calls, the statistical properties of that process, and the response of the subscriber to a fault condition, how long he holds it, whether, when and how often he makes subsequent attempts to establish the connection.

Intrinsic Load: As with most traffic analyses we assume that the generation of first attempt calls is an independent, constant probability process. Any variability over time is ignored — either short or long. This results in exponentially distributed call arrival times (to the grading in question).

Subscriber Reaction to Fault: The response of the subscriber to a fault condition has not been documented nearly as satisfactorily. Apart from Clos (Ref. 1), who dealt with subscriber responses to blockages only (the results however are drawn on despite this restriction), there are no published studies on the phenomenon so far as the author can determine.

First consider the holding time of faulty calls. There are three distinct components:

(a) time between lift off of receiver and seizure of faulty item of plant
(b) time between seizure of faulty item and completion of dialling
(c) time between end of dialling and hang-up by subscriber.

While the subscriber considers the total to be the time wasted, as far as the system performance is concerned (b) and (c) make up the period for which the faulty item is held. We will call these the mechanical and psychological components respectively and for all practical purposes they are independent.

The mechanical component is determined by the rank of the fault (e.g. if the fault was in the third stage. In general four more digits need be dialled before the call could be established), the number dialled at each digit and the interdigital pause time, part of which is imposed by the equipment and the remainder depends on subscribers' habits. Considerable data (Rothert & Evers, Ref. 2) on these last two components is available because of their importance in another context. Approximate representations of these last two distributions and their total effect are shown in Fig. 3.

The psychological component is that interval between completion of dialling and the subscriber's termination of the call on recognition of the fault. This author has made some studies of the distribution of this component and these are reported (1). Data on 179 faulty calls and the response of the subscriber were collected and analysed. Frequency distributions of three classes of fault condition manifestations:

(a) immediate faulty call identification (busy signal, recorded voice etc.)
(b) no faulty call identification (dead line — no progress)
(c) more complex identification (wrong number, triple connection)

are shown in Fig. 4.

The following observations are pertinent:

(a) the psychological component is usually dominant over the mechanical component (from 1:1 to 10:1)
(b) the total response depends on the identification process
(c) the total response depends on the rank of the fault
(d) the total response is a complex convolution of which the log normal might be a reasonable approximation.

(1) It is worthwhile observing that this distribution could be influenced by the experience of the subscriber. If a subscriber has been used to poor service he might recognise faulty calls more quickly and hence reduce the hold time. "Averages" are used in this paper where quantified examples are made but cognisance would be taken in situations where this assumption might not be valid.

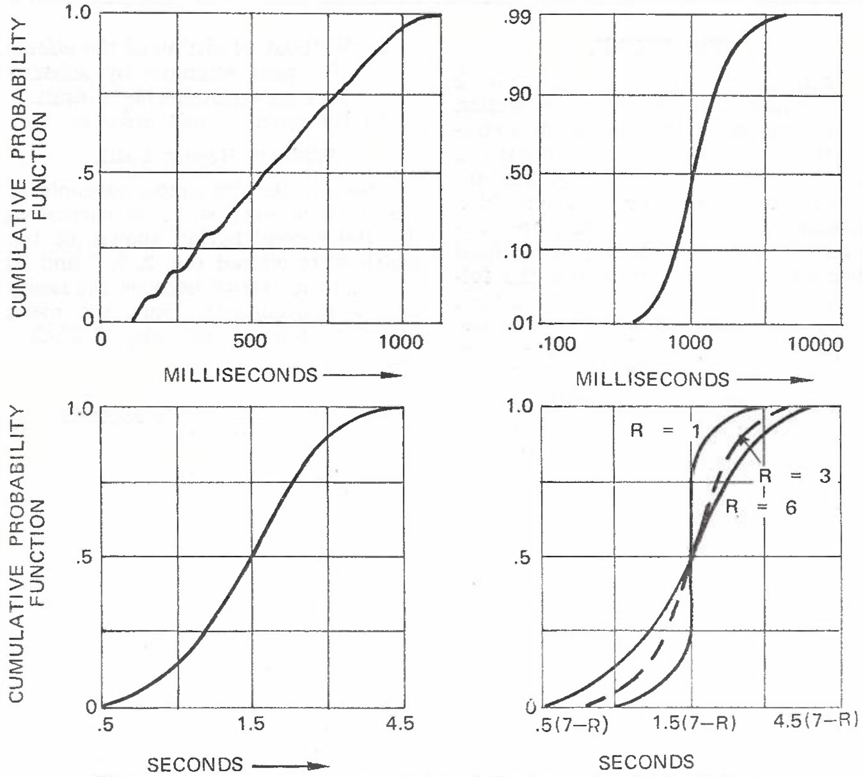


Fig. 3 — Mechanical Component of Faulty Call Holding Time.

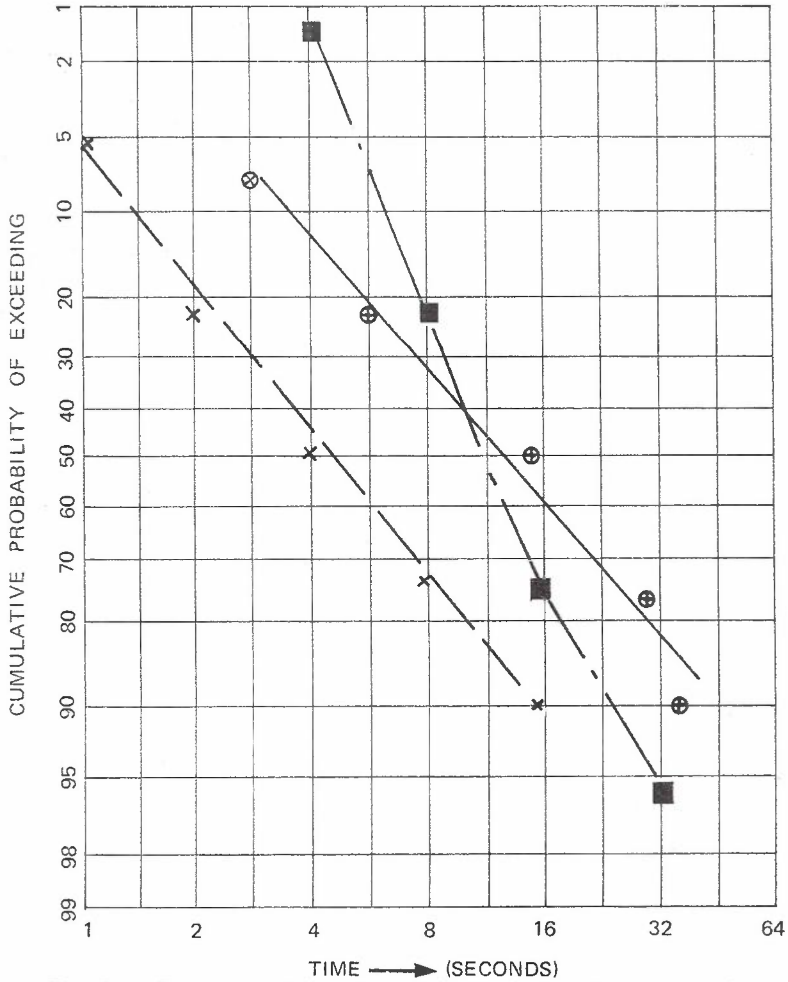


Fig. 4 — Frequency Distribution of Psychological Component of Faulty Call Hold Time.

The second aspect of the subscriber's reaction to a faulty call involves whether, and how much later he makes another attempt to establish the connection. Clos found that, within a period of 100 minutes after receiving a busy signal, 90% of subscribers had made a repeat attempt. He also found that except for the first minute following the call, where the distribution of times was almost constant, that the separation times closely approximated the exponential distribution.

As it is virtually impossible to derive an analytical model which admits of repeat calls the analysis of the simulation model will be in two stages:

(a) assuming no repeat calls (there is precedent for this in that many traffic models ignore the effect of repeat calls or if they include them their effect is essentially their static contribution) and then
(b) allowing repeat calls according to Clos' findings (2) to determine what modifications are needed to (a).

Physical Variables.

These variables include the type of selection process, the position in the grading (choice), the number of outlets available to each inlet (availability), the grading pattern and the type of fault condition.

Selection Process: There are three basic types of selection processes:

(a) sequential — fixed start
(b) sequential — random start i.e. starts on last used etc.
(c) random.

As an example of each, consider the grading of Fig. 5.

OUTLET ⊗ ⊗ ⊗ 0 0 ⊗ 0 ⊗ 0 0

OUTLET NUMBER 1 2 3 4 5 6 7 8 9 10

0 REPRESENTS A FREE OUTLET

⊗ REPRESENTS AN OCCUPIED OUTLET

Fig. 5 — Simple Grading Pattern.

In the case of (a) sequential — starting at outlet No. 1 the "first" free outlet is No. 4 and hence this would be chosen. If the selection had been (b) — sequential starting on the last used — and the last used trunk

(2) The parameters involved (90% and 150 seconds) are variables in the model and hence sensitivity to these could be examined if desired.

had been No. 8, then outlet No. 9 would be selected first, then No. 10, then No. 4 etc.

If the selection had been random, trunks No. 4, 5, 7, 9 and 10, would be selected with equal probability. This paper is mainly concerned with the first type. However the approach is extended to random selection in the appendix.

Position in the Grading: The "choice" of the outlet then only has significance in the case of sequential selection. Nevertheless, in the absence of a design, the first choice, outlet No. 1, is "offered" all the incoming traffic, No. 2 is offered all the traffic that No. 1 does not carry, etc. Thus not only does the position in the grading determine the amount of traffic which is offered, and carried, by any given outlet but also, as we move to higher choices, the relative variability of the offered traffic increases. In practice the choice ranges from 1 to the "availability" which is usually 5, 10, 20, 25, or 50 (in the example of Fig. 4 it was 10, i.e. the maximum number of outlets to which any one outlet has access).

Grading Pattern: In practice, to improve the distribution of traffic among outlets, a grading of the outlets over the inlets is made so that earlier choices can be accessed from fewer groups. The number of combinations rapidly approaches infinity. However most of the situations the author has found follow the "pure grading" classification of Trautmann (Ref. 3) and, indeed, for purposes of analysis can be reduced to their equivalent "simple" grading.

Type of Fault Condition: The actual nature of the fault condition affects the system response to a fault in two ways:

(a) by its selectivity (or lack of it) on whom it affects e.g. some faults affect only certain classes of calls — calls in which a certain digit is dialled while some are selective in time e.g. intermittency of a fault during deterioration stage, and

(b) by causing the subscriber to terminate the call by different stimuli e.g. if busy signal is returned to the subscriber he may hang up more quickly than if the line goes dead. Thus the faulty call hold times will be different in each case. The first effect will be accommodated later by decomposing the time for which the switch is in each state while the second is allowed for by considering the faulty call hold time a variable.

STRUCTURE.

From the variables shown in Fig. 2 and expanded in the previous section it is apparent that it would be extremely difficult to systematically analyse a model of that complexity. We are faced with finding a reduced set which retains, when reconstituted, the explanatory power of the whole. Without discussing why in any detail the following "stripped down" model is used for analytic and simulation purposes:

(a) Only sequential choice will be considered. A summary of the results for random choice appears in the Appendix.

(b) Only "simple" grading patterns of the type of Fig. 5 will be considered. The impact in a "pure" grading can be readily derived from this.

(c) The analysis will be carried out by a two stage process
   (i) by ignoring repeat attempts and then
   (ii) relaxing this assumption making adjustments to (i) as necessary.

Hence the variables with which we are left are

1. Traffic offered to faulty outlet
2. Choice of switch
3. Holding time of faulty calls.

In order to make 1. more operational we transform it to the mean time between calls offered (MTBCO) to the faulty outlet

$$E = \frac{AHT}{MTBCO} \text{ erlangs}$$

where E is the traffic and AHT is the average hold time of a successful call. Similarly we will measure the actual effect of the fault by mean time between calls carried (MTBCC).

RESULTS

Having considered in some detail how the various factors which contribute to the final result are related and the dimensions on which they are scaled we turn to an analysis of the form of this "equation".

It is convenient to move in two stages:

(a) Without admitting of the effects of repeat attempts by subscribers on encountering a fault.

(b) By relaxing this assumption.

Without Repeat Calls.

Structure: In the simple example of Fig. 1 there were six calls carried in the 100 second period shown, of ten which were offered (i.e. 2, 5, 7 and 10 could not be carried because the faulty unit was occupied). Thus, the mean time between offered calls (MTBCO) was:

$$MTBCO = \frac{100}{10} = 10 \text{ seconds}$$

While the mean time between carried calls (MTBCC) was

$$MTBCC = \frac{100}{6} = 16\ 2/3 \text{ seconds}$$

Effect of Choice: If the events of a faulty call departure and the arrival of the next (offered) call were independent we would expect that

$$MTBCC = MTBCO + FCHT \quad \text{.........(1)}$$

(i.e. whenever a faulty call ends we would expect, on the average, to have to wait one "MTBCO" till the next arrival). In the case of a first choice this is true, however as we increase the choice of the fault we find that the call interarrival-times depart from an exponential distribution. As this always increases, the equation above provides a convenient "bound" on the relationship.

Effect of Faulty Call Hold Time (FCHT): If we consider what happens as FCHT tends to zero, it is apparent that a unit could handle all the calls it was offered. Similarly, as we increase FCHT so we begin to "mask" more and more of the offered calls. In this case however it is not only the absolute level of FCHT which is important but also the relative size of FCHT to MTBCO. We can see intuitively that, regardless of the dispersion of MTBCO, if MTBCO is small compared to FCHT, that the

$$MTBCC \longrightarrow (MTBCO + FCHT)$$

The total effect is seen in Table 1.

TABLE I.

FCHT	MTBCO / FCHT: "Small"	MTBCO / FCHT: "Large"
"Small"	No deviation from equation (1)	No deviation from equation (1)
"Large"	No deviation from equation (1)	REGION OF INTEREST

Analysis of Simulation Model: From the essential qualitative description of the expected behaviour of the model outlined in the previous sections we move to a more detailed analysis of the effects of the variables on the parameter of interests, i.e. Mean Time Between Carried Calls. While the relationships which emerged are now quite clear and can mostly be rationalized adequately (with the benefit of hindsight) this process was in fact the most tortuous section of the project. A clear statement of how the emerging patterns were recognised; how the variables were extracted in their appropriate form, is not attempted. Some of the considerations include:

(a) We may have prior beliefs about the direction of influence of variables. For example, as we increase the choice, the likelihood of new calls being offered when the unit is occupied relative to when it is not occupied increases. That is, the between calls arrival time distribution becomes increasingly dispersed (hyper-geometric), with a greater concentration about zero, for the same MTBCO.

(b) Beliefs about direction may also include some impressions about inflection points or the shape of the curve. For example, we could see no reason why the effect of choice discussed above should not continue indefinitely. We also had no expectations of either concave or convex shapes. It turned out to be linear!
On the other hand, it was clear that, as MTBCO became small compared to the faulty call hold time, the events of a new call arrival and a faulty call departure would tend to become independent. Thus we had the suggestion of saturation.

(c) We often have knowledge of "special cases". For example when a parameter is 0,1, or tends to infinity, we can often make useful statements about the result. More subtly, when two variables have some relationship between them — equality, constant difference, product equals one, etc. we may have a simplified special case which enables us to generalize on one or more dimensions.

(d) Finally, the knowledge that an equation must be dimensionally balanced provides a useful check and clues to missing parameters. For example, it was clear that one effect of MTBCO "saturated" as we increased its value and that it appeared to be of the form;

$$1 - e^{-\text{MTBCO} \times \text{constant}}$$

Thus we were immediately led to look for a constant of dimension $(\text{TIME})^{-1}$.

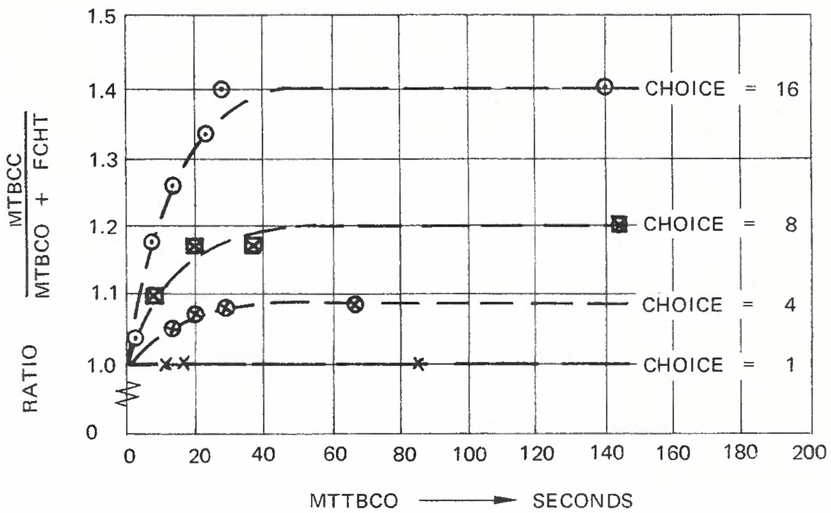


Fig. 6 — Simulation Model Results (1).

Using the approach outlined above we proceeded through the following steps, approximately in this order.

As we expected deviations from the random case to emerge we looked at the ratio of

$$\frac{\text{MTBCC}}{\text{MTBCO} + \text{FCHT}}$$

as a function of MTBCO, FCHT and choice.

Fig. 6 illustrates this ratio for FCHT = 10 for various combinations of MTBCO and choice.

We note that:

(a) Up to a point, this ratio increases, then flattens out as we increase MTBCO (Note: MTBCO was increased over the range 200 to 3,000 seconds and this maximum remained).

(b) That increasing the choice increases the level at which the ratio flattens out but appears to have no effect on the basic shape.

This leads us then to extract this choice effect and consider separately:

(a) How the final level is determined by choice (Fig. 7) and

(b) How the proportion of the final level is determined by MTBCO and, as it turns out, FCHT (Fig. 8).

Thus from Fig. 7 it appears that the final level of the ratio is a linear function of choice such that

$$\text{MAX} = (C - 1) \text{ slope} \qquad (2)$$

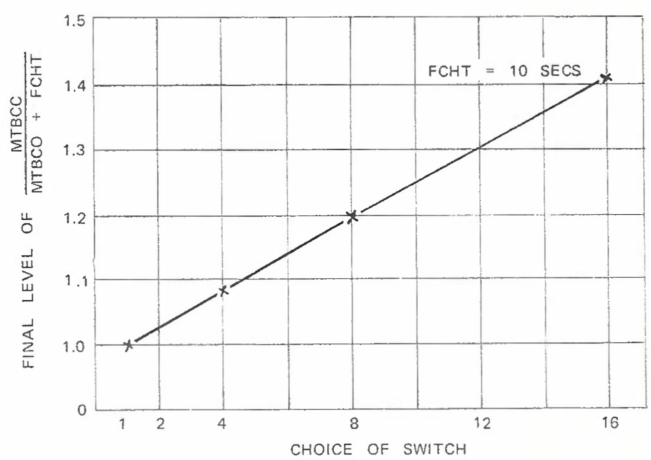


Fig. 7 — Contribution of Choice.

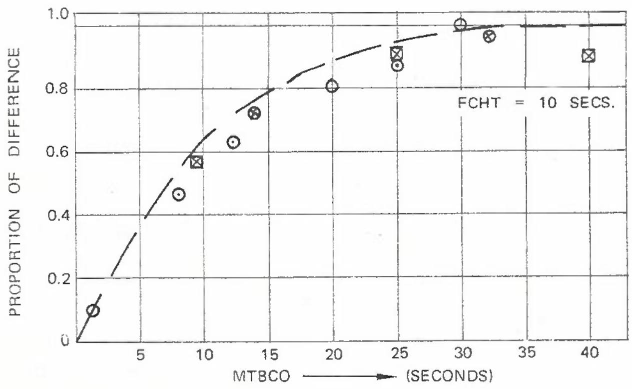


Fig. 8 — Contribution of MTBCO.

From Fig. 8 we see that the proportion of MAX

$$\text{Prop} = \left[1 - e^{\frac{-\text{MTBCO}}{\text{constant}}}\right] \quad \ldots\ldots (3)$$

We are left then with determining how FCHT enters into the relationship. First by varying FCHT we noted that the "constant" of (3) was in fact identically equal to FCHT and second, that the "slope" of (2) was related to FCHT by

$$\text{Slope} = .008 \sqrt{\text{FCHT}} \quad \ldots\ldots (4)$$

(See Fig. 9)

Thus we are left with the complete relationship

It is important to note that the analysis was an interaction between the generation of simulation results; structuring or ordering these results; selections of new values or dimensions which should be explored by more simulation runs. This method is contrasted against one which generated a number of results and proceeded by least squares regression to "best fit" the results, with some structure. The distinction is more than one of economy. (Only 68 runs were necessary to derive the final equation above which has three major dimensions, all of which are non-linear.) A detailed discussion of the use of least squares regression in the analysis of the model is beyond the scope of this paper, but suffice it to say that assumptions underlying least squares regressing were violated to an unacceptable degree.

$$\text{MTBCC} = (\text{MTBCO} + \text{FCHT})\ (1 + (\text{C-1}) \times \sqrt{\text{FCHT}} \times .008 \left[1 - e^{\frac{-\text{MTBCO}}{\text{FCHT}}}\right] \text{ seconds} \quad \ldots\ldots (5)$$

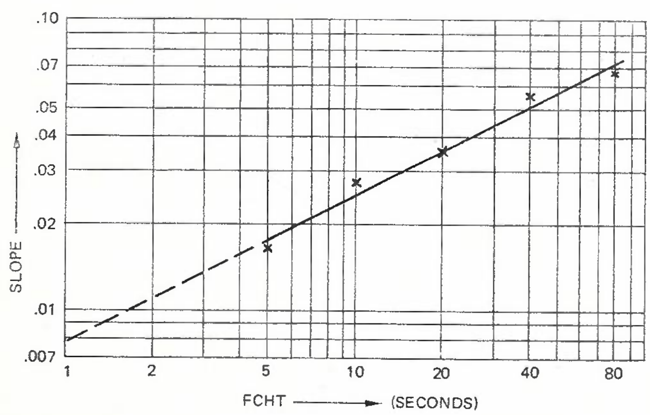


Fig. 9 — Contribution of FCHT.

With Repeat Calls.

Taking the results of the previous section as a starting point, we can consider that modifications to the formula developed in that section, necessary by the admission of repeat calls by subscribers, could stem from two sources:

(i) because by making a repeat call, subscribers are placing an additional load on the system, over and above the "normal" load, which will lead to more calls being offered to the faulty trunk and hence carried by it

(ii) because the timing of the repeat call could be such as to make the likelihood of the repeat attempt striking the fault higher than if that call had been generated randomly.

It was recognised that (i) was present and active and hence compensation was expected. On the other hand the contribution of (ii) was much less clear. The subjective evidence in support of (ii) was along the following lines:

"if one, in live traffic, experiences a faulty call the likelihood of the next call being faulty is considerably higher"

i.e. there has been observed serial corelation in faulty calls. This could be explained however by the fact that the repeat call was along essentially the same path and it was possible that along that closely defined path the average faulty call rate was significantly higher than "average" for some period of time, e.g. 20-30 minutes.

The simulation model was modified to allow for these repeat attempts. A number of runs were made under a variety of conditions and the formulae (5), modified to allow for (i) above, was applied and compared to the actual runs. No systematic deviation and no deviation which could not be explained by the variance inherent in the simulation of this stochastic process was encountered. This leads us to believe that, if (ii) is present, its effect is slight indeed and well inside the accuracy desired of this function.

MAKING THE RESULTS OPERATIONAL.

The equation (5) and the modifications proposed are complex and it is not immediately clear how one can make these results operational. Specifically we must show how to make allowances for:

(i) a simple grading rather than the full availability grading assumed above

(ii) the fact that we will know only the traffic in erlangs offered to

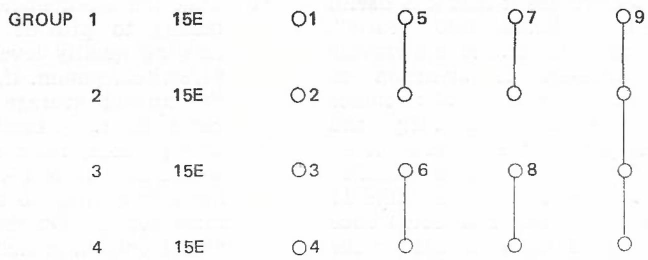


Fig. 10 — Simple Example of Application of Results.

the group as well as the factors in the equation of (5)
(iii) choice
(iv) faulty call hold time which is a function of the rank and type of fault and
(v) the intermittency or otherwise of the fault condition.

In practice it was recognised that the calculations would be tedious if done manually and would lend themselves to ready adaption to automatic computation. We will work through a very simple example to see how each of the factors is accommodated.

In Fig. 10 let us find the rate at which trunk No. 7 handles faulty calls if it develops a fault condition.

We know or can assume:

(i) choice = 3
(ii) average holding time of successful calls is 180 secs
(iii) average holding time of faulty calls is 20 secs.

Without Repeat Attempts.

Using a set of traffic tables we can calculate that with 1.5 Erlangs offered group 1 that 0.6 Erlangs will be carried by trunk number 1 and hence 0.9 offered to trunk No. 5 — from group 1. Similarly 0.9 will be offered to trunk No. 5 from group 2. Hence total offered traffic to trunk No. 5 is 1.8 Erlangs. Now using the tables in reverse — for 1.8 Erlangs to be offered to a second choice trunk it is as if 2.5 Erlangs had been offered a single group. Again using the traffic tables, if 2.5 Erlangs had been offered a single group the 3rd choice i.e. trunk No. 7, would be offered 1.2 Erlangs. Hence:

$$\text{MTBCO} = \frac{180}{E} = \frac{180}{1.2} = 150 \text{ seconds}$$

From the equation

$$\text{MTBCC} = (150 + 20)\ (1 + (3 - 1)\ (.036)\ (1 - \frac{-150}{29})$$

$$= 170\ (1 + .072)$$
$$\div\ 182 \text{ seconds.}$$

i.e. it would carry approximately 20 calls/hour in the faulty condition compared with 10 calls/hour in O.K. condition — a ratio of two to one.

With Repeat Attempts.

However 90 per cent of those who are unsuccessful will try again hence an additional load equal to;

$$90\% \times \frac{180}{182} \text{ Erlangs}$$

i.e. 0.9 Erlangs is placed on the system. Hence group 1 and 2 offer 1.95 E each and, following the same process as before, we find:

$$\text{MTBCO} = \frac{180}{1.9} = 95 \text{ seconds}$$

and hence

$$\text{MTBCC} = (95 + 20)\ 1.072$$
$$\div\ 123 \text{ seconds}$$

i.e. it would carry approximately 29 calls/hour in the faulty condition compared with 10 calls/hour in the O.K. condition, a ratio of almost three to one.

It was also recognised that "convenient" was not independent of the application to which the results would be put. Hence a variety of forms might be used to achieve a different impact or in a different context. The following section, by considering some specific applications, provides further insight into the forms which might be appropriate.

APPLICATIONS.

In part to provide a rationale for this exercise and also to demonstrate the variety of areas to which this model is applicable a number of simple, specific examples are made. As is usual with most design problems, there exists a large number of variables which can be influenced by the decision maker. Two important characteristics of these design variables are:

(i) the leverage which they provide over the problem
(ii) the delay between taking action and the response of the situation.

Hitherto the only measure which management had of these characteristics in telephone equipment maintenance was the collective experience of responding to various stimuli and observing crude measures of performance. The complexity of the interactions however means that maintenance is still in the "art" stage, with considerable difference between experienced practitioners and much uncertainty about "optimum" courses of action. Fig. 11 shows in a very aggregate form some of these relationships. The model which was developed in the previous sections impacts on describing the relationships between each one of those factors mentioned.

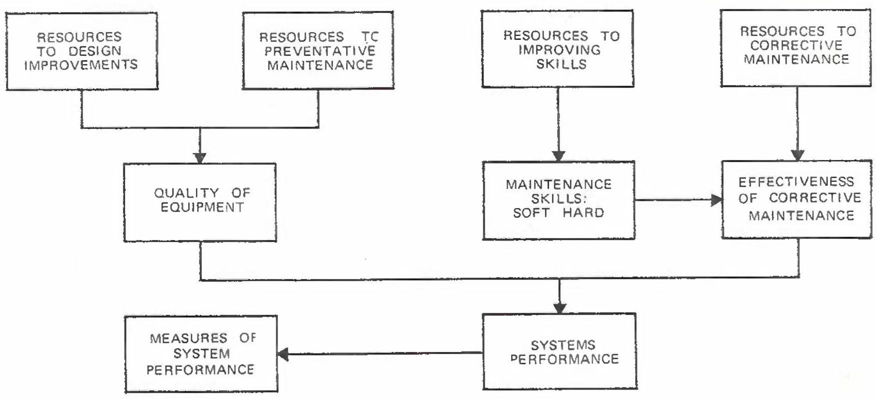


Fig. 11 — Interaction of Maintenance Activities.

We shall consider its use in some of these relationships:

(a) Determining test periodicities in corrective maintenance
(b) System Design
(c) Performance measurement.

Determining Test Periodicities.

In determining the level of corrective maintenance, one component, the amount of time spent on periodic tests of equipment is a major variable cost. The frequency of these tests have traditionally been determined on the basis of trial and error.

Rudeforth et alia in an Appendix, derived a basis for determining periodicities of these tests to obtain any given level of service. However they begin with;

"Assume that:—

Q percent lost calls arise from an average of Q percent of the selectors being out of order at any time. ...."

and proceeds to show that the period between tests should be;

$$P = \frac{7.3\,Q}{n} \text{ days}$$

Where n is the fault incidence in faults/item/annum.

Ignoring the impact of repeat calls (which only serve to increase the ratio anyway) the equation can be used to derive the relationship shown in Fig. 12 (for FCHT of 20 seconds). Thus we can see that at no time does Rudeforth's assumption hold — particularly around the region of operation where in fact this ratio (d) varies between $1\frac{1}{2}$ and 3. The periodicities suggested by Rudeforth therefore will be out by between 50% to 200% (or more if the system is particularly heavily loaded).

Thus we should modify the formula:

$$P = \frac{7.3\,Q/d}{n}$$

Another immediate application is to the evaluation of various maintenance tactics. Folklore has it that it is useful to segment switches into "early", "middle" and "late" choice and provide different maintenance attention to each. For examples, switches of choice 1 to 4 may be considered "early" and tested once per week whereas switches 5 to 10 might be considered "middle" and tested every two weeks while 11 to 20 would be "late" and tested once a month. Fig. 12 suggests that for the same traffic load the relative liability of the 1st choice is actually lower than that of the 16th. This suggests the practice should be re-evaluated.

Design of System (3).

Traditionally plant provision has been based on the establishment of an acceptable grade of service, e.g. 0.2 percent lost calls due to congestion, and design of an optimum configuration, e.g. one which uses the minimum number of switches. Maintenance staffs have often felt that maintenance costs were ignored in the calculation of the optimum. Using Fig. 12 above and making the assumptions below about costs it is possible to derive a "total" cost curve as a function of the average plant load. Assume;

(a) That the capital cost of providing an extra switch is approximately $225. This is an annual cost of $15 based on a 30 year life and 5% rate of interest. If it handles an average of 1 erlang then the annual capital cost is $15/erlang. If it only handles 0.5 erlang then the annual capital cost is $30/erlang etc.

(3) The analysis in this section neither includes all relevant information nor necessarily accurately uses that which is considered. It is designed to show how the information derived in previous sections can be applied to operations problems rather than to come to any specific conclusion.

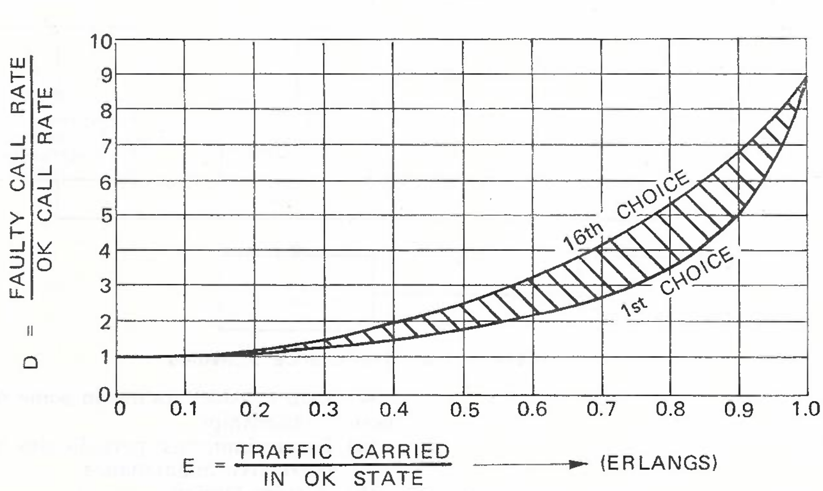


Fig. 12 — Potential Disturbance of Switch.

(b) That the maintenance costs in testing to provide service at existing quality levels costs us $4/switch/annum. If, instead of the current average of 0.5 erlangs the traffic carried was 1.0 erlangs then, from Fig. 12 we would have to test 4 plus times more frequently to achieve the same service. On the other we would only have half the number of switches hence the costs would be slightly more than twice. Proceeding for all traffic levels we generate the second curve — maintenance costs in Fig. 13.

We can see from Fig. 13 that maintenance costs are very flat from 0.3 erlangs to 0.75 erlangs and that total costs are at a minimum at about 0.75 to 0.8 erlangs.

Two other facets of equipment design lend themselves to analysis using the results of this paper and an investigation would seem warranted for step by step, crossbar and electronic switching systems. The first concerns the desirability of various interconnecting schemes from an operational, as opposed to purely traffic carrying capacity, point of view. An investigation of the fault liability of the various configurations may yield a preference for one or other types of grading. Practical experience suggests that the most efficient gradings are also most sensitive to faults and perhaps we may pursue increased grading efficiency to the detriment of total system performance. The second involves the possibility of influencing the technical aspects of equipment design. For example it is possible to vary the holding times of various pieces of equipment or equipment operating under different conditions e.g. throwout condition. The model allows us to evaluate the potential benefit from such actions. Similarly we can evaluate the benefits of improved reliability (at a cost) through redundant elements of self diagnostic circuitry.

A similar "problem" has been the often observed relationship between congestion and switching performance. While there are some conditions, e.g. absence of busy tone, which do causally relate congestion and performance, another source of the relationship is that they are both strongly a function of offered traffic. As the offered traffic varies, from month to month, so both the congestion and lost calls due to switching failures vary (see Fig. 12).

Performance Measures

Various methods are used to measure the performance of a telephone

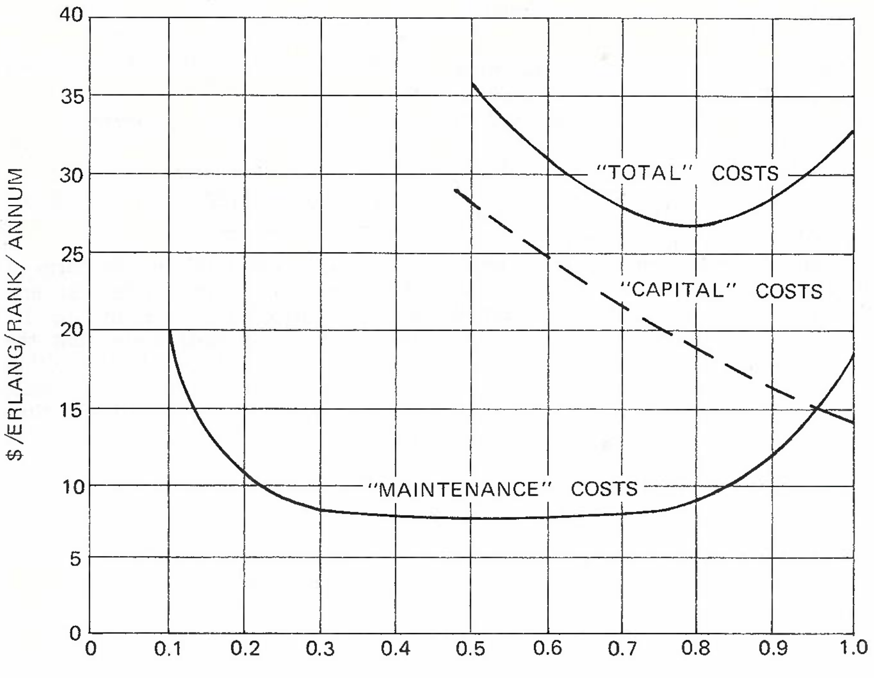


Fig. 13 — Simple Cost Analysis.

system, route or other segment of a system. In some cases they are used directly to guide corrective action and in others solely as a measure of management performance. The most commonly used measures are:

(i) test calls of various types — manual/automatic
(ii) subscribers complaints
(iii) checks of the performance of live traffic.

As each of these is a sample in some sense ((ii) in that a combination of performance and subscriber is involved) and as the underlying distributions of these variables is not intuitively clear, doubt is expressed about the significance of these measures — about sample size, confidence limits and even about the bias and consistency of the estimators.

The simulation model allows us to examine the properties of each of these indicators in any given configuration. By examining a sufficient variety of configurations some general statements about their properties should be possible.

Test Calls: Test calls are introduced into the model as an "independent" sequence of calls generated in any fashion e.g. regular, random etc. which we like. Fig. 14 shows the results of 30 runs made on a typical final selector grading. The testing device resembled a "Traffic Route Tester" (TRT) in that the calls were generated about 2 per minute on a selected path. Observe:

(a) the actual performance of the grading
(b) the performance as "seen" by the TRT.

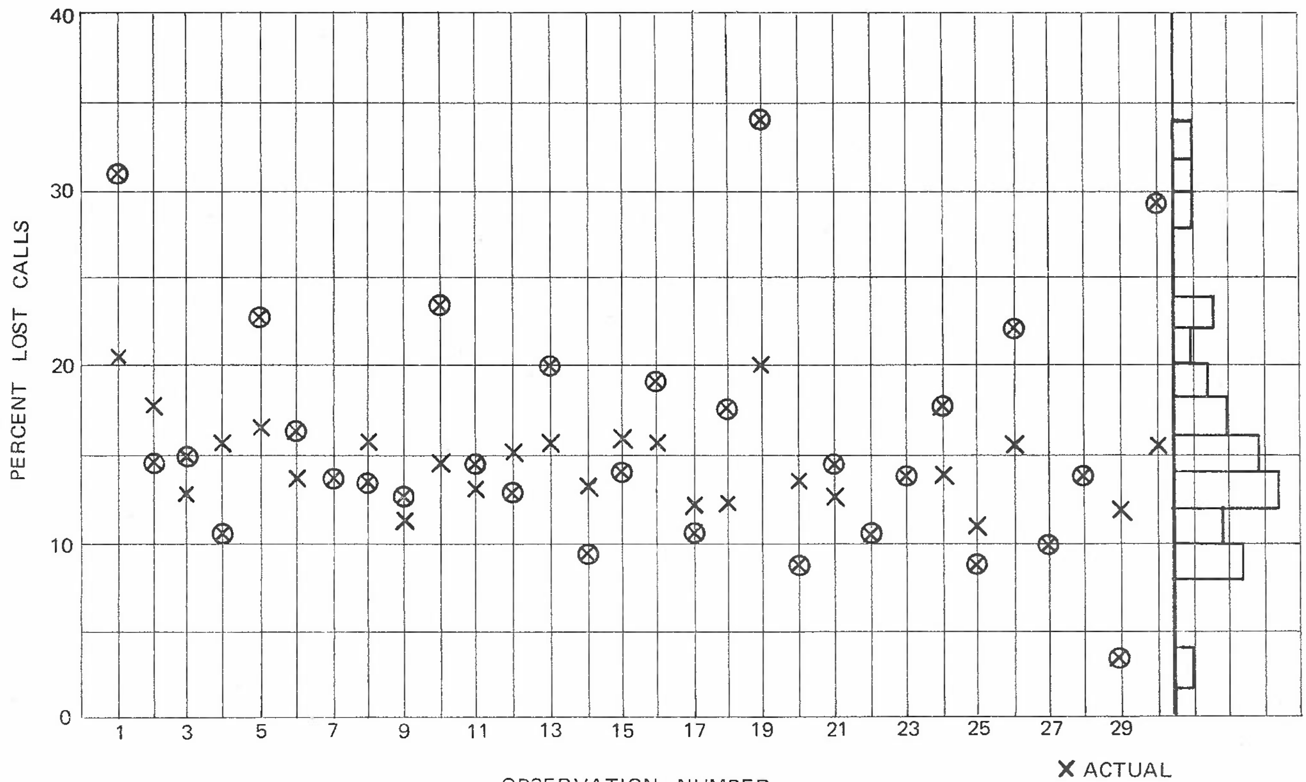


Fig. 14 — Sampling Performance.

We note:

(a) that the actual performance averages 14.1% lost calls

(b) that we cannot reject the hypothesis the samples are binominal (at 5% level)

(c) on the basis of (b), (a) lies within the 95% limits of the observed sample mean i.e. 15.8± 2.2% lost calls.

Subscribers Complaints: To make any useful analysis of the relationship between performance and subscribers complaints a model of the subscriber propensity to complain is needed viz. what proportion of subscribers will complain on getting r successive failures — let this be = fr. The simulation model produces a record of the number of subscribers encountering a fault and the total number of subsequent attempts which are also faulty. From these two pieces of information we can determine what proportion of subscribers will encounter r successive failures — let this be = kr.

The percentage of complaints generated will then be:

$$\sum_{r=1}^{\infty} \text{fr.kr} \times \frac{100}{1}$$

It may be possible to relate this to the actual performance by considering a number of examples.

CONCLUSION AND SUMMARY

We set out to derive the relationship between common equipment faults in a telephone system and the performance which results. This was considered desirable in itself and a necessary ingredient to further normative models in maintenance.

Analytic and simulation models of the process were developed and analysed. By reducing and resynthesising the model an accurate function describing the relationship was found. We then showed some examples in which the results were applied.

In this section we will consider in what way the model can be extended or improved.

Other Modes of Selection: In this paper we have treated the two most common modes of selection of outlets, viz sequential — fixed start and random. This was done to keep the project in manageable proportions. Other modes of selection invite similar attention. In particular we have:

(i) "slip multiple" and

(ii) alternate routing configurations.

In the former an outlet appears as a different choice for each inlet group. In the latter one block of outlets is accessed first; if all are occupied attention is directed to an alternate block of outlets. These both can be considered hybrids of the "pure" models discussed here.

Increased Precision in Measurement of Variables: The model structure and, in particular, the parameters used in this paper reflect data available to the author. In some cases it reflects small samples or extropolation of existing results. While the general nature of the model and tests of robustness provide protection, a more precise model may be required as techniques of maintenance are refined or alternate equipment configurations develop.

Other Levels of Aggregation: The model was formulated at the lowest level of aggregation possible because it was at this level that the data which existed was relevant. It would be desirable if a more general model could be developed. This could proceed in two ways:

(i) by selecting representative gradings from a system, evaluating them using our micro-model and, by multiple regression or otherwise obtain a more aggregate descriptive function or

(ii) search for a more general statement of our micro-model.

While the second is more elegant, the first guarantees a solution.

APPENDIX — RANDOM SELECTION

The procedure adopted for the analysis of the sequential selection mode was repeated for the case of random selection. Here the "choice" of the faulty outlet is not important as each outlet is "equally likely" to be selected. On the other hand, it was thought that the number of outlets would be a factor in determining the fault liability of any unit. While it is a determinant of the traffic carried by each outlet for any given total traffic, the results can be "normalized" to eliminate this variable from the expression.

One form of the resultant expression is:

MTBCC = FCHT + MTBCO' seconds

where

MTBCO' = MTBCC (in O.K. state) − 180 seconds.

We can present this in the form of the "liability" of the outlet for any level of carried traffic as in Fig. 12. In this case we must allow that the faulty call hold time can be either equipment or subscriber determined. Where both the faulty call hold time and O.K. call hold time are subscriber determined then the result is similar to choice = 1.

The general equation for the liability (d) is

$$d = \frac{1}{1 + \frac{\text{FCHT} - \text{AHT}}{\text{AHT}} .E}$$

and is graphed for some values of the ratio $\frac{\text{FCHT}}{\text{AHT}}$ in Fig. 15.

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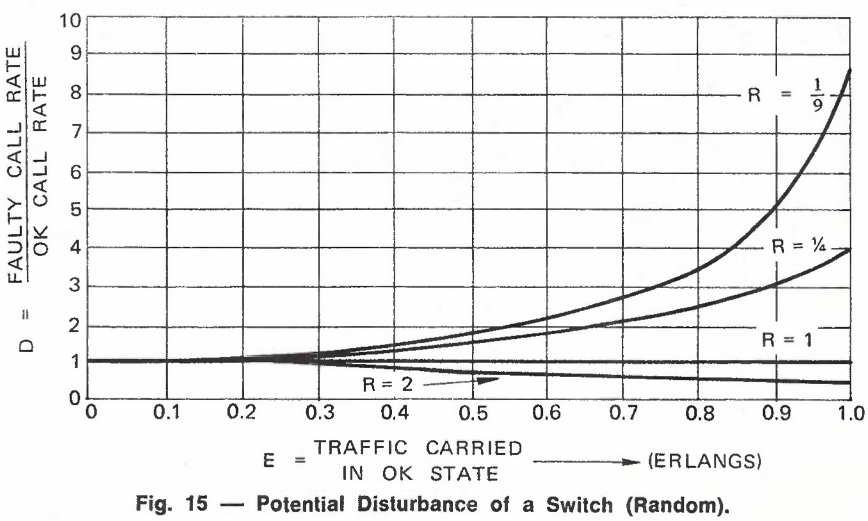

Fig. 15 — Potential Disturbance of a Switch (Random).

DATA FLOW AND DATA FORMATS IN THE COMPUTER CONTROL OF AN ELECTRONIC TELEPHONE EXCHANGE

*F. J. W. SYMONS, B.E., D.I.C.**

INTRODUCTION

Communication networks have recently entered an era of the widespread introduction of computer techniques to the control of telephone exchanges. By 1980 a significant percentage of the telephone exchanges in the industrialised countries of the world will be controlled by computer based systems of one type or another. The introduction of processor control to telephone exchanges involves important changes in the philosophy of operation, staffing and maintenance of telephone exchanges, as well as in their technology, facilities and economic characteristics. One of the basic differences between processor controlled exchanges and those currently conventional is that the mode of operation of the control system of a processor controlled exchange is much more abstract. To the technician in the field a program control system can appear completely intangible after the reality of units like group selectors, registers and markers, whose function and mode of operation are easily identifiable.

Two important features of the mode of operation of processor controlled exchanges are those of the data flow and the data formats in the program control system. This paper describes in some detail the data flow and data formats of the program control system developed for the fully electronic digital telephone exchange in the IST (integrated switching and transmission) project being carried out by the Research Laboratories of the Australian Post Office (A.P.O.). A general description of the IST program control system, which is the first complete exchange program control system designed in the APO, is given in Reference 1. That paper concentrates on describing the overall operational software system and the way in which the programs function. It makes only passing reference to the important aspects of data flow and data formats. This paper is essentially complementary to Reference 1, and by describing the way in which the IST program control system works from the data point of view, it should demonstrate the important role played by data flow and data formats in the computer control of telephone exchanges, and it could also be of some value to those people interested in obtaining an appreciation of the way in which stored program control of a telephone exchange works.

This paper concentrates on describing the mechanisms involved in the call handling programs, and does not deal directly in any detail with the test, security and man-machine communications programs, as the techniques used with these programs are very similar. It must be mentioned that the way in which the program control system and the data formats have been arranged in the IST project are not necessarily claimed to be optimum; and some simplifications have been made in this paper in the interests of clarity.

This paper takes no account of modifications, improvements and extensions made to the program control system since September, 1970. The most notable of these concern changes to the device allocation and path search procedures as made by Mr. D. J. King and Mr. A. Baker, and the detailed design of the interprocessor messages system carried out by Mr. D. J. King and Mr. D. Penery.

A glossary of the abbreviations used in the text and figures is given as an Appendix.

THE BASIC IST EXCHANGE.

The IST exchange consists of three main parts, as shown in Fig. 1. These are the digital switchblock or speech matrix, the interfaces, and the control processors. Security of the control capability is provided by two processors each with independent access to the switchblock through its own interface equipment. The processors exercise complete control of the exchange by means of the programs stored in their memories. They gather information from the switching network, and pass instructions to the network by means of the interface equipment.

The IST exchange switches traffic between four conventional exchanges using crossbar (XB) and step-by-step (SXS) equipment. The exchanges are linked by digital transmission using 24 channel Pulse Code Modulation (PCM) systems as described in Reference 2. The IST exchange switches 1.536 Mbps PCM line signals and is fully electronic. Some details of the exchange hardware can be found in References 3 and 4. As shown in Fig. 2, all lines from other exchanges, and all connections to signalling senders and receivers and all service units, such as tone generators, recorded announcements and test units, are made to the single full-availability switch-block. The incoming PCM pulse trains are switched across the speech matrix by means of general purpose interconnection units called junctors. The junctors can maintain a connection between any incoming line and any outgoing line. The form of the speech matrix is shown in Fig. 3. All

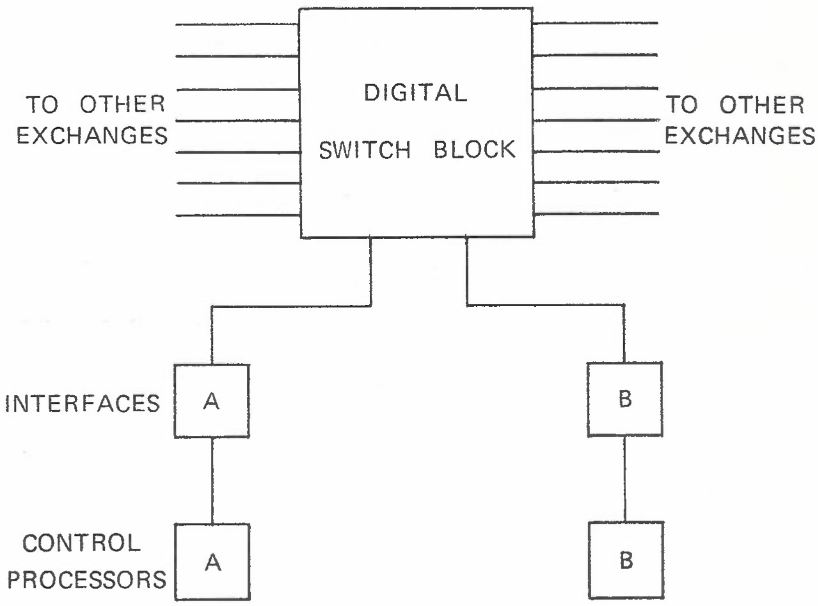

Fig. 1 — The Basic IST Exchange

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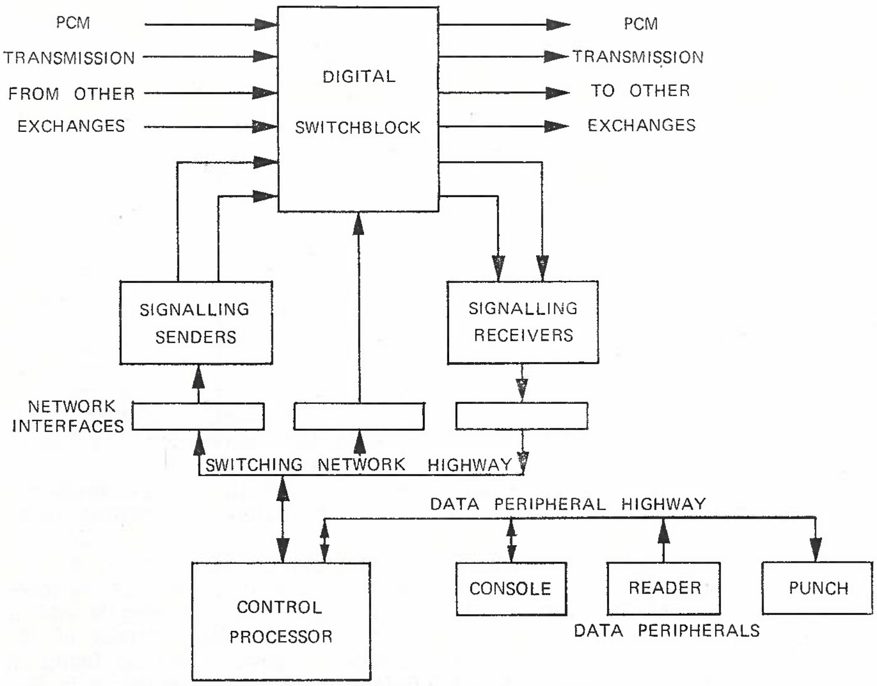


Fig. 2 — IST Exchange Topology

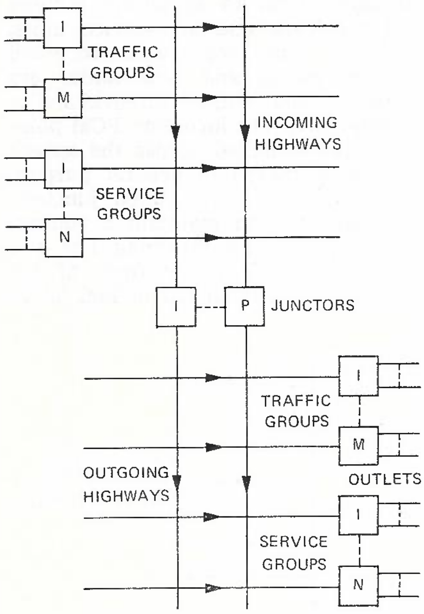


Fig. 3 — The Form of the Speech Matrix

lines to other exchanges are connected to the traffic groups, and all other units are connected to the service groups.

In the initial phase of the project the IST exchange will have no telephone subscribers of its own, and will carry only junction or transit traffic between other exchanges. At a later stage in the project it is planned to add remotely controlled subscribers concentrators. This paper is restricted to the initial phase of the project.

The two major data highways connected to the processors are shown in Figure 2, being firstly the switching network highway to and from the telephone switchblock and its associated units, and secondly the data peripheral highway to and from the data peripherals of console, tape reader and tape punch. The latter peripherals are used mainly for man-machine communications and for high speed program loading and dumping when required.

DATA INTERFACES.

The exchange control processor sees the rest of the telephone exchange as a data interface by means of its input/output switching network highway, or bus system. All information concerning the state of the exchange, and all signals received from other exchanges, as well as all instructions passed to units of the exchange, and all signals sent to other exchanges, are part of the switching network input/output data format of the program control system.

THE SWITCHING NETWORK INPUT/OUTPUT DATA FORMAT.

The switching network input/output data format for messages to and from the processor and the switchblock is organised according to the various functions which have to be carried out. A list of the various functions is given in Table 1, under the two headings of Call Handling and General Exchange Control. The functions included under Call Handling are only the basic ones involved in straightforward call handling. The functions included under General Exchange Control are those involved in the administration of the exchange to ensure that it is continuing to provide service.

MAN-MACHINE COMMUNICATIONS DATA FORMAT

Essentially all man-machine communication messages are passed by means of the console ASR33 teletypewriter. Messages are typed on the ASR33 by the operator to initiate tests, to inform the programs that

TABLE 1 — SWITCHING NETWORK INPUT/OUTPUT INTERFACE DATA FORMAT FUNCTIONS.

Function		Input	Output
Call Handling	Information To and From Other Exchanges	Supervisory Scan	Supervisory Drive
		Signalling Receiver Scan	Signalling Sender Drive
	Path Control	—	Path Connection
			Path Disconnection
General Exchange Control	Device Control	Scan Signalling Units	Reset DPR
		Scan Path Setting Fault Flag	—
	System Control	Scan Alarms	Set System Configuration
	Transmission Quality	Scan Tester	Drive Tester
	Interface Operation	Scan Tester	Drive Tester

new lines and devices have been connected, to initiate the loading of special on-demand test programs, to request information from the processors and so on. Output messages, originated by the processor, provide data concerning system performance, faults detected or suspected, traffic statistics, and so on.

The man-machine messages conform to a data format which overall can be essentially independent of the data format used for input and output messages to the switching network, but some parts of the format such as those used for description of exchange devices are the same.

The IST man-machine communications system is described in the article by Mr. F. P. Hutchings in this issue of the journal.

EXCHANGE DATA DESCRIPTION

Apart from the two input/output data formats described above, all other data formats are completely internal to the processors.

In order for the program control system to function, it is necessary to build up a complete data description of the whole exchange. This is provided in the memory of the processors as a set of tables. The information in these tables consists of three main types, semi-permanent data, exchange state information and call state information. These are shown in Fig. 4 together with the data flows involved in controlling the exchange.

Semi-permanent data consists of that information which is not normally changed except by manual intervention, or else when the exchange is expanded, or when conditions in the rest of the telephone network change.

The exchange state information is basically that information which indicates the current condition of lines, devices and paths. It includes the free or busy status, the faulty or healthy status and the record of the last signal received on a line or device, commonly referred to as "last look" information. The free or busy, faulty or healthy information is used when allocating lines, devices and paths. The last look information is used to detect when a change of state has occurred on a line or device.

Every call handled by the exchange is an entity in itself, and has its own individual existence and characteristics. As far as the exchange equipment is concerned, a telephone call is the temporary association of lines, devices and paths. A particular call can use any one of a number of devices, outgoing lines, paths and even outgoing routes in its passage through the exchange. Call state information is necessary to enable individual calls to be handled correctly, and has a lifetime dependent on the duration and type of call.

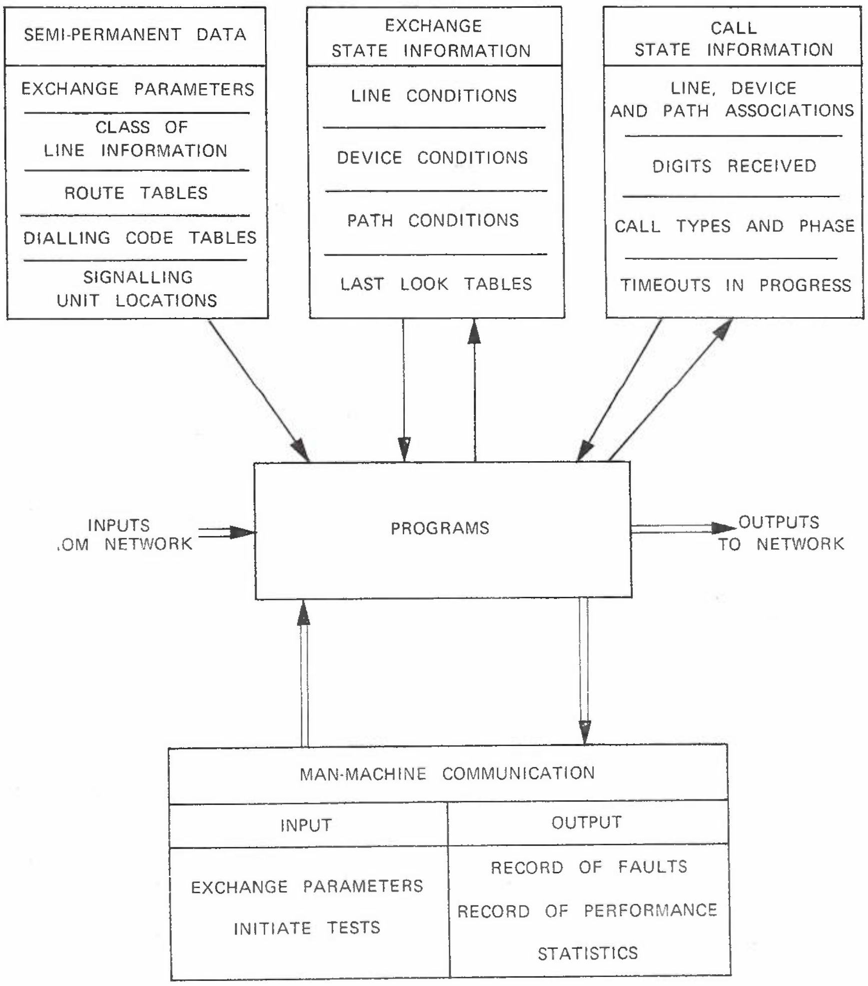


Fig. 4 — Exchange Data Tables and Data Flow

Semi-permanent Data.

Some examples of semi-permanent data are listed in Fig. 4. As this information is normally only referenced and never altered by the call handling programs, only the arrow from the table to the programs is shown in Fig. 4 to indicate reading of the data.

Exchange Parameters: These parameters are items like the number of signalling units or junctors or systems which are equipped, or the number of attempts which are allowed to try to find a path across the exchange for a particular type of call, or the number of devices of a certain type which must be scanned during a specific time interval.

Class of Line Information: Class of line (COL) information describes whether a particular line is equipped or unequipped, whether it is a normal or a special line, whether it is an incoming or an outgoing or a bothway circuit, whether it is connected to a XB or to a SXS exchange, and any other useful information of this type.

Route Tables: The route tables contain information indicating which lines are connected to which routes outgoing from the exchange.

Dialling Code Tables: These tables contain information which enable decisions to be taken concerning what action is appropriate to each of the possible dialled digit combinations which can be transmitted to the exchange.

Signalling Unit Location Tables: These tables contain information describing where the various types of signalling senders and receivers, test units and recorded announcement devices, and so on, are connected to the switchblock.

Exchange State Information.

As this information is both consulted and changed by the programs, arrows are shown in Fig. 4 going to and from the tables and the programs, to indicate reading and writing by the programs. Examples of the types of exchange state information are listed in Fig. 4.

Call State Information.

Line, Device and Path Associations: There is a need to know which signalling units, and which paths are associated with the call on a particular line, so that, for example, digits detected by a particular receiver are associated with the correct line and call. The digits have to be stored in case of a need for retransmission and to facilitate digit analysis.

Dialling Buffers and Supervision Buffers: The digits and all other information peculiar to an individual call are stored in a table called a dialling buffer (DB). During its setting up phase, each call is allocated a dialling buffer of 16 words for its exclusive use. After the call has been established, a table called a supervision buffer (SB) of only 4 words is sufficient.

Call Types and Phases: Different types of calls need to be treated differently. In the dialling buffer, information is maintained concerning both the type of call in progress and the stage which it has reached. The type of call determines the action code. The stage the call has reached is indicated by the call phase.

Timeouts in Progress: In order to check that processing of the call is proceeding correctly, and to provide a sense of real time to the programs, there is a need for various timing counters to be active during the handling of a call. During the setting up of a call in the IST exchange there is always at least one and sometimes up to three timeouts in progress. The timing counters are special types of tables which are incremented regularly until a predetermined value is reached, when it is possible to say that a certain time interval has elapsed since the time when the timing counter was activated.

DATA AND PROGRAM INTERACTION.

In the preceding sections an indication has been given of how a complete description, or picture, of the exchange is built up using a collection of data tables and data formats. This data is completely passive in nature, and serves in the same way as a library of reference books. An active element is required to allow the data tables to play their part, and this is provided by the programs. The programs generate data flow, and can be looked upon as vehicles for transforming data. They all take a set of data as input, and they all have as output another set of data; and in most cases the programs are taking data prepared by one program and transforming it for use by another program. A mechanism is required to enable data to flow in an orderly manner from one program to another, and the main one provided takes the form of hoppers.

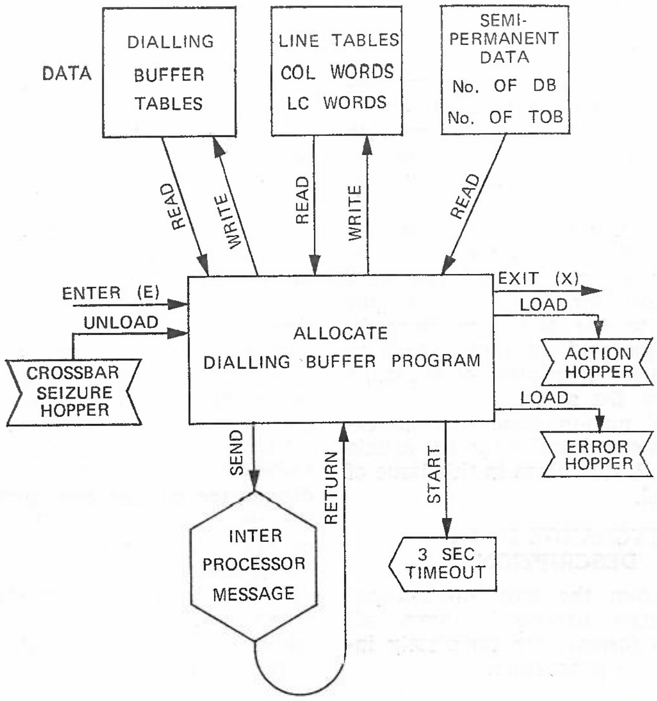


Fig. 5 — Allocate Dialling Buffer Program

Hoppers: These are tables of job lists arranged in the form of an ordered queue with first-in, first-out. In the general case any program which unloads a hopper, has only one hopper to unload, but it can load one or more hoppers, depending on the circumstances.

Allocate Dialling Buffer Program: The roles of programs and data are illustrated by Fig. 5, which shows the Allocate Dialling Buffer (ADB) program. This program is used, whenever the origination of a new call has been detected on an incoming line, to search for and to allocate a dialling buffer for the call on that line. Its action can be understood by referring to Fig. 5. On entry the program unloads the first cell from the Crossbar Seizure Hopper. This is a one word cell containing only the identity of the line requiring the dialling buffer. The program performs a circular sequential scan of the dialling buffer tables, until it finds a dialling buffer which is marked free. It changes the data in the first word of the dialling buffer to indicate that the dialling buffer is now busy and is allocated to own processor. It also loads the identity of the incoming line into the first word, and then sends a message to the other processor indicating that it has seized this particular dialling buffer for a call which it is to handle.

The identity of the dialling buffer is written in the line condition (LC) word of the incoming line. Two bits are read from the COL word (see Fig. 6) and are written into the first word of the dialling buffer to indicate that the line, in this case, is a normal XB line. The address of the dialling code tables (actually called prefix translation tables) relevant to XB calls, is placed in the 6th word of the dialling buffer.

A 3 second timeout is started and its identity is placed in the fourteenth word of the DB. This timeout is used to check that all the digits expected on this line are received within about 3 seconds of detecting the seizure. If the timeout expires before all the digits have been received, then it is most likely that there is some fault either in the IST exchange hardware or software, or in the distant exchange, or in the line between them, and appropriate action is initiated. The last task of the ADB program before exit to the next program, is to load the Action Hopper with an indication of the next program which should be executed for this call. The

O_1 O_2	C_6 C_7	M	△ △ △ △	B_1 B_2	C_1 C_2 C_3 C_4 C_5

O_1 O_2 = 00 Free, unallocated
01 Busy, own processor
10 Busy, other processor
C_1 = 0 Normal line
1 Special line
C_2 = 0 In service
1 Faulty
C_3 = 0 Equipped
1 Non-equipped
C_4 = 0 Incoming
1 Outgoing
C_5 = 0 Line to SxS exchange
1 Line to crossbar exchange
C_6 = 0 Line normal
1 Line blocked
C_7 = 0 One-way circuit
1 Both-way circuit
B_1 B_2 = 0 Call state information
M = 0 Normal
1 Maintenance block
△ = Spare

Fig. 6 — Class of Line Word

Action Hopper and the Action program provide a versatile mechanism, with extensive provision for modification, to enable the ordered execution of many different sequences of tasks, once the handling of a call has commenced.

One error hopper is indicated in Fig. 5. It could happen that when the ADB searches for a free DB, that they are all busy. This could occur because of a peak traffic overload condition, a fault somewhere, or because of other unusual circumstances. In any case the fact that this situation has occurred is recorded by loading an error hopper with all relevant data. This normally results in a message being printed out on the ASR33 by means of the man-machine communications programs.

In searching for a free DB and a free timeout buffer (TOB), the ADB program has to consult two items of semi-permanent data, the number of dialling buffers provided in the memory, and the number of timeout buffers provided in the memory, as shown in Fig. 5.

Once the program has completed its execution, it is interesting to consider what effect it has had. The net effect is that the contents of the data tables of the exchange, including hoppers, have been changed slightly. The execution of this particular program has transformed selected parts of the exchange data tables in specific ways.

The example of the ADB program has brought to light another data format, which is slightly independent of the other data formats. This is the format which applies to the interprocessor channel (IPC) messages, or the flow of data between the two processors.

Interprocessor Channel Data Format.

The second processor is provided so that in the occurrence of a hardware or software fault in one processor, the proper functioning of the exchange can continue under single processor control until the fault is remedied. In order to enable the two processors to share the load, and to take over from each other when necessary, the two processors interchange certain data at appropriate times. It is most important that the IPC messages should be transmitted and received with great accuracy as an error in this data flow could easily make both processors fail simultaneously and take the exchange out of service. The IPC messages are made to conform to definite formats and error protection data is added to the messages. If the message received does not conform to the prescribed format, the receiving processor does not act on it.

THE SWITCHING NETWORK INPUT/OUTPUT DATA FORMAT.

Some examples of the network input/output data format used in the IST exchange are described below.

Input Information.

All information coming in from the input highway consists of a single 16 bit word at a time. As all input information is immediately preceded by an output signal from the processor specifically requesting that information, there is no need to add identification labels to the input information, and so the whole of the input word can be allocated to useful information. A typical example of an input word is that received from a dial pulse receiver, as shown in Fig. 7.

The functions of the seven bits of the word actually conveying information are explained in Fig. 7. The remaining nine bits are not used for various reasons and will appear as zero when scanning is carried out. As it has deliberately been arranged so that all devices scanned by the Signalling Receiver Scan program present their information in exactly the same format to the processor, Fig. 7 is completely representative of all signalling receivers.

Output Commands.

The messages passing over the output highway have two main parts, identification of the type of signal and the unit for which it is intended, and the command itself. The output messages are of either one, two or three words in length. A typical example is the two words used to drive a dial pulse sender (DPS) as shown in Fig. 8. Decoding of the information in the two words is done in convenient stages in the interface equipment, and information is absorbed until eventually the appropriate individual DPS is given the direct command to transmit digit C_1 C_2 C_3 C_4. It has deliberately been arranged so that all devices driven by the Signalling Sender Drive program can be given their information in exactly the same format. The format has been designed to cater for at least eight different signalling sender and receiver types, with up to 64 units of each type.

Path Setting: In the IST exchange the setting up of a path across the

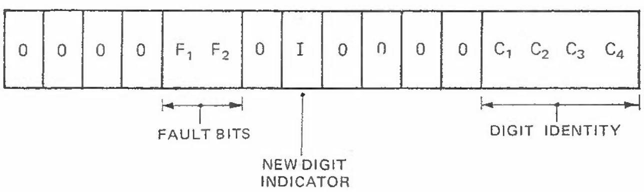


Fig. 7 — Input Word Obtained by Scanning a Dial Pulse Receiver

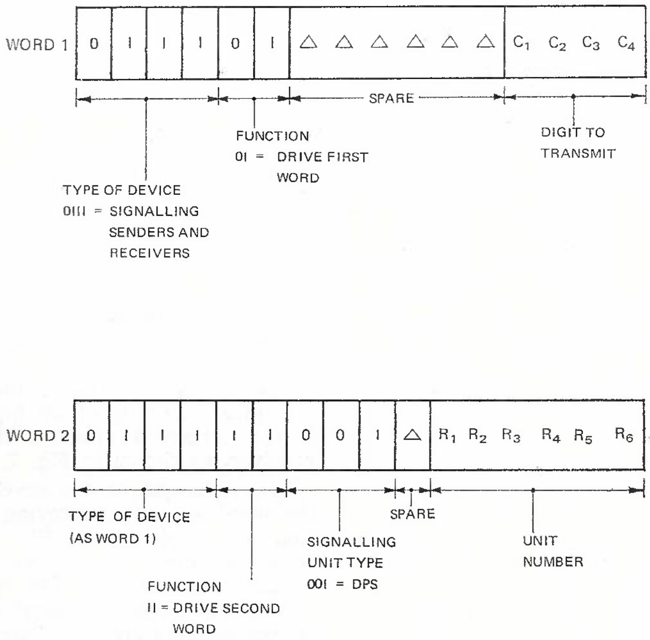


Fig. 8 — Output Words Used to Drive a Dial Pulse Sender

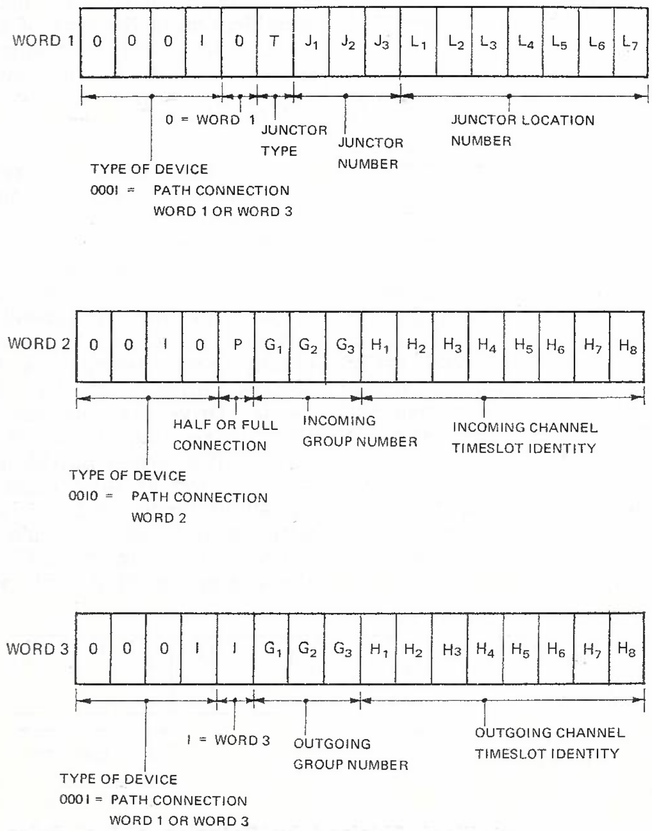


Fig. 9 — Path Connection Drive Words

speech matrix requires three words as shown in Fig. 9. Basically, the first word identifies the type of junctor, the particular junctor, and the location, which is the part of the junctor which actually makes the connection. There are two types of junctor, a delay junctor which can handle up to 96 simultaneous conversations between channels with different timeslots, and a zero delay junctor which can handle up to 192 simultaneous conversations between channels having the same timeslot.

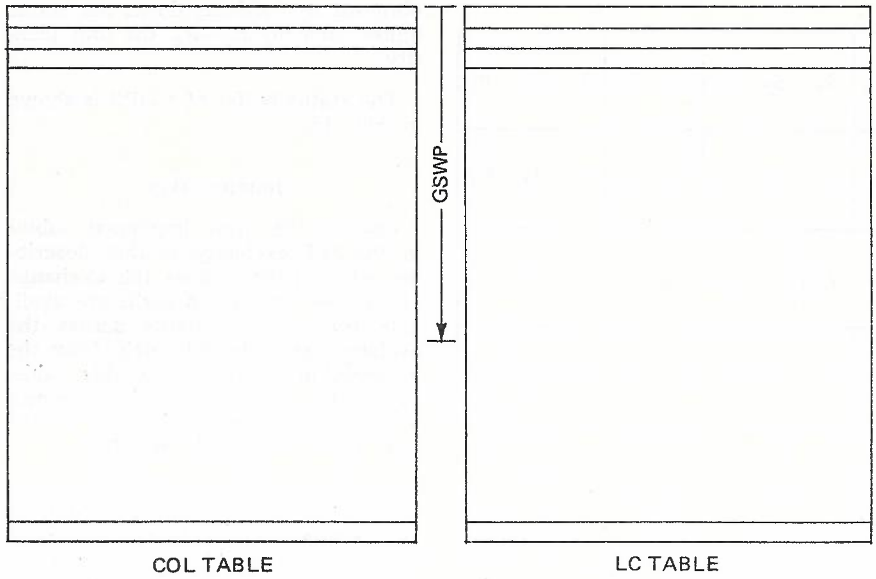
The data format caters for up to 8 delay junctors, and up to 4 zero delay junctors. All these junctors fully equipped would allow 1536 simultaneous conversations. As the delay and zero delay junctors can be extended independently, and as each of the junctors can be equipped in convenient modules of 8 locations, the speech matrix can cater efficiently for a wide range of traffic values.

The second word identifies the incoming channel, one of up to 192, and its group, one of up to 8. The third word identifies the outgoing channel in the same way. Once this three word command has been passed from the processor to the interface and from there to the particular junctor, the conversation is maintained indefinitely by the junctor until a breakdown command for that particular connection is received from the processor. Once the interface equipment has received all three words, the path across the exchange is established in less than 3μs.

The data format caters for up to 6 Traffic Groups, and 2 Service Groups, as shown in Fig. 3. Each traffic group serves up to 8 PCM systems of 24 channels. This means that the data format allows for a total of 1152 junction circuits, in any combination of incoming, outgoing and bothway circuits. Each service group serves up to 192 inlets plus outlets, for services like signalling senders and receivers, tone generators, recorded announcements, and automatic test senders and receivers. It is calculated that 2 service groups would be sufficient for at least 14 traffic groups, but a minimum of 2 is provided for reasons of security.

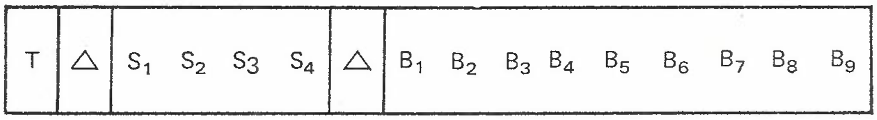
IST EXCHANGE DATA TABLES.

Although there are fundamental differences in the nature of the different types of data, as explained earlier, it is frequently convenient in practice to combine them together in the data tables used, and this has been done in the actual tables used in the IST exchange. Some typical tables are described below.



GSWP = LINE IDENTITY

Fig. 10 — Line Tables



T = 1 — Dialling buffer
1 — Supervision buffer
B_1———B_9 = Buffer identity
S_1 S_2 S_3 S_4 = Special line information
△ = Spare

Fig. 11 — Line Condition Word

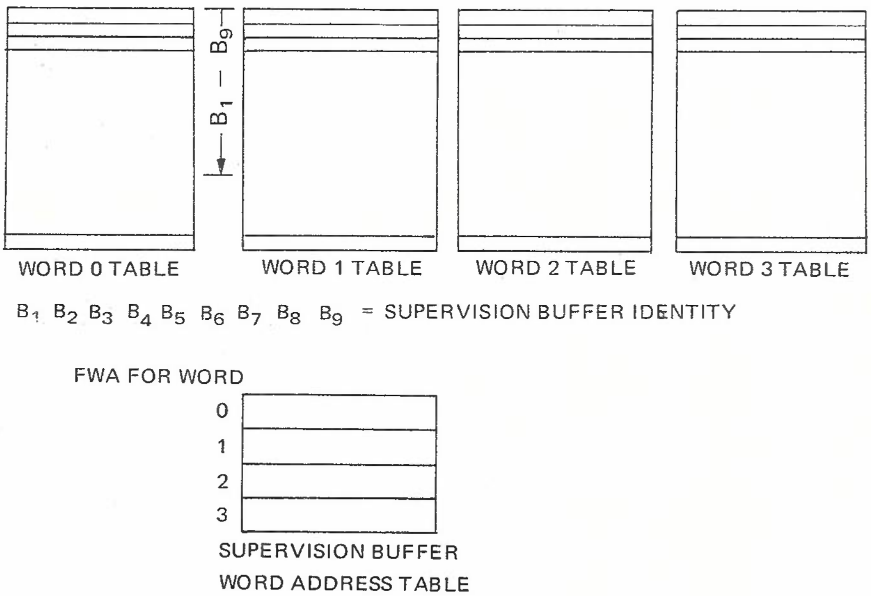


Fig. 12 — Supervision Buffer Table

Line Tables.

Two words, called respectively the Class of Line (COL) word and the Line Condition (LC) word, are allocated to each traffic line connected to the exchange. They are arranged in memory in simple tables as shown in Fig. 10. Each line connected to the exchange has a unique identity given by GSWP,

where $G = G_1G_2G_3$ = group identity, 0 to 7
$S = S_1S_2S_3$ = system identity, 0 to 7
$WP = W_1W_2P_1P_2P_3$ = channel identity, 0 to 23.

The address of the first word (FWA) of each of the tables is stored in a special area of the memory, so that the desired COL or LC word can be accessed by a program located anywhere in memory with a knowledge of only GSWP. This is achieved by a combination of indirect addressing and indexing.

The COL word is shown in Fig. 6, and the LC word is shown in Fig. 11. The meanings of the various bits and combinations of bits are listed in Figs. 6 and 11.

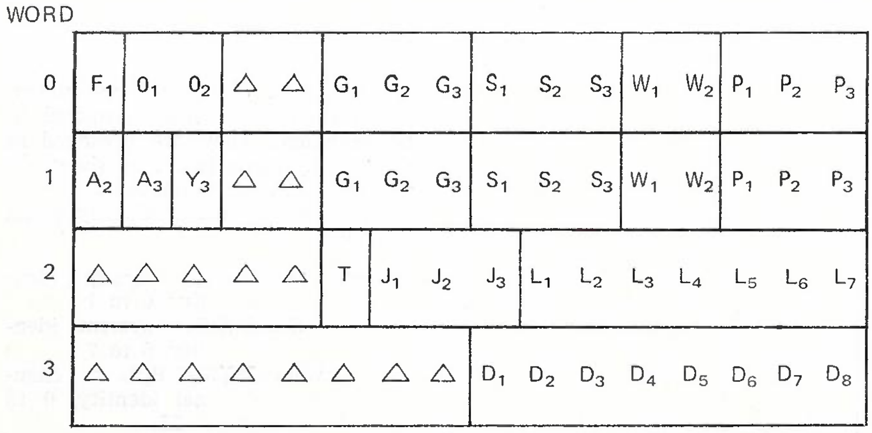
Supervision Buffer.

The supervision buffer contains the identities of the lines and the path involved in a conversation connection, together with various control bits. The supervision buffers are arranged in the memory in tables as shown in Fig. 12. The FWAS of each of the four word tables are stored in a special area of the memory. The desired supervision buffer word is accessed by indexing down the appropriate word table by an amount equal to the supervision buffer identity. The data format caters for 512 supervision buffers, one of which is needed for each call in the conversation stage.

The contents of the supervision buffer are shown in Fig. 13, together with a list of the meanings of the bits and groups of bits.

Device Status Buffers.

Information concerning the signalling senders and receivers is stored in tables of device status buffers. Each device has a status buffer of at least one word. The status buffer tables are arranged as shown in Fig. 14. The FWA of the appropriate status buffer table is obtained by indexing down the Status buffers address table by $T_1T_2T_3$, the unit type, and the status buffer of the particular unit is



F_1 = 0 Free
1 Busy
$O_1 O_2$ = 00 Unallocated
01 Own processor
10 Other processor
Word 0 GSWP = Incoming channel identity
Word 1 GSWP = Outgoing channel identity
T = Junctor type, path identity
$J_1 J_2 J_3$ = Junctor number, path identity
L_1—L_7 = Junctor location number, path identity
$A_2 A_3 Y_3$ = Control bits
D_1—D_8 = Timeout buffer identity

Fig. 13 — Supervision Buffer

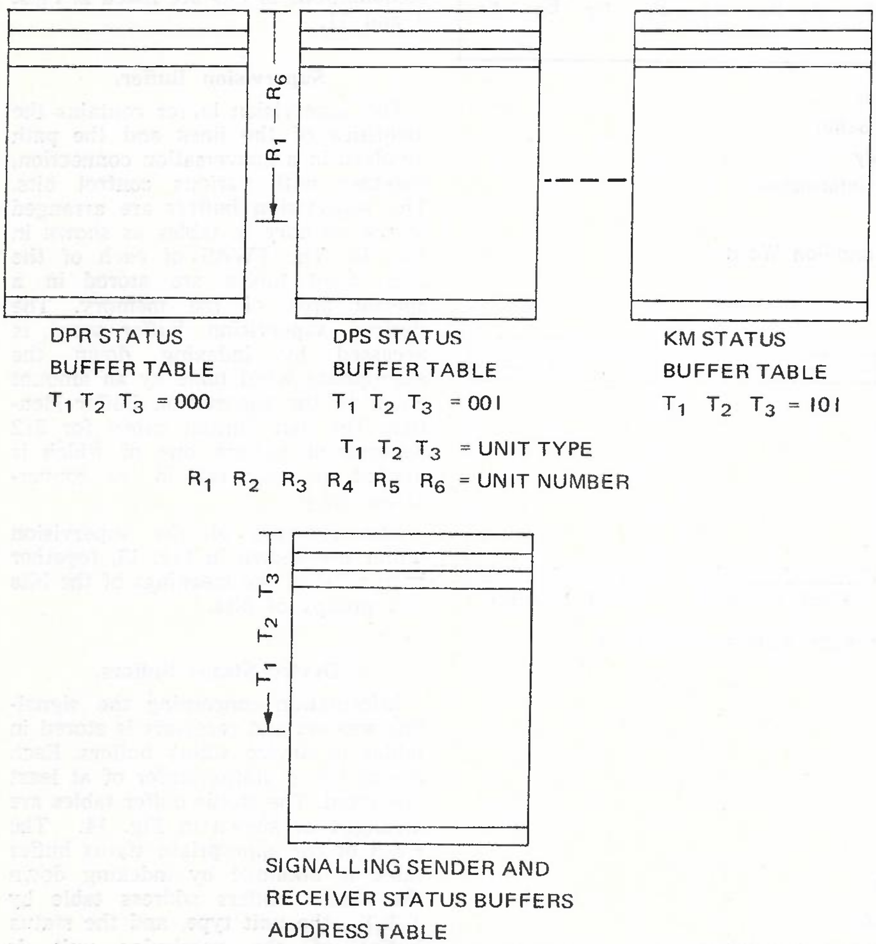


Fig. 14 — Signalling Unit Status Buffer Tables

obtained by indexing down the status buffer table by R_1—R_6, the unit identity.

The status buffer of a DPR is shown in Fig. 15.

Junctor Map.

One of the most important tables in the IST exchange is that describing which paths across the exchange are in use, and which paths are available for use. All paths across the exchange are selected solely from the information contained in this table, called the junctor map. No reference is made to the network itself at the time when a path is selected.

The junctor map contains a complete description of the condition of all possible connections or paths across the switchblock. If a path is required between an incoming channel with timeslot x, and an outgoing channel with timeslot y, all that is required is a junctor which

(a) has timeslots x and y free, and

(b) has a free location.

The timeslot occupancy and the location occupancy of a junctor are essentially independent, as any timeslot can use any location, and the junctor map consists of two tables, the timeslot occupancy table, and the location occupancy table. The trunking arrangement of the switching matrix is very simple, and this is reflected in the simplicity of the junctor map.

Timeslot Occupancy Table: The timeslot occupancy table and the timeslot occupancy word are shown in Fig. 16. The table is indexed by SWP to find the word appropriate to the timeslot involved. This word indicates which junctors have this timeslot available and which junctors are already using this timeslot. Whenever it is decided to use a particular timeslot on a particular junctor the relevant bit is changed from 1 to 0.

Location Occupancy Table: Each junctor can use any of the timeslots at any time subject to only one physical limitation. The number of calls which a junctor can handle simultaneously depends on how many locations have been equipped, with a maximum of 96 for delay junctors, and 192 for zero delay junctors. Each location of a junctor can handle one conversation. This means that before a junctor can handle a particular connection it must have both the timeslots available and a location available. The location occupancy table and the location occupancy word are shown in Fig. 17.

F	0	O_1	O_2	T_1	T_2	M	I	△	B_1	B_2	B_3	B_4	B_5	B_6	B_7

F = 0 — Free
1 — Busy
O_1 O_2 = 00 — Unallocated
01 — Own processor
10 — Other processor
T_1 = Last look of type 1 fault 0 = healthy
T_2 = Last look of type 2 fault 1 = faulty
I = Last look of new digit indicator
B_1——B_7 = Dialling buffer identity
△ = Spare
M = 0 — Normal
1 — Maintenance block.

Fig. 15 — DPR Status Buffer

In practice the Path Search program checks the timeslot occupancy table first, and having found a junctor with both timeslots available, it then searches the location occupancy table for a free location.

TELEPHONE CALL HANDLING.

The way in which the data flow and data formats are involved with the programs in the handling of a telephone call will be illustrated by describing in some detail a simple successful call as handled by the IST exchange. A telephone call consists of a natural set of sequences involved in the origination, setting up and clearing down of the call. The detailed way in which the call is handled depends on where the call came from, the digits dialled, and the current state of the exchange and the rest of the telephone network. In Reference 1 a description is given of the way in which many calls of different types can be handled simultaneously by the use of action code, call phase programs and the operation of the clock level and base level functional program loops. The description given below will cover only the events involved in one particular call. In order to fully appreciate both how a single call is handled and how the program control system works, it is necessary to keep several pictures in mind simultaneously. These are essentially:

(i) the sequence of the programs and the data flow involved in this call alone,

(ii) the total time pattern of the processor in executing the clock level and base level and other programs for many calls at various stages, being handled simultaneously,

(iii) the state of the various data tables involved in the call,

(iv) the condition of the switching network and other devices of the exchange,

(v) the behaviour of the subscribers and the other exchanges involved in the call.

In comparison with many other types of programs, those involved in handling telephone calls are comparatively short, and are executed over and over again, with different paths being taken through the programs depending on the changing data being presented to the programs. The programs can be viewed as an endless sequence of interrelated decisions being taken mostly as a result of changing external events.

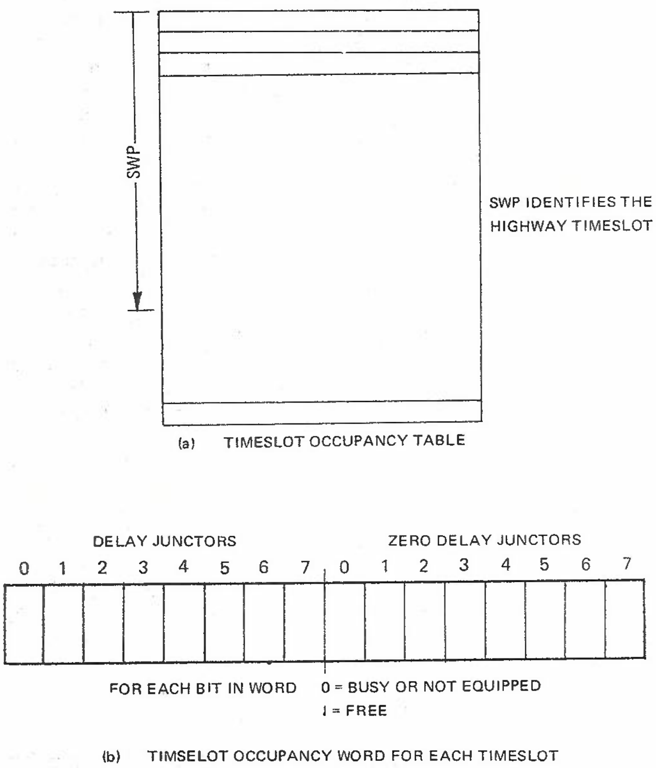


Fig. 16 — Junctor Timeslot Occupancy Table and Word

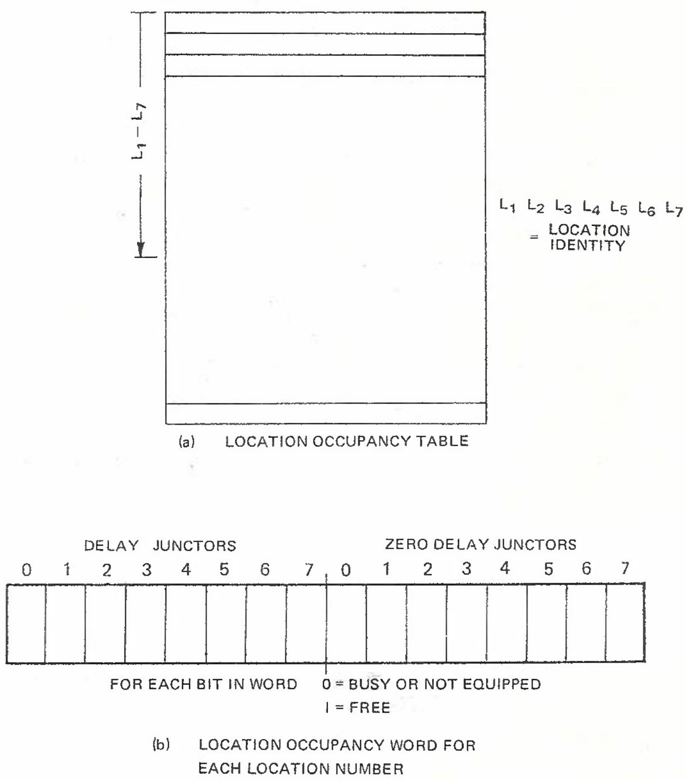


Fig. 17 — Junctor Location Occupancy Table and Word

△	△	△	△	△	G_1	G_2	G_3	S_1	S_2	S_3	W_1	W_2	P_1	P_2	P_3

GSWP = Incoming channel identity
△ = Spare

Fig. 18 — Crossbar Seizure Hopper

R	△	△	△	△	△	△	△	△	B_1	B_2	B_3	B_4	B_5	B_6	B_7
CALL PHASE									ACTION CODE						

B_1—B_7 = Dialling buffer identity
R = Type of entry
△ = Spare

Fig. 19 — Action Hopper

C_1	C_2	C_3	C_4	△	△	T_1	T_2	T_3	△	R_1	R_2	R_3	R_4	R_5	R_6

$C_1 C_2 C_3 C_4$ = Received code or digit
$T_1 T_2 T_3$ = Receiver type
000 = DPR
010 = KS
100 = KM
R_1——R_6 = Receiver number
△ = Spare

Fig. 20 — Signalling Receiver Scan Hopper

△	T_1	T_2	T_3	△	R_1	R_2	R_3	R_4	R_5	R_6	△	C_1	C_2	C_3	C_4

$T_1 T_2 T_3$ = Sender type
001 = DPS
011 = KS
101 = KM
R_1——R_6 = Sender number
$C_1 C_2 C_3 C_4$ = Code or digit to be transmitted
△ = Spare

Fig. 21 — Signalling Sender Drive Hopper

Z	△	M_1	M_2	Q	G_1	G_2	G_3	S_1	S_2	S_3	W_1	W_2	P_1	P_2	P_3

Z = Signalling transparency indicator
$M_1 M_2$ = Signalling bits to be transmitted
GSWP = Channel identity
Q = Refer back bit

Fig. 22 — M Lead Drive Hopper

A SIMPLE SUCCESSFUL TELEPHONE CALL

A simple successful call from Clayton to South Oakleigh will be described as if it were the only call being handled by the processors. Thirteen hoppers will be involved in the call described, and several of these will be described briefly before the call handling is outlined.

EXAMPLES OF HOPPERS

Crossbar Seizure Hopper: Whenever a valid seizure signal is detected on an incoming line from a crossbar exchange, an entry is placed, or loaded, in the Crossbar Seizure Hopper, as shown in Fig. 18. This entry simply identifies the line on which the seizure has occurred.

Action Hopper: Each entry, or cell, in the Action Hopper consists of two words, in contrast to the Crossbar Seizure Hopper which consists of cells of one word each. The number of cells provided in memory for each hopper depends on the size of the exchange and the traffic load and the grade of service required, in much the same way as the number of registers provided in a crossbar exchange is dimensioned according to the number of lines, the traffic per line, and the grade of service required.

There are two basic types of entry made in the Action Hopper, depending on the value of R as shown in Fig. 19. When R = 1, a change to the new action code, call phase indicated in the second word of the hopper is required. The call involved is completely identified by the dialling buffer, as there is one dialling buffer for each call in the process of being set up. When R = 1, a change can be made from any action code, call phase to any other action code, call phase.

When R = 0, the Action Hopper entry virtually indicates that the call is to proceed another step, using the action code, call phase currently stored in the dialling buffer. In this case the second word of the hopper is not used. For simple successful calls, most of the Action Hopper entries have R = 0.

Signalling Receiver Scan Hopper: All signalling receivers are scanned regularly by the processors to detect new digits and control signals sent to the IST exchange. Whenever a new digit is detected by the Signalling Receiver Scan program an entry is placed in the Signalling Receiver Scan Hopper, as shown in Fig. 20. The receiver is identified by the T and R bits, and the code or digit detected is given by the C bits.

Signalling Sender Drive Hopper: This hopper is the transmitting or sending equivalent of the Signalling Receiver Scan Hopper. Whenever the IST exchange wants to send a digit or code to another exchange, it uses this hopper, as shown in Fig. 21.

M Lead Drive Hopper: Whenever the IST exchange wishes to send a line or supervision signal, such as seizure, clear forward or seize acknowledge over a particular line to a distant exchange over the E and M leads, it loads this hopper, as shown in Fig. 22. This hopper has two special bits, the Z and Q bits. When the transparency bit Z = 0, the exchange is transparent to the line signalling conditions. This is the normal situation where changes in the signalling bits reaching the IST exchange are transmitted straight through the IST exchange, for example the answer signal and clear forward. During part of the setting up time for a call, and occasionally during a conversation, it is either convenient or necessary to prevent the line signals passing unchecked through the IST exchange. One example occurring in the IST exchange is that of some non-metering calls. In this case the exchange is transparent in the forward direction from calling to called subscriber, and non-transparent in the backward direction. When the answer signal (which normally causes the subscribers meter in the originating exchange to register a charge) reaches the IST exchange, it gets no further. When Z = 1, the signal transmitted to line is the last one which the processor commanded to be sent. In this case it is a seize acknowledge.

The refer-back Q bit is used whenever it is absolutely necessary to carry out certain actions in a strict sequence. Sometimes two or more actions can be initiated at about the same time and it is not really important in which order the events actually happen, as it is known that normal tolerances will produce acceptable results. In these cases Q = 0 and it causes no special action. In some situations the sequence in which several events take place is of importance, and at these times the hopper entry includes Q = 1. After the hopper is unloaded, an R = 0 entry is placed in the Action Hopper so that the next event is initiated.

Route Search Hopper: Whenever a free outgoing channel on any route is required, an entry is placed in the Route Search Hopper as shown in Fig. 23, identifying the particular route and the call requiring the outgoing channel.

Path Search Hopper: Whenever a path across the speech matrix is required, an entry is placed in the Path Search Hopper, as shown in Fig. 24, identifying the call and the inlet and outlet between which the path is needed. The two H bits indicate the type of path required, incoming line to signalling receiver, signalling sender to outgoing line, tone generator to incoming line, or conversation connection.

Path Connection Hopper: Whenever a connection is required to be either established across the exchange or broken down, an entry is placed in the Path Connection Hopper, as shown in Fig. 25. The H bits are the same as the H bits in the Path Search Hopper. The Q bit has the same function as in the M Lead Drive Hopper. The Y and T bits are explained in Fig. 25. For a normal two-way or full connection, the P bit = 0. For some situations a full connection is either not required, or is inconvenient. Examples are the busy tone generators and recorded announcements, where only a one-way transmission is required. Establishing only a one-way or half connection simplifies the method of connecting a single generator to several lines.

CLAYTON TO SOUTH OAKLEIGH CALL.

The way in which this call is handled can be seen from Fig. 26, which shows every program and hopper involved, and the data tables consulted and altered.

X_1	X_2	X_3	X_4	△	△	△	△	△	B_1	B_2	B_3	B_4	B_5	B_6	B_7

$X_1 X_2 X_3 X_4$ = Route identity
B_1——B_7 = Dialling buffer identity
△ = Spare

Fig. 23 — Route Search Hopper

H_1	H_2	△	△	△	△	△	△	△	B_1	B_2	B_3	B_4	B_5	B_6	B_7
△	△	△	△	△	G_1	G_2	G_3	S_1	S_2	S_3	W_1	W_2	P_1	P_2	P_3
△	△	△	△	△	G_1	G_2	G_3	S_1	S_2	S_3	W_1	W_2	P_1	P_2	P_3

$H_1 H_2$ = Type of path
B_1——B_7 = Dialling buffer identity
GSWP = Channel identity

Fig. 24 — Path Search Hopper

H_1	H_2	Q	Y	P	△	T	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9

$H_1 H_2$ = Type of path
Q = Refer back bit
Y = 0 = Path connection
= 1 = Path disconnection
P = 0 = Full connection
= 1 = Half connection
T = 0 = Dialling buffer
= 1 = Supervision buffer
B_1——B_9 = Buffer identity

Fig. 25 — Path Connection Hopper

Detection of Seizure.

Every 20 ms each processor scans the two signalling leads of all channels by means of the E Lead Scan program (ELS — program number 1 in Fig. 26). This program detects changes of signalling conditions by comparing the present state with the previous state stored in the Line Last Look Tables. In the case of a new seizure on line x the present state will be 11 and the last look state will be the idle condition 01. After detecting the change of state, the ELS consults the COL word corresponding to line x discovering in this example that the line is an idle, unallocated, normal, healthy, equipped, non-blocked, incoming line from an XB exchange. After making some other checks, the ELS concludes that this is a valid seizure. It marks the line as busy, own processor in the COL word, sends an IPC message to the other processor, indicating that it has accepted the call on line x, and changes the line last look table state to 11 for line x. The ELS then loads the Crossbar Seizure Hopper with the identity GSWP of line x, and continues scanning the remaining channels. During its operation the ELS must consult some semi-permanent data. Only those groups which have been equipped to some extent are actually scanned by the ELS, and a record of the number of groups equipped is kept as semi-permanent data. The number of new seizures detected during each 20 ms scan is counted and only the first N of these are accepted. The remainder are ignored and accepted in the next scanning cycle by the simple mechanism of not updating the Line Last Look Tables. This has the effect of spreading out the work initiated by several simultaneous seizures, and helps to guard the processors against fault conditions which could initiate simultaneous seizures on several lines or groups of lines. The parameter N is stored as semi-permanent data.

Allocate Dialling Buffer.

The action of the ADB program (number 2 in Fig. 26) is described earlier in this paper, and it allocates DBz to the call on line x.

Allocate KM.

Program number 3, Action Handling, unloads the Action Hopper and causes program number 4, Action Code, Call Phase program (AC, CP) 3,ϕ to be entered. This program loads the KM Queue Hopper indicating that the call being handled by DBz requires a KM code receiver to enable it to receive the dialled digits. AC, CP 3,ϕ also starts a 1 second time-out to check on the actual allocation of a KM to this call.

The Allocate KM program searches for and allocates KMn to this call in much the same way as the ADB program deals with a request for a DB. It loads the DB with the identity of KMn. Program No. 7, AC, CP 3, 1 is entered via the Action Handling program and it initiates the search for a path between line x and KMn.

Search for Path to KM.

The Path Search program (number 8) allocates a path between line x and KMn and loads the relevant information in DBz.

Connect KM.

Now that KMn and a path between line x and KMn have been allocated, AC, CP 3,1 (number 10) stops the 1 second timeout started by AC, CP 3,ϕ (number 4), initiates the actual connection of KMn to line x by loading the Path Connection Hopper, and initiates the sending of a seizure acknowledge signal to the originating exchange by loading the M Lead Drive Hopper. In both these hoppers the refer back bit Q = 0, as the tolerances are such that it does not really matter whether the path connection or the seizure acknowledge actually occurs first.

Receive First Digit.

At about the same time that the Clayton exchange places a seizure signal on line x, it also places the first digit on the line in the form of two audio tones (called MFC signals). As soon as the path between line x and KMn is completed, the MFC signal will be presented to KMn, which will detect the presence of a new digit (or code). In basically the same way as the E Lead Scan program works, the Signalling Receiver Scan program (SRS — number 13) scans all signalling receivers at a regular rate. After detecting that a new digit, or code, has been detected by KMn, the SRS consults the status buffer of KMn to see if KMn is busy, own processor and not faulty. If all these conditions are satisfied, the SRS concludes that a valid digit has been received for a call being handled by own processor, and loads the Signalling Receiver Scan Hopper with the identity of the digit detected, in this case D_1, and with the identity of the receiver concerned. The SRS also updates the last look condition of the new digit indicator in the status buffer of KMn.

Analysis of First Digit.

The Digit Analysis program (DA — number 14) unloads D_1 from the Signalling Receiver Scan Hopper, and from the KMn status buffer derives the identity DBz of the dialling buffer handling the call. The DA stores D_1 in DBz, and then loads another hopper depending on the value of D_1. In this example D_1 is the digit 5, and the DA loads the Signalling Sender Drive Hopper (SSDH) with the code meaning "send next digit" (SND) to be transmitted back to the Clayton exchange. As shown in Fig. 26, in the case of the Windsor IST exchange in the initial phase of the IST project, if D_1 had had any other value, the DA would have loaded the Action Hopper with an R = 1 entry and AC, CP = 3,2, and this would have resulted in the call on line x being switched through to the Windsor XB tandem exchange with D_1 still on line x. If $D_1 = 5$, the DA also starts a timeout of one second to check on the response of the Clayton exchange to the SND signal (see program number 17 for stopping of this timeout).

In the analysis of the digits the DA consults the dialling code prefix translation tables (PTT). The words in the PTT indicate information such as the next program to be executed, and the word to be consulted in the PTT is determined by the value of the digit received.

The Signalling Sender Drive program arranges the actual sending of the SND signal to the Clayton exchange. On reception of this SND signal the Clayton exchange turns off D_1. This change from D_1 to "no tones" (NT) is detected by the SRS (number 16) and an entry placed in the SRSH. As the response of the IST exchange to NT is always to send NT, the DA (number 17) loads the SSDH with NT, and the SRS (number 18) turns off the SND signal. On the reception of the NT from the Clayton exchange the DA (number 17) stops the one second timeout started by the DA (number 14), as the compelled sequence of MFC signals appears to be working satisfactorily.

Receive and Analyse Second Digit.

After the Clayton exchange detects the turning off of D_1, it places D_2 on the line. This is detected and analysed in exactly the same way as D_1. In our case $D_2 = 7$, and this causes the sending of another SND signal to the Clayton exchange, as shown in the DA (number 20).

Receive and Analyse Third Digit.

The third digit D_3 is received and analysed in the same way as D_1 and D_2. In our case $D_3 = 9$, which means that the call is intended for South Oakleigh GIV crossbar switching stage, and the Action Hopper is loaded with an R = 1 entry, with AC, CP = 3,5. As digit analysis is now complete a 10 second control timeout is started by the DA (number 26) to check that the call reaches the conversation phase within 10 seconds, and the 3 second timeout started by the ADB program (number 2) is stopped.

Route Search.

AC, CP 3,5 initiates the search for a free outgoing channel to South Oakleigh by loading the Route Search Hopper. In our example the Route Search program (RS — number 29) discovers that all outlets to South Oakleigh are busy, and an alternate route must be chosen. The RS places information in DBz indicating that the route search was unsuccessful, and then loads the Action Hopper with R = ϕ. Program 3,5 (number 31) arranges for the appropriate second choice route to be chosen by transferring the call to AC, CP 3,2.

Error Hopper.

The RS also loads an error hopper with a message that the route to South Oakleigh GIV has become congested. This message will eventually be printed by the ASR33 by means of the man-machine communication programs, either by itself, or as part of some statistics derived from several error hopper messages. The information from the error hopper can be used in a simple way to indicate how often a particular route is becoming congested, and can be analysed manually to decide when more circuits are needed. It could also be a small part of a more sophisticated "exchange and network management" control system which, in conjunction with other exchanges, would arrange some kind of dynamic network behaviour, to optimise the overall traffic carrying capacity of the network, in tune with the changing traffic patterns in both normal and abnormal conditions. In the early stages of the IST project, no dynamic network behaviour is being planned, but it is realised that both studies and field trials of dynamic network behaviour must be carried out as soon as possible.

Second Choice Route Search.

The RS (number 34) searches for and finds a free outlet on the second choice route, which in this case is to Windsor. The chosen line m is marked busy and own processor in the COL word, and the identity of DBz is placed in the LC word, and information is placed in DBz identifying line m and the fact that the route search was successful. An IPC message is sent to the other processor indicating that line m has been seized for the call being handled by DBz.

Path Search.

The Path Search program (PS — number 37) consults the junctor maps in an attempt to find a free path from line x to line m. In our example, no free path is available, and the path search is unsuccessful. This fact, by means of AC, CP 3,2 (number 39) initiates a search for another free outlet to Windsor. Line m is released and an IPC is sent to indicate this.

The RS (number 40) allocates another outlet line y, and the PS (number 43) is successful in finding a path between line x and line y. The various data tables are marked accordingly, and an IPC is sent.

Seize Outgoing Channel.

The stage has now been reached where line y can be seized and this is done by the M Lead Drive program (number 46). A timeout on the reception of the seizure acknowledge signal from Windsor exchange on line y is started. The call from Clayton has been diverted to Windsor in the hope that Windsor has a free outlet to South Oakleigh GIV. As the Clayton exchange has already transmitted the digits 579 to the IST exchange, and as the Windsor exchange will also need these digits to switch the call to its required destination, the IST exchange sends a "Restart" signal to the Clayton exchange, as arranged by AC, CP 3,2 (number 45). AC, CP 3,2 changes the AC, CP in DBz to 3,6 which is the next AC, CP involved in setting up the connection between line x and line y.

Programs 48, 49 and 50 of Fig. 26 complete the sequence of turning off the tones.

Disconnect and Release KM

AC, CP 3,6 initiates the disconnection of the path from line x to KMn. Certain safeguards and procedures have to be taken to ensure that KMn is not reseized for another call before it is really free and in a stable quiescent condition. These are organised by programs 53, 54, 55 and 56. These procedures are mainly due to the fact that the programs can take decisions and issue instructions in total times less than 100μs, while the relay sets, filters, and detection circuits in a KM work in time scales measured in tens and hundreds of ms.

Make Conversation Connection.

As soon as KMn and the path from line x to KMn have been released cleanly, AC, CP 3,6 (number 58) initiates the establishment of the "conversation" connection between line x and line y by the Path Connection program (number 59). Although this connection will not immediately result in a conversation between subscribers, it has entered the conversation phase as far as the IST exchange is concerned, because no further analysis is required. This means that the 16 word DBz is not needed any longer, and AC, CP 3,6 and the Transfer DB to SB (supervision buffer) program, arrange the release of DBz, and the allocation of SBk to this call. The latter program also stops the 10 second timeout started by the DA (number 26) when digit analysis was completed.

Make Signalling Transparent.

As this is a normal call the IST exchange is made transparent to E and M signalling in both the forward and backward directions by the M Lead Drive program (number 63).

In normal circumstances the IST exchange takes no more action on this call until the clear forward signal is detected on line x by the E Lead Scan program.

CALL HANDLING TECHNIQUES.

It is hoped that the brief description given above of the handling of a simple successful call has illustrated how important aspects like digit analysis, alternate routing, reception and sending of line and information signals, and the control of individual calls can be achieved using program control. It is also hoped that the description has given an indication of the inherent power and flexibility offered by program control systems. This type of control system has tremendous potential which could be exploited to great advantage in the operation of a communications network. At the same time it must be realised that the full range of flexible features which are so attractive to telephone administrations do not come automatically with all exchanges using stored program control. It is quite possible to build a stored program control exchange which is operationally and/or commercially inflexible. The whole program control system design must be carried out very carefully and deliberately in order to ensure that the required performance is obtained.

Data and Program Roles.

The data formats and programs both make their own contributions to the features and flexibility of a program controlled exchange.

It is hoped that the description above has indicated the relative roles of data formats and the programs, and has shown how they both contribute to the operation of the telephone exchange. The data formats are the static component and are essentially independent of the actual application of the exchange, as either a trunk, local tandem, or terminal exchange. The programs are the dynamic component and determine how the exchange operates.

If the data formats are well organised then it is a simple matter for the programs to simultaneously control a space division switching matrix and a time division switching matrix such as the IST exchange, and to control an exchange which has any combination of trunk, tandem and terminal functions, and which combines a telephony and data switch in the one matrix. With well organised data formats and program structures it is possible to combine call handling, maintenance and diagnostic functions efficiently. For example, a DB could be used for either a live traffic call, or a maintenance call, and this could be indicated by setting a single "maintenance bit" in the DB. The SSD program and the SRS programs can be used to carry out routine cyclic maintenance tests on the signalling senders and receivers.

If the programs and hoppers are well organised, as well as the data formats, new or modified facilities can be incorporated in a simple manner. The need for special maintenance, traffic measuring and recording equipment can be avoided, and useful exchange performance monitoring can be achieved efficiently.

STAFFING FUTURE EXCHANGES.

By 1980, telephone exchanges employing stored program or computer control will be commonplace in the network of the Australian Post Office, and almost every engineer, technical officer and technician will have a sound understanding of how they work, and their particular foibles and characteristics. In the same way as vacuum tubes, transistors, integrated circuits, broadband multichannel multiplexing, mathematics, digital modulation, common control crossbar switching and other devices, systems and techniques have been included in the repertoire of the engineering and technical staff of the APO, so the technique of programming will soon become just another tool in the kitbag to be used when and where appropriate. It is just another step in the natural evolution of telephone exchanges after manual, step-by-step, and crossbar exchanges. As with all other new techniques, care will be needed in the early stages of introduction, until confidence is built up to a high level by a sufficiently long period of exposure to the new techniques. All that the APO engineers and technical staff require is some special training well in advance of the cutover of the new exchanges.

ACKNOWLEDGEMENTS.

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APPENDIX 1 — GLOSSARY OF ABBREVIATIONS USED IN THE TEXT AND FIGURES.

ADB	Allocate dialling buffer program
AH	Action handling program
AKM	Allocate KM program
ACH	Action hopper
AC, CP	Action code, call phase
COLT	Class of line table
COL	Class of line
DA	Digit analysis program
DB	Dialling buffer
DPR	Dial pulse receiver
DPS	Dial pulse sender
D	Digit
ELS	E lead scan program
EH	Error hopper
FWA	First word address
GSWP	Line or channel identity
IPC	Interprocessor channel
JEI	Junctors equipped information
KMQ	KM Queue
KM	Code receiver
KMSB	KM Status buffer
KMLT	KM Location table
LLLT	Line last look table
LCT	Line condition table
LOM	Location occupancy map
LC	Line condition
MFC	Multi frequency code
MLD	M lead drive program
MSB	Map status buffer
MLDH	M lead drive hopper
NXB	Number of crossbar seizures allowed
NGE	Number of groups equipped
NDB	Number of dialling buffers
NTOB	Number of timeout buffers
NKM	Number of KM
NUE	Number of units equipped
NUS	Number of units to scan
NT	No tones
NSB	Number of supervision buffers
PCH	Path connection hopper
PC	Path connection program
PS	Path search program
PTT	Prefix translation tables
PSH	Path search hopper
PCM	Pulse code modulation
RS	Route search program
RSH	Route search hopper
RT	Route tables
SB	Supervision buffer
SRS	Signalling receiver scan program
SSD	Signalling sender drive program
SUCD	Signalling unit cleardown program
SPD	Semi-permanent data
SXS	Step by Step
SUSB	Signalling unit status buffer
SRSH	Signalling receiver scan hopper
SSDH	Signalling sender drive hopper
SND	Send next digit
SUCDH	Signalling unit cleardown hopper
TDBSBH	Transfer dialling buffer to supervision buffer hopper
TDBSB	Transfer from dialling buffer to supervision buffer program
TO	Timeout program
TU	Timeout update program
TOM	Timeslot occupancy map
TH	Timeout hopper
TOB	Timeout buffers
XB	Crossbar
XBS	Crossbar seizure

Fig. 26 — Program Sequence for a Simple Successful Call from Clayton to South Oakleigh

MAN-MACHINE COMMUNICATION SYSTEM FOR THE IST PROJECT

*F. P. HUTCHINGS, B.E. (Elect.)**

MAN-MACHINE COMMUNICATION

The evolutionary development of telephone exchanges has been characterised by an ever-increasing tendency towards centralisation of the control functions. Control functions are those functions involving the decision-making implicit in the complex processes of telephone switching.

From systems using step by step control, this centralisation process has led, via devices such as markers and registers, to the concept of stored-program control located in a central processing device. With each step in this process, the decision making centres have been given control of larger portions of the telephone exchange, until the stage has been reached of one control centre for a complete exchange. This concept will be realised in Australia in the 1970's, and indications are that centralisation will continue still further. The use of central processors to control switching at remote locations, and network control based on direct communication between processors, are ideas currently being developed.

In the progression towards more centralised control, the functioning of the control centres grows more difficult to observe, and intervention by man becomes a more complex task. The functioning of the control centres becomes progressively less tangible until, in an exchange with one central control device, this device may appear as a rather abstract entity. The term "software" does not discourage this feeling. The papers of References 1 and 2 have described the organisation and operation of the stored program control system, being developed in the A.P.O. Research Laboratories, to control an IST (Integrated Switching and Transmission) exchange, which is shortly to be used for a field trial in the Melbourne network. This paper describes the method designed for the exchange staff to communicate with the stored program control system.

Although the operation of a processor controlled exchange is very different from that of exchanges with electromechanical control, there are still many functions which are essentially equivalent. It is only the method of effecting these that differs. With stored program control, many functions which are performed by hardware devices in electromechanical exchanges are transferred to software, and software equivalents replace many of the devices previously realised in hardware. A software dialling buffer, for example, contains essentially the same information as a register in a crossbar exchange, e.g. a record of the digits dialled, etc., see Ref. 2. The current states of devices such as senders are contained in "status buffers" which are really lists of data in the processor store. In an electromechanical exchange, such data might be contained on relays, strapping fields, busying plugs, etc., these being devices to which the exchange staff have ready access. A connection through an electromechanical exchange can be traced by observing the position of switches; crossbar, rotary or step by step. In a stored program controlled exchange, this information is stored within the processor memory.

Such information may be required by the exchange staff in the course of day to day operation. Not only is access to this data necessary, but it must also be possible to change or overwrite it, e.g., to busy out a device. There are many possibilities associated with communication with control processors, but all can be defined in terms of the accessing of processor memory locations.

Man machine communication, therefore, involves basically the facility of reading out from or writing into the processor memory. This must also be carried out while the processor continues to perform all the other functions necessary to control the exchange. In the IST exchange configuration, there are two processors, each with its own store, to which only it has access. Each memory unit, therefore, is accessible only via its associated processor.

To communicate with the processor memory, the processor itself must first be signalled. The programs required to effect this communication, and then access memory in the required way, must be able to operate in timeslots so as not to interfere with the operation of the other programs. This is achieved by fitting the man-machine programs into the IST program structure, so that effectively they form part of the operational software system.

Since the man-machine programs require a finite amount of time to execute, their operation must reduce to some extent the call handling power of the control processors. This effect is small, however, for two reasons. Firstly, the quantity of data to be transferred to and from the processors is not large, and can therefore be transferred at a slow rate. This means that man-machine programs are called up relatively infrequently. Secondly, most of the processing time involved in man-machine communication is assigned to base level programs which are executed only when there are no more urgent tasks to be carried out. The effect of the man-machine programs on the system operation is therefore minimal.

Communication between man and the processors involves not only the transfer of data, but also its conversion between the machine language form used by the processor, and some form which is readily intelligible to the operating staff. The conversion can be done by stored program, but the complexity and memory space requirements of the program are reduced if the input and output messages have a simple form. The processor can be programmed to recognise practically any input message in any format, but a simple mnemonic coding system has been chosen which requires the transfer of only a few characters for each message.

The operational or on-line situation which the man-machine system is designed to serve is fundamentally different from a system test set-up. In system testing large quantities of data may have to be output, and it may also be necessary to suspend the functioning of the operational programs at any given point in order to investigate the "instantaneous" conditions. A system of simulation (see Ref. 1) has been devised for testing the IST software. This system uses a separate processor to simulate the exchange conditions and outputs test data on a line printer at high speed.

The ASR33 teletypewriter, with the facility of bothway information transfer, is the device used for all man-machine communications. It provides a convenient printed record of all input and output messages. Input messages to the processor can be typed in directly from the typewriter-style keyboard, without any special preparation.

The software system for controlling the IST trial exchange is designed to cope with fault conditions. In the case of failure of the software system of a processor, provision is made for this processor to be reloaded and the program re-started. Where hardware faults can be detected, the system is programmed to put the faulty device

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out of service. The system is designed so that the exchange need not be continuously attended, and none of the man-machine output messages should require immediate action on the part of the exchange staff. Rather, the role of man-machine communication is to record faults, together with any relevant information.

HARDWARE CONFIGURATION.

The processors being used for the IST system are capable of manipulating 16 bits of binary data in parallel, and have a memory cycle time of 1 micro-second. This means that one basic function (e.g. addition) may be performed on a 16 bit "word" every micro-second. The processor memory capacity is 16,384 words.

These processors have the facility for interworking with a variety of different peripheral devices. The devices are communicated with by means of device controllers, or interfaces, which convert signals from the low level high speed logic of the processor, to the types of signal required by the devices, and vice versa. In the case of the ASR33 teletypewriter, the interface must send and receive serial impulses.

The processor communicates with the interfaces, located in the processor main frame, by means of a data highway comprising an input and an output bus. This provides for the transfer of one character at a time, or 8 bits in parallel. A seven bit ASCII code, plus parity bit, is used, which provides a standard alpha-numerical 64 character ASCII set.

The ASR33 teletypewriter provides for transfer of data, in both directions, at a rate of 10 characters per second. It produces a printed record of all input and output messages, when the printing characters of the set are used, and if required a record may also be kept on paper tape. Input messages may be generated by means of a typewriter-style keyboard, or from paper tape via the tape reader on the teletypewriter.

The ASR teletypewriter allows data transfer at the rate of one character every 100 milliseconds, while the IST system is using an interrupt clock interval of 20 milliseconds. To operate the input/output device continuously, therefore, requires the processing of one character of information every five clock periods. Since it is possible to assign most of the processing to base level, thus doing it only when no more urgent jobs are waiting, the man-machine system has a very small effect on the call-handling capacity of the processors.

In the two-processor configuration of the IST system it is possible to arrange for each processor to have its own teletypewriter, or to have one or two ASR's shared by the two processors. This latter method is the one chosen. It allows both processors, or one at a time, to be called from a single machine.

For output purposes, however, this method of connection permits only one processor at a time to use the ASR's. Under software control only one processor at a time may "seize" the ASR's for output. With two ASR's, output messages are sent to both machines simultaneously from one processor, and inputs from either machine may be directed to both processors simultaneously. The hardware configuration is illustrated in Fig. 1. The use of two ASR's enables one to be located remotely, with one in the exchange equipment room. This arrangement is particularly convenient if the exchange is to be left unattended.

The processor controls all information transfer between itself and its ASR interface, but can effect a transfer only when the interface is ready. In order to avoid a waste of processor time in checking for this condition, the ASR is operated in interrupt mode. The interrupt system enables the interface to signal the processor when it is ready for transfer. Under software control, this signal may be acted on immediately, or ignored until a more suitable time. The interrupt system provides a convenient means of economically matching the high speed of the processor with the slower speed of peripheral devices.

When the ASR is being used in output mode (messages from the processor to the ASR), an interrupt signal is sent when the device controller is ready to receive another character from the processor, having transmitted the previous one in serial pulses. In input mode, interrupt occurs when a full character has been received from the ASR and stored in the interface buffer, ready for input by the processor.

ASR interfaces are always in either input or output mode, and the setting of the mode is under the control of the processor. The ASR itself has no change of state associated with change in mode, and the processor must keep a record of the mode status in software. The facility exists, however, for a processor to determine whether or not the other processor of the pair is using the ASR in output mode. By means of a device known as the interprocessor link, the processors may communicate directly with each other. This facility is important

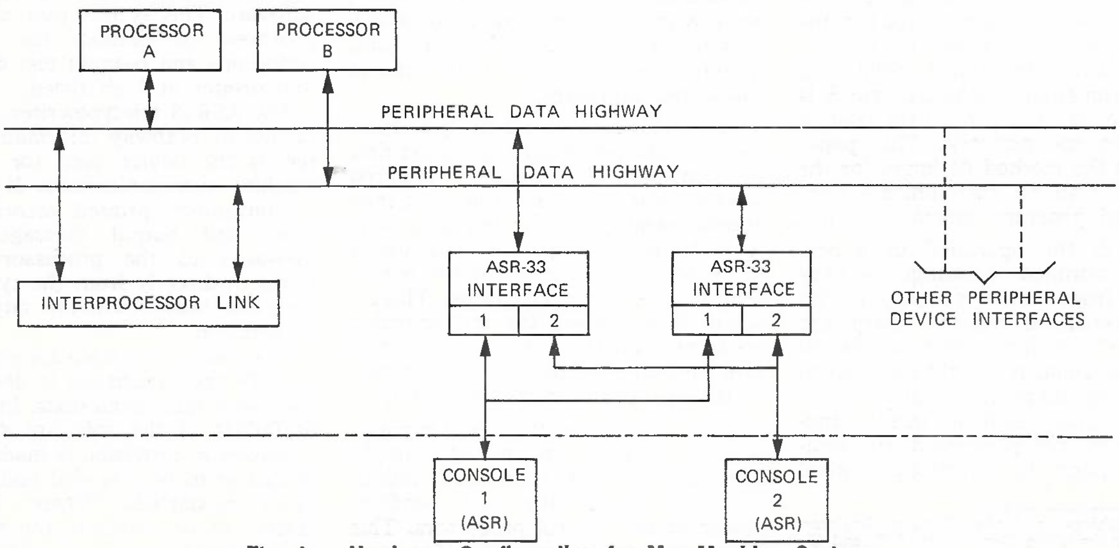

Fig. 1. — Hardware Configuration for Man-Machine System.

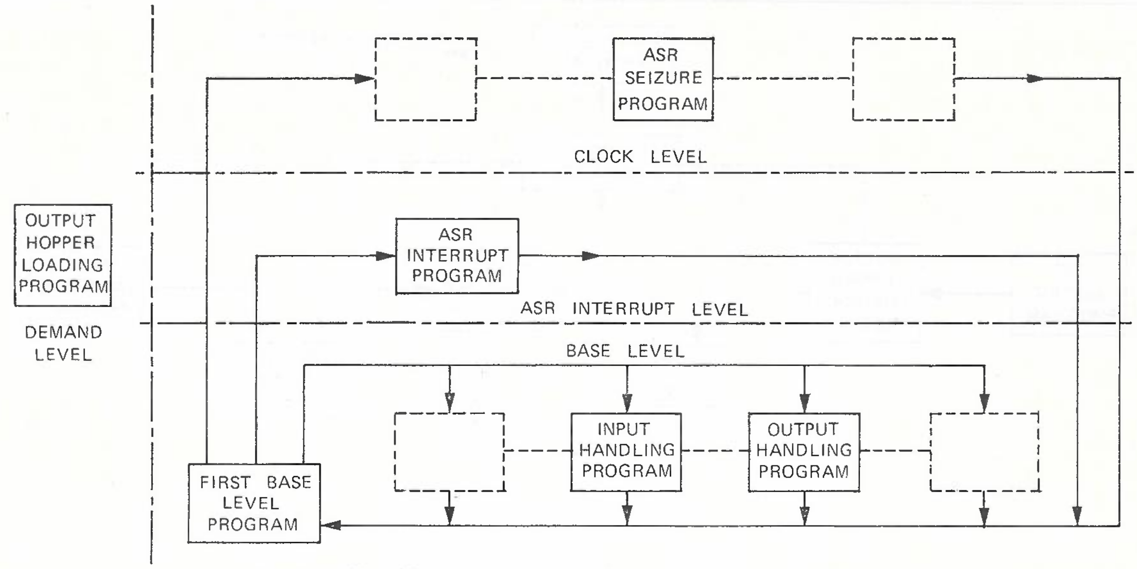

Fig. 2. — Man-Machine Programs in IST Program Framework.

to the man-machine system, although only used by it to a small extent. So that communication may be established with the processors when required, the normal state of the ASR interfaces when the man-machine system is quiescent, is input mode.

SOFTWARE SYSTEM.

The IST software system (see Refs. 1 and 2) is arranged in groups of programs, or "levels", the two chief levels being clock and base level. Clock level is entered every 20 milliseconds, the clock interrupts in the two processors alternating so that only one operates in clock level at a time. Base level programs are executed, under control of the first base level program, when there is work for them to do. Demand level programs are called up by any program, in any level, as required. After completing its task, a demand level program returns control to the calling program.

A simplified version of the IST software configuration, showing the man-machine programs only, can be seen in Fig. 2. The ASR interrupt level, comprising one program only, takes precedence over base level, but has a lower priority than clock level.

Man-machine functions, as with other functions in the IST system, are assigned to a group of programs, each program in the group having certain specific tasks. Each of the two basic man-machine functions, input and output, is executed in stages. These two functions are depicted in Figs. 3 and 4, which show the sequences in which the individual programs are called up. The functions of the separate programs, as now described, can be related to the overall system concept by reference to Figs. 2, 3 and 4.

As previously described, the ASR33 input-output device is operated in interrupt mode. The basis of the man-machine software system is thus the program initiated by interrupt from the ASR, for it is this program which controls the actual transfer of data between the processor and the ASR33 in ASCII characters. However, this ASR *Interrupt Program* may be initiated at a time when urgent work is required to be done by the IST operational programs, and to minimise the delay caused, the execution time of the interrupt program is made as small as possible. This is achieved by assigning only the essential functions, directly associated with the data transfer, to this program. These functions depend on whether input or output mode is set.

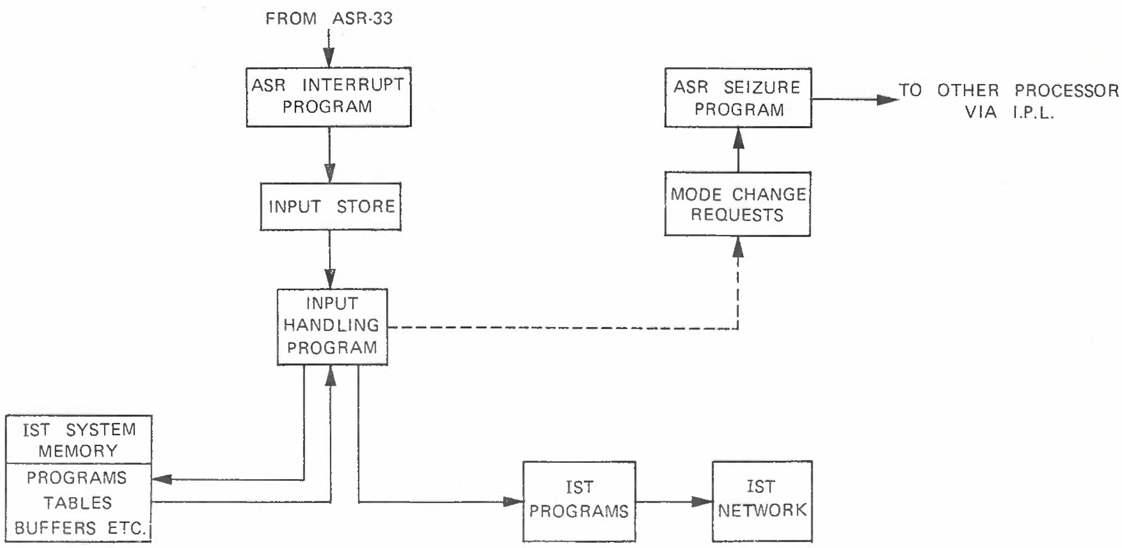

Fig. 3. — Input Sequences — Program Functions and Data Flow.

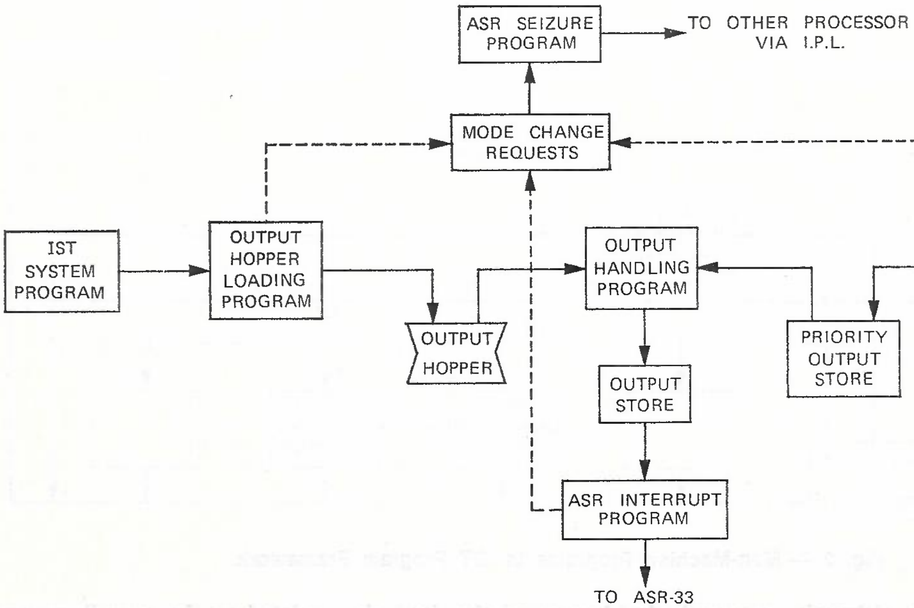

Fig. 4. — Output Sequences — Program Functions and Data Flow.

(a) In input mode a character is input from the ASR and placed in a special store. An indicator is set to show that this input has taken place, so that another program will later be activated to process the input character.

(b) In output mode, a character is taken (already in ASCII form) from an output store, and output to the ASR33. A pointer is incremented so that, on the following interrupt, the next character in sequence will be taken from the store. The program also detects the end of the message, setting an indicator to show this.

The man-machine system of programs is arranged to operate in three distinct modes. Because of the hardware configuration, only one processor can output a message at a time. To accomplish this, a processor "seizes" the ASR33 for output, and is then said to be in *output mode*. On completion of an output message, output mode is cancelled, thus returning to the normal quiescent state of the system.

Although in this *normal mode* of the man-machine system the ASR33 is in input mode, there is nothing to prevent either processor from setting output mode and printing out a message. If it is desired to input a message to one or both processors, the input sequence is protected from interruption by either processor for output. This is done while *input active mode* is set in one or both processors. It occurs in both when a special "call sign" sequence is keyed in at the ASR. The call sign consists of two carriage return characters followed by a line feed. In the normal or neutral state, this call sign is the only input sequence that the processors will respond to. It has the advantage of positioning the ASR carriage to the left, at the same time providing a blank line between each message on the printed record.

While input active mode is set in either processor, normal output messages are inhibited in both processors. There are, however, certain outputs, associated with input functions, which occur during input sequences. Such outputs are permitted while a processor remains input active, and are termed priority outputs. This implies the setting of output mode in a processor which is input active at the time, a condition possible because input active is a software state, and involves no physical change to the hardware. While input active mode is set, therefore the ASR33 may be used for either input or output purposes.

Each processor keeps a software record, not only of its own status (output mode, normal mode or input active mode), but also of the status of the other processor. Output mode in the other processor can be detected by program but changes in its input active status are immediately communicated via the interprocessor link. In order to avoid confusing situations, where both processors try to change mode at one time and neither is certain of the instantaneous status of the other, all mode changing is controlled by one program which is assigned to clock level. Since only one processor can be in clock level at a time, this method avoids such difficulties.

The man-machine system therefore includes one clock level program, the *ASR Seizure Program*. This program carries out all mode changing in response to requests from other man-machine programs. These requests are made by setting certain bits ("flags") to the "1" condition in a special indicator word. If a flag is set, the ASR Seizure Program changes mode accordingly, after first consulting a set of indicators to determine whether the request can be carried out in the current circumstances.

The *Input Handling Program* is entered after each input character has been accepted by the ASR Interrupt Program. It processes each character as it is received, checks for valid format, and when required, initiates output messages to conform with specified input sequences. On completion of input requests this program also carries out the functions specified.

This program has a large number of different branches, signifying program phases. As an input message progresses, the input phase is updated, so that the appropriate part of the program is immediately called up after receipt of each character.

Processing of each character as it is received achieves two purposes:

(a) By distributing the processing of an input message over a large number of entries to the program, it avoids an excessively long execution time for any one entry. A large number of short operations, widely spaced, have less effect on the functioning of the IST system than would one entry with a very long execution time.

(b) By processing each character as it comes, any variation from the prescribed input sequence or format is detected much sooner than otherwise, and should the operator wish to cancel the input function, he can do so at any time in the input sequence. The Input Handling Program is the most complex of the man-machine programs, occupying about 1000 memory locations, or more than half of the total man-machine memory requirement.

The *Output Handling Program* prepares all output messages in ASCII character form, and places them in the output store so that they are suitable for treatment by the ASR Interrupt Program. The messages are extracted from the Output Hopper or from the Priority Output Store. Each hopper or store entry contains the complete specification of the message it defines, including the format type. The Output Store is large enough to contain messages of up to 72 characters, or one full line of print on the ASR33. Longer messages are treated in parts, the output store being filled as many times as required. The Output Handling Program is entered once for each part of such a message.

The man-machine system being relatively slow in operation compared with the IST operational system, output messages may well be requested while the man-machine system is in use, either for input or output purposes. Such messages are stored in the Output Hopper until such time as they can be processed by the Output Handling Program. The Output Hopper is a special hopper capable of storing messages of varying lengths. As with other hoppers, it operates on a first-in first-out basis. It is loaded by means of a special demand level program, the *Output Hopper Loading Program*, and is unloaded by the Output Handling Program.

Timeouts.

Whenever the man-machine system is in any state other than the normal input (inactive) mode, a timeout is activated to ensure that the system cannot be locked out. If, for example, an operator completes a series of input functions, and leaves the input active mode set, output messages will be inhibited while this condition exists. In this case a timeout will expire after ten seconds, and the input active mode will be dismissed.

The 10-second timeout is always operative in input active mode, so that any pause longer than ten seconds results in a return to normal mode. A 20-second timeout is activated when an output message has been transferred to the output store by the Output Handling Program. If a message requires more than one loading of the output store, this timeout is restarted each time. If it expires before completion of output, a fault condition is indicated.

A further timeout is started when an output is requested by placing an entry in the Output Hopper. This is a 60-second timeout, but it may expire through no fault condition if there is a valid lengthy input function being carried out. The three timeouts serve as a check on the normal functioning of the man-machine system.

SECURITY AND INPUT PROCEDURE.

With a continuously operating real time control system, it is important to ensure, as far as is possible, that operation will continue uninterrupted, without being inadvertently upset in any way by interference from man.

The processor control panels are normally locked, by means of a key, so that their push-buttons are rendered inoperative. The only means of access to the processors is therefore via the teletypewriters of the man-machine system, and the operation of this is designed to provide as much security as possible.

In the processor memories there are three main types of data, permanent, semi-permanent and temporary. Permanent data is made up of programs; IST operational programs and man-machine programs. Semi-permanent data consists of exchange parameters, device status information, route tables, etc., and temporary data comprises hoppers, dialling buffers, etc., which vary from call to call, and are used by the processors to record temporary conditions.

It is with changes in the semi-permanent data that the man-machine communication system is primarily concerned. Any change in the permanent data may affect the functioning of the whole system, possibly drastically, while changes in temporary data are likely to disrupt the processing of particular calls. Most of the temporary data changes too fast, in any case, for meaningful alterations to be made by man.

Most of the normal functions associated with exchange operation and maintenance are effected, via the man-machine system, by the use of symbols. For convenience, these symbols are usually in a simple mnemonic form. When functions are carried out in this way, the man-machine system protects other data by accepting only those inputs referring to memory in the range containing semi-permanent data. Each mnemonic symbol refers to a list of data having fixed limits. The man-machine system always checks that the location accessed is within the limits associated with the specified symbol.

Each type of input message must conform accurately to a prescribed format. Any deviation from this format is detected by the man-machine system, and the message rejected. Apart from effectively prohibiting the use of the system to anyone not fully familiar with it, this virtually eliminates the possibility of a change being made by accident.

As a further security measure for any function which will change data in the memory, a procedure is adopted which is designed to encourage maximum checking of the input request by the operator. It also insures against possible errors in transmission between the ASR33 and the processor. After first typing in and checking the input message, a special "proceed" character (*) is keyed. The processor then responds by repeating the complete input, which should again be checked by the operator. A second "proceed" character is then keyed, to initiate the execution of the function requested.

WA — Write in absolute memory location

RA — Read from absolute memory location

WM — Write in location specified by mnemonic symbol

RM — Read from location specified by mnemonic symbol

H — Maintenance busy

U — Unbusy

L — Load program into memory

E — Execute program

T — Transfer to or from system spare

Fig. 5. — Summary of Input Function Types.

INPUT FORMATS.

In the normal, or neutral mode, any input combination other than the call sign (CR CR LF) is ignored by both processors. This gives the opportunity, if desired, of typing any message or heading for the man-machine printed record. When the call sign is sent, input mode is set in both processors.

The processor to which the input is being directed is then specified by one of the characters A, B or C followed by a space. Although the sets of programs stored in the memory of each processor are identical, the program is able to determine which processor it is in, A or B, by means of a special instruction. The character C is used to specify both processors simultaneously.

Next in sequence, the type of function is specified, followed again by a space. The functions available are shown in Fig. 5.

In the case of WA and RA, the absolute memory address is then specified in octal form, between the limits 0 and 37777, which are the limits of the processor memory. For a read function, a "proceed" character (*) is then keyed to initiate the printout of the information, while for write function another space character is keyed, followed by the data to be written in. This input data may be specified in one of two ways:—

(a) Octal form: This is indicated by beginning with an apostrophe. Up to six octal digits follow, having a maximum value of '177777, the full capacity of a 16 bit word.

(b) Binary form: In this form, each of the sixteen bits must be specified by 1, 0 or X, where X indicates that the state of the bit is not to be altered from its current value.

In either case, the sequence is terminated by a proceed character, whereupon the input message is reprinted by the processor. A further proceed character then causes the function to be executed.

Where the specification of the memory location is by mnemonic symbol (WM and RM), this is done in two parts, separated by a space, e.g. KM 14. The first part specifies the list, in this case, the list of MFC Receiver Status Buffers, and the second part the number of the list item, in octal form. After the specification of the list and item number, the WM and RM functions then proceed according to the same formats as the WA and RA functions respectively. Fig. 6 shows examples of the full input formats for the functions WA WM RA and RM.

Lists specified by mnemonics are composed of elements, each of which is not necessarily a complete 16 bit word. Elements may consist of "slices" of 2, 4 or 8 bits or else they may refer to more than one memory word. Writing into a slice-length list element must be done using binary format, and specifying the requisite number of bits in each case. There are two cases, DB (Dialling Buffer) and SB (Supervision Buffer) where more than one memory word is referred to. These symbols may be used for reading only. Writing into these buffers can only be done one word at a time, using the symbols DB00 to DB15 or SB00 to SB03, followed by the buffer identity.

Maintenance busying (H) and unbusying (U) functions are valid only for certain specified mnemonics. The H or U character is followed by a space, after which the mnemonic symbols and list element number follow. These completely specify the function and a proceed character then causes the printing out of the input for checking. A further proceed character initiates execution of the function. Fig. 7 illustrates the formats for maintenance busying and unbusying.

```
C H DPS 14*   ————————   Input request
C H DPS 14    ————————   Response by Processor A
C H DPS 14*   A MB B MB
\_________/   \_______/
Response by   Indications from both processors
Processor B   that device is now blocked

C H DPR 8*
C H DPR 8
C H DPR 8*    A BY B BY
              \_______/
              BY instead of MB
C U KS 4*     indicates device still in use
C U KS 4
C U KS 4*
```

Fig. 7. — Formats for Maintenance Busying and Unbusying Functions.

All the functions W R H and U have the facility that sequential memory locations, or list items, may be accessed successively without having to respecify the function each time. After the completion of a function on one location, the same function is initiated for the next location in sequence by keying a carriage return. The processor then automatically prints out the required format, just as if it had been keyed by the operator. In the case of a write function, the new information to be written must still be keyed in. Fig. 8 shows examples of this feature.

Certain mnemonics require the list element number to be specified in a special way, i.e. by reference to a particular channel. Channels are specified by four digits: GSWP, where G S and P are octal digits (0 to 7) and W is a digit from 0 to 2. GS specifies the group and system, and WP the channel within the system.

The load function is specified by the symbol L, followed by a proceed cha-

```
A WA 7014 '104771*
A WA 7014 '104771*

B WM COL 1306 XXXXXXXXXXX00011*
B WM COL 1306 XXXXXXXXXXX00011*

C RA 21764* A 007260 B 007260

A RM COL 0224* A 040102
```

Fig. 6. — Formats for WA WM RA RM Input Functions.

```
A RM DPR 10* A 110012  } Read functions in sequence,
A RM DPR 11* A 001000  } after printing out of the third
A RM DPR 12            } sequential location by the processor

B WA 20700 '64*        }
B WA 20700 '64*        } Write functions, after the third
B WA 20701 '209*       } sequential location has been
B WA 20701 '209*       } printed out by the processor
B WA 20702             }
```

Fig. 8. — Sequencing of Similar Functions.

```
A L* A LD ◄—        ———— Load request and response
A E 24*             ———— Execute request for program 24
A DISMISS INPUT

A 006 14 22 40      ———— Processor identity and time of day
TEST 6              ———— Message heading
146602 029613       ———— Program output data
```

Fig. 9. — Load and Execute Sequence.

racter. The processor prints out a message when loading is complete.

The execute function is specified by the letter E, followed by a space, and the program identity in the form of an octal number. A proceed character then causes the message to be reprinted, and execution follows a further proceed character. Fig. 9 shows a load and execute sequence as described later.

The transfer function is specified by either TS, transfer to spare, or TN, transfer to normal, as described later. A space, followed by a GSWP specification of the channel completes the function request. Again, a proceed character initiates reprinting of the input message, and another proceed character causes the function to be executed.

At any time during the input sequence the operator may cancel the current function by keying a special character which is always recognised when input active mode is set. The message CANCEL INPUT is printed out, and the man-machine system is returned to the same stage as if the input active mode had just been set. The same sequence occurs when an input message does not conform to the required format, or other conditions. Another chaıacter which is always recognised is the dismiss character, which causes the dismissal of input active mode, at the same time printing out the message DISMISS INPUT.

INPUT FUNCTIONS.

Although basically the man-machine system provides the facility for accessing any memory location of either processor for the purpose of reading out data, or changing the contents of the location, most normal functions are concerned with accessing certain tables and buffers. As described in the papers of Refs. 1 and 2, the current status of the IST exchange is stored in the processor memory in buffers, tables, etc., and for accessing the more important of these, the man-machine system uses special mnemonic codes.

If desired, the absolute address of a memory location may be specified, and this method must be used if a symbol is not available for the location to be accessed. The functions which can be executed without specifying absolute memory locations are: reading data from lists or buffers, writing new data into lists or buffers, maintenance blocking and unblocking of certain devices, loading of off-line, on-demand programs into memory, enabling the execution of a program, and transfer of a PCM system to or from system spares.

Reading Out Data.

To illustrate the use of this feature, consider the problem of determining the current status of a certain channel, and to which other channel, if any, it is connected.

The current information relative to each channel is contained in two words, the class of line word (Fig. 10), and the line condition word (Fig. 11). By accessing the class of line word, the line status can be determined from the ownership bits $0_1 0_2$. These indicate either that the line is free or else the identity of the processor which has set up the call involving the channel. If busy, the line condition word can then be accessed, to obtain the identity of the relevant supervision buffer (assuming that a connection exists). This supervision buffer contains all the information relevant to the call.

The complete supervision buffer (4 words) can be accessed by means of the symbol SB, or, if only part of the information is required, any of the four words may be read out separately, using one of the symbols SB00 . . . SB03. This data gives the identity of the channel to which the originally specified channel is connected.

$O_1 O_2$	$C_6 C_7$	M	△△△△	$B_1 B_2$	$C_1 C_2 C_3 C_4 C_5$

$O_1 O_2$	=	00	Free, unallocated
		01	Busy, own processor
		10	Busy, other processor
C_1	=	0	Normal line
		1	Special line
C_2	=	0	In service
		1	Faulty
C_3	=	0	Equipped
		1	Non-equipped
C_4	=	0	Incoming
		1	Outgoing
C_5	=	0	Line to SxS exchange
		1	Line to crossbar exchange
C_6	=	0	Line normal
		1	Line blocked
C_7	=	0	One-way circuit
		1	Bothway circuit
$B_1 B_2$	=	0	Call state information
M	=	0	Normal
		1	Maintenance block
△			Spare

Fig. 10. — Class of Line Word.

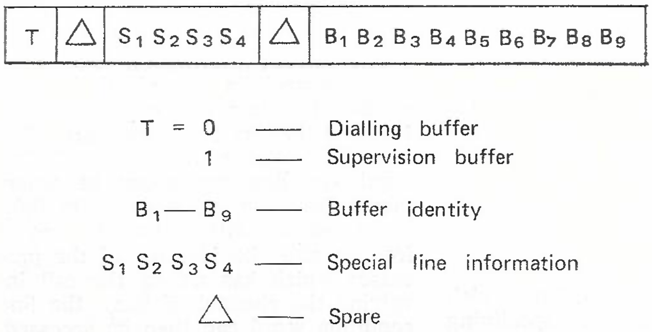

Fig. 11. — Line Condition Word.

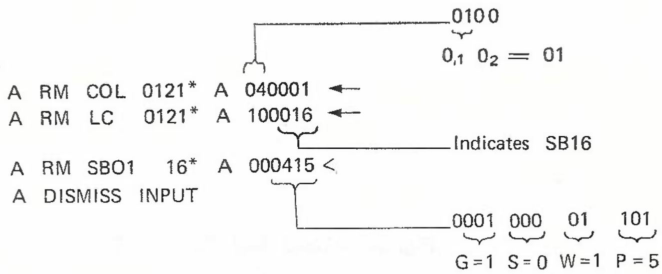

Fig. 12. — Tracing a Connection.

The complete record of the operation, as printed out by the ASR33, is given in Fig. 12. Although the output data is given in octal form, where often particular bits only may be of interest, this is not a handicap in interpreting the information. With a little practice, conversion from octal to binary is not difficult, and for a 16 bit word, octal format is less confusing than binary.

It should be noted that all the above information could have been obtained by accessing the absolute addresses of the memory. These addresses, however, would have had to be calculated first, by reference to the program listings of the IST system, involving considerably more time. Further, errors in calculation could be made. It is intended that all frequent functions be carried out by means of symbols.

Writing In Data.

This is defined as changing the contents of a memory location. In general, the type of data changed in this way would be semi-permanent data, such as status records, parameters, etc. Fig. 13 shows the printed record of the introduction of an equipped normal in-service outgoing crossbar channel by overwriting the class of line word. The maintenance blocking bit is set so that the channel will not yet carry traffic (see Fig. 10).

A WM COL 1327 '4003*
A WM COL 1327 '4003*

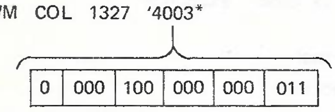

Fig. 13. — Introduction of a New Channel. (For bit designations, see Fig. 10.)

Maintenance Blocking and Unblocking.

Maintenance blocking is the putting out of service of a hardware device for the purpose of maintenance (normally replacement), or for other reasons. The device may or may not be in use at the time, but if it is in use, the maintenance blocking requirement is that the current call using it be completed normally. On release of this call, the processor is required to treat the device as blocked. In an electromechanical exchange a busying plug might be used for the same purpose.

In the IST system a special bit is provided in the status buffer associated with the device. The setting of this bit places the device in the maintenance busy condition. On carrying out a maintenance busying function, the man-machine system also prints out a message indicating whether or not the device is currently in use. If it is, the operator must first wait until it is released before unplugging any hardware. In some cases the device may be held up during the entire duration of a conversation, and the simplest way to check its release is to repeat the maintenance blocking request, when the status will be printed out. Alternatively, the contents of the status buffer may be read out, and the appropriate bits examined.

Such devices as senders, receivers, channels and junctor locations may be blocked in this way. In the case of junctor locations, hardware units may be associated with groups of 2 or 16 locations. Before removing a hardware unit it is necessary to block all the associated locations, and the facility has been provided for doing this with one command from the ASR33.

Another special case is that of incoming channels. When these are busied in the processor records, a blocking signal must also be returned on the channel to prevent seizure from the remote end. When busying a channel, the man-machine system also initiates this function.

The printed record of the maintenance busying of a Dial Pulse Sender is shown in Fig. 7.

Loading and Executing Programs.

A program loaded and executed would normally be some kind of special test program, and would require to output the results of the test. An immediate output message would therefore be expected following an execute function. Fig. 9 shows the record of a typical sequence of load, execute and output message.

After placing the object tape of the desired program in the ASR33 reader, the loading function is specified from the keyboard. The ASR reader is then started by the processor, the tape read in and the reader stopped. A short output message then indicates completion of loading.

The program which has been loaded into the memory may then be executed using the man-machine execute function. Each program is specified by means of an octal number. When the execution of a program is requested, the man-machine system sets the corresponding "activity bit", so that the program will be entered in the course of base level operation. All base level programs have associated activity bits, each program being entered only if its corresponding bit is set.

Transfer to system spares.

The hardware provides spare sets of equipment for PCM systems for both the incoming and the outgoing bit streams. On the incoming side the spare is for the equipment which receives the incoming bits and transfers them to the group speech memory store. The outgoing spare constructs the outgoing bit stream. Any system may be transferred to or from the outgoing and incoming spares. The printed record of the transfer of a system to a spare is shown in Fig. 14.

A TS 10*
A TS 10*

Fig. 14. — Transfer of a System to the System Spare.

OUTPUT FUNCTIONS.

The man-machine system provides for the output of messages, which may be initiated by any of the IST system programs. Basically, an output message consists of a number of memory words of information expressed in one of four different formats. To identify the message type, a heading of six characters precedes the information.

The processor identity and the time of day of the print-out are also given with each message.

The output format is designed to be sufficiently flexible for the presentation of any type of data required to be printed. Each heading will be associated not only with a message type, but with a unique data format. In order to fully interpret a message, a reference table will be required, explaining the details of the format. It is intended that output messages supply information on faults, congestion, statistics, etc., although few of the details of such messages have been specified at the time of writing (May, 1971). The output system, however, provides for the introduction of new message types at any stage.

In the general message format, the time of day and processor identification always appear in the same format on the first line of the message. The heading appears on the second line, and the message information starts on the third line. The contents of the information words are printed out across the line, with a double space between each word.

The data formats available for output are binary, octal, decimal and text. In each case, the sixteen bit memory word is converted by the output system into the specified format and successive words are printed out across the page. The maximum number of words per line depends on the format chosen. In binary format each word requires 16 characters, each 0 or 1, and four words can be printed out per line. In octal and decimal formats, six characters per word are printed. In each of these cases a numerical value is given, but when decimal is used, the number range is from —32768 to +32767, with the sign of the number depending on the first binary bit of the word. This corresponds to the number that the content of the word would represent if operated on by the arithmetic logic of the processor.

Text format implies that the message has already been converted to ASCII characters, and stored, two per word, from left to right. The limit for the length of a message is 64 words of data. If the message is too long for one line, it is continued on the next. However, it is anticipated that most messages will consist of only one or two data words, with the possible exception of statistical data outputs. Fig. 15 shows a typical output message. The heading ERR1 indicates that the message is reporting an error, class 1 (error information in 1 word). A reference chart would show that, for this message type, the last five bits of the word form a code indicating the source of the error. Each error source represents a different type of error, with its own unique word format for the output of relevant data.

Such word formats would be listed in the message reference information for the exchange, enabling the full interpretation of the message. The word format illustrated in Fig. 15 provides for the specification of the channel with which the fault was associated.

Outputs from the processors during input sequences are also output messages, using the same output system as ordinary output messages, except that they always have priority. The messages almost invariably use the text format, and usually do not print the processor identity or start the information words on a new line. They are not accompanied by a time of day output. These messages are tailored to suit the input format rather than conform to a standard output procedure.

PRACTICAL APPLICATION OF THE MAN-MACHINE SYSTEM.

The trend towards difficulty of observation and decreasing accessibility of telephone exchange equipment leads to a requirement for new maintenance techniques. In the IST system, for example, there is no physical point in the exchange where a Buttinski may be plugged in, either for speaking or listening.

In general, the procedure for clearing a fault will be to replace the smallest pluggable module with a spare. However, this can only be done when the faulty equipment has been located, and much of the fault locating work must be given to the processors, the only devices capable of monitoring the exchange.

The technique for fault finding will, in many cases, be to initiate tests by means of communication with the processors. Even from these tests, however, the processors will sometimes be unable to directly indicate the location of the faulty equipment, and some deductive work will be left for the maintenance staff. The man-machine communication system will provide the means for carrying out such tests as mentioned above. Its greatest flexibility lies in its ability to load any test program into the processors, and command its execution.

The full range of functions necessary for an efficient man-machine communication system in an operational exchange are not easy to predict accurately. It is hoped, however, that the system designed will prove sufficiently flexible to meet all the requirements that arise during the course of the field trial period.

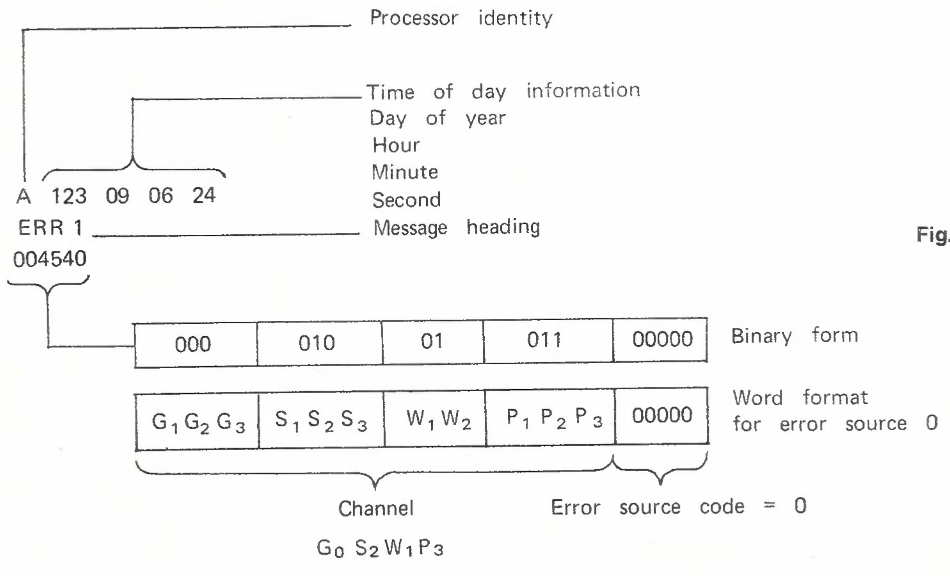

Fig. 15. — Typical Output Message.

New mnemonic symbols for accessing special parts of memory may be added simply by extending tables, and a large variety of output message types is provided for, with up to 64 different output headings. However, it may be found desirable to introduce new functions, necessitating additions to one or more of the man-machine programs.

Experience will, no doubt, also show that some of the functions provided are little used, or unnecessary, but the aim, at this stage, is to provide a functional system, capable of being modified, not necessarily a fully optimised one. This conforms with the general purpose of the IST field trial.

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APPENDIX 1.

GLOSSARY OF TERMS

Processor	— a computer-like device, specially programmed to control a system such as a telephone exchange; also central or control processor.
Hardware	— physical equipment.
Software	— programs stored in a processor memory.
Memory	— that part of the processor used for storing data, including programs.
Main frame	— the equipment which constitutes the control logic of a processor.
Interrupt clock	— a device which signals a processor at regular intervals, e.g. 20 milliseconds.
Loading a program	— transferring a program into the memory of a processor.
Bit	— a unit of information which can have two conditions, 0 or 1.
Word	— a sequence of bits, e.g. 16 bits. The "word length" of a processor is defined as the number of bits the processor can operate on as a unit. The memory is arranged so that the processor can access one word at a time.
Slice	— a sequence of bits, shorter than a word.
Binary	— a numbering scheme using two digits only, 0 and 1.
Octal	— a numbering scheme using eight digits, 0 to 7. This is convenient for use with processors, because conversion between binary and octal is much easier than between binary and decimal.
Stored program control	— a system of control in which all decisions are made by software.
Hopper	— a software device used to store messages, usually requests, on a first-in first-out basis.
Buffer	— a software device used to store current data, often the status of some physical device.
Exchange parameters	— data which defines the current status of an exchange, e.g. the number of MFC senders equipped.
Mnemonic	— literally a memory aid: here used to describe a symbol that is deliberately chosen as easy to remember.

USE OF AN ARM 20 EXCHANGE FOR INTERNATIONAL TELEPHONE SWITCHING

*J. D. HAMPTON, B.E.**

INTRODUCTION.

Prior to the introduction of the Trans-Pacific COMPAC cable to New Zealand in 1962, all international telephone services from Australia had been operated as manual services over High Frequency (H.F.) radio circuits. With the commissioning of the COMPAC cable to New Zealand, a semi-automatic 2VF service was introduced without any Gateway Exchange in New Zealand or Sydney, whereby the operators obtained direct access to the international circuits in Sydney and Auckland and dialled direct into the national network of the distant country. When the COMPAC cable was completed to Vancouver in December, 1963, it was connected to a Trans-Canada microwave system which in turn had connections to the CANTAT cable across the Atlantic and thus, Australia had, for the first time, high quality circuits to many of the important centres of the world. At the time that the COMPAC cable network was commissioned beyond New Zealand, The Overseas Telecommunications Commission (Australia) (O.T.C.(A)) commissioned, at the Overseas Telecommunications Terminal at Paddington, Sydney, their first International Gateway Exchange which was an ATE 5005 four-wire transit switching exchange using C.C.I.T.T. No. 5 type signalling on the international side. At the time of commissioning this Gateway Exchange, it interworked directly with exchanges in Oakland in U.S.A.; Montreal and Vancouver in Canada; and London in U.K. The initial installed capacity of this exchange was 50 international bothway circuits and 50 one way out of Australia junction interconnections with the A.P.O. and 50 one way into Australia junction interconnections with the A.P.O. Since that time, in December 1963, the total traffic handled by the exchange has grown at an average rate of 37% per year.

To cope with this growth in traffic the ATE 5005 exchange was expanded to 120 international circuits and a total of 130 interconnections with the A.P.O. in 1967 when the SEACOM cable was commissioned. In December, 1969 the ATE 5005 exchange was replaced by an ARM 20 exchange manufactured by L. M. Ericsson with a further increase of capacity to 300 international circuits and 210 interconnections with the A.P.O. The ARM 20 has since been expanded to its present capacity of 620 international circuits and 540 interconnections with the A.P.O. and a final expansion of this exchange to 750 international circuits and 690 interconnections with the A.P.O. is presently planned for completion by early 1973. This should provide sufficient capacity for future growth of the international service until the end of 1973.

Meanwhile for diversity reasons as well as other factors including the need for a new type of signalling system and the need for further expansion, a new computer controlled exchange is presently on order for installation at O.T.C.(A)'s Second International Terminal in Sydney to be located at Broadway.

Fig. 1 shows a block schematic of the major units in the ARM 20 Exchange installed at Paddington. It illustrates the method of interconnection of several of the specialised features which will be discussed later in this paper.

FUNCTIONAL ROLE OF THE INTERNATIONAL EXCHANGE.

The international Gateway Exchange switches all outgoing semi-automatic traffic from Australia to overseas countries. This traffic originates at five major National Operating Centres within the A.P.O. network located at Sydney, Melbourne, Brisbane, Adelaide and Perth. It handles all incoming semi-automatic traffic to Australia direct to subscribers via the Australian national network or alternatively, where operator assistance is required, it routes the call to a pool of assistance operators in the appropriate state. It handles a wide range of international transit traffic and is a major switching centre for the Pacific region. Finally, it switches calls that are received on a semi-automatic basis incoming to Australia, which are destined for other countries which can only be obtained via manual H.F. radio circuits, to the appropriate operator in the Sydney G.P.O.

The international traffic which this Exchange handles is now carried over circuits in the COMPAC submarine cable, the SEACOM submarine cable, the Pacific Ocean Satellite via the Moree Earth Station, and the Indian Ocean Satellite via the Ceduna Earth Station.

Signalling.

The Exchange is capable of receiving information from a number of different sources utilising different signalling systems and is also capable of forwarding signalling information of varying types.

Incoming Signals: The type of signalling systems that must be dealt with incoming to the exchange are as follows:—

Multi Frequency Code (MFC): This is the multi frequency code system used throughout the S.T.D. network in the Australian Post Office and this signalling format is received on those calls which reach the Gateway Exchange via the Australian S.T.D. network.

Loop Disconnect Signalling: The signalling format that was previously used throughout the Australian national network was a 2VF signalling system which is being progressively replaced within that network by the MFC signalling system. This 2VF signalling is converted to Loop Disconnect signalling over the Cailho circuit of the junctions between the Gateway Exchange and the operator controlled network in the A.P.O. In the case of calls originating in Sydney, no 2VF signalling is involved, as the Loop Disconnect signalling originates at the Sydney switchboard.

Modified MFC: This form of signalling is basically very similar to the MFC signalling system employed within the A.P.O. network with specific modifications to permit interworking between the Gateway Exchange and an Exchange at Lae in Papua-New Guinea. It is thus received on all semi-automatic circuits between Australia and Papua-New Guinea.

C.C.I.T.T. No. 5 Type Signalling: This is the signalling system which is defined in Recommendations Q140 to Q157 of Volume VI of the C.C.I.T.T. White Book that is used on all semi-automatic international circuits connected to Australia, with the exception of those circuits between Australia and Papua-New Guinea.

Outgoing Signals: The types of signalling that must be used outgoing from the Gateway Exchange are as follows:—

Multi Frequency Code: This is identical to the MFC signalling system used within the A.P.O. network and is utilised on almost all calls which are dialled direct to a subscriber.

Loop Disconnect Signalling System: The signalling system previously used within the A.P.O. network was a 2VF

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signalling system which is being progressively replaced by the MFC signalling system. This 2VF operator controlled network is accessed by a Loop Disconnect signalling system on the Caihlo of the junction circuits between the Gateway Exchange and the A.P.O. operator controlled network. The Loop Disconnect to 2VF conversion takes place at the A.P.O. Dalley Street Exchange except in the case of calls to Sydney operators where no conversion is required. This signalling system is utilised on calls to Australian assistance operators and a very small percentage of calls dialled direct to subscribers.

Modified MFC: This is a signalling system very similar to the MFC system employed within Australia and is used for traffic destined for Papua-New Guinea.

C.C.I.T.T. No. 5 Signalling System: This signalling system is used outwards from Australia on all semi-automatic international calls except those destined for Papua-New-Guinea.

Not all of the above signalling systems contain signals that have direct equivalents in the others and, as the Gateway Exchange must cope with all possible combinations of the above incoming and outgoing systems, it has been necessary to devise a number of artificial means of forwarding the appropriate information in one system, that has been received from another system, by the employment of various translation facilities.

Numbering.

Before turning to an examination of the specific translations that have been necessary to make the signalling systems compatible, it is first necessary to consider some general aspects of numbering plans and routing procedures to establish the background in which the translations must take place.

On the international side there exists a unified World Numbering Scheme which comprises a country code with a maximum of 3 digits, followed by a language digit which permits access to an operator speaking the required language in the event of difficulties being encountered with a call, followed by provision for a national number containing a maximum of 10 digits. This national number does not include a trunk access digit which is sometimes included at the front of the national number, as, by international agreement, such trunk access digits are not sent on international circuits. Thus the maximum size of the international number is 14 digits. The Australian Gateway Exchange has a capacity to store 16 digits as there were some uncertainties still existing in the World Numbering Scheme at the time the original equipment was ordered.

It is normally only necessary for the exchange to examine the country code digits to route a call, however, there are some exceptions to this as follows:—

(a) On the North American continent, Canada, U.S.A. and some other countries have a unified continental numbering scheme and only one country code has been allocated to this continent. Thus, as different routings are used for traffic to Canada than traffic routed to U.S.A., it is necessary to examine the area codes within the North American continental numbering system to determine the country of destination and thus the routing of the call.

(b) In some countries, notably Canada and U.S.A., there are two Gateway Exchanges and calls to a certain part of such countries are accessed via one Gateway Exchange and calls to another part of such countries are accessed by the second Gateway Exchange. For these reasons it is again necessary to examine area codes to determine the appropriate routing.

(c) In the case of calls to U.K. some special circuits have been established which carry traffic to the London area only. For this reason again, in the case of calls to U.K., it is necessary to examine the area codes to determine whether the call is for the London area or some other part of the U.K. and thus to determine the appropriate routing for such calls.

(d) In the case of calls to the Caribbean area, which are also part of the unified North American continental numbering scheme, the routing of calls to British Commonwealth countries or territories is sometimes different to the routing employed to non-British countries or territories. In this case, however, instances exist of small islands which have the same area code in the North American continental numbering scheme which are subdivided such that one part of the island is a British Commonwealth country or territory and the other part of the island is a non-British country or territory. In these circumstances it is necessary to examine beyond the area code within the North American continental numbering scheme and examine some of the digits of the subscriber's number before the appropriate routing out of Australia can be determined.

To cope with the exceptions mentioned in (a), (b) and (c) above it is only necessary to examine the area code of the country to determine the appropriate routing and this can be accommodated in all cases by analysis of the first 5 digits which is the capacity for analysis that exists in the Route Marker of the Gateway Exchange. In case (d) above it is necessary to examine up to the first 8 digits of the international number before the appropriate routing can take place. To do this, an examination of the first 8 digits always takes place in the Register and, where the special combinations applicable to the Caribbean area are detected, the Register provides a special mark to the Route Marker.

On the national side of the Gateway Exchange there are 2 numbering schemes. There is the operator controlled numbering scheme and the S.T.D. numbering scheme. The operator controlled numbering scheme grew from the rapid development of the Australian national telephone network earlier in this century when the growth tended to take place in closed areas. The trunk network that was set up to interconnect these areas did not have a unified numbering scheme, which is to say that the number dialled by an operator in area A to obtain a trunk to area B may not have been the same number dialled by an operator in area C to obtain a trunk to area B. The Australian Post Office is converting their network to a Subscriber Trunk Dialled (S.T.D.) network progressively replacing the access codes used in the operator controlled network with a unified numbering scheme; however, this process is not yet complete. At the time of ordering the first International Gateway Exchange, a decision was taken jointly by the A.P.O. and O.T.C.(A), that the dialling information that would be forwarded to overseas operators for access into the Australian network should reflect the final unified numbering scheme to be applied in the S.T.D. network and that the Gateway Exchange would perform appropriate translations to the numbering scheme applicable in the operator controlled network. These translations would be gradually phased out as the S.T.D. network expanded. Thus the progressive implementation of the unified numbering scheme was able to take place without constant up-dating of information to operators located in a large number of countries overseas.

To perform this translation the exchange is capable of examining 3 digits of received area code and it is capable of translating this received area code into any number containing up to 6 digits.

In the case of calls to the S.T.D. network with its unified numbering scheme an examination of the area code is also necessary as some direct circuits to places with large volumes of traffic have been established from the Gateway Exchange and thus it is necessary to examine the area code not only to determine whether the call is to the operator controlled network or to the S.T.D. network, but also to determine the group of circuits within the S.T.D. network that the call should be connected to.

Routing.

Semi-automatic access is available through the Australian Gateway Exchange to 39 overseas countries and these 39 countries are accessed over 19 direct routes out of Australia. The present destination of these direct routes is as shown in Fig. 2. Many of these direct routes comprise both satellite and cable circuits and some comprise cable circuits that are carried over Time Assigned Speech Interpolation (T.A.S.I.) derived circuits and others over non-T.A.S.I. derived circuits. The order of selection of these types of circuits within a given route can be quite important, as it is necessary to take account of such factors as minimising the loading of the T.A.S.I. derived circuits and ensuring that a call is sent forward on a cable circuit if it is subsequently likely to encounter a satellite circuit, as the transmission time involved when two satellite circuits are connected in tandem can cause conversation difficulties. Thus, while a call is normally routed to its destination with a maximum of three direct routes out of Australia available to it (i.e., to a maximum of three different international exchanges in other countries) there can be as many as nine different route alternatives from the Australian Gateway Exchange's point of view, as each of the three direct routes may be subdivided into three circuit groups comprising satellite circuits, T.A.S.I. derived cable circuits and non-T.A.S.I. derived cable circuits. For this reason, although the ARM 20 Exchange was originally installed with a capacity of only 5 route alternatives to a given destination, it is being modified to allow for 10 route alternatives.

The number of routes that connect the Gateway Exchange to the Australian national network are as shown in Table 1 and it is expected that in the future this list of routes into Australia will be expanded to accommodate additional groups of direct circuits to centres with large volumes of international traffic.

TABLE 1 — ROUTES FROM THE AUSTRALIAN GATEWAY EXCHANGE TO THE NATIONAL NETWORK.

Gateway to	Signalling
Sydney Code 11	Manual
Sydney Code 12	Manual
Dalley Exchange	Loop Disconnect
Haymarket ARM Exchange (Sydney calls only)	MFC
Haymarket ARM Exchange (Non-Sydney calls)	MFC
Melbourne ARM Exchange	MFC

Compatibility Between Different Signalling Systems.

As was mentioned previously, there are a number of signalling systems that have to be handled by the exchange on an incoming basis and an equal number on an outgoing basis and each combination of these presents its own difficulties. All these signalling combinations are handled by one type of Register. The combinations of particular interest are as follows:—

C.C.I.T.T. No. 5 in — C.C.I.T.T. No. 5 out;
MFC in — C.C.I.T.T. No. 5 out;
Loop Disconnect in — C.C.I.T.T. No. 5 out;
Modified MFC in — MFC or Loop Disconnect out;
MFC or Loop Disconnect in — Modified MFC out;
C.C.I.T.T. No. 5 in — Loop Disconnect out;
C.C.I.T.T. No. 5 in — MFC out.

These are now examined in turn.

C.C.I.T.T. No. 5 In to C.C.I.T.T. No. 5 Out: The main point of significance in this class of call, which comprises transit switched calls from one country to another via the Australian Gateway Exchange, is that the C.C.I.T.T. No. 5 signalling system incorporates a special digit at the front of the digit sequence called a Key Pulse Digit and there are two different types of Key Pulse (KP) digit designated KP1 and KP2. A KP1 digit indicates that the call is terminal at the received country and a KP2 digit indicates that the call is to be transit switched by the exchange at which it is received. Thus, if the call is received with a KP2 digit it will be necessary to determine the forward routing for that call and to then decide whether that routing will require a further transit switch at the next international exchange or whether the call will be terminal at the next international exchange. If it is to be a terminal call at the next international exchange, then a KP1 digit must be forwarded. Secondly, on international calls, the country code is not transmitted on the terminal leg of a transit switched call because the KP digit will indicate to the terminal exchange that the call is destined for the country associated with that exchange and thus signalling time can be saved on the international circuits. Thus for all calls received on No. 5 signalling and transmitted on No. 5 signalling it is necessary for the exchange to determine whether or not to change the KP signal and whether or not to transmit the country code. All other signalling information for this class of call is transmitted as received.

MFC in to C.C.I.T.T. No. 5 out; The digital information in this class of call is sent forward without any translation; however, at present no "end of dialling" signal is received from the Australian Post Office and consequently, the exchange performs a number anlysis to determine when all the digits have been received on those calls where such number analysis is possible. For other calls within this class, it determines the end of dialling by a time supervision sequence. There is provision within this class of call for the automatic insertion of language digit zero which designates an international subscriber dialled (I.S.D.) call in the international numbering scheme. This digit would be inserted on recognition of the appropriate dialled category digit in the MFC signalling system. The digits transmitted forward untranslated must be preceded by the appropriate KP signal and the country code must be eliminated if the call is to terminate at the next exchange.

Loop Disconnect In to C.C.I.T.T. No. 5 Out: The prime difficulty in this class of call is that the C.C.I.T.T. No. 5 signalling system includes a digit 11 and a digit 12 and these are used to obtain access to assistance operators and delay operators respectively, whereas the loop disconnect system does not have the ability to signal digit 11 or digit 12. Consequently, all calls originated by Australian operators over loop disconnect junctions have what is termed a "dummy digit" dialled at the front of the remaining dialled information. When this dummy digit is 1 it signifies that the digits transmitted forward should not contain a digit 11 or a digit 12. When the dummy digit is 2 it signifies that a digit 11 should be transmitted immediately after all the remaining digits. When the dummy digit is 3 it signifies that a digit 12 should be transmitted immediately after all of the other digits. When the dummy digit is 4 it signifies that digit 12 followed by the digit immediately following the dummy digit should be transmitted immediately after other digits received. When the dummy digit is 5, 6 or 7 it signifies that digit 12 followed by the 2, 3 or 4 digits respectively received immediately after the dummy digit should be transmitted immediately after all of the other digits received have been transmitted.

In addition to the above problem, there is no "end of dialling" signal available in the Loop Disconnect system and so a ring forward signal is sent by the operator, as soon as she has completed dialling. This advises the register that all digits have been received. As the ring forward signal also has a direct equivalent in the C.C.I.T.T. No. 5 signalling system the Gateway Exchange classifies it as an end of dialling signal if the register is still connected and as a genuine ring forward if the register is disconnected. The Gateway Exchange also has the normal task of determining from the routing of the call whether or not the country code should be transmitted and which KP signal should be sent.

Modified MFC In to MFC or Loop Disconnect Out: The modified MFC system used from Lae to the Gateway Exchange is similar to the MFC system used on outgoing calls. The Gateway Exchange receives the Australian country code, followed by area code and subscriber's number. The language digit is not dialled, and this must be inserted by the Gateway Exchange register. End of dialling is determined by timeout, and switching occurs as for other incoming traffic, but the country code is not sent forward. It is necessary for country code to be received so that the register can determine that the call is destined for Australia, as normally, calls received on MFC junctions are outgoing from Australia.

MFC or Loop Disconnect in to Modified MFC out: To obtain access to the Sydney-Lae circuits, the Australian operators must dial country code 675 followed by language digit then area code and subscriber's number. The digits forwarded to Lae are first an 0 followed by 75, language digit, area code and subscriber's number. The Lae exchange will recognise the 0 as an access digit, the 75 plus language digit as own area code and delete it from its store and route the call on the basis of the remainder of the number. These special numbering arrangements were adopted as a temporary measure to permit semi-automatic working to Papua-New Guinea prior to the introduction of their Gateway Exchange which is expected to be commissioned in 1972.

C.C.I.T.T. No. 5 In to Loop Disconnect Signalling Out: As mentioned earlier, overseas operators were issued with a numbering plan for Australia that reflected the ultimate S.T.D. numbering scheme and thus, calls to Australia will contain S.T.D. area codes which must be translated to the appropriate codes when the call is transmitted over the operator controlled network. This translation is from a maximum of 3 digits of S.T.D. area code to the access code, with a maximum of 6 digits, applicable to the operator controlled network. This translation is performed by translation analysers associated with the decadic senders.

In addition, as there is no provision for digit 11 or digit 12 within the loop disconnect signalling system, receipt of these digits also results in translation to an appropriate routing code, to obtain the correct assistance operator and this translation also takes place in the translation analysers.

C.C.I.T.T. No. 5 In to MFC Out: As mentioned previously trunk access digits which must be used in national networks are not transmitted over international circuits; however, Australian trunking arrangements are such that it is necessary for the Australian exchanges to receive the trunk access digit on calls from the Gateway Exchange. Thus, in this class of call, the Gateway Exchange arranges for the insertion of digit 0 in front of the Australian area code. The MFC signalling system is also unable to accept digit 11 or digit 12 from the Gateway Exchange and consequently, on receipt of these signals in the C.C.I.T.T. No. 5 signalling system, a translation to 0141 and 0142 respectively is arranged by the Gateway Exchange and these digits are transmitted after the area code into the Australian national network, which then routes the call to the appropriate operator.

PERFORMANCE CRITERIA.

The Gateway Exchange and the associated networks are dimensioned, for the present semi-automatic service, such that the grades of service of the various major items are as shown in Table 2.

Transmission Limits

National networks have been developed in most countries of the world with transmission standards that provide a satisfactory transmission quality for all national connections but which, because of cost considerations, contain little margin for any further degradation. Consequently, when two such networks are connected together, the various components of the interconnection of the networks must be designed to quite stringent tolerances. The following transmission limits were specified as requirements for the Gateway Exchange and the ARM 20 provided for the Gateway Exchange performs within these limits.

Loss/Frequency Distortion: The loss introduced in any connection when referred to the loss at 1000 Hz is within 0±0.2 dB for frequencies between 300 Hz and 3.4 kHz and 0+0.5 dB or —0.2 dB for frequencies between 200 Hz and 300 Hz.

Variation of Loss with Time: For any connection, over any period of time up to 12 months, the mean loss measured at 1000 Hz does not differ from the mean value appropriate to that connection by more than 0.1 dB with a standard deviation not more than 0.1 dB.

Variation of Loss with Routing: The loss introduced by the exchange is in-

TABLE 2 — PROVISIONING CRITERIA FOR CIRCUITS AND COMMON EQUIPMENT.

Unit	Grade of Service
Register	0.1%
Links	0.1%
International Circuits	3.0%
National Circuits	2.0%

dependent to within 0.1 dB of the origin and direction of the connection.

Overload Point: The overload point at any unit in the exchange is not less than 12 dBm0, the overload point being defined as the point at which a 1 dB increase in the input level causes an increase of only 0.75 dB in the output level.

Total Harmonic Ratio: Total harmonic ratio on any connection through the exchange is less than 40 dB when the input level to the exchange is 0 dBm0 (+2 dBm).

Noise: The mean psophometrically weighted noise power, averaged over any hour, does not exceed —70 dBm0 in the worst connection, when such connection is terminated in its nominal impedance. The unweighted noise power averaged over any hour does not exceed —40 dBm0 in the worst connection when such connection is terminated in its nominal impedance. Any noise, either directly, or indirectly, attributable to impulses caused by loop disconnect dialling, causes peaks no greater than —60 dBm0 unweighted on any circuit in the exchange.

Crosstalk: The go to return crosstalk attenuation at equal level points is not less than 55 dB for any connection at any frequency in the range 200 Hz to 3.4 kHz when the corresponding inputs and outputs are appropriately terminated. The crosstalk attenuation between two different connections at equal level points is not less than 70 dB, with 90% of the possible combinations being better than 80 dB at any frequency in the range 200 Hz to 3.4 kHz when the corresponding inputs and outputs are appropriately terminated.

Group Delay Distortion: The group delay distortion, defined as the time difference between the maximum and minimum group delays, does not exceed 100 microseconds in the frequency range 500 Hz to 3.4 kHz and does not exceed 400 microseconds in the frequency range 300 Hz to 3.4 kHz.

Impedance: The return loss against a resistance of 600 ohms of any input or output channel is not less than 20 dB over the range 300 Hz to 3.4 kHz, and not less than 15 dB over the range 200 Hz to 300 Hz when the corresponding input or output channel is appropriately terminated.

SPECIAL FEATURES.

The ARM 20 exchange installed as the Australian Gateway Exchange incorporates a number of features worthy of special mention. Not all of these are special in the sense that they are not available in other ARM exchanges, but it was felt that it would be of interest to briefly mention all of the features that were not essential to the functioning of the exchange, with greater detail provided on those which are less likely to be found on other ARM exchanges.

10 Wire Switching

The exchange switch is basically a 10 wire switch and these 10 wires are utilised as follows:—

- 4 speech path wires;
- 1 hold wire;
- 1 call hold and trace wire (more details later);
- 1 echo suppressor switching wire;
- 3 wires for the transmission of various line and other signals through the exchange.
  There are more than 3 such signals that require transmission through the exchange; however, the time of arrival of these signals is such that differentiation between the various signals can be made by knowledge of their timing within the signalling sequence.

Echo Suppressor Switching.

Echo suppressors are currently located on the national side of the exchange and, while this remains the case, there is no real need for an echo suppressor switching signal through the exchange; however, echo suppressors were previously located on the international side of the exchange and various future developments of echo suppressor techniques could conceivably require their location on the international side of the exchange once again. In this case it would become necessary to have a connection through the exchange so that in the event of a transit switched call, the echo suppressor at the transit point could be disabled on each of the two international circuits so that the only echo suppressors remaining in the international circuit would be at the originating and terminating ends of the circuit. The Gateway Exchange is equipped with this facility.

Hold and Trace Facility.

The Gateway Exchange is equipped with a facility that permits any connection through the exchange to be held, independent of whether the A or B party clears the call. This facility also allows the identification of the other half of the connection. This facility is arranged so that if a key is operated, associated with either the incoming or outgoing circuit, a permanent earth is placed on the hold wire of the connection and a lamp associated with the other circuit of the connection flashes. This facility has been provided as a maintenance aid which permits the routing of a particular call to be checked, to ensure that it was properly routed. It also provides a very quick check of the outgoing circuit when a complaint is received concerning some incoming circuit. In addition, the holding facility allows a check on the routing of calls, that may otherwise have cleared due to some fault condition, before any tracing action could be completed.

Individual Test Block Facility.

The individual test block (ITB) facility is one which permits a call to be steered from any input to the exchange to a nominated outgoing circuit. The operating procedure involved is to seize an incoming relay set and signal into that relay set with a digit 11 which advises the exchange that the ITB facility is to be utilised, followed by a 4 digit number which specifies the particular outgoing circuit the call is to be connected to, followed by any digits that the exchange is required to transmit forward to the next exchange. This facility permits a ready check on the possibility of seizing all circuits and it also provides a rapid means of seizing all of the circuits in a particular route, in turn, to check that the signalling on all of those circuits is performing satisfactorily.

Origin Marking.

The exchange is a major transit switching point for the Pacific area, handling a large volume of transit international traffic. The routings that may be available for Australian originated traffic to a given country of destination, may not be the same routings as are available to other originating countries. This can come about because of particular international agreements. Notably there are routings which are available to British Commonwealth countries which may not be available to other countries. In addition, there are technical considerations, such as the undesirability of having two satellite circuits in tandem, owing to the long propagation time involved. Consequently, the exchange must examine the circuits on which any given call is received, to determine the permissible route alternatives available for forward switching of that call. To this end, information is passed from the incoming relay set to the Route Marker as to the category of the incoming circuit. The exchange has a capacity for recognising 60 different incoming categories of circuits and can have a completely different set of route alternatives available to a given destination with one origin category mark to the route alternatives which may be available with a different origin category mark.

Voice Announcements.

The exchange is equipped with a recorded voice announcement machine which has 12 tracks capable of transmitting 12 different 15 second recorded announcement messages. At present only 4 of these are utilised as follows:—

No Circuits Obtainable Announcement: This recorded announcement is connected to indicate to an operator that a call failed because there were no international circuits available to handle the call.

Australian International Recorded Voice Announcement: This announcement, more commonly referred to in A.P.O. and O.T.C.(A) circles as the Female Voice Announcement because of the sex of the speaker, indicates that the call failed at the Australian Gateway Exchange for some reason other than lack of international circuits.

Overseas International Recorded Voice Announcement: This recorded announcement, more commonly referred to in A.P.O. and O.T.C.(A) circles as the Male Voice Announcement, indicates that the call was switched by the Australian Gateway Exchange, but that a busy flash signal was received from an overseas exchange indicating that the call failed at that exchange for congestion or other reasons.

Call Proceeding Announcement: This announcement, which is presently only available on outgoing calls from the Australian S.T.D. network, is connected when the call is first switched by the Paddington Exchange, to advise that the call has been switched and is disconnected when the answer signal is received or after a six second timeout period, whichever occurs first.

All Circuits Busy Indicators.

This is perhaps not so much a facility of the exchange but one related to it. On the major routes out of Australia an indicator has been extracted from the exchange as to when all circuits in these routes are busy and this information is forwarded to the various operating centres throughout Australia, thus giving some guide to the operators, as to the likely chance of success, of a call on each of these routes. In the case of calls to U.K. from Australia, it has an added refinement. Calls to the U.K. are routed on direct London circuits as first choice and as a second alternative on Sydney-Montreal circuits. The all lines busy indicator to London indicates that either all the London directs and all the Montreal direct circuits are busy, or alternatively, that all the London directs and all the Montreal-London circuits are busy. The information for this latter case is received from Montreal on a telegraph circuit.

Test Relay Sets.

The exchange is equipped with several test relay sets, some of which are specifically provided for test calls from overseas and some of which are provided for test calls from the A.P.O. The test relay sets are as follows:—

Code 100 Relay Set: This relay set takes it name, as do the next 3 relay sets, from the digits that must be received to gain access to it. The Code 100 relay set merely arranges for the transmission of an answer signal and then places a termination on the line.

Code 102 Relay Set: This relay set arranges for the transmission of an answer signal followed by a 1000 Hz tone at a level of —10 dBm0.

Code 103 Relay Set: This relay set arranges for the checking of the majority of the line signals in the C.C.I.T.T. No. 5 signalling system. When it is seized, it provides an answer signal. If a forward transfer signal is then sent forward to it, it responds with a clear back signal. If an additional forward transfer signal is transmitted to it, it responds with alternating answer and clear back signals. The only line signal in the C.C.I.T.T. No. 5 signalling system that is not checked by this relay set is the busy flash signal which may easily be checked by other means.

Code 104 Relay Set: This relay set permits measurement of transmission loss of a circuit in both directions. After selection of the Code 104 relay set, it is necessary to send forward to it a tone at a level of —10 dBm0 for a few seconds. On receipt of this forward tone, the Code 104 relay set transmits in the backward direction two tones each of 1000 Hz—separated by a short pause. The first tone is transmitted at a level of —10 dBm0, thus permitting measurement of the backward transmission loss. The second tone is transmitted at the level that the Code 104 relay set received the forward tone. Thus by subtraction the forward transmission loss can be calculated.

T-CARS Relay Set: This relay set is accessed via Code 1173 and provides all of the facilities of the standard A.P.O. T-CARS relay set.

The T-CARS is designed to provide an answer condition and 820 Hz identification tone on receipt of a test call. It is fitted with a level sensitive receiver with a threshold level of—20 dBm. When the receiver is triggered an oscillator is connected and an 820 Hz signal at 0dBm0 is transmitted to line. This unit enables automatic and semi-automatic transmission tests (level) to be conducted on amplified or derived circuits.

Code 1174 Relay Set: Connection to this relay set, which is also similar to one provided in many exchanges in the Australian national network, causes a recorded announcement to be initiated which identifies the Gateway Exchange, followed by a 1 kHz tone at a level of —10 dBm0.

Route Diversion.

The exchange is equipped with a facility to permit, by operation of a key, the rerouting of all traffic normally carried over a given group of circuits, to some other destination. When this facility was first envisaged, only cable circuits were available, and a failure of a cable could cause all traffic to a large number of destinations to be completely eliminated. Thus, this facility was originally used to divert all call attempts to the Code 11 operators in Sydney, who could then advise any other operators attempting to make a call, the nature of the failure. With the added diversity now available through satellite circuits, this facility is no longer particularly useful in that role; however, other possible uses of this facility are presently being examined.

Centralograph.

This facility is the standard centralograph that is provided with all ARM 20 exchanges, with the one exception that it has been modified to include information concerning the origin mark associated with a failed call.

Control Desk.

A control desk is associated with the Gateway Exchange which incorporates the following facilities:—

(a) A busy/blocked light and a blocking key is provided for each line relay set.

(b) A register lamp display is provided which indicates for each register:—
Busy/blocked;
Incoming signalling complete;
Proceed to send received (C.C.I.T.T. No. 5 signalling).

(c) A route marker lamp display which indicates for each route marker:—
Idle;

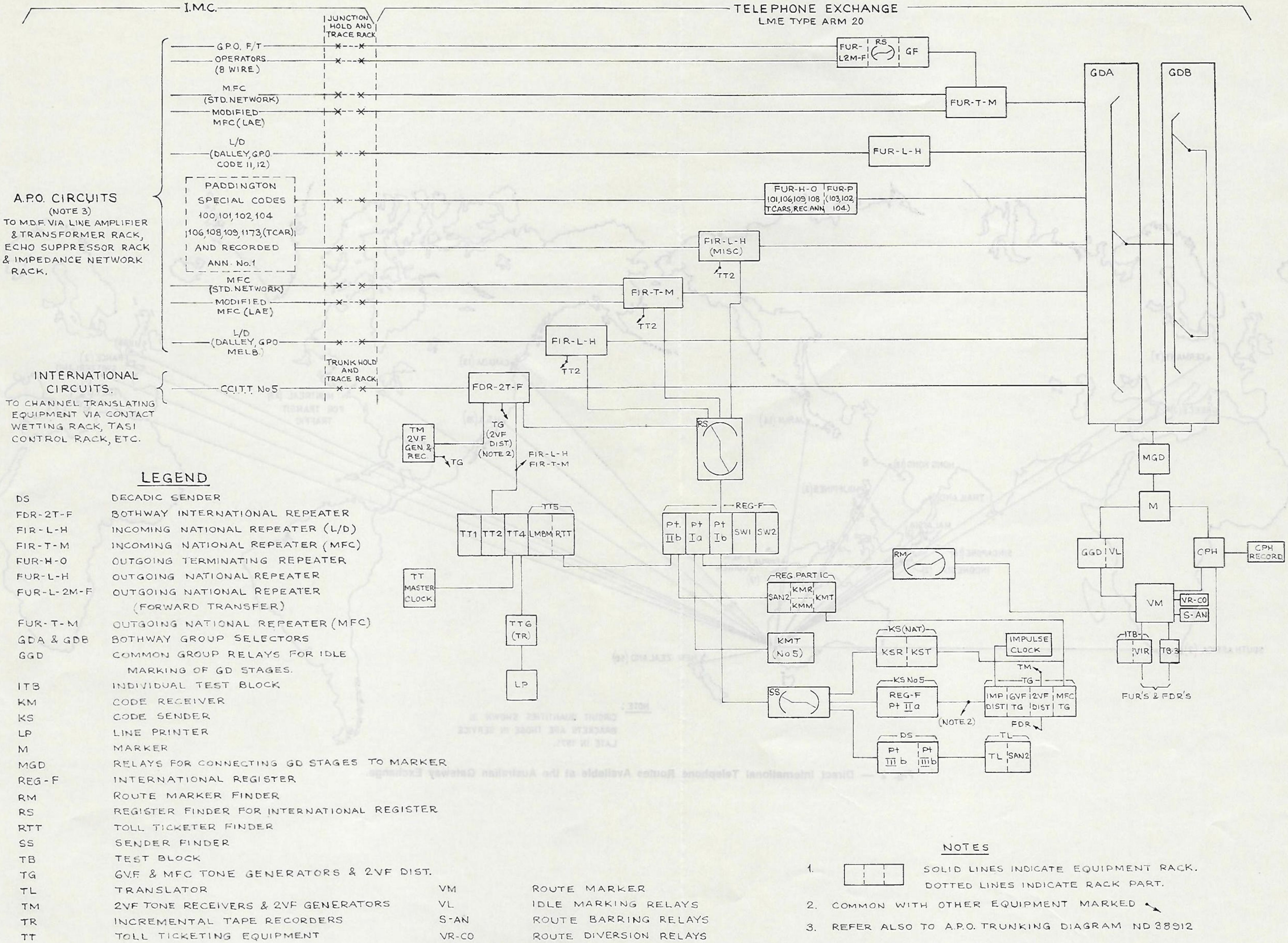

Fig. 1.—Block Schematic of the Australian Gateway Telephone Exchange.

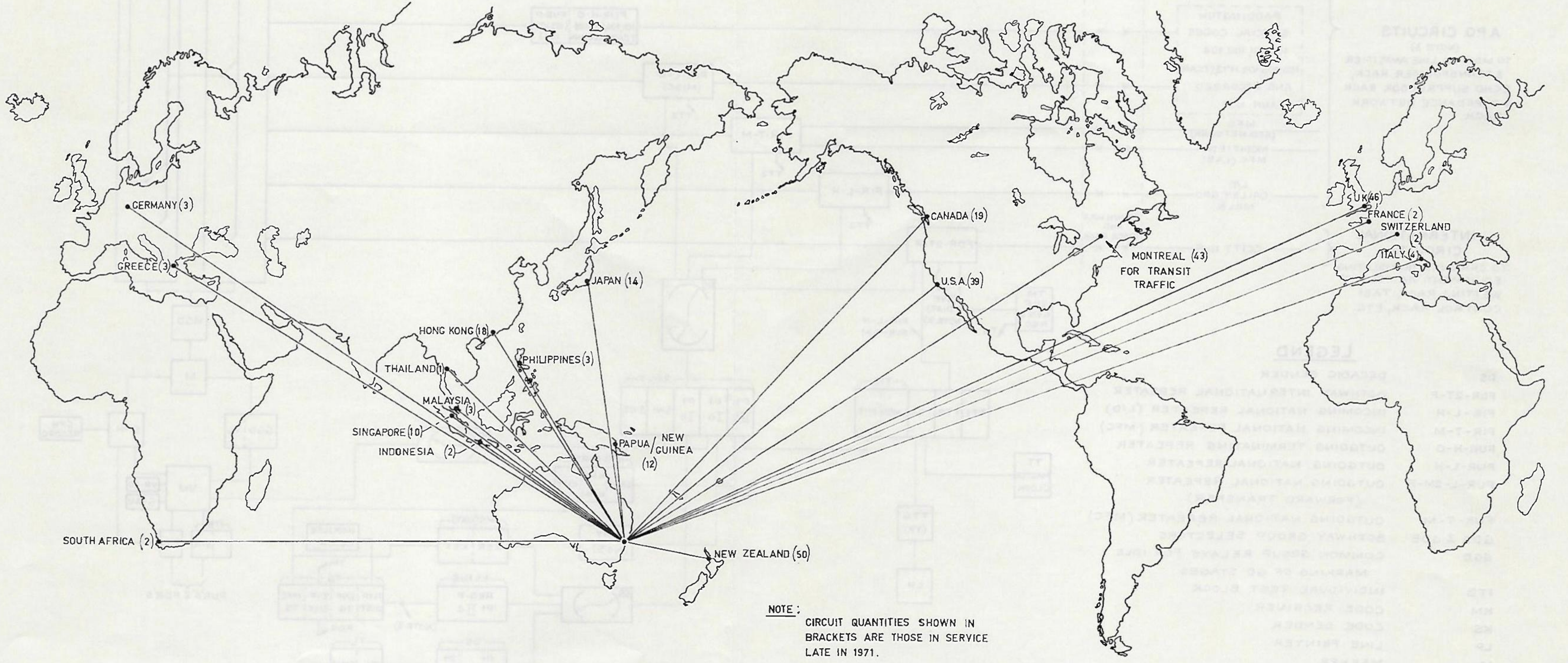

Fig. 2 — Direct International Telephone Routes Available at the Australian Gateway Exchange.

Preselected for next call;
Busy;
Test block connected;
Marker connected.

(d) A marker lamp display which indicates for each marker:—
Busy;
Switching commenced.

(e) A pair of occupation lights for each GD group, one for incoming usage and one for outgoing usage.

(f) A test block busy light for each test block.

(g) For each toll ticketer group, a lamp display indicating transfer of information to the toll ticketer.

(h) Metering facilities incorporating 40 resettable six digit counters, and 30 two way keys. By throwing a key, a group of common equipment devices have their metering leads connected to a group of 20 of these counters. Thus two keys may be operated at one time. In this way the failure rates of individual registers, senders, and other devices can be monitored.

(i) Service alarms which monitor the failure rates of groups of equipment. If a set number of failures is exceeded within a certain number of calls the alarm operates.

Other Metering Facilities.

200 five digit non-resettable counters are used to monitor important common equipment groups, and are also used to measure the total time during which all circuits in each route are busy as well as the number of seizures occurring on each route.

A group of traffic meters is also provided, which permit the recording of total traffic flow on each route. The technique used is one in which all circuits are sampled every 36 seconds.

Call by Call Recording Equipment.

This equipment, which is commonly referred to as the toll ticketing equipment, records details about every call attempt that is handled by the exchange, which at present represents about 28,000 attempts per day. The information is recorded on magnetic tape by the use of incremental magnetic tape recorders and there are 44 characters recorded concerning each call. Any one of 15 different values can be recorded in each character position. The information that is recorded is set out in Table 3, which shows the meanings of the different values in each character position. To summarise the important aspects of the table, the details recorded include the time the connection was set up, the time the connection was answered and the time the connection was cleared. It also records the first 12 digits of the dialled number, from which the destination may be determined; it includes the route alternative over which the call was connected and the identification of the incoming relay set number, from which the origin of the call may be determined.

The information is stored during the period that the call is in progress, in a ferrite core memory associated with the incoming line relay set of the given connection. Information is passed to this temporary store at two stages during the progress of the call. The information passed at the time of switching the call includes the first 12 dialled digits passed from the register, the route alternative chosen passed from the route marker and the time of the switching. In addition, the miscellaneous switching and fault indications are recorded at this time from a variety of sources. The second stage at which information is passed to the temporary store is when the call is answered and the time of receipt of the answer signal is then transmitted to the temporary store. Finally when the call is completed, the stored information is transferred to a buffer memory store, by means of a multiwire connection and, at the same

TABLE 3 — TOLL TICKETING CHARACTER MEANINGS.

Character Position	Values	Meaning
1	Special (13)	Beginning of Message.
2 to 5	0 to 9	Date in Month and Day of Month.
6	1	Answered call, successfully recorded.
	2	Answered call, recorded with a fault.
	3	Unanswered call.
7	1 to 10	Toll Ticketer fault indicator.
8 to 11	1 to 10	Incoming Line Relay Set Number.
12 to 16	1 to 10	Time of switching of the call in hours, minutes and tenths of minutes.
17	1 to 9	Switching advice digit, which is used by the Register to indicate if the call was switched and if not, for what reason.
18	1 to 8, 9, 10	Route alternative used by the Exchange if the call was switched. 9 indicates an ITB call, and 0 indicates call was not switched.
19	1 to 10	Type of signalling used incoming, and in the case of MFC the type of call, e.g. operator or subscriber originated.
20	1 to 10	Combination of incoming and outgoing signalling types.
21	1	Code 11 signal received.
	2	Code 12 signal received.
	0	No Code 11 or Code 12 signal received.
22 to 33	1 to 10	Received digits (B Party's number).
34 to 38	1 to 10	Time of answer of the call in hours, minutes and tenths of minutes.
39 to 43	1 to 10	Time of clear of the call in hours, minutes and tenths of minutes.
44	Special (14)	End of message, no fault.
	Special (15)	End of message, toll ticketer fault detected.

time, the time of clearing the call and the incoming circuit number information are also signalled to the buffer memory. The buffer memory then gains access to the magnetic tape recorder and the information is recorded on the 7 track magnetic tape unit in the form of binary coded digits.

There are two incremental magnetic tape recorders which are normally accessed in turn; however, each is capable of recording at a rate sufficient to handle the whole of the output from the toll ticketer, if one of the tape recorders should fail.

Having recorded the details shown in the table onto the tape, it will readily be seen that a very wide range of statistics concerning the international telephone traffic can be obtained by suitable computer processing of the data. A program to extract statistics from this data has been written by IBM Australia Ltd. to an O.T.C.(A) specification. The performance of the toll ticketer and the program have been successfully demonstrated in recent months and the type of information that is being obtained from this processing includes half hour by half hour profiles of the total holding time on any nominated route, both incoming, outgoing or bothway; the total conversation time on any route; the total holding time on any stream of traffic from a given origin to a given destination, independent of route. It also provides such factors as ratio of conversation time to total holding time for any route or stream. It provides information such as the average time to answer (again as a profile, if required), of calls to Australian subscribers or Code 11 or Code 12 operators, as well as overseas subscribers, Code 11 and Code 12 operators. It provides information concerning the distribution of calls into Australia, once again on a half hour by half hour profile if required. It also provides such factors as the ratio of call attempts to answered calls on any stream, route or route part and can also provide this information for specific types of calls such as subscriber only calls or operator only calls.

A complete listing of all the types of information that can be obtained from our current program has not been included as the full range of options is very extensive. However, the above examples provide a guide to the type of information that is currently being extracted. A full listing of the present program would also have limited value, in that an examination of the details of the information that is recorded will reveal many other useful statistics that can be extracted and thus, when the need arises for any particular piece of information that may not exist in the current program, it is only necessary to write a modification to the program to extract such specialised statistics.

In the few months that this information has been available, it has proved invaluable in the details that it has provided about the performance and the patterns of traffic flow in the international telephone network, many of which have been unobtainable by conventional methods. As a maintenance tool it has already served very well in indicating some problem areas in the international switched network and finally, because it permits more precise timing of the commissioning of additional international circuits it is considered that the whole capital cost of installing the toll ticketer may be offset in the first 12 months of operation by reduced circuit costs.

SUMMARY.

The ARM 20 exchange installed at O.T.C.(A)'s terminal building at Paddington, acting, as it does, as a major switching point for the Pacific region, performs some specialised tasks particularly with respect to the number of types of signalling systems and numbering schemes that have to be handled. To accommodate this, while it is basically a standard ARM 20 exchange, it incorporates a large number of special features as necessary adjuncts to its unique role.

The future of international telephone switching for Australia must include provision for faster and more complex signalling systems than those that presently exist. In addition, it will be necessary to provide for a greater degree of automation in the maintenance and measurement of the performance of the exchange itself, because of the anticipated high rate of growth of international telephone traffic in the future — the rate of growth over the past eight years having averaged 37% per year. For these reasons a second international Gateway Exchange is to be installed, which will supplement the Paddington exchange. It will be a computer controlled exchange located at the Second O.T.C.(A) Terminal Building at Broadway, and will have facilities for C.C.I.T.T. No. 6 signalling as well as the signalling systems handled by the existing Paddington exchange and a large range of self-testing procedures. For similar reasons it is envisaged that within the next few years it will also be necessary to replace the Paddington ARM 20 exchange with another computer controlled exchange, also capable of C.C.I.T.T. No. 6 type signalling.

ACKNOWLEDGEMENTS.

The Author wishes to acknowledge the assistance of the Overseas Telecommunications Commission (Australia) in the preparation of this paper and also the very considerable assistance on many aspects of this paper that was received from Mr. K. N. G. Hungerford, Engineer at O.T.C.(A).

DEVELOPMENTS IN CABLE DISTRIBUTION IN SOUTH AUSTRALIA

*M. J. GOOLEY**

INTRODUCTION

In South Australia, small telephone cables in the suburban distribution network which extends from cabinets or pillars to street terminal points have been, for many years, laid direct in the ground. The position which the cables occupy on the footpath has been chosen by mutual agreement with other reticulation authorities. These alignments are defined in the Allocation of Space booklet issued by the Public Utilities Advisory Co-ordinating Committee, on which the Australian Post Office is represented.

Small distribution cables are usually laid on an alignment between 5 feet and 7 feet from the fence line. The trench is excavated with a V-30 Ditch-witch trencher and the cable placed in position by hand after levelling the bottom of the trench to ensure that the cable is uniformly 20 inches below the top of the kerbing. Back filling is done by hand and the back-fill is tamped with a small petrol-engine driven vibratory tamper.

The Electricity Trust of South Australia (E.T.S.A.) is allotted an alignment between 3 feet and 5 feet from the fence line, but relatively little underground cable has been laid in suburban areas.

The standard method of connection of individual residential telephone services to these cables is to run an overhead drop wire from a cable terminal box connected to the underground cable. This method results in several drop wires running from the one 'island terminal' pole to nearby houses.

Electricity supply mains and service leads are usually carried overhead on steel and concrete poles of the stobie-design owned by the E.T.S.A. Many of the telephone cable terminal boxes are mounted on E.T.S.A. poles, while the remaining boxes are mounted on pressure-treated pinus wood poles owned by the A.P.O.

This article describes some aspects of changing from the part-overhead part-underground system of suburban telephone lines to a system of fully-underground lines sharing a trench with the electricity supply mains. This technique, although not novel, has been successfully applied in the case of two authorities in a particular locality, South Australia.

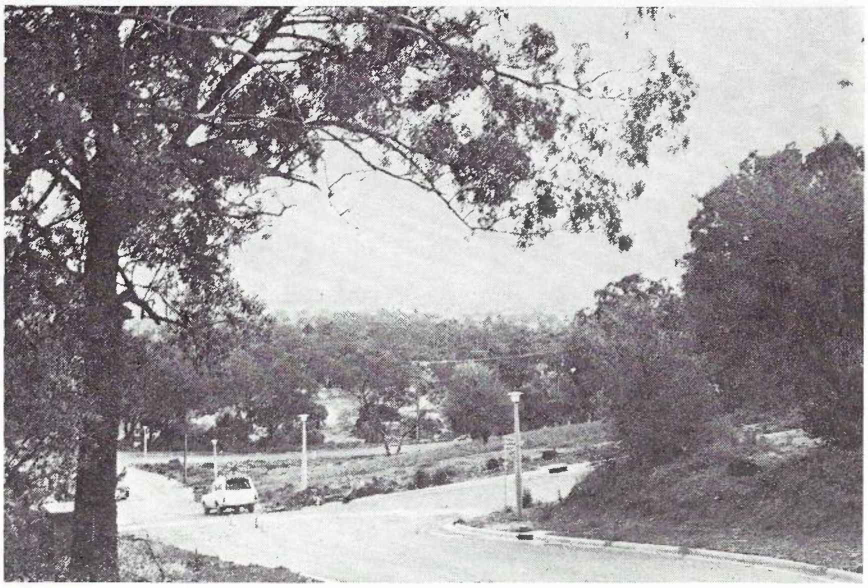

Fig. 1 — Advanced Preparation of an Estate.

THE CHANGING BACKGROUND

It is Departmental policy that an underground lead can be provided instead of an overhead drop-wire if the extra cost of the underground lead is paid by the property owner. The E.T.S.A. has a similar policy. The public has usually been unwilling to meet the extra cost, and therefore, most negotiations have lapsed. Likewise, land development organisations have also been unwilling to meet the additional cost of a fully underground system in areas of land which they are preparing for sale as residential allotments.

The recent increasing public interest in matters relating to environment has caused land developers to give closer consideration to the relatively small cost which a fully-underground electricity and telephone distribution system would add to the preparation of land and there is now a more general acceptance of the cost of the scheme as part of subdivisional costs.

In Fig. 1, portion of an estate being prepared by a progressive developer shows the aesthetic advantages of a fully-underground scheme. Here, the telephone and electricity cables are both underground along and across the streets. It is more economical to install cables along one side of each street with many road crossings provided during the preparation of an estate, than to have cables on both sides of the street. When the preparatory work has been completed, the estate can be offered for sale with the knowledge that there will be no overhead wires and, secondly, that for many years to come the only excavations in the streets will be those for lead-ins to each house.

CONSIDERATIONS OF JOINT-USE TRENCHES

In South Australia, it has been agreed that telephone cables and electricity cables (both mains operating at 11 kV and distribution cables at 240/415 volt three phase) can occupy the same trench. A particularly suitable arrangement is to have trenching as well as pipe and cable laying undertaken by the one authority. It was felt that by combining several activities under the one contractor, a number of costly problems of co-ordination would be eliminated. The merits of using the roadmaking contractor as the pipe and cable laying contractor, provided his tender is satisfactory, point to some further possible savings from co-ordination.

The road-making contractor can co-ordinate the pipe-laying in stages if necessary, with the road construction and more readily avoid having the one task (Fig. 2) interfere with another

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Fig. 2 — An Early Stage in Road Making.

Fig. 3 — Trenching for Cables.

(Fig. 3) as well as reducing the overall completion time by avoiding delays between tasks.

The joint-use trench has a clear advantage over separate trenches in economy of trenching and associated costs, even though the telephone cable must have the protection of a pipe in the joint-use situation.

Relative Costs of a Fully-Underground Scheme

In the streets, the A.P.O. installation costs are reduced because the telephone cable can be easily drawn into the pipe provided by the developer, thus avoiding the cost of expensive excavation.

On private property, underground cable will cost much more than the standard overhead drop-wire, particularly if the cable is to be laid in an established garden, which is the case in a substantial proportion of telephone services because they are required some years after the house is initially occupied.

The extra costs of work on private property will exceed the savings made on joint-use trench work in the street.

Chargeable Costs

For the purpose of assessing the costs chargeable to the developer, it is assumed that every allotment will have a telephone service at some time in the future. The chargeable costs for all services are collected at the outset and a plan record maintained of the areas concerned.

The chargeable costs are the difference between the extra cost of work on private property and the savings in street cable installation. The average charges in an estate range from about $10 to $20 per allotment, depending upon the layout of the estate. Where a 4 inch conduit is required in place of the $1\frac{1}{4}$ inch pipe in any part of the estate to carry main cables through to an adjoining subdivision, the chargeable costs are reduced to allow for the extra cost of a 4 inch conduit.

Current Projects

Quotations of chargeable costs have now been accepted by developers for 10 estates.

At August, 1971, the position in the several estates was:—

(a) Pipe completed and cable installed: 143 allotments.

(b) Pipe being installed or agreement reached: 590 allotments.

(c) Areas under consideration, agreement not yet reached: 690 allotments.

(d) Possible additions during 1971/72: 2,500 allotments.

CO-ORDINATION ON PRIVATE PROPERTY

The preceding paragraphs refer to general situations where the distribution cables in the streets are provided now and underground leads on private property are provided later when residents individually make application for telephone service. In these cases, opportunity for joint-use trenching in private property arises at the time of application for service but only in the case of a house about to be constructed or where the construction is at a very early stage. The attention of electrical contractors to joint-use trenching has been invited through their trade association.

Fig. 4 illustrates the situation when a pipe and cable are run into a house at an early stage of its construction. The telephone pipe is laid while the trench is open from the E.T.S.A. service pillar to the house foundations near the meter box on the wall. On the footpath the pipe is continued into the pre-cast cable pit. A cable marker post is left in position close to the cable pit until building work is completed, when the footpath is cleared and levelled again. The post reduces the incidence of costly damage to pits.

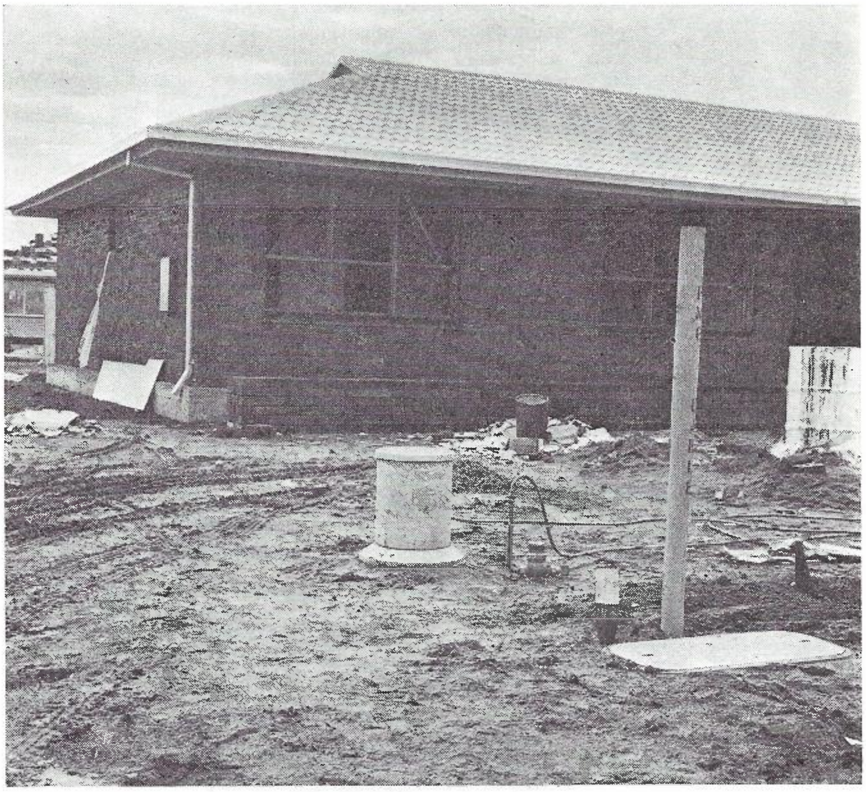


Fig. 4 — Finished Cable Installation.

FURTHER DEVELOPMENT OF CO-ORDINATED WORK

While the public facilities are first being provided, the South Australian Housing Trust usually builds a house on every allotment in the sub-divisions which they prepare. In such circumstances, it is economical to provide the underground lead for the telephone service into each house while it is being constructed, without any assurance that a telephone will be required by the future owner.

The savings are increased if the electrical contractor lays a $\frac{1}{2}$ inch plastic pipe for the telephone cable in the trench which he excavates for the power cable. The Housing Trust has agreed to specify the pipe in a trial at Elizabeth Downs, where the same contractor will install a telephone cable instead of a draw wire in the pipe.

There is an overall saving of costs of the underground leads notwithstanding the point that probably only one third of them will be used in the first five years after installation. This saving is achieved because many problems of working in established gardens and occupied houses are completely avoided. Installation costs are estimated to be reduced to one quarter. Inside the house the cable terminal is labelled 'TELEPHONE' so that householders will be in no doubt as to its purpose.

CONCLUSION

The engineering practices for the sharing of trenches for underground electricity and telephone distribution cables have now been tested in a number of localities both in South Australia and elsewhere. Sound economic engineering is evident in the current practices. The more noteworthy advantages seen in South Australia are:

(1) a saving in overall capital costs,

(2) more economical use of footpath space, and

(3) improved aesthetics in suburban streets.

In future,

(1) maintenance costs will be less in these areas and

(2) breaking of pavements and other disturbance will occur less frequently.

The author's opinion is that sharing of trenches is so advantageous that it merits the inclusion of additional authorities in a more complex system where this is practicable.

A SOLID STATE AUTOMATIC TELEPRINTER EXCHANGE FOR CONFERENCE CALLING

*R. A. RANKIN, B.Sc., M.I.E. Aust.**

INTRODUCTION

A 600 line solid state teleprinter exchange has been designed, built and cut into service by the Victorian Telegraph Installation Division of the Australian Post Office. The exchange has no mechanical crosspoints, and uses dual in line flat pack logic components and other solid state discrete components mounted on printed circuit boards. The exchange, including its line filters and jacking arrangements, is mounted on one rack of equipment measuring 2,590 mm (eight feet six inches) high by 1,676 mm (five feet six inches) wide. A view from the front is shown in Fig. 1, and construction details are discussed later.

The exchange has capacity for 600 lines and can handle 62 simultaneous calls. Its most important facility is the ability to provide automatic conferencing of any number of subscribers. It is designed for telegraph signalling at 50 bauds to CCIT Telegraph Code No. 2. To establish a through connection signalling is done from the teleprinter keyboard and, as in Telex, it uses service codes:—

GA: Go Ahead.
NC: No Circuits.
NP: Subscriber Not Connected.
OCC: Subscriber Busy.
DER: Subscriber out of order.

REQUIREMENT FOR THE EXCHANGE

In the Melbourne area, eight suburban sales branch offices cater for applications for new telephone services and alterations to services for customers in the metropolitan area. The resulting "telephone order" is distributed to the relevant line depot, subscribers installation depot, exchange and district works office to effect the required work and to Directory Section, Statistics Section, Data Transcription Unit of Accounts Branch, and fault despatch centres for notation.

Centralised sales offices deal similarly with telegraph requirements, provision of broadcast lines and other miscellaneous communication needs of the community and again the requirements are communicated to the work areas by means of a telephone, telegraph or broadcast order which contains all the information for the work to be carried out.

The June, 1970, issue of the Journal carried an article "Telephone Orders by Teleprinter", which described the trial of a system in the Melbourne Western area for the simultaneous broadcast of telephone orders direct from the sales office by teleprinter to the stations concerned. The orders are printed at the stations on pre-printed perforated stationery in multi copy, the machine paging up to the commencement point on the next form after receipt of each order. The success of the trial led to extension of the system to the whole of the Melbourne metropolitan area.

The electro-mechanical equipment designed and built specifically for the trial in the western metropolitan area was not suitable to extend the system, because it provided only one way communication and restricted use of the machines at outstations to receipt of telephone orders. Extension of this system would have resulted in eight discrete networks similar to the trial area one. Such a system has limited application and poses problems in areas where the boundaries of various operational groups within the Australian Post Office do not coincide.

It was decided that an integrated system was required to handle not only the broadcast of telephone orders

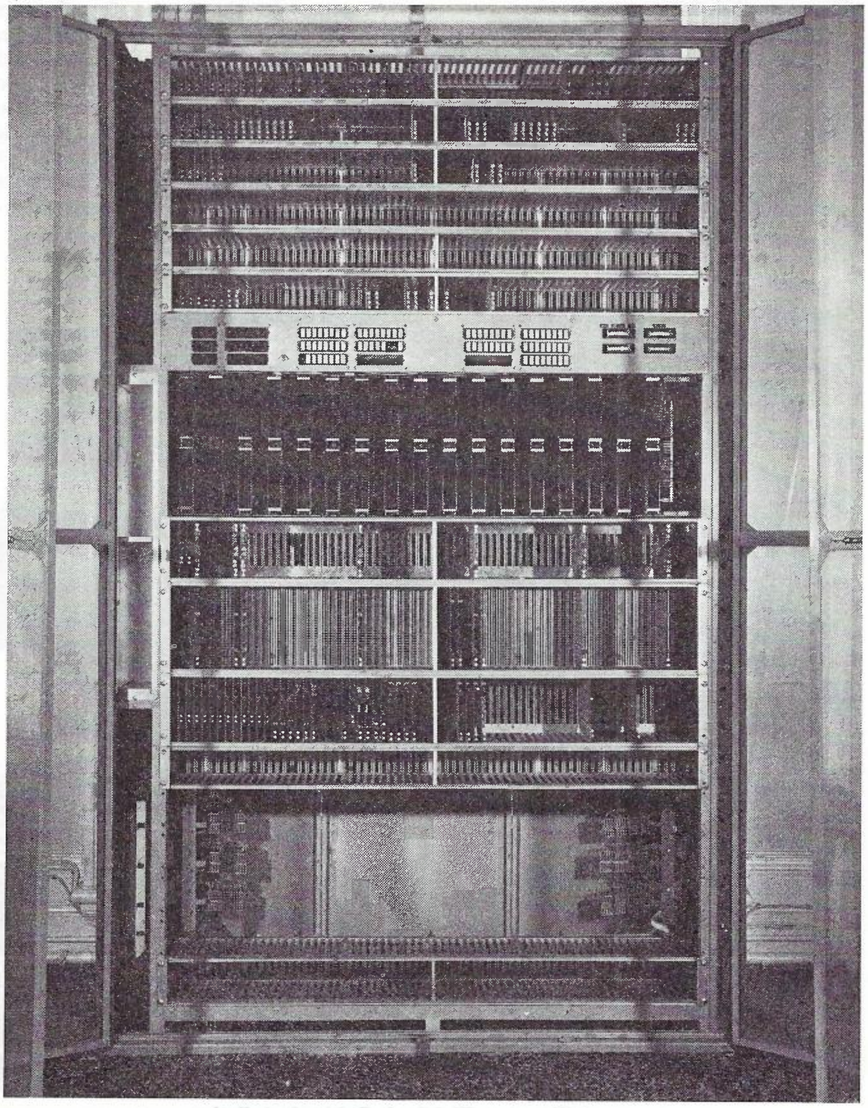


Fig. 1 — 600 Line Solid State Teleprinter Exchange, Front View.

* Mr. Rankin is Engineer Class 3, Telegraph Installation Division, Victoria.

from the eight suburban sales offices but also telephone orders from Central Sales Office which concern stations anywhere in the other eight areas. Provision of such services as extension lines, data lines, telegraph lines, etc., may concern stations anywhere in the metropolitan area and it is desirable to broadcast the order to all stations simultaneously.

One central exchange was designed providing two way communication for all stations to facilitate all the requirements of the telephone order procedure and providing spare capacity and facilities for future requirements.

It was envisaged that completion advices on telephone orders, at present sent by post on form "TEL 2" may be required to be sent by teleprinter broadcast call from suburban exchanges to Directory, Statistics and sales branch offices. There are other teleprinter requirements within the Post Office, and for economy in the use of costly terminal equipment namely the teleprinter and its associated terminal unit, an integrated system is essential.

A typical requirement of the other communication needs where post or telephone communication is unsuitable, is the disconnection lists forwarded to exchanges by the Accountant for subscribers who have not paid their accounts, and deletions from these lists for those who have made last minute payments. The speed and accuracy requirement with such information and the amount of information to be handled, calls for transmission by teleprinter.

TRAFFIC CONSIDERATION

Nearly 200 outstations are required in Melbourne metropolitan areas for receipt of telephone orders by teleprinter.

Approximately 1,200 orders per day originate from the eight metropolitan sales offices and are sent to an average of five stations. The busiest office distributes approximately 185 and the least busy 80. For the most part each sales office is concerned only with the stations in its own area so that simultaneous broadcasts can be made from all sales offices without encountering the busy subscriber condition.

Traffic from the completion advices on orders will originate from 85 exchanges and is estimated to amount to 1,000 calls per day. This and other administrative traffic, stores traffic and disconnection notice traffic could cause congestion on the network and it has been necessary already to inhibit groups of stations from originating calls in certain hours. This is arranged automatically by means of a time clock.

Banks of machines are installed at Directory Section, Statistics Section and Data Transcription Unit of Accounts Branch. Rotary grouping of the lines to Directory Section and Statistics Section effects an economy of machines and some measure of protection against faults in machines. At Data Transcription Unit of Accounts Branch, individual machines are associated with each sales office to provide sorting of orders into area groups. Spare machines with locally controlled patching facilities are provided in this instance.

In order to prevent hold up of the flow of orders from sales offices, a bank of machines has been set up at one location and held available to patch out faulty station machines or lines. The orders are then posted from this location to the relevant station.

OUTSTATION OPERATION

Fig. 2 shows a normal outstation. In this instance a Creed Model 7 teleprinter is used and is fitted with a sprocket feed attachment to take preprinted multi-copy stationery. The terminal unit beside the machine contains one printed circuit card of solid state components for signalling and a miniature relay for control of the teleprinter motor. Call and clear buttons are mounted on the terminal unit. At busy locations where more than 60 orders are received each day, it is proposed to install Siemens Model 100 machines. These are newer and more reliable machines and will lower the fault incidence at heavily loaded stations. The same terminal unit is used with Siemens Model 100 or Creed Model 7 machines.

To originate a call, the operator presses the "CALL" button on the terminal unit. His machine starts and the exchange causes "GA" to be printed out on the machine. The operator keys in figures shift and the three digits for the required subscriber. The exchange connects that subscriber to the circuit and causes the called subscribers machine to start and to revert an answer-back of the same three digits to identify itself. This answer-back prints out on the calling subscribers machine.

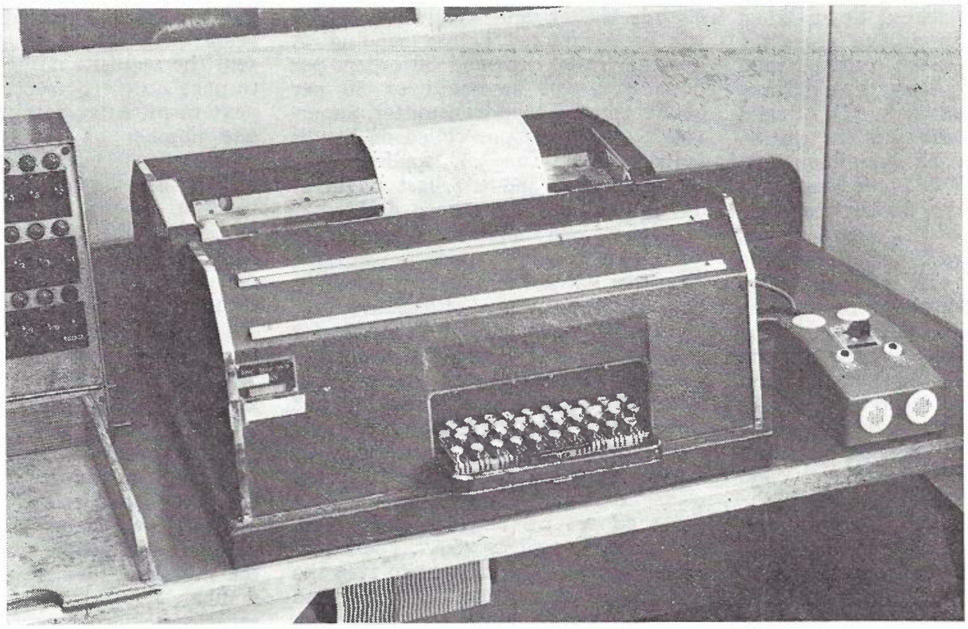


Fig. 2 — Normal Outstation Showing Teleprinter and Terminal Unit.

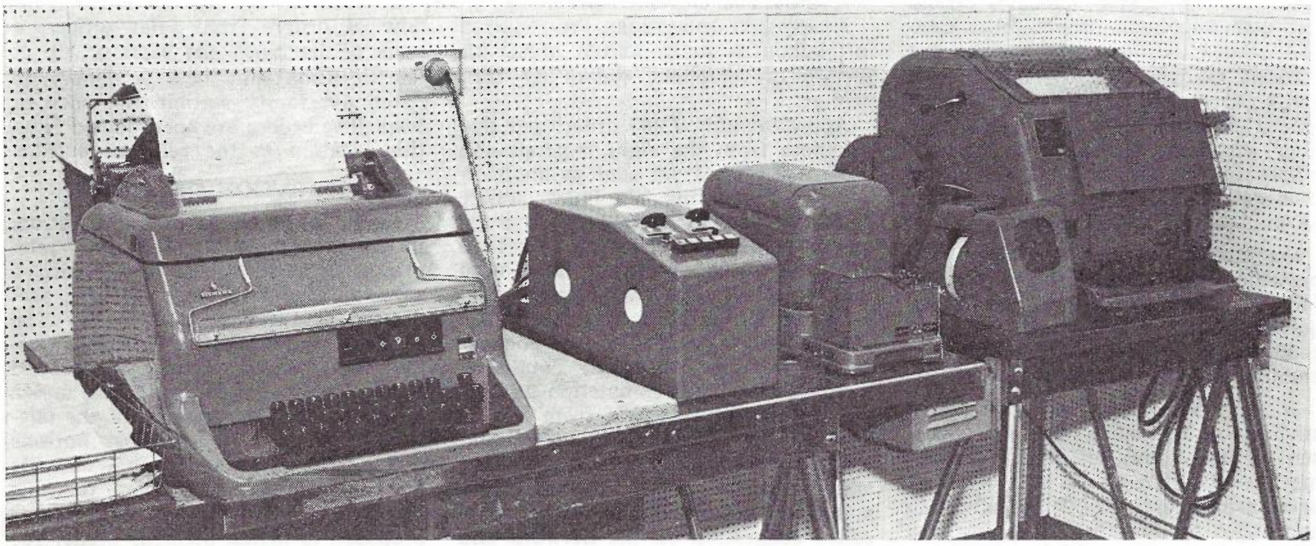


Fig. 3 — Sales Office Outstation, Showing Home Copy Machine, Terminal Unit, Tape Transmitter and Tape Preparation Machine.

If an additional subscriber is required to be connected to the circuit, the operator keys in figure shift VM. The exchange causes his machine to print out "GA" again and by sending in F/S and the three digits for the next subscriber the additional subscriber is connected in the same fashion as the first, sending its identifying answer-back to both machines already on line. Any number of additional stations may be called in this fashion. A conference call has then been established and mutilations occur if more than one station sends at the one time. Sending F/S VL causes automatic insertion of time and date.

The circuit is cleared down when any of the stations on line press the "CLEAR" button on the terminal unit. If a station called is busy, the exchange reverts the service code "OCC" and clears the circuit down. If the station called is out of order in either line, machine or just fails to answer-back, the exchange reverts the service code, "DER" and clears the circuit down. If the number called is not a legitimate number or no machine is connected to that number the exchange reverts the service code "NP" and clears the circuit down. If no connect circuits are available in the exchange or no registers are available to be connect circuit, or the operator takes too long in sending in after receipt of "GA" the exchange reverts the service code "NC" and clears the circuit down.

On clearing down a circuit all stations whose exchange circuit card has been adapted for page-up facilities, are sent the requisite number of line feeds so that the total message takes up five inches or 30 line feeds. The machine is then in the correct position to start the next message on the form of the pre-printed stationery. The telephone order stationery is perforated to tear into five inch forms.

TAPE FACILITIES.

Sixty subscribers circuits in the exchange are wired for use as four wire circuits to provide the tape facilities required at sales offices. The four wires are used for send and receive legs, "camp on" and "transmitter control".

Although broadcast of telephone orders can be carried out direct from the keyboard, transmission by tape is slightly faster and errors in typing can be eliminated before sending. A good operator can send 30 orders per hour from the keyboard or 50 per hour through a tape transmitter. Supervision of the stations called on line is better in the case of sending from the keyboards and the best mode of operation has not yet been decided.

A larger and more complex terminal unit is required for tape transmission and the extra facilities provided at these stations. Sales offices are provided with a machine in local run for preparation of tape, and a send receive machine in series with a tape transmitter on line to the exchange. Fig. 3 shows the sales office arrangement.

A tape is prepared comprising a series of orders and placed in the transmitter gate. On closing the gate the send receive machine starts and the exchange reverts "GA". The transmitter control wire is used to step the transmitter after receipt of "GA", and F/S and three digits are read into the exchange. The tape transmitter stops until after receipt of answer-back from the called station and then steps again to send in F/S VM; stops until "GA" is received again; steps again to send in F/S and three digits for the next station to be called, stepping in this fashion until all stations required are on line and have reverted their answer-back. It then steps again to send in F/S VL and stops while time and date is inserted by the exchange, starting again after time and date to send the text of the order. At the end of the order the end of message signal F/S Z on the tape is recognised by the local terminal unit which sends a clearing signal to the exchange. The call is cleared down and all stations called including the sales office home copy machine are sent the requisite number of line feeds to page up the correct position on the next form. After receipt of the requisite number of line feeds the sales office subscribers circuit clears down and if there are further messages to be sent on the tape, another call is originated and the exchange reverts "GA" as before. This procedure carries on until the end of the tape runs through the transmitter.

The sales office terminal unit has four control buttons plus the normal "CALL" and "CLEAR" buttons for keyboard operation. Pressing the "ALARM ON CODE" button causes the transmitter to stop and an alarm to sound if any service code other than "GA" is received, e.g. if a called station is "OCC" or "DER", or if "NP" is reverted from the exchange because the number called is not a legitimate number. The service code "NC" is not reverted to four wire stations for lack of connect circuits as these are priority

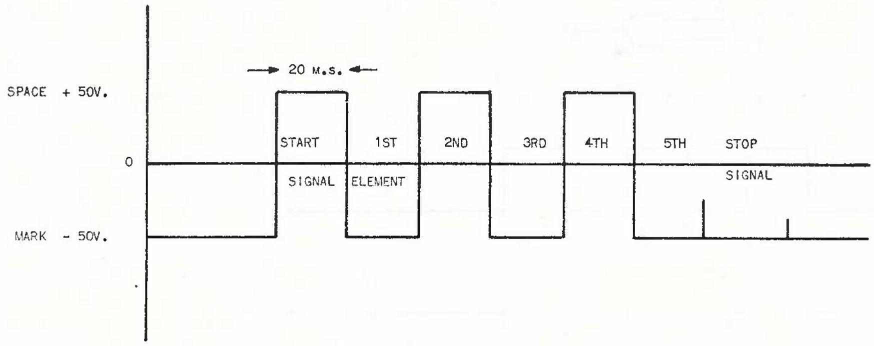


Fig. 4 — Telegraph Line Signals for Letter "Y".

circuits and are permitted to wait, having registered a call until a connect circuit is free. They receive "NC" only when the transmitter fails to run after receipt of "GA" and in this case the circuit is cleared down.

If the alarm sounds and the tape transmitter stops, the operator may either reset the alarm with a "RESET" button and carry on with transmission or remove the tape from the gate and so clear the call down. The "CAMP ON" button is operated where the operator wishes to stop the tape and wait for a busy subscriber to become free. Under these circumstances the service code "OCC" is suppressed and the called station is connected as soon as it is available.

A "SKIP MESSAGE" button when operated, causes the call to be cleared down when service codes "OCC", "DER" or "NP" are received and runs the tape through to the end of message signal. The tape then carries on with the next message in the formal fashion.

THE EXCHANGE.

Logic Application.

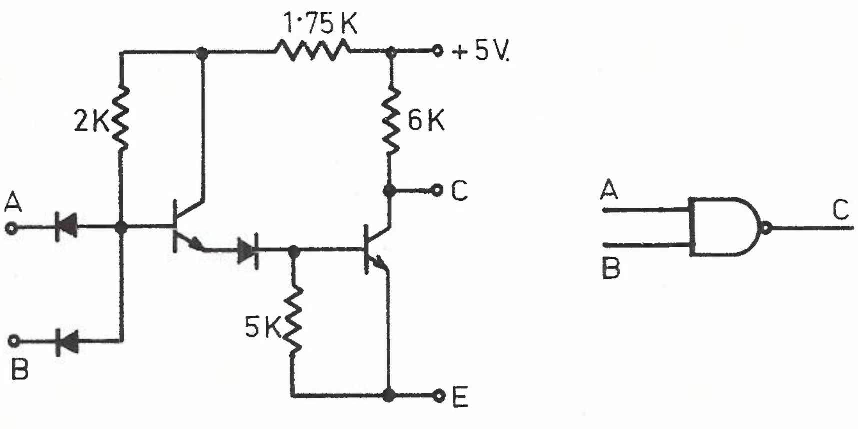
Telegraph signals are binary being either mark or space condition. Letter Y in double current telegraph signals appears as in Fig. 4. Because we are not concerned with the amplitude of the signals, this type of signalling lends itself to transmission via logic circuit gates, whereas the analogue waveform of speech signals requires a direct mechanical connection. A brief description of a particular type of logic circuit gate, (DTL NAND gate), will illustrate this.

We define logic circuit conditions as being Hi or Lo, meaning +5V or earth potential. Fig. 5a shows the circuitry of a logic circuit gate and 5b the graphic symbol. Four such gates are contained in one flat pack. If both inputs A and B are Hi, output C is Lo and a truth table as in 5c may be written.

Now consider telegraph signals imposed on input A while input B is held to Hi. Signals from the teleprinter as mark 50V —ve or space 50V +ve are first converted to earth potential and 5V +ve respectively to suit the logic gate. On space signals output C is Lo and on mark signals C is Hi. The gate could be closed by holding input B Lo, but while B is Hi the telegraph signals are transmitted through to output C in inverted form. This is illustrated in Fig. 6.

If this gate leads to a further circuit the incoming telegraph signals are then transmitted through to that circuit while the gate is open. We could have one such gate to each circuit we wish to connect to, and by opening a particular gate connect the signals through to that particular circuit. To cater for both the sending leg and the receiving leg of a teleprinter circuit, two gates would be required as in Fig. 7, which shows two teleprinters connected to one connect circuit and so connected to one and other.

Note that the send lines of teleprinters, after passing through their respective gates, are coupled together into a sending hub and similarly with the receive hub. In the exchange built, we need eight hubs for various purposes two of which are send and receive hubs. If each teleprinter circuit



A	B	C
Hi	Hi	Lo
Hi	Lo	Hi
Lo	Hi	Hi
Lo	Lo	Hi

(a) (b) (c)

Fig. 5 — Two Input NAND Gate; (a) Circuit. (b) Logic Symbol. (c) Truth Table.

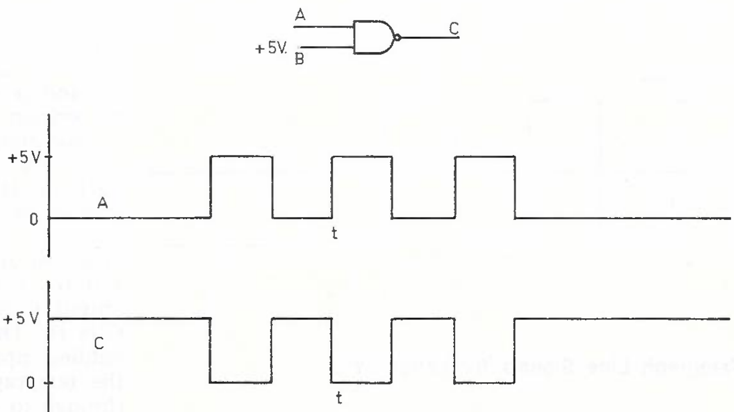


Fig. 6 — Transmission of Telegraph Signals Through a Logic Gate.

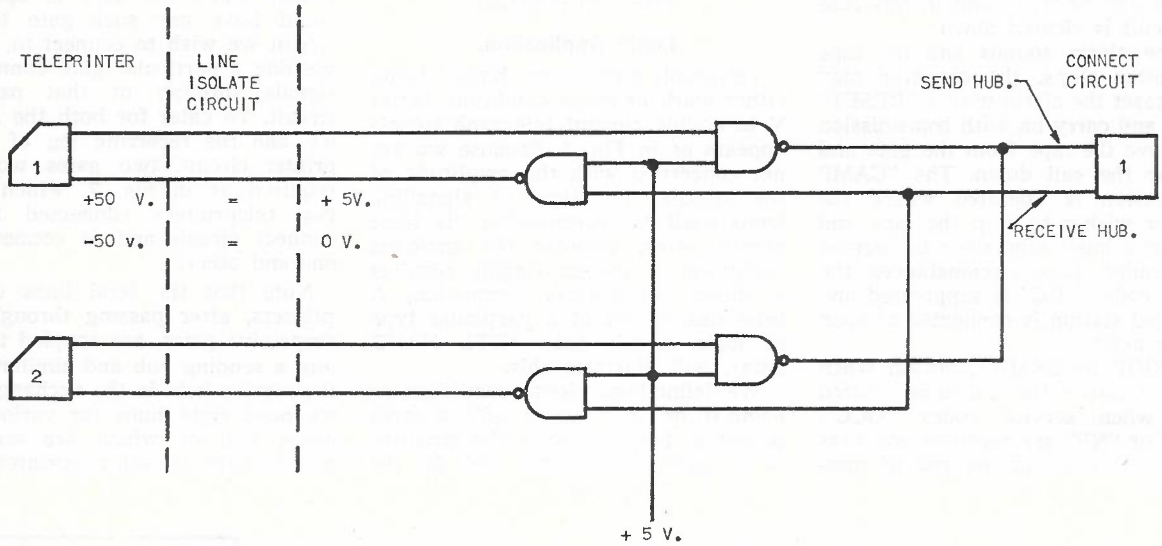


Fig. 7 — Connection of Two Teleprinters Through Logic Circuit Gates.

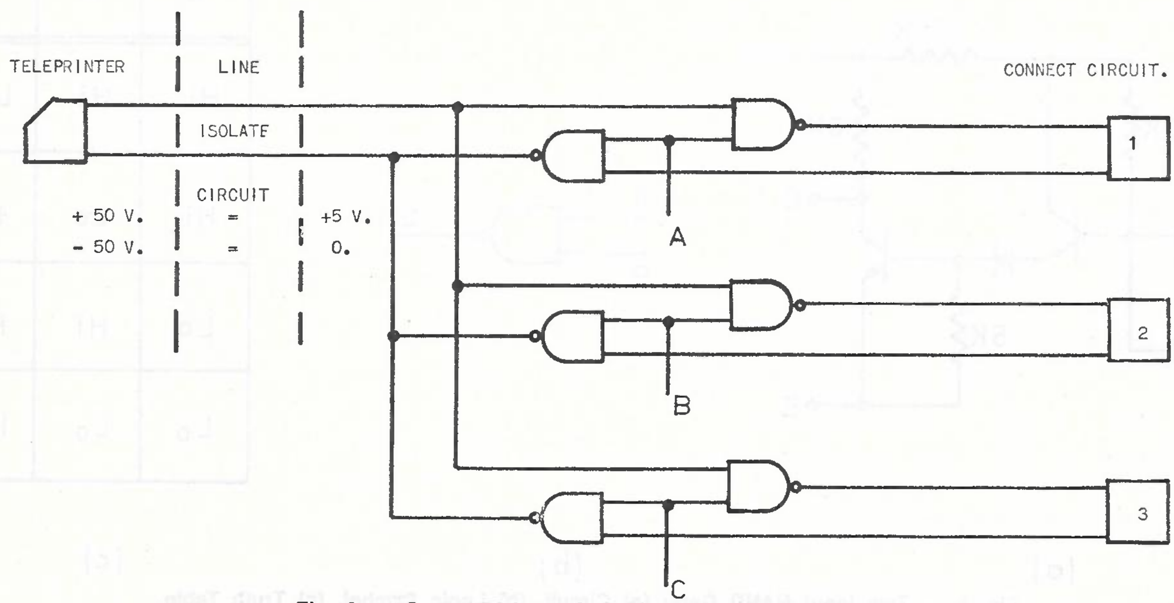


Fig. 8 — Space Division Switching using Logic Gates.

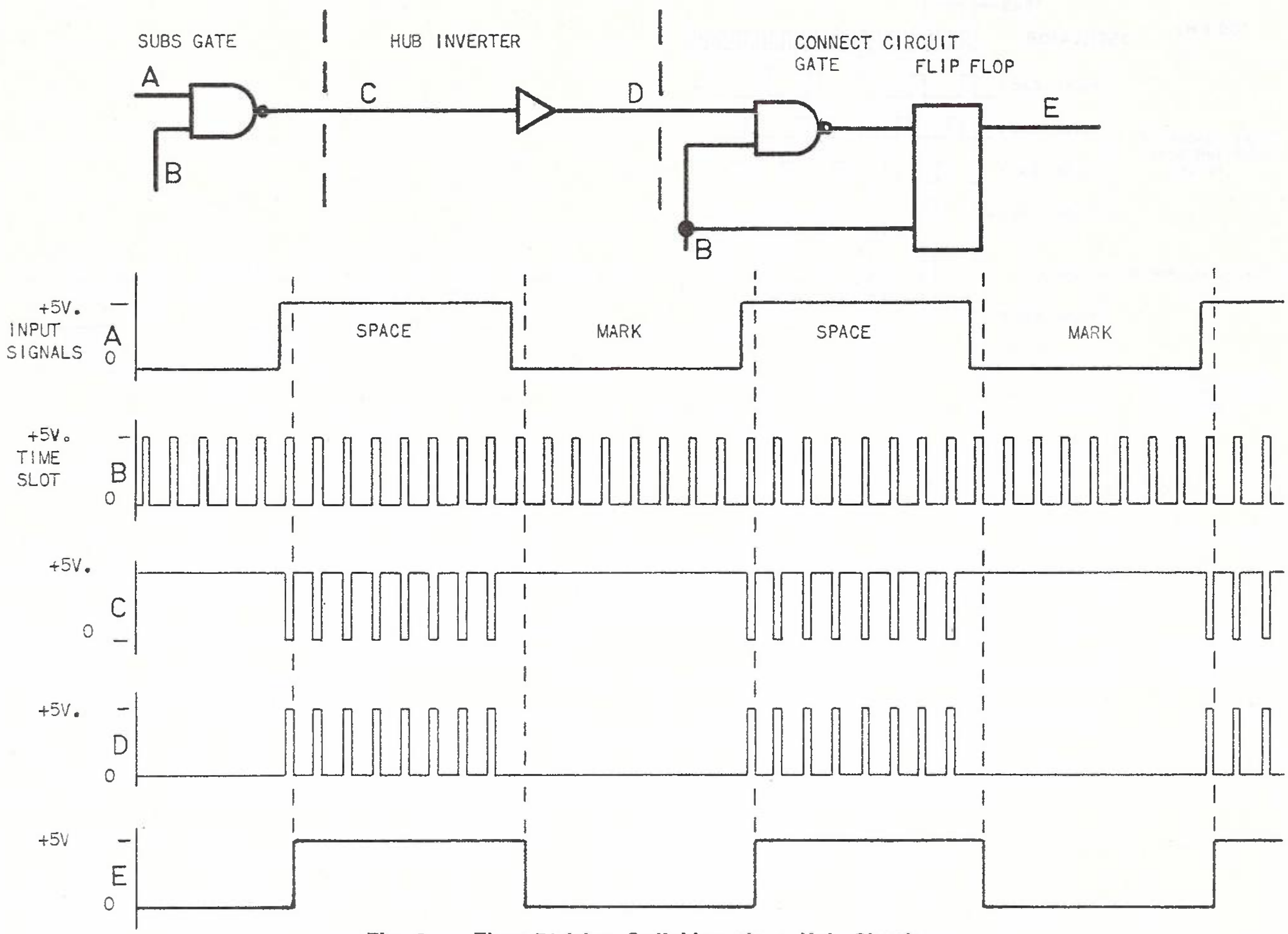


Fig. 9 — Time Division Switching via a Hub Circuit.

required to connect to any one of n connect circuits, n sets of gates would be required. Fig. 8 shows how this can be done. By making either A, B or C high the teleprinter circuit is connected through to connect circuit 1, 2 or 3. This method becomes very cumbersome because as the exchange gets bigger the switch for each subscriber grows bigger. For this exchange with 62 connect circuits, 62 sets of eight gates would be required in each subscribers switch.

Time Division Switch.

If we consider only one set of gates per subscriber and arrange to open these for a short period in a time cycle (say 10 micro seconds every 640 micro seconds), then space signals from the subscriber will appear on the send hub as a series of short pulses as in Fig. 9. If we also have a gate leading into the connect circuit and this is opened for the same 10 micro seconds in the cycle then the series of pulses will appear in the connect circuit and we can arrange circuitry to be set by the presence or absence of a pulse during this particular time slot, and to hold this state until the next pulse.

We have now re-constituted the incoming telegraph signals but have occupied the hub for only one time slot in a 64 time slot cycle. Sixty-three other teleprinters can send signals into 63 other connect circuits over the same hub.

The economy provided by time division switching lies in the method of deriving the time slot pulses. These are derived by imposing a selection of three out of 12 pulsing leads on the inputs of a three input NAND gate. Pulses on the 12 leads shown in Fig. 10 are generated in a pulse generator. A simplified version of the pulse generator is shown in Fig. 11.

A 100 kHz square wave oscillator is used to clock the first line of four flip flops connected in twisted ring formation so that the Q output of each goes Lo for one period in a cycle of four periods. The output of the fourth is used to clock the second chain and the Q outputs of the four flip flops in the second line will pulse Lo for four periods in a cycle of 16. Output eight is used to clock the third chain and each Q output in the third chain goes Lo for 16 periods in a cycle of 64.

Pulse leads 1, 5 and 9 are only all Hi together for the first 10μsec period in a cycle of 640μsec and other combinations derive the other 63 time slots. Since time slots are allocated to connect circuits, only pulse leads 1, 5 and 9 are taken to connect circuit No. 1; 2, 5, 9 to No. 2, etc., and all 12 pulse leads are taken to each subscribers circuit where three can be selected to derive the required time slot. The time division switch in the subscribers circuit is shown in Fig. 12.

Twelve marking leads from the marker are used to indicate to a subscriber which three pulse leads should be used to derive the required time slot. Assuming time slot No. 1 is required (for connection to connect circuit No. 1), marking leads 1, 5 and 9 will be Hi and all others Lo. On calling or receiving a call, gates 1B to 6B and 1A to 6A are opened and flip flop outputs 6A11, 2A11 and 4B11 set Hi to open gates to accept pulse leads 1, 5 and 9. Gate 7A 8 output

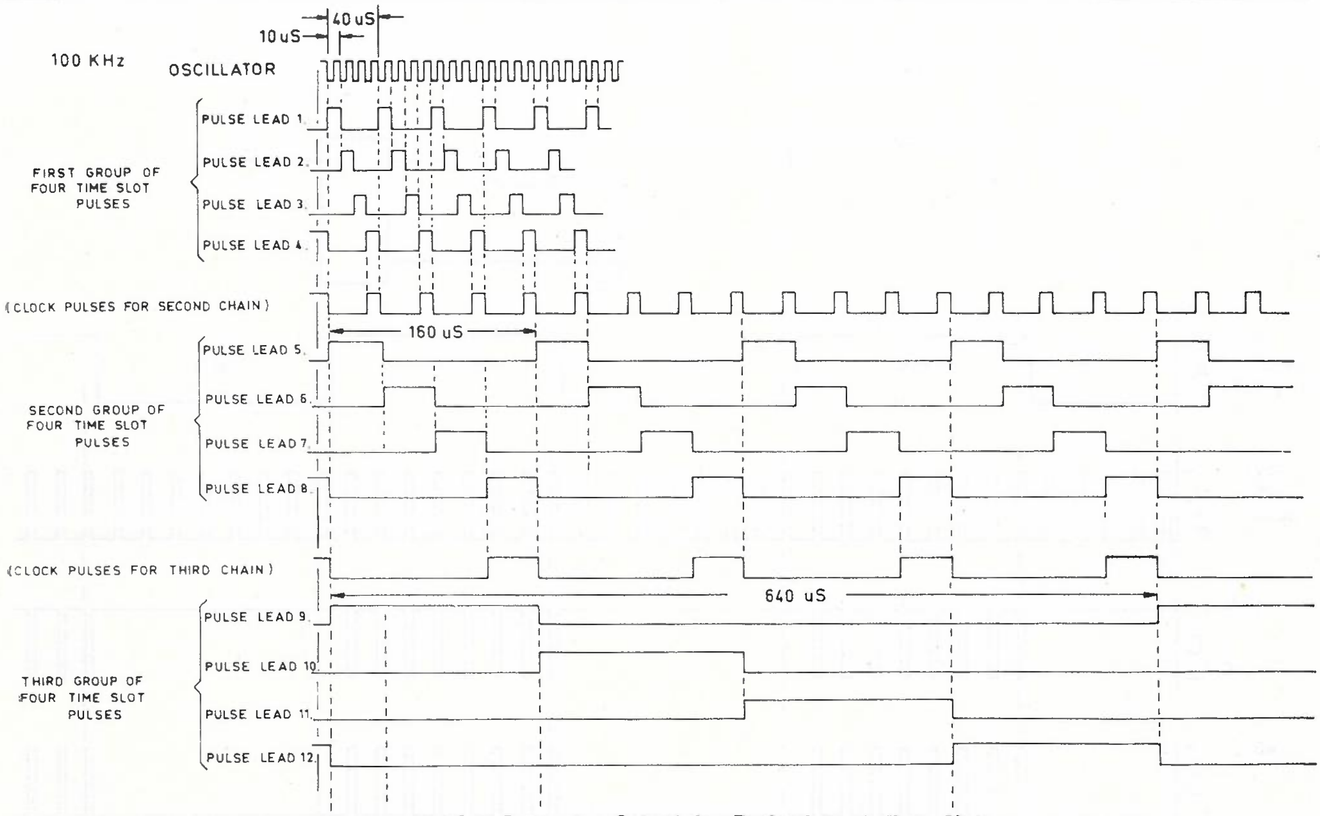


Fig. 10 — Pulse Generator Output for Derivation of Time Slots.

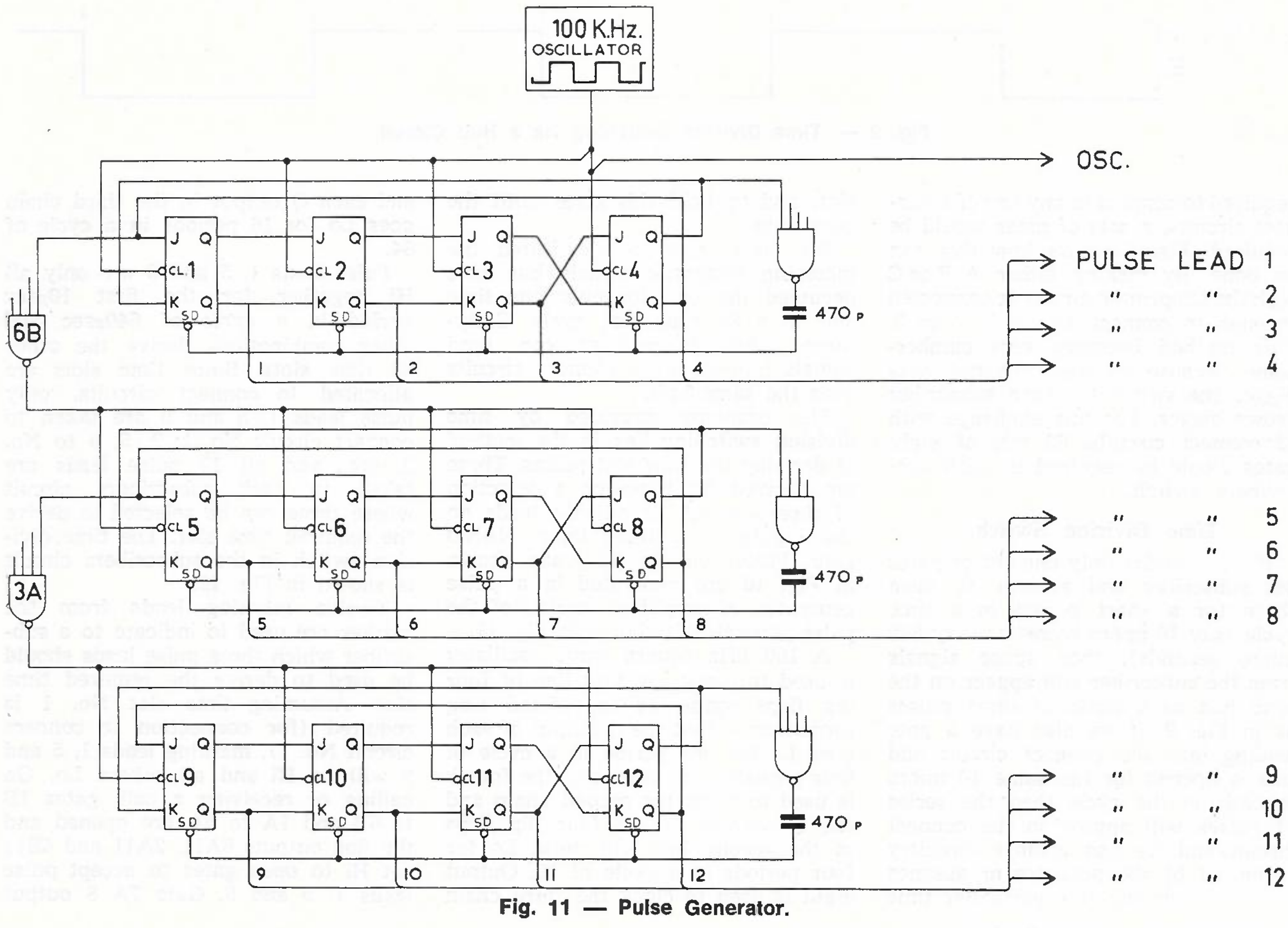


Fig. 11 — Pulse Generator.

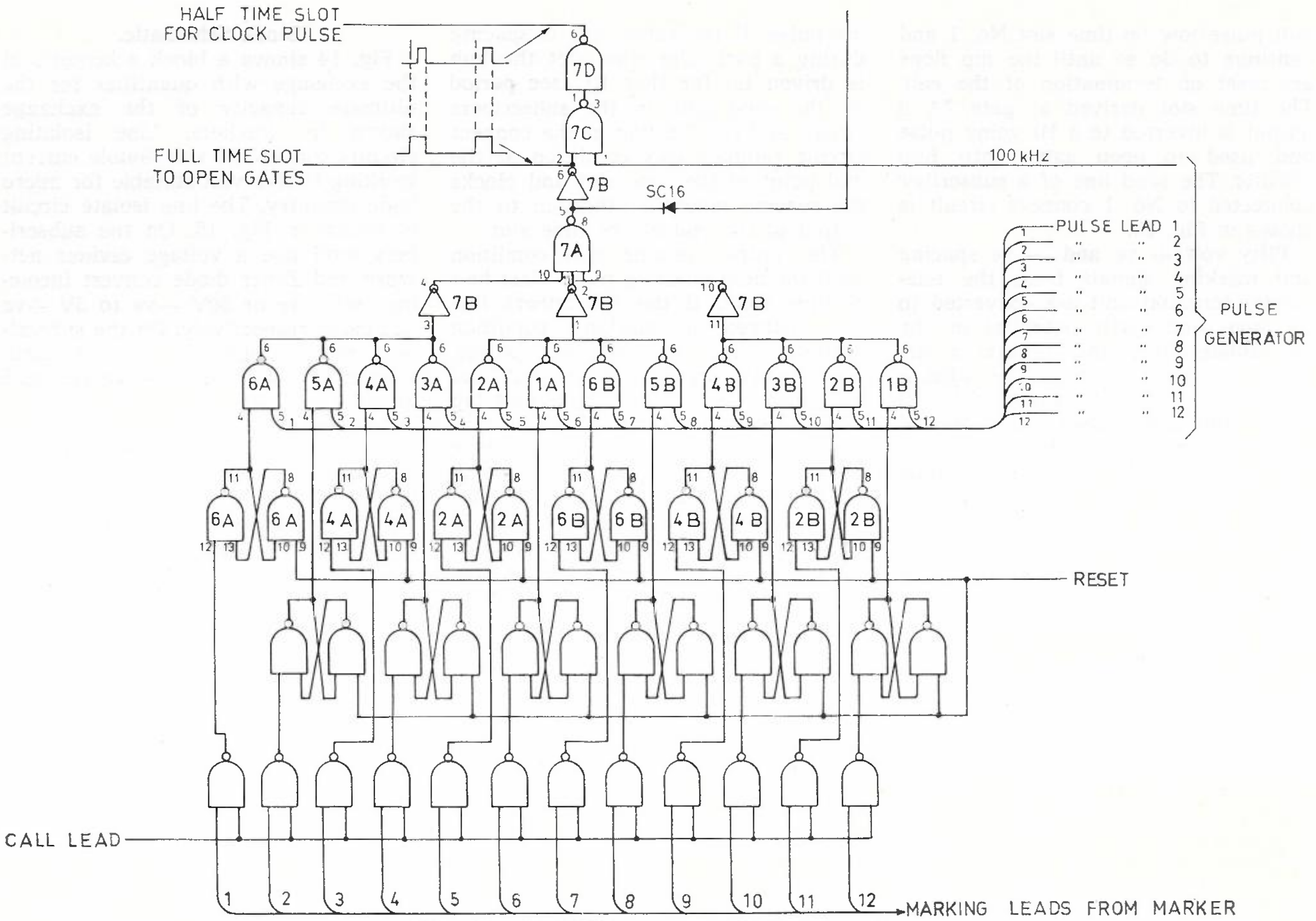


Fig. 12 — Subscribers Time Division Switch.

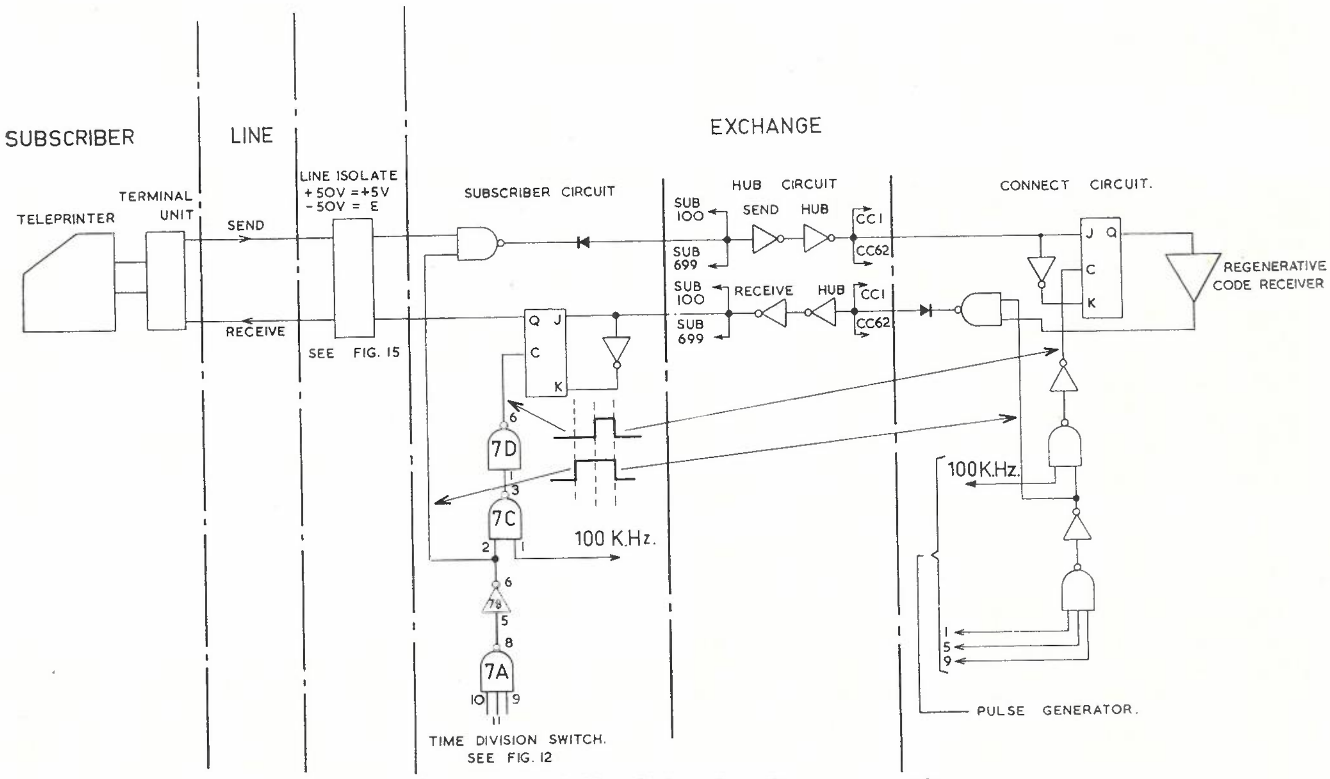


Fig. 13 — Through Circuit for Time Division Switching.

will pulse low on time slot No. 1 and continue to do so until the flip flops are reset on termination of the call. The time slot derived at gate 7A 8 output is inverted to a Hi going pulse and used to open gates into hub circuits. The send line of a subscriber connected to No. 1 connect circuit is shown in Fig. 13.

Fifty volt + ve and — ve spacing and marking signals from the teleprinter terminal unit are converted to 5V +ve and earth potential in the line isolate circuit and imposed on one input of a NAND gate in the subscribers circuit. The gate is opened by Hi going time slot pulses on a second input and spacing condition (5V +ve) will then appear as a series of Lo going pulses on the hub. In the connect circuit the hub is connected to the input of an edge triggered flip flop which is clocked with a half time slot pulse derived from the time slot pulse and the pulse generator square wave oscillator.

Thus the information on the hub at the middle point of the time slot is locked into the flip flop and clocked through to the output on the Hi to Lo transition of the half time slot clocking pulse. If the subscriber is spacing during a particular time slot the hub is driven Lo for that 10 μsec period by the send gate in the subscribers circuit and the flip flop in the connect circuit samples this condition at the mid point of the time slot and clocks the spacing condition through to the output at the end of the time slot.

The output retains this condition until the next clocking pulse (last half of time slot). If the subscribers line has changed to marking condition between these two time slot pulses, no Lo pulse appears on the hub and the output of the connect circuit flip flop clocks to marking condition.

The transition from space to mark could be undetected for a period of up to 640 μsec (interval between two successive time slot pulses). For 50 baud signalling where the elements of mark and space are 20 m sec duration this represents 3% distortion introduced by the time division switch. The same applies to the subscribers receive line and in this case pulses for spacing condition are gated from the connect circuit into the receive hub and clocked from the hub into the subscribers circuit.

Block Schematic.

Fig. 14 shows a block schematic of the exchange with quantities for the ultimate capacity of the exchange shown in brackets. Line isolating circuits convert 50 volt double current working to five volt suitable for micro logic circuitry. The line isolate circuit is shown in Fig. 15. On the subscribers send line a voltage divider network and Zener diode convert incoming 50V +ve or 50V —ve to 5V +ve and earth respectively. On the subscribers receive line 5V +ve or earth trigger 50V +ve or 50V —ve via SC.5 or SC.4 to line.

To originate a call, a subscriber sends marking condition to the exchange by pressing the "CALL" button and the exchange reverts marking condition when the subscriber is connected to a connect circuit. A subscribers search cycle from the pulse generator steps from one subscriber to the next with each complete time slot cycle to offer each subscriber in turn opportunity to originate a call. Allocation of a free connect circuit is done in the connect circuit itself and the time slot pulse allocated to connect circuits offers each in turn the oppor-

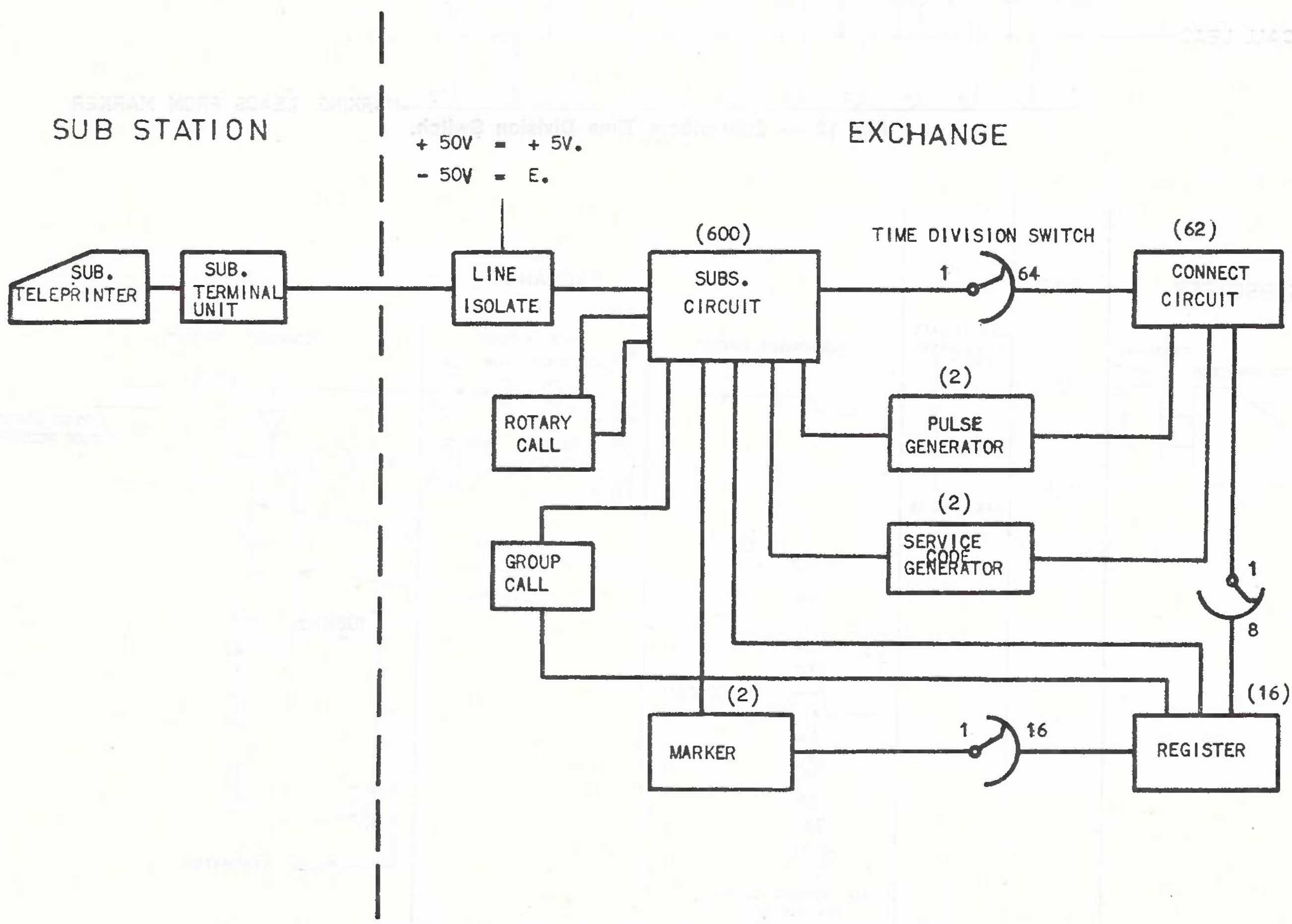


Fig. 14 — Exchange Block Schematic.

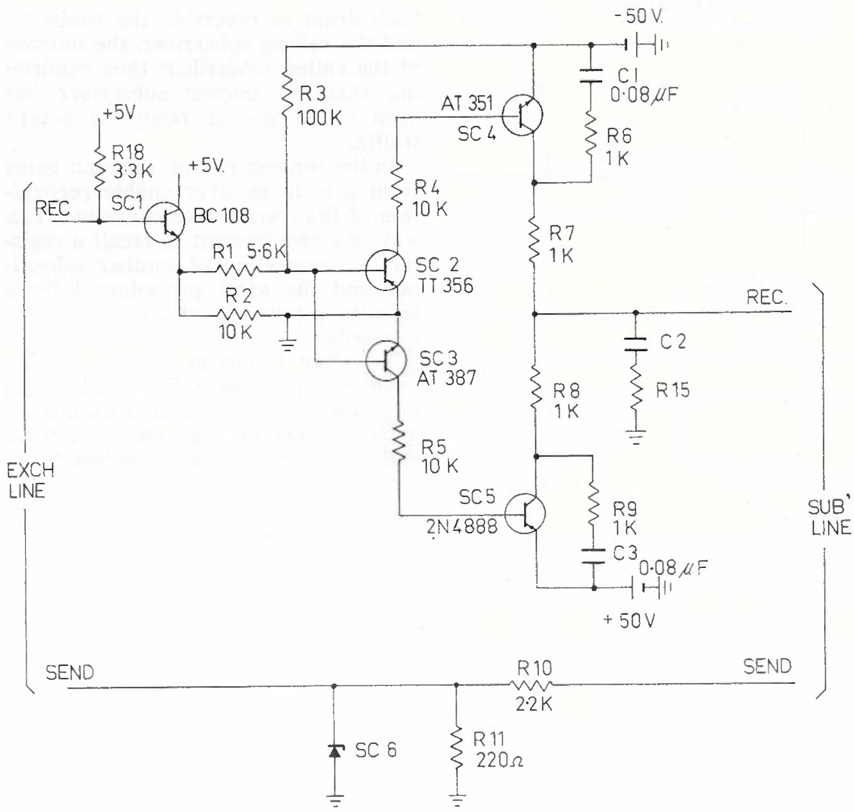


Fig. 15 — Line Isolate Circuit.

tunity of setting into the presenting condition if no other is already presenting. A marking indicating the presenting connect circuit is distributed via the marker in the free condition to all subscribers on three out of 12 marking leads. On originating a call and co-incident with the subscribers search cycle pulse, the subscribers time division switch sets to accept pulses on the three leads indicated and sends pulses on the busy hub to busy the connect circuit. Another free connect circuit then presents ready for the next calling subscriber. When busied, a connect circuit calls for connection to a register.

Time slots 63 and 64 are used for "all circuits busy" and timing functions respectively. Provision of 62 connect circuits gives capacity for 62 simultaneous calls and as subscribers circuits can switch to the same time slot, one connect circuit handles a broadcast call to any number of subscribers. Connect circuits are broken into two groups of 32 and 30, each with access to eight of the 16 registers.

Access to each register is provided by an individual set of 10 gates and eight sets of these are mounted on one register finder card associated with each connect circuit. Selection of a free register is done by the register selector shown in Fig. 16 and on call from one of the connect circuits, the connect circuit time slot is used to set a flip flop opening the appropriate set of 10 gates to establish connection. Establishment of this connection causes the connect circuit to gate service code "GA" to the calling subscriber.

Line signals are received in the connect circuit on a regenerative code receiver and the five elements of the code for each character and a readout pulse are fed through six gates in the register finder to read out gates in the register. Recognition of figures shift in the register opens routes to the first rank of flip flops in the store such that the next character received will set one of ten flip flops if it is a legitimate number, and the second character (10's digit), is steered into the second rank of flip flops. Similarly with the units digit.

When one flip flop in each set of 10 representing the hundreds, tens and units digits of the called number, has been set, the register calls for connection to the marker. Two markers are provided and take alternate calls. Each has a calling register selector of two similar circuits to Fig. 16, to select one out of the calling registers. A Lo out of the register calls for marker and a Lo back on marker connected lead indicates connection. The register is then enabled to indicate to the marker, the three pulse leads denoting the time slot of the connect circuit working with it.

When free, the marker indicates to all subscribers circuits a marking on three out of 12 leads representing the time slot of the presenting connect circuit (next free one to be used by a calling subscriber). However, when connecting a called subscriber this marking must be removed and a marking substituted to indicate the particular time slot the called subscriber is to select. This is indicated from the register finder through the register to the marker. The marker substitutes this time slot marking and at the same time inhibits all subscribers from originating a call lest a calling subscriber should connect to the already busy connect circuit.

The register is then permitted to send out a Lo marking on three out of 30 leads to the subscriber multiple on the appropriate hundreds, tens and units leads and the called subscriber responds by setting the switch to the appropriate time slot, thus connecting it via the connect circuit to the calling subscriber. The marker takes four m-sec to effect this connection and in dropping off the register sends a marker off pulse through the register and register finder to the connect circuit which then drops off the register.

In setting up the connection the marker looks for a call confirmation pulse from the called subscriber and matches it with the appropriate time slot. Absence of a matching call confirmation pulse causes the marker to send a pulse back to the connect circuit via register and register finder to initiate sending service code "NP" back to the calling subscriber. This pulse can also be originated in the register before connection to marker if figures shift and three characters are seen but any or all of the characters are not digits and the store has not been filled with one in each set of ten flip flops set to indicate a legitimate number. Thus the "not legitimate number" or "subscriber not connected" conditions both cause reversion of service code "NP".

When calling a busy subscriber a Lo is sent out from the subscribers card on a busy common to the marker and causes a pulse to be sent back to the connect circuit via register and register finder to initiate sending service code "OCC". However, if the calling subscriber is camping on, time slot pulses on the "camp on" hub set the connect circuit such that the marker off pulse is neglected if an "OCC" pulse is received and the

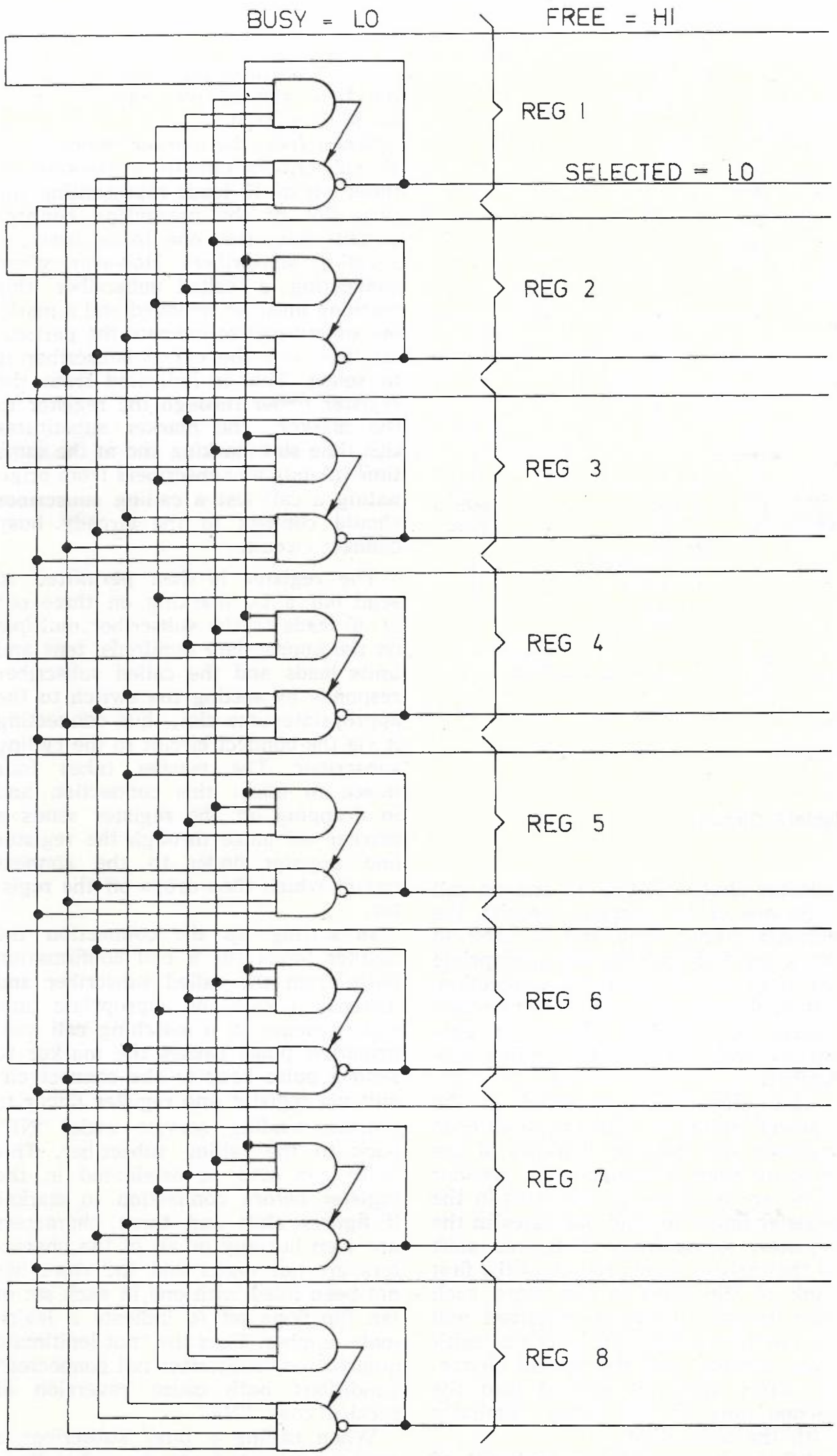


Fig. 16 — Register Selector.

connect circuit does not drop the register off. The register then retains in store the number of the called subscriber and calls for connection to marker at one second intervals until the required subscriber is free.

When a subscribers card receives a call as described, marking battery is sent on the subscribers receive line and the terminal unit associated with the teleprinter causes the motor to start and marking battery to be sent back to the exchange. Telegraph signals forming figures shift and D, supplied from the service code generator, are then gated to the subscriber from the subscribers card and cause the machine to trip off an answer-back drum to revert to the exchange and the calling subscriber, the number of the called subscriber, thus confirming that the correct subscriber has been called and is ready to accept traffic.

In the connect circuit, read-out gates from a code receiver enable recognition of the consecutive characters F/S VM as a requirement to recall a register for connection of another subscriber and the same procedure follows as with connection of the first called subscriber.

To clear a circuit down, spacing condition sent for 0.5 seconds from any subscriber connected to the circuit, is recognised in the connect circuit, and causes disconnecting pulses to be sent from the connect circuit over a disconnect hub to all subscribers cards. Disconnect pulses are matched with the time slot the subscriber is switched to and only those switched to this particular time slot clear down.

The eight hubs used to connect subscriber circuits via the time division switch to connect circuits are:—

(a) **Send Hub:** Send lines of all subscribers connected on the one time slot are gated through to the send hub during that time slot and the hub condition is sampled by the connect circuit in the middle of the time slot and the state is clocked through to the input of a regenerative code receiver in the connect circuit. In a conference circuit where all subscribers not sending are marking, spacing condition must predominate over marking condition on the hub. With the logic circuitry used, "Lo" condition predominates over "Hi" and circuitry is so arranged that only subscribers spacing condition is gated through and is "Lo" on the hub.

(b) **Busy Hub:** In the free condition a subscriber sends spacing condition to the exchange; to call, he sends marking condition and is switched to a time slot. However, since the marking condition is not gated through to the send hub, the connect circuit still has no indication that a subscriber is connected to it. A separate busy hub is arranged to send time slot pulses to the connect circuit whenever a subscribers line is connected to that particular time slot.

(c) **Figures Shift D Hub:** When a subscriber is called, the exchange sends F/S D to the called subscribers machine and this causes the machine to revert its answer-back. In a group call when a number of subscribers are called simultaneously, if "Figures Shift D" were sent simultaneously to all, all would answer-back simultaneously and the signals would be mutilated. A subscribers search cycle causes one of the group called simultaneously to set into a condition to receive "Figures Shift D" and to answer-back. This condition causes pulses to be sent on the "Figures Shift D Hub" in the particular time slot and inhibits other subscribers of the group from setting into the same condition until the first subscriber has answered back. So the answer-backs are received in sequence.

(d) **Camp On Hub:** The exchange is wired to provide some four wire circuits for busy stations. One of these wires is used to indicate that camp on busy facilities are required and a subscriber so indicating causes pulses on the "Camp On Hub" at the appropriate time slot to set the connect circuit into the "Camp On Busy" condition.

(e) **Receive Hub:** The receive hub carries regenerated signals from the connect circuit to all subscribers. Signals from all connect circuits are sent out on the one common hub in their appropriate time slots and the condition of the hub clocked into subscribers circuits on the appropriate time slot.

(f) **Release Hub:** A long space condition is recognized by the connect circuit as call release, and initiates pulses on the release hub again in the appropriate time slot. Subscribers connected to the same time slot release.

(g) **Line Feed Hub:** A code receiver in the connect circuit sends out one time slot pulse on the "Line Feed Hub" each time a line feed is recognised. This is clocked into each subscribers card connected to the particular time slot and counted. On release, additional line feeds are gated to the subscriber until the counter on his card reaches the home condition of 30. For each message then the subscriber receives a total of 30 line feeds arranged to suit the form size on the sprocket feed pre-printed stationery used.

(h) **Transmitter Control Hub:** For four-wire heavy traffic subscribers requiring to send a number of messages from a tape transmitter, the clutch to stop and start the transmitter must be

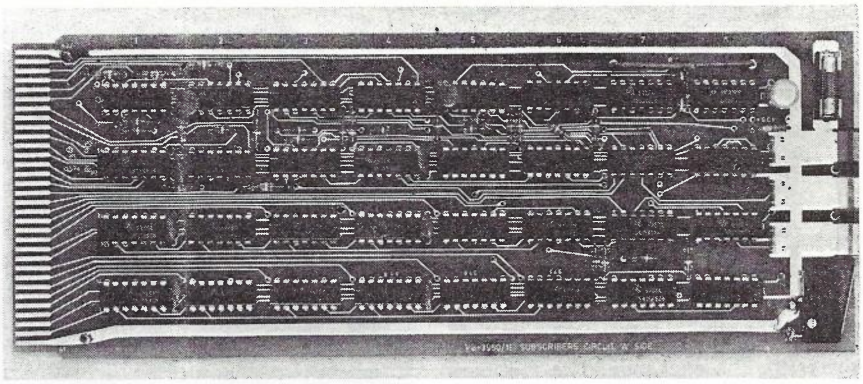


Fig. 17 — Subscribers Circuit Board Incorporating Time Division Switch.

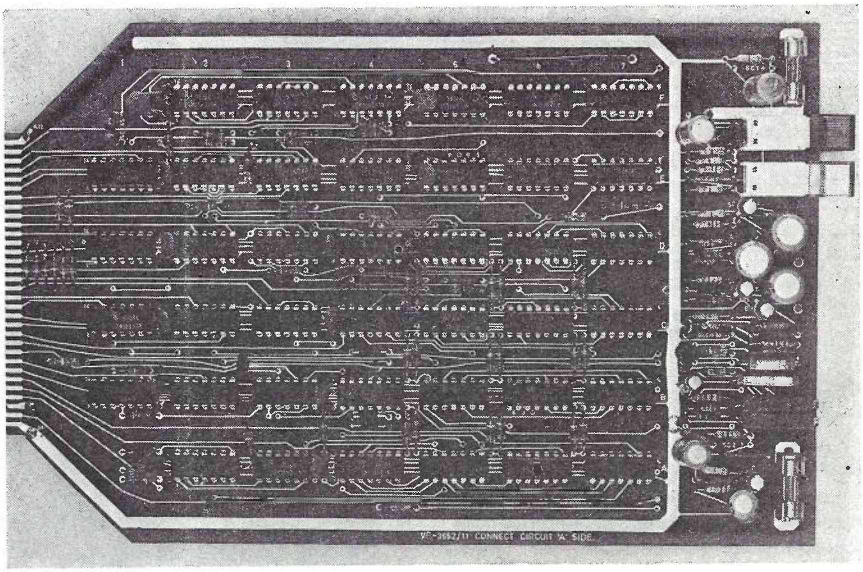


Fig. 18 — Connect Circuit Board.

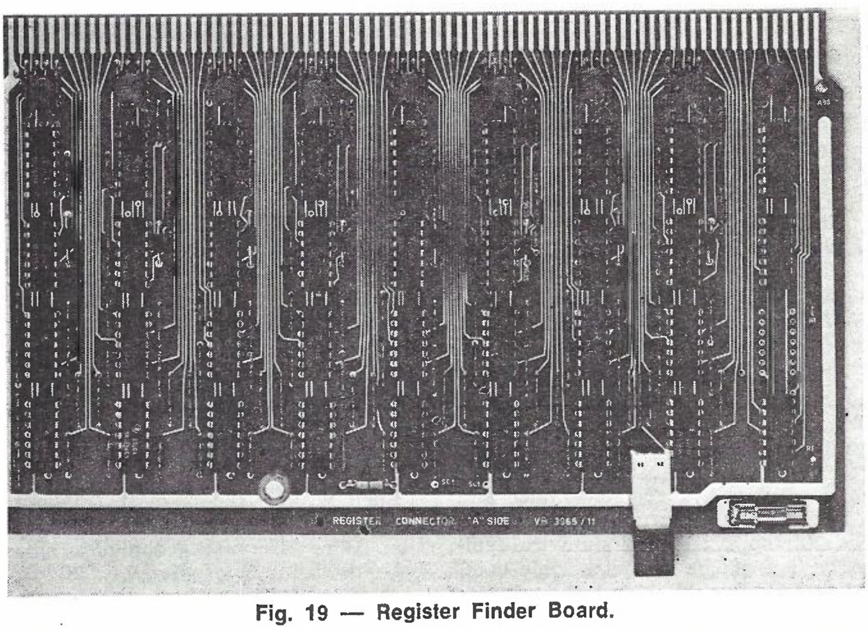


Fig. 19 — Register Finder Board.

controlled by the exchange since the transmitter cannot interpret the service codes "GA", etc., as an operator can. The connect circuit sends this information via the transmitter control hub to the subscribers circuit and from there via an additional line isolating circuit to the subscriber.

POWER SUPPLY.

Two 200 ampere 5.7 volt rectifiers mounted on a 19 inch rack supply power for the exchange. The rectifiers are provided with automatic change over and have automatic supply change over from "no-break" to "emergency" A.C. supply. The operating rectifier feeds through a choke filter system and has a 45 ampere hour nickel cadmium battery across the output. Voltage control is effected with transducers in the rectifiers. Interference via the power supply is minimised by a 16,000 μF capacitor across the rack busbars, 50 μF capacitors on each board across the power supply and further 0.01 μF capacitors along each rail feeding logic components.

CONSTRUCTION.

A front view of the exchange is shown in Fig. 1. The cabinet doors are open and shelves 10 to 14 are not fitted. Only a few circuit boards are shown in the rack.

Each shelf holds 66 printed circuit cards and 15 shelves are arranged in the following manner:—

Shelf 1	Line isolating Boards
Shelf 2	Subs. (60)
Shelf 3	Subs. (60)
Shelf 4	Subs. (60)
Shelf 5	Subs. (60)
Shelf 6	Subs. (60)
Control Panel	
Subs. Jacks	
Shelf 7	Connect Circuits
Shelf 8	Registers Finders
Shelf 9	Registers, Markers, etc.
Shelf 10	Subs. (60)
Shelf 11	Subs. (60)
Shelf 12	Subs. (60)
Shelf 13	Subs. (60)
Shelf 14	Subs. (60)
Shelf 15	Line Isolate

The printed circuit boards used are double sided, through-hole plated, gold plated boards with contacts etched on both sides at one tenth inch spacing. Fig. 17 shows a subscribers board. A connect circuit, a register finder and a register are shown in Figs. 18, 19 and 20 respectively and show the typical layout of the flat pack logic component blocks. All circuit boards for this rack are plugged into "Cannon Varistrip" edge connectors of 64, 88 or 160 pins. Fig. 21 shows a front view of the connect circuit shelf and register finder shelf. The Cannon connectors can be seen better in the vacant positions.

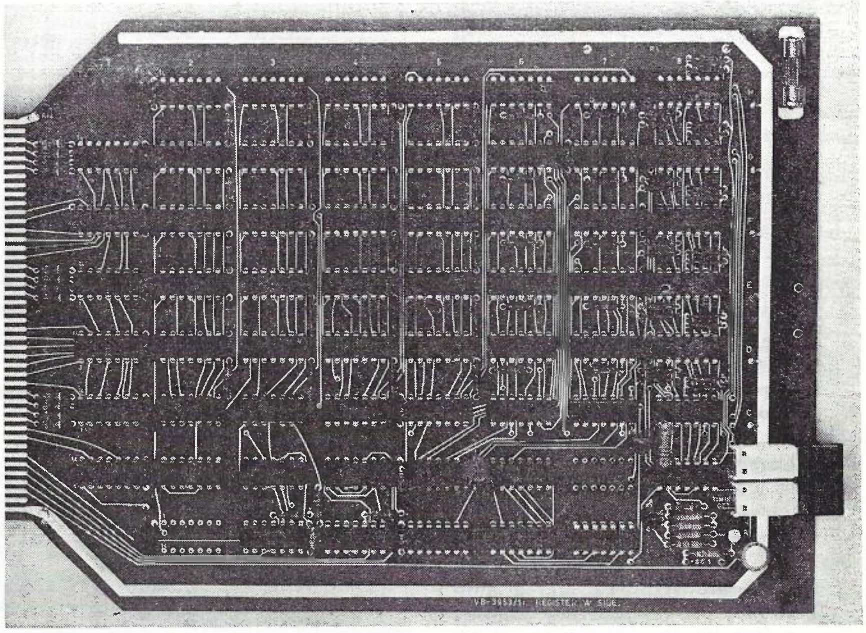


Fig. 20 — Register Board.

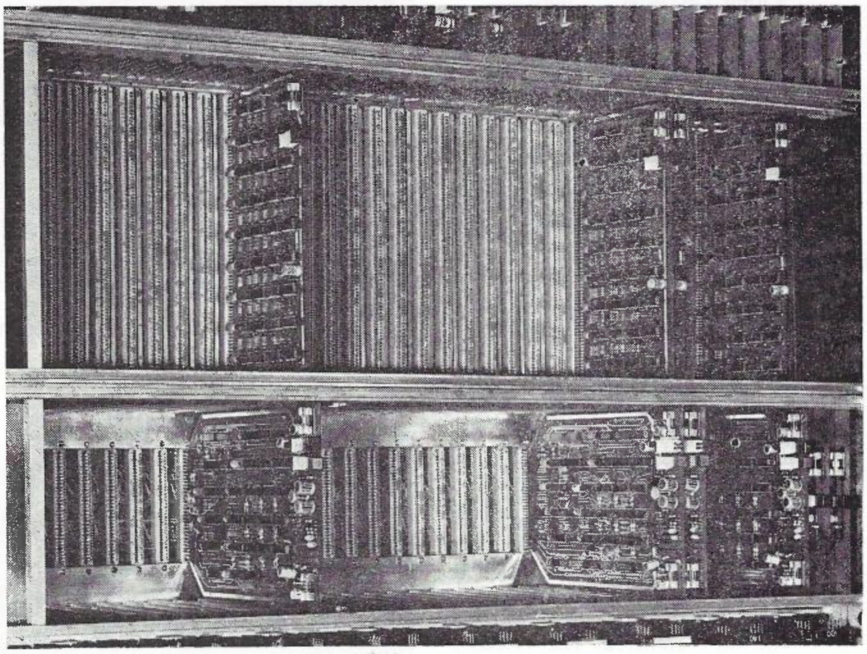


Fig. 21 — Front View of Connect Circuit Shelf.

Shelf wiring is done with 0.25 mm copper with 0.05 mm Teflon insulation. Wire wrapping techniques have been used for approximately 90 per cent of the wiring. There were approximately 150,000 terminations to be made in the rack wiring and most of these were on tag pins spaced at one tenth inch. The spacing made it essential to use wire wrapping and the technique has proved to be very successful in this case.

Each subscriber receive line passes through a line filter to reduce interference to adjacent telephone lines in underground cable. The filters have been card mounted with 40 circuits per card, and are mounted in a cradle

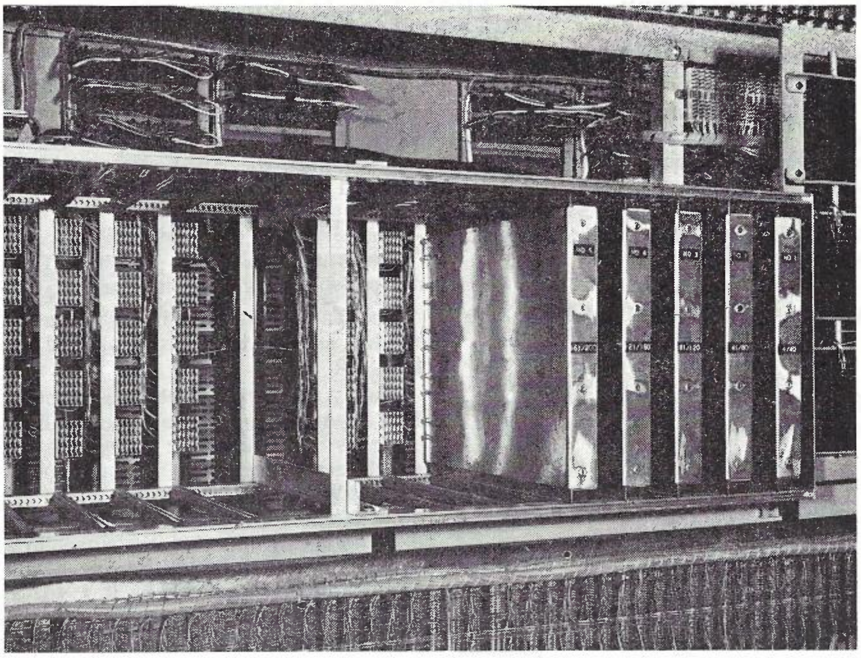


Fig. 22 — Line Filter Boards in Shielded Casing.

at the rear of the rack. Fig. 22 shows this.

The shelves were made by R.C.A. in Melbourne and use I.C.E.P. guides and guide rails. Shelves for subscribers cards are plugged into the rack as required.

CONCLUSION.

Use of micro logic circuitry for such a project has indicated that initial costs, maintenance costs, space and current drain can all be reduced substantially with this circuitry. The exchange is in service and is operating satisfactorily but since it was necessary to make the prototype the final product, there are a number of features about it which could be improved.

Long single wire connections have been given resistive and capacitor loading to reduce interference below switching voltage. In many instances the length of these lines could have been reduced by different rack design, and for those which could not be shortened, conjugate output devices with twisted pair or small co-axial wiring would be preferable to single gate or buffer output and single wire lead.

Critical equipment such as the pulse generator and the service code generator have been duplicated on the rack with automatic changeover, but circuitry to permit this becomes in itself a critical fault hazard and the whole philosophy of duplication for security is somewhat in doubt for this type of circuitry since inherent equipment reliability is such that duplication of critical equipment may not be necessary.

For this exchange the design concept of allocation of a time slot to the connect circuit, and location of the switch in a subscribers circuit, is particularly appropriate since it facilitates the conference facilities necessary for the traffic to be handled. The design has drawbacks of introducing inherent distortion and requiring a high sampling or pulsing rate, which in turn makes rack design more difficult in limiting interference from capacitive and inductive coupling. A balance between these two had to be struck.

However, the design and construction of such an exchange has provided experience which will lead to improved versions both in design and physical construction applicable to telegraph or data switching.

ACKNOWLEDGEMENTS.

The author acknowledges the substantial contribution to design, building, testing and commissioning of this exchange from officers of Telegraph Installation Victoria, Drafting Section Victoria, and the Victorian Postal Workshops.

THE COMMISSIONING AND MAINTENANCE OF ARM EXCHANGES (PART 3)

C. E. F. FLETCHER, A.R.M.I.T. and E. A. LIUBINAS, A.R.M.I.T., M.I.E. (Aust.)***

INTRODUCTION.

Part 1 of this article, which appeared in Vol. 21, No. 2 (June 1971), of this Journal, described commissioning tests and procedures for the common control equipment, switching stages, registers and analysers in the ARM exchange.

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Part 2, which appeared in Vol. 21, No. 3 (October 1971), described incoming circuits and tariff equipment and outgoing circuits.

Part 3 in this issue describes services aids and the maintenance of ARM exchanges.

A MAINTENANCE PLAN FOR ARM EXCHANGES.

To facilitate efficient maintenance of this highly complex switching machine, testing has to be supplemented by automatic surveillance devices, with all of it constituting an overall maintenance plan for ARM exchanges, as outlined in Fig. 68.

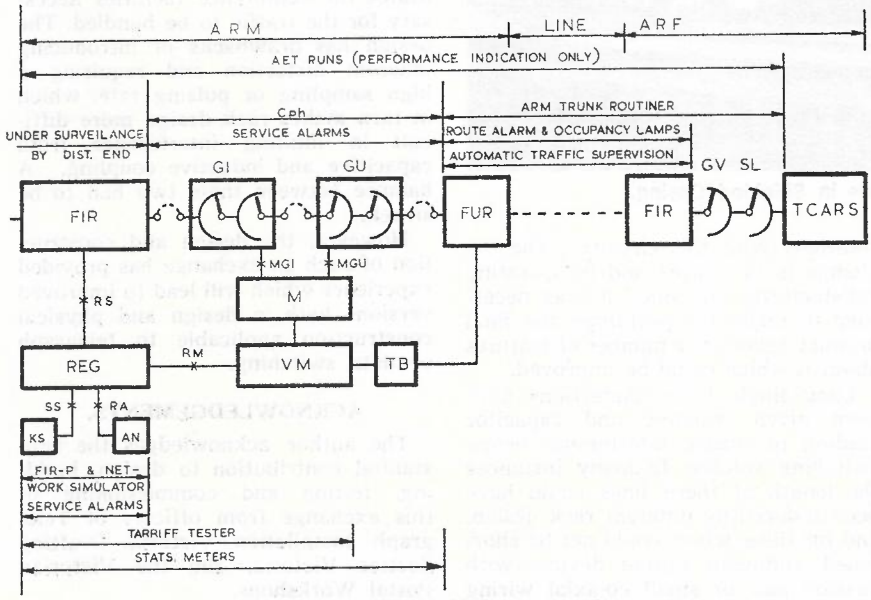


Fig. 68 — ARM 20 Maintenance Plan.

Routine Test Devices.

The Automatic Trunk Routiner: This device was explained in Part 2.

The Tariff Tester: The functioning of this service aid was explained in Part 2.

The Automatic Exchange Tester: The automatic exchange tester (AET) contains all equipment necessary to simulate various items of equipment as follows (see Fig. 69):—

— When testing in the FIR mode, distant originating exchanges are simulated and calls can be originated through the ARM to a distant destination.

— When testing in the FUR mode, the ARM is simulated and signalling forward to the next traffic point is possible.

— Access to both sides of the FUR is possible in the "FUR only" mode and here the ARM as well as the distant terminating end are simulated. The FUR can thus be put through a functional routine, i.e. pick-up, answer, clear back, repeat.

Fig. 70 shows the photograph of an ARM exchange tester with some of the equipment mounted on it. To assess the performance of the ARM switching machine AET test runs are originated from selected FIR's in the ARM to TCARS in distant exchanges,

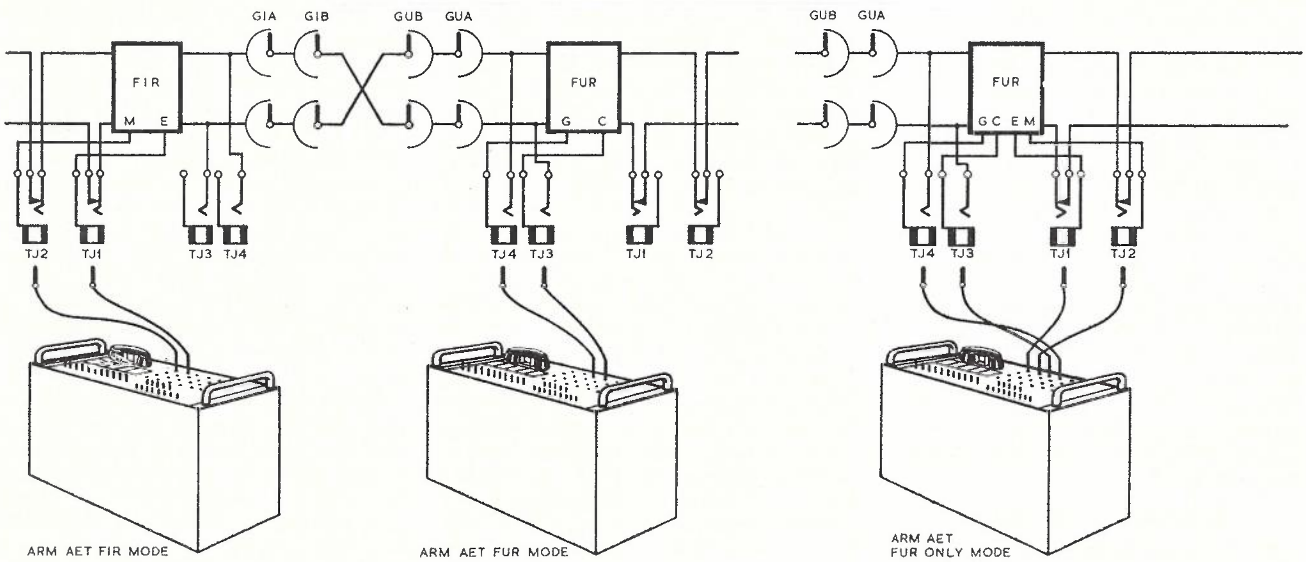


Fig. 69 — Connection of ARM A.E.T.

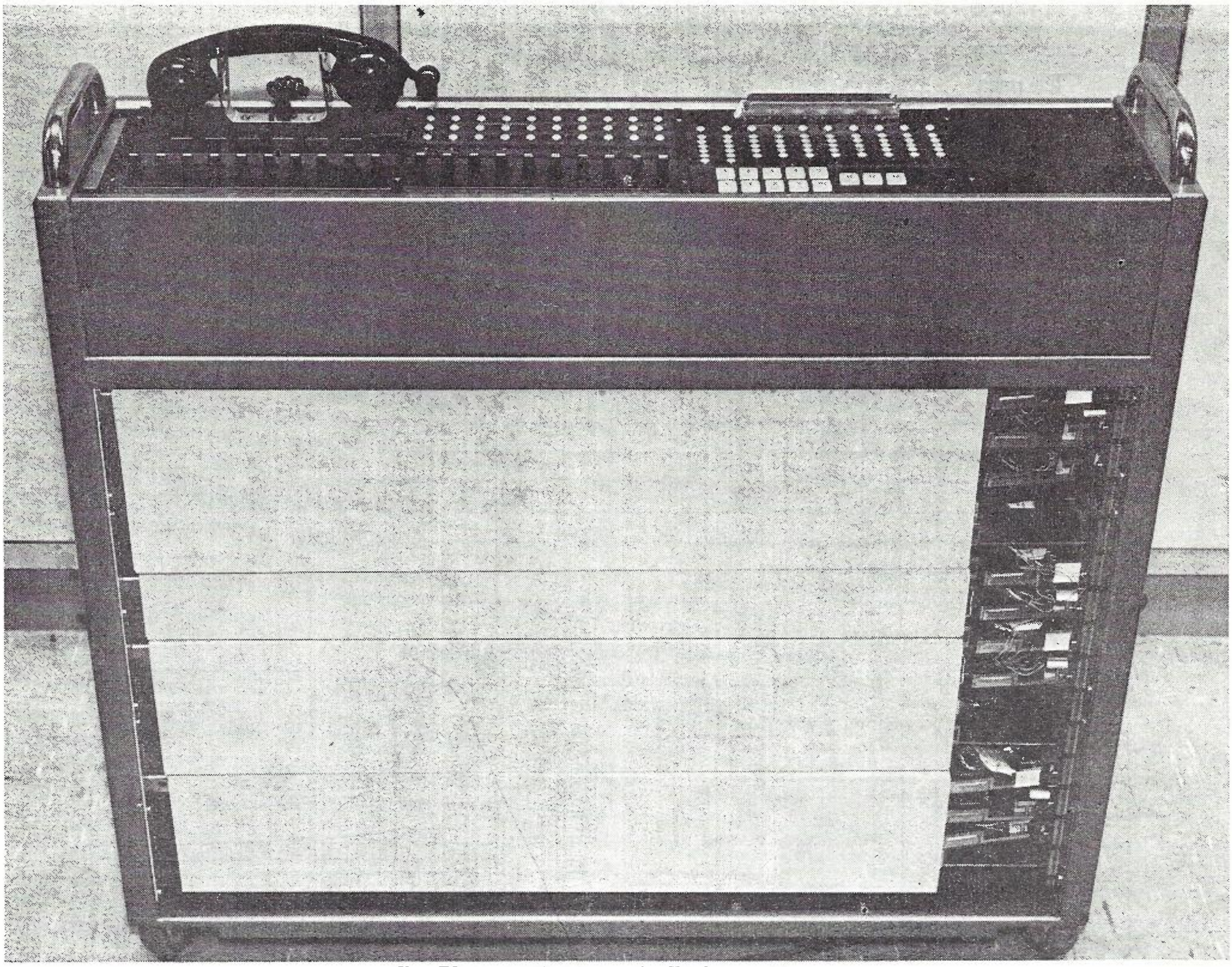


Fig. 70 — ARM Automatic Exchange Tester.

with statistical meters on the AET providing such data as:—

- Number of calls made.
- Number of failures.
- Number of KS time releases.
- Number of busy signals encountered.
- Number of congestion signals encountered.

The effectiveness of the tester has been further enhanced by a modification including a tuned service tone detector, so that whereas previously a busy TCARS was recorded as a failure with the service tone detector the "busy" meter is operated instead. After a run of say 200 test calls the percentage rate of failure and congestion can be calculated to give an indication of the performance of the particular ARM exchange and outgoing route under test.

Supervisory Equipment.

Fig. 71 is a schematic representation of supervisory equipment provided in the ARM. The method of presentation is an adaption from an article on maintenance of ARF exchanges published in Ericsson Review (Ref. 8), and details which items of the ARM switching equipment are supervised by the various alarm and recording systems.

The Service Alarm System: Each item of common control equipment, and even some of their subsidiary units, are placed under time supervision at various stages when a call is being established. Each time a "time-out" occurs a pulse is transmitted to a "fault" lead, and the service alarm equipment counts the number of fault pulses (DL relay set) and the number of seizures of the devices (NR relay set) (see Fig. 72). The DL relay set circuit consists of a simple relay counting chain R1-R12, which counts positive pulses received in binary fashion. Appropriate strappings of the R1-R12 contacts will cause R13 (A2 alarm) and R14 (A1 alarm) to operate. The NR relay sets consist mainly of a Hengstler Isameter and a few associated relays. The Isameter can be pre-set to a specific count after which a make contact closes to operate relay N1. N1 operates N2 which releases N1 slowly and operates N3. With N1 and N2 operated the Isameter is re-set to its original pre-set count. N3 disconnects holding positive from the counting chains of the associated DL circuits. If the fault count pre-strapped in a particular DL is not reached when the associated NR re-sets the counting chain, no indication is given. However, when the ratio of faults to seizures exceeds a certain percentage an A2, or later an A1, alarm is initiated.

An A2 alarm can be released by operating the appropriate key on the service control rack and the operation of this key also steps the DL circuit on one step to ensure that if no further fault pulses are received the A2 alarm is in fact released. Should an A1 alarm (R14 operated) occur, then the alarm

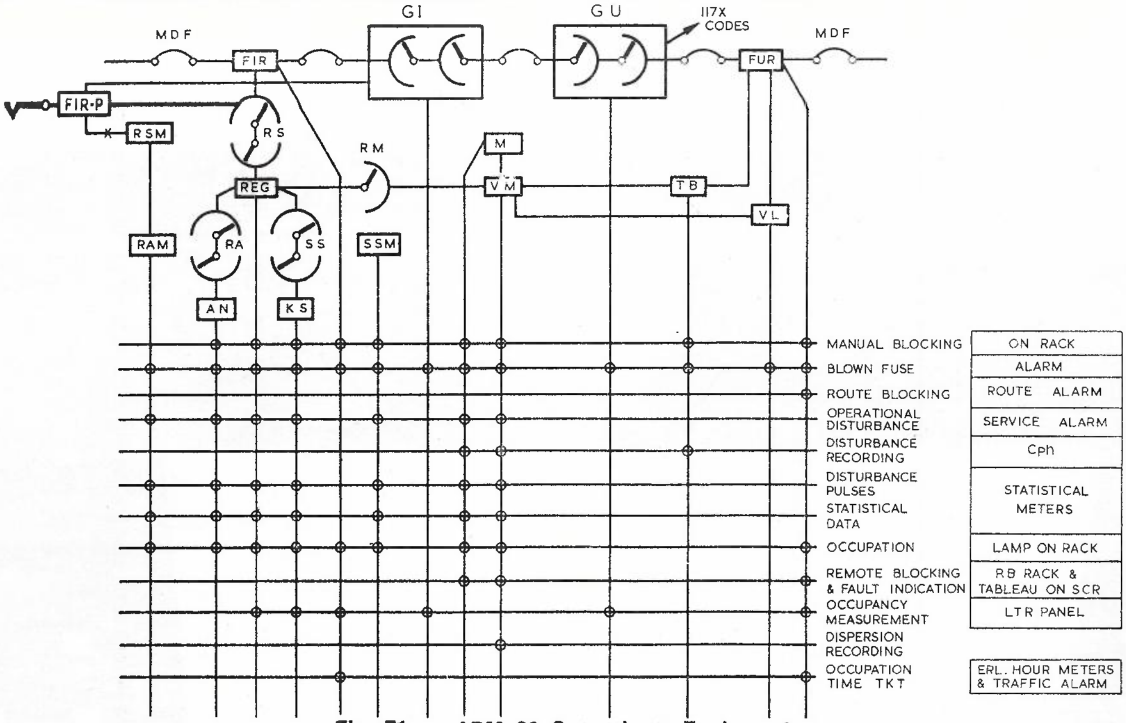


Fig. 71 — ARM 20 Supervisory Equipment.

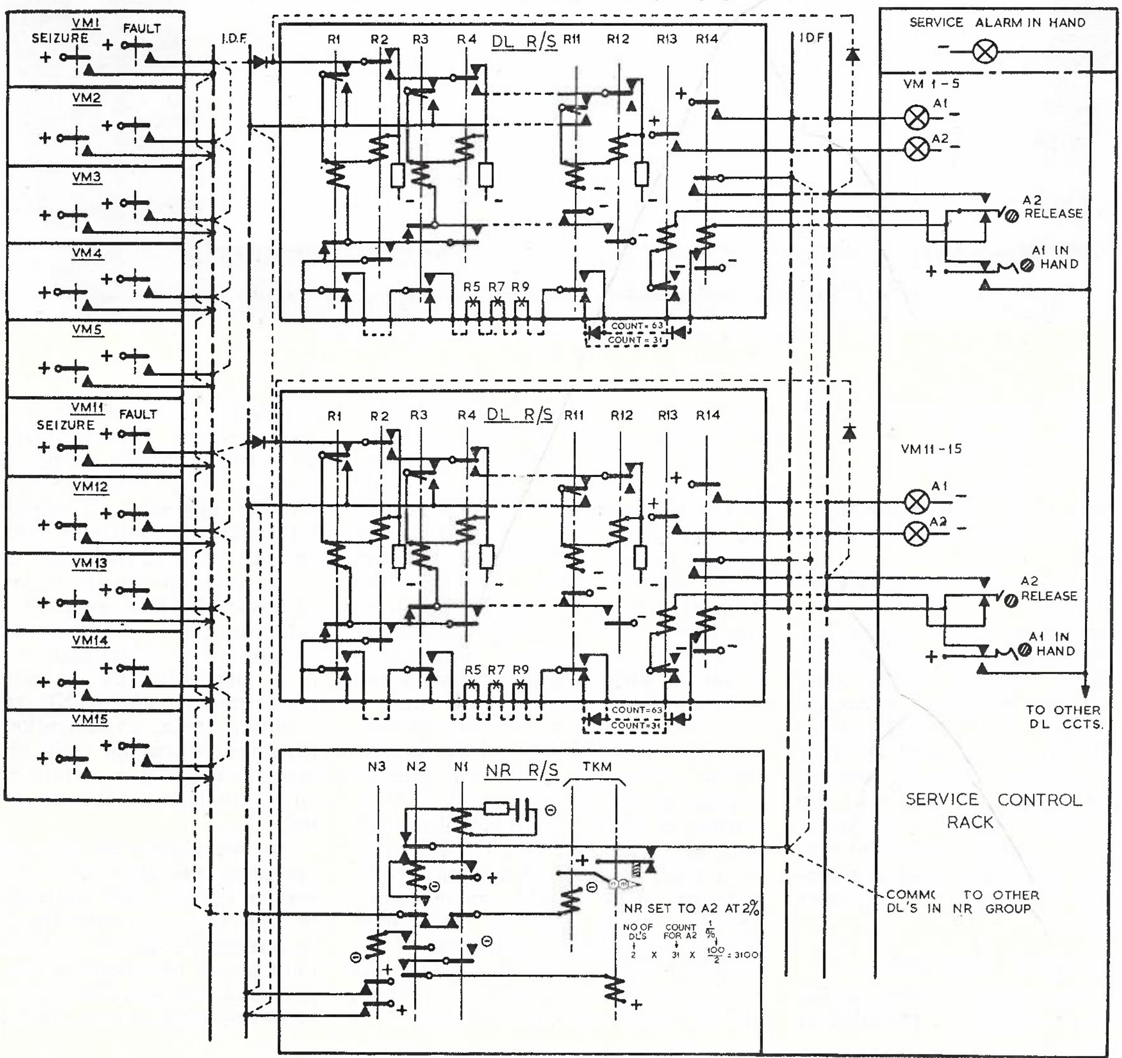


Fig. 72 — Service Alarm Survey.

condition should be investigated and the "A1 in hand" key operated. The A2 release key will re-set the associated NR via R14 operated.

Line Signalling and Register Time Supervision: During the progress of a connection, the various interworking items of signalling equipment, i.e. Line Relay Sets and Registers, are placed under time supervision as shown in Fig. 73.

Time supervision periods applicable to the various relay sets are as follows:—

— *Line Signalling Time and Fault Supervision*

A. Time out before answer for crossbar. B3 (MFC signal) disconnects time out on call to step number.

B. Time out after B party clear.

C. B party clears — FUR-L releases after 72-144 seconds in case forward clearing fails.

D. Circuit seized — line signalling fails during call set up or call clearing — when calling end clears circuit is blocked and checked for pick up and release every 72-144 secs. until it comes clear.

E. Circuit blocked when junction guard relay releases. (A.P.O. drawing). CE-11256 relay set includes SOB detection on local side; call is disconnected and caller gets busy tone.

Register Time Out (15-45 secs.) (H1, H2, Y1, Y2) — Provides supervision of overall time register is engaged and checks —

(a) Register seized and no digits or insufficient digits received,

(b) No end of selection sequence, i.e. A3+B signal not received.

Normally all registers on line at the time would time out and —

(a) ARF caller gets busy from REG-L time out.

(b) Step caller gets busy from FIR-ZL or FUR-T (forced release from FIR-ZT) when REG-H2 releases.

— *Register Initiates Congestion Signal*: Regs. H1, Y1 send back A3+B4 to initiate busy to caller; Regs. H2, Y2 initiate busy tone from FIR-ZL or FUR-T when FIR-ZT sends back forced release.

Caused by:

(a) Fault condition recognised in VM, M.

(b) Congestion in switching stage or on o/g route.

(c) Premature reversal received on any digit (NLK) or prior to 4th digit for NLU on decadic outpulsing.

(d) Forward MFC signal not removed after 7-14 secs.

(e) REG-Y1 only — Time to call and occupy VM exceeds 4-10 secs.

— *Voice Announcement re VM Overload*: Regs. H1, H2, Y2. Time to call and occupy VM exceeds 4-10 secs. Reg. gives VA for 45-75 secs. followed by register time out as above.

— *Reg-L 45 sec. Overall Time Supervision* from seizure to receipt of B signals.

If any of these time out conditions become effective, service alarms (see above) or route alarms (see below) are operated.

Route Alarms: Similar to ARF exchanges, each ARM FUR connects a 9.6K ohm negative to a route alarm lead common with each route alarm lead connected to a WL element in a route alarm relay set.

Fig. 74 shows a survey diagram of the route alarm system, as improved by maintenance staff at Haymarket ARM, to provide the following facilities:—

— An indication is given if one or more FUR's on the route are blocked, but the number is insufficient to bring in a route alarm. (Lamp on Service Control Rack is at half glow.)

— A route alarm is initiated if a pre-strapped percentage of FUR's on the route are blocked. (Lamp lights at full glow.)

— The alarm can be placed "in hand" by operating the associated magnetically locking key on the service control rack, while remedial action is undertaken.

— When the number of blockings has been reduced to below the alarm level, the system is automatically re-set.

If a particular FUR is blocked, the negative on the route alarm lead will operate WL1. WL1 will light the lamp in the route alarm key to half glow, indicating that a blocking exists but that the pre-set alarm level has not been exceeded. If 33% of the FUR's are blocked, WL2 operates and an interaction cycle is set up. WL2 energises the thermal relay TK3 via K1 normal which, after a delay, operates K1. With K1 operated K2 operates, and after TK3 has cooled sufficiently, K1 is force-released. K2 remains locked to WL2. With K1 released and K2 operated, K3 operates and locks to WL2. K3 emits an A2 alarm. K3 and WL2 operated light the lamp in the route alarm key brightly. When the alarm is identified, it can be put in hand by operating the key on the service control rack. The key will lock to WL2, and K2, K3, etc. are released. The lamp in the key is con-

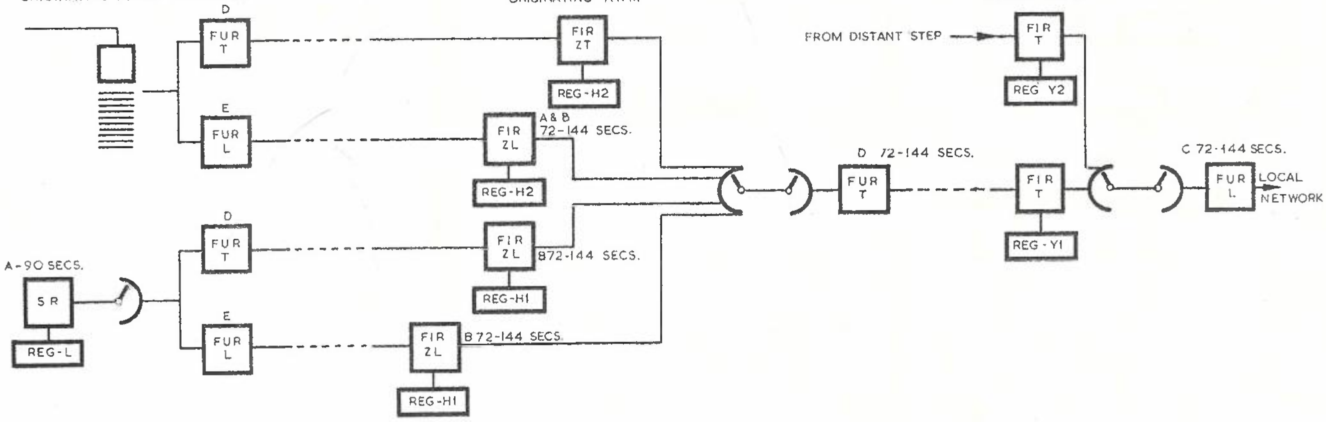


Fig. 73 — Line Signalling and Register Time Supervision.

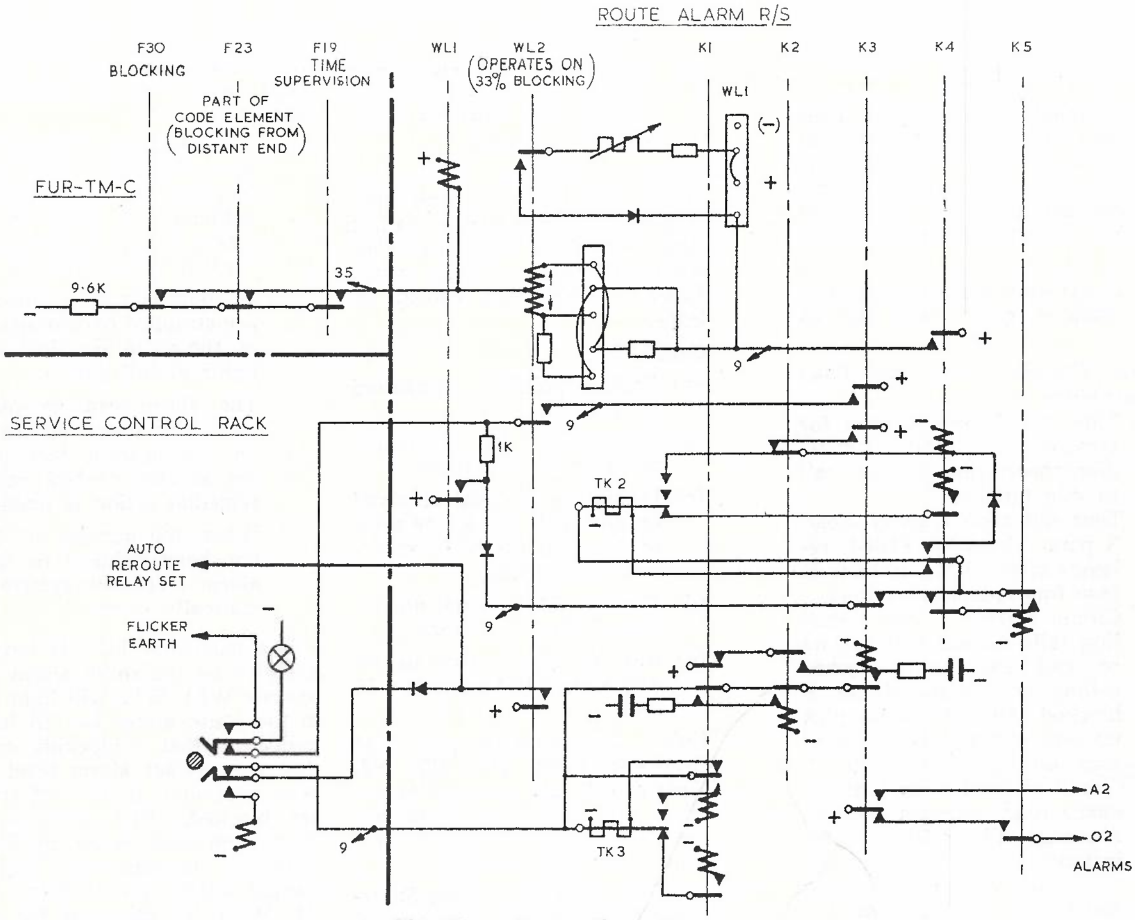


Fig. 74 — Route Alarm Survey.

nected to flicker earth and flashes until the key restores. WL2 also signals the route alarm condition to the auto re-route relay set for possible voice announcement connection (see below). With WL2 operated an opposing bias is connected to the WL2 coil circuit, and if the number of FUR blockings reduce to below the alarm level WL2 will release. When this occurs the magnet in the route alarm key is de-energised and the circuit restores to normal. By installing the trunk circuit supervision racks in close proximity to the route alarm panel, the actual lines blocked in the event of a route alarm can be immediately identified, and conclusions can immediately be drawn in regard to whether a broad-band bearer or radio system have failed.

Automatic Re-routing to Recorded Announcement: If a major route failure occurs, resulting in most lines to a particular centre being blocked, an avalanche effect can occur if normal congestion indication is returned to calling subscribers, as subscribers receiving busy tone will hang up and immediately attempt another call. Meanwhile other subscribers are trying to reach the centre for the first time and receive congestion, and so the number of calls waiting for service in the ARM increases sharply. More and more register equipment is taken into use in unsuccessful attempts to call the failed route, and eventually the stage is reached where no registers are available to process calls to centres which can be reached, with the whole exchange tied up in serious congestion. To overcome this, voice announcement outlets are provided to which the subscribers calling to an area where a major failure has occurred, are switched advising them to delay their calls until later.

Fig. 75 explains how this automatic re-routing to voice announcement takes place. In the example, there are two routes to Sydney, both of which have failed. As all FUR's are blocked, the associated VL relays are released and route markers cannot establish a connection to these routes. The VL relays for the backbone route connect 1 second pulses (congestion meter pulses) to the auto re-routing relay set thus operating one of relays VL1-80. This relay will lock and a test is made every 10 seconds whether the congestion condition still exists. As all FUR's on the two routes are blocked, a route alarm will occur, and the particular WL2-20 relay operated in the route alarm relay set will operate one of relays RA1-80 in the auto re-routing relay set as described above in Route Alarms. Thus with a route alarm existing on a congested route a negative will be extended to operate one of relays R41-R45 in a particular VR relay set in all route markers and the lamp in the re-route key for the Sydney route on the service control rack will light to indicate this condition. If a call is now originated to code 02, the VR for the first choice route to Sydney will operate first, followed by VR of the backbone route, and then the recorded voice announcement VR via R41. The last VR will operate R38 in VMR, indicating that all VR's are operated. As there are FUR-S relay sets available on the announcement route, the associated VL relays will be operated, and the call will thus overflow from the Sydney routes to the voice announcement advising the subscriber to hang up and delay his call until later. As soon as the congestion or the route alarm condition

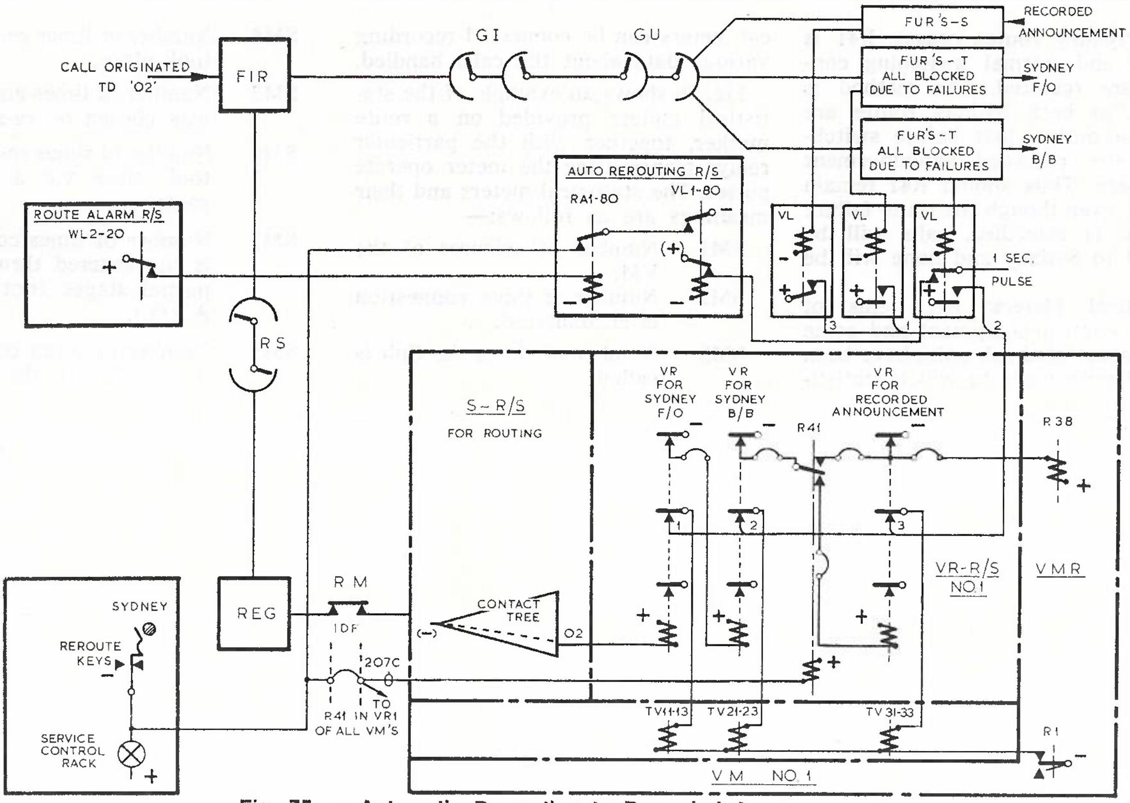


Fig. 75 — Automatic Re-routing to Recorded Announcement.

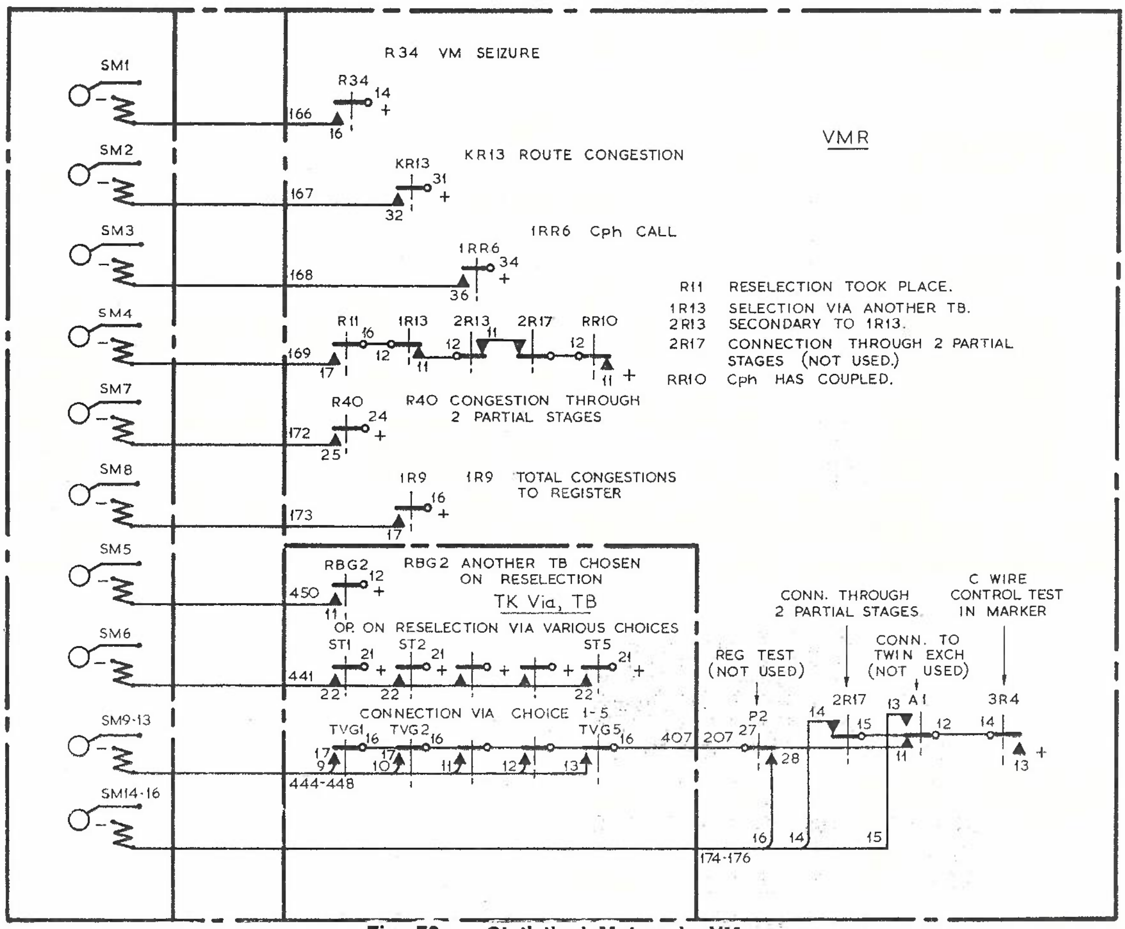


Fig. 76 — Statistical Meters in VM.

on the Sydney routes ceases, R41 is released and normal switching conditions are restored. The method is fail-safe, as both Sydney routes are tested for outlets first before switching to the recorded announcement takes place. Thus should R41 remain operated, even though the route failure condition is remedied, calls will be switched to Sydney and none will be lost.

Statistical Meters: All items of common control equipment and some of their associated sub-units have been provided with leads to which statistical meters can be connected recording various data about the calls handled.

Fig. 76 shows an example of the statistical meters provided on a route marker, together with the particular relays transmitting the meter operate pulses. The statistical meters and their meanings are as follows:—

- SM1 Number of seizures of the VM.
- SM2 Number of times congestion is encountered.
- SM3 Number of times the Cph is called.
- SM4 Number of times re-selection took place.
- SM5 Number of times another TB was chosen on re-selection.
- SM6 Number of times re-selection took place via a different route.
- SM7 Number of times congestion is encountered through two partial stages (not used in A.P.O.).
- SM8 Number of times congestion is signalled to the register.

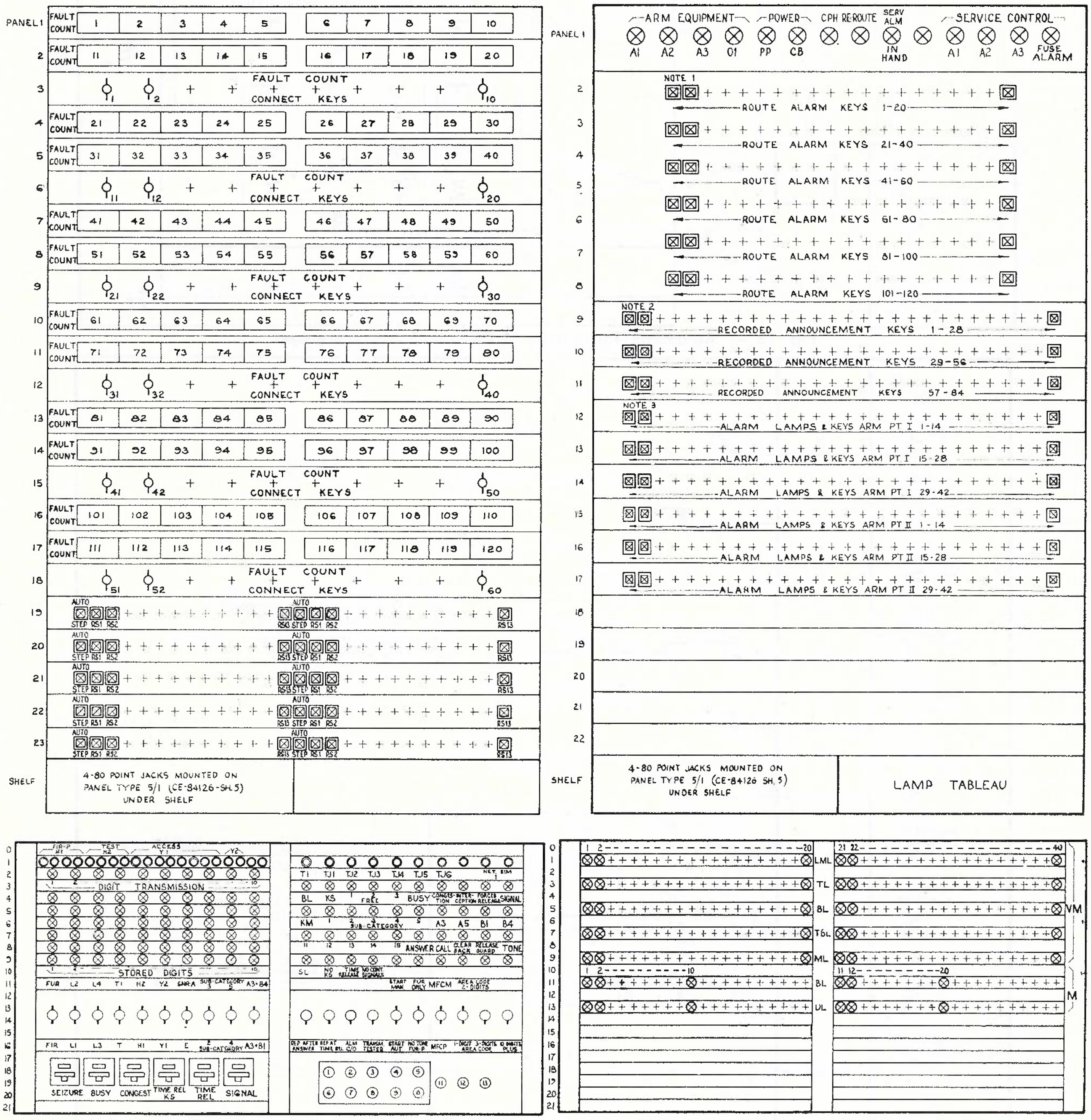


Fig. 77 — Layout of Service Control Racks for Lonsdale 'A' ARM.

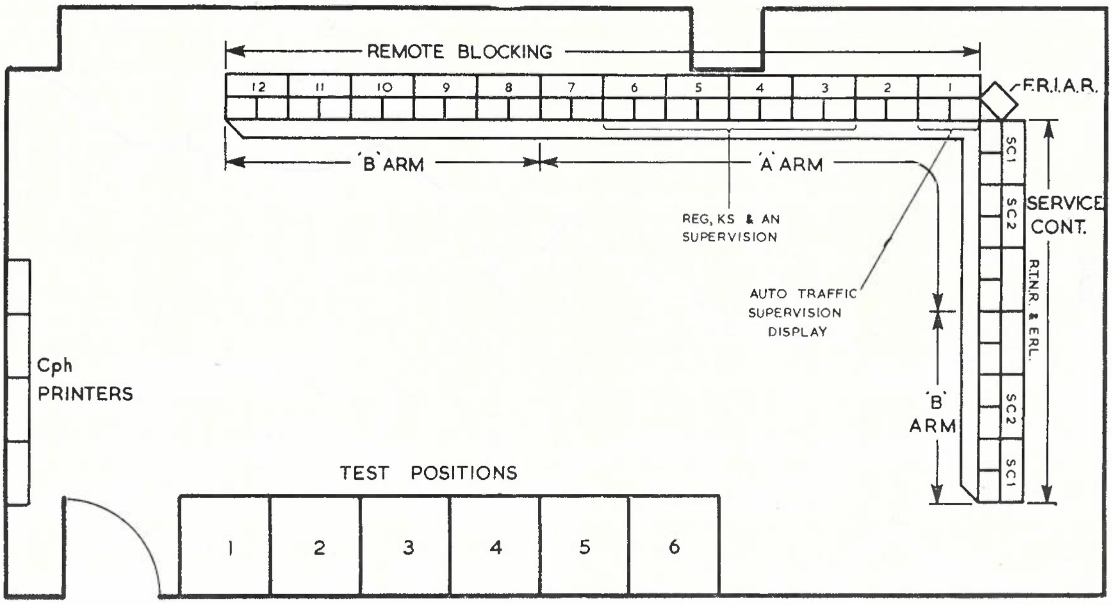


Fig. 78 — Floor Layout of Lonsdale Service Control Room.

SM9	Number of times the call is routed via the first choice route.
SM10	Number of times the call is routed via the second choice route.
SM11	Number of times the call is routed via the third choice route.
SM12	Number of times the call is routed via the fourth choice route.
SM13	Number of times the call is routed via the fifth choice route.
SM14	Number of times a call was completed via 2 partial stages (not used in A.P.O.).
SM15	Number of times connection is established via a twin exchange (not used in A.P.O.).
SM16	Number of times a register test is performed (not used in A.P.O.).

Readings obtained from these meters provide the exchange staff with indications regarding the area of a malfunction and an efficient analysis of the statistical indicators is invaluable in the maintenance of an ARM exchange. For example, percentage route congestion can be obtained from the formula—

$$\% \text{ Congestion} = \frac{SM2}{SM1} \times \frac{100}{1}$$

Percentage calls lost can be found:

$$\% \text{ Tech. Loss} = \frac{SM8\text{-}SM2}{SM1} \times \frac{100}{1}$$

The percentage of calls requiring the Centralograph can be found from —

$$\% \text{ Cph} = \frac{SM3}{SM1} \times \frac{100}{1}$$

Many other statistical data can be obtained from these meters; if for example route congestion percentages on a particular VM are much higher than those on other VM's, circuit elements in the TK-VIA relay set may be faulty.

Particular KSR's may have a higher time-out rate than others due to some fault condition.

Service Control Racks: Fig. 77 shows the layout of the two service control racks provided at the Lonsdale "A" ARM exchange. The rack at the left largely contains the re-settable statistical meters which can be connected by means of keys to all route markers with 20 meters connected to a VM, and 10 to a marker. Below the counters are situated the FIR-P-RS selection keys. The jack box has been equipped with the control panel of an AET, with its relay sets mounted on a miscellaneous rack. Register testing is normally carried out by this AET.

The rack on the right contains the route alarm key panel, then the re-route to recorded announcement keys, and finally the keys associated with service alarms. The jack box contains a lamp display extended from each route marker and progress of any call through the exchange can be observed on this display, giving an immediate indication of route markers or markers out of service or not receiving any calls due to faulty allotters, etc. Another rack, not shown, contains an erlang meter panel and the control panels for the three automatic routiners.

Fig. 78 gives the floor layout of the Lonsdale Service Control Room designed to service two ARM exchanges. It will be noted that the equipment in the room has been kept to a minimum by installing only the remote display and control equipment, with the rest of the equipment located in the ARM switching area.

SUMMARY OF MAINTENANCE EXPERIENCE AT NORTH MELBOURNE ARM

The North Melbourne ARM was placed into service during December, 1968, and the experience gained since then helped to establish some of the procedures and methods described previously.

Fig. 79 shows the relationship between total number of calls handled, number of faults found, percentage technical loss and percentage calls to the Centralograph, since May, 1969. It shows that, despite rising numbers of calls and additional equipment installation, the numbers of faults found remained relatively constant. Technical loss and calls to Cph reduced from an initially high figure to an acceptable low level.

Fault Analysis.

The faults found during this period are tabulated on Table 5 under the four main headings discussed previously.

As the relative proportions of equipments do not vary significantly with exchange size, the percentage stated can be taken as a guide for all exchanges. Clearly the most fault-prone area is the register complex, responsible for some 35% of the total number of

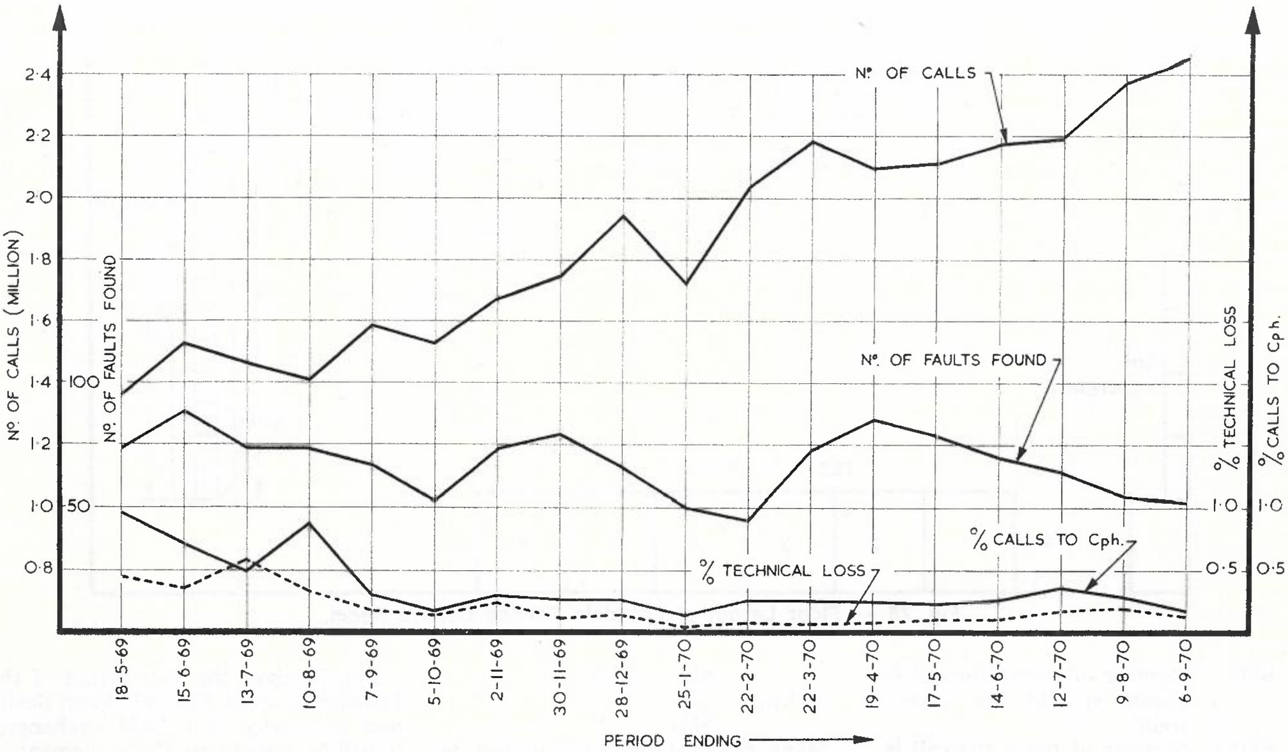


Fig. 79 — Performance Graph, North Melbourne ARM.

TABLE 5 — NORTH MELBOURNE ARM — FAULT ANALYSIS SUMMARY 21/4/69 TO 6/9/70.

Equipment	Total Faults		Method of Detection: Cph		Service & Route Alarms		A.E.T. Routines		NPAC		Reported		Stats. Meter & Chance Detection	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Common control Equipment and Switching Stages	250	23	177	71	9	3.6	23	9.2	2	0.8	12	4.8	27	10.8
Register Complex	385	35.4	34	8.8	67	17.4	142	36.9	4	1.0	26	6.8	112	29.1
Incoming Circuits and Tariff Equipment	230	21.1	14	6.1	26	11.3	54	23.5	2	0.9	78	33.9	56	24.3
Outgoing Circuits	223	20.5	10	4.5	48	21.5	98	43.9	6	2.7	11	4.9	50	22.4

faults. Routine testing is the main detection method, highlighting the need for the service testing procedures outlined previously in Part 1. Within the Common Control Complex the Cph is responsible for the detection of 71% of the faults, showing clearly the importance of efficient analysis in this area. Faults on incoming circuits are mainly reported by distant exchanges which agrees with the proposed maintenance plan as outlined previously. However, it should be noted that routine functional testing of FIR's (Auto Tariff Testing) also detects a substantial proportion of defects and supplements supervision by distant exchanges. Routine testing is the most important method for the maintenance of outgoing circuits, underlining the importance of the automatic Trunk Routiner, followed by Route Alarm as the next main detection method in this area.

Table 6 gives a detailed break up of faults found on the various equipments and the detection methods and indicates that overall the routine tests and the Centralograph Analysis are the most effective aids in maintaining the ARM system.

Transmission Testing.

Since October, 1969, automatic transmission tests by means of A.E.T. with attached A.T.T.U., as described in Outgoing Circuits, have been carried out. The tests have been scheduled so that each amplified and carrier circuit is tested once per week, with an average fault rate per test over a period of nine months as follows:—

Interstate circuits — 8.6%
Intrastate circuits — 3.1%

The introduction of automatic gain regulation equipment (Supergroup Pilots), with more frequent transmission tests using the automatic routiner, are expected to substantially reduce the percentages, so that the objective of 0.3% fault incidence may be achieved. In this case, the distribution of link losses would approach the normal curve with a standard deviation of 1 dB from nominal.

Recommended Testing Frequencies.

From the above discussion and the maintenance experience at North Melbourne ARM, the following testing frequencies are recommended:—

Register Testing should be scheduled so that all registers are tested on one working 'B' code per day.

Functional Testing of FIR's by means of the Automatic Tariff Tester should be carried out on every relay set once per month. FIR-TM-Y1 relay sets can be included provided the tariff tester has been modified.

Functional and Transmission Testing of Outgoing Circuits by means of the Automatic Trunk Routiner with Printer should be carried out once every 48 hours, with pad switching tested every fourth day. Where applicable, the "B" test to a P.L.M. should be carried out once every two weeks.

ARM Performance: To gauge the overall ARM Performance, an A.E.T. run of 200 calls should be directed to each outgoing route once per month. No remedial action should be taken during the course of this run, as otherwise the result will not reflect the true service performance.

Analysis of Indicators (Cph, Stats. Meters, etc.) should be continuous, with the meters read at least weekly.

CONCLUSION

The experience at North Melbourne ARM indicates that there is still some room for further integration of installation testing with service requirements. The installation testing aids developed to date have proved quite effective in reducing testing time and effort and have contributed to achieving an acceptable level of post-cutover fault incidence. The provision of built-in maintenance aids such as Cph and the statistical meters appear to be adequate in providing effective means for maintaining the common control equipment. However, as the majority of the maintenance effort has been found to be in the area of the inter-exchange network, additional maintenance aids are necessary.

This need is filled by the Automatic Trunk Routiner, T.C.A.R.S., P.L.M., etc., with emphasis on rapid transmission checks to test all circuits at frequent intervals as 19 out of 20 transmission faults at present are located in the carrier systems, including broadband bearers. However, the universal provision of Automatic Supergroup regulation equipment is expected to bring about a substantial improvement in link loss stability, with resultant savings in maintenance costs.

Some gains in productivity have also been achieved by modifying testing aids such as Automatic Tariff Tester and Exchange Tester, to enlarge their area of application.

The aim of the above discussion has been to integrate the available ARM installation and service experience, and to survey developments in the field of testing and maintenance aids,

TABLE 6 — DETAILED FAULT ANALYSIS 24/4/69 TO 6/9/70.

Equipment	Av. No. of Units	No. of Faults	Method of Detection: Cph	Service & Route Alarms	Routine Tests	NPAC	Reported by Technical Field Staff	Stat. Meters and Chance Detection
FIR	1079	215	14	17	54	2	78	51
RS	27	81	2	10	25	1	10	33
RM	3	3	1	1	—	—	1	—
Reg H1	25	53	10	7	18	—	3	15
Reg EHY2	44	130	16	20	55	2	—	37
Reg Y1	25	52	6	3	31	—	3	9
VM	10	121	83	4	16	1	7	10
M	7	21	9	2	1	—	—	9
TB	14	18	16	—	1	—	—	1
AN/SAN	6	36	—	19	2	—	10	5
RS-AN	2	12	—	6	3	—	—	3
GI-GU	14	85	66	2	5	1	4	7
GGI/GGU	8	2	2	—	—	—	—	—
MGI/MGU	3	—	—	—	—	—	—	—
FUR	1096	223	10	48	98	6	11	50
Pulse	—	15	—	9	—	—	1	5
KSR	27	21	—	2	8	1	—	10
Others	—	115	8	14	34	1	5	53
TOTAL No.		1203	243	164	351	15	132	298
			20.2%	13.6%	29.2%	1.2%	11.0%	24.8%
			Percent of Total Faults					

Av. No. of faults/month = 67

TABLE 7 — CIRCUIT REFERENCES

Equipment Item	Circuit Drawing	Description
ARM Link Tester	VX(A) - 1098/901	C.I.D. 187, Issue 2
Centralograph Equipment	CE(A) - 15180-85	E.I., Telephone, Exchanges, C7452; CID.94
VM, AN Strapping Tester	VX(A) - VX5769/11	V.124
REG-KV Strapping Tester	VX(A) - 5776/11	V.127
Register Test Rack	VX(A) - 1169/558 Sh.1-4	V.136
FIR-P Survey, M-wire Switching	VX(A) - 5762/10, 11	V.106
FIR Tester	VX(A) - VX5768/11	V.125
Tariff Tester (Modified)	VX(A) - 15300 - 306	E.I., Telephone, Exchanges, C7498
R/S ZS (Modified for Tariff Fault Print)	VX(A) - 15115	
FUR-P-TCARS	VX(A) - 5719	CID146
TCARS	CE-21005, CEA-21005	CID52
Network Simulator	VX(A) - 5734/11, 12	CID175
Self Answering Relay Set (Code 1174)	VX(A) - 5736/11	
ARM Test Access Equipment	VX(A) - 5720/11-24	CID184
Test Access Pre-selector	ND35672, ND32565	
Test Console Equipment	ND34442, ND32592/3 ND32575, ND34378	CID184
Automatic Trunk Routiner:		
Rack	VX(A) - 5755/11	V.135
Access Control	VX(A) - 5756/11-15	V.135
Test Unit	VX(A) - 5757/11-16	V.135
Control Panel	VX(A) - 5758/11, VB3698/10-37	V.135
Remote Blocking Facilities	VX5771/11, 12	
Automatic Exchange Tester (Modified)	VX(A) - 5765/11-15	E.I., Telephone, Exchanges, C7499
Automatic Transmission Test Unit	CE(A) - 21016	CID51
Automatic Traffic Supervision	VX1169/404	
Service Alarm System	CE(A) - 15292 - 3	CID169
Route Alarm System (Modified)	ND-37733, ND-36278	E.I., Telephone, Exchanges, C7012 (Part only)
Auto Re-route Relay Set	ND-38610, NG-32733	
Lonsdale Service Control Rack	VX-1169/442443	
Lonsdale Service Control Misc. Racks	VX-1169/551, 552, 559	
Statistical Meters	VX-1169/553	CID127
Routiner Control Rack	VB-3698/10-37	V.135
Lonsdale 'A' Floor Plan	VSK-X-1169/11	

Notes:
CID 187 means Crossbar Information Distribution Item No. 187, available from Victorian Design Co-ordination Group.
V.124 means Victorian Circuit Report No. 124, available from Victorian Design Co-ordination Group.

in order to present a co-ordinated approach to the commissioning and maintenance of the S.T.D. grid.

ACKNOWLEDGEMENT

The many valuable suggestions by the installation and maintenance staffs at Haymarket, North Melbourne and Lonsdale ARM's, as well as the initial work done by the Victorian ARM Design Co-ordination group, is gratefully acknowledged. The authors wish to express special thanks for the help rendered by officers of the Victorian Drafting Section in preparing the diagrams for this article.

REFERENCES

8. V. Eriksson, 'Equipments for Maintenance of ARF 102 Automatic Telephone Exchanges'; Ericsson Review No. 2, 1969.

FURTHER READING

Circuit Drawings and Descriptions

Table 7 gives the circuit drawing numbers of all installation and maintenance aids discussed in the article as well as details of any descriptions available.

Australian Post Office Internal Documents

1. **Headquarters Publications:**
   (a) ARM Commissioning Test Instructions, Issued 1967.
   (b) Technical Training Publication, HXM 006, "Survey Description — ARM 20 Exchanges (Telephone)".
   (c) Telephone Exchange Equipment Letter No. 12A, "Echo Suppressors in the National Trunk Network".
   (d) Telephone Equipment Section, ARM Maintenance Notes, Issued 1967.
2. **Victorian Administration Publications:**
   (a) Metro. Exchange Installation, Central Division, CID 272, "Pulse Test Guide".
   (b) C. Fletcher, Survey of Pad Switching—CID 28.
   (c) C. Fletcher, Transmission Testing Practices — CID 242.

Telecommunication Journal of Australia

C. Fletcher, "Automatic Trunk Transmission Testing"; Feb. 1965, Vol. 15, No. 1.

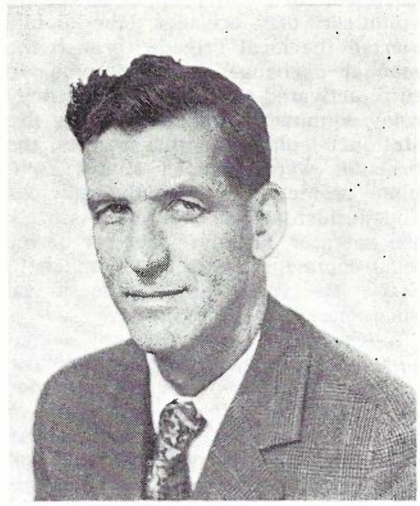
R. McCarthy, "The Establishment of an ARM Network in New South Wales"; Feb. 1968, Vol. 18, No. 1.

CHANGE OF EDITORS

Mr. V. J. White.

With regret the Council of the Telecommunications Society has accepted the resignation of Mr. Vern White, B.Sc., B.A., as Editor-in-Chief of this Journal. Vern succeeded Mr. N. M. MacDonald in this office in 1964, and the Society is appreciative of his fine work in maintaining a high standard for the Telecommunication Journal of Australia during his term of office. Vern has taken up duty as Assistant Secretary of the Training Branch in the Department of Labour and National Service, and the Council congratulates him on this promotion.

The new Editor-in-Chief is Mr. George Moot, M.I.E. (Aust.). George commenced his Departmental career in New South Wales as a Technician-in-Training in 1942, and after 4 years service as an Engineer Class 2 on Internal Plant Service, he was promoted to Engineer Class 3, Exchange Service at Headquarters in 1957. He is currently Supervising Engineer, Network Performance at Headquarters. He joined the Board of Editors as the Telephone Exchange Equipment representative in February, 1966.



Mr. G. Moot.

NEW DIRECTOR-GENERAL

The appointment of Mr. Eber Lane to the position of Director-General of Posts and Telegraphs was announced by the Minister the Honourable Sir Alan Hulme on 2nd December, 1971. He succeeds Sir John Knott, C.B.E.

Mr. Lane joined the Australian Post Office as a Telegraph Messenger in 1927. He spent the early part of his career in Queensland working in various areas of the Post Office. In 1954 he transferred to Tasmania where he was promoted to the position of Assistant Director (Telecommunications) and subsequently as Director, Posts and Telegraphs, Tasmania.

In the last 10 years Mr. Lane has occupied senior Administrative positions in the Post Office Headquarters in Melbourne, and as Director, Posts and Telegraphs in Queensland, and since last August, New South Wales.

Mr. Lane is married and has one son and two daughters.

The Board of Editors on the behalf of Telecommunications Society of Australia congratulate Mr. Lane on his new appointment, and we look forward to working with him in our capacity as editors of this Journal.

The Post Office has seen some big changes under Sir John Knott's leadership. No doubt the most significant are those associated with the introduction of Area Management and Engineering Restructuring as described elsewhere in this Journal. Another significant change was the establishment of an Industrial Relations Division at Headquarters.

The Board of Editors wish Sir John a long and happy retirement.

Mr. E. F. Lane, Director-General, Posts and Telegraphs, A.P.O.

NEW DIRECTOR FOR VICTORIA

We offer our congratulations to Mr. I. M. Gunn, M.B.E., on his appointment as Director, Victoria.

An outline of Mr. Gunn's career in the Department is given on Page 106 of the June, 1970, issue of this Journal, on the occasion of his appointment to the position of First Assistant Director-General, (Engineering Works) at Headquarters. More recently Mr. Gunn has been detached from normal duties to assist in the investigations into the re-organisation of the Department's telecommunication activities reported in this issue of the Journal.

On behalf of all readers the Board of Editors wish Mr. Gunn well in his new appointment.

FIRE REPORTING SYSTEM FOR VOLUNTEER FIRE BRIGADES

S. E. JELLEY and R. NELDER***

INTRODUCTION

Prior to the advent of automatic telephony to country areas served by volunteer fire brigades, the public alerted the local brigade through the manual exchange operator, who, in turn, activated the fire alarm siren by relay equipment connected to the fire station telephone. In this manner, the brigades were afforded almost complete protection from both malicious and accidental false alarms. As well, the operator, usually a member of the local community herself, did much to assist the volunteer brigade in an emergency.

When the telephone system is converted from manual to automatic operation, major problems arise for the volunteer brigades to ensure a prompt response to a genuine alarm call, and to prevent malicious and accidental false alarms from activating the siren alarm. Of course, if unchecked, these false alarms will seriously undermine both membership and morale of the brigade. Subscribers' dialling errors in using the S.T.D. facility contribute to these false alarms.

INTERIM SYSTEMS

Many and varied arrangements have been devised in automatic exchange areas to satisfactorily replace the functions performed for the volunteer fire brigades by the manual exchange operators.

A typical arrangement provided interception facilities by a system of intermediate telephones (generator signalling) and outdoor extensions, connected from point to point at the premises of volunteer firemen and terminating at a telephone and the siren control equipment at the unmanned fire station. To alert the brigade, the interceptor operates his extension switch and activates the siren control equipment by the hand generator on his telephone. Because of the line limitations and other considerations, this system is limited to no more than two intermediate telephones and incoming calls are monitored by arrangement between the two interceptors. When neither can provide the service, the extension switches are operated so that all incoming calls terminate at the fire station telephone and siren alarm. This system is both technically and operationally insecure as a line fault, or an interceptor leaving his premises without operating the extension switch, will render the service ineffective. It is also too demanding on the attention of the members involved.

Recently, a modification has been introduced to make this system secure. Should the call remain unanswered for a pre-determined period, usually 30 seconds, a timing device at the exchange switches the call directly to the fire station telephone and siren alarm. In A.R.K. exchanges, this equipment is associated with the relay set connected to fire brigade services to prevent the caller "timing out" if unanswered in 90 seconds.

Although fulfilling a general requirement, the above system does little to help the volunteer fire brigades operate efficiently. For instance, the siren alarm is a fairly effective alerting device during the working day when a volunteer fire crew is reasonably close to the fire station; however, outside of working hours, whilst members are at their homes, radio and television programmes and also weather conditions can provide much opposition to the effectiveness of the fire station siren. As well, the reliability of the siren is no better than the continuity of the commercial power supply to drive it. A power failure could be the result of an incident at which the brigade's services are required.

DESIGN OF NEW FIRE REPORTING SYSTEM

To minimise these problems, a reliable and economical interception and signalling system, known as the "Fire Reporting System" (F.R.S.) has been developed in close liaison with the Country Fire Authority of Victoria. This organisation has a voluntary fire service component, numbering approximately 112,000 members, who form 1,264 urban and rural fire brigades. This fire reporting system, described in this article, is primarily designed to fulfil the operational requirements of the volunteer brigades in urban communities.

The Fire Reporting System (F.R.S.) is designed to use, as far as possible, the existing exchange line telephone services of the volunteer firemen. It consists of two relay sets — one installed at the exchange, and the second and smaller relay set installed at the fire station. A maximum number of 12 exchange services can be connected into the exchange relay set to provide this fire reporting system. Six of the services can be accommodated as firemen's intercepting telephones (F.I.X. lines) and the other six as firemen's alerting alarms using the telephone bell. These are referred to as house alarm tele-bells (H.B.X. lines). These H.B.X. lines may be supplemented, if required, by the provision of magneto bells at the premises of eight additional firemen which are connected by private lines to the exchange relay set. These are known as house alarm bells (H.A.B.). The reporting line also rings a C.B. telephone located adjacent to the smaller relay set at the fire station. An incoming fire report call is connected through the exchange relay set and rings the fire station and the six F.I.X. lines, if free, with a distinctive repeated interrupted ring. When one answers, the ring continues on the other unanswered telephones but with an altered periodicity. This facility warns the firemen to "answer without speaking" and so avoid interrupting any conversation already in progress. The F.I.X. telephones are equipped with a push button, which, connected between one side of the line and local earth, may be used to operate the firemen's house alarms and siren, if required. This push button is only effective whilst a fire brigade call is connected.

The number of firemen required to respond to an alarm is determined by the size of the fire. A small fire may be attended by only the F.I.X. men who answer. A larger fire may require the services of firemen connected to house alarms (H.B.X. and H.A.B.) and these bells are code rung by operation of a push button at an F.I.X. telephone. A large fire would require the services of all available firemen and 10 seconds continuous pressure on the push button will operate the siren in addition to alerting the H.B.X. and H.A.B. firemen. A distinctive tone is heard by the F.I.X. telephones, indicating that the signal has been sent to operate the siren. Because it has been the experience of some brigades that operation of the fire siren can attract the attention of sightseers causing traffic and other congestion problems for the brigade, these brigades prefer, on occasions, to alert a fire crew without the use of the siren.

As the F.I.X. and H.B.X. lines connected into this service are primarily private services, incoming fire brigade

* Mr. Jelley is Communications Officer, Country Fire Authority, Victoria.
**Mr. Nelder is Senior Technical Officer, Grade 2, Country Service, Victoria. See Vol. 20 No. 3 Page 281.

calls do not interfere with any call that may be in progress at the time. However, a distinctive background tone is fed into the line to indicate the presence of a fire brigade call. The level of this tone is not sufficient to inhibit the existing conversation. If the private call is terminated, the F.I.X. telephone is immediately connected to the fire brigade call if it is still current. In a similar manner, an H.B.X. telephone receives this background tone as an alarm signal if his telephone is in normal use at the time.

In the unlikely event of all six interception points and the fire station being unattended at the time of an incoming call, timing equipment in the exchange relay set will automatically ring the house alarms and operate the fire station siren should a call remain unanswered for a pre-determined length of time—usually set at 30 seconds.

The reliability of the system is assured for the reason that the F.I.X. and H.B.X. lines are normal subscriber services and any fault condition on a service will not remain undetected for long periods. A looped or earthed F.I.X. line will test busy to the exchange relay set and the rest of the system will not be impaired.

Fire Station Operation. The relay set installed at the fire station provides the termination for the special supervised line from the exchange relay set to operate the siren and is connected to the siren control equipment. A relay normally held operated by line supervisory current extends a signal back into the exchange alarm system should an external fault occur on the alarm line. The siren is activated by reversing the alarm line polarity. A change-over key is provided so that the F.I.X. telephones may be disconnected from the system and all calls taken at the fire station when the station is attended, such as on days of "Total Fire Ban", etc. Failure to restore the key to normal on leaving the fire station is safeguarded in the same manner as an unanswered call. All firemen connected to the system may be alerted by the operation of a push button on the relay set at which time all bells will ring.

Protected Premises Alarms. Alarm lines from the automatic fire detection and sprinkler systems installed in various premises — telephone exchanges and the like, hospitals, commercial and industrial premises and various Government properties — are normally connected to terminal equipment at the fire station and an alarm signal will activate the siren alarm. Provision is made on the F.R.S. fire station relay set so that alarm signals originating from these systems are also extended into the F.R.S. causing all bells to ring for an adjustable time period—usually 30 seconds. On answering, the interceptors will hear a distinctive tone which will indicate to them that an alarm has been received from protected premises. All firemen responding to these alarms report to the fire station to ascertain the location from which the alarm originated.

Fig. 1 shows a typical layout of the equipment at a volunteer fire station. The large relay set is the fire station end of the F.R.S. and the 10 smaller units are associated with protected premises alarms, for which provision has been made for four additional systems.

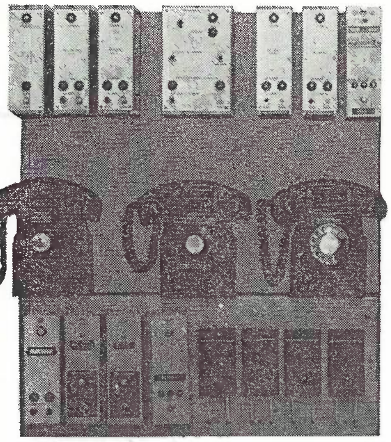


Fig. 1 — Equipment at Volunteer Fire Station.

TECHNICAL DESCRIPTION OF F.R.S.

The original concept upon which this system is based, was designed by Mr. R. Summarsell, Divisional Engineer of Equipment Design Control in South Australia, in 1965.

This was modified to C.F.A. requirements and a prototype unit was produced. Two progressive models followed, using additional safeguards and facilities, which advanced the system to the present stage where Ericsson "R" series relays, crossbar mountings and solid state timer and detectors are used. As apparatus is manufactured and maintained by P.M.G. personnel, all departmental standards and practices have been observed.

The following data applies to installations in crossbar exchanges but the exchange relay set may be strapped for step exchanges.

Drawings & Apparatus

Drawings

VD3229/1:	Index to Drawings.
„ /10:	Trunking Diagram. See Fig. 2.
„ /11:	Siren Control Unit. C.F.A. equipment.
„ /18:	P.M.G. Protected Premises R/S at Fire Station. Formerly /13.
„ /40:	Station Panel. Formerly /14.
„ /39:	Exchange Relay Set, Issue I. Formerly /27.
VDA3229/39:	Sheets 1-11: Technical Data. VD5505-Timers. VD5527 — C wire testers.

Note: The above circuit drawings, other than VD3229/10 (Fig. 2), have not been reproduced in this article.

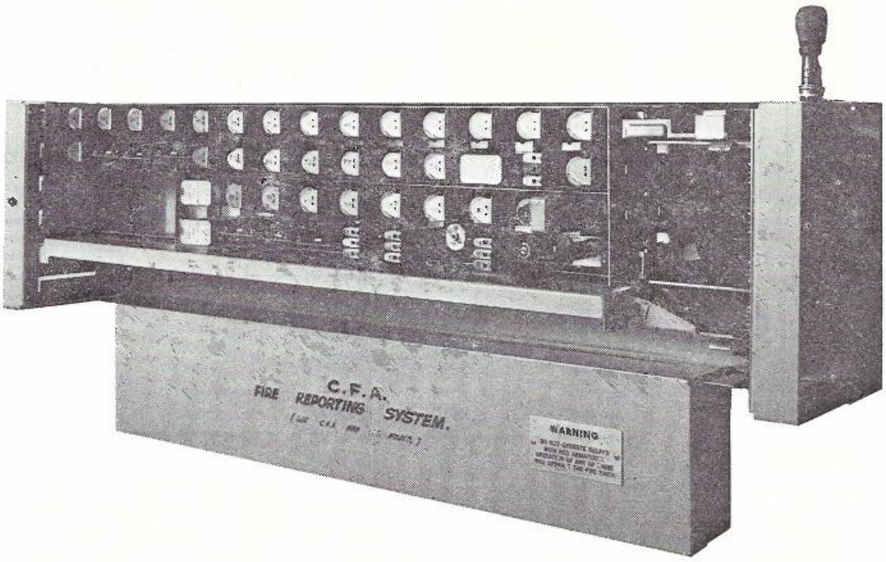


Fig. 3. — Wall Mounted Exchange Relay Set.

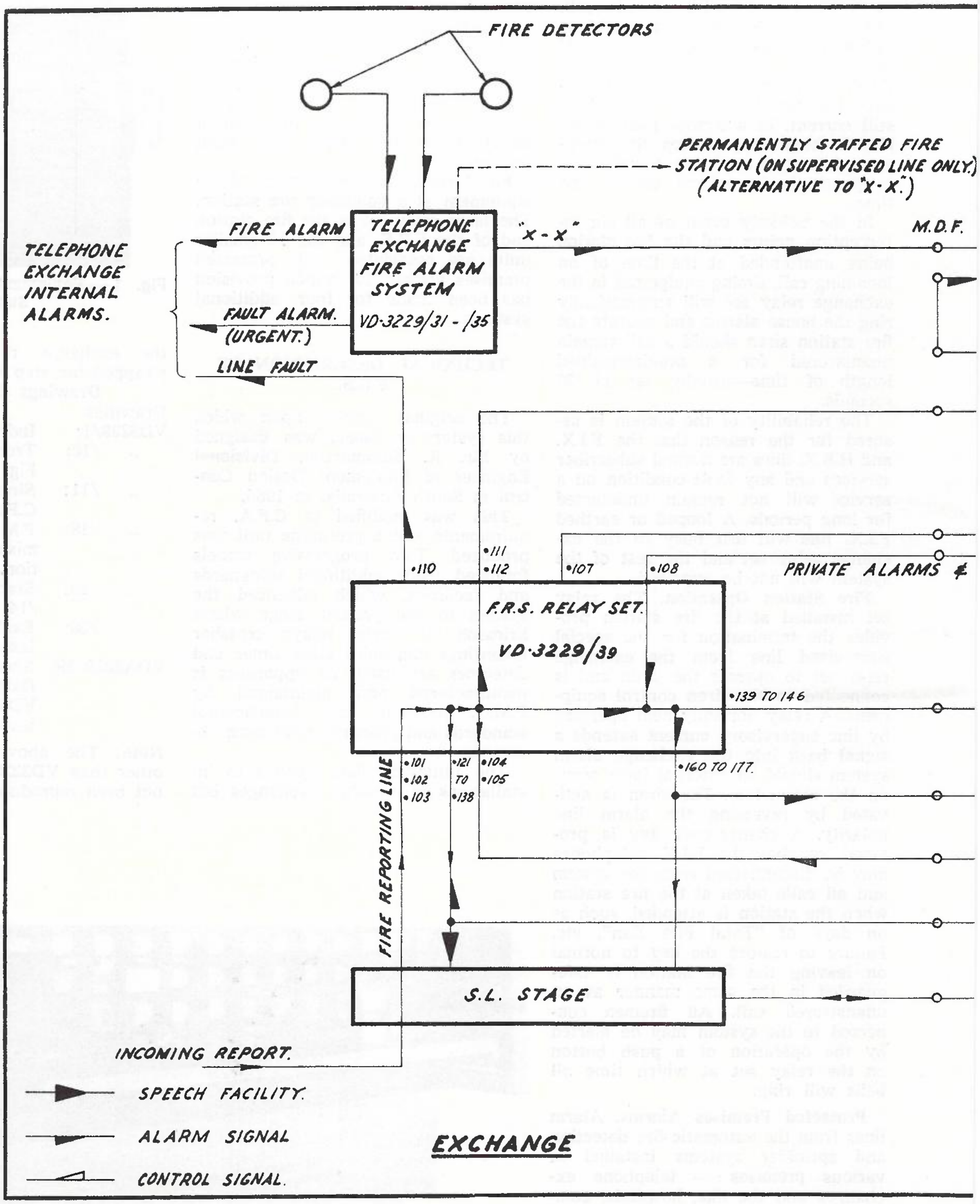
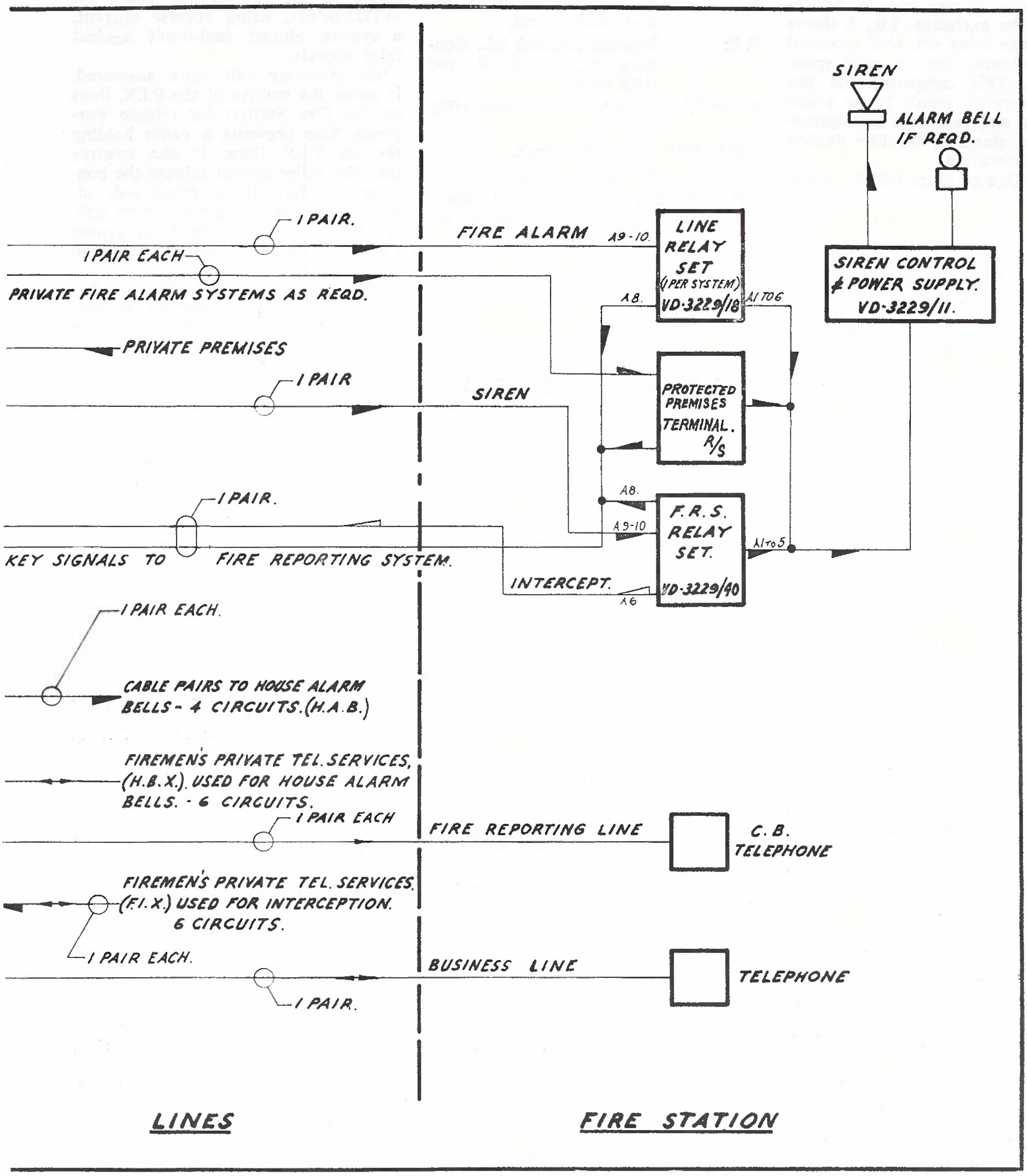


Fig. 2. — Trunking Diagram.


SIREN
ALARM BELL IF REQD.
1 PAIR.
FIRE ALARM
A9-10.
LINE RELAY SET (1 PER SYSTEM) VD-3229/18
1 PAIR EACH
PRIVATE FIRE ALARM SYSTEMS AS REQD.
A8.
A1 TO 6
SIREN CONTROL & POWER SUPPLY. VD-3229/11.
PRIVATE PREMISES
1 PAIR
SIREN
PROTECTED PREMISES TERMINAL. R/S
1 PAIR.
A8.
A9-10
F.R.S. RELAY SET. VD-3229/40
A1 TO 5
KEY SIGNALS TO FIRE REPORTING SYSTEM.
INTERCEPT.
A6
1 PAIR EACH.
CABLE PAIRS TO HOUSE ALARM BELLS - 4 CIRCUITS. (H.A.B.)
FIREMEN'S PRIVATE TEL. SERVICES, (H.B.X.). USED FOR HOUSE ALARM BELLS. - 6 CIRCUITS.
1 PAIR EACH
FIRE REPORTING LINE
C.B. TELEPHONE
FIREMEN'S PRIVATE TEL. SERVICES. (F.I.X.) USED FOR INTERCEPTION. 6 CIRCUITS.
1 PAIR EACH.
BUSINESS LINE
TELEPHONE
1 PAIR.
LINES
FIRE STATION

Apparatus

Exchange: One 4 panel B.C.H. relay set, /39, which uses Ericsson "R" series relays, is required to be installed at the exchange. Fig. 3 shows this exchange relay set, wall mounted in this instance, due to rack space limitations. This comprises the fire reporting service, men's house alarm bell control and exchange termination of extended alarm to the Fire Station for siren operation.

Station: One or more P.M.G. panels and one C.F.A. panel at the Fire Station.

/11 C.F.A. equipment which provides power to and accepts alarm signals from P.M.G. equipment.

/40 Station Termination of F.R.S. System—4 relays.

/18 Signals from P.M.G. premises. Formerly /13.

/15 Station Termination of Ring Down Private Premises Alarm if required. Supersedes /12.

External and Subscribers' Plant. Four or more cable pairs required between exchange and station. A CB telephone at the station to answer the exchange number advertised for fire reporting.

Six intercepting telephones fitted with a press button and earth wire.

An exchange line with outgoing access only, as advertised, for fire reporting.

Summary of relays and their functions

VD.3229/39—Exchange:

P.	Starts F.R.S. from incoming call, or signal from station /18 or /40.
PR:	Tests F.I.X. lines.
PA:	Relief of P. Holding circuits. Various.
HA to HF:	Prepares connection of ring to F.I.X. lines if free.
HR:	Connects ring after BR has operated.
F:	Ring trip on station line.
FA to FF:	Ring trip on F.I.X. lines.
D:	Battery feed, and hold conference. Station line.
AD:	Battery feed, and hold conference. Fix lines 1, 2, 3.
DD:	Battery feed, and hold conference. Fix lines 4, 5, 6.
FR:	Relief on D, AD and DD.
TR:	Trips incoming ring. Tone feed.
TTR:	15 second thermal, limiting /18 signal.
AL:	Responds to unbalance from F.I.X. lines 1, 2 and 3.
DL:	Responds to unbalance from F.I.X. lines 4, 5, and 6.
TAL:	30 second thermal, if report unanswered.
R.B:	Repeats AL and DL. Controls ring to HAB and HBX lines.
RT to RY:	2 triple relays. Tests HBX lines.
RM to RS:	Rings HBX lines.
SR:	10 second delay.
CP, J. & TL:	—Sends signal to siren. —Effects time-out if reporting line held. —Relief on TAL.
TC:	Intercepts F.I.X. lines and diverts reports to station.
PP:	Call system from station or protected premises.
PH, IE:	—Holds to /18 signal. —Interrupts ring or tone.
LF:	Accepts and extends siren line failure alarm.
AK:	Prevents time-out for ARK exchanges.
R:	Forced release.

VD.3229/40, 18, 11—Station:

DX/40:	Accepts alarm from /39. Signals siren.
BG/40:	Break glass alarm.
SX/40:	Resets siren.
MF/40:	Line monitoring.
DP/18:	Accepts alarm. Signals siren.
SP/18:	Siren reset.
M/18:	Monitoring.
AR/11:	Siren control. C.F.A. equipment.

BRIEF DESCRIPTION AND FEATURES OF FIRE REPORTING SYSTEM

When a fire report is given by dialling the special advertised telephone exchange number, this call is switched via the exchange relay set (VD3229/39) and rings the six nominated interceptor firemen's exchange telephones, the F.I.X. lines, if free, also the fire station telephone 750 ms ON, 750 ms OFF. When one answers, the periodicity of the ring is altered to 200 ms on, 200 ms off. This notifies other F.I.X. men, who answer without speaking to avoid interruption of reports.

As each telephone is answered, the firemen may consult together and each one has the facility, by pressing a button on his telephone, to code ring all firemen's house alarm bells. Alternatively, if required, he may press the button for ten seconds continuously to operate the siren. The exchange relay set will ring the house alarm bells for ten seconds of continuous ring and then extend the alarm to the fire station relay set (VD3229/40), using reverse current, a system almost fool-proof against false signals.

An incoming call, once answered, is under the control of the F.I.X. lines or the Fire Station for release purposes. This prevents a caller holding the six F.I.X. lines. It also ensures that the caller cannot release the conference before it is completed, although he can release his own call. An unanswered fire report call ceases ringing should the caller hang up within 40 seconds.

Should the person reporting the fire fail to hang up, the reporting line will test busy for 1.5 minutes and then the caller goes into the P.G. lockout condition. When all F.I.X. lines who have answered hang up, the reporting line tests free and any F.I.X. line may resume normal calls.

Calls to this number are metered when answered. ARF equipment is strapped to ensure that the standard "time-out" facility, operative after 90 seconds, is cancelled. In ARK exchanges, the additional relay is fitted for this purpose.

The 220 Ohm resistors in series with the F.I.X. lines may be varied if necessary to approximately equalize line currents in the group of three.

Should no answer be made to an incoming fire report in 30 seconds, firemen's bells will ring for ten seconds and then the siren will be operated, if the caller has not hung up.

Reverse current is used to forward the alarm signal to the fire station to trigger off the siren. This avoids false alarms due to open circuits, earths or short circuits. Any of these fault conditions are brought to notice by an alarm in the exchange.

One faulty F.I.X. line will rarely affect operation of the remaining F.I.X. lines. However, an earth on either side of one will provide unbalance and initiate siren operation when that line answers. A fire call conference is forced released six minutes after answer. This ensures that, should one F.I.X. line fail to hang up or be held by a low insulation condition, the system and other F.I.X. lines will be released.

Should an F.I.X. line be speaking on a normal call when a fire report is received, he hears tone. He may hang up, lift off and hear report. If all six lines are engaged, they all hear tone. Some will accept report, as above.

Should it be required that one or up to three of the remaining F.I.X. lines cease ringing as soon as one F.I.X.

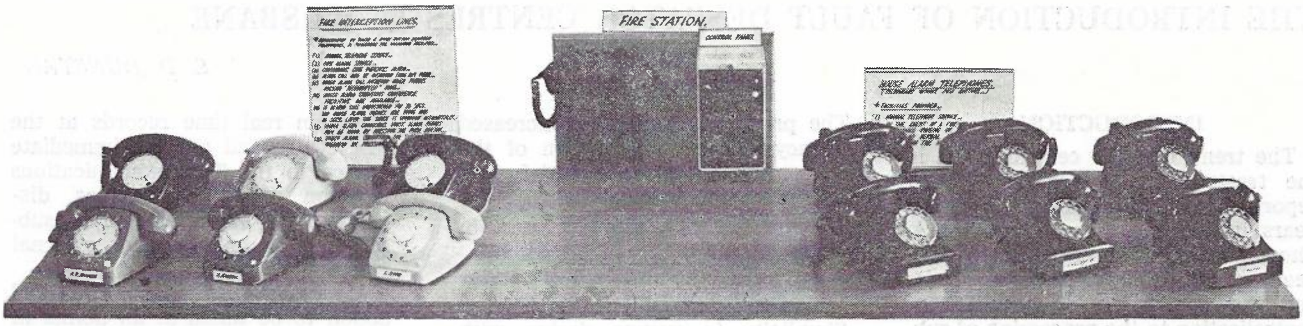


Fig. 4. — Demonstration Equipment.

line answers, the appropriate strap 46, 47 or 48 for F.I.X. 1, 2 or 3 may be inserted. It may be required that some F.I.X. lines are connected for night calls and others for day calls. This can be done by the TC relay, which is operated by the key KI at the station. Alternatively, if the station is staffed at night, the key operation could remove all F.I.X. lines from the interception. F.I.X. or H.B.X. lines may be disconnected from fire reports for a period by removing link mounting at the M.D.F.

Distribution of Ringing Current: Under maximum conditions, this system may be required to ring 13 bells simultaneously. This peak current drain is estimated to be 80 mA which, in most exchanges, can be supplied. In ARK exchanges where a 7 watt machine is installed, it may be necessary to use a auxiliary ring supply.

P.M.G. Premises with Fire Detection Systems: The alarm condition of the fire detection system will be forwarded to the fire station relay set using the reverse current principle, and operates the siren immediately. All firemen's alarm bells are code rung for 25 seconds.

Non P.M.G. Premises Protected with Fire Detection Systems: Contractors provide a terminal relay set at the Fire Station to suit their system at the protected premises and achieve a similar result to that described above.

A detailed description is contained in Ref. 1.

SELECTION AND TRAINING OF PERSONNEL

Close co operation is maintained between the Authority and the P.M.G.'s Department with each installation, particularly at the local level, to ensure that both the technical staff and the brigade members fully understand the system and how it functions. Prior to the commencement of an installation, a briefing meeting is arranged with the brigade and a communications officer from the Authority explains the system in detail to the members. The brigade then decides which of its members are to be connected into the system. Those members whose telephone services are to be utilised for this secondary function are required by the Authority to submit at authorisation form signed by the lessee of the telephone service and these are forwarded to the District Telephone Office, along with other details concerning the installation. Generally, even the smallest brigades are able to offer the total complement of 12 exchange services for connection to the system. Many of these services are the members' business services and are night-switched to their residences, thus increasing the overall coverage.

Prior to the F.R.S. being cut into service, a practical demonstration is organised at the telephone exchange and the members fully instructed in its use. The layout of this demonstration is shown in Fig. 4; F.I.X. lines at left, H.B.X. lines at right and fire station telephone and relay set in the centre.

CONCLUSION

Following the favourable reports received from the brigades equipped initially, the Country Fire Authority planned an extensive three-year installation programme. At present, 58 systems are in service in Victoria, to which another 100 will be added during the next two years.

A system, similar in many respects to that described in this article, is currently being developed for application in rural areas where the community and brigade members are widely scattered, and the alerting and turnout requirements differ accordingly. This system will be described in a future article when the development and field testing have been concluded.

The installations in Victoria are being co-ordinated in the Engineering Division Victorian Administration by Mr. Nelder, and in the Country Fire Authority by Mr. Jelley. Postal Workshops (Melbourne) manufactured the equipment, the quality of which has contributed much to the efficient operation of the Fire Reporting System.

REFERENCE

1. Victorian Circuit Report No. V.84, Issue 6.

THE INTRODUCTION OF FAULT DESPATCH CENTRES IN BRISBANE

*E. D. DUNSTAN**

INTRODUCTION

The trend towards centralisation in the treatment of subscribers repair reports has been apparent in recent years in Western Europe and U.S.A. These overseas developments have been examined by A.P.O. engineers and the application of a policy of centralisation to the processing of subscribers reports was recommended.

This article describes the methods employed in the development of the new system and its organisation that now serves the Greater Brisbane area. Two F.D.C.'s (Fault Despatch Centres) are now serving an area of approximately 400 square miles, in lieu of 38 exchanges which were formerly operating as independent substation maintenance and testing centres. This description is followed by an evaluation of the effectiveness of the new system, which has annual savings approaching $0.25 million.

The project contained four main stages which are discussed in the following order:—

- Determination of the objectives
- System design and development of the organisation
- Phasing-in of the new system and its organisation
- Effectiveness of the new system

OBJECTIVES

The F.D.C. organisation was developed primarily to increase the efficiency of the subscriber repair service operations by reducing the time to attend and clear faults and by reducing the costs of the service. The design of the F.D.C. organisation took account of both immediate and long term requirements. A secondary aim was to provide the complete recording, and testing when necessary, of all changes in subscribers equipment, including P.A.B.X.'s and the forwarding of advice of these connections, alterations, and disconnections to the Telecommunications Division. This function, when analysed, represented a large portion of the test centre cost structure and a survey of the annual man-hours consumed by this activity in exchanges, before centralisation, was examined and numerous improvements developed. This side effect of improved telephone order procedure is not described in this article, but details are available from the author.

The primary objective of increased efficiency required the design of the system to be optimized to satisfy two conflicting requirements, namely:—

- Reduction of costs incurred in performing the functions.
- Increasing the standard of service provided to the customer.

Simplicity in system design with minimum capital outlay was regarded as a sound base on which attempts to satisfy these requirements could be made.

Full advantage at the time of the introduction of the new system was taken to introduce a wide range of improvements, subject to the limitations of available equipment, lead time, and the existing organisation of other sections involved.

The F.D.C. system design took account of the following constraints:—

1. The geographic features of the metropolitan service exchange areas and accommodation available.
2. Exchange after-hours staffing arrangements — required because of the economic necessity to employ one staff only to administer both the exchange network control centre and the F.D.C. after-hours.
3. Telecommunications Division operating practices, e.g. telephone order traffic, and repair traffic from the Service Centre (1100).
4. Subscribers equipment installation division's practices and areas of responsibilities. A side effect of this research was a change in responsibilities for installing activities in respect of "Plan 13" and "Plan 14" orders for P.A.B.X.'s, to the benefit of both the subscribers equipment installation division and the metropolitan service divisions. This change reduced visits to the subscribers premises by 30%.
5. The effect of the departmental grading formula for supervisors, and the award conditions, in defining and establishing clear cut areas of responsibilities within the service divisions, i.e. between the exchange Officers-in-Charge and the F.D.C. Officers-in-Charge.
6. District works (line plant) division's practices and policies.

The F.D.C. System had to meet the following specific requirements:—

1. Maintain correct priority of attention to minor service defects.
2. Avoid excessive delays in attention to minor service defects.
3. Maintain real time records at the test centre and provide immediate advice to the Telecommunications Division of all connections, disconnections, and alterations to subscribers equipment and external plant.
4. Clearly assign responsibilities and action to be taken at all points in the system and its interface with other sections' staff.
5. The provision of a statistical data system to provide management with the necessary criteria to determine the standard of service to the customer, the effectiveness of the F.D.C. organisation, and the fault liability of the various types of equipment in service.

SYSTEM DESIGN

During period March, 1963 to May, 1964, a successful trial of centralised despatch only of subscribers equipment faultmen has been conducted in a portion ("4" and "9" networks) of the Brisbane area. This experience provided the basis for optimising the hardware for this despatch function. During the period 1965/66, the design of a complete system to embrace testing, recording, despatching and all subscribers equipment activities, performed by the metropolitan service divisions, was completed. Installation of the necessary facilities followed.

An examination was made of the range of F.D.C. organisation sizes that could be employed without any appreciable change in unit costs, i.e. cost per 1,000 telephones serviced. This was done to test the F.D.C. system design for adaptability to growth and changes in divisional boundaries.

The following basic methods of handling subscriber repair requests were critically analysed and evaluated:— (Ref. 2)

- System No. 1 Centralised Subscribers Reporting Centre with a centralised Test and Despatch Centre at a separate location using the then current methods.
- System No. 2 Centralised Subscribers Reporting and complete testing centre with a separate despatch centre using the then current methods.
- System No. 3 Centralised Reporting Testing and Despatch Office using an

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American Telephone Fault Centres "Keysort" Fault Docket system (No reference is made to the subscribers master card in this system.)

System No. 4 Identical to that described in System No. 3 except the fault docket system is replaced with the New Master Card System developed in Brisbane for F.D.Cs.

System No. 5 Centralised Reporting Centre with Testing with Despatch Centres at separate lolations.

The processing times estimated for each of the above systems are:—

(Times include 1 R.W.T. action in addition to a repair cycle of operation).

System 1 — 4.53 mins.
System 2 — 5.37 mins.
System 3 — 3.84 mins.
System 4 — 1.43 mins.
System 5 — 1.57 mins.

System 4 required the addition of the time required to convey a docket to a test position with the possible exception of a conveyor belt in which case, another activity, "obtain master card", will increase due to the absence of sifting of the incoming repair traffic. Further, a pneumatic tube is inefficient when used for "urgent" single docket despatch.

System 5 time could possibly be reduced in the following elements:—

(a) Activity. Transmit on teleprinter. This could be reduced by key operation of printer switching in lieu of dialling switching code. A further possible reduction is the elimination of the text, i.e. "Rep'd by (Subs. No.)" in Tech. Repair Traffic.

(b) Activity Insert date and time. The acceptance of time shown on teleprinter sheet as time of receipt, rather than glance at a clock and translate the hand position to the 24 hour clock equivalent could result in a reduction of 4-5 secs. (Ref. 1) Much of this saving could also be achieved by a 24-hour digital display clock at the Test Centre.

An analysis of the above times reduced the evaluation to Systems 4 and 5 with the tendency for handling times to favour System 4. System 5 was chosen for the reasons set out below. The absolute minimum degree of dispersion of Reporting Centres, required by the Service Divisions of the Engineering Division using the system, would be one situated on the north side and one on the south side of the Brisbane River. This arrangement would offer the following penalties to the Telecommunication Division in their employment of young female labour:—

* Cost of providing accommodation and amenities for the centres.
* Supervision costs would increase.
* Inability to deploy staff from other positions e.g. Trunks & Information, to Service Reporting positions during peak workloads.
* Loss of flexibility in disposition of staff.
* Inability to provide training time on Service Reporting position for operators when they are not fully occupied at their trunk position, etc.
* Difficulties in night staffing a remote station.

The Engineering Division would lose flexibility in determining the location of maintenance control centres and possibly divisional boundaries with attendant loss of efficiency. In addition, no pre-sifting of repair traffic (this can be done automatically by teleprinter) would be available and additional staff would be necessary to cater for this in a large centre.

An advantage is the reduced teleprinter network requirements, but the exchange Network Performance Cen-

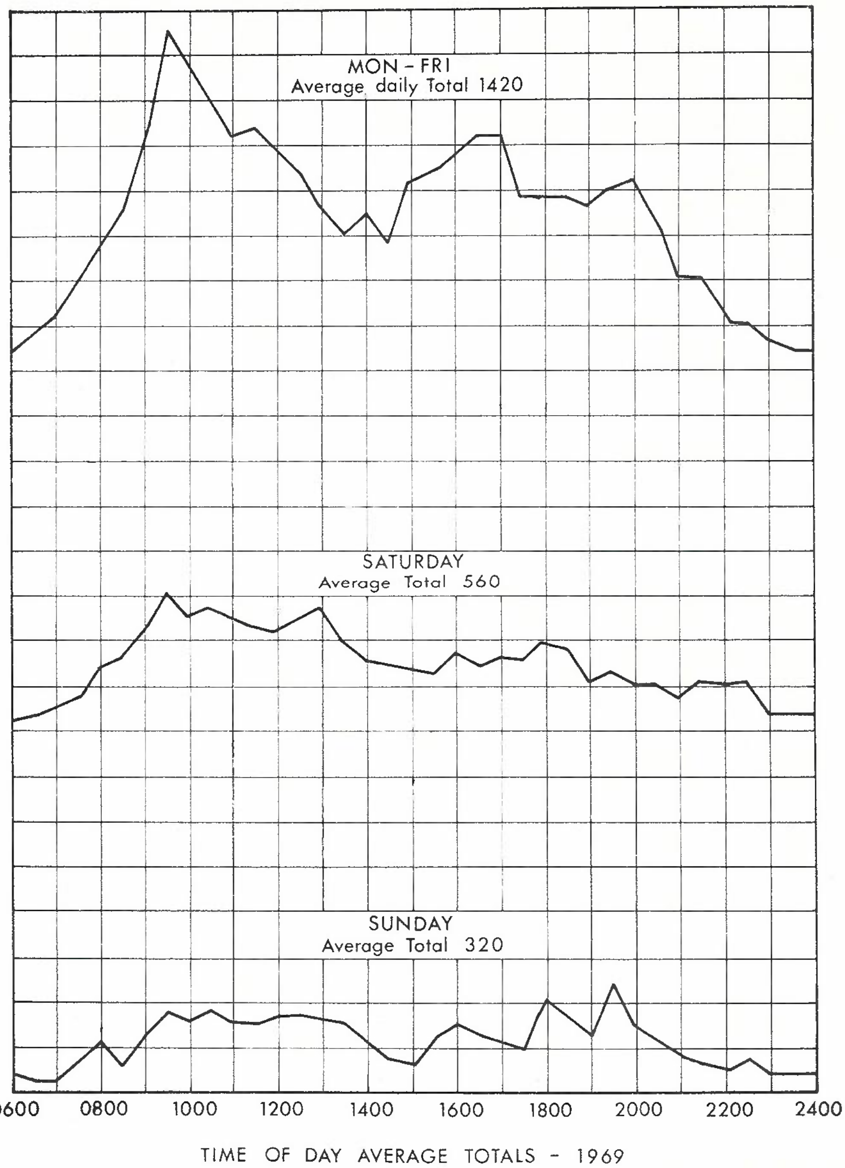


Fig. 1. — Average Distribution of Daily Repair Traffic, Brisbane.

tre would still require a repeat from at least one reporting centre, even if it also were included in a Reporting Centre.

System No. 5 was selected, but a different choice might have been made if basic changes could have been made in Service Centre (1100) practices, and in the switching and numbering system. However, it was not expedient or practicable to pursue these at the time.

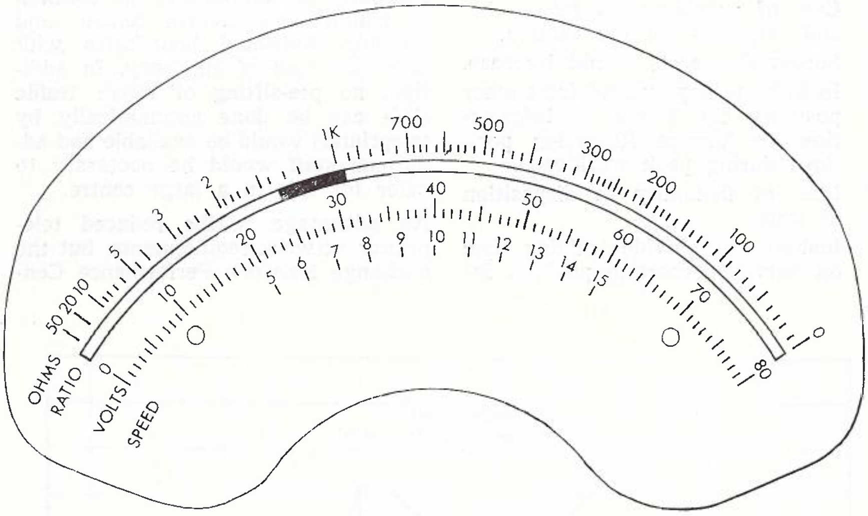
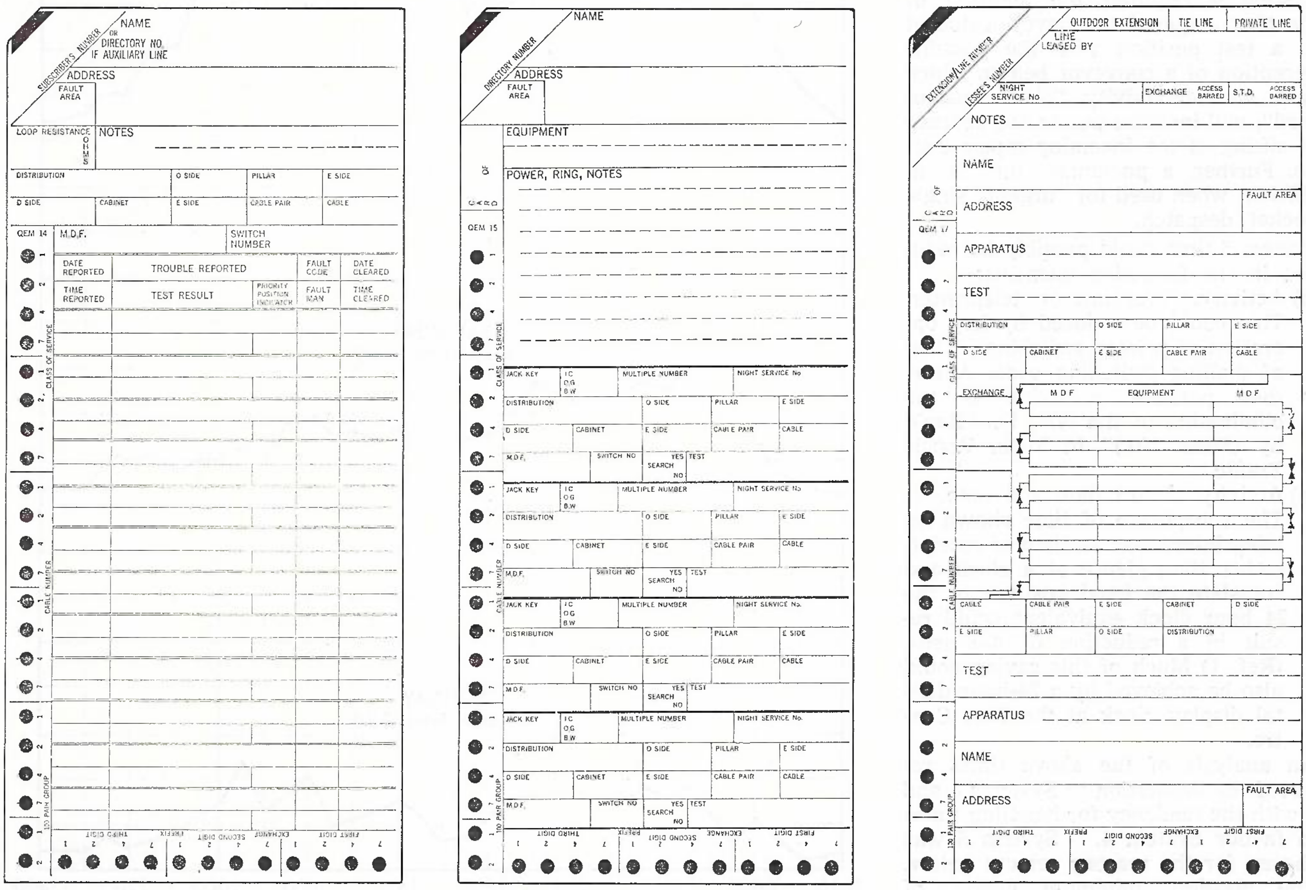


Fig. 2. — Test Desk Meter Scales.

The daily load arising from subscribers repair requests was measured and the distribution determined. The average distribution of daily repair traffic originated by Brisbane subscribers is shown in Fig. 1.

The next design stage was to determine the hardware (test desks, master card catelogues, etc.) forms and practices for the F.D.C's test room functions load. To keep capital costs and equipment design effort to a minimum, existing equipment, modified where necessary, was used. Modified 2,000 type exchange test desks were employed throughout. Loud speaking order wires to exchanges, and consoles with switching arrangement for automatic transfer of calls from subscribers equipment installing staff to their depots were also developed. This facility reduced calls from the installer to subscriber's premises by approximately 50 per cent.

The testing facilities of the standard desk, including all dial testing facilities, were modified. Test circuit transmission bridges were modified to per-



SINGLE LINE MASTER CARD

MULTIPLE LINE MASTER CARD

MASTER CARD FOR SERVICES USING JUNCTION CABLES AND INTERMEDIATE EQUIPMENT

Fig. 3. — Subscribers Record Cards.

mit the testing of circuits up to 3,000 ohms loop resistance. The subscribers line relay control circuit has a test centre to exchange (2,000 type) range of 7,000 ohms. Circuit modifications were developed to increase the response time of the test desk meter because of the larger capacitance encountered, and direct reading resistance scales were added. Fig. 2 shows the new test meter scales used. An increase in detail and reliability of historical information, i.e. subscribers equipment fault history, was achieved although the total recording effort was considerably reduced. The practice of using test desk registers and fault dockets was abolished. The new master card developed with this aim is shown in Fig 3. A simplified flow chart of the processing of a fault report is shown in Fig. 4.

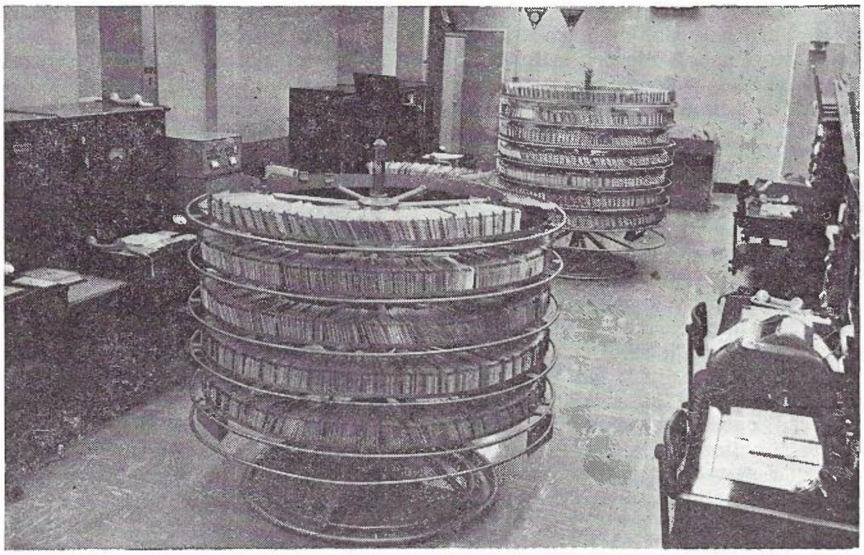


Fig. 5 — Plant Layout — The Two Modules of Edison F.D.C. — Capacity 60,000 Telephone Stations per Module.

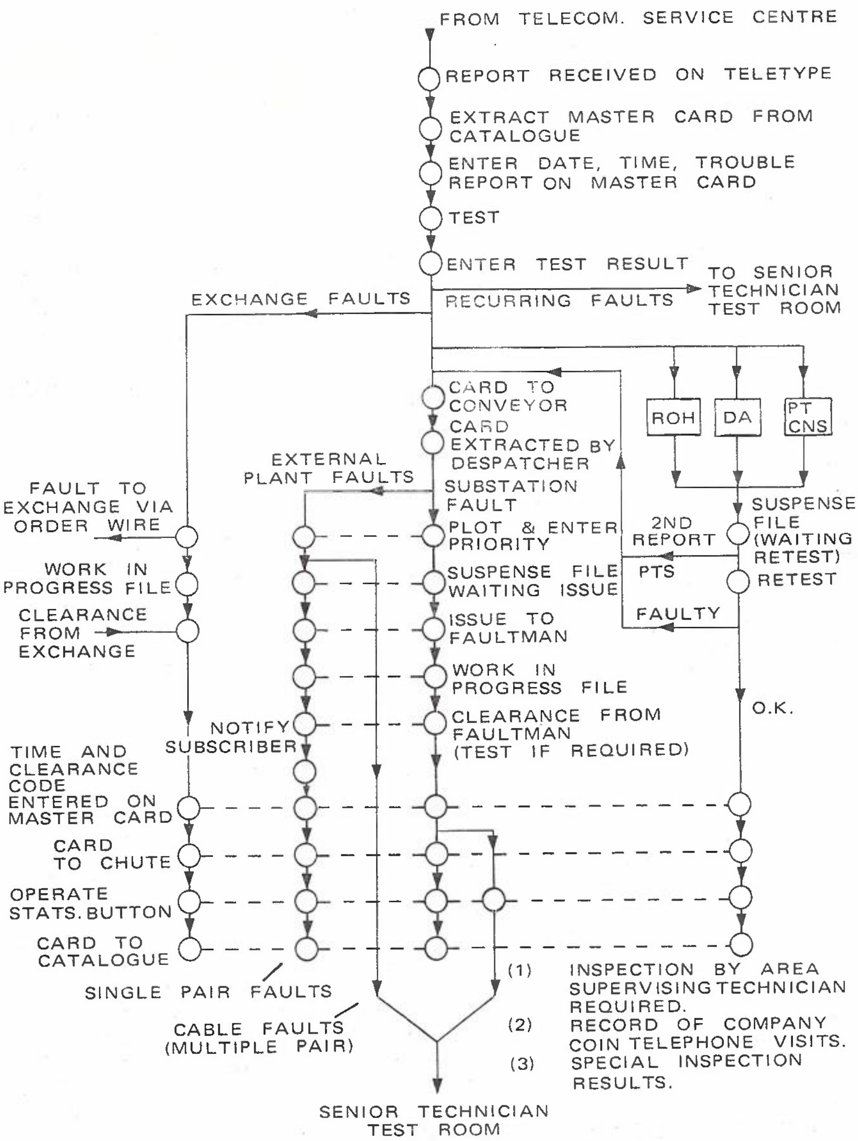


Fig. 4. — Flow Chart of Repair Traffic — F.D.C. Test Room.

DUNSTAN — Brisbane F.D.C.

The next stage was that of plant layout design. After considering the possible operating ranges required to cater for growth and the hour to hour work load statistics, modular construction was developed to optimise the plant layout to cater for these variations ensuring minimum staff movement at all times. Fig. 5 shows the layout used.

Two test centre modules are shown in Fig. 5. A module consists of a rotary master card file, four test desk positions, a teleprinter, a magnetic map and two statistic recording panels fitted with a photo sensitive card shute. Each module has facilities to allow operation by one to four technicians. All lines and facilities are common to each position, and can cater for all the processing and testing of substation equipment, external plant and exchange faults arising from 60,000 telephone services.

Because of the sweeping changes in responsibilities, duty statements were compiled in detail for all supervisory staff.

PHASING IN THE NEW SYSTEM

The introduction of the new system was scheduled, using the critical path method. All substation installing work i.e. processing of telephone orders and any installation testing required, was transferred to the F.D.C. before the repair traffic for each network to provide real time records for the F.D.C. test centre. This approach also allowed the transfer of any exchange staff required for the F.D.C. to be effected with the transfer of the exchange test desk work load. Test desks of exchanges are now not manned.

The cutover of repair traffic was staged on the basis of one complete network at a time. In addition Sunday was chosen for the first day of operations for each test centre module, and all staff rostered for the following week manned test positions for short periods during the Sunday morning to provide them with experience on "live" traffic.

This approach was used because the equipment and the quantity of staff required and the distribution of work in the F.D.C. testing positions was calculated on the basis of fully experienced operators being employed. As the situation at cutover would be that of a new staff with completely new forms, methods, procedures, considerably modified test circuits and a new environment, their output initially was expected to be reduced.

The schedule was used to control and co-ordinate all stages of the phasing-in, e.g.

- Training programme for F.D.C. supervisors and staff.
- Test out of F.D.C. test room equipment, and test distributor network.
- Issuing of advice of cutover dates to other sections, e.g. area exchanges, Telecommunications Division, transport, telegraph, subscribers installing divisions, district works divisions, and other service divisions.
- Transfers of staff, vehicles, outstanding service order work, etc.

PERFORMANCE ANALYSIS

In evaluating the performance of the new system all the improvements cannot be directly credited to the concept of centralisation. The very fact that a particular area of activity which is to undergo a radical change is given detailed scrutiny often improves its efficiency. A contributory factor is the staff reaction to this management attention. Many improvements are effected even if the proposed change never eventuates. For example the comparative time for the processing of fault report (substation work elements excluded) is:—

Old System (Exchanges)
(Using fault dockets, paper clips, test desk registers, docket sorting cabinets and manual statistical recording procedures.) 4.53 mins.

New System (F.D.C.)
(Using new master cards and methods which eliminate all items mentioned above under old system.) 1.57 mins.

The main criteria chosen to assess the effectiveness of the organisation was:—

- Service standard given to customer in terms of elapsed time from lodgement of repair request by subscriber to restoration of service.
- Manhours incurred by test centre operators.
- The average number of faults cleared per faultman per day (8 hours)
- Miles per fault.
- The manhours consumed per plant unit (a telephone service) per year which is compiled and published by the Costing Section of the Department.

The following data indicates the effectiveness of the new system.

The percentage of substation inoperative faults, reported between 0800 and 1600 hours, Monday to Friday, that are cleared within four hours is shown in Fig. 6. The inoperative fault category is the classification describing all services which cannot originate and receive calls. The operative fault category describes those services which are usable but require attention e.g. frayed cord, change of dial label, bell adjustment. Protection against excessive delays in the fault clearance of operative services is built into the despatch system procedure wherein all operative service reports lodged before 1600 hours on any day are reclassified the following day into the inoperative priority system to ensure service is given within a reasonable time; this avoids irritating inconvenience to the subscriber, repeated reports by subscribers which cause duplicated effort in the F.D.C.,

The manhours consumed on testing and despatch operations are shown in Table 1.

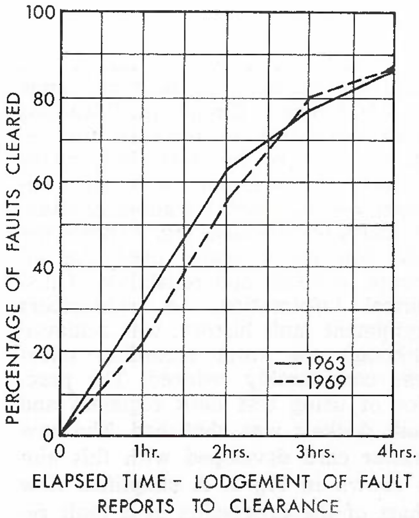


Fig. 6. — Comparison of Clearance Rates of Inoperative Substation Faults Recorded Between 0800-1600 Hours Monday to Friday.

ticularly the test room technical officers, perform work indirectly associated with the test desk activities e.g. checking fault history when special or written complaints are received and liaison with other sections. The supervisory staff have been in both cases excluded from the comparison.

A precis of performance data covering faults cleared per man and miles per fault is shown in Table 2.

The increased fault rate shown in Table 2 can be attributed to a change

TABLE 1 — MANHOURS COMPARISON

	Exchange System	F.D.C. System
Service No. 1 Division (8-5 Monday to Friday)	1030 hours	320 hours
Service No. 2 Division (8-5 Monday to Friday)	915 hours	240 hours

After making an allowance of 20% for remaining exchange testing activities (cable breakdowns and transpositions) the percentage productivity increase indicated by these figures is 51%, i.e. approx. 49,000 manhours per annum. In addition, four years' growth (at 5.5% per annum) has been absorbed between the pre-centralisation survey (1965) and the centralised survey (1969) in figures quoted above. During this period there has been no reduction in the fault generating rate of the equipment serviced.

The F.D.C. supervisory staff, particularly the test room technical officers, perform work indirectly associated with the test desk activities e.g. checking fault history when special or written complaints are received and liaison with other sections.

in method of recording statistics. In the decentralised arrangement exchange supervisors did not record visits to subscribers premises if the fault was not cleared by the substation technician e.g. passed to a line depot for attention, or the fault was detected from an exchange routine test. These faults are excluded in the F.D.C. statistics.

The data in Table 3 has been extracted from the annual report by the Department's Costing Section, and represents manhours per plant unit, i.e. a telephone service, per year (XIM account).

TABLE 2 — PRECIS OF PERFORMANCE DATA

Area	Year	Telephone Stations	In-crease	Average Faults Per 7-Day Week	In-crease	Average Faults Monday-Friday	In-crease	Faults Per 1,000 Phones Per Week	In-crease	Average Staff Level	Faults Per Man Per Day	In-crease	Men Per 1,000 Phones	Improve-ment	Vehicle Miles Per Fault
Service No. 2	1963	65,209		698		640		10.7		23	5.6		0.353	52%	5.2
	1969	94,512	45%	1,149	64%	1,048	64%	12.1	13.1%	13.1	16	134%	0.169		5.9
Service No. 1	1965	91,386		908		841		9.9		28	6.0		0.307		
	1969	113,349	25%	1,372	51%	1,270	50%	12.1	22.2%	26	9.8	63%	0.230	23%	
Service No. 1 (City Area)	1965	43,439		536		506		12.3		17	5.9		0.392		
2, 31, 5, 58	1969	52,098	20%	789	47%	747	47%	15.2	23.5%	15	9.9	68%	0.289	26%	
Service No. 1 (Suburban Area)	1965	47,947		372		335		7.7		11	6.1		0.229		5.3
55, 56, 57, 59, 36, 38 and 7 Network	1969	61,251	27%	583	56%	523	56%	9.5	23.4%	11	9.5	56%	0.180	21.4%	4.5

TABLE 3 — MANHOURS PER PLANT UNIT

Metropolitan	Decentralised	Centralised
Service No. 1 Division	1.93 This division embraces the inner city area which has a larger ratio of telephones and switchboard, to telephone services, than suburban areas and will continue to show a higher unit cost, if all other factors are equal, until the practice of employing a telephone service as the base unit is altered. (Telephone service represents exchange numbers in use, not the number of telephones.)	1.86 (1969/70)
Service No. 2 Division	1.5	1.07 (1967/68)

The Commonwealth average for metropolitan areas for 1967/68 is 1.52.

SUMMARY

If the same improvement per plant unit per annum is achieved in Service No. 1 division as has been realised in Service No. 2 division, the performance figures presented indicate that considerable savings have been achieved in both the testing, recording and despatching area; (approximately $100,000 per annum) and in the substation maintenance area of operations (approximately $140,000 per annum).

It has also been empirically established that the improved maintenance, management, and control techniques will permit a reduction in the P.A.B.X. maintenance account.

This productivity increase has been achieved without any significant lowering of service standards. These standards compare internationally, as well as nationally, quite favourably with other administrations, e.g. Orebro, Sweden — Fault clearance rate, substation and external plant faults, in built up areas equals 65% cleared within 8 hours — (Ref. 3) — as compared with approximately 89% in Brisbane (Ref. 2).

The productivity indices currently used for the Substation plant account i.e. manhours per telephone service is biasing the Costing Section figures heavily against high density office and industrial areas. This situation is caused by the change in ratio of telephone stations to telephone services due to the large quantity of extension telephones on P.M.B.X.s and P.A.B.X.s and is further aggravated by the attendant switchboard faults e.g. Brisbane suburban area has approximately 7.2% of reported faults assigned to switchboards ('B' clearances) while the inner city area has approximately 34% in the same category.

The above distortion plus discrete staffing factors could cause the productivity indices of metropolitan service No. 1 division F.D.C., for the first year of operations to be lower than were anticipated.

In conclusion, it is suggested that the degree of improvement be considered short term phenomena until the effect of the following motivational factors are apparent.

- Concentrated Management Attention (during reorganisation).
- Reduction in Identity. A large substation maintenance group now exists.
- Increase in Group Affinity. The suburban substation technician is no longer "The Outside Man" in a predominantly exchange maintenance group.

Although substantial gains in productivity have been achieved and the effectiveness of the organisation can be favourably compared with that of the highly developed organisations in overseas countries, there still remains much to be done in this area of operations.

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(1) R. Torkington, "Service Centre for Telephone Complaints"; Telecom. Journal of Aust., Feb, 1965, Vol. 15, No. 1, Page 35.

(2) "Work Study Report No. 6504"; Metropolitan Branch, Queensland, March, 1965. (An Internal A.P.O. document.)

(3) B. J. Carroll, "Centralised Maintenance Practices Overseas"; Telecom. Journal of Aust., Feb, 1969, Vol. 19, No. 1, Page 20.

Dunstan-Brisbane F.D.C.

TECHNICAL NEWS ITEM

NEW SCALE OF UNIVERSAL TIME

Important changes in time keeping were introduced by time signal broadcasters throughout the world on 1 January 1972. These changes were recommended by the Interim Meeting of C.C.I.R. Study Group VII in Geneva in February 1971. The recommendations mean that the time scale used for time signal broadcasts and civil time will use the SI unit of time interval which was defined by the 1967 General Conference of Weights and Measures in terms of a particular transition of the caesium atom.

Time signals to date have not followed uniform scales but have been adjusted at intervals in an attempt to provide a scale which closely matches the non-uniform rotation of the earth on its axis. The new time scale (known as UTC) transmits the SI second and thus provides a scale of high uniformity and gives the user access to the fundamental unit of time, the second.

A large number of time signal users, e.g. navigators and surveyors, require a knowledge of the earth's angular position on its axis, which is given by the astronomically derived Universal Time, UT1. To cater for this application, the new UTC scale will be kept within 0.7 second of UT1 by occasional (about once per year) step adjustments of precisely one second. This method of adjustment maintains a continuity of second intervals, but means that a certain minute (to be stipulated in advance by the International Time Bureau in Paris) will be 61 seconds long.

To provide more precise information on the relationship between the new UTC scale and UT1, time signal broadcasting stations (such as VNG, Lyndhurst, Victoria) transmit specially coded signals to enable users to determine UT1 time to the nearest 0.1 second; this being sufficient accuracy for most navigating and surveying work. The coding scheme simply requires the user to note the position and number of specially emphasized seconds markers from which he can determine the difference between UT1 and UTC time.

The new UTC scale therefore provides, in the one transmission, the fundamental unit of time interval (the second), a uniform time scale of high precision and, by means of this special code, astronomical (UT1) time. All civil time signals controlled by the Australian Post Office such as the hourly time signals broadcast by medium and high frequency radio stations, coastal shipping time signals and telephone time-of-day (speaking clock) services and the Australian Post Office Standard Frequency and Time Signal Service VNG, have operated on the new UTC scale from 1 January, 1972.

TELECOMMUNICATION JOURNAL OF AUSTRALIA
AUSTRALIAN TELECOMMUNICATION RESEARCH

Increasing costs have forced an upward revision of subscription rates for the above journals with effect from 1972 calendar year, which is also the volume year.
The new annual subscription rates and the first volume affected are shown below:

Telecommunication Journal of Australia : $2.50 ($1.80)* as from Vol. 22 Nos. 1-3 (1972).

Australian Telecommunication Research : $3.00 ($2.50)* as from Vol. 6 Nos. 1-2 (1972).

Single copies of the current subscription year are available:

Telecommunication Journal of Australia : $0.85 ($0.60)*

Australian Telecommunication Research : $1.50 ($1.25)*

Back numbers (other than current subscription year), if available, are sold at the following rates:

Telecommunication Journal of Australia : $0.75 ($0.50)*

Australian Telecomunication Research : $1.25 ($1.00)*

(*The bracketed rates so marked apply only to residents of Australia (and Papua-New Guinea) who are also members of the Telecommunication Society of Australia.)

The subscriptions are quoted in Australian Currency, and proper conversion must be made from other currencies, including U.S. and Canadian dollars. All rates include surface mail postage.

OUR CONTRIBUTORS

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J. BUDDEN, author of the article 'The Effect of Common Equipment Faults on Switching Systems', joined the P.M.G.'s Department as a Cadet Engineer in 1958. After graduating Bachelor of Engineering at the University of New South Wales in 1962, he joined the newly formed Service Co-ordination Centre of the Sydney Metropolitan Equipment Service Section. During the next four years he was associated with the development of switching equipment maintenance techniques. From 1964 to 1967 he served as Secretary to the Network Signalling and Supervision Committee. In 1965 he was transferred as Engineer Class 2, Parramatta Equipment Service. He gained a Bachelor of Economics, majoring in Statistics, at the University of Sydney in 1967 and in that year was awarded a Commonwealth Post-Graduate Scholarship to undertake study at Massachusetts Institute of Technology. He graduated Master of Science in 1969 with a thesis which formed the basis of the article in this issue. On return to Australia he was transferred to Trunk Service where he was concerned with the extension of Network Performance techniques to the maintenance of Country transmission and switching networks in New South Wales.

In January, 1970 he was seconded to Office of the Economic Advisor in the Public Service of Papua and New Guinea to assist in the development and implementation of economic programmes for the Territory.

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E. D. DUNSTAN, author of the article 'The Introduction of Fault Despatch Centres in Brisbane', was employed for a period on electrical work in private industry. He served in the Army from 1943-47 as Staff Sergeant and for the latter half of this period was responsible for the operation and maintenance of a variety of electrical equipment.

He joined the P.M.G. Department in 1948 in Metropolitan Service Division, Brisbane, qualifying as a Technician Telephony in 1950, Technician Radio and Broadcasting in 1952, and as a Senior Technician in 1954.

During the period 1953-62 he was Supervising Technician in charge of 14 different stations. In 1963 he was given the task of organising the substation maintenance of 14 separately controlled exchange areas into a Centralised Despatch System. Subsequently, as Technical Officer Grade 2 (Work Study), he undertook the project of complete centralisation of the subscriber's repair service, Brisbane.

He was admitted to the Institute of Radio and Electronic Engineers as an Associate in 1952 after completion of a Radio Engineering Course with a private college and is a Graduate Member of the Institute of Industrial Engineers. He holds a certificate from the Royal Melbourne Institute of Technology and completed a Work Study Certificate Course with the Queensland Technical College.

★

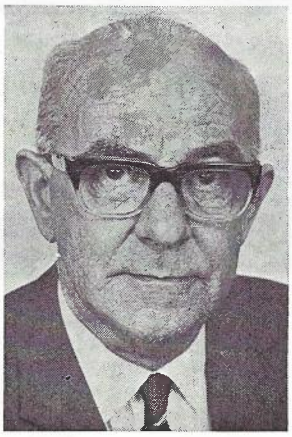
J. D. HAMPTON, author of the article 'Use of an ARM 20 Exchange for International Telephone Switching', graduated as a Bachelor of Engineering from the N.S.W. University in 1956. He spent two years with T. S. Skillman and Co. employed on the testing and development of carrier telephone equipment, followed by 3 years in Canada employed by the Canadian Marconi Company on operation and maintenance aspects of the "Mid Canada Early Warning Line", an aircraft detection system.

He joined the Overseas Telecommunications Commission (Australia) as an Engineer Grade 2 in 1962 and was promoted to Engineer Grade 3 in 1966. During his period as a Grade 2 and Grade 3 Engineer he was in charge of the installation of the first Australian International Gateway Telephone Exchange, the ATE 5005. He also was responsible for the expansion of that Exchange and the installation of its replacement, the ARM 20 Exchange, which is the subject of this paper, as well as the installation of the Australian Telex International Gateway Exchange. In December, 1968 Mr. Hampton was promoted to the position of Sectional Engineer (Transmission) in the Operations Branch of the Commission, which is his present position. In this position he is responsible for the maintenance of the International Telephone Exchange, the operation and maintenance of the Commission's four cable stations and all of the Commission's telephone transmission equipment.

★

S. E. JELLEY, co-author of the article 'Fire Reporting System for Volunteer Fire Brigades', joined the Postmaster-General's Department as a Technician (Light and Power) on discharge from the R.A.A.F. early in 1946.

In 1954 he became a field officer and subsequently a Senior Technical Officer in the Buildings Engineering Services sub-section. During this latter period he designed the standard



S. E. JELLEY

R. A. RANKIN

F. J. W. SYMONS

control unit for departmental fire alarm systems. It was at this time that he, along with Mr. Nelder, became involved with the problems confronting the Country Fire Authority of Victoria in providing a line communications network that would be adequate to the rather complex requirements necessary to facilitate the operations of the volunteer fire brigades. He was seconded to the Authority in 1968 to re-organise and standardise the C.F.A. line communications and alarms network.

★

F. P. HUTCHINGS, author of the article, 'Man-Machine Communication System for the IST Project', graduated from the University of Canterbury, Christchurch, N.Z., with the degree of Bachelor of Engineering (Electrical) in 1960. In the same year he joined Standard Telephones & Cables Pty. Ltd. in Sydney, and was soon afterwards transferred to Melbourne, where he worked on the French Pentaconta crossbar exchange installation at Kew, Victoria. In 1963 he returned to Sydney, and was involved in the design of the Australian Pentaconta P.A.B.X. series. Mr. Hutchings was transferred to Stuttgart, Germany, in 1966, where he did further P.A.B.X. design work at Standard Elektrik Lorenz, A.G. The following year he moved to Bell Telephone Manufacturing Company in Antwerp, Belgium, where he was employed on the 10C system, specialising in the ITT central processors used for the system control. He returned to Australia in 1969, and spent two years in Melbourne. During this time Mr. Hutchings installed and commissioned three ITT processors at the A.P.O. Research Laboratories, and contributed to the software system of the IST project.

R. A. RANKIN, author of 'A Solid State Teleprinter Exchange for Conference Calling', first joined the Postmaster-General's Department in 1946 as a Cadet Engineer and obtained a B.Sc. degree from Melbourne University in 1949. He spent a number of years in country lines divisions at Colac and Geelong before establishing the Mildura country division in 1956. In 1961 he established the seventh Metropolitan Lines Division in Melbourne and two years later transferred to Telegraph Installation Division where he is at present an Engineer Class 3. He is a member of the Institution of Engineers.

★

F. P. HUTCHINGS

F. J. W. SYMONS, author of the article 'Data Flow and Data Formats in the Computer Control of an Electronic Telephone Exchange', joined the Postmaster-General's Department as a cadet engineer in 1955. After graduating from the University of Adelaide with First Class Honours in Electrical Engineering in 1959, he worked for fifteen months as an Engineer Grade 1 with the Planning Section, South Australia. In 1961, he left for England to accept a GEC Overseas Fellowship.

Mr. Symons spent two years with G.E.C. in the Telecommunications Division, Coventry, and the Research Laboratories, Wembley, and one year at the Imperial College of Science and Technology, London, where he completed the post-graduate course in Communications and Electronics.

On return to Australia, Mr. Symons joined the Research Laboratories and worked as an Engineer Class 2 in the Multichannel Systems Division for 18 months, mostly on the delay tests over the COMPAC cable. Late in 1965 he was appointed acting Engineer Class 3 in the Probability Division and in early 1967 he was transferred to acting Engineer Class 3 in the Semiconductor Circuitry Division, where active work on the IST project was just commencing. Since that time Mr. Symons has been concerned mainly with the design and development of the programs for the IST project, initially as Engineer Class 3 in the Semiconductor Circuitry Division, and from early 1968 as Engineer Class 3 in the Switching Processors Division. In August, 1970, Mr. Symons was transferred to Engineer Class 4, Network Studies and Techniques in the Switching and Signalling Section, where he has been concerned mainly with planning the further phases of the IST project.

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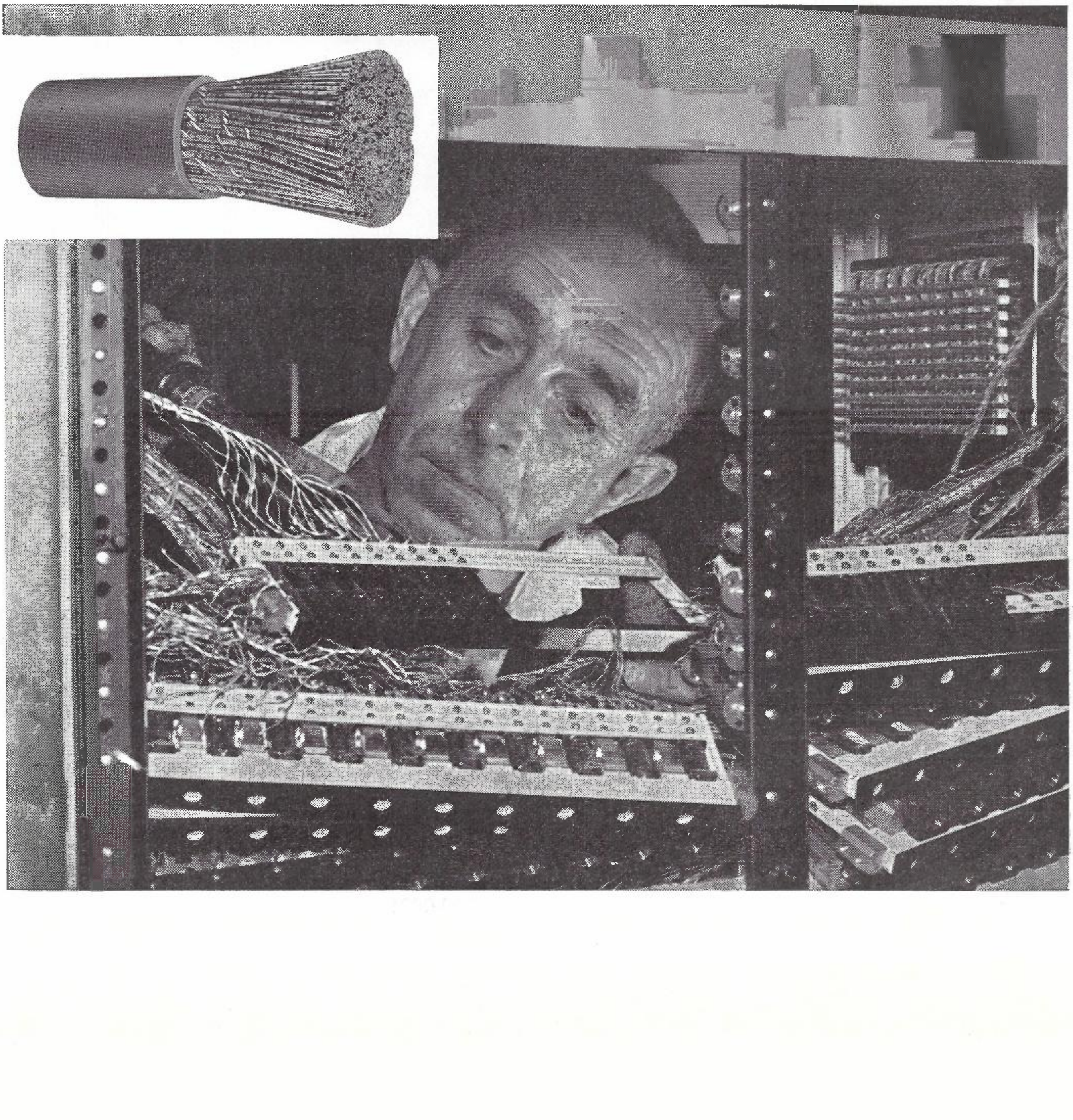

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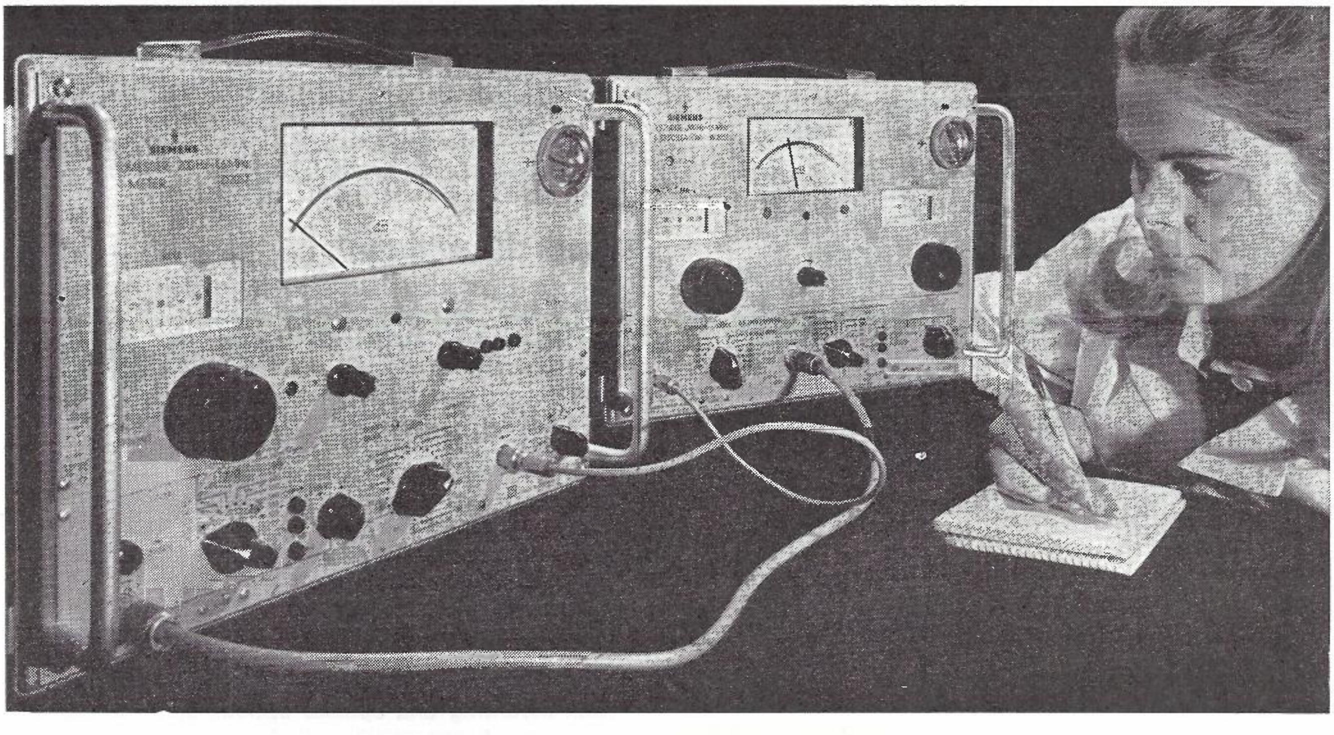

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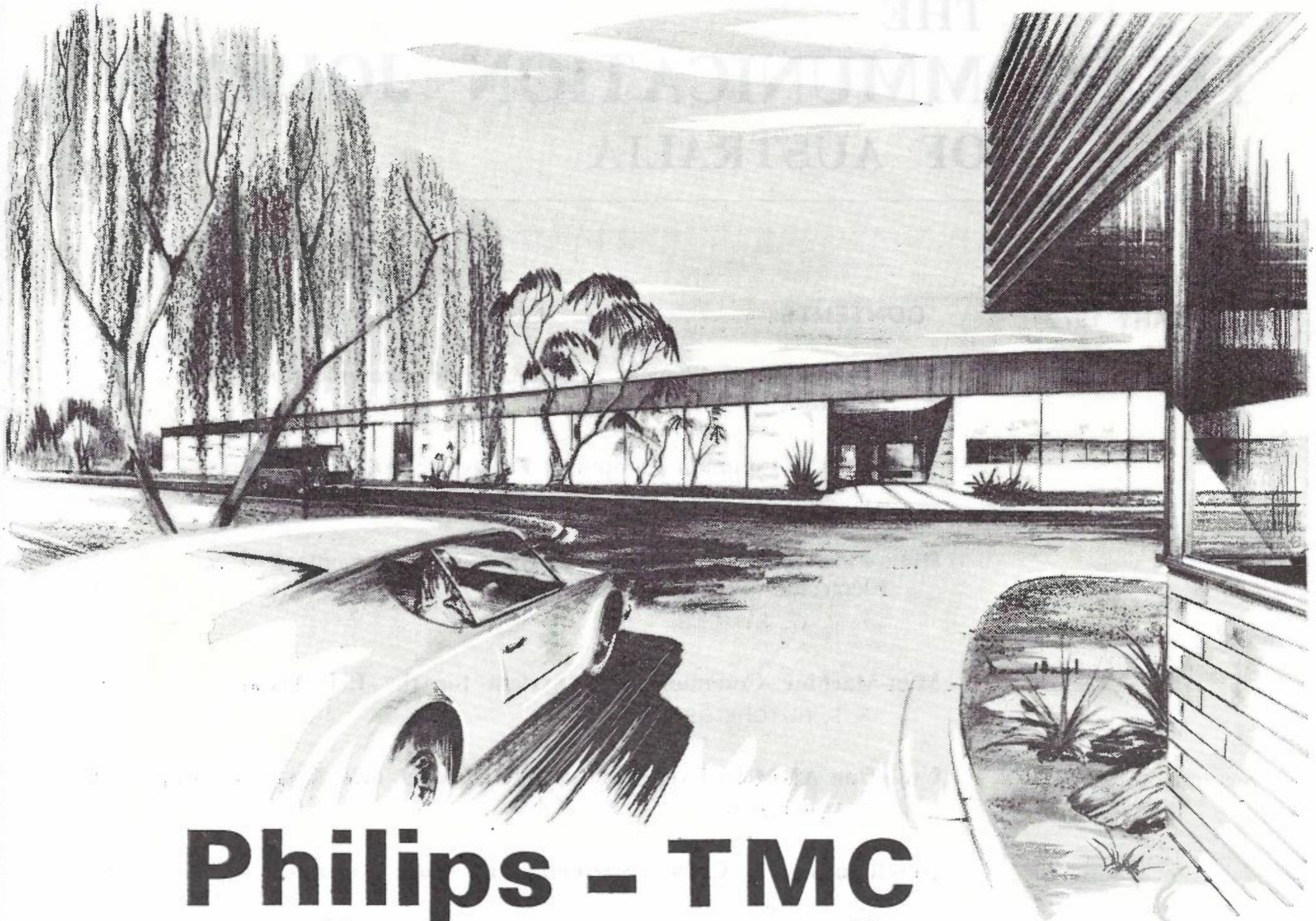

THE TELECOMMUNICATION JOURNAL OF AUSTRALIA

VOL. 22, No. 1
FEBRUARY 1972

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The TELECOMMUNICATION JOURNAL of Australia

ABSTRACTS: Vol. 22, No. 1

BUDDEN, J.: 'The Effect of Common Equipment Faults on Telephone Switching Systems'; Telecom. Journal of Aust., February 1972, page 9.

When an item of common equipment in a telephone system develops a fault condition, service to the subscriber suffers until that fault is detected and the item withdrawn from service. The extent to which service is impaired is a complex function of the technical characteristics of that system and the aggregate response by the subscriber to the unsuccessful calls. A model of this system is developed and explored in this paper. The most general expression for the relationship between the physical and environmental parameters and the resultant quality of service is derived. Examples of the application of these results to design and maintenance strategies in automatic telephony are given.

DUNSTAN, E. D.: 'The Introduction of Fault Despatch Centres in Brisbane'; Telecom. Journal of Aust., February 1972, page 90.

This article describes the approach used to design and instal a Fault Despatch Centre, i.e. centralised testing, fault control and maintenance organisation for the Brisbane Metropolitan area. The plant layout and facilities are briefly discussed and survey detail of the effectiveness of the new system is included.

FLETCHER, C. and LIUBINAS, A. E.: 'Commissioning and Maintenance of ARM Exchanges'; Telecom. Journal of Aust., February 1972, page 72.

In a series of three articles the authors describe testing procedures developed for the commissioning of ARM exchanges. The emphasis is on those tests which ensure satisfactory interworking of the ARM equipment with the telephone network. The principles of the maintenance of ARM equipment are also covered.

GOOLEY, M. J.: 'Developments in Cable Distribution in South Australia'; Telecom. Journal of Aust., February 1972, page 55.

A brief description of application of trench-sharing techniques for telephone and electricity cables in South Australia is given. The satisfactory results of co-ordination of cable and pipe laying are considered to justify action to place the several activities in the hands of one contractor.

HAMPTON, J. D.: 'Use of an ARM 20 Exchange for International Telephone Switching'; Telecom. Journal of Aust., February 1972, page 45.

This paper examines the specialised role of the ARM 20 Exchange installed by O.T.C.(A) which acts as the Gateway Exchange for all international telephone traffic to and from Australia. It also acts as a major international switching point in the Pacific region, handling a considerable amount of international transit switched traffic. The paper examines the range of signalling systems that are handled by the exchange and the translation facilities utilised to overcome incompatibilities between the various signalling systems, and outlines the performance criteria of the Exchange, including grade of service limits and transmission limits. It then outlines the facilities which are incorporated in the Exchange that are not totally essential to the normal function of an Exchange, but which are necessary adjuncts to the specialised role played by this Gateway Exchange, including some details of the statistical information that is obtained from call by call recording equipment (Toll Ticketer).

HUTCHINGS, F. P. 'Man-Machine Communications System for the IST Project'; Telecom. Journal of Aust., February 1972, page 35.

Stored program control creates new problems in telephone exchange maintenance. This paper describes the system provided for the exchange staff to communicate with the central processor in the IST system being developed in the A.P.O. Research Laboratories. The equipment, the programs, and the method of operation are discussed, and an indication is given of the practical applications of man-machine communication.

JELLEY, S. E., and NELDER, R.: 'Fire Reporting System for Volunteer Fire Brigades'; Telecom. Journal of Aust., February 1972, page 84.

This paper describes a communications system that has been developed to assist the operations of the volunteer fire brigades in Victoria. Utilising extensively the private telephone services of the brigade members, the system provides in a most economical way a number of communications facilities. These will assist considerably the brigades' response to calls from the public and, if required, the speedy alerting of additional members.

RANKIN, R. A.: 'A Solid State Automatic Teleprinter Exchange for Conference Calling'; Telecom. Journal of Aust., February 1972, page 58.

A 600 line solid state teleprinter exchange has been built and installed in the Central Telegraph Office, Melbourne, primarily for the broadcast of telephone orders from Sales Branch offices, but with spare capacity to handle other teleprinter communication needs of the Victorian Administration of the Australian Post Office. It comprises one rack of equipment eight feet six inches high by five feet six inches wide holding 1,000 printed circuit cards of D.T.L. micrologic circuitry and other solid state discrete components. The exchange uses time division switching with no mechanical cross points and is designed on common control principles. It is regenerative and operates on up to 8,000 ohm line loops. Conference calls can be set up by calling stations sequentially or by a pre-arranged group call code with sequential answer back.

SYMONS, F. J. W.: 'Data Flow and Data Formats in the Computer Control of an Electronic Telephone Exchange'; Telecom. Journal of Aust., February 1972, page 19.

The introduction of processor control involves many important changes in the characteristics of telephone exchanges. One of the major changes is that the control system of a processor controlled telephone exchange is much more abstract than the control system of conventional exchanges, and it can appear completely intangible to the technician in the field. This paper describes the data flow and data formats, together with the relative roles of programs and data, in the program control system developed for the integrated switching and transmission project being carried out by the Research Laboratories of the Australian Post Office. An example is given of the data flow and data formats involved in the handling of a simple successful telephone call.

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