THE

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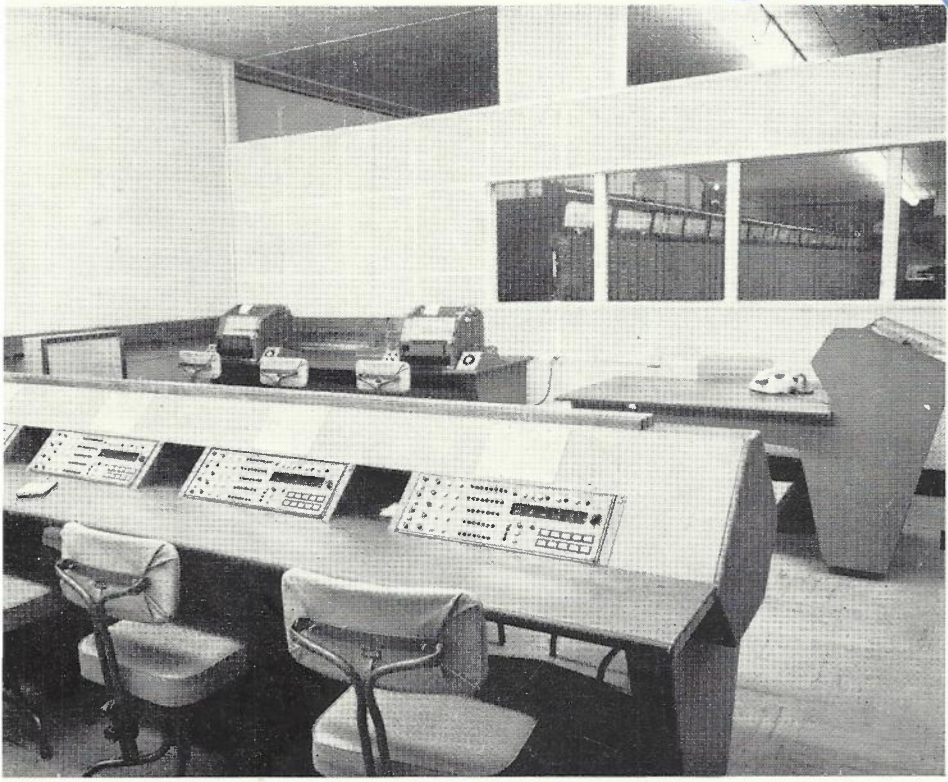

BRISBANE SERVICE CENTRE

IN THIS ISSUE

VOL. 15, No. 1 Registered at the General Post Office, Melbourne, for transmission by post as a periodical. FEBRUARY, 1965


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TELECOMMUNICATION JOURNAL

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*For addresses see page 58.

SEACOM SUBMARINE CABLE SYSTEM: SYDNEY-CAIRNS LAND SECTION — OVERALL PLANNING ASPECTS

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INTRODUCTION

In subsequent issues of the *Journal* a series of papers will be published on the detailed planning, installation and testing associated with the Sydney-Cairns broad band system and its use as a link in the SEACOM submarine telephone cable system. Apart from catering for terminal traffic to and from South East Asia, it provides the link for through traffic on the SEACOM and COMPAC submarine cable systems.

The purpose of this introductory paper is to set down some general features and historical background of the system, the relationship of the land section to the submarine cable, and overall planning aspects of the land system. In this connection and in view of the overall importance of the international circuits that are involved, very close co-operation has been necessary with the Overseas Telecommunications Commission (Australia), who are responsible for the submarine cable part of the system.

The land route divides conveniently into three sections:—

Sydney-Lismore,
Lismore-Brisbane,
Brisbane-Cairns.

On the Sydney-Lismore and Lismore-Brisbane sections, plans had already been developed and installation commenced on broad band systems prior to the agreement to proceed with the SEACOM cable. On the other hand, the decision to proceed immediately with the Brisbane-Cairns broad band system was directly associated with the SEACOM cable proposal. For this reason the detailed papers will be related in a large measure to this section of the land route.

SEACOM CABLE SYSTEM

In London in 1958 a meeting of representatives of Commonwealth overseas telecommunication authorities recommended the adoption of a proposal for the provision of a Commonwealth owned and operated round the world submarine telephone cable scheme. This scheme was subsequently agreed to in principle at a meeting of representatives at Government level held in Montreal later in 1958. The trans-Atlantic section (CANTAT) and trans-Pacific section (COMPAC) were implemented in 1961 and 1963 respectively, Refs. (1) and (2), with the installation of an 80 circuit 3 kc/s channel spacing, light-weight, submerged repeater, submarine telephone cable. This type of cable which consisted, except at shore ends, of an armourless coaxial cable with a central steel core for strength purposes, represented a major change from conventional submarine cable practice. One of its main advantages was that it considerably simplified the use of a two-way submerged repeater installed on a single cable. A development of the British Post Office and Submarine Cables Limited, it has since been adopted for all subsequent long distance submarine telephone cable systems.

In 1961 and 1962, meetings were held in Kuala Lumpur to discuss the extension of these cables from Australia to South East Asian countries and at the meeting in 1962, at which U.K., Canada, New Zealand, Singapore, Malaya and Australia were represented, agreement was reached on the provision of a similar 80 channel cable between Australia, Singapore and Hong Kong. This agreement was subsequently ratified by the respective Governments and laying of cable between Singapore, North Borneo and Hong Kong commenced in 1964. It is planned that the complete system be cut into service between Sydney, Singapore and Hong Kong about mid 1966. During 1963 and the early part of 1964, the 1962 planning of the cable was modified to provide a 160 channel cable between Australia and New Guinea. This capacity cable with associated repeaters had been developed in the meantime and for an expenditure of less than an additional 20 per cent. in capital cost, it was practicable to double the traffic capacity of this section of the cable and permit a through capacity of 80 channels to Hong Kong and Singapore, exclusive of New Guinea or similar traffic routes. This will involve the provision of additional circuit capacity between Sydney and Cairns at an appropriate stage in the development of submarine cable traffic, probably in the early 1970s.

The agreement provided for the circuits over the section Cairns-Brisbane-Sydney to be routed via a land line system forming part of the Australian national network. (See Fig. 1.) This decision was reached after careful consideration of the relative costs, the suitability of a landing for the submarine cable at Cairns, circuit performance and time factors. Detailed ocean surveys by the Cable & Wireless cable ship "Recorder" showed satisfactory sea bed conditions between Cairns and New Guinea.

SPECIFICATION OF REQUIREMENTS

The 1962 SEACOM agreement laid down certain technical requirements to be met by the land line system in the extension of the 3 kc/s channels from Cairns to Sydney. These were aimed primarily at maintaining the rigid performance limits established for the submarine cable itself. The main requirements are:—

(1) A performance involving outage time not in excess of 0.1% over a four-week period.
(2) No-break power supply to be provided at all terminals and repeaters.
(3) Automatic standby with preference for the SEACOM channels and the break in transmission during change over to be less than 2 milliseconds.
(4) No spurious tones affecting any 3 kc/s channel to be in excess of −60 dbmo. (Subsequently changed to −66 dbmo.)
(5) Mean psophometric noise during any hour averaged over all channels not to exceed:—
Lismore-Brisbane-Cairns (1785 km), 1 pw/km.
Sydney-Lismore (668 km), 3 pw/km.
(6) Design objectives for noise with reference to telegraphy transmission to be in accordance with the appropriate C.C.I.T.T. recommendations (G.442, Pages 180-181, Vol. 3 of C.C.I.T.T. Red Book).

THE LAND SYSTEM

The overland portion of the route between Sydney and Cairns will be provided by Departmental broad band communication links which, in addition to providing for the SEACOM international traffic will also carry domestic telegraph and telephone traffic, as well as making provision for television programme relays. The total route distance involved is 1,535 miles along the north eastern coast of Australia and the link will consist basically of the following components connected in tandem:—

(a) A broad band radio system between Sydney and Lismore.
(b) Coaxial cable system between Lismore and Brisbane.
(c) A broad band radio system between Brisbane and Cairns.

The geographical locations of the main stations involved and the overall system arrangements are shown in Fig. 2.

The provision of 3 kc/s spaced channels on the SEACOM supergroup in lieu of standard 4 kc/s spaced channels necessitates the use of special measures to avoid interference in the speech bands. With 3 kc/s spaced channels, any spurious signals resulting from group carrier leak or harmonics of the group carriers may well cause interference in a speech band; however, when 4 kc/s channel spacing is employed these spurious signals fall in innocuous positions in the frequency spectrum and are therefore of no consequence.

In order to control this source of spurious interference with the 3 kc/s spaced channels on the SEACOM supergroups, through supergroup filters will be employed on certain other supergroups to reduce the group carrier leak

*Mr. Griffiths is First Assistant Director-General, Engineering Works, Headquarters. See Vol. 14, No. 2, Page 166 and Vol. 14, No. 4, Page 256.

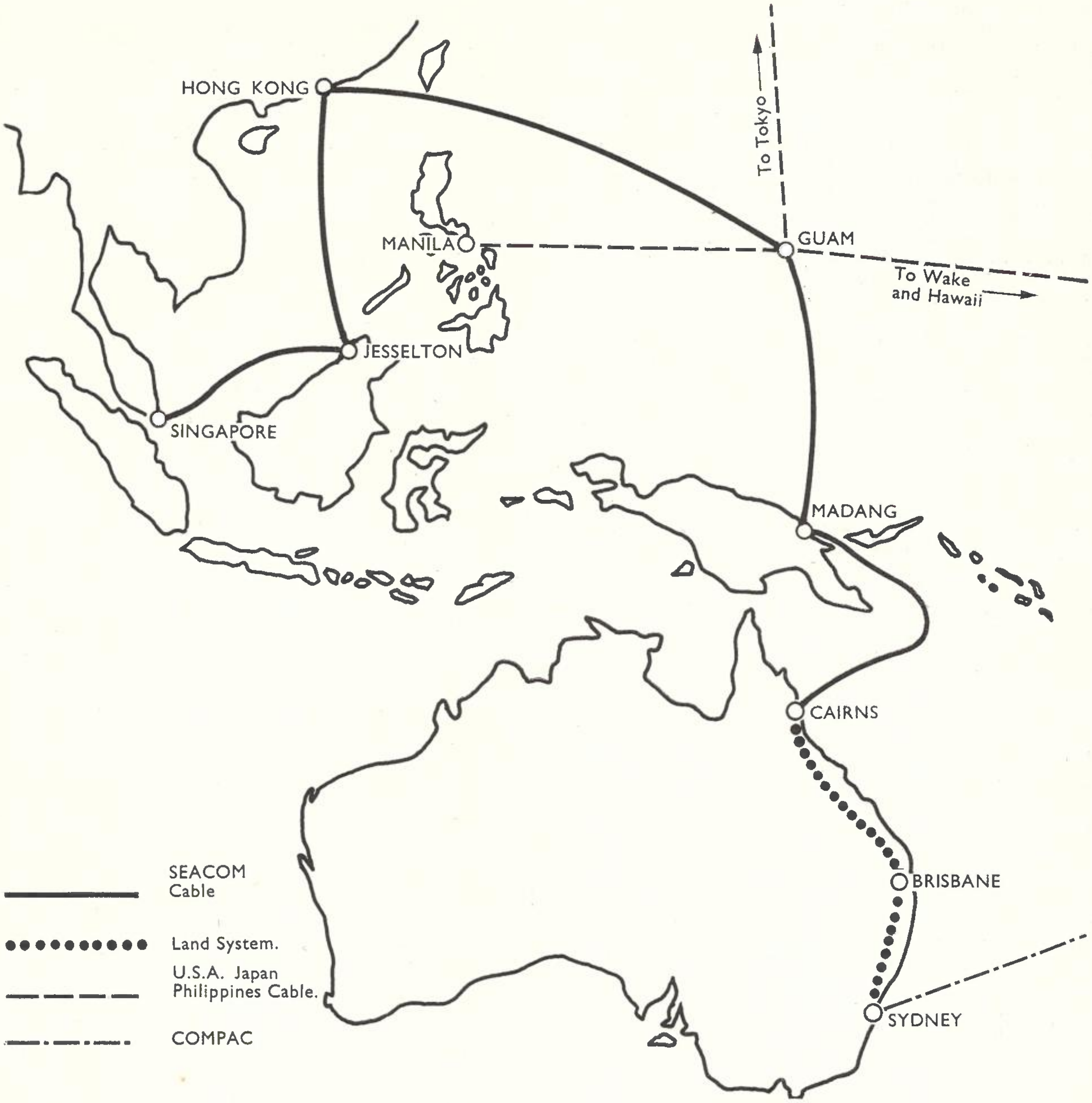


Fig. 1.—SEACOM Submarine Telephone Cable System.

and group carrier harmonics to an acceptable level to permit the specified –66 dbmo limit on spurious signals to be met.

TRAFFIC CONSIDERATIONS

As mentioned earlier, broad band systems were already being installed between Sydney and Brisbane based on 16 supergroup 960 channel operation and the requirement of two supergroups for SEACOM has no important effect on overall planning. Television relay needs, together with longer term planning, envisages the completion of a broad band radio bearer link from Lismore to Brisbane. At the same time, extension of the coaxial cable between Lismore and Sydney is planned to cater for intermediate development. In due course this planning will provide two main types of broad band system Sydney-Brisbane and thus improve overall circuit reliability.

Between Brisbane and Cairns domestic development of telephone and telegraph traffic pointed to the need for replacement of the existing open wire pole route carrying 3 and 12 circuit systems with a broad band system. 1960 planning contemplated a progressive extension of such a system north from Brisbane over a period of years consistent with saturation of the various main sections of the open wire route.

However, the inclusion of Maryborough, Mackay and Cairns in Phase 4 of the extension of television service to country areas, together with Rockhampton and Townsville which were included in the earlier Phase 3, made the provision of a television relay channel to connect all these centres to the main Brisbane studio desirable.

The SEACOM requirement therefore advanced the overall planning to meet domestic trunk development and enabled the establishment of the Phase 4 television stations on a relay basis rather than from local studios.

Domestic traffic development on this section is shown in Fig. 3. Fig. 3a shows the development based on a 1958 traffic study which was used in the original design basis for the SEACOM radio system. In view of the stringent noise requirements for the SEACOM circuits the system design was arranged to restrict loading on the bearer carrying these circuits and the specification called for a capacity of 600 circuits between Brisbane and Maryborough with 300 circuits in the Maryborough to Cairns section. This capacity catered for the 20 year requirements for domestic circuits as then envisaged and simplified meeting the low noise specification. However, the increased traffic which has led to the proposal to expand the capacity of the submarine cable system has also occurred on the domestic trunk system and a recent review of this traffic has indicated a considerably higher requirement. The new development prediction is shown in Fig. 3b. This indicates the need for a second telephone bearer as far as Rockhampton by about 1970 depending upon whether the channel noise characteristics achieved in practice will allow the 600 and 300 channel capacities to be exceeded.

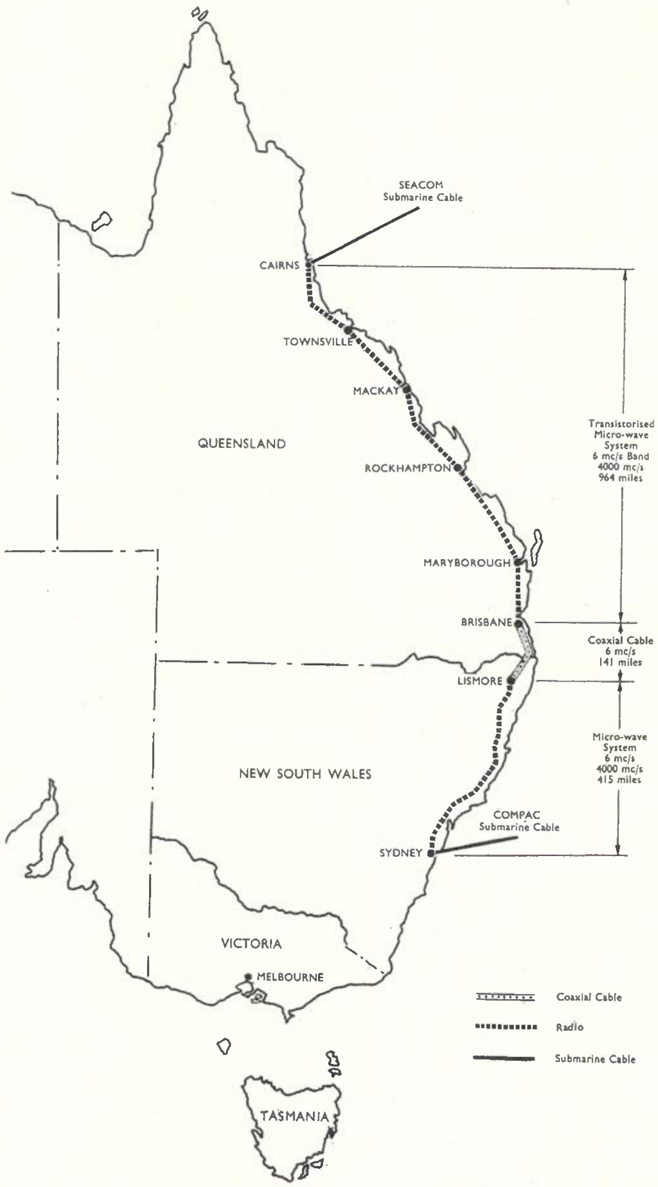


Fig. 2.—Geographical Layout Sydney—Cairns.

SYDNEY-LISMORE RADIO SYSTEM

Between Sydney and Lismore, a route distance of 415 miles, a broad band radio bearer system operating in the 4000 Mc/s band and with a capacity of 960 telephone channels has been installed, complete with standby or protection channel facilities. The Sydney terminal is at the Redfern radio telephone terminal station and the northern terminal is at Goonellabah on the outskirts of Lismore. There are twelve intermediate repeater stations, of which one, at Port Macquarie, is a demodulating station and will be attended. The remainder are unattended and located at convenient mountain top sites spaced at about 30 mile intervals.

The radio bearer equipment is manufactured by Standard Telephones & Cables Ltd., London, and has a capacity of 960 telephone channels over the frequency band 60-4028 kc/s. The radio equipment is normal valve type equipment of high reliability and is equipped with full supervisory and control facilities which enable the telemetering of circuit performance and fault data from any repeater back to the terminal, so that the appropriate action can be speedily taken. The state of the automatic controls and the nature of failure are displayed on a panel at the terminal station from information available on the telemetering equipment. In addition, certain remote control facilities are provided so that, for instance, the emergency diesel engine supplying power at a repeater station can be started from the terminal.

The aerial system used on this route is a ten feet diameter parabolic reflector which is supplied with the microwave energy from the radio equipment by a horn feed assembly located at the focal point of the paraboloid, the connection between the aerial and the transmission equipment being made by rectangular wave guides. The aerial systems are mounted on towers, the heights of which are dependent on the nature of the terrain between adjacent stations. A single parabolic reflector aerial can carry both the transmitted and received signals on one leg of the path, the two signals being separated by means of wave guide directional filters.

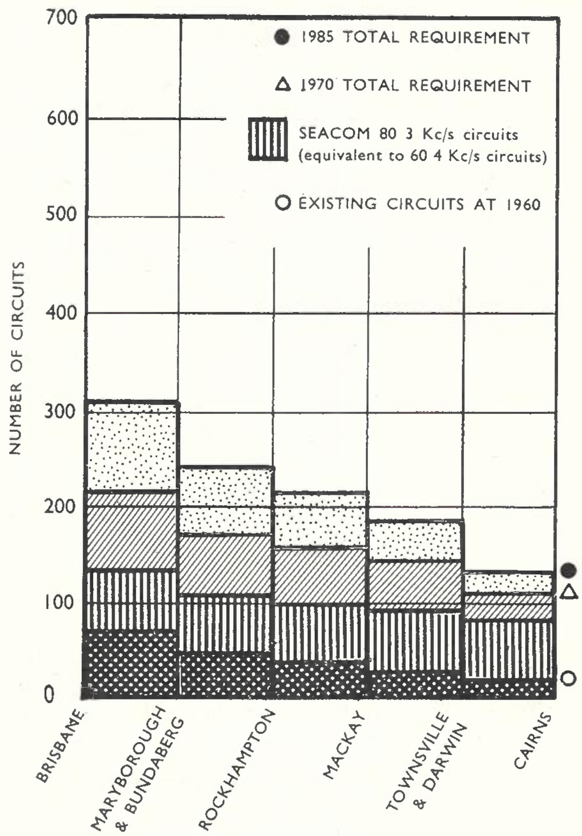
The radio equipment provides a broad band main line both-way radio bearer and operates in the frequency band 3600-4200 Mc/s per second with individual stations allocated frequencies in accordance with the plan for the Australian network. The bearer provides facilities for up to 960 telephone circuits each with a bandwidth of 300-3400 c/s and meeting C.C.I.T.T./C.C.I.R. recommendations for long distance circuits.

At the Goonellabah radio terminal, the base band output of the radio system is fed over a short coaxial tail to Lismore long line equipment station for transfer to the Lismore-Brisbane coaxial cable.

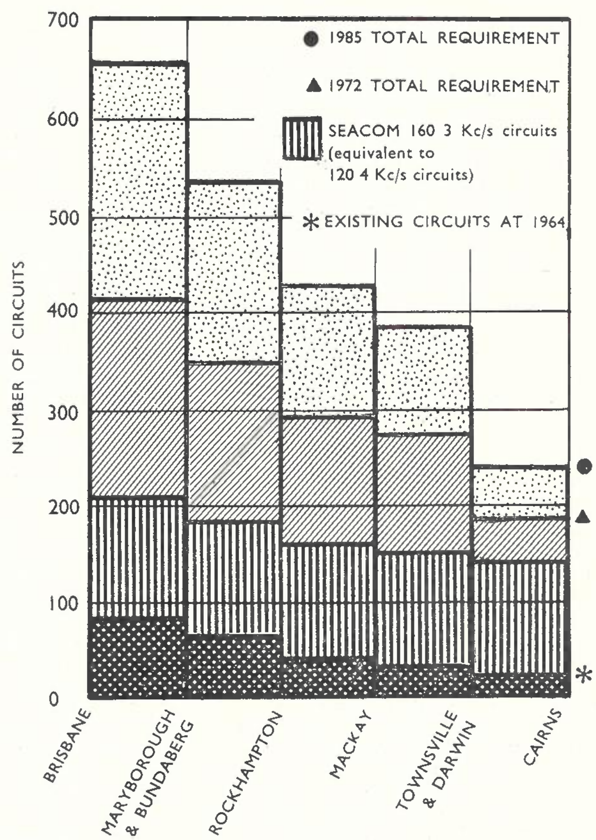
The basic design of this system had been set before the 1962 submarine cable negotiations and the noise limits were not as stringent as those applying to the submarine cable. It was designed to the C.C.I.T.T. specification for national circuits. Overall noise and intermodulation distortion measurements have been made between Sydney and Brisbane in both directions of transmission and the total weighted signal to noise ratio measured at the line frequency of SEACOM supergroup 4 (1002 kc/s) conforms with the C.C.I.T.T. requirement of 3 pw/km. and the specified limit for Sydney-Lismore referred to earlier in this paper.

LISMORE-BRISBANE SECTION

A four-tube 0.375″ standard coaxial cable exists on this section (141 miles). Repeaters are at slightly less than six-mile spacing and the equipment provides a 6 Mc/s channel on one pair of tubes, the second pair being available



3a. Based on 1958 Traffic Study.



3b. Based on 1964 Traffic Study.

Fig. 3.—Brisbane-Cairns Route—Trunk Circuit Requirements Between Major Centres.

for standby purposes. The bearer provides facilities for 960 telephone circuits each with a bandwidth of 300-3400 c/s and meeting C.C.I.T.T./C.C.I.R. recommendations for long distance circuits.

There are 25 intermediate repeater stations of which two are main partially attended stations, three are minor partially attended stations and 20 are unattended dependent stations. The unattended stations are placed at approximately six-mile intervals between partially attended stations and are fed with A.C. power (50 c/s) from the minor partially attended stations over the centre conductors of the coaxial cable.

The equipment is manufactured by Standard Telephones & Cables Ltd., England, and the line system has a capacity for 1260 telephone channels with C.C.I.T.T. frequency spacing in the frequency band 60-5564 kc/s but is equipped with translating equipment for 960 channel operation only over the frequency band 60-4028 kc/s. In the frequency structure 60-4028 kc/s SEACOM traffic occupies the position of supergroup 4 (812-1062 kc/s).

No-break power standby facilities are provided at main power feed stations on the same basis as in the broad band radio bearer Sydney-Lismore.

BRISBANE-CAIRNS SECTION

This is the longest section of the route, being 964 miles from Brisbane to Cairns. It is the largest single microwave communication project to be undertaken by the Department and when completed early in 1966, will provide a broad band route to cater for the SEACOM traffic and to satisfy the immediate and future trunk and television relay requirements of towns and cities along the east coast of Queensland. The Brisbane-Cairns microwave radio project will provide a telephony bearer with standby facilities between Brisbane and Cairns to supply SEACOM requirements and wayside traffic, with provision for expanding the capacity of the route to provide for future expansion of trunk facilities. In addition, a television relay channel from Brisbane to Cairns provides programme to existing and proposed National Television Service stations at Maryborough, Rockhampton, Mackay, Townsville and Cairns. There are 30 intermediate repeaters, of which four will be demodulating stations which will be attended, the remainder being completely unattended. The radio equipment is operated from a 48 volt battery supply so that no-break performance is obtained. The battery is floated from a mains rectifier with an emergency diesel engine alternator automatically operated in the event of the main supply failure. The system provides a 6 Mc/s television relay channel (625 lines) throughout from Brisbane to Cairns, a telephone bearer providing a maximum of 600 channels Brisbane-Maryborough and 300 channels Maryborough-Cairns within the 1 pw/km limit, and a standby channel.

The standby bearer is available also for protection of the television bearer channel under fault conditions, and arrangements have been made so that the telephony bearer has priority of access over television to the protection bearer at all times. As the television bearer is provided in the north bound direction only, in the south bound direction the protection channel serves the telephony bearer only. Because of the nature and importance of the route and its role in international communications, it was necessary to pay particular attention to reliability aspects, and in order to improve the reliability and reduce circuit outages at all times, an unusual arrangement of radio channels was devised. Under normal conditions the protection bearers will carry traffic in parallel with the respective telephony bearers, so that protection bearer switching occurs only if required by failure of the television bearer in the north bound direction.

The radio equipment will be fully transistorised, with the exception of the travelling wave output tube in the transmitters, and it is expected that the reliability of such equipment will be markedly superior to the more conventional valve type equipment. In addition to the increased reliability afforded by this equipment there has been a number of other advantages. The equipment is smaller in size and hence has reduced the size of building required, although there have been later factors which have tended to complicate building design. In addition, the power requirements are very much less than for conventional equipment and enable the equipment to run from batteries so providing economical no-break operation. The smaller power plant required results in a further reduction in building area.

The route is long and subject to weather hazards from cyclones, etc. To enable early restoration of service in the event of a catastrophic occurrence at a repeater or terminal station, a set of transportable radio and power equipment, and portable massts are being purchased. The radio and power equipment will be mounted in a trailer unit capable of easy transport from one area to another as quickly as possible.

This section of the route will be completed in a total period of about four and one-half years from August 1961 when the preliminary planning was commenced until the commissioning of the radio channels for SEACOM traffic in the first half of 1966. This has been possible only by the closest team work and co-operation on a very wide scale, not only within various sections of the Department, but also between various Commonwealth Government Departments and equipment contractors and suppliers. The majority of the route is through sparsely populated areas which have not been previously surveyed from a radio viewpoint and this very big task has been carried out by Departmental personnel. The acquisition of sites and road surveys have been undertaken by the Department of the Interior, whilst the road and building construction works have been arranged by the Department of Works. The radio equipment, aerial structures and power plant are being supplied and installed under contract by Standard Telephones & Cables Pty. Ltd., Sydney, with sub-contracts to Australian and overseas suppliers.

SYSTEM SECURITY

Special consideration has been given to achieving maximum security of service for SEACOM traffic throughout the Sydney to Cairns link and with the precautions to be taken it is expected that the specified maximum system outage time of 0.1% over a four-week period will not be exceeded. The following are some of the design features associated with the planning to secure this high degree of reliability.

Radio System

Special attention has been paid to reliability in the design and layout of the radio repeaters and terminal stations, and associated equipment; vital cable links are maintained under gas pressure. Duplicate bearers having base band and I.F. switching with frequency and space diversity are used. Furthermore, the adoption of a transistorised system between Brisbane and Cairns with its reduced power consumption and other advantages is an important factor. Although a number of repeaters are established in isolated locations, good access roads will be available to facilitate maintenance.

Coaxial Cable

Protective measures taken during cable installation include burying the armoured cable to a depth of four feet, special cable protection in manholes and route selection to avoid natural hazards such as areas prone to flood damage or lightning. A gas pressure alarm system is applied to the cable. The use of cable markers and regular patrols throughout the cable route will minimise damage due to constructional works. A spare pair of coaxial tubes is provided.

Coaxial Cable Line Equipment

All active elements in the line system such as amplifiers, oscillators, etc., are provided in duplicate with continuous monitoring and automatic changeover facilities to ensure immediate replacement of the working element by the standby element in the event of failure. The switching break involved is 2 milliseconds. Where remote power feeding of unattended station equipment is employed, facilities are provided to effect automatic change over to a regulated local A.C. mains power supply in the event of failure of the power feeding equipment. Amplifiers in frequency translating equipment are provided either with duplicated parallel connected valves, or are transistorised. All carrier supply equipment is duplicated with monitoring and automatic change over facilities.

Power Plant

Commercial A.C. mains supply is available at each terminal and repeater station and two main types of power plant installation are used throughout the link for standby purposes. System equipment installed at stations between Sydney and Brisbane requires no-break A.C. power, while system equipment between Brisbane and Cairns is transistorised and requires D.C. no-break power.

(i) At stations where no-break A.C. power is required power plant is installed comprising:—
   (a) all-electric A.C. no-break set and associated 63 or 60 cell reserve battery.
   (b) standby diesel alternator set.

(ii) At stations where no-break D.C. power is required, the power plant installed comprises:—
   (a) main rectifier (duplicated),
   (b) 23 cell lead-acid battery (duplicated),
   (c) normally stationary diesel alternator set.

Commercial A.C. mains are deemed to have failed when the voltage between any phase and neutral falls below 83% of the nominal value and rises above 110% of the nominal value. When this occurs, the normally stationary diesel alternator starts automatically and replaces the mains as the primary power source.

CONCLUSION

The land section Sydney-Brisbane-Cairns, apart from forming a major backbone link in the national network, provides an important section of the rapidly expanding international complex of communication circuits in long distance submarine cables. It brings new responsibilities to design, construction and maintenance staffs of the Australian Post Office. How some of the problems involved are being met will be described in detail in the later papers to be published in this *Journal*.

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EXPANSION OF TRANSMITTING STATION FACILITIES FOR THE NATIONAL TELEVISION SERVICE

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Summary.—In accordance with a recommendation of the Royal Commission on Television, the expansion of television services in Australia has been planned in clearly defined stages. The first and second stages resulted in the establishment of separate commercial and national services in Sydney and Melbourne (1956) and then in the other State capitals (1958, 1959). The following paper discusses the work undertaken by the Postmaster-General's Department in providing transmitting station facilities for the Phase 3 (thirteen stations in the major regional centres) and Phase 4 (twenty stations in the country areas) stages of the expansion programmes which cover the period from 1961 to 1966. The general features of the programmes are discussed and descriptions are given of typical Phase 3 stations installed during 1962 and 1963.

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INTRODUCTION

After several previous efforts to introduce television services into Australia which date back to June, 1948, the first regular transmissions commenced in Sydney and Melbourne during the latter part of 1956.

The establishment of these inaugural services stemmed from the decision by the Australian Government in 1950 to introduce the dual system of separate National and Commercial television services in Australia and later, in 1953, to allow the conditions which should apply to the establishment of these stations, the areas to be served, the programme standards to be observed, etc., to be considered and reported upon by a Royal Commission.

This Commission was set up in 1953 under the Chairmanship of Professor G. W. Paton, Vice Chancellor of the Melbourne University. The report of the Commission was published early in 1954 (Ref. 1) and has been used since that date as a guide to the programme of expanding Australian television services. In general this expansion has been in

Fig. 1.—Map of Australia Showing Location of National Television Transmitting Stations.

TABLE I.

STATION			SITE		AERIAL		SUPPORT STRUCTURE	
Area serving	Callsign	Opening date	Location	Elevation (ft.)	Polarisation	Horizontal pattern	Type	Height (ft.)
Phase 1								
Sydney, N.S.W.	A.B.N. 2	1956	Gore Hill	300	Horiz.	Omni	Tower	500
Melbourne, Vic.	A.B.V. 2	1956	Mt. Dandenong	1980	Horiz.	Omni	Tower	400
Phase 2								
Brisbane, Q'ld.	A.B.Q. 2	1959	Mt. Coot-tha	870	Horiz.	Omni	Tower	500
Adelaide, S.A.	A.B.S. 2	1960	Mt. Lofty	2200	Horiz.	Omni	Tower	440
Perth, W.A.	A.B.W. 2	1960	Bickley	1130	Horiz.	Omni	Tower	410
Hobart, Tas.	A.B.T. 2	1960	Mt. Wellington	4100	Horiz.	Omni	Tower	300
Phase 3								
Canberra, A.C.T.	A.B.C. 3	1962	Black Mt.	2657	Vert.	Omni	Mast	511
Bendigo, Vic.	A.B.E.V. 1	1963	Mt. Alexander	2401	Vert.	Dir.	Mast	439
Ballarat, Vic.	A.B.R.V. 3	1963	Lookout Hill	3177	Horiz.	Dir.	Mast	512
Hunter Valley, N.S.W. (Newcastle)	A.B.H.N. 5	1963	Great Sugarloaf	1220	Horiz.	Omni	Tower	494
North East, Tas. (Launceston)	A.B.N.T. 3	1963	Mt. Barrow	4507	Horiz.	Dir.	Tower	273
Latrobe Valley, Vic. (Traralgon)	A.B.L.V. 4	1963	Mt. Tassie	2435	Horiz.	Dir.	Tower	335
Illawarra, N.S.W. (Wollongong)	A.B.W.N. 5A	1963	Knights Hill	2549	Horiz.	Dir.	Tower	451
Darling Downs, Q'ld. (Toowoomba)	A.B.D.Q. 3	1963	Mt. Mowbullan	3485	Horiz.	Dir.	Tower	515
Goulburn Valley, Vic. (Shepparton)	A.B.G.V. 3	1963	Mt. Major	1214	Vert.	Dir.	Mast	496
Rockhampton, Q'ld.	A.B.R.Q. 3	1963	Mt. Hopeful	2004	Horiz.	Omni	Tower	500
Central Tablelands, N.S.W. (Orange)	A.B.C.N. 1	1964	Mt. Canobolas	4503	Vert.	Omni	Tower	546
Richmond-Tweed, N.S.W. (Lismore)	A.B.R.N. 6	1964	Mt. Nardi	2681	Horiz.	Omni	Tower	419
Townsville, Q'ld.	A.B.T.Q. 3	1964	Mt. Stuart	1900	Horiz.	Omni	Tower	500
Phase 4								
Upper Murray, Vic. (Albury)	A.B.A.Y. 1	1964	Baranduda	2400	Horiz.	Dir.	Mast	500
S.W. Slopes and E. Riverina, N.S.W. (Wagga-Cootamundra)	A.B.M.N. 0	1965	Mt. Ulandra	2490	Horiz.	Omni	Mast	550
Spencer Gulf North, S.A. (Port Pirie)	A.B.N.S. 1	1965	The Bluff	2390	Vert.	Omni	Tower	550
Bunbury, W.A.	A.B.S.W. 5	1965	Mt. Lennard	1120	Horiz.	Omni	Mast	550
Swan Hill, Vic.	A.B.S.V. 2	1965	Goschen	200	Vert.	Omni	Mast	550
Grafton/Kempsey, N.S.W.	A.B.D.N. 2	1965	Mt. Moombil	3420	Horiz.	Dir.	Mast	400
Wide Bay, Q'ld. (Maryborough)	A.B.M.Q. 6	1965	Mt. Goonaneman	2180	Vert.	Dir.	Tower	500
Mildura, Vic.	A.B.M.V. 4	1965	Yatpool	260	Horiz.	Dir.	Mast	550
Upper Namoi, N.S.W. (Tamworth)	A.B.U.N. 7	1965	Mt. Dowe	4810	Horiz.	Dir.	Mast	550
Mt. Gambier, S.A.	A.B.G.S. 1	1965	Mt. Burr	800	Horiz.	Omni	Mast	500
Central Agricultural Area, W.A. (Northam)	A.B.C.W. 4	1965	Mawson	1237	Horiz.	Omni	Mast	600
Manning River, N.S.W. (Taree)	A.B.T.N. 1	1965	Middle Brother	1830	Vert.	Dir.	Tower	500
Murrumbidgee Irrigation Area, N.S.W.	A.B.G.N. 7	1966	Mt. Bingar	1400	Horiz.	Omni	Mast	500
Broken Hill, N.S.W.	A.B.L.N. 2	1965	Rocky Hill	1140	Vert.	Omni	Mast	100
Southern Downs, Q'ld. (Warwick)	A.B.S.Q. 1	1966	Passchendaele Ridge	3220	Horiz.	Dir.	Mast	500
Southern Agricultural Area, W.A. (Albany)	A.B.A.W. 2	1966	Mt. Barker	1400	Vert.	Omni	Tower	550
Cooma, Bega, N.S.W.	A.B.S.N. 0	1966	Brown Mt.	3800	Vert.	Dir.	Mast	500
Mackay, Q'ld.	A.B.A.Q. 4	1966	Mt. Blackwood	1470	Horiz.	Dir.		
Central Western Slopes, N.S.W. (Dubbo)	3	1966	Cenn Cruaitch	4000	Vert.	Dir.	Tower	500
Cairns, Q'ld.	A.B.N.Q. 9	1966	Bartle Frere	5100	Horiz.	Dir.		

TABLE II: TELEVISION TRANSMITTING STATION ESTABLISHMENT COSTS—PHASES 3 AND 4.

	Maximum	Minimum
Access roads	£230,000	£1,000
Power line	£50,000	£200
Site and site works	£12,000	—
Building and building services	£120,000	£50,000
Television external plant	£100,000	£30,000
Television internal plant	£130,000	£90,000
Estimated total cost Phase 3		£3,500,000
Estimated total cost Phase 4		£5,900,000
		£9,400,000

order of population density, commencing with the larger capital cities, Sydney and Melbourne, followed by the remaining capital cities in order of population, Brisbane, Adelaide, Perth, Hobart, then Canberra, and the twelve major regional centres of the Commonwealth. Further expansion to twenty additional regional and country areas is now proceeding.

Location and major technical features of the services so far provided or in the course of provision throughout the Commonwealth are set out in Table I and further illustrated in Fig. I.

ADMINISTRATION

The overall control of planning, technical and programme standards, and licensing of Australian television stations is vested in the Australian Broadcasting Control Board.

The establishment and operation of the National Television Service, apart from the planning and control aspects handled by the A.B.C.B., are the responsibility of:

(a) The Australian Broadcasting Commission as far as the establishment and operation of studios and the production of programmes are concerned.

(b) The Postmaster-General's Department as far as the establishment and operation of both transmitting station facilities and programme circuits between the A.B.C. studios and the transmitting stations are concerned.

The Postmaster-General's Department has also the responsibility for providing programme relay facilities for Commercial station operators, with the exception of the studio-to-transmitter links, which are usually provided by the Commercial station.

The establishment of the transmitting station facilities for the National Television Service, although co-ordinated by the P.M.G.'s Department, involves in addition to the A.B.C.B. and A.B.C. the active participation of the Department of the Treasury in relation to financial aspects, the Department of Works in the provision of buildings, roads and power supplies, and the Department of the Interior for the survey and acquisition of sites, access roads etc.

PROGRAMMING

Table I sets out details of the various National television stations provided or to be established during the successive stages of their establishment.

Details of the major establishment costs for the stations are shown in Table II.

Table III sets out the countries of origin of the main items of equipment ordered to date. In the case of thirten Phase 3 stations, equipment has been obtained from some fifteen contractors in five countries which has posed considerable problems in the integration of the differing types of equipment as well as from the inherent communication difficulties of language and distance.

ROLE OF THE POSTMASTER-GENERAL'S DEPARTMENT

As stated earlier, the P.M.G.'s Department is responsible for the establishment of transmitting station facilities for the National Television Service.

TABLE III

Item / Country	Australia	Britain	Western Germany	Japan	Italy	U.S.A.
Transmitters	×	×		×		
Aerial systems	×	×	×	×	×	
Masts and towers	×					
Diesel alternator sets	×					×
High power coaxial cable			×			
Programme control and test equipment	×	×	×	×		×

In more detail, this responsibility involves the following engineering functions:—

(i) Estimation of likely expenditure and preparation of draft programmes both for the efficient establishment of individual stations and for the co-ordinated completion of the various groups of stations which are to be provided.

(ii) General site selection investigations, including propagation measurements in collaboration with the Australian Broadcasting Control Board, to locate preferred areas for the establishment of stations.

(iii) More detailed investigation of particular sites for stations in association with Local Government bodies, the Department of the Interior and the Department of Works.

(iv) In association with appropriate Commonwealth and State Departments, planning and co-ordination of road works, site works, power and water supplies, buildings and building services.

(v) Preparation of specifications and ordering of equipment for transmitting stations, e.g., television transmitting equipment, vision and sound programme input and control equipment, monitoring and testing equipment, aerial systems and high-power radio frequency feeder cables, aerial support towers or masts, and emergency power supply diesel alternator equipment.

(vi) Installation of equipment listed in (v) using Departmental staffs and/or private contractors.

(vii) Training of transmitting station operating staff and direction of future operations and maintenance of transmitting stations.

The programme relay systems (by coaxial cable and microwave radio) are also planned, established and operated by the P.M.G.'s Department, but this latter work is not covered in the present paper.

SELECTION OF STATION SITES AND LAYOUT OF EXTERNAL PLANT AND BUILDINGS

Site Selection

In 1955 the Australian Broadcasting Control Board (Ref. 2) published a frequency assignment plan for Australia and gave general principles of coverage of the population with two or more television services in each locality.

The provision of the Phase 1 and Phase 2 National and Commercial stations in the capital cities proceeded on the basis of this plan. By 1959, when the Australian Broadcasting Control Board invited applications for commercial licences to cover the thirteen major provincial areas comprising Phase 3, it had become apparent that the ten original VHF Channels used in the 1955 Frequency Assignment Plan could not provide sufficient services to meet future public demand in certain key areas of the Commonwealth. Four services in the State Capital cities and two in the major provincial areas were the practical limits of the 1955 Assignment Plan.

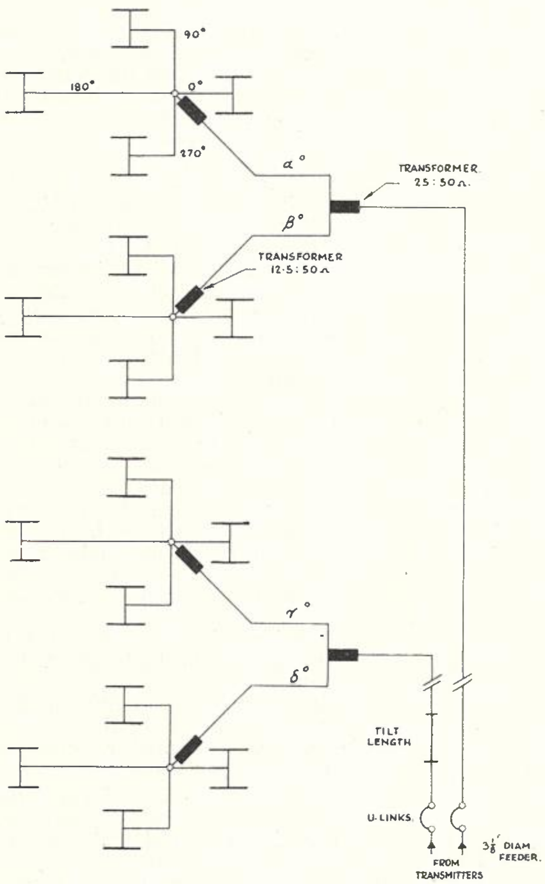
Furthermore, by 1959 one of the original ten Channels had ceased to be available for television use in Australia.

A representative Committee, under the Chairmanship of Professor L. G. Huxley, exhaustively reviewed the frequency allocations in the VHF spectrum. As a consequence it was found possible to make available thirteen VHF Channels for television service in Australia.

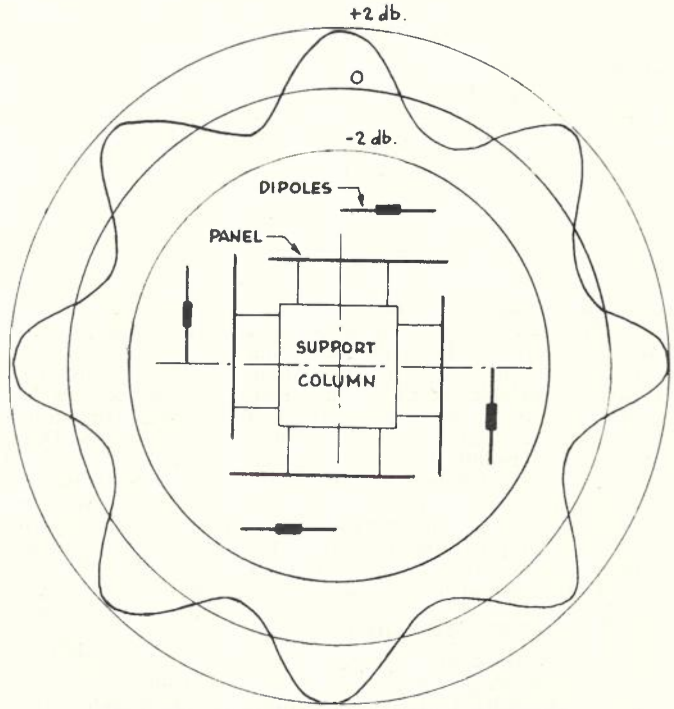
The Frequency Assignment Plan based on these Channels makes possible the ultimate development of five services in the State Capital cities and four in the provincial and country areas.

The selection of each television site in Phases 3 and 4 has been basically in accordance with this plan. In these phases, each National station is associated with a Commercial station on the same or nearby sites.

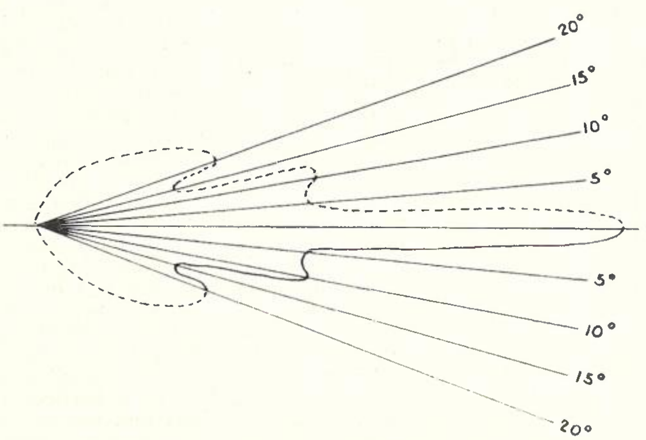
The general location of television stations has so far been to a pattern to cover all population groups of at least



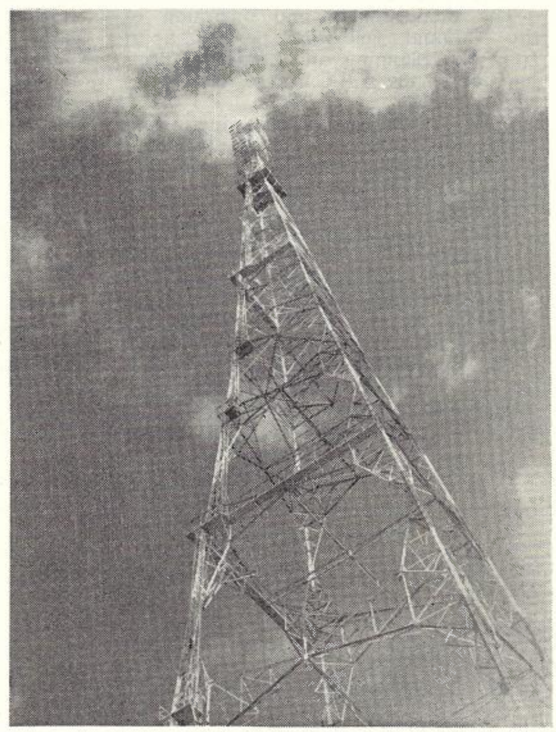
(a) Typical Aerial Installation.



(b) Section view of aerial and horizontal patterns.



(c) Vertical pattern.



(d) View of tower erected at ABHN-5, Great Sugarloaf, Hunter Valley, N.S.W.

Fig. 2.

a size calculated to make Commercial stations viable, and to provide a National programme to the maximum number of viewers possible, subject to frequency and mutual interference problems, and other non-technical limitations. In the general area of the stations determined by the Australian Broadcasting Control Board, the Department examines various sites for their physical and economic properties in relation to operating a television station. The following properties are sought in the ideal site:—

(a) Sufficient area to accommodate a National station and up to three Commercial stations on the site, no two stations being separated by more than one mile.

(b) Adequate V.H.F. transmission paths to the major centres required to be served, taking into account the frequency allocation of the station and any directional properties of the transmitting aerial.

(c) Absence of possible natural reflecting surfaces likely to cause multiple path transmission.

(d) Easy and permanent access for staff to a town of reasonable size.

(e) Low costs of services to the site, i.e., road, power, telephone, water, etc.

(f) Sufficient flat area to accommodate, where possible, one or more guyed masts which are more economical than self-supporting towers but which require greater site area.

(g) Adequate path for the microwave radio relay system from the programme originating sources.

(h) Ground of suitable bearing quality for masts and buildings.

(i) Unencumbered site.

(j) Acceptable climatic conditions.

Estimates and surveys are made of the above factors from which the relative qualities of possible sites are gauged. From these factors, and other considerations, the Australian Broadcasting Control Board makes the final recommendation on the site.

Layout of External Plant and Buildings on the Site

Once the specific site area has been selected, the layout of buildings and aerial support structures for one or more stations is decided, requiring consideration of several factors, the more important of which are concerned with these large masts or towers.

The requirements for positioning the structures are:

(a) If two or more masts or towers are used, they should be more than 250

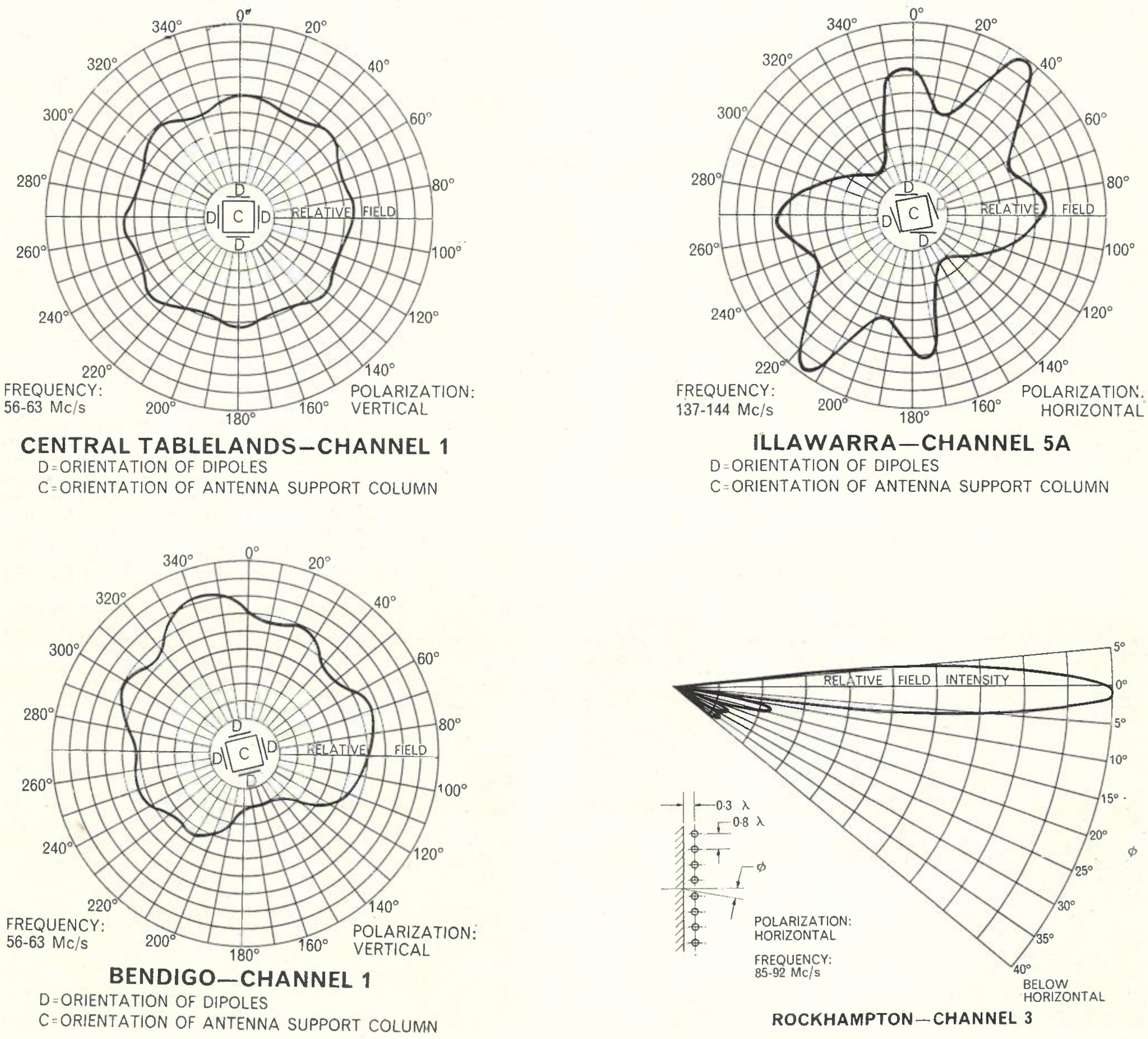


Fig. 3.—Horizontal and Vertical Patterns of Typical Aerial Systems.

ft. apart to reduce the mutual reflecting effect and separated by not greater than one mile.

(b) For similar reasons, the large reflecting surface of aerial panels on a pair of neighbouring structures are staggered in height and orientated to minimise the effects of reflections.

(c) Large masts or towers should be at least 100 ft. from buildings. This clearance avoids the danger of objects falling on the building from the top of the structure during erection or maintenance. With this provision the distance should then be a minimum to reduce the cost of, and losses in, the feeder cables which are approximately £3 per foot and 0.1 db per 100 ft. at 100 Mc/s respectively.

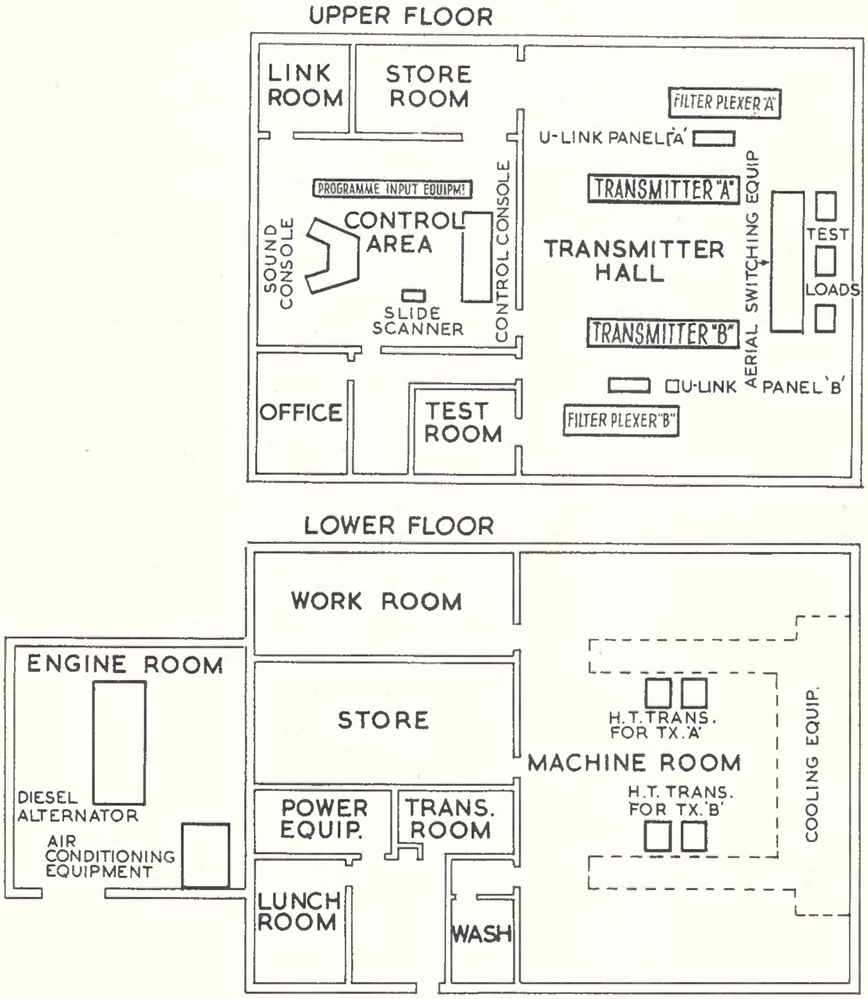
(d) Even when an array is classed as omnidirectional in azimuth, there can be differences of ± 2 db. from the mean horizontal radiation, and the structure should be orientated to take advantage of these unavoidable but predictable fluctuations to direct the signal to best advantage (see Figs. 2, 3).

(e) Guyed masts, preferred because of their economy, require to have all guys, which are attached at one level of the masts, of equal slope and of equal length within ±3 per cent. Self-supporting towers should be built on ground reasonably level in a square area approximately twice the size of the tower base.

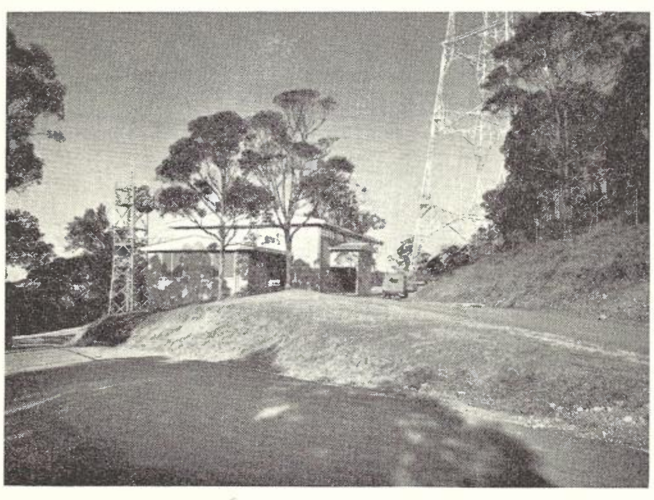
Transmitting buildings and ancillary items of the station are less exacting in their space requirements and therefore less difficult to accommodate on a restricted site than the towers or masts.

TRANSMITTER BUILDINGS

The type of building provided to house the transmitting equipment is influenced by the time available between the initiation of firm planning for the station and the required station completion date. The period between the establishment of the building requirement by the Post Office and its occupancy is in the order of two years. Up to a further year is required for the installation of equipment within the building, testing and commissioning of this transmitting equipment and the overall testing of the programme relay system and transmitting plant. In these circumstances it is necessary for all technical aspects of the station which will influence the building facilities to be known some three years before the station opening date if the optimum matching of building facilities



(a) Floor Plan of Standard Building.



(b) View of Building at ABHN-5.

(c) Interior of ABHN-5, Control position looking through to transmitter hall.

Fig. 4.

to radio equipment requirements is to be achieved.

The required three-year planning period has not been available during the Phase 3 programme nor for the early stations of the Phase 4 programme and, to enable the desired station opening dates to be achieved within periods as short as 18 months from establishment of the building requirement, a standard building design has been adopted. This standard building (Fig. 4) is capable of accommodating the largest complement of equipment necessary to meet any television channel and transmitter power output allocation, as well as providing facilities to enable the diverse cabling and air ducting requirements of the various equipment manufacturers to be met.

The adoption of this standard building has resulted in somewhat greater building capacity being provided at certain stations than would have been used had it been possible to plan the building to suit the exact equipment installation, but the use of standard building facilities has introduced economies in certain other areas, notably in the engineering and architectural areas of Department of Works.

In the case of the later Phase 4 stations, for which building planning is presently proceeding, use is made of standardised facilities for non-technical areas and technical areas which are common to all stations, but other areas are modified from station to station to match the known details of the radio plant which will be installed.

The building also allows for ready extension of the main technical areas in the future, should this be necessary to accommodate additional transmitting equipment.

Certain of the new buildings to be provided for these later stations differ widely from the Phase 3 "standard" building as may be seen from the architect's sketch and floor plan shown in Fig. 5. This building is best suited to a flat site and is of single storey construction compared with the earlier two-storey building. Its adoption results from the greater use of Australian made transmitting equipment which has been developed for installation on a single slab floor with no under floor connection of cabling or air ducting.

TRANSMITTING STATION PLANT

Internal Equipment

The equipment installed within a transmitting station building (Ref. 7) is divided into seven broad functional categories, the disposition of some of the items of which are seen in Fig. 4, as follows:—

Power (Commercial and Emergency Supply): The mains power supply for the television transmitting stations is derived from high-tension three-phase commercial supplies transformed to 415 volts 3 phase. Consumption varies with each station from 100 kW to 300 Kw, being greater for stations with lower frequency channels and particularly high at stations where anti-icing aerial heating is employed. An emergency diesel alternator plant of rating 170 to 375 kVA at 0.8 power factor is installed at each station. This emergency power plant is suitable for future adaptation to automatic operation but, as installed, is manually started by the station staff if the normal mains supply fails or becomes unusable due to large voltage fluctuations or to unbalance of the phase voltages. One thousand gallons of fuel oil storage is provided in a buried tank outside the building, feeding a 150-gallon service tank within the engine room. With a fuel consumption of from 10 to 15 gallons per hour the oil stored is sufficient for one week of station operation. At stations located above the snow line, the capacity of the oil storage is increased to 4,000 gallons which, except for prolonged dislocation of road access coupled with failure of the mains supply, is sufficient to ensure the continuation of station transmissions.

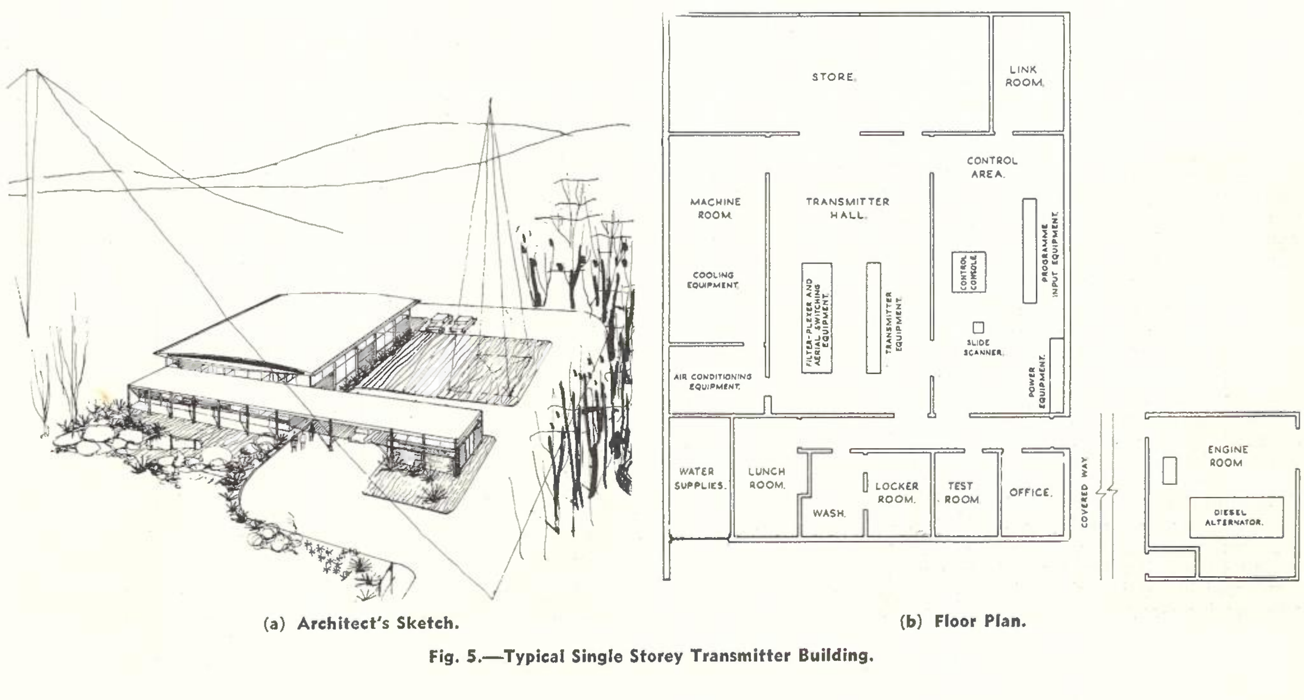
Programme Receiving and Adjusting Equipment (Link Room and Control Area)

Incoming Programme. — The sound and vision programme may be fed in two ways from the A.B.C. studios to the station, either diplexed on a microwave radio bearer system or by coaxial cable (vision) and wire pairs (sound), or by a combination of both systems in tandem. These circuits are duplicated and switch automatically or manually to the alternative circuit in the event of failure of the working circuit. The transmission quality is to C.C.I.R. standard (Ref. 6).

In one case (Mt. Barrow, Tasmania), a relay receiver is installed at the transmitting station to supply programmes directly by off-air reception of the neighbouring Hobart station. In other areas, this method is used, when the received signal field strength is better than 0.5mV/m and not subject to undue interference, to provide an alternative programme which may be utilised should the normal programme system be interrupted. However, the reliability of the programme transmission systems is high and the relay receiver is only occasionally used for this particular purpose.

Stabilising Amplifier.—The incoming video programme is fed to a stabilising amplifier which functions to remove certain distortions from the waveform, a typical line of which is shown in Fig. 6. The functions of the stabilising amplifier are:

(i) to stabilise the D.C. blanking level so that the output level is constant; by so doing, low-frequency hum and



(a) Architect's Sketch. **(b) Floor Plan.**

Fig. 5.—Typical Single Storey Transmitter Building.

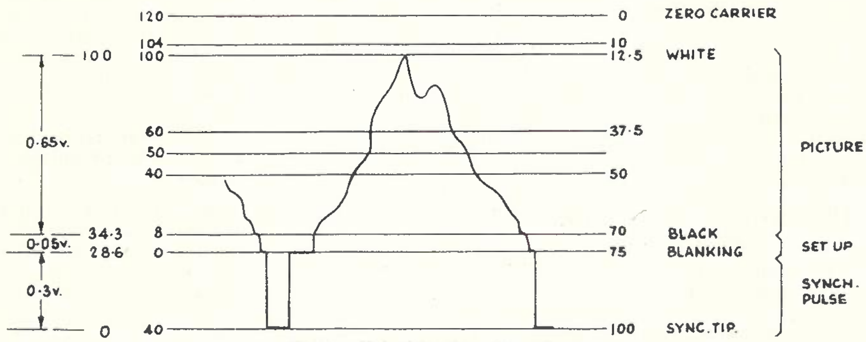


Fig. 6.—Television Line Waveform.

tilt affecting the whole waveform are removed;

(ii) to regenerate the synchronising pulses in their correct shape;

(iii) to control, separately, the picture, synchronising pulse and set-up intervals.

Local synchronising and blanking pulses from the station can be added to the amplifier, and there is also the facility for locking the incoming synchronising pulses in their regenerated form to a locally-produced video signal, say, from the slide scanner. The stabilising amplifier will produce a standard waveform output of 1 volt peak-to-peak and blanking level stability of .035 volts with an input signal in the range from +3 db. to —10 db. of standard and an unwanted A.C. component of 1 volt peak-to-peak.

Phase Adjusters and Filters.—The purpose of the phase adjusters is to correct the overall phase characteristics of the transmitter and associated equipment. At the transmitter input one adjustable phase network is required to pre-equalise the phase changes which occur throughout the transmitting system, and particularly in the shaping of the lower sideband to produce the standard vestigial sideband requirements. The second network is required to produce the variation in phase delay for compensation of phase non-linearity of the average domestic receiver. A lowpass filter with a cut-off of 5.3 Mc/s is used to limit the video circuit bandwith and thus assist in reducing the out-of-band radiation of the transmitter. Amplifiers are provided to make up the losses in these filters and equalisers. The distortion effects of phase and amplitude changes and their measurements are discussed later.

Local Emergency Vision and Sound Sources: *(a) Slide Reproducer.*—A slide reproducer, using the flying spot scanning principle, is used as a source of test signals and also for emergency programme purposes. The flying spot raster scanned on a cathode ray tube is directed upon and through the transparent slide by means of a mirror and lens. The light modulated by the slide is converged on to a photo multiplier cell with a transparent cathode whence the output is fed to a wide band amplifier where synchronising pulses from local generators are inserted.

(b) Sound Reproduction. — Each station is also equipped with complete duplicate record reproducing equipment, comprehensive amplifying and control equipment and a microphone, for testing and emergency programme purposes.

Programme Switching Equipment: Each station is equipped with an extensive switching system to control the incoming programme signal and the locally generated test waveforms and programme signal sources. This programme input equipment is shown in Fig. 7. Basically, there are two identical channels, main and reserve, in both the vision and sound transmitters' input equipment. Each channel is switchable to both its respective sound or vision transmitters in parallel. (The filter and equaliser amplifiers are classed as part of the vision transmitter and the modulated exciter as part of the sound transmitter for this purpose.) All sources of programme and test sources are fed to the main and reserve switching banks in the case of vision or to the crossbar switch in the case of sound, and thence to either the main or reserve channel. Various points in the input channels to the transmitters may be monitored and compared with sample points through and in the output of the system. The transmitters may be switched on in stages, and either or both of the duplicated pair of transmitters selected for operation.

Transmitters: The function of the transmitters is to generate the V.H.F. radio energy at the appropriate carrier frequencies and to modulate these carriers with the sound and vision information, frequency-modulated in the former case and amplitude-modulated in the latter. There are normally four transmitters in operation simultaneously, namely, a vision and sound pair duplicated. In the event of a fault in either pair, it may be removed automatically or manually without interruption to service but at a reduction in power of 6 db. By further manual switching, removing the diplexer from circuit, the reduction in power may be reduced to 3 db. Each transmitter pair is driven from a common R.F. exciter and has a phase comparator associated with its output circuit from which the relative phases of each of the pairs of transmitters are indicated. Phasing equipment in each of the split outputs of the exciter is adjusted so that each transmitter can be correctly combined with its opposite number either in the station or in space after being radiated from separate halves of the aerial.

The combining and switching system, which is seen on the right of Fig. 7, permits numerous combinations of transmitters and aerials to be selected. As discussed later it is desirable to combine the outputs of both pairs of transmitters in the station and then split the combined output to each of the duplicated aerial.

A description of an Australian transmitter similar to those used in Phase 3 has been given by Maycock (Ref. 7). Descriptions of earlier equipment are given by Kenna (Ref. 10).

R.F. Exciter.—A typical exciter, such as is used in the A.W.A. Canberra trans-

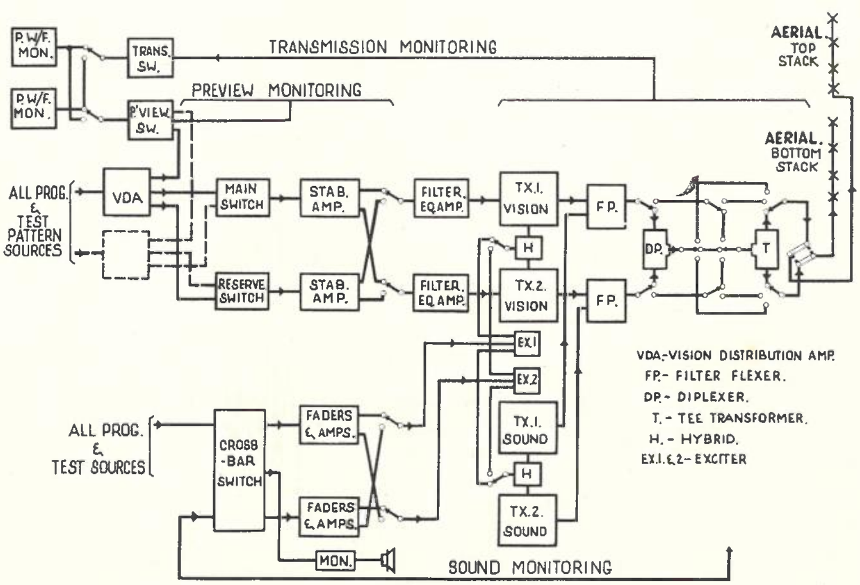


Fig. 7.—Simplified Schematic of Complete Television Transmitting Station Equipment.

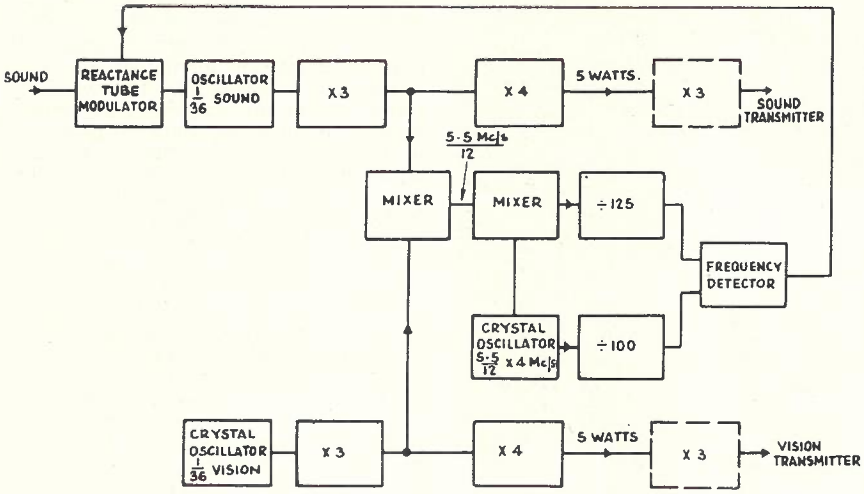


Fig. 8.—Basic Transmitter Exciter Unit.

mitter, is illustrated in Fig. 8. It provides:

(a) a crystal-controlled R.F. output of 5 watts to drive the pair of amplitude-modulated vision transmitters;

(b) a frequency-modulated 5-watt R.F. output to drive the pair of sound transmitters and spaced from the vision frequency by a sub-multiple of 5.5 Mc/s. This frequency spacing is maintained by comparison with a reference crystal circuit, as seen in the simplified circuit.

The two outputs (a) and (b) are fed to two hybrid circuits whence the divided outputs, capable of being individually phase adjusted, drive the appropriate pairs of transmitters. A close tolerance is required on the vision/sound carrier separation to cater for the inter-carrier sound systems in the majority of television receivers. The exciter crystals are temperature-controlled to ensure a frequency stability of 0.0005 per cent or 500 c/s in 100 Mc/s.

Vision Modulator.—The requirements of the vision modulator are:

(a) to provide the video power and large reactive currents required in the modulated amplifier. This is frequently achieved by use of the high efficiency shunt-regulated cathode follower output circuit. Both high and low level modulation have been used in transmitters in Phase 3.

(b) to pre-correct the linearity of the vision signal from white to black level, to clip the white peaks at frequencies below 1 Mc/s and to stabilise the amplitude of the synchronising pulses. The pre-correction is necessary to overcome the inverse curvature at either end of the valve characteristic of the modulated stage.

(c) to invert the signal for negative modulation and to clamp the D.C. blanking level.

An interesting feature of the Australian and the British transmitters is the blanking level feedback circuit which ensures high blanking level stability. From a detector in the output of the transmitter, the composite video waveform is extracted with any variations in the blanking level. The synchronising pulses in this waveform are clipped at a constant D.C. level and the resultant synchronising pulses of varying heights are separated and used in a clamp circuit in the modulator to fix the reference blanking level at the commencement of each line. Blanking level stability is of prime importance as, in its absence, the picture contrast and general illumination will fluctuate with the picture information over the whole or parts of the picture.

R.F. Power Stages.—The power stages of the transmitters amplify and, if necessary, frequently multiply the output of the exciter until the final desired output power is achieved. Video modulation can be effected at an intermediate level in the R.F. amplifying chain or at the final level.

The larger valves used in these stages are generally tetrodes with grounded grid or cathode, and their resonant circuits are frequently of the distributed resonant line type. In many cases, the components and circuits of the sound transmitter final stages are of similar design to the intermediate stages of the vision transmitter.

Externally to the transmitters the vision and sound transmitter outputs are combined in a filterplexer and then further combined with the output of a filterplexer associated with the duplicate pair of transmitters.

Filterplexer.—The filterplexer has two functions:—

(a) To filter off the unwanted portions of the lower side band to provide the required vestigial side-band characteristics, a function which has already been partially achieved in the tuned circuits of the final transmitter stage or stages.

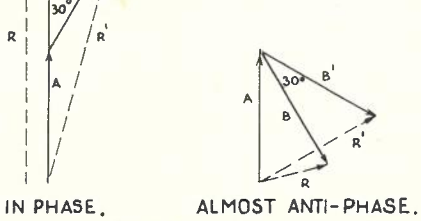


Fig. 9.—Vector Diagram showing Production of Amplitude Variations with Small Changes of Phase.

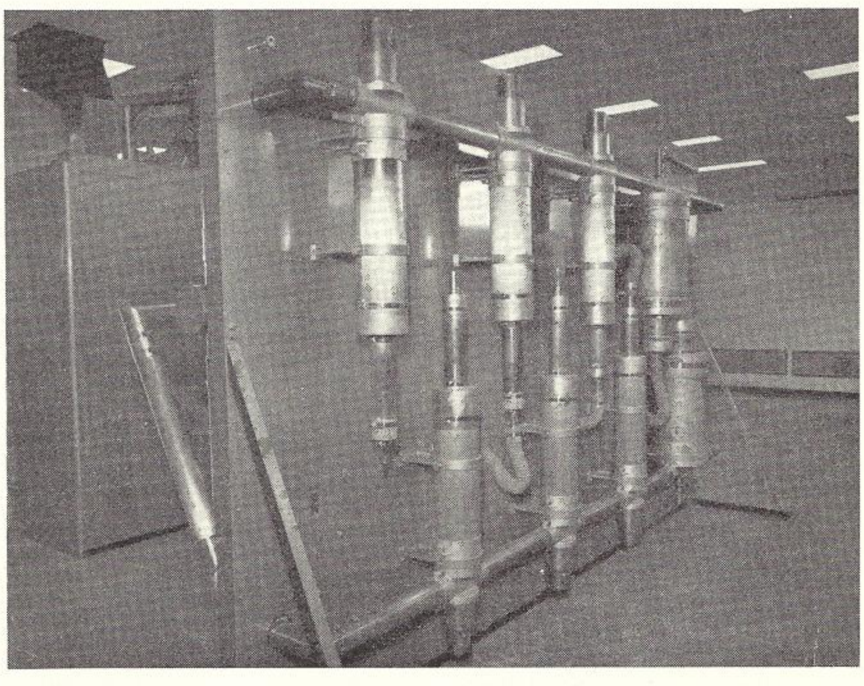


Fig. 10.—Installed Filterplexer Equipment at ABHN-5.

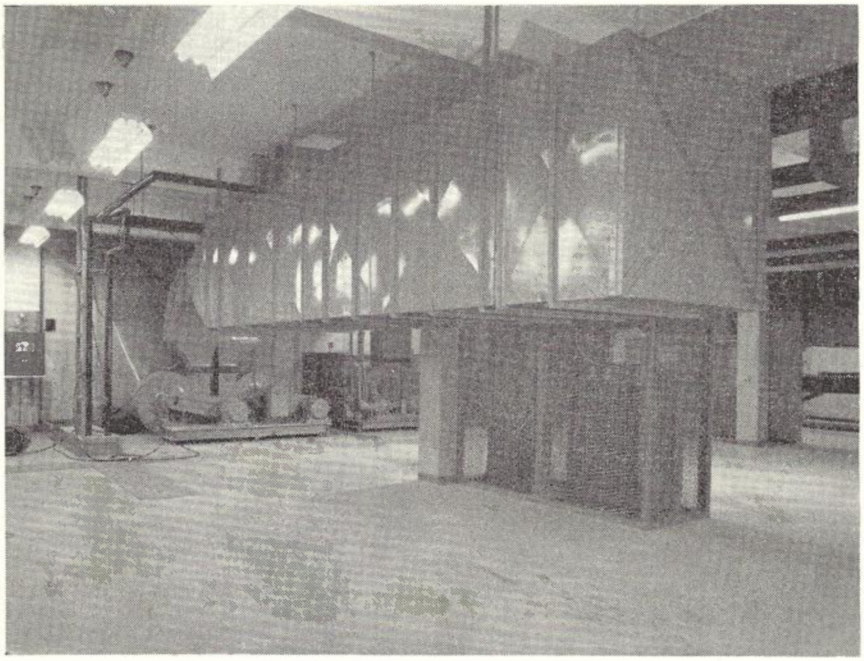


Fig. 11.—Air Cooling Blowers, Ducts and Plenum Chambers, ABHN-5.

(b) To combine the outputs of one vision and one sound transmitter in the transmitter hall so that only one coaxial feeder carries both outputs to one of the radiating system pair, directly or via the diplexer/transformer system.

The filterplexer should have:

(i) a reflection coefficient of less than 3 per cent over the range from —5 to +5 Mc/s from the vision carrier;

(ii) isolation between sound and vision channels greater than 40 db. and low losses in the working bands;

(iii) a frequency response substantially constant between —0.75 and +5.0 Mc/s and greater than 20 db. down between —1.25 and —5.5 Mc/s with reference to the vision carrier.

A view of the ABHN-5 filterplexer installation is shown in Fig. 10, and consists of two sets of four resonant cavities on one side of the panel, and two diplexers, only one of which is partially visible, and an absorbing load on the other side of the panel. The smaller resonant cavities reflect only the unwanted parts of the vision side-bands to the absorption load and the larger cavities reflect the sound spectrum in the correct phases relationships to be combined with the vision R.F. output, Refs. (7) and (8).

Diplexer/Transformer Circuits and Switching Frame.—The combined vision and sound output from each pair of transmitters is normally totally combined in a diplexer, the output of which is then split in a transformer and fed to each half of the aerial. The purpose of diplexing and splitting again, instead of feeding each half of the aerial by one transmitter pair, is to avoid spurious amplitude modulation being produced by dissimilar behaviour of the instantaneous phase of the vision signal of the individual transmitters. This spurious amplitude modulation effect when the vision transmitters are fed separately to the upper and lower sections of the aerial varies throughout the service area and may be extremely severe in areas where the large angle vector addition of signals from the upper and lower halves of the aerial occur. As shown in Fig. 9, a small change (say 30°) in the phase of one vector when almost 180° out of phase with the other vector causes a much greater proportionate change in the amplitude of the resultant than when the two vectors are closely in phase. Thus, unless both aerials radiate vision signals which are identical in phase relationship over the desired bandwidth, considerable amplitude and phase distortion may occur in sections of the service area. This problem is overcome by the combining and splitting process described. In this case, the undesired amplitude modulation effects caused by dissimilar phase relationships are constant throughout the service area and may be effectively monitored and corrected at the transmitter. The switching frame permits not only both transmitter pairs in the diplexed condition to be fed to both aerial stacks, but each transmitter pair to be fed to both or either stack and also both transmitter pairs to be fed to each stack (Fig. 7). The switching frame also caters for the switching-in of test loads to assist in testing various combinations of transmitters.

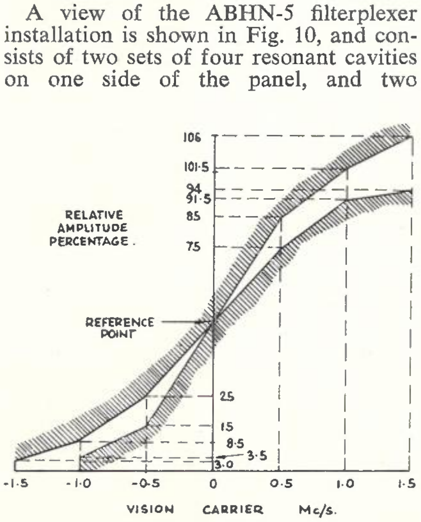


Fig. 12.—Standard Vestigal Sideband Monitor Nyquist Slope Limits.

Cooling Requirements.—The adequate cooling of the transmitters, particularly in the region of the larger valves and rectifiers, is an important consideration. A view of the transmitter input air-cooling equipment in the machine room at ABHN-5 is shown in Fig. 11. Cooling is carried out by forced air-circulation employing a pair of blowers and a closed-duct system through each sound/vision pair of transmitters from an inlet to an outlet both situated in one external wall of the building. The inlets and outlets are provided with filters and situated well above ground level to avoid dust problems. Placing them in a common wall reduces any retarding effect to the air flow due to strong winds. The air flow through the transmitters is interlocked with the filament power supplies which cannot be energised without an adequate air flow being present. After cooling the transmitter, there are facilities for recirculating the warm air through the building for general building heating purposes when required.

Testing and Monitoring Equipment: Stations are comprehensively equipped to carry out monitoring of picture quality, waveform shape and sound quality, at the output of the internal equipment and at selected points throughout the chain of equipment. High quality receivers are also provided to monitor the radiated signals to detect any signs of degradation of quality.

Similarly sufficient testing equipment is provided on the station to detect and assist in the rectifying of any type of fault. The testing of vision equipment is largely in the form of observing and recording the deformation of transients

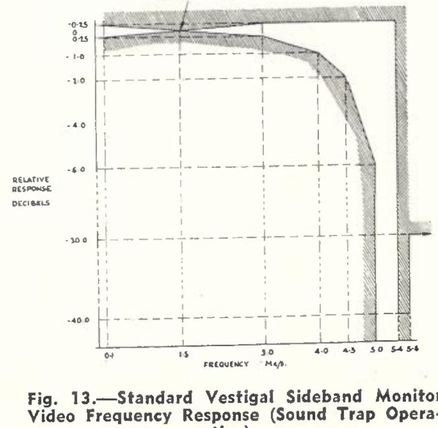


Fig. 13.—Standard Vestigal Sideband Monitor Video Frequency Response (Sound Trap Operative).

or squarewaves of black to white changes at various cyclic periods. The so-called static measurements of amplitude and phase responses against frequency, although fulfilling a certain requirement, are not so clearly indicative of marring effects on the picture as the transient tests. Phase and amplitude changes with frequency can occur throughout the system and particularly, firstly, in the circuits providing the cut-off of the vision radio frequencies, adjacent to the sound radio frequencies, and, secondly, in the circuits producing the vestigial side-band characteristics required in the system. The quadrature distortion effect of the latter and a method of its pre-correction which is being studied in the Department is discussed in Ref. 11.

The overall measurement of transient response requires careful treatment and the use of a receiver of suitable demodulating characteristics at the output to the aerial or off-air. The receiver (Ref. 4) must introduce negligible distortion and its side-band response in the nyquist slope region (Fig. 12), overall amplitude response (Fig. 13), group delay characteristics and of course its transient responses must be closely specified.

The transient impulses and step functions which have been fed through the system are displayed on a cathode ray oscilloscope and require to fall within a graticule placed over the screen, examples of which are shown in Figs. 14 and 15.

Transients used to test the equipment are detailed in Refs. 4 and 3 and consist of the very fast step function of 50 nanoseconds rise time, the 1T or 2T sine squared pulses and bars, the 50 c/s squarewave and a very low frequency squarewave for observing instability in standard levels. Some of the limits adopted for the complete station equipment, from vision distribution amplifier input to diplexer output, are as follows—

- Differential Gain (G factor) less than 20 per cent.
- Asynchronous Noise, less than —50 db. below peak power.
- Synchronous Noise, less than —45 db. below peak power.
- Line Bar, K Rating within 1 per cent.
- Low frequency (50 c/s), K Rating within 0.5 per cent.
- Frequency response within limits set out in Ref. (4).
- Transmitter High Frequency Response. (Ref. 4).

External Plant

Aerial Support Structures: To provide the required coverage from the television transmitting station the aerial system used to radiate its transmissions must be raised above the surface of the earth. The height of the aerial varies with the frequency channel in use and with the ground profiles between the transmitting station site and the surrounding areas. Heights between 300 ft. and 550 ft. are usually required.

Because of their lower capital cost, guyed, uniform cross section masts are preferred where sufficient flat area is available for the erection of such structures. In cases where sufficient space cannot be provided, self supporting towers are erected.

The structures used are designed, supplied, and erected by private contractors to rigid Departmental specifications, and the structural designs submitted are analysed and approved by Post Office engineers before fabrication is allowed to commence. Concrete foundations, construction materials and erection processes are carefully supervised and tested throughout the process of their provision to ensure that the structure has the specified strength. Typical mast and tower dimensions and wind loadings are shown in Figs. 2 and 16 together with a view of the tower erected at ABHN-5, Great Sugarloaf.

The siting of these structures on mountain tops to achieve optimum coverage from the station subjects them to severe stresses from winds, and in certain areas from icing. In most areas the structures surmount the natural features and are thus very prone to lightning strikes. In areas where the sparse and rocky soil conditions result in poor ground conductivity, the protection of station equipment and personnel becomes a difficult problem and special consideration has had to be given to this aspect of station installation (see Ref. 5).

Icing Problems: In other areas (notably Tasmania) special problems have been encountered due to ice formation on aerial systems and structures.

The phenomenon of serious icing on aerials and masts occurs generally at heights of between 3,000 ft. and 7,000 ft., where prevailing winds are sufficiently moisture laden and the temperature is between 26° and 32°F. causing super-cooling of the moisture droplets in the atmosphere. Under these conditions a dense clear blue glazed ice is formed, building up around the members of the mast and aerial. Unless precautions are taken, ice formations of up to about 25 tons weight can fall from the aerial and cause considerable damage to the support structure and anything in proximity on the ground. In addition the presence of ice formations on the important radiating elements affects the radiation performance of the aerial, and by affecting the impedance characteristics may give rise to multiple images on the received pictures. The ice formations are also a source of extreme danger to maintenance personnel who may have to undertake repairs on or in the vicinity of the antenna system or its supporting structure.

Where conditions are colder a white granular ice formation may build up into the wind on steelwork. This is not so dense and breaks off more easily in the wind or due to gravity into smaller fragments and is therefore less dangerous than the glazed ice condition.

Two solutions have been adopted to date in preventing the formation of ice on aerial systems and structures. These are:

(a) At Mt. Wellington (Hobart) and Mt. Canobolas (Orange) where heating cables are fitted to the aerial system in such positions that the radio freqency performance of the aerials will not be affected but where heating of the critical aerial members will be achieved. Costly power consumption of from 100 kW to 150 kW

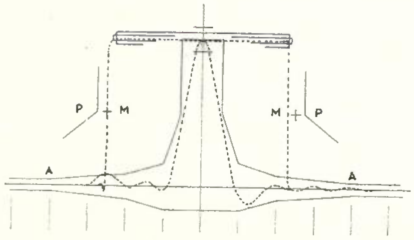


Fig. 14.—Graticule for Limits of 50 c/s; Pulse and Bar Functions (2% K Factor).

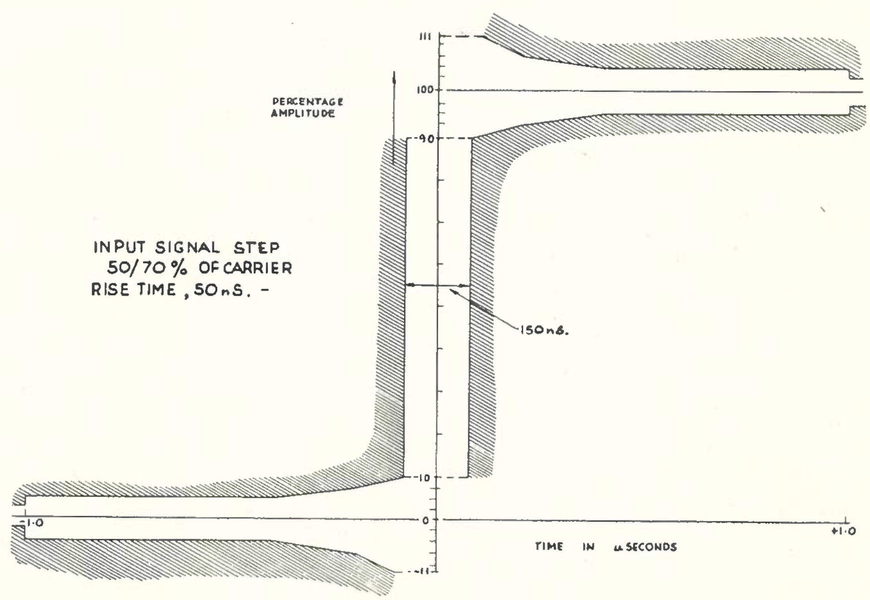


Fig. 15.—Transmitter Output Waveform Limits (to Step Function Input).

is required to achieve adequate de-icing, but the capital cost of installing the heating systems is not great in comparison with the alternative method.

(b) At Mt. Barrow (Launceston) and as proposed at Mt. Dowe (Tamworth) which involves the provision of a fibreglass sheath or radome to encase the aerial system (see Fig. 17) and thus prevent ice from lodging on the antenna. The main problem in providing such a radome is that it must be constructed of material which does not absorb or reflect the radio frequency energy radiated from the antenna. The field of materials is thus reduced to non-metals which have low radio frequency losses or reflectivities, are light and yet mechanically strong to resist high wind loadings. The material used must also be unaffected by operation at both high and very low temperatures, have long life without expensive maintenance such as painting, and must be easily fabricated and fixed at the summit of tall radio towers.

After a series of full scale tests a special fibreglass material was chosen for the cylindrical outer skin of the Mr. Barrow radome. This material is sandwich constructed having an outer and inner membrane of fibreglass reinforced polyester and a central filler of foamed poly-urethane. The total thickness of the sandwich is $\frac{7}{8}$ in. and the completed radome which is constructed in the form of a conical roofed cylinder 80 ft. high by 22 ft. dia. is formed from 56 sections of this fibreglass sandwich.

Although ice formation on the aerial system is prevented by the use of the radome, ice may still form on the outer surfaces of the radome until its weight overcomes the adhesion to the fibreglass at which point the dislodged ice will fall. In the event of serious build up on the surface of the radome, sections of ice large enough to damage lower tower members may be dislodged. To minimize the danger of damage from such ice falls the outer surface of the Mt. Barrow tower is clad in steel sheet which deflects the ice from the tower members. The radome and steel tower sheeting also permit maintenance work to be carried out on the aerial under all weather conditions.

Aerial Systems: The majority of the aerial systems used for the National television stations are dipole arrays comprising numbers of basic aerial panels, each of which consists of two or four half wave length or full wave length dipoles mounted in front of a plane reflecting screen formed from parallel bars or tubes. The basic reflector panels are mounted on the four faces of a square supporting column and stacked vertically to increase the gain of the aerial system.

The complete aerial system (see Fig. 2) is divided into two halves (or stacks) each of which is fed separately from the transmitting equipment.

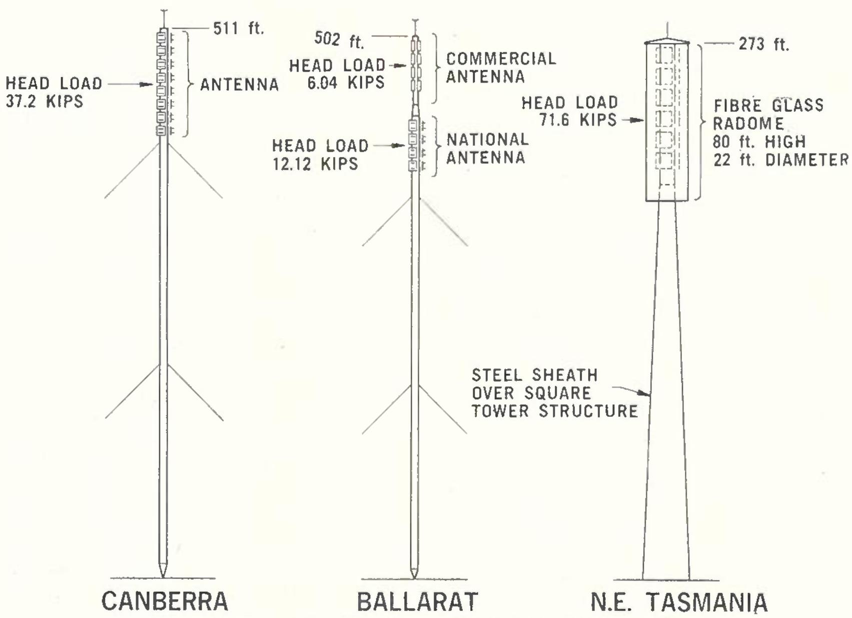


Fig. 16.—Heights and Head Loadings of Typical Aerial Support Structures.

As described earlier the two aerial sections together provide the required vertical concentration of power (i.e., aerial gain) but in the event of failure of either half, or of its associated high power feeder cable, the station transmissions may be carried by the remaining half under full power conditions but with altered vertical radiation pattern.

The desired horizontal directivity is achieved by varying the horizontal plane physical spacing and/or azimuthal orientation of the panels used in the aerial systems and by adjusting both the amplitude and phase of the power fed to the horizontal sets of panels. Similarly vertical directivity (e.g., reductions of radiation above the horizontal, depression of the main lobe from the vertical, null fill at certain vertical angles) may all be achieved by varying the vertical plane spacing of the panels and the phase or power of the energy fed to the vertically spaced bays of the system.

To improve the impedance characteristics and reduce reflections on feeder cables the four panels forming a bay are frequently fed in phase rotation so that adjacent panels are electrically 90° apart, and form conjugate pairs as far as impedance irregularities are concerned. Having used this phase rotation feed as an impedance matching device, the approximate circularity of the horizontal pattern is then established by moving the panels off the centre line of the supporting mast. A variation to this technique occurs in the case of the channel 1 aerial on Mt. Canobolas, where a British aerial of 6 bays using 24 Batwing grating radiators is employed. These have good broadband qualities and are all therefore fed in phase except for the slight delay in the 3 lower bays to obtain the necessary tilt in the beam.

At installation each aerial panel is measured for frequency impedance characteristics prior to being hoisted aloft and connected to the panel feeder system. The impedance of each half of the complete aerial is finally measured to ensure that the aerial is satisfactorily matched to the feeder so that reflections and multiple images are minimized. The two aerial feeders are then measured electrically and cut to the designed difference in lengths to an accuracy of one centimetre. This close measurement is necessary to avoid unscheduled tilting of the vertical pattern. Finally the horizontal pattern, vertical pattern, and horizontal "gain" of both stacks and each stack are measured at low power by utilizing a small aerial of known gain and directivity placed just above the main aerials and observing the change in field strength at various locations as power is switched from the reference aerial to the main aerial system. This technique is desirable to minimize errors due to uneven terrain and reflections of the radiated signal from the ground.

Coaxial Feeders: The two feeders to the pair of aerials consist of nominal $3\frac{1}{8}$ in. dia. coaxial lines which are pressurized with dry air to about 6 lb./sq. in. Three varieties have been used—

(a) A rigid copper line which requires expansion joints at intervals, owing to the differential expansion with temperature between the line and the steel tower. This is now infrequently used.

(b) A semi-flexible line with smooth extruded aluminium outer conductor, helical spacer and copper inner conductor.

(c) A flexible line with a continuously seam-welded corrugated copper coated steel outer and corrugated copper inner, also provided with a helical dielectric spacer.

Line (b) is normally hung from one point below the aerial and is only restrained laterally down the length of the mast.

Line (c) is normally clamped every 8 to 10 ft. or so along its length. It has two advantages, firstly it has a strong helically corrugated tube outer which helps to prevent mechanical damage to the cable, and secondly it is easier to install due to its inherent flexibility.

Feeders are specified to have an average characteristic impedance of 50 ± 0.5 ohms over their working frequency range of 45-222 Mc/s and so that the maximum value of any extreme of voltage standing wave ratio is no greater than 1.06. This involves very close control over the cable construction but is essential to minimize the production of "ghosts" or multiple images.

The Department is at present investigating the possibilities of specifying the performance of high power feeders in terms of the magnitude of echoes produced with transmission through the cable.

MAINTENANCE STAFF AND TRAINING

The staffing of transmitter stations is a major factor in the extension of television to country areas and is always closely considered when investigating sites and areas for new television stations. The present staffing of national stations is based on two shifts per day of two men per shift in the charge of a higher grade supervising technician, involving a total of seven technicians attached to each station. The staff for the stations are recruited from various sections of the Department, often at the present from broadcasting stations which are changing to unattended operation, and frequently from other organisations. They will thus have varying or little television experience.

It has been found that the most efficient way to train these officers for their maintenance duties is to:

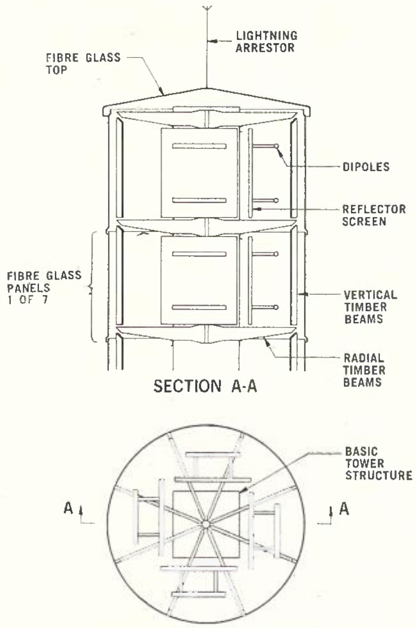
(a) Select one or two of the proposed staff for a short intensive course of up to six weeks, on television fundamentals applied to the operation and testing of transmitters.

(b) Use all members of the future operating staff for the installation of the equipment. During the installation the staff absorb the techniques and language of television transmission, supplemented by short periods of further instruction and demonstration by those who have attended the course or the visiting supervisory officers. This combining of installation and training does, however, involve more supervisory effort to ensure continuity of installation techniques between stations.

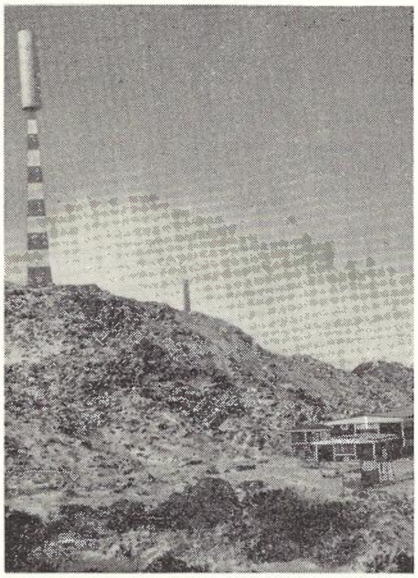
STANDARDS AND PRACTICES

Technical Standards

An important advantage which was gained from the introduction of television to Australia some time after services had commenced in other countries was that the art had become stabilised and the standards which have been adopted are the now internationally accepted standards which are unlikely to be changed for many years. A brief comparison of the Australian and other overseas standards is shown in Fig. 18.



(a) Mechanical details.



(b) View of erected structure.

Fig. 17.—Aerial Radome at Mt. Barrow, Tas.

For all stations in Phases 1 to 4 of the programme, with the exception of Broken Hill (1 kW), an effective radiated power of 100 kW for the vision aerial, averaged in the case of directional aerials, has been set as a standard. Each associated frequency-modulated sound transmitter, in the case of the C.C.I.R. system used in Australia, has a power output rating of one-fifth that of the vision transmitter.

The power rating of V.H.F. television services is stated as the product of the mean R.F. power output of the vision transmitter during transmission of synchronising pulses and the gain of the radiating system (relative to that of a single half wavelength dipole radiator). Thus the 100 kW station may (in the case of a low band, i.e. low-frequency, station) provide for 20-kW transmitter power delivered to an aerial system having a gain of five times. Alternatively, a high-frequency station may utilise a transmitter power of 10 kW and an aerial system having a gain of 10. The steps up the range of channels from 0 to 11 at which the transmitter power is reduced and the aerial gain increased in the same ratio is a matter of economics spread over the useful life of the whole transmission system, such that capital costs are balanced against operating costs.

Technical Practices

There are various regions in the engineering of high power television stations where conflicting ideas are en-encountered and in which standardization and uniformity will not be reached until knowledge and experience grow. Typical regions which present scope for comment or for further engineering investigation, together with a brief review of present practices, are set out below:—

Unattended Operation: Each national station with programme commitments of approximately thirteen hours daily requires a technical staff of seven for operating and monitoring purposes. Not only does the provision of this staff account for about half the total cost of the station, averaged over its life, it also causes a strain on the limited highly skilled staff resources of the Australian Post Office, and is becoming harder to meet as the number of stations increases, particularly as the expansion is towards the remote areas. The introduction of automatic unattended or partially attended operation is, therefore, seen as a worthwhile objective.

In automatic operation of transmitters, the detection and overcoming of complete failure of programme or carrier is relatively simple; however, the detection of degradation of the programme from a desired standard presents more difficult problems, generally requiring the comparison of the output signal with a standard undistorted reference signal.

Unattended automatic working of sound broadcasting stations has been successfully in operation in Australia for some years, and devices to detect distortion and noise in the transmission by comparing the transmitted output with the source signal are available to allow switching in of standby equipment in the event of fault conditions. In vision transmissions, the amplitude and shape of the recurring line synchronizing pulses form an ideal point of comparison with a standard. There is, however, also available the opportunity of injecting test signals at the source of the programme during the vertical blanking interval after the post-equalizing pulses and the means of accomplishing this continuous quality monitoring feature, using pulse and bar and modulated sawtooth or stepped grey scale signals, is currently being investigated in

	BRITISH SYSTEM B.B.C. STANDARDS	AMERICAN SYSTEM F.C.C. STANDARDS	AUSTRALIAN AND EUROPEAN SYSTEMS C.C.I.R. 625-LINE STANDARDS
Total width of T.V. channel	5 Mc/s	6 Mc/s	7 Mc/s
Vision -			
Number of lines double interlaced	405	525	625
Line frequency	10,125 c/s	15,750 c/s	15,625 c/s
Frame or picture frequency	25 c/s	30 c/s	25 c/s
Field frequency	50 c/s	60 c/s	50 c/s
Modulation	A.M. positive	A.M. negative	A.M. negative
Black level	30% of peak carrier	75% of peak carrier	75% of peak carrier
Transmitter characteristic	Upper sideband suppressed	Lower sideband suppressed	Lower sideband suppressed
Approx. bandwidth	3 Mc/s	4 Mc/s	5 Mc/s
Polarisation	Vertical	Horizontal	Not standardised, usually horizontal
Aspect ratio	4:3	4:3	4:3
Sound -			
Modulation	A.M.	F.M.	F.M.
Max. deviation	—	± 25 kc/s	± 50 kc/s
Pre-emphasis time constant	—	75 u secs.	50 u secs.
Sound carrier	3.5 Mc/s below vision carrier	4.5 Mc/s above vision carrier	5.5 Mc/s above vision carrier

Fig. 18.—Comparison of Television Standards.

the Department. By detecting variations from normal in these signals beyond predetermined limits, standby equipment can be automatically switched in and faulty equipment switched out. It is, of course, also possible, by using remote switching circuits, to control the operation of a station from a remote point, where monitoring of the transmission can be carried out automatically, or visually by staff with other responsibilities.

For successful unattended operation, all transmitting, fault detecting and switching equipment must be conservatively rated, uncomplicated and, where necessary, provided in duplicate. The unattended station should be situated within reasonable distance of the town in which the emergency maintenance staff are living.

Parallel Operation of Equipment: It is becoming standard practice to operate as much duplicate equipment as possible in parallel. Not only does this mean that there is less standby equipment lying idle, but, in the event of failure of an item of equipment, it can be removed from circuit with little or no interruption to programme. In the National stations, it is standard practice to operate in parallel, duplicate sound and vision transmitters and some of their ancillary equipment, aerial feeders and aerials. Careful measurement and adjustment of the relative phases in each of the duplicate transmission paths is necessary to avoid undesirable distortions.

Transmitter Circuitry: The transmitters and their ancillary equipment supplied to date from three countries are remarkably similar in general concept, the noteworthy exception being the low level modulation and consequent use of linear amplifying stages in the Japanese transmitters. The trend in transmitters is towards high level modulation, i.e., of the final amplifying stage, which readily allows the use of blanking level feedback circuits for the important factor of blanking level stability. Transmitters using high level modulations have also less problems of:

(a) changes of linearity with modulation depth, and
(b) frequency response stability

than those employing low level modulation. Modulator circuit problems in the former case, using high power modulators, are not significant.

Two other minor differences of technique in the transmitters supplied are:

(a) The use of the F.M.Q. or frequency modulated quartz crystal circuit in the sound transmitter exciters in the British transmitters. This circuit produces the frequency deviation by direct frequency modulation with a reactance tube of a crystal oscillator. Only a special crystal, free of spurious outputs, is suitable for this type of circuit. The more general master oscillator/reactance tube circuit, the output of which is compared with a reference crystal, was discussed in the earlier section on transmitters.
(b) The combining of the H.T. and auxiliary H.T. supplies to the vision and sound transmitters in the A.W.A. transmitters, as supplied at A.B.C.3 Canberra, and the placing of the H.T. transformer and complete auxiliary H.T. supply outside the transmitter proper. Although, to some extent, this restricts flexibility in the switching of transmitters, the arrangement allows considerable latitude in the layout of the transmitter and savings in space.

Reflections from Other Aerial Systems and Aerial Supporting Structures: As discussed in other sections of this paper, it is highly desirable, in the interests of simplified aerial systems at viewers' premises, to locate in one area all transmitting stations serving a particular region. Under these conditions, it has been usual to have two or more 300 ft.-550 ft. aerial support towers or masts with their V.H.F. aerial systems located in close proximity (250 ft.-5,000 ft.) to one another. Energy radiated from the aerial systems (usually omnidirectional) may, in these circumstances, be reflected from adjoining aerials or towers to produce, along with the direct transmission, multi-path transmissions from the transmitting aerial to the viewers. From the geometry of the respective radiating systems and reflecting surfaces (considered in both horizontal and vertical planes) the time difference between the multiple transmissions will vary throughout the service area to produce "ghost" signals which may vary from very closely trailing and faint ghosts of minimum nuisance value to widely trailing strong ghosts which represent a serious marring of the transmitted picture.

Observations and measurements of these mast reflection difficulties are still proceeding; however, the following empirical rules are being observed during the current planning of stations where the obvious preventive measure of sharing a common support structure cannot be achieved—

(a) Separate structures by at least 250 ft.
(b) Stagger the heights of aerial systems so that no aerial system intrudes upon the main lobe of radiation of an adjacent aerial system.
(c) Arrange that the angle of depression joining the centre points of pairs of aerial systems is greater than the

maximum depression angle required for coverage of the area around the transmitting site.

(d) Ensure that both structure and aerial array faces of adjacent radiating systems are at least 20° off parallel.

(e) In the case of large transmitting aerial arrays for low channel stations adjoining high channel stations, arrange that the larger aerial array reflector screens are oriented in azimuth to prevent specular reflections from these screens falling in areas of high population density.

The growing tendency to share a common aerial support structure for the mounting of both national and commercial aerial systems eliminates completely the problem of reflections from structures.

Engineering of Highly Directional Radiation Patterns for V.H.F. Transmitting Stations: Depending upon the distribution of population around the transmitting station, the elevation of the aerial-system and the location of other stations sharing the same operating channel, it is possible to optimize the efficiency of the service by concentrating radiation from the station to those areas requiring service, while conserving energy by minimizing radiation to areas of low population density or in directions of remote stations sharing the same frequency channel. However, the degree to which this may be achieved is restricted by practical considerations.

The aerial designer has a relatively small number of degrees of freedom available to him in achieving particular radiation characteristics because of problems of mechanical strength of the complete assembly, the need for economy and standardization in the design of the tall support structures, the necessity to provide facilities for the antenna feeder system and for maintenance, and also the limited range of power distribution components and of radiating elements available if the most economical antenna production is to be achieved.

The above are important limitations and lead to difficulties, in the case of some stations, in economically achieving the aims of the television service planners.

Many of the current stations have directional radiation patterns in the horizontal plane (see Fig. 3a, b, c), and very rigid control of the vertical radiation pattern is also aimed at for all stations (Fig. 3d). Of particular importance in this regard is the need to restrict the radiation of signals at low angles above the horizontal in the case of low frequency channels (Channels 0, 1, 2) where long distance transmission of signals radiated at these low zenithal angles is sustained by sporadic E layer ionization. If the radiation of these low "above the horizontal" signals cannot be controlled at the aerial system, the resultant co-channel interference will limit the degree of sharing of the low frequency channels.

A further aerial system problem arises in meeting the requirement to radiate a strong and stable signal to areas close in to the station which are at relatively steep angles of depression from the centre of the aerial system, particularly when a higher frequency channel is in use.

Continuous investigation is proceeding within the Australian Post Office on the difficulties of calculating and controlling aerial radiation patterns which are aimed at achieving more economical and technically adequate aerial systems.

A recent departure from earlier practice is the decision to share a single transmitting aerial between the national and commercial transmitters at certain Phase 4 stations where the frequency channels allocated make this arrangement a practical proposition. The problems of reducing interference between the signals of the respective stations and of controlling the impedance and radiation pattern performance of the aerial for both channels have required special study.

SHARING OF TRANSMITTING STATION FACILITIES

It is the practice in planning the television services in each district to group all transmitters in one locality. This arrangement obviates the need for viewers to select an alternative aerial or to alter the orientation of a single multichannel aerial when changing from one channel to another. There is also generally one locality in each district which is predominatly suitable as a transmitting station site and it is logical to group all transmitters at this site— generally on top of a hill or mountain. In such circumstances there are obvious merits in sharing facilities at a particular site, between the stations concerned. In the case of the television service in Australia, particularly in country areas, substantial economies are available to all parties by sharing the transmitting station facilities on the mountainous sites which are used. The main facilities which may be shared are:

access road, power lines, transmitter buildings, aerial support structures, aerial systems where suitable frequency channels are allocated, emergency power supply equipment, radio link systems and operating staff.

In the cases where sharing of these items between the National and Commercial interests can be introduced, arrangements are made for the costs of establishing and/or operating the shared facilities to be also shared between the two bodies. The first cases of such sharing involved sharing the cost of roads and power lines. Later, in the case of Ballarat in Victoria, an aerial supporting mast was shared between the National and Commercial stations followed by, in the case of Mt. Hopeful, Rockhampton, the full sharing of the station facilities, including the installation of the Commercial station equipment in an integrated form with the National station equipment thus enabling the joint equipment to be efficiently operated by the National station staff. In the case of the projected Phase 4 stations, most of which are to be established in the more remote areas of the Commonwealth, the full sharing of building, aerial support structures and operating staff in a manner similar to Rockhampton will be frequently adopted. From an engineering viewpoint the sharing of facilities in the manner described has several attractions.

Consider first the advantage of sharing the aerial supporting tower or mast. Not only are costs saved by both parties but reflection of radiated energy from either aerial by the other aerial or structure, as discussed earlier, is avoided and multiple transmission paths and reflections causing spurious images from this cause are eliminated from receivers.

Secondly the installation of two sets of transmitting equipment within a single building not only introduces substantial capital savings in the cost of buildings, but also enables the equipment to be provided in an integrated manner such that the maximum use may be made of "common equipment" (test loads, emergency programme facilities, testing and control equipment, emergency power supplies, etc.) which would normally be provided at each station.

The final important advantage of building sharing is that the two stations may now be readily operated by one staff with further financial gains to both stations. Due to the physical hardship of continuous critical monitoring of the radiated picture and synchronizing signals on the kinescope display of a station monitor it is necessary to employ at least two operators at each National station. By arranging for the critical monitoring of the Commercial station signal to be carried out at the nearby Commercial studio installation, it is possible to utilize the two National station operators to monitor the National station signal and also to operate and maintain both National and Commercial transmitting station plant (Ref. 2).

CONCLUSION

The combined Phase 3 and Phase 4 plans for the expansion of National television services involve the completion of 33 high power transmitting stations within the five years 1961-1966. By late 1964 all thirteen of the Phase 3 stations have been completed and the first of the Phase 4 stations, Albury, which is a "shared" station housing both National and Commercial transmitters, is also in service. Progress with the establishment of the remaining stations is satisfactory

The problems associated with the detailed engineering and the management of this project have been overcome to date, notwithstanding the difficulties which have arisen from the diversity of sites, origin of equipment, and necessity to co-ordinate the contributions of a large number of Government and private organizations.

During the progress of the programmes the major variations introduced have been to encourage the manufacture of a greater percentage of the equipment within Australia, to provide closer co-ordination of building design and equipment requirements, to increase the extent to which the transmitting station facilities are shared between the National and Commercial interests, and lastly to give greater consideration to the possibility of some measure of automatic operation of the stations being required in the future.

ACKNOWLEDGMENTS

The satisfactory progress of the Phase 3 and Phase 4 projects is a testimony to the willing co-operation of the many Government and private organizations. The information contained in the current paper has been sought and readily provided by the various bodies concerned. The authors acknowledge the assistance received from these sources and also that of their colleagues in the Engineering Divisions at P.M.G. Headquarters, in Melbourne and in Sydney. This paper is published by permission of the Engineer-in-Chief, Postmaster-General's Department.

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TECHNICAL NEWS ITEM

BROADCAST TIME SIGNAL SERVICE

A new time signal service has been introduced by the Postmaster-General's Department. On the 21st September, 1964, the Department began broadcasting a continuous time signal service from Lyndhurst, Victoria. It uses the call sign VNG.

The immediate purpose of the new service is to provide accurate time signals for the Woomera rocket range area and for the surveying activities of the Department of National Development. It will also be of use for other surveying operations in outback areas, and for seismic and other measurements carried out by various University groups, State Government bodies and other exploration parties. The time transmitted is co-ordinated time, which has a second of fixed length in terms of vibrations of the caesium atomic clock. The length of the second in co-ordinated time is fixed by international agreement at the beginning of each year. It has an offset from the nominal value, the length of the second in the year 1,900, which is intended to ensure that, on the basis of predictions, co-ordinated time will be in phase with universal time at the end of the year. Universal time is determined by the actual rate of rotation of the earth relative to the sun, which is not constant. Phase adjustments of the co-ordinated time signals are made during the year, again by international agreement, as necessary to keep the signals within 100 milliseconds of UT2 (universal time corrected for polar and seasonal variations of the earth).

The time signals are radiated 24 hours per day, except for short breaks when transmitter frequency changes are made. They are generated at the City West Telephone Exchange Speaking-Clock installation in Melbourne by equipment designed and constructed in the P.M.G. Research Laboratories, and transmitted to Lyndhurst by landline. A continuous series of pips is emitted at one second intervals, with the minutes marked by elimination of the 59th pip of each minute. Recorded voice identification of the station is given during the first minute of each hour. The accuracy of the signals is controlled by the Research Laboratories using quartz crystal clocks which with those of the National Standards Laboratory and the Mt. Stromlo Observatory form the working standards of time interval for the Commonwealth. Errors in the radiated time signals are being kept to much less than one hundredth of a second.

At present two transmitters, modulated by the same time signals, are being used. Frequency changes are made twice per day in a pattern designed to allow for different propagation conditions between day and night, thus achieving Australia-wide coverage. At the present stage of the sunspot cycle, the signals are broadcast on frequencies of 5,425 kc/s and 7.515 kc/s between 10.15 p.m. and 8.00 a.m. E. S. T. and on 7,515 kc/s and 12,005 kc/s between 8.15 a.m. and 10.00 p.m.

As equipment becomes available, improvements will be made to the service to increase the accuracy of the time signals and to provide highly stabilised carrier frequencies for the transmissions.

ANALYSIS OF SUBSCRIBER TROUBLE REPORTS — C.A.R.G.O.

*M. D. ZILKO, Dip.E.E., A.M.I.E.E.**

INTRODUCTION

The product which any telephone organisation has to sell is its services, and we should therefore direct our maintenance efforts to give the telephone users a satisfactory service at a reasonable cost. Unfortunately we cannot inspect each call and withhold the defective ones until they meet acceptable specifications. We can, however, measure the quality of our service on a 'sampling basis' and ensure that the probability of defective calls is small.

There are three principal means, referred to as service quality indicators, by which we may measure our results and each has its proper place in any telephone organisation. The three service quality indicators used in the Australian Post Office are: Service observation results, Results of the Traffic Route Tester runs, and Analysis of subscriber reports; it is this last method which will be discussed in this article.

A Complaints Analysis Centre (Fig. 1) known as C.A.R.G.O. (Complaints Analysis Recording Graphing Organisation) was established in January 1962 at Batman Exchange, Melbourne, for the purpose of providing a systematic analysis of subscriber reports thus facilitating the location and rectification of faults involving exchange switching equipment and at the same time, keeping the incidence of subscriber reports under constant surveillance as a service quality indicator.

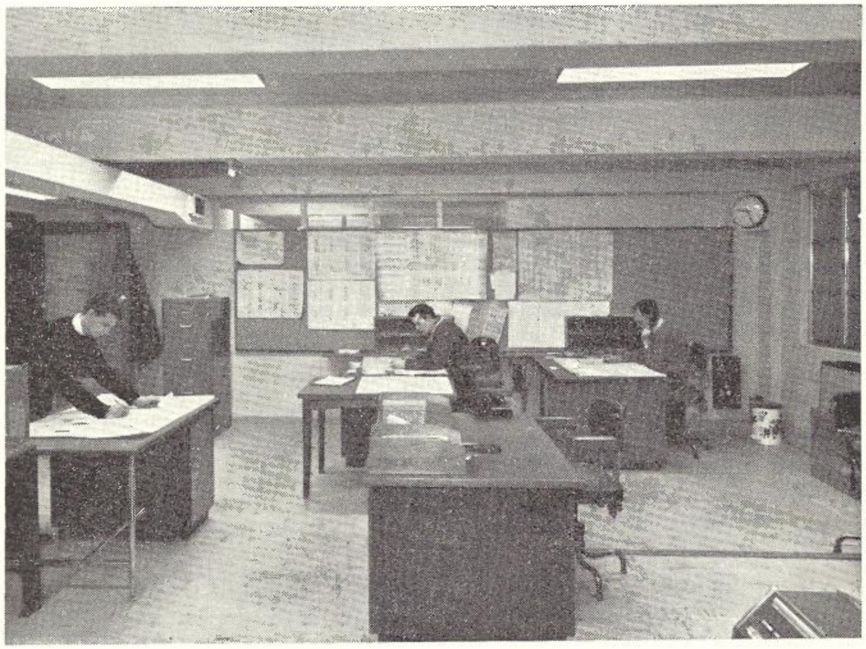

Fig. 1.—The Melbourne C.A.R.G.O. Room.

Analysis of subscriber reports is the only means for promptly detecting many types of individual troubles and clearing them.

The Metropolitan network is served by a number of 'Service Centres' previously known as 'Complaints Desks' whose functions are to receive reports from subscribers having difficulties when either making or receiving a call. When a report is received at the Service Centre, the operator queries the subscriber to obtain information on the difficulties experienced by the subscriber. The operator records this information on a trouble report docket (See Fig. 2) and tries to connect the subscriber through to the wanted number.

Before May, 1963, the Metro network was served by 13 Service Centres (See Fig. 3). This system proved to be cumbersome and somewhat inefficient, as the subscribers had to remember a number, or sets of numbers, which had little or no relation with the exchange area from which the call was made. Also this decentralization of Service Centres created problems in supervision, training and line of communication aspects. In order to improve this position and to make it easier for subscribers to report their service difficulties, complaints desks have been centralised to three centres with one calling number, 1100, serving the whole of the Melbourne Metropolitan network. The Service Centre to which the subscriber is connected is determined by the geographical location from which the report is made. The number of exchanges, lines connected and number of telephones served by each of the three Service Centres is shown in Table 1. The number of reports received has almost doubled since the uniform call number has been introduced.

In order to expedite the reporting of subscriber reports to C.A.R.G.O. and to the exchanges, a teleprinter switching network has been installed so that each of the three Service Centres has access to any staffed exchange and to C.A.R.G.O. To initiate a call, the Service Centre Operator throws her call key and dials the 4 figure number of the exchange required.

As a number of branch exchanges are not staffed after hours and during the weekends, it has been necessary to install a concentrator unit at each of the 'After Hour' testing exchanges. The 'After Hour' subscriber report is transmitted to the 'After Hour' testing exchange, where a test is carried out and if attention is not required, the nature of the report and result of the test are transmitted to the Branch exchange for attention the next day.

CLASSIFICATION OF TROUBLE REPORTS

Another function of the Service Centres is the classification of the subscriber reports in one of the following three categories:—

Technical Assistance: Reports classified under this category are those

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TABLE 1: DETAILS OF MELBOURNE METROPOLITAN NETWORK AND SERVICE CENTRES

Service Centres	Russell	Windsor	Hawthorn	Total
Number of Operators	24	13	6	43
Number of lines connected	168,776	155,352	62,609	386,737
Number of Telephones	278,296	185,733	71,351	535,380
Number of P.T.'s	2,564	1,344	563	4,471
Number of Exchanges (Staffed + Minor Metro.)	36 + 17 = 53	30 + 2 = 32	15 + 2 = 17	102

caused by network troubles or exchange equipment faults, rather than individual subscriber's apparatus.

Technical Repair: Reports classified under this category are those which can be attributed to a particular subscriber service.

Telephone Service Assistance: This category includes all reports where no fault condition is obvious or suspected in any equipment. These three classifications are shown on the docket (Fig. 2) as C. R. and A. The types of fault conditions for each of the above classifications have been described by Omond (1).

Technical Assistance reports are passed to C.A.R.G.O. for analysis, Technical Repair reports are passed to the exchanges for attention and Telephone Service Assistance reports are kept at the Service Centres for Statistical purposes.

Fig. 4 shows the results of a recent survey conducted in the Melbourne Metropolitan network for a period of 4 weeks. It will be seen that the Technical Assistance component is a small percentage of the total number of reports received at the three Service Centres.

C.A.R.G.O.

Statistics

Technical Assistance reports are passed to C.A.R.G.O. on a 24 hour basis although the centre is only staffed between the hours of 8 a.m. and 5 p.m. weekdays and 7.30 a.m. to 12 noon on Saturdays and Public Holidays. However, reports received after these hours are plotted and analysed the next day.

Reports received at C.A.R.G.O. are plotted on a specially designed chart so that the whole path of the call is plotted. The purpose of plotting the reports is to show the build-up of reports in the form of a pattern indicating the existence of a fault condition. (See Omond (1) for details of plotting techniques.)

On an average 4,000 reports are received at Melbourne C.A.R.G.O. every week for analysis, from which 150 patterns are detected. The operational efficiency is expressed in terms of the number of faults found compared with the number of patterns detected. This is of the order of 65 per cent. The number of reports for the five fault conditions analysed by C.A.R.G.O. and the number of patterns and success figure detected on different switching stages are shown in Tables 2 and 3. It will be noted that the statistics on Public Telephones in Table 2 are shown separately and this is because experience has shown that a large proportion of P.T. reports are of a spurious nature.

A recent survey has shown that on an average 20% of the total reports received at C.A.R.G.O. are included in patterns as follows:—

27% of no progress (N.P.) reports are included in patterns.

13% of wrong number (W.N.) reports are included in patterns.

7% of busy during dialling (BYdd) reports are included in patterns.

Due to the small number of reported triple connection (T.C.) troubles very few patterns are detected. However, a new procedure is being introduced whereby the T.C. reports are analysed over a period of 12 to 16 weeks. Up to date the information obtained is that this system is detecting more patterns. For N.P. and W.N. reports only one week's information is used for analysis purposes.

A survey is conducted once a year for a period of four weeks to determine the amount of time spent by the exchanges to investigate C.A.R.G.O. patterns. The results for the last two surveys are as follows:—

13/5/63 to 7/6/63—44 minutes spent per investigation.

2/3/64 to 27/3/64—37 minutes spent per investigation.

This type of survey was not conducted during the first year of operation as it was felt that a certain period of familiarisation with this new procedure would be required by the staff at the exchanges as well as by the staff at the Analysis Centre.

In order to assess the efficiency of C.A.R.G.O. three yardsticks must be taken into consideration:—

- percentage success,
- percentage reports fitted in patterns,
- time spent per investigation.

The first yardstick, "percentage success", serves to gauge the efficiency of the analysing techniques used in determining whether or not a pattern is to be referred to the exchanges for attention. There is no set rule that can be applied relating the number of reports that constitute a pattern. Factors such as time between reports, routes traversed by the call, number of switches that may have to be tested etc., have to be considered before deciding whether or not the number of reports represent a fault pattern. Another equally important use of this "percentage success"

TROUBLE REPORT Tel. 337

TIME	OPERATOR	DATE
SUBS. OR P.T. No.		N.S. TIMEC OM.
No. CALLED		No. OBTAINED
MISS MRS. MR.	REPORTED BY	
NATURE OF FAULT/REMARKS		

Connected		Metered		Rebated	SEQ.	
C	BY d d 1, 2, 3 up	N P		WN one	TC 1, 2, 3 up	CO
R	BY o o o	DA faulty	WN freq.	CBDT / NDT / NRR	CNS	Sub./PT Equip.
A	BY spkg.	DA o k		NSN		C C

O/N C.2767—2/63 C.1059/63—PL

LEGEND: C = CARGO.
BYDD = Busy during dialling.
NP = No progress.
WN = Wrong number.
TC = Triple connection.
CO = Cut off.
R = Repair.
BY = Busy, out of order.
ooo
DA = Doesn't answer.
CBDT = Can't break dial tone.
NDT = No dial tone.
NRR = Not receiving rings.
CNS = Coins no service.
NSN = No such number.
CC = Customer comment.

Fig. 2.—Standard Trouble Report Docket.

TABLE 2: TROUBLE REPORTS REFERRED TO C.A.R.G.O. DURING PERIOD OF 4 WEEKS

	Busy During Dialling	No Progress	Wrong Number	Triple Connection	Cut-Off	Total
Subscriber Reports	1,310	7,731	6,389	327	1,136	16,893
% of Total	7.7	45.7	38.0	1.9	6.7	
P.T. Reports	258	657	1,397	36	811	3,159
% of Total	8.1	20.7	44.2	1.4	25.6	

TABLE 3: ANALYSIS OF PATTERNS DETECTED DURING PERIOD OF 4 WEEKS

Switching Stage	Number of Patterns Detected	Number of Faults Found	% Success
D.S.R. & S.S.R.	41	23	56
Group Selector	315	207	65
Final Selector	240	152	63
Repeater	25	24	96
Overall Total	660	448	67

Telephone "Out of Order" or Service Difficulties on Local Calls —

If Your All-figure No. Commences with	Dial Only:	If Your All-figure No. Commences with	Dial Only:	If Your All-figure No. Commences with	Dial Only:	If Your All-figure No. Commences with	Dial Only:	If Your All-figure No. Commences with	Dial Only:
20, 21	5000	34, 35, 36	3400	50	5000	64	6900	85, 86, 87	8100
23	8100	37	3700	51, 52	5100	65 (Except 654)	6800	88, 89	8300
24	5100	38	3400	53	5300	654	6700	90	9200
25	8100	39	3700	54, 56, 57, 58	5000	66	6800	91	5100
26	5100	41, 42, 43	4100	60, 61, 62, 63	6700	67	6700	92, 93	9200
27, 28, 29	8100	44	4800			68	6800	94	5100
30	3400	45	4100			69	6900	95, 96, 97, 98, 99	9200
31	6800	46, 47, 48	4800			74	5000		
32	6700	49	4100			80, 81, 82	8100		
33	3700					83, 84	8300		

Fig. 3.—Extract from Melbourne Telephone Directory, May, 1962.

yardstick is to be able to assess whether the testing equipment or testing methods used at the exchanges are adequate, especially in exchanges with a constantly high no fault found component.

The second yardstick, "percentage reports fitted in patterns," is used to determine whether the adopted action limit has to be increased or decreased depending whether the percentage is low or high. The figure of 20% of the reports fitted in patterns may appear to be low, but it must be remembered that although analysis occurs on a 24 hours' basis the centre is only staffed between 8 a.m. and 5 p.m. A large number of reports received after hours are not fitted into patterns, because testing is carried out at the exchanges early in the morning and thus fault conditions are removed before being detected by C.A.R.G.O.

The third yardstick, "time spent per investigation", enables management to assess whether the amount of time taken to investigate C.A.R.G.O. patterns is economical or whether it would be cheaper to rely on conventional fault finding methods.

Care must be exercised that improvement in any of these three yardsticks is not achieved at the expense of the other two. The figures obtained up to date for the Melbourne network are percentage success, 65; percentage reports fitted in patterns, 20; and time spent per investigation, 37 mins. These are considered satisfactory.

Parameters

One objective of trouble report analysis systems is the production of parameters that would reflect the performance of the network as well as of the individual exchanges, thus enabling a standard of satisfactory operation to be set down. Experience in Melbourne as well as in Adelaide where these techniques were developed has demonstrated that the number of trouble reports and the number of calls originated does provide an approximate measure of service quality. Consequently the following two performance evaluation parameters have been adopted—

- Total number of originating reports per 1,000 calls,
- Total number of terminating reports per 1,000 calls.

All subscribers reports received at C.A.R.G.O. show the calling number, the called number, the type of fault encountered and where applicable the number obtained, see Fig. 2. To derive the originating figure for each exchange all dockets are sorted into their calling exchange numbers and totalled for each exchange. The dockets are then sorted into their called exchange numbers and totalled once more giving the terminating figure.

If a trouble report docket shows a Coburg Exchange subscriber calling a Preston exchange subscriber, then for statistical purposes the call is originated against Coburg exchange and terminated against Preston exchange. In the "WN" and "BYdd" categories the subscriber often gives sufficient information to show to the analyser the point of failure to the call. In these cases, the docket is adjusted so that it is terminated against the exchange of the point of failure and not the normal called exchange.

The number of calls originated from each exchange is derived from the revenue figures obtained from the Telephone Accounts Branch. It is realised

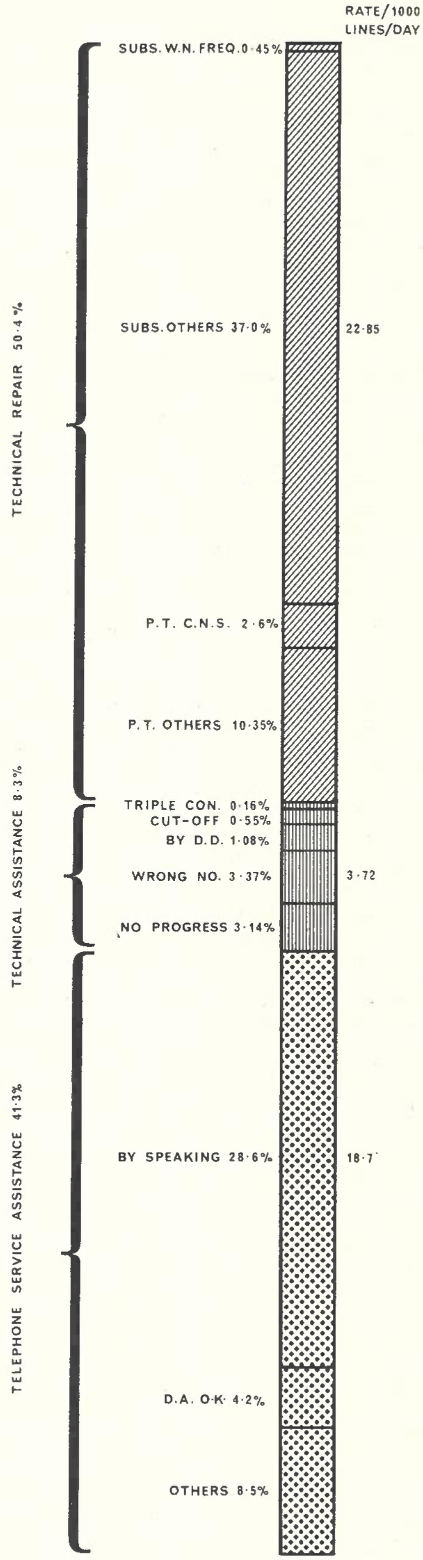

Fig. 4.—Analysis of Trouble Reports Received in Melbourne Network between 6/4/64 and 1/5/64.

that the parameters described do not take into account growth and seasonal fluctuations in traffic, however, it is felt that providing these figures are obtained at six-monthly intervals, the error accruing does not materially affect the accuracy of the weighting basis used.

The first parameter, "originating reports per 1,000 calls", is used to show the satisfaction of the service as seen by the subscriber, as only one switching stage is used in setting up the call. Whilst the second parameter, "terminating reports per 1,000 calls", reflects the condition of the exchange as three or more switching stages are used in setting up the call.

The exchange figures and network figures for these two parameters are passed to the exchanges weekly and are plotted on a linear graph. This allows the supervising technician to judge not only how his exchange is progressing from week to week but also to compare it against the performance of the whole network. Similar figures based on a 4-week period, instead of weekly, are forwarded to the controlling engineer and are plotted on a pingraph. The controlling engineer is more concerned with trends which are constant over a longer period, whilst the supervising technician is more concerned with the day to day activities.

However it must be stressed that good judgment and experience are needed to interpret these ratios. For one thing all subscribers do not have the same standard of judgment. For another, people become accustomed to a particular level of service; even poor service, if it continues for a long period does not generate a large number of complaints. On the other hand the question of increased rates invariably causes a sudden but temporary influx of trouble reports. Therefore, reference to other indicators is usually necessary to establish the degree of corrective action required.

Until August, 1963, these statistics were compiled manually, but use is now being made of the computer at the P.M.G. Research Laboratories to process these figures automatically. Details of the method used are discussed in another article in this issue of the *Journal*.

Extension of Activities

Since January, 1964, C.A.R.G.O. activities have been extended to embrace the analysis of subscriber reports for outer Metropolitan areas within the unit fee area, and for the Geelong area, outside the unit fee area. Local traffic as well as traffic to the Metropolitan network are analysed at C.A.R.G.O.

The outer Metropolitan area is served by six Service Centres, of which three e.g. Chelsea, Ferntree Gully and Werribee are connected to manual exchange areas. Reports received from these manual centres are analysed differently from those received from automatic exchange areas, because every unsuccessful attempt is reported. Experience has shown that automatic subscribers usually try at least twice, if not more, before reporting their service difficulties.

On an average 4,500 reports are received every four weeks from which 72 patterns are detected. The percentage success figure is of the order of 80.

The total number of lines connected for these two areas are:—

Outer Metropolitan	21,917
Geelong	6,379
Total	28,296

Crossbar Exchanges

The introduction of crossbar equipment in the Metropolitan network has introduced a new set of problems to the analysis of subscriber reports. With step by step equipment, a call has only one route available to reach its destination, except for inter-access routes which are limited to within the group area, and therefore, it is easy to plot the path of the call and to analyse the probable points of failure. With crossbar having alternate routing facilities, plotting the path of the call is more complex. Also as crossbar is based on random selection it is improbable that the subscriber making successive calls will be connected to the same outlets, with the result that if a subscriber experiences difficulties on the first attempt, he is more likely to get through on the second attempt. Therefore, this would tend to reduce the number of subscriber trouble reports.

Since May 1964, a limited amount of crossbar equipment has been introduced in the Metropolitan network as follows—

Blackburn—3,000 lines installed.
East Doncaster—2,000 lines installed.
Fawkner—2,000 lines installed.
Newport—4,000 lines installed.
West Essendon—3,400 lines installed.
Clayton—1,000 lines installed.
Burwood—1,000 lines installed
North Melbourne—1,000 lines installed.

IGV stage has been installed at Gardenvale, Beaumaris and Sunshine exchanges. Three tandem crossbar exchanges at Windsor, Hawthorn and North Melbourne serve this crossbar network.

Although experience with crossbar equipment has been limited up to date, it has been found that C.A.R.G.O. is able to pinpoint troubles relating to junction faults and some equipment faults. However, the majority of equipment faults are more readily detected by the maintenance aids available at the exchanges.

CONCLUSION

The analysis of subscriber trouble reports is not an end, but a means to an end; it helps to pinpoint trouble spots in the network based on the cumulative effect of several subscriber reports. This principle is not new, it has been practised by the exchange staffs for many years. However, what is new is that C.A.R.G.O. is not concerned with any particular exchange area, group area or divisional area, but with the whole network. Therefore, it is the first time that this information has been concentrated at one location and processed and analysed in a systematic manner. Another important factor is that this system has enabled the analyser to devote the whole of his time to the analysis of subscribers reports and thus has been able to build up a valuable source of knowledge and experience of the network. Another factor which has contributed substantially to the success of this system is the co-operation and assistance which has been received from the field staffs and personnel connected with Metropolitan Service activities.

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COMPUTER COMPILATION OF SUMMARIES OF TECHNICAL ASSISTANCE REPORTS

I. T. HAWRYSZKIEWYCZ, B.E. (Hon.)*

INTRODUCTION

In another article in this issue of the *Journal,* Zilko (1) discusses the collection and classification of subscriber trouble reports originating in the Melbourne Metropolitan network. In this article, computer compilation of statistical information on the reports and the results of the analysis of reports in the technical assistance category is discussed. A computer program has been developed for the CDC-160A computer at the P.M.G. Research Laboratories in Melbourne to produce weekly and four-weekly summaries for the Service Co-ordinating Centre.

In the processing scheme that has been adopted the reports are recorded during the week on paper tape using telegraph type paper tape reperforator punches. At the end of the week these tapes are despatched to the computing centre at the Research Laboratories where they are processed. The information that is received at the computing centre consists of:—

(a) the tapes holding the subscriber reports,

(b) a list of adjustments that are to be made to the sorted results, and

(c) details of the fault patterns that have been found at the Service Co-ordinating Centre during the week. The adjustment and pattern information is punched onto paper tape at the computer centre and all tapes are processed using the computer program. The output from the computer is the sorted information punched on paper tape. The information on paper tape is then listed and returned to the Service Co-ordinating Centre.

The weekly summary that is obtained consists of the reports sorted into originating and terminating sections. The originating section is obtained from the calling number in a report and the terminating section is obtained from the called number. The results of the weekly summary are then used at the conclusion of each four-weekly period to produce a four-weekly summary.

One essential aspect of the processing scheme has been the standardisation of the method of recording of the subscriber reports on paper tape for computer processing. It is necessary to use a scheme which satisfies both the human user and the computer. The method of recording that is used is described in the first part of this article. This is followed by a description of a technique used on the computer to derive from a subscriber number the exchange to which a subscriber is connected, and the methods used in decoding the tape holding the subscriber reports, sorting of information and preparation of summaries.

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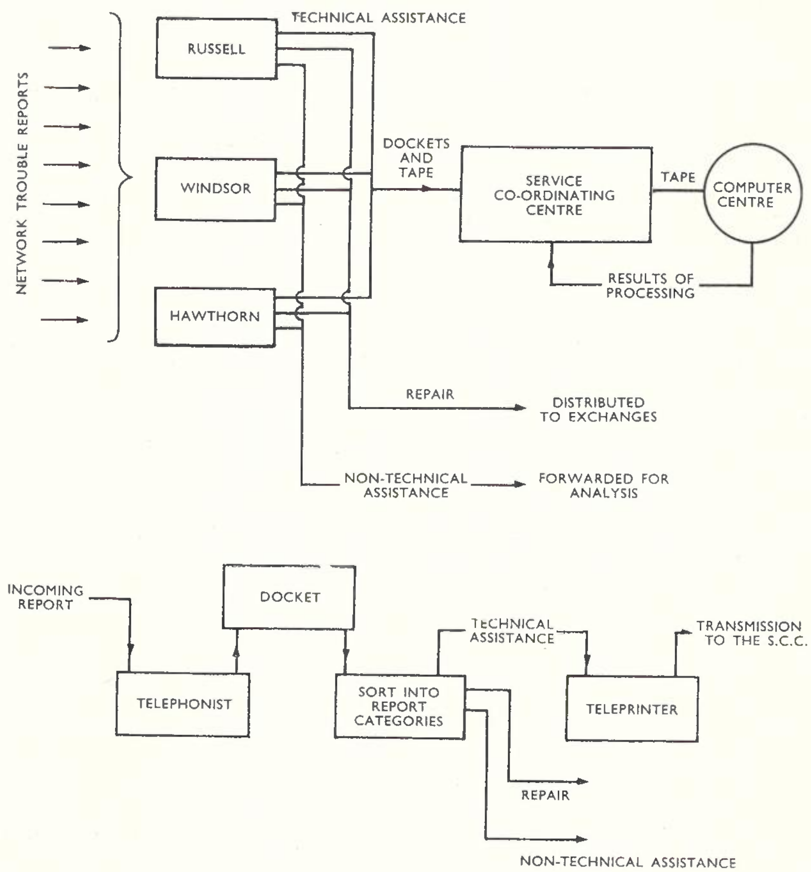

Fig. 1.—Collection of Trouble Reports.

RECORDING OF REPORTS

The system used in reporting and collecting subscriber reports has been previously described (1) and is briefly summarised here. Subscribers experiencing trouble in the metropolitan network can report this trouble to one of three service centres, Fig. 1, by dialling the number, 1100. At the service centres the reports are collected and classified. The manner of classification has been described, (1) and (2), and is based on the action that is to be subsequently taken on the reports. Three broad categories are used; these being the repair, non-technical assistance and technical assistance categories. Only the technical assistance component is considered in this article. This component deals with trouble caused by exchange switching equipment and is composed of five report kinds. These are:—

busy during dialling (BYDD)

no progress (NP)

wrong number (WN)

triple connection (TC), and

cut-off while speaking (CO)

The technical assistance component of reports is passed to a Service Co-ordinating Centre for analysis. These reports are transmitted by telegraph channels from the Service Centre to the Service Co-ordinating Centre. At this latter centre the reports are collected on teleprinter tape and this tape is forwarded to the computer centre at the conclusion of each weekly period.

As a computer requirement it was necessary to standardise the method of transmitting the reports between the Service Centre and the Service Co-ordinating Centre because it is here that the subscriber report tapes are prepared for computer use. Further as the punching of teleprinter tape is carried out in parallel with the printing of messages for use by the staff of the Service Co-ordinating Centre it has been found necessary to use a scheme that is suitable for visual interpretation and for computer use. In the method that has been adopted each technical assistance report is transmitted and recorded as one independent message. This message, illustrated by an example in Fig. 2, consists of four lines. These lines are:—

CARGO 6/10 9.45 a.m.
PT 521067 WN 670321
REC 670411
RV 2

LEGEND

6—Day
10—Month
9—Hour
45—Minute
PT—Public Telephone Call
521067—Calling Number
WN—Report Kind
670321—Called Number
670411—Received Number
RV—Service Centre
2—Teleprinter number

Fig. 2.—A Technical Assistance Report Message.

(a) *First Line or Heading Line:*

The word "C.A.R.G.O." commences this line and is followed by the time and date at which the report originated.

(b) *Second Line or Report Description Line*

This line shows the number of the calling subscriber, the number of the called subscriber and the kind of report. If the report originated from a public telephone this line is preceded by the letters PT. The letters BYDD, NP, WN, TC and CO represent the kind of report.

(c) *Third Line*

This is a second line of the report description. Information additional to the calling and called numbers is shown in this line. This information may be:—

(i) the number received if a wrong number condition has been reported. In this case the line commences with the letters REC and is followed by the received number. The letters NK follow REC if the received number is not known.

(ii) an extension of one of the numbers in the second line. The line commences with EXT followed by the extension number. The letters EXT are punched under one of the numbers in the second line.

(iii) the stage of dialling at which busy tone was obtained in the BYDD condition. The letters BY are punched at the beginning of the line and are followed by the number of the digit at which busy tone was first observed. The letters NK follow BY if this is not known.

(d) *Fourth Line or Message Origin Line.*

This line identifies the Service Centre and teleprinter from which the message was sent to the Service Co-ordinating Centre.

The coding used is:—

RU—Russell
WN—Windsor
HN—Hawthorn

with the teleprinter number following the letters.

In deriving weekly and four weekly summaries the second line of the message is used. The procedure followed is to identify the exchanges to which the subscribers in the message are connected and the report kind. An originating section is then derived from the calling numbers and a terminating section from the called numbers. The method of derivation of exchanges from the subscriber numbers is discussed in the following section.

DERIVATION OF EXCHANGES

During computer processing it is convenient to use a numerical code number rather than the exchange name to represent an exchange. Each exchange in the Metropolitan area has been allotted a number by which it is identified by the computer. In printing out information the computer uses this number to locate the proper alphabetic name under which information related to the exchange is printed.

One possible technique that can be used to derive the exchange number from a subscriber number is to store a "table of correspondence" between the first four digits in a subscriber number and the exchange. This procedure is found to be inefficient as in many cases four digits are used in the table where two would be sufficient. However, four digits must be used to permit the smaller exchanges in the network to be derived.

The alternative approach that has been adopted is to use an ordered graph (3). In this context an order graph is a digit by digit plot of a subscriber number. This graph is so constructed that it examines successive digits of a subscriber's number at successive points in the graph and directs this examination or plotting until a terminating point is reached. The code number of the required exchange is given at this terminating point.

Each successive digit is examined at a nodal point or node on this graph and information stored at this node determines the branch to be taken from this node to a further node to examine the next digit. The branch taken from a node is determined from the number dialled in the digit position that is being examined at the node. There are at most ten outgoing branches from each node. In using this graph only a minimum number of digits are used in deriving an exchange.

A portion of this graph is shown in Fig. 3 and an example of using it is given.

Two subscriber numbers are shown and the exchanges to which they are connected are to be found. The numbers are 635235 and 6806521.

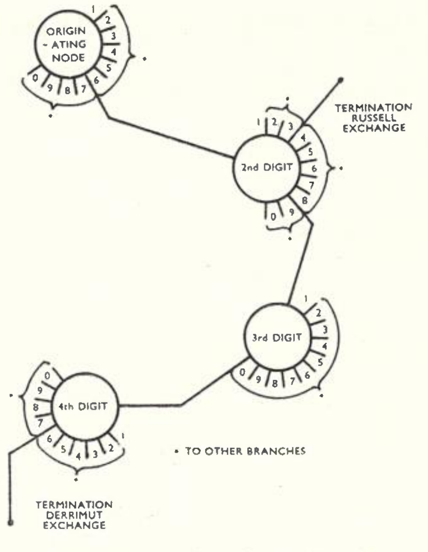

Fig. 3.—Part of the Ordered Graph.

A search for each number is commenced at the originating node. The first digit dialled is 6 in both cases and in both cases a branch would be made to the same node. At this second node the first number is branched out on branch 3. This branch is a terminating point. This terminating point contains a code number of the exchange (in this case the Russell exchange). A terminating point is reached only when sufficient digits have been examined to determine the exchange. In the case of the second number two additional digits must be examined (Fig. 3) to determine the Derrimut exchange.

In the computer memory the graph is stored as a number of nodes. Each node consists of a maximum of ten locations. Each of these locations contains the number of the node to which a branch is made on dialling on one of the ten numbers in a digit position. The location of this node in the store is located by referring to a table holding the commencing addresses of each node. Where in some cases some of the branches from a node are to the same termination or where some branches are not used, all the ten locations in the node are not used and a coding scheme is

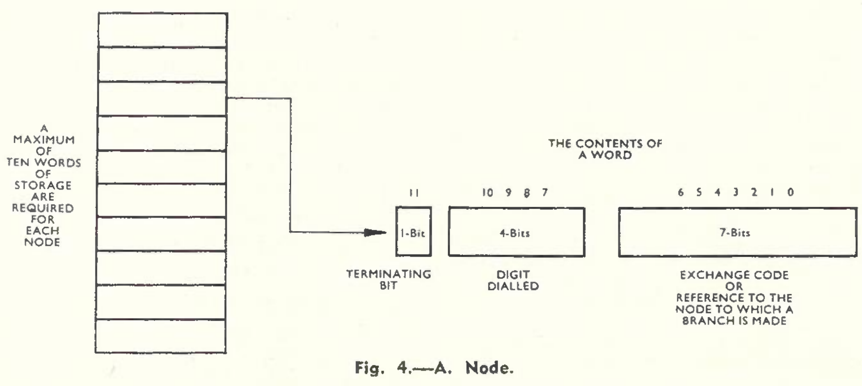

Fig. 4.—A. Node.

arranged where all redundant branches may be commoned.

The coding scheme is explained by considering the method by which the graph is held in store. The 12 bits of a word in a node are divided into three parts (Fig. 4).

(a) bit 11—a terminating bit. It is 0 if the branch is not terminating and 1 if it is a terminating branch;
(b) bits 7-10 — the binary form of the number dialled in the digit position; Here the number 0 dialled is represented by the binary equivalent of 10 and the numbers 1 to 9 by their respective binary equivalents.
(c) bits 0-6 — the coded form of the exchange if the branch is terminating or the node number of the node to which a branch is made.

When the number dialled into this node is found, it is compared with bits 7-10 of the first entry in the node. If these are the same then the terminating bit indicates whether a branch is to be made to a further node or whether a termination is reached. If the number does not compare with bits 7-10, the comparison is repeated with the following entries in the same node until an entry is found where bits 7-10 are the same as the digit dialled.

In cases:—

(a) Where some digits dialled are to the same termination, then in the last entry in the node the terminating bit is set to 1 and bits 7-10 are set to 0. If on searching through the node this condition is found, the required exchange is given in bits 0-6, for all the digits that have not been shown in bits 7-10 of the previous entries of the node.
(b) Where there is no branch or termination for some of the numbers dialled in the digit position, zero is stored in the last entry in the node. This location can only be reached when the number has been erroneously recorded and is in effect to a group that does not exist. An error indication is given if this condition is reached.

Thus summarising, the search through a node commences at the first entry in the node and continues until:

(a) The number dialled in the given digit position corresponds to the number given in bits 7-10 of a node entry.
(b) A condition is reached where the terminating bit is 1 and bits 7-10 are zero.

The code number of required exchange is then found in bits 0-6 of the entry, or

(c) The value zero is found in the entry.

The amount of storage required to hold the ordered graph is 182 12-bit words.

COMPUTER PROGRAM

The weekly program is divided into the following sections:—

(a) the reading in of subscriber trouble messages.
(b) the decoding of the messages.
(c) the reading in of the adjustment and pattern data.
(d) the output of the summary.
(e) the output of information to be used as input in the 4-weekly summary.

The sequence of using the sections is shown in Fig. 5. Each report is initially read-in and passed to the decoding and sorting sections. These sections decode the message and make an entry in a table in the internal store. This table contains the sorted information. On the completion of the reading-in of the trouble reports the adjustment data and pattern data are read-in. The adjustment data adjusts the information in the internal table and the pattern data forms an additional internal table. When these two tapes have been read the summary is output and this is followed by the output of information to be used in the 4-weekly analysis. These sections are now outlined in detail.

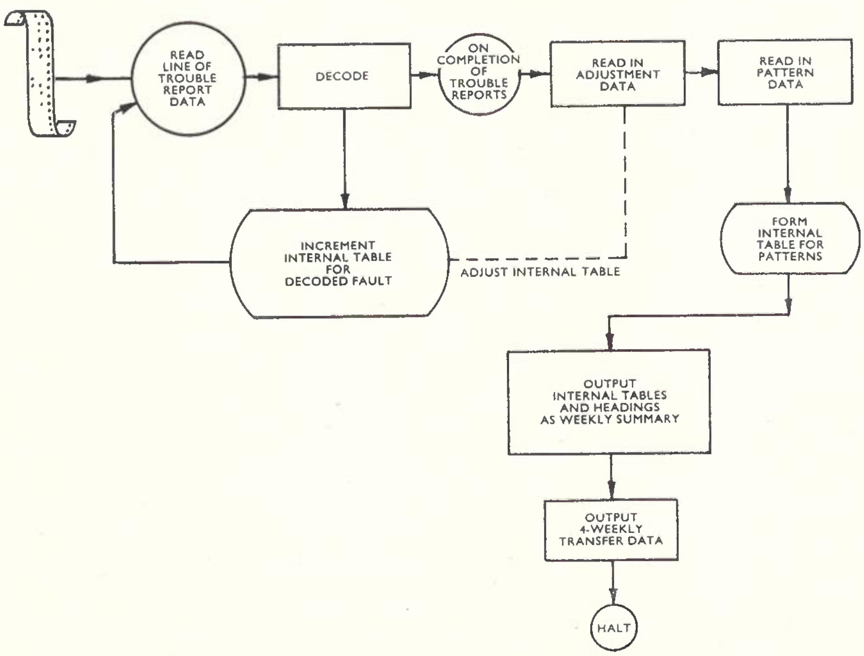

Fig. 5.—The Steps Followed During Processing.

Reading-In of Messages

Each message is read as a sequence of lines and only the line describing the type of report is passed to the decoding part of the program. To determine whether a line is to be decoded, a number of tests are made. These are carried on the first character of a line. The results for the following characters are:—

(a) C—the line is neglected, as it is a heading line.
(b) W, H, R—the line is neglected, as it is a message origin line.
(c) E, R—the line is neglected, as it is the second line of the fault description section.
(d) P or a decimal figure—this line is not neglected and is passed to the decoding program.
(e) a line commencing with any other character is considered to be in error and is neglected.

Decoding of a Message

The decoding is carried out on the report description line. The steps (Fig. 6) in the decoding are:

(a) to identify whether the call is from a public telephone booth. The call is from a public telephone booth if the first character is a P. Otherwise the call is from a private connection.
(b) The originating exchange is derived from the originating number, using the ordered graph.
(c) The type of report is obtained from the first letter in the type of report part of the line. This letter may be B, N, W, T. C. In each case the letter is converted to the machine representation of the report kind which is 1, 2, 3, 4 and 5 respectively.
(d) The terminating exchange is derived from the terminating number in a manner similar to the originating exchange

The decoding is carried out only if the report description line is punched to the predetermined specification. If an error is found in the form of this line, the line is neglected and an error indication is given.

Sorting

The sorting consists of increasing a value in an internal sorted table by one. The internal table is divided into four parts. These are:—

(a) originating exchanges for a private subscriber report;
(b) terminating exchanges for a private subscriber report;
(c) originating exchanges for a public telephone booth report;
(d) terminating exchanges for a public telephone booth report.

For each message two values are incremented by one. These are a value in an originating and a terminating section in either the subscriber or the public telephone booth classification. The relative location in the table of the values to be incremented is calculated as:—

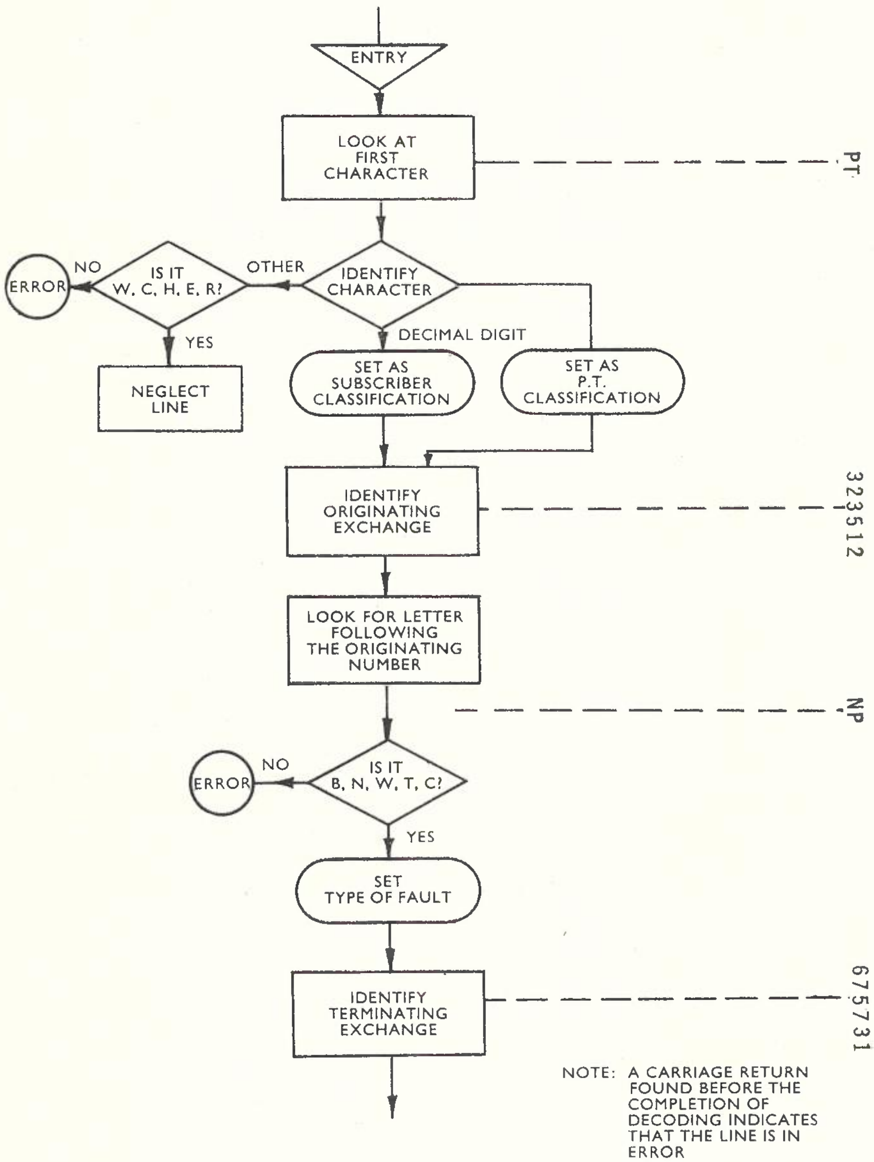

Fig. 6.—Decoding of a Line.

$$(a \times 1020) + (s \times 510) + (e \times 5) + f \quad \ldots\ldots\ldots\ldots (1)$$

where a = 1 if the report is from a public telephone
= 0 if the report is from a private subscriber
s = 1 for the originating section
= 0 for the terminating section
e = exchange code
f = type of report code.

From equation [1] the arrangement of the internal table (Fig. 7) is such that the incremented entry is that which corresponds to the exchanges and the type of report that is identified by the decoding.

Adjustment and Pattern Data

Adjustments are used to reallot reports sorted by the sorting section. In a number of cases where a pattern results in a fault being found in an exchange other than the terminating exchange given in the report message, the reports in the pattern are transferred from this latter exchange to the former. This is carried out only in the terminating section which is used as in indicator of exchange performance (1).

The adjustment data is punched as a number of lines, these being of the form:— (code number of an exchange) followed by (letters specifying the kind of report) followed by a (sign) and a (number specifying the magnitude of the adjustment). An example of a line is:—

5 NP + 3

where 5 = the code of the exchange to whose terminating section the adjustment is made
NP = the report kind
+3 = the adjustment.

The first two parts of this are used to calculate the location of the value to which the adjustment is made. The adjustments are only carried out on the terminating section of the private subscriber classification. Thus, in using equation [1] for this calculation, a = 0 and s = 1. The value following these codes is added to this location. The adjustment data consists of all the adjustments necessary as a number of successive lines. The pattern data describes the patterns that have been despatched by the Service Co-ordinating Centre during the week and the results that are obtained. One line of data is punched for each pattern and is of the form:—
(code number of exchange) followed by a (letter describing the kind of equipment in which a fault was found) followed by a (number representing the kind of fault found).

An example of this is:—

5 G 7

where 5 = the code number of the exchange to which a pattern has been despatched.
G = the equipment in which a fault has been located
7 = the kind of fault that is found.

The code representations of the equipment and type of fault is given in Table 1. On reading the pattern data an additional three internal tables are formed. These are:—
(a) a table of 102 values showing the number of patterns sent to each exchange in the network;
(b) a table of 102 values showing the number of N.F.F. results in each exchange, and
(c) a table showing the equipment in which the faults have been found and the kind of fault that is found in this equipment.

Output of the Weekly Summary

The internal tables formed during the reading-in of the trouble report data and adjusted by the adjustment data are output. The first two tables formed by the

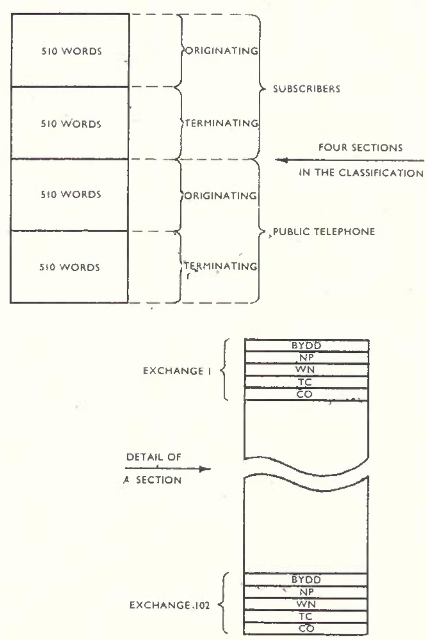

Fig. 7.—The Internal Table Used to Store Sorted Information.

WEEK ENDING 29/2/1964

TECHNICAL ASSISTANCE FAULTS
WEEKLY ANALYSIS
ORIGINATING

GROUP 2

Exchange	BYDD	NP	WN	TC	CO	TOT.	C/10³	PAT.	N.F.F.
Tally Ho	3	12	12	0	3	27	.72	0	0
Toorak	5	4	20	0	3	27	.23	1	0
Glen Iris	5	11	28	1	1	41	.40	2	1
South Yarra	10	30	18	1	1	50	.42	3	1
Wantirna South	0	3	5	1	1	10	1.86	2	1
Jordanville	3	19	16	0	3	38	.87	5	2
Burwood	4	11	13	0	1	25	.43	2	2
Hartwell	0	8	15	1	5	29	.36	0	0
Kooyong	6	9	11	1	1	22	.28	2	1
Group Total and Complaints/1,000 Calls						269	.42	17	8

GROUP 3

Exchange	BYDD	NP	WN	TC	CO	TOT.	C/10³	PAT.	N.F.F.
Flemington	0	4	5	0	0	9	.16	0	0
West Essendon	1	2	5	0	2	9	.32	0	0
Keilor	0	0	1	0	0	1	.33	0	0
Ascot	3	16	44	4	3	67	.60	2	1
North Essendon	4	20	19	0	1	40	.41	1	1
North Melbourne	10	16	17	0	0	33	.23	2	2
Somerton	0	0	0	0	0	0	.00	0	0
Craigieburn	0	0	0	0	0	0	.00	0	0
Broadmeadows	0	0	0	0	0	0	.00	0	0
Broadmeadows East	1	4	6	0	1	11	2.22	0	0
Greenvale	0	0	0	0	0	0	.00	0	0
Bulla	0	0	1	0	0	1	.43	0	0
Tullamarine	0	0	0	0	0	0	.00	0	0
Glenroy	2	9	19	1	0	29	.70	3	0
Carlton	7	32	37	0	3	72	.28	5	3
Coburg	5	6	32	0	6	44	.36	1	1
Moreland	9	17	27	0	4	48	.36	2	0
Brunswick	1	13	13	0	7	33	.25	0	0
Civic	3	14	6	1	2	23	.10	0	0
Group Total and Complaints/1,000 Calls						420	.31	16	8

Fig. 8.—Part of weekly Summary Showing the First Two Groups of the Melbourne Network.

pattern data are also output. The binary numerical data in the tables is output in decimal form together with suitable headings and page layout information. The latter is in the form of carriage returns to provide suitable spacing between the groups of output.

The layout of a number of groups of exchanges in the weekly summary is of the form given in Fig. 8. The summary consists of four parts, these being:—

(a) originating exchanges for subscribers' reports;
(b) terminating exchanges for subscribers' reports;
(c) originating exchanges for public telephone reports;
(d) terminating exchanges for public telephone reports.

Each part consists of the reports categorised under their kinds for each exchange in the network. The exchanges are grouped and a group total of the reports is given. The first two groups of the originating exchange reports are shown in Fig. 8.

In addition to the reports for each exchange, some additional information is computed. This consists of:—

(a) the total number of reports for an exchange. The BYDD reports are excluded in the summation;
(b) the number of reports for each 1000 calls originating at the exchange in a weekly period;
(c) the patterns and N.F.F. for the exchange;
(d) a group total and number of reports for each 1000 calls for each group are given;
(e) network totals in the same form as (d);
(f) the total number of each kind of report in the network is given.

Transfer Information to the 4-Weekly Program

The information output by the weekly program for summary by the 4-weekly program consists of all the internal tables assembled during the reading-in of the input data tapes. The tables are punched in binary form on the tape.

The Four-Weekly Program

The four-weekly program is used at the conclusion of each four-weekly period. The running of the program consists of:—

(a) reading-in of the transfer data prepared by the four previous weekly programs, and
(b) the output of the summary.
The output consists of two parts:
(a) the subscriber reports, and
(b) the public telephone reports.

Each part is divided into the exchanges in the network which in turn are grouped as in the weekly analysis.

The information output consists of:—

(a) the total number of reports excluding the BYDD reports in the originating and terminating sections, and the number of these for a 1000 calls originating and the exchange in a four-weekly period;
(b) the number of patterns and N.F.F.'s for the exchange in a four-weekly period;
(c) the number of BYDD reports for each exchange in the four-weekly period;
(d) the total number of reports in each group;
(e) the total number of reports in the network;
(f) a table showing the number of faults found for the different type of switch in the network during the four-weekly period. These are further subdivided into the kinds of fault in each type of switch. This table is formed for the type of switches and kinds of faults given in Table 1.

TABLE 1:
CODE REPRESENTATIONS OF EQUIPMENT AND TYPE OF FAULT

Equipment	*Code*
Junction Uniselector	J
Group Selector	G
Final Selector	F
SSR and DSR	A
Line Finder	L
Repeater	I
Distributing Frame	D
Subscriber Fault	S
Miscellaneous	M

Type of Fault	*Code*
Department Officer	0
Mechanical	1
Relay	2
Wiper Cord	3
Wiper	4
Bank	5
NS and S Springs	6
Wiring Fault	7
Miscellaneous	8
Came Clear Ring 100 c/sec test	9
No Fault Found (N.F.F.)	10

A listing of a group of exchanges in the four-weekly summary is shown in Fig. 9. The fault summary table is shown in Fig. 10.

Traffic Figures

The number of calls that originate in each exchange during a week are

GROUP 9

	BYDD		COMPLAINTS		C/1000			
Exchange	Orig.	Term.	Orig.	Term.	Orig.	Term.	Pat.	N.F.F.
Elwood	17	37	111	115	.57	.60	5	1
Dingley	1	1	19	16	.70	.59	0	0
Brighton	19	8	124	180	.26	.40	9	1
Cheltenham	29	10	127	149	.28	.33	6	2
St. Kilda	15	13	145	115	.27	.21	3	2
Highett	16	6	111	197	.25	.46	9	4
Gardenvale	6	5	75	100	.22	.30	5	3
Bentleigh	6	4	83	71	.25	.21	2	0
Sandringham	23	1	196	212	.40	.43	14	2
Beaumaris	2	1	33	62	.10	.20	3	1
Mordialloc	20	3	79	77	.25	.24	3	1
Group Totals			1103	1294	.29	.33	59	17

	BYDD	NP	WN	TC	CO	
Complaints Totals	1614	4274	5068	268	938	
	1214	5904	5418	316	1009	
Network Totals	10548	12647	.31	.37	674	211

Fig. 9.—A Portion of the Four-Weekly Summary Showing One Group and the Network Totals for Subscriber Reports.

stored in computer memory. These are used in computing the reports for each 1,000 calls for the exchanges. The number of calls for each group of exchanges and the number of calls for the whole network are also stored.

A new set of traffic figures is read-in and stored every six months to take changing traffic conditions into account.

Processing Time

The overall time required for the processing at the computing centre is subdivided into:—

(a) the time required to prepare the adjustment tape and the pattern tape for the computer;
(b) the computer time required;
(c) the listing of the paper tape output from the computer.

The listing of paper tape is carried out using a flexowriter. The flexowriter converts the punched paper tape to a paper copy. A mechanical reader on the flexowriter is used to read the tape. The flexowriter can also be used for punching paper tape. The flexowriters at the Research Laboratories punch and read tapes using a six channel code.

In the processing scheme it is desirable to keep the computer time at a minimum as this is by far the most expensive, although an excessive amount of time spent using the flexowriter or in the preparation of tapes is also undesirable.

The time used by the computer is further divided into the time taken during the input and output of paper tape. The input and output of tapes is of a mechanical nature and significantly contributes to the total time.

The break-up of time taken in the weekly processing scheme is:

(i) 2-hrs. tape preparation time
(ii) 45 mins. computer time. This consists of:
 (a) 35 mins. reading in of the input data
 (b) 10 mins. punching of the output tape
 (c) less than 1 minute computation
(iii) 80 mins. flexowriter time.

The time required by the 4-weekly program is of the order of 10 mins. This is divided into 4 mins. reading time and 6 mins. output time.

In both cases the computing time is short as the greater portion of computations is addition.

CONCLUSION

The conversion from manual to computer compilation of the statistics described in this article has not resulted in a substantial economic saving. The computer scheme, however, introduces some economies and two intangible advantages by improving on the accuracy of computations and the removal of one onerous component of the work of the analyser.

Further work is presently in progress that is concerned with the plotting and analysis of reports by computer. An attempt is being made to eliminate the onerous processes carried out at the Service Co-ordinating Centre by using computer processed results to aid the analyser. Some aspects of this work are described in References (4) and (5).

ACKNOWLEDGMENT

The author wishes to acknowledge the assistance provided in this project by the staff of the Service Co-ordinating Centre in Victoria. Of these the author is particularly grateful to Mr. M. D. Zilko, for many helpful discussions during the course of this work.

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FAULT ANALYSIS SUMMARY

	Junct. U/S	G/S	F/S	S.S.R. D.S.R.	L/F	Reptr	Dist Frame	Subs Flts	Misc
Dept. Off.	1	12	4	0	0	7	0	1	5
Mech.	0	54	66	4	0	0	0	0	1
Relay	0	16	66	2	0	6	0	0	1
Wiper Cord	0	5	2	2	0	0	0	0	0
Wiper	1	27	6	7	0	0	0	0	0
Bank	0	2	0	0	0	0	0	0	0
NS. S. Springs	0	26	23	0	0	0	0	0	0
Wiring Flts.	0	10	5	3	0	1	7	0	3
Misc.	1	21	8	1	0	7	10	2	13
Came Clear	0	17	4	2	0	1	0	0	0
N.F.F.	0	94	93	16	0	2	1	1	4

Fig. 10.—The Fault Analysis Summary Produced at the Conclusion of Each Weekly Period.

SERVICE CENTRE FOR TELEPHONE COMPLAINTS — BRISBANE

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

INTRODUCTION

The handling of subscribers' complaints has been receiving increased attention for some time, not only from the viewpoint of rendering a more efficient and courteous service to the public, but also because the information, if alertly analysed, is a valuable aid to clearing faults in the network. Swift handling of network faults is gratifying to the subscriber whose complaint is received with an amicable response and avoids irritation of the many other subscribers who experience the same fault but do not bother to complain. Reception of complaints must be regarded as one of the more critical "front window" activities of the Australian Post Office as in this situation the subscriber is most likely to be annoyed. Therefore it is imperative that the maximum of pleasantry and tactful interest be displayed by the operator. This is difficult to achieve unless the overall working atmosphere of the operators is comfortable, congenial, and interesting. Far too often one sees operators seated on high chairs, with arms bent at an uncomfortable angle in order to write on an inadequate keyshelf, and facing aspects of black keys and lampstrips in dark varnished upright cabinets. The design of the new Service Centre was intended to remove as many of these discomforts as possible.

An entirely fresh design approach was warranted; one which placed simplicity of operation above simplicity of equipment; which gave comfortable and relaxed seating; with colourful surroundings and an atmosphere of cordiality; and which was moderate in cost. This was the guide for the design presented in this article, which was for a centralised service centre for the northern sector of Brisbane.

This centre of 12 positions replaces four of the six centres at present in operation, and is trunked on the code 1100. Complaints are then dispatched as appropriate by teleprinter to the Complaints Analysis, Recording and Graphing Organisation (C.A.R.G.O.) centre and to all exchanges greater than 3,000 lines. For operational convenience it was located in the Main Trunk Exchange, but constructed as a quite individual and separate unit.

SUITE DESIGN

The basic profile of the main suite illustrated in Fig. 1 was resolved logically from functional requirements. The floor space available was in the Main Trunk Exchange. The restricted space, and the desire to eliminate the factory assembly line effect made a double sided suite design mandatory, which also ensured economical usage of a central conveyor belt.

From an ergonomic study by Peres (1) it was apparent that the most comfortable seat height for a girl is 17 in. In this position the elbows are a height of 28 in. above the floor, which was chosen for the bench height. A depth of 12 in. on the bench surface allows easy pivoting of the forearms without lifting them from the rounded edge. Incidentally, this would have to be extended by 1½ in. if the design were for male operators.

To be perpendicular to the line of vision the control panel was aligned at 40° to the horizontal. This was confirmed to be a comfortable angle at which to press buttons; but would probably not have been the best if keys were included. Extending the board above the operating panel for an information display brought the overall height to 38 in., which allows a clear outlook to the operators and effective observation by the supervisors. When a central section was allowed above the panels for the conveyor belt, and a trough below the panels for cabling, the pattern of a hexagon with wings emerged. This hexagonal motif was perpetuated in essence throughout the whole design, but not heavily featured in order to preserve an impression of functional elegance. Simplicity, of course, in all these utility designs, is necessary in order to avoid the visual ennui so often experienced with more traditional equipment.

The two remaining dimensions of 2 ft. 3 in. spacing between operators and 24 in. legroom were determined by experiment. All the dimensions agreed with the relevant British Standards. Suite legs were placed between every second operating position.

The finish is in colours and textures of feminine appeal. For this reason, timber and pseudo-timber laminate surfaces were considered unsuitable. Vinyl fabrics were selected and glued to the timber for all the facings. The desk top is of Olive Caribou-Elk Vynoid laid over foam calico for cushioning. Gull Grey, from the Vynoid Pacific range covers the turret top and kickplates, and the pockets in the turret top for the operators' accessories and the suite legs are relieved in Ocean Blue. Tapa Tan is used for minor featurings, and a similarly tinted coppertone paint finishes the metal fittings. The sandy surface texture of these Vynoids integrates the different coloured finishes, which is further assisted by upholstering the slim coppertoned typists' chairs with Gull Grey Vynoid.

A Lamson conveyor belt linking the service desks with the teletype suite consists of two channels in which the docket stands on end. This is a compact unit, with the unusual facility of turning the two channels at right angles, without transfers, within a total radius of nine inches. It discharges onto the centre of the teletype suite in front of the sorter, who is between two teletypists.

This suite was created in a form which is consistent in styling and colour with the main suite. The teletypes, resprayed coppertone with opaline green message plates to match the other control panels,

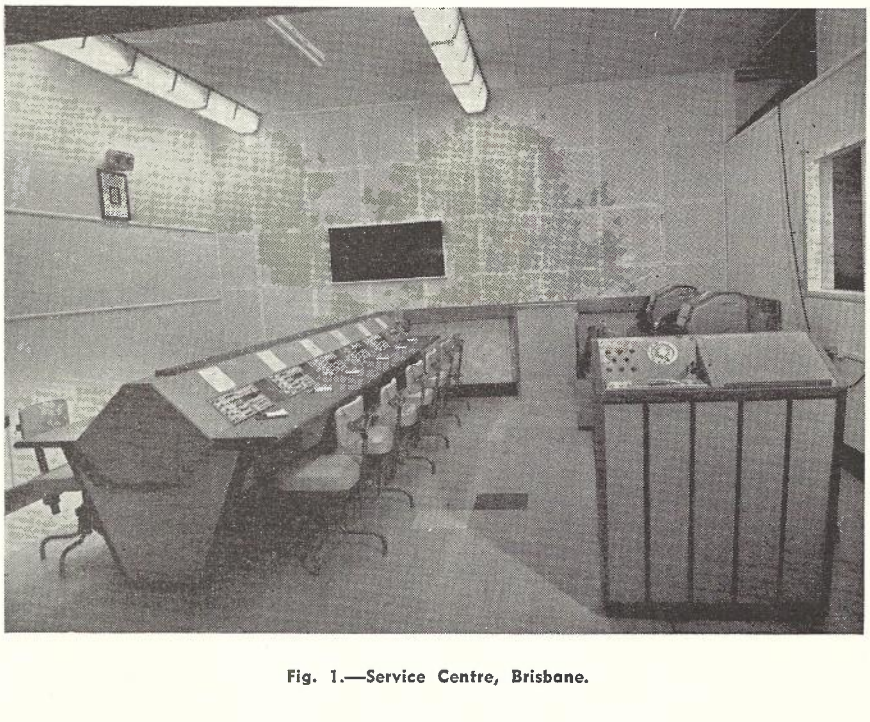

Fig. 1.—Service Centre, Brisbane.

* Mr. Torkington is Engineer Class I, Brisbane. See page 82.

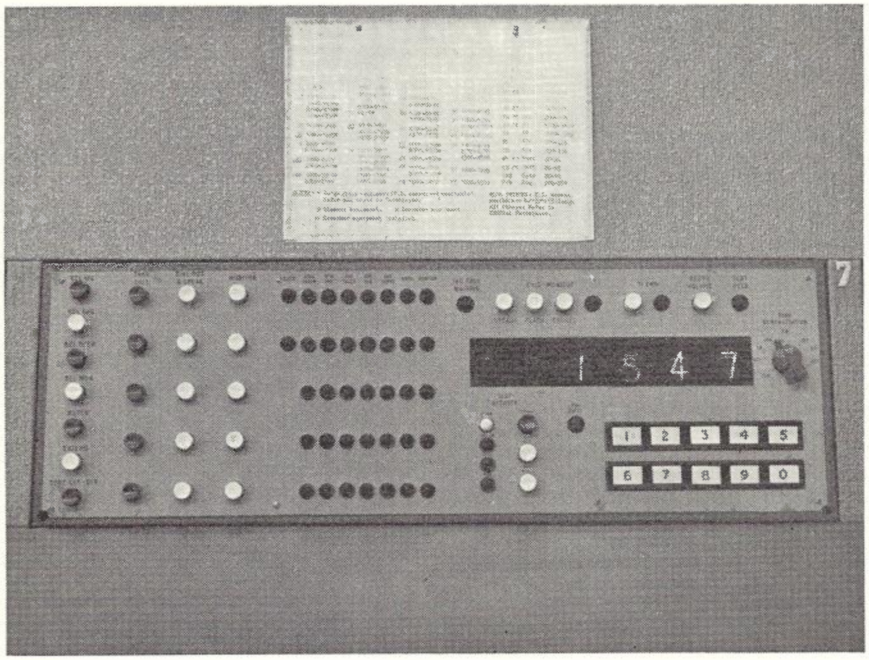

Fig. 2.—Control Panel on Service Desk.

are flanked by low turrets containing the controlling keys and dial. Ornamesh baskets are provided for holding the sent dockets.

To preserve space, a composite suite was designed for the overseer's desk and the monitor's post. As with the teletype table, the desk top is at the optimum height of 28 in. A variation on the hexagon motif relates the two functions, and blends with the whole scheme.

Accessories on the walls are a Movietex Notice Board for display of messages affecting fault clearance, an illuminated display panel, a call waiting meter, and a Cifra digital clock. The walls are painted in flat pastels of off white, lemon, and a relief of salmon.

FACILITIES

Operator's Position

The operator's pushbuttons are concentrated in a panel 20 in. by 6¾ in., illustrated in Fig. 2, which allows all operations except dropping the docket in the conveyor to be carried out without lifting the forearms off the desk.

The line circuits and associated operations are under her left hand, and to her right are the test network and dial. The lamps for the line circuits are in the centre, unobscured by the hands, and dissociated from the keys because they indicate the state of the call rather than the state of the keys. The time and number dialled display is above the right hand, and rarely used facilities are above this.

At the time of design, magnetically locking pushbutton keys were becoming available, and these were chosen for their apparent reliability, and lower operating force and cost than microswitch push-buttons. It was initially hoped that by having a key for each function in each line circuit, it might be possible to perform nearly all operations directly on the key springs. However, the limitation of 12 springs per key made this impractical, and a moderate complement of relays had to be associated with the line circuits.

Each operator has access to five line circuits, of which the top two are shared between four positions. The three pushbuttons on each line circuit are for taking an incoming call, taking an outgoing line, and for overlapping monitoring. All the buttons are in mutually releasing patterns, so that the release of one key is achieved by the operation of another. This eliminates the tedium of releasing keys, and the time operators lose between calls. In fact, unless the "Release Operator" key is depressed, the operator is always actively engaged in handling a call.

The "function" keys in a row to the left of the line circuit are associated with whichever line circuit has the "active" key depressed. The nett effect of the arrangement is that the operator's left hand rarely has to traverse an area greater than 3 in. by 4½ in.

Under her right hand are the three Test Network keys, for seizure and dialling, testing for D.A., and speaking. Lamp indication is given for busy, and receipt of a condenser kick on the 'Doesn't Answer' (D.A.) test. Close to this is the pushbutton dial, composed of "Rafi" keys. This dial stores only one digit, with overlapping, and was preferred to a full key sender because of cheapness and the necessity of listening between digits when handling complaints. Also both types can only send at standard decadic speed in a step by step network so no time is lost. Pushbutton dialling greatly reduces the room noise level and relieves a great source of fatigue in an operating position.

This grouping reduces the area traversed by the right hand on the panel to 7 in. by 2 in., and by positioning the docket holder on her desk the operator can write without moving her elbow. The holder is of ¼ in. steel with a clip and backed with stippled rubber to allow writing and tearing off with one hand.

The digital display comprises six digitrons mounted behind a circularly polarised light filter to obviate reflections. Normally the time in 24 hour digits is

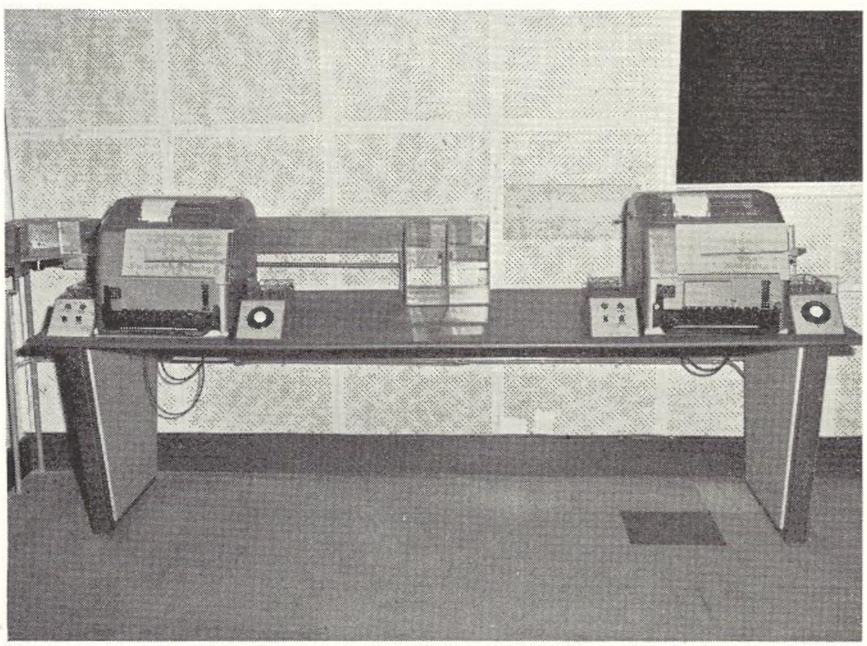

Fig. 3.—Teletype Suite.

displayed on the last four, but immediately the dial is used the time is erased and the dialled number appears. Operating another key resets the display to the time. This digital display of time should eliminate errors in recording, and eliminate the 4 or 5 seconds taken on each call for the operator to glance up at a clock and translate the hand positions into numbers.

The less important facilities above the digital display are buttons for calling the monitor with a steady or flashing lamp, an order wire to the test desk, an amplifier on the earpiece, and a tone demonstration switch for educating subscribers.

Teletype

Because of their low noise level, Teletype Model 15 machines, cushioned on foam plastic, were used at the central point. The switching controls are quite simple, being two keys, one to switch the machine on, the other to restore the selector. The dial controlling a 100 line selector is mounted on the right hand turret as in Fig. 3.

As with the test network, the numbering has been rationalised so that the operator dials simply the first two digits on the docket to send to the correct exchange. Receiving teleprinters are installed at all exchanges over 3,000 lines, and those which close down after hours have their answer back leg passed through a break contact on the extended alarms key. An automatic back-busying circuit on the selector multiple switches the line over to the nearest all-hours exchange for receipt of dockets.

Monitor's and Overseer's Positions

These are relatively simple, being key-switching for telephone lines, and a few ancillary keys. The wall display panel is directly in their line of sight. The overall view is shown in Fig. 4.

CIRCUITRY

In broad outline the circuitry is conventional. The incoming lines terminate in line relay sets, equipped with four stage gating. The gating control relay set is equipped with a transistor discharge circuit which will cause the "call waiting" lamps on the operator's panels to pulse if calls have been waiting for more than fifteen seconds.

Motor uniselector linefinders coupled to each panel appearance have full access to these lines, and bring the speech wires into the operator's panel. A repeating bridge and outgoing line are controlled from the operator's keys.

The dial uses one decade relay and four others. This is coupled into the counting chain of six decade relays with another for allotting in the digit display. The time is generated in 24 hour digits by counting 1 minute pulses from the speaking clock on four uniselectors. Changeover from time to dialled number is achieved with one changeover contact by switching between two anode power supplies, one rectifying on the first half cycle of transformed mains, the other on the second. The dialled number and time patterns are generated from oppositely phased but similarly polarised voltages, so the digitrons glow only on the selected half cycle.

Each position has a simple mutual key release circuit which permits only one speaking key and one monitoring key in a different line circuit to be locked at the same time. It also has interlocks to permit the shared line circuits to be used by only one operator at a time.

FUTURE DEVELOPMENTS

This design was conceived as an integrated unit for a specific purpose, not as a particular application of a general design. In extending the design to other applications most of the details could be preserved, but some modular construction would probably be advisable, not only in the suite to allow for easy extension, but also in the operators' panels to allow for ready alteration. The basic profile, being designed for operator comfort rather than the specific application, could well be duplicated.

However, in a large installation involving many suites, a basic cleanness of form and suppression of incidental featurings is mandatory if the appearance is not to grow wearisome. Unfortunately it usually appears that the simpler the form, the greater is the skill and care required for a satisfying result.

Nevertheless, it is not too soon for more enlightened thought and discussion to be stimulated on the aspect of working conditions of operators. Even if some of the new facilities, which seemed satisfactory in a single prototype position constructed earlier, are not entirely successful over a long term, at least they should show the way to better formats and facilities. Some new approaches may be engendered; one point which needs discussion is whether to provide cheap, comfortable, and colorful upholstering and covering materials which can easily be replaced in preference to the durable but uncomfortable facing laminates and timbers conventionally used.

The operational advantages of the magnetically locking pushbuttons should have been adequately demonstrated by now in Pentaconta equipment. The superiority of the pushbutton dial over the mechanical counterpart is quite apparent, and the low cost should warrant its installation for all operating positions. However, the material cost for the digital display, which can be regarded more as an accessory rather than a necessary accompaniment to the dial, is higher, but possibly it could be built for much less if a digitron with a wide separation between striking and sustaining voltages were available. The group could then be struck by transient voltages in a co-ordinate grid, requiring no associated memory.

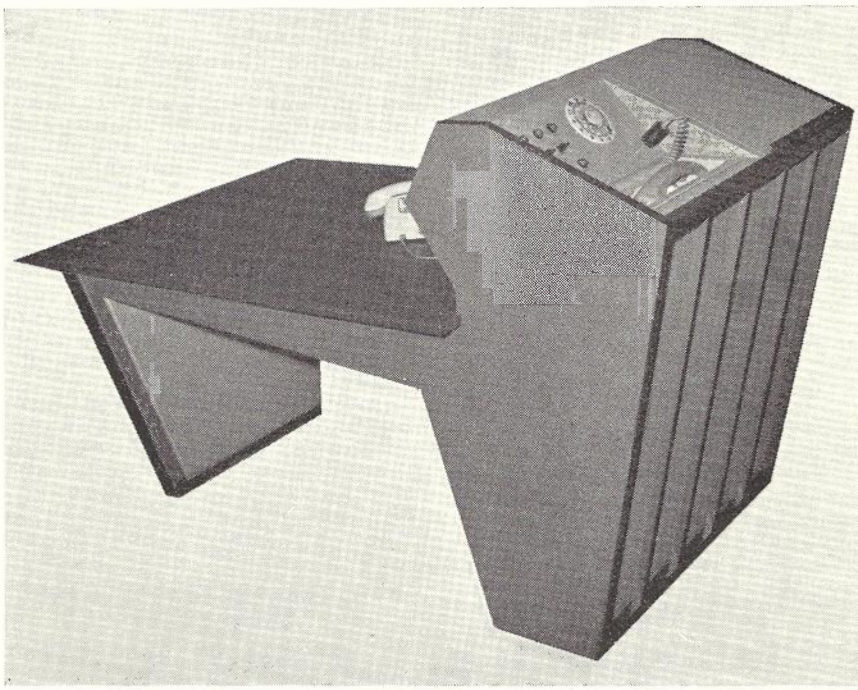

Fig. 4.—Monitors and Overseers Position.

Whatever the degree of success enjoyed by this installation as a whole in future years, it is hoped that those new features which are of value will be used and developed into better designs for other and wider applications.

ACKNOWLEDGMENT

I wish to acknowledge assistance received from colleagues in the Telecommunications and Engineering Divisions.

REFERENCE

1. N. J. C. Peres, "Human Engineering and the Factory"; Australian Factory, April, 1961, Vol. 15, No. 10, page 44.

CROSSBAR TRUNK EXCHANGES FOR THE AUSTRALIAN NETWORK — PART II

*L. M. WRIGHT, B.Sc., A.M.I.E.Aust.**

CHARGING REQUIREMENTS

Metering Rates

The introduction of Extended Local Service Area working in 1960 was accompanied by a very great degree of simplification of the trunk charging structure. There are now seven separate trunk metering rates with separate day and night scales of tariff, and provision must also be made for unit fee and for no charge calls. In principle there are nine possible metering conditions to be set therefore, but seven of these will result in differing charges during the day and the night rate periods. Multi-metering has been adopted and a meter pulse is given immediately the called subscriber answers. Subsequent meter pulses are applied at regular intervals r seconds apart with the first occurring at a time t seconds after the answer signal where $r \leq t < 2r$

The actual metering periodicity for the seven trunk rates is as follows:—

Day	Night
45	60
30	45
15	20
10	15
6	9
5	6
4	5

Number Analysis for Charging

The number analysis required to determine the charge rate sometimes involves analysis down to the E digit (the Australian national number is usually designated OABCDEFGH in general discussion) so that up to 6 digit analysis may be necessary. The charge analysis equipment is required to determine the charge rate applying from any exchange in its service area to any other place in Australia. Since calls to places more than 400 miles away, however, are all charged at the maximum rate, this is not quite so severe a requirement as it may appear at first sight. Within its own charge district and to exchanges in adjacent charge districts the charges must be computed on a zone to zone basis. Beyond these immediately adjacent charge districts, the call charges are computed on a charge district to charge district basis. In practice the former requirement is the one which results in more complication of the equipment. More detail on the charging rules is given in Reference (7). (See Part 1.)

Access Barring

In general any action required to bar subscribers or public telephones from access to the trunk network will be carried out as required at the local exchanges rather than at the trunk exchange. The Department's policy is that subscribers should be encouraged to use the trunk dialling service and only in special cases is access to the trunk network barred. Where the ARM exchange is used as a control centre for dependent ARK exchanges, class of service information is forwarded from the ARK to the ARM which must then take action to bar calls as required.

Originating Charge Zone Identification

The ARM exchange will normally determine trunk charges for exchanges in many charge zones. The charge analysis equipment must know the charge zone to which the originating exchange belongs so that it may correctly compute the metering rate, and this information can generally be supplied by D.C. marking techniques from the incoming relay set via the register to the charge analysis equipment which is associated with the marker. In some cases however calls will be forwarded via ARF minor switching centres or tandem exchanges which will not necessarily be in the same zone as the originating exchange. For this reason provision has also been made for the originating zone to be identified by means of a MFC signal given in answer to an interrogation from the ARM.

Provision is being made for the charge analysis equipment to cater for 12 originating charge zones normally, with easy extension to 24 zones when required. There are a few areas in Australia where the ARM will serve more than 24 originating zones, and these will be treated as special cases when they arise.

TRAFFIC CHARACTERISTICS

Traffic Loading

In calculating the traffic handling capability required in the ARM exchange the normal loading of trunk circuits has been taken as approximately 0.7E per bothway circuit, 0.6E per uni-directional circuit and allowance has been made for 50 per cent of the circuits connected to an exchange to be bothway circuits. The average holding time used in the computations was 2 minutes per call attempt.

Congestion

In Speech Trunking: With normal traffic loading the ARM 20 exchange has been specified to have a grade of service such that the probability of being unable to establish a connection from an arbitrary inlet to an outlet on any desired route should not exceed 0.002 when there is a free circuit available. If the traffic offering is 25 per cent higher than the normal loading given above then the corresponding probability should not be degraded further than to 0.02.

In the ARM 50 exchange, similar performance is required but in this case it is obtained mainly by the correct allocation of circuits and in some cases by multiple appearance of outgoing circuits. To ensure reasonable access to individual routes the overall probability of being unable to establish a connection between an arbitrary inlet and a specific arbitrary outlet should not exceed 0.25 normally, and this should not rise to higher than 0.4 if the traffic is 25 per cent above the normal traffic specified.

In Common Equipment Access: The normal grade of service of access to registers and other common equipment is required to be better than 0.002 for normal traffic loading, and better than 0.01 when there is a 25 per cent. rise above the normal loading specified above.

Switching Time Delay

Because of the use of common equipment there is a probability of switching delay over and above the minimum time required to effect switching. The probability of a delay of one second beyond this minimum switching time should not be greater than 5 per cent for normal traffic. Under overload conditions this delay probability rises fairly rapidly and for the 25 per cent overload conditions specified the probability of a delay of two seconds beyond the minimum switching time should not be greater than 10 per cent. The Department has foreshadowed that it intends to specify in future that the normal one second delay probability should not exceed 1 per cent, particularly on transit switching applications.

REGISTERS, LINE RELAY SETS, SPECIAL FACILITIES AND OTHER ASPECTS

Several different types of register are required and they fall broadly into three categories concerned with calls coming from the service area of the ARM, from the trunk network generally, and special registers for incoming and outgoing international calls.

The detailed operation of these registers and particularly the way in which they are either retained or released at particular stages of the connection, their special operation in the case of echo suppressor switching and the handling of international calls will be covered in a subsequent article which will outline in detail the flow of signals through the whole of the local and trunk system on typical calls.

Registers used on Calls from the Local Area

Register H: Reg. H accepts information from the local network, and in cooperation with the other ARM control equipment is involved in the switching of the call through the ARM exchange and also in the determination of the call charge, this latter function requiring that it know the charge zone of the originating exchange.

Reg. H1 accepts MFC information signals on its input side and Reg. H2 accepts decadic signals. MFC or decadic

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signals are used as required on the outgoing side of both registers. They have a nine digit storage capacity and cyclic operation, the latter facility being necessary to cope later with international subscriber dialling.

Register E: Reg. E is the control register for a dependent ARK exchange. It accepts decadic impulses from the ARK exchange as dialled by the subscriber, and when necessary uses MFC to revert information to the dependent exchange to set up the switching equipment for a local call or a directly switched call. MFC is also used for the transfer of class of service information to the Reg. E. Because Reg. E. is very similar to Reg H2 in many respects it has been decided to combine these two registers and the composite register has the title Reg. EH2.

Registers Used on Calls from the Trunk Network

Register Y: Reg. Y receives information from the trunk network and is not involved in charge determination. There are two versions of Reg. Y, Reg. Y1 accepting MFC information and Reg. Y2 decadic information. In practice it is not expected that there will be very much application for Reg. Y2. These registers also have cyclic storage and on the output side operate either in MFC or decadic signalling Because there are marked similarities between Reg. H1 and Reg. Y1 and also between Reg. EH2 and Reg. Y2 the combination of the facilities necessary in these registers into single register designs is currently being investigated, but this has not yet been resolved.

Registers Used on International Calls Only

Register F(Y): This register will be used on calls incoming from the international system. It will receive on its incoming side signals in C.C.I.T.T. No. 5 Signalling System, and on the outgoing side it will operate in the same way as Reg. H or Reg. Y.

Register F: This register will be used on calls outgoing to the international system and may be involved in charge determination on such calls. There is no immediate intention to set up international calls on a subscriber dialled basis and there are some fairly severe problems to be solved in international accounting. Reg. F will accept MFC on its incoming side from the national system, and will operate on its outgoing side in the C.C.I.T.T. No. 5 Signalling System.

Line Relay Sets

The line relay sets are related mainly to the line signalling system to be employed and also to the direction of working of the circuit. There are therefore incoming relay sets (FIRs), outgoing relay sets (FURs) and bothway relay sets (FDRs) and there are many variants to cater for the many different line signalling conditions. In the case of D.C. circuits there are also variants necessary to cover normal application up to 2,000 ohms loop resistance, and a more expensive version covering the range from 2,000-3,7000 ohms. In some cases the type of register which will be associated with the line relay set makes further variation necessary, and the inclusion of hybrids and level adjusting pads, etc., adds to the complication. In listing all possible combinations, it is obvious that some rationalisation is necessary, and only the relay sets actually required will be designed. An effort is being made to restrict the number of types designed and to have the maximum amount of composite design by using strappings to

TYPE OF RELAY SET	TYPE OF DISTANT EXCHANGE				TYPE OF INFORMATION SIGNALLING		TYPE OF LINES NOTE 1				TYPE OF LINE SIGNALLING				TYPE OF REGISTER				HYBRIDS	TYPE OF PAD			
	ARM	ARF	ARK	S-X-S AND RAX	MFC.	DP	2W 0 TO 3700Ω	4W 0 TO 3700Ω	STANDARD CARRIER	RURAL CARRIER	L.D.	L.D. OVER PHANTOM	L.M.E. PULSE	AUST. RURAL CARRIER SIGNALLING	REG H1	REG EH2	REG Y1	REG Y2		FIXED PAD 0-3db NOTE 2	8 db NOTE 3	GO PATH 30-55db NOTE 4	RETURN PATH 0-2.5db NOTE 4
FIR - ZL1 - H1		X			X		X				X				X				X	X			
FIR - ZL2 - H1		X			X			X				X			X						X		
FIR - ZT - H1		X			X				X				X		X						X	X	X
FDR - ZL1 - H1		X			X		X				X				X				X	X			
FDR - ZL2 - H1		X			X			X				X			X						X		
FDR - ZT - H1		X			X				X				X		X						X	X	X
FDR - ZT1 - H1		X			X					X				X	X						X	X	X
FIR - ZL1 - H2				X		X	X				X					X			X	X			
FIR - ZL2 - H2				X		X		X				X				X					X		
FIR - ZT - H2				X		X			X				X			X					X	X	X
FDR - ZL1 - H2				X		X	X				X					X			X	X			
FDR - ZL2 - H2				X		X		X				X				X					X		
FDR - ZT - H2				X		X			X				X			X					X	X	X
FDR - ZT1 - H2				X		X				X				X		X					X	X	X
FIR - ZL1 - E			X		X	X	X				X					X			X	X			
FIR - ZL2 - E			X		X	X		X				X				X					X		
FIR - ZT - E			X		X	X			X				X			X					X	X	X
FDR - ZL1 - E			X		X	X	X				X					X			X	X			
FDR - ZL2 - E			X		X	X		X				X				X					X		
FDR - ZT - E			X		X	X			X				X			X					X	X	X
FDR - ZT1 - E			X		X	X				X				X		X					X	X	X
FIR - L2 - Y1	X	X	X		X			X				X					X				X		
FIR - T - Y1	X	X	X		X				X				X				X				X	X	X
FDR - L2 - Y1	X	X	X		X			X				X					X				X		
FDR - T - Y1	X	X	X		X				X				X				X				X	X	X
FIR - L2 - Y2				X		X		X				X						X			X		
FIR - T - Y2				X		X			X				X					X			X	X	X
FDR - L2 - Y2				X		X		X				X						X			X		
FDR - T - Y2				X		X			X				X					X			X	X	X
FUR - L1 - H		X		X	X	X	X				X								X	X			
FUR - L2 - H	X	X	X	X	X	X		X				X									X		
FUR - T - EHY	X	X	X	X	X	X			X				X								X	X	X
FUR - L1 - E		X	X		X	X	X				X								X	X			
FUR - L2 - EY	X		X		X	X		X				X									X		
FDR - L1 - H2 (ML)	MANUAL LOOP OUT FROM ARM					X	X			X						X			X	X			
FDR - L1 - H2 (MR)	MANUAL RING OUT FROM ARM					X	X			X						X			X	X			

NOTES:—

1. The 3700 ohm. resistance limit quoted is a nominal figure only. The actual resistance will be determined by interworking relay set at distant end.
2. The 0-3 db fixed pads are to be located on the 4W side of the hybrid one in the "Go" and one in the "Return" path and are adjustable in steps of 0.5 db from 0-3 db.
3. The db pads are to be inserted in both the "Go" and "Return" paths.
4. The values of the "Go" and "Return" path pads shown are the normal values. They may be varied from 0-7.5 db in 0.5 db steps in the "Go" path and from 0-3.5 db in 0.5 db steps in the "Return" path. This covers the values required for some non standard systems.
5. Charging facilities to be included in all relay sets with "Z" appearing in the type column.
6. FIR-H2 type relay sets may be used in lieu of the equivalent FIR-Y2 types (but not vice versa).

Fig. 4.—ARM Exchange Junction and Trunk Line Relay sets.

allow one particular relay set design to meet several needs. Lists of the relay sets so far evolved and the facilities provided by each are included in Appendix III and Fig. 4.

Because of the large number of relay set types it has become necessary to have a systematic designation which conveys as much as possible about the application of each particular relay set. For convenience the Swedish designations and abbreviations have been retained and these are rapidly becoming well understood in Australia. The designation is generally made up of three parts, the first part indicating whether the relay set is used on an incoming, outgoing or bothway circuit, the second part indicating the type of line signalling for which it is designed, and the third part indicating either the register with which it will be associated or its broad purpose, e.g., the FUR is not associated with a register and it is normally designated to show whether it is intended to work with the trunk or local network.

Special Facilities

Testing Facilities and Test Access: Sufficient test equipment to allow effective functional testing and the checking of any critical conditions during installation and subsequently in service has been ordered. Provision is also being made for automatic access to trunk circuits for testing purposes as distinct from manual jack access for checking of particular items of equipment. In particular a testing officer should be able to check quickly over a group of circuits when he has received a report specifying trouble on a particular route but has no information concerning the particular circuit on which the trouble is occurring.

The test equipment supplied will include such items as:—

(i) General exchange tester.
(ii) Tariff tester.
(iii) Function check lamp panels.
(iv) Test route relay sets.
(v) Statistic recorders.
(vi) Concentration toward a remote maintenance control room.

Observation: Provision is being made for observation on the trunk lines, but it is anticipated that most of the service sampling will be carried out at the originating exchanges except in country areas.

Traffic Recording: Provision is being made for the use of A.P.O. type traffic recorders. These are of the analogue pattern in which 100,000 ohm resistors are used and there is a current increment at the recording point for each line or device taken into use. Provision is also being made for call dispersion equipment of A.P.O. design to be operated in conjunction with the ARM exchange to record the following information:—

(i) The dialled number up to the F digit.
(ii) The identity of the originating exchange.
(iii) The identity of the outgoing route.
(iv) The time of establishment of each call.

Fault Recording: Centralograph fault recording equipment has been ordered for all of the initial ARM 20 exchanges.

Traffic Route Programming: It is foreseen that there will be occasions when failures of all circuits on particular routes will occur, or possibly some circuits only on particular routes will fail. There will be occasions also when unusual traffic demand patterns will arise and these can be quite embarrassing to the operating administration. The alternate routing patterns required are "stored" in the marker by means of a

APPENDIX III

Relay Sets Interworking with Intercontinental Exchange

Relay Set	Interworks with Reg-	Line Signalling
FIR-F(Y)	F(Y)	C.C.I.T.T. No. 5
FUR-F	F	C.C.I.T.T. No. 5

Relay Sets Interworking with Exchanges for which Charge Determination not Required.

Line Signalling	Distant Exchange Type and Information Signalling			
	ARM. MFCT	ARF. MFCM OR MFCP	ARK. MFCK & DP	S x S. DP
L.M.E. pulse -T-	FIR-T-Y1 FDR-T-Y1 FUR-T-Y	FIR-T-Y1 FDR-T-Y1 FUR-T-H	FIR-T-Y1 FDR-T-Y1 FUR-T-E	FIR-T-Y2 FDR-T-Y2 FUR-T-H
Australian rural carrier -T1-		FIR-T1-Y1 FDR-T1-Y1 FUR-T1-H	FIR-T1-Y1 FDR-T1-Y1 FUR-T1-E	FIR-T1-Y2 FDR-T1-Y2 FUR-T1-H
Loop disconnect 2w * 0-2000 ohms -L1-		FIR-L1-Y1 FDR-L1-Y1 FUR-L1-H	FIR-L1-Y1 FDR-L1-Y1 FUR-L1-E	FIR-L1-Y2 FDR-LI-Y2 FUR-L1-H
Loop disconnect 2w * 2000-3700 ohms -L1A-		FIR-L1A-Y1 FDR-L1A-Y1 FUR-L1A-H	FIR-L1A-Y1 FDR-L1A-Y1 FUR-L1A-E	FIR-L1A-Y2 FDR-L1A-Y2 FUR-L1A-H
Loop disconnect 4w phantom * 0-2000 ohms -L2-	FIR-L2-Y1 FDR-L2-Y1 FUR-L2-Y	FIR-L2-Y1 FDR-L2-Y1 FUR-L2-H	FIR-L2-Y1 FDR-L2-Y1 FUR-L2-E	FIR-L2-Y2 FDR-L2-Y2 FUR-L2-H
Loop disconnect 4w phantom * 2000-3700 ohms -L2A-	FIR-L2A-Y1 FDR-L2A-Y1 FUR-L2A-Y	FIR-L2A-Y1 FDR-L2A-Y1 FUR-L2A-H	FIR-L2A-Y1 FDR-L2A-Y1 FUR-L2A-E	FIR-L2A-Y2 FDR-L2A-Y1 FUR-L2A-H

* The 2000 ohms quoted is nominal only, particularly in relation to S X S equipment the characteristics of which may necessitate a much lower limit.

Relay Sets Interworking with Exchanges for which Charge Determination is Required.

Line Signalling	Distant Exchange Type and Information Signalling		
	ARF. MFCM OR MFCP	ARK. MFCK & DP	S x S. DP
L.M.E. pulse -ZT- -T-	FIR-ZT-H1 FDR-ZT-H1 FUR-T-H	FIR-ZT-E FDR-ZT-E FUR-T-E	FIR-ZT-H2 FDR-ZT-H2 FUR-T-H
Australian Rural Carrier -ZT1- -T1-	FIR-ZT1-H1 FDR-ZT1-H1 FUR-T1-H	FIR-ZT1-E FDR-ZT1-E FUR-T1-E	FIR-ZT1-H2 FDR-ZT1-H2 FUR-T1-H
Loop disconnect 2w -ZL1- * 0-2000 ohms -L1-	FIR-ZL1-H1 FDR-ZL1-H1 FUR-L1-H	FIR-ZL1-E FDR-ZL1-E FUR-L1-E	FIR-ZL1-H2 FDR-ZL1-H2 FUR-L1-H
Loop disconnect 2w -ZL1A- * 2000-3700 ohms -L1A-	FIR-ZL1A-H1 FDR-ZL1A-H1 FUR-L1A-H	FIR-ZL1A-E FDR-ZL1A-E FUR-L1A-E	FIR-ZL1A-H2 FDR-ZL1A-H2 FUR-L1A-H
Loop disconnect 4w phantom -ZL2- * 0-2000 ohms -L2-	FIR-ZL2-H1 FDR-ZL2-H1 FUR-L2-H	FIR-ZL2-E FDR-ZL2-E FUR-L2-E	FIR-ZL2-H2 FDR-ZL2-H2 FUR-L2-H
Loop disconnect 4w phantom -ZL2A- * 2000-3700 ohms -L2A-	FIR-ZL2A-H1 FDR-ZL2A-H1 FUR-L2A-H	FIR-ZL2A-E FDR-ZL2A-E FUR-L2A-E	FIR-ZL2A-H2 FDR-ZL2A-H2 FUR-L2A-H

* The 2000 ohms quoted is nominal only, particularly in relation to S X S equipment the characteristics of which may necessitate a much lower limit.

strapping field. These straps will be accessible so that routing patterns may be varied under direction when either breakdowns or unusual traffic patterns arise. It is envisaged that before long it will be necessary to have a central control exercising constant supervision over the whole of the Australian trunk network. Congestion on routes or congestion in markers would be displayed at this centre and if it considered that action is necessary it would direct cancellation of alternate routing or possibly complete changes of the routing pattern to meet the unforeseen requirements. In the future this would probably be further refined to enable the control centre to automatically reset these conditions, and perhaps in the even more remote future the traffic conditions may be monitored and the routing pattern changed automatically to give the best use of the plant available.

Other Aspects: Some of the other factors which have been given consideration and have been covered in the detailed specification are:—

(a) Voltage limits;
(b) Ambient temperature;
(c) Interconnection with the semi-automatic network;
(d) Interconnection with manual assistance centres;
(e) MFC sending and receiving levels and frequency tolerances;
(g) DC limits when interworking with step-by-step equipment.

CONCLUSION

The foregoing has been mainly a review of the factors taken into account in the specification and design of the ARM crossbar trunk exchange. A subsequent article will describe the way in which calls will be set up through an ARM exchange and through the other parts of the network. The times during which registers are in use, the detailed treatment of the echo suppressor switching, the way in which it is proposed that international calls would be handled, and the way in which the originating charge zone will be identified, etc., will also be covered, and descriptions in diagrammatic form of the information signals involved in the setting up of various classes of call will be included.

Deliveries of this equipment have already commenced, and it is anticipated that the first of the Australian ARM exchanges will be in service in Sydney by December 1965.

ACKNOWLEDGMENT

The author would like to acknowledge that very many people within the Australian Post Office and the L M Ericsson Telephone Company have been involved in the formulation of the fundamental philosophy and the detail which underlies a project of this nature, and that much of the early discussion took place before he joined the Headquarters Administration.

BOOK REVIEW

PRINCIPLES OF TELEGRAPHY

N. N. Biswas, 1964. Asia Publishing House, pp. 187.

The book is available from the Asia Publishing House, Calicut Street, Ballard Estate, Bombay 1, at a cost of 30/- (sterling). The book may be obtained through Australian booksellers but the price is indefinite, possibly about 37/6 (Australian).

Chapter headings: Telegraph Codes—Telegraph Instruments and Relays—Telegraph circuits—Teleprinter and Telex—Facsimile and Picture Telegraphy—Submarine Cable Telegraphy — Voice Frequency Telegraphy — Appendices —Answers to Numerical Problems — Name Index — Subject Index.

The author has written this book primarily for use during a B.E. degree course in Telecommunication and Electrical Engineering of a University. Principles rather than specific practices are emphasized and it can be said that the author probably achieves his aim, the standard required for particular B.E. courses being the deciding factor. The book would no doubt be a valuable text for engineers engaged on telegraph engineering work in an administration such as the Australian Post Office.

Apart from a few of the very early pages the printing and diagrammatic representation in the book are quite satisfactory. A few of the early pages are difficult to read because impressions from the reverse page show through. In some places the English expression is incorrect but it is not difficult to assess the meaning intended by the author.

At the end of each chapter there are references and problems. The references are quite useful and refer to known and well-circulated technical journals. The problems are quite extensive and are answered at the back of the book.

The chapter on Telegraph Codes includes description of the Morse, Cable, five-unit and Hellschreiber (called Hellscriber) and compares the transmission capability of each in words per minute for a given signalling speed in bauds. It is surprising that there is no specific mention of redundancy in this comparison and it is a pity that no mention is made of information theory.

The chapters on Telegraph Instruments and Relays and Telegraph Circuits include material describing some of the components and circuits used in manual telegraphy.

The chapter devoted to Teleprinter and Telex is the largest in the book and occupies 49 pages. A description of synchronous machine telegraphy and its attendant problems are included. The pages describing the principles of start-stop machine mechanism are excellent and include accounts of the methods employed in many modern machines. Considerations of Telex, including networks, numbering schemes and subscribers' terminal equipment are discussed generally; signalling diagrams for local and trunk calls are given but no mention is made of the release of a connection and the associated guard arrangements required. No mention is made of the possibility of using keyboard transmission to generate the signals required for the selection of the required subscriber.

The chapter discussing Facsimile and Picture Telegraphy includes excellent descriptions of equipment in this field, including "flat-bed" transmitters.

The chapters for Submarine Cable Telegraphy and Voice Frequency Telegraphy cover their subject satisfactorily.

As far as Australian readers are concerned, this book is a useful text for anyone interested in the engineering principles employed in telegraphic communication. It would be a particularly handy reference for engineers engaged on telegraph work.

N.R.C

THE L M ERICSSON ROBOT TEST DESK

*R. M. TAYLOR, B.E.**

INTRODUCTION

A major proportion of fault location work in any telephone network involves individual subscribers' services. The investigation of many of these faults involves sending a technician into the field; he contacts the exchange from the subscriber's telephone and has tests applied from the exchange to the subscriber's line and equipment. These tests are applied from the exchange test desk, which is manually operated by an exchange technician.

The trained area technician has a necessary function, being able to intelligently assess the performance of the subscriber's equipment and line, and to either replace subscribers' equipment or make simple on-the-spot repairs. On the other hand the technician at the exchange test desk performs a task that is at times arduous and often thankless. In the field are area maintenance technicians, fault linemen and substation installation staff, all requiring the services of the test desk. This large potential for test desk usage often results in peak demands being created with which the test desk staff cannot cope. Consequently the field staff are faced with frustrating delays on test desk calls. Now in many cases, the desk technician only performs a "slave" function; applying tests requested from the field and then passing on the results. One can readily envisage such tests being applied by automatic equipment, enabling the test desk technician to devote his time to work appropriate to his training and experience. Such automatic equipment would act as a "robot test desk".

The provision of automatic testing devices is a natural extension of automatic telephone switching. Over the years various devices have been evolved, some of which are commonly used in Australian Post Office exchanges, such as "transmission test", junction test", "ring back" and "permanent reversal test". However, all these automatic test devices that have hitherto been designed, are limited in having a single function. The testing technician simply dials an access code and the tester, upon being seized, automatically applies a prescribed test. The device described in this article, the L M Ericsson robot test desk (APR), differs from automatic testers previously used by the A.P.O. in that the tester is under the control of the testing technician. Having gained access to the robot test desk, the technician may then, by dialling further digits, select (in any order) any of the range of tests available.

The above system could provide a complete automatic test desk in the form of one set of equipment having one access code. The equipment described in this article is only a first step to this goal and does not fulfil the complete list of requirements for an automatic test desk. However, it does provide a range of useful tests.

AUSTRALIAN POST OFFICE REQUIREMENTS

The requirements for an automatic test desk are governed by the technical standards laid down by the particular telephone administration, which are in turn based on the operating requirements of the various types of exchange and substation equipment when working in conjunction. The A.P.O. has a large quantity of various types of step-by-step equipment in situ, whilst recent installations have been of L M Ericsson crossbar equipment, which now forms an appreciable component of A.P.O. telephone networks. The requirements for services working into step-by-step equipment are generally more stringent than for those working into crossbar equipment. The A.P.O. has decided to provide robot test desks wherever they appear economically justified and there are no technical difficulties. At present this includes all crossbar and step-by-step exchanges over 1,000 lines, except where the testing path is blocked to direct current by a transmission bridge, e.g., exchanges containing D.S.R. switches which do not eliminate the repeating element on local switching.

The original robot test desk was designed by L M Ericsson of Sweden to suit their standards for subscribers' services connected to crossbar exchanges. These standards differ from those at present applied in A.P.O. exchange areas. In particular the A.P.O. insulation resistance standards are much higher and an additional loop resistance test must be applied to lines connected to 400 series telephones to ensure that the resistance is not too low (under 200 ohms), resulting in transmitter burning.

To meet the A.P.O. standards, modifications to the L M Ericsson equipment were designed by Mr. A. D. Pettersson, Divisional Engineer, Toowoomba, Queensland. The modified equipment was installed in the Toowoomba crossbar exchange and has been in use for some time. Furthermore, to ensure that the equipment was also suitable for use in step-by-step exchanges, a second modified robot test desk was installed in York exchange, Sydney, N.S.W. This installation was carried out under the control of the author, who then subjected the equipment to detailed tests. The robot test desk was made available to the York area maintenance staff for field tests in January 1964.

FUNCTIONS AND USE OF THE ROBOT TEST DESK

General

The robot test desk automatically performs a range of tests on a subscriber's line and equipment. The choice of tests is under the control of the technician or lineman working in the field, who selects the tests by dialling various digits. The robot is a GO-NO GO device, classifying the various test results into discrete ranges. The result of each test is indicated by a result tone, transmitted from the robot test desk to the technician. Table I shows the tests and a typical arrangement of result tones.

Table I is only typical. The ultimate scheme of tones will depend on later equipment designs produced by L M Ericsson for A.P.O. use and on the tones available in each exchange.

The use of a GO — NO GO device provides only limited information concerning the nature of faults on subscriber's services, but usually this is sufficient, and often all that is desirable. Faulty services are tested from the manual test desk before sending a technician into the field. The detailed information from this test is usually sufficient and GO — NO GO tests are then used to trace the fault.

TABLE I: TYPICAL TESTS AND RESULT TONES

Test	Test Code Digit	Handset	Result Tones		
			Dial	Ring	C.N.
Dial speed (10 i.p.s.)	10	Off	Slow	8.5-12.5	Fast
Dial speed (20 i.p.s.)	20	Off	Slow	15.5-21.5	Fast
Ring test, full voltage	3	Restore	Assess by listening		
Ring test, half voltage	4	Restore			
I.R. +ve wire	5	Restore	Below 0.5 meg	0.5-1 meg	Above 1 meg.
I.R. —ve wire	6	Restore	Ditto	Ditto	Ditto
I.R. between	7	Restore	Ditto	Ditto	Ditto
Loop resistance *	8	Off	Below 200 ohms	200-1200 ohms	Over 1,200 ohms
Robot check	9	Off	900	c/s	

* For line loop short circuit terminals within 5 secs and remove short after 5 secs.

* Mr. Taylor is Engineer Class I, Metropolitan Equipment Installation, N.S.W. See page 82.

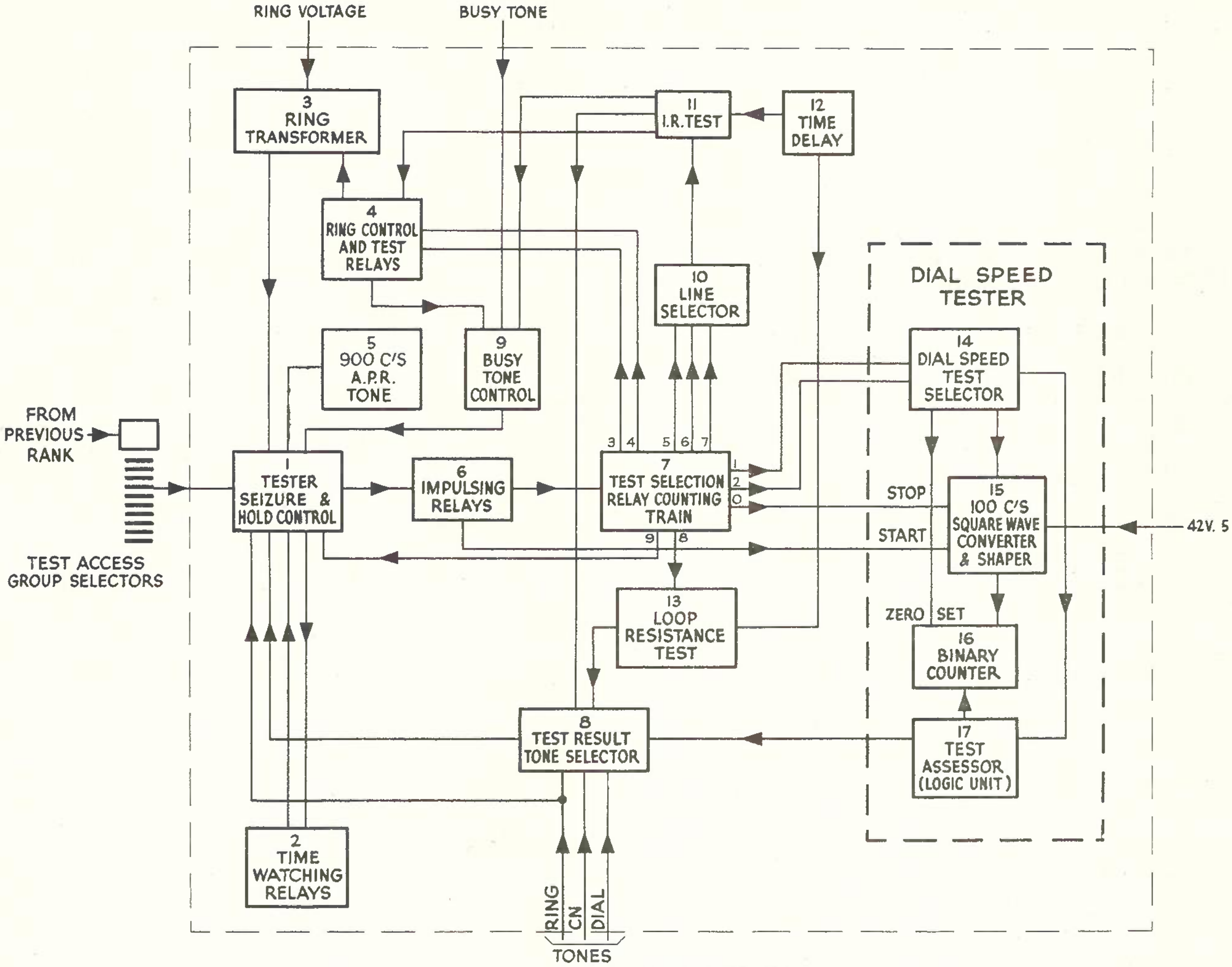


Fig. 1.—Block Diagram of Robot Test Desk.

The location of line faults sometimes requires precise measurements to be made. However, in subscribers' reticulation networks the line plant is often of mixed construction and route distances are difficult to estimate because of changes in route direction. This results in precise measurements from the exchange being of little value, much more useful information being obtained from measurements made with portable instruments in the vicinity of the fault. Most line fault location tests only involve distinguishing between "subscriber's side" and "line side", for which GO — NO GO tests are ideal.

Before being able to perform any tests it is necessary to gain access to the robot test desk. In ARF 101 and ARF 102 system crossbar exchanges the robot is connected to the REG-L's via the I.D.F. In step-by-step exchanges an outlet from a rank of group selectors is used, usually off one of the levels assigned to the various test facilities such as test desk, ring back, permanent reversal test, etc. It is possible to trunk the one robot from both crossbar and step-by-step equipment.

The technician dials the access code. On being seized the robot returns ring tone and the technician then replaces the receiver. On detecting the removal of the loop the robot connects ring voltage to the line. The technician again removes the receiver and the re-application of the loop operates the ring trip relay. The robot now emits a special 900 c/s oscillator tone, known as "APR tone". This indicates to the technician that he is connected to the robot and may select the required tests by dialling the appropriate digits. The tests may be selected in any order, simply dialling the next test upon finishing the previous one.

Certain tests require the telephone receiver to be restored. When these tests are selected the robot emits busy tone, indicating to the technician that he should replace the receiver.

Tests

Dial Speed: The technician dials code digit 1 for a test on a nominal speed 10 i.p.s. dial and code digit 2 for a nominal speed 20 i.p.s. dial. He then dials code digit 0, which is the test impulse train. After the finish of the test train the robot sends back result tones indicating whether the dial speed is fast, slow or within acceptable limits.

Speed 20 i.p.s. dials are not at present used by the A.P.O., but the test facility has been provided by L M Ericsson since it is possible to use such dials on services connected to crossbar exchanges where the registers employ reed relays (e.g. ARF 102 exchanges).

Bell: The technician dials code digit 3 for a test at full ring voltage and code digit 4 for a test at half ring voltage. The robot emits busy tone and, upon the receiver being replaced, connects ring voltage to the line. The technician then assesses the performance of the bell by listening.

Insulation Resistance: The technician dials code digit 5, 6 or 7 according to the line connection on which he wishes to make the insulation resistance test. The robot sends back busy tone and the technician replaces the receiver. There is a delay of approximately 5 secs. before the test commences, which allows time for the capacitance of the subscriber's line and equipment to charge fully. When the test has been completed, the robot connects ring voltage to the line. The technician removes the receiver and then hears a result tone indicating whether the insulation resistance is below 0.5 megohm (unacceptable), between 0.5 and 1.0 megohm (acceptable for existing services only), or over 1.0 megohm (acceptable for new and existing services).

Loop Resistance: The technician dials code digit 8. As in the insulation resistance test, there is a delay of approx. 5 secs. before the test commences. This gives the technician time to apply a short to the telephone terminals. This short must be maintained for at least 5 secs. On removing the short the technician hears a result tone indicating whether the loop resistance is over 1,000 ohms (unacceptable), between 1,000 and 200 ohms, or under 200 ohms (both acceptable).

It is often possible to short circuit the line by moving the telephone dial off normal. This is not a good practice since there is a possibility of signalling a spurious impulse, or of having the line looped but not short circuit.

Robot Check: The technician may check the robot test desk by dialling code digit 9. On dialling this digit the 900 c/s. APR tone should be heard. This indicates that the robot has correctly counted 9 digits and is not locked to one of the tests.

Release and Automatic Disconnection of Robot: The technician may release the robot test desk simply by replacing the receiver when any of the result tones, or the APR tone, is being emitted. Time supervision is provided by means of a thermal relay. If the robot is left in any state, i.e., when sending ring or *any* tone, for longer than 2-3 minutes, the robot completely disconnects automatically. Other technicians can then seize the robot. This facility prevents the equipment being blocked by spurious connections or carelessness.

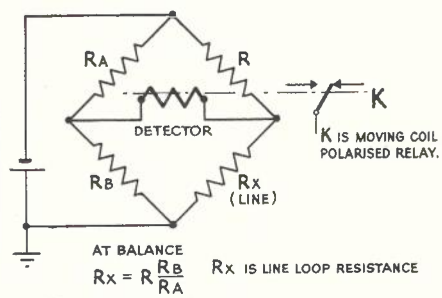
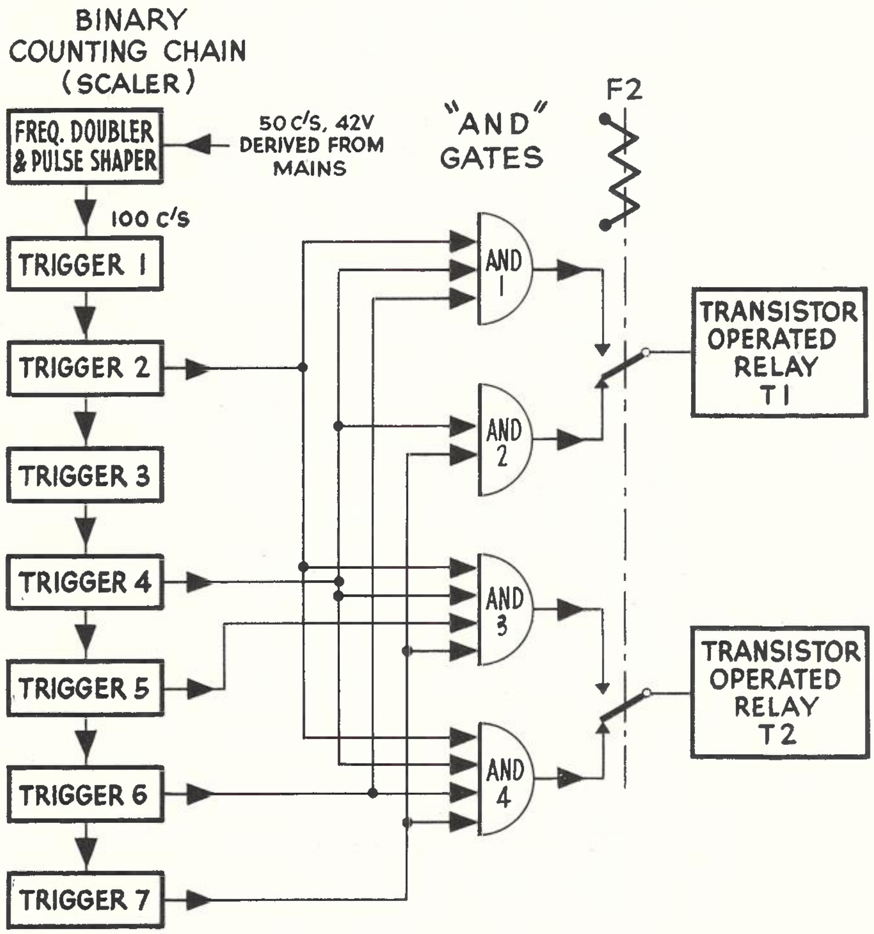


Fig. 3.—Basic Circuit of Loop Resistance Test Bridge.

Functions

The various relays, transformers and transistor circuits in the robot generally have distinct functions. It is thus possible to break the circuit up into functional blocks and to outline the working of the robot on the basis of a block diagram (Fig. 1). For reference in the text, a number is shown in each block.

Seizure of Robot: The technician dials the robot test desk access code. In crossbar exchanges the register tests for battery (via 1,000 ohms) on the d_1 wire. In step-by-step exchanges the group selector tests for open circuit on the c_2 wire, which is connected to the private multiple. When the robot is seized the A relay operates to the loop. Other relays in the seizure and hold control [1] then operate and holding earth is returned on the c_2 wire. The earth on the c_2 wire also serves to busy the robot to step-by-step equipment, whilst open circuiting of the d wires gives busying to crossbar equipment.



TRUTH TABLE FOR TRIGGER FLIP-FLOP

INPUT	TRIGGER STATE	TRIGGER SWITCHING ACTION	TRIGGER OUTPUT
0	0	NO CHANGE	0
1	0 ↓ 1	ON	0 ↓ 1
0	1	NO CHANGE	1
1	1 ↓ 0	OFF	1 ↓ 0
0	0	NO CHANGE	0

TRUTH TABLE FOR "AND" GATE OUTPUTS

DIAL SPEED TEST LIMIT	"AND" GATE	BINARY COUNTER STATE 7	6	5	4	3	2	1*	DECIMAL EQUIVALENT NUMBER
21·5 I.P.S.	1	0	1	0	1	0	1	0	42
12·5 "	2	1	0	0	1	0	0	0	72
15·5 "	3	1	0	1	1	0	1	0	58
8·5 "	4	1	1	0	1	0	1	0	106

* TRIGGER FLIP-FLOP NUMBERS

Fig. 2.—Typical Logic Block Schematic and Truth Tables for Dial Speed Test Circuit.

The robot sends back ring tone and the technician replaces the receiver. The seizure and hold control now connects ring voltage to the line and the technician removes the receiver again. The seizure and hold control then connects the 900 c/s APR tone [5] to the line, indicating that the tester is ready to receive test code digits.

Dial Impulse Speed Tests: The technician dials test code digit 1 or test code digit 2. The appropriate relay in the dial speed test selector [14] is operated, via the impulsing relays [6] and the test selection relay counting train [7]. The dial speed test selector removes earths from the flip-flops in the binary counter [16] which hold it off (i.e. at zero) when not in use, and sets the test assessor (diode logic unit) [17] to give test limits according to the nominal speed of the dial.

The technician now dials code digit 0. Shortly after the beginning of the first break impulse the impulsing relays connect a 50 c/s A.C. supply voltage to the 100 c/s square wave converter and shaper [15]. Shortly after the beginning of the tenth break impulse the 50 c/s A.C. voltage is disconnected. Hence the A.C. voltage has been connected during the occurrence of nine complete successive impulses. The binary counter counts the 100 c/s rectangular pulses received from the pulse converter and shaper during this period. The total number of pulses counted is held in binary language in the counter, and the test assessor, by means of diode logic circuits, determines which speed range the dial falls into. The test assessor then actuates the appropriate relays in the test result tone selector [8].

Bell Tests: The technician dials test code digit 3 or test code digit 4. The test selection relay counting train selects the ring test [4]. The busy tone control [9] is actuated and busy tone is emitted. The technician then replaces the receiver and assesses the performance of the bell by listening to the ring. For the half ring voltage test the ring control and test relays [4] are operated so that only one half of the centre tapped secondary of the ring transformer [3] is connected to the line.

Insulation Resistance Tests: The technician dials code digits 5, 6 or 7. The test selection relay counting train actuates the line selector [10] so that the desired line connections are made to the insulation resistance test. These connections are:

Digit 5: +ve leg of line and earth
Digit 6: —ve leg of line and earth
Digit 7: both legs of line.

The busy tone control is actuated and the technician replaces the receiver. The time delay circuit [12] is started and, when 6 secs. have elapsed, the insulation resistance test [11] is applied.

If the insulation resistance exceeds 0.5 megohm an additional time delay [12] of 70 millisecs is started. When this time has elapsed a second test is applied to determine whether the insulation resistance is above or below 1 megohm. The appropriate relays in the test result tone selector are operated. Ring voltage is applied to the line, the technician lifts the receiver and listens to the result tone.

Loop Resistance Test: The technician dials code digit 8. The test selection relay counting train selects the loop resistance test [13]. As in the insulation resistance tests the commencement of testing is delayed by 6 secs.

If the loop resistance exceeds 200 ohms, a second test, to determine whether the resistance is above or below 1,000 ohms, is applied after a 70 millisecs delay. The appropriate relays in the test result tone selector are operated. After having held a short circuit on the line for at least 5 secs. the technician removes the short and listens to the result tone.

Robot Check: The technician dials code digit 9. The test selection relay counting train selects the 900 c/s APR tone oscillator [5].

Release: If the line loop is broken when the robot is emitting a test result tone, or APR tone, the seizure and hold control removes the holding earth from the c_2 wire and the robot is released.

Automatic Disconnection: Once the robot is in a particular state, i.e. emitting a tone or ring voltage, the seizure and hold control starts the time watching circuit [2]. When the robot operates to another state the time watching is re-commenced.

CIRCUIT DETAILS

General

Many portions of the robot test desk circuit are typical of L M Ericsson relay circuit design. It would not be proper to discuss such portions of the circuit here, since this article is not intended to be a circuit description or a treatise on L M Ericsson relay circuits. On the other hand several of the testing circuits incorporate interesting principles.

Dial Speed Tests

To explain the dial speed test circuit to those who are unacquainted with diode and transistor logic circuits would require a lengthy discussion that is beyond the scope of this article. However, for the benefit of the more sophisticated reader, the circuit is shown in logic block diagram form in Fig. 2. The function of the various logic devices may be studied in numerous tests. Readers of the *Journal* may refer to a series of articles by Arter (1).

The principle of the dial speed test is to count the time that elapses between the beginnings of the first and the tenth break impulses of the test train (nine complete impulses). This time is counted by a binary counter which counts the 100 c/s rectangular "clock" pulses received during the time limits. These "clock" pulses are derived from the 50 c/s A.C. mains. The mains voltage is stepped down and isolated, and then fed into a frequency doubler and pulse shaper circuit. The average mains frequency is held to close accuracy but short time fluctuations can occur. However, the frequency should generally be within acceptable limits for a dial speed standard.

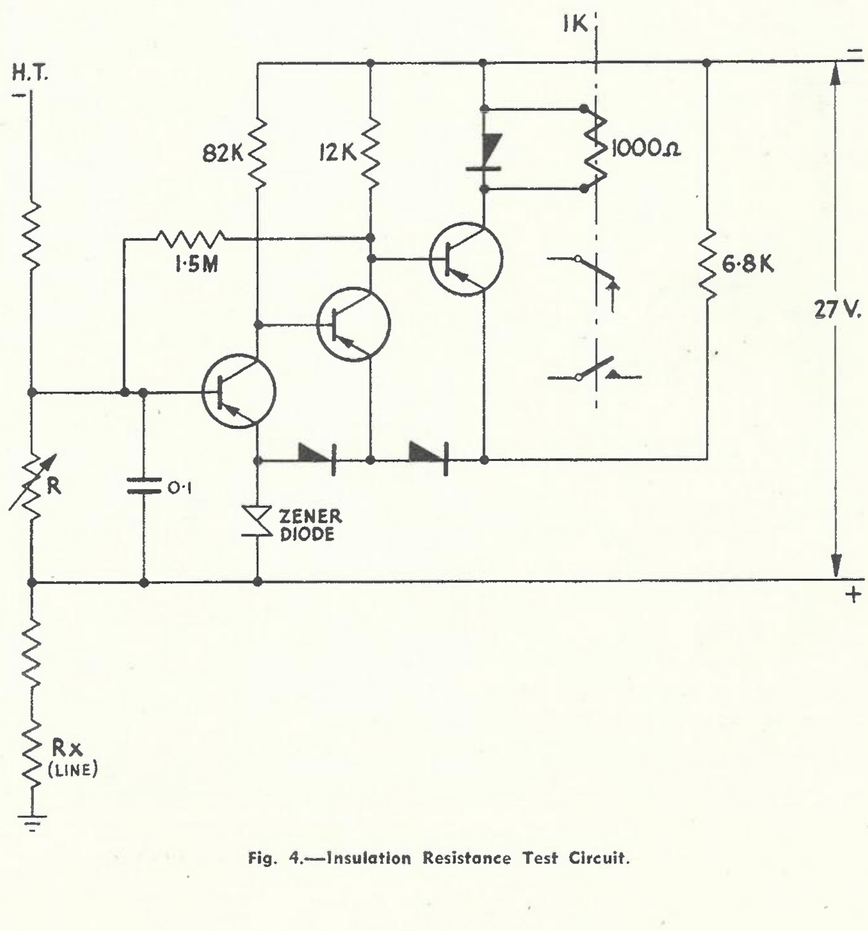


Fig. 4.—Insulation Resistance Test Circuit.

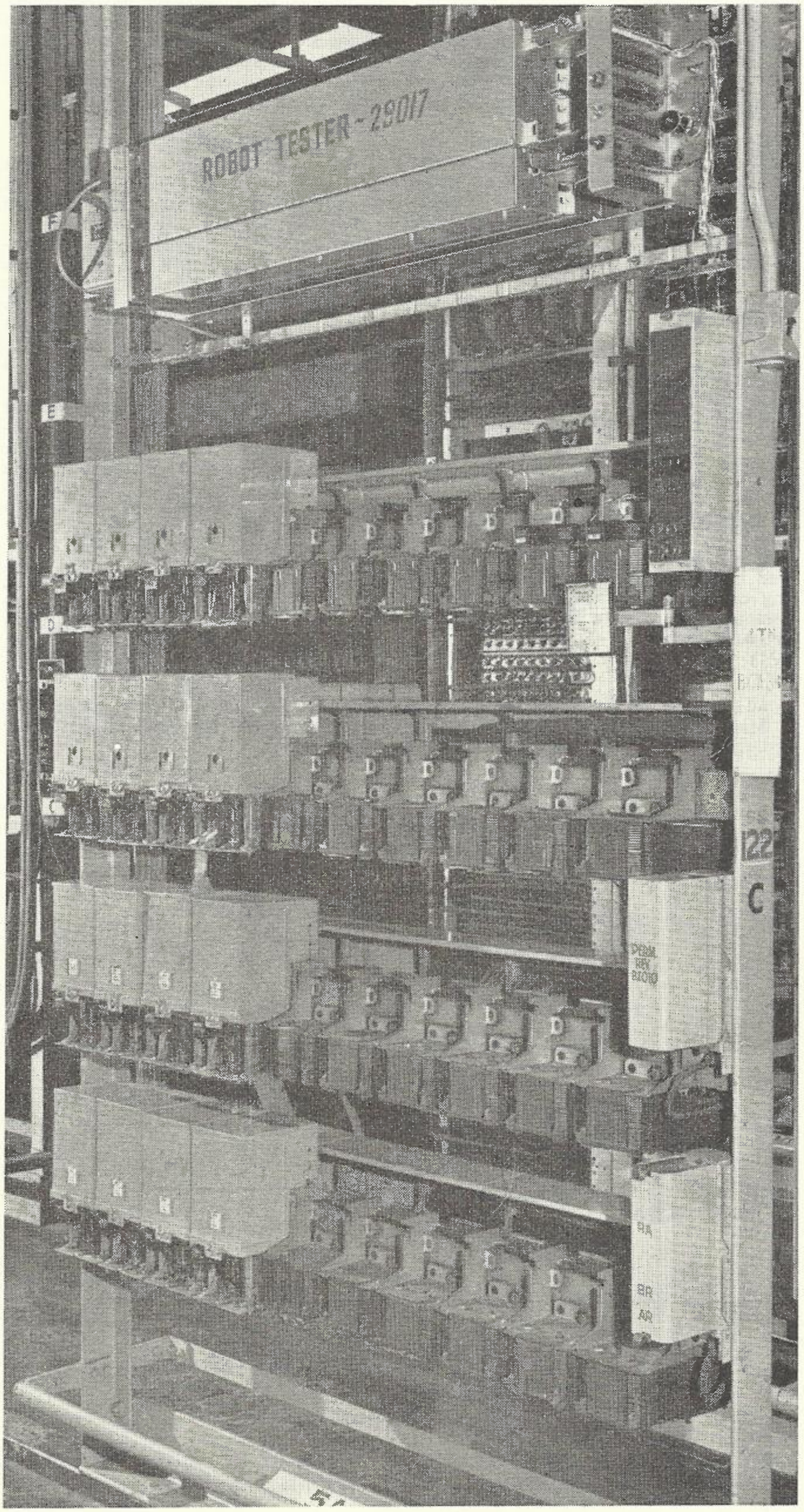


Fig. 5.—Robot Test Desk Installation at York Exchange, Sydney, N.S.W.

The binary counter comprises seven trigger type transistor flip-flops connected in a "scaler" circuit. The principle of this circuit is successive stages of division by two, i.e., the first flip-flop counts at 100 c/s, the second at 50 c/s, the third at 25 c/s, and so on. The scaler thus counts in the 8421 binary system.

The counter is read by diode "AND" gates, which are selected by a relay to suit a test on a nominal speed 10 i.p.s. dial or a nominal speed 20 i.p.s. dial. The outputs of these AND gates feed to the transistor operated relays T1 and T2. An AND gate gives an output *only* when *all* the inputs are *simultaneously* energised. If the dial speed exceeds the upper test limit the counter will not have time to reach a state where either of the AND gates can give an output. If the speed lies within the acceptable range the counter will have time to pass through a state where the AND gate associated with relay T1 gives an output. Relay T1 has time to operate and lock via one of its own contacts before the counter advances to the next clock pulse, which switches the AND gate off again. If the dial speed is less than the lower test limits both relays T1 and T2 operate. According to the state of T1 and T2, the appropriate result tone selection relays operate.

Fig. 2 incorporates truth tables for the trigger flip-flop and for the counter states for AND gate operation, for crossbar dial speed limits.

If the test train contains less than ten impulses the counter is not stopped by the test selection relay counting train, but stops when the 50 c/s supply is disconnected by the release of the slow operate relay which holds up during impulse trains. This form of operation is a malfunction and the test result is meaningless. A meaningless test also results if the 50 c/s supply fails.

This is a rather elaborate circuit for a dial speed test. An obvious alternative is to measure the elapsed time by means of the rise or decay of the voltage developed in a resistance capacitance circuit. Whether or not this arrangement is less expensive to provide than the binary counter depends on the degree of precision required for the dial speed test limits. If the accuracy required is not high a relatively simple and cheap circuit could probably be constructed. On the other hand the binary counter measures the elapsed time to the nearest hundredth of a second, which gives approx. ± 1% accuracy for tests on 10 i.p.s. dials and ± 2% accuracy for tests on 20 i.p.s. dials. It also has the very useful feature of requiring no marginal adjustments, which would require the generation of standard impulse trains at the dial speed test limits. The speed limits are set by arranging the input diodes of the AND logic gates so that relays T1 and T2 operate to the appropriate binary counter states. The L M Ericsson designers have provided a basic printed circuit board that caters for diode circuits covering a wide range of dial speed test limits.

Loop Resistance Test

The loop resistance test is performed by an automatic Wheatstone bridge for which a basic circuit is shown in Fig. 3. The heart of this device is the detector, which is a sensitive polarized moving coil relay. This relay, which is referred to in the L M Ericsson circuit description as a "plunger coil relay", uses the same construction as a moving coil loudspeaker, the moving contact assembly of a change-over set taking the place of the diaphragm. A constant magnetic flux is provided by a permanent magnet, which has an annular gap in which the coil moves. The relay energising current has negligible effect on the magnitude and direction of the magnetic flux. This results in two important relay properties:

(i) polarized operation, and,

(ii) negligible difference between operating and release currents.

The low mass and loading of the moving coil results in a very sensitive relay. The moving coil relay in the test desk robot installed at York exchange was connected to a current test set. It was found to operate to 0.6ma current and no difference between the operate and release currents could be detected. When this relay serves as an automatic bridge detector all of the above characteristics are put to use.

This automatic bridge relies on a fundamental property of the Wheatstone bridge: as R_x is varied through the balance point the direction of the detector current reverses passing through zero at the balance point. Thus the polarized relay detector will operate only for values of R_x to one side of the balance value, although current flows in the detector for all unbalanced bridge conditions. For values of R_x to the other side of the balance value, the polarized relay does not operate. Because the operate and release currents of the relay are practically the same, the demarcation of the balance point is quite precise. The high sensitivity of the relay results in the actual bridge discrimination point lying very close to the theoretical balance point. An important feature of the bridge circuit is that the effect of variations in exchange battery voltage is negligible.

It was possible to adjust the bridge in the robot at York exchange to within ± 2% of the loop resistance limits. However, greater precision could probably have been achieved if the variable resistors in the bridge arms had been capable of finer adjustment. The current through some of the bridge resistors is appreciable and some bridge drift could result from the variation of resistance with temperature. However, the greatest source of error lies in the additional resistance inserted by the exchange switches and wiring between the subscriber's line and the robot test desk.

The moving coil relay is suspended by springs and must be mounted in a horizontal position since the moving coil restoring force is mainly imposed by gravity.

Insulation Resistance Tests

In the original L M Ericsson robot test desk circuit the insulation resistance test, for which a 52 kilohm limit was sent, was also performed by the automatic bridge. The A.P.O. standards for insulation resistance involve much higher limits. These limits are beyond the scope of the bridge, since the high ratio of the arms (i.e. $R_B : R_A$) results in too great a loss of balance sensitivity. The robot was modified to provide an insulation resistance test based on an L M Ericsson transistorized current detector.

The basic circuit is shown in Fig. 4. It is fundamentally an automatic ohmmeter. The current detector occupies the position of the current meter in an ohmmeter circuit and takes the form of a transistor component board. It comprises a transistor switch connected across a resistor, R, two values for which are provided in the form of "trimpot" variable resistors. This resistor is connected in series with the insulation resistance, R_x, and a high tension source to form a voltage divider. The other resistors are provided to protect the transistors when R_x is short circuit. When the voltage developed across the fixed resistor exceeds the emitter bias voltage the transistor circuit switches to the "on" condition, causing relay 1K to operate. The emitter voltage is closely regulated by the zener diode. Hence the current through R_x, above which the transistor circuit switches on, is held within close limits. Thus the circuit forms an automatic ohmmeter which can be set to close limits.

The errors associated with this circuit are generally those associated with ohmmeters. Since we only have to discriminate about particular values of R_x, a gradual drop in the high tension voltage as R_x decreases will have no effect on the accuracy of discrimination. However, random fluctuations in the h.t. voltage will alter the insulation resistance test limits.

INSTALLATION ASPECTS

General

The installation aspects discussed here are mainly based on the author's experiences at York exchange.

Regardless of whether the robot test desk is installed in a crossbar or step-by-step exchange certain supplies, which are not available on the equipment racks, have to be provided. The binary counter requires a 42v, 50 c/s input. This is derived from a double wound step down transformer which is normally mounted on the A.C. distribution panel or in one of the rectifier cubicles. The insulation resistance test may be operated from the 80v. internal supply of the robot but it is preferable to use the same voltage as is supplied to the manual test desk, to prevent discrepancies due to insulation resistance breakdowns. A feed from the high tension supply should be taken to the robot via heavily insulated cable.

The test desk robot itself comprises two crossbar type relay sets which have to be suitably mounted.

Crossbar Exchanges

The installation is straightforward, the relay sets being mounted on the miscellaneous rack. A test access jack and busying key are provided in the rack jack box. The a, b, c_1, c_2, d_1 and d_2 wires appear on the I.D.F. where they are jumpered to the registers.

Step-by-Step Exchanges

Here the main problem is to provide a suitable mounting for the crossbar type relay sets. Fig. 5 shows the York exchange installation. The relay sets are mounted in an ARK crossbar system wall frame. The frame is mounted in spare space on the rack of special 5th selectors which provide access to the various test facilities. The group selector outlet is taken direct from the rack blocks to the relay set plug unit.

The 42v, 50 c/s step down transformer is mounted to the right of the wall frame. This non-standard position was selected since the specified location was not suitable in this particular exchange.

At the right hand end of the wall frame, at the front of the plug unit bracket, are mounted the test jack and busying key. A lamp is also provided to indicate to the exchange staff that the robot is seized.

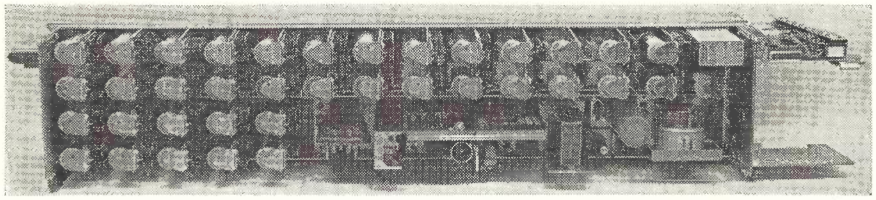
Circuit Modifications

The provision of robot test desk equipment to suit A.P.O. test standards is currently being undertaken by L M Ericsson. In the meanwhile locally modified equipment has been installed at Toowoomba exchange (crossbar equipment) and York exchange (step-by-step equipment). The modified relay sets installed at York exchange are shown in Fig. 6 (a) and (b). The location of the major modification components can be seen. The moving coil relay is shown in the lower right hand corner of Fig. 6 (a). The current detector board is in the lower middle of Fig. 6 (a) with the "trimpot" variable resistors at the front right hand side of the board. The major portion of installation labour at York exchange was used in modifying relay set APR1.

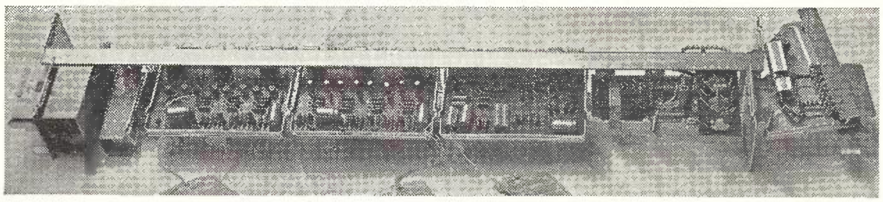
A 5 watt transistorized DC-DC converter described in (2) was used to provide a high tension of approximately 200 volts. The regulation of this converter is quite good, except for a sharp rise in output voltage at very low loads, which is easily suppressed by loading the output with a suitable resistor. The DC-DC converter is the matrix board circuit at the right of Fig. 6 (b). Its input voltage is supplied by a series resistor with zener diode regulation. These components are mounted at the right hand end of the wall frame, Fig. 5.

Testing and Adjustment

The writer made extensive tests on the robot test desk installed at York exchange, prior to its being put into service. An interesting problem occurred with the transistor operated relay circuits used in the dial speed test. These circuits are sensitive to quite small pulses.



(a) Relay Set APR1. From lower middle to lower right are: polarised impulsing relay, 900 c/s oscillator (older version), insulation resistance test circuit component board, ring transformer, electrolytic capacitor in time delay circuit and polarized moving coil relay.



(b) Relay Set APR2. Top left to right are: full wave rectifier (rectangular can), pulse shaper and first three flip-flops of binary counter, remaining four flip-flops of counter, diode logic gates and relay operating transistors, and DC-DC converter h.t. supply.

Fig. 6.—Modified L M Ericsson Robot Test Desk Relay Sets Installed at York Exchange.

Positive feedback is provided via secondary windings on the relays, T1 and T2. It was found that these relays were operating to pulses picked up by coupling, the pulses being caused by the release of the adjacent dial speed test selection relays in relay set APR2. This trouble was eventually eliminated very simply by reversing both windings on each of the dial speed test selection relays, F1 and F2.

A range of equipment was used for testing and adjustment. A test phone was provided so the robot could be seized and the test code digits dialled. The insulation and loop resistance tests were set using variable resistances formed of decade boxes in conjunction with fixed resistors where necessary, all resistances being accurate to ± 1%. The accuracy of setting specified for the resistance limits was ± 5%. However, it was quite easy to make settings within ± 2%, which allowed a safety margin for subsequent drifts in component values.

The dial speed test limits were approximately checked using deliberately maladjusted dials, which were calibrated on the manual test desk. An oscilloscope was used to check the binary counter and associated transistor circuits.

FIELD TRIAL EXPERIENCE

The York exchange robot test desk was installed at the request of A.P.O. Headquarters for the specific purpose of conducting a field trial in a step-by-step exchange. The equipment was put into service at the end of January 1964. Meters were provided to count effective calls to the robot and lost (overflow) calls. During the period to August 1964 the average rate of usage was roughly 17 calls per day. This estimate is on the basis of a five day week and allows for a proportion of calls being made to check or demonstrate the robot (these were deducted).

For a city co-main exchange having over 8000 lines and many large subscribers this does not appear to be a very high figure. However, use of the robot has been limited to area maintenance technicians. Greater usage should result if linemen and substation installation technicians are initiated into the use of the tester. The lack of a dial impulse weight test is also a handicap in a step-by-step exchange area. Another factor is that this is a comparatively well-staffed exchange. In smaller exchanges the staff cannot always cope with manual test desk demands. Here, faced by the ensuing delays, the field staff should quickly turn to the robot test desk.

The most popular facility provided by the York exchange robot test desk was the insulation resistance tests. Of facilities *not* provided, the greatest demand was for a dial impulse weight test.

One instance of a discrepancy between the manual and the robot test desks occurred. This was on an insulation resistance test. The test from the manual test desk was made on the high resistance range, which uses an 80 volt supply. When the robot insulation resistance test, using a higher voltage, was applied, insulation breakdown apparently occurred.

Approximately 7% of calls to the robot test desk were lost (overflow). This figure is high when the usage rate is taken into account. The robot was not out of service for long periods. However, the daily usage rate of the tester could vary widely, peak usage probably occurring during wet weather. Also fault location work is likely to produce usage patterns typified by bursts of use, these being due to successive tests being made as a fault is traced. This problem of lost calls requires careful observation and analysis, to determine whether more than one robot test desk is necessary. Delays in gaining access to the robot would certainly discourage its use.

It was found the robot would operate to public telephones only if the positive wire of the line was connected to the "a" wire of the robot, and the negative wire to the "b" wire. This was due to the presence of a rectifier in the P.T. loop circuit. The required line polarity is governed by the polarity of battery and earth fed via the impulsing relay, not the seizure (A) relay.

POSSIBLE FURTHER IMPROVEMENTS

The conclusion to be drawn from the York exchange field trial is that use of the robot test desk can effect a useful reduction in the demand for tests from manual test desks, but that the full benefit can only be obtained when the robot offers a full range of test facilities.

The additional facility that is most urgently required is a test of dial impulse weight. The present consensus of local opinion is that this facility could best be provided by adding a pulse length monitor to the robot. The writer's suggestion is that the dial speed and pulse length monitor tests be applied simultaneously. An additional result tone is provided to indicate a dial that fails the pulse length monitor. Where a dial fails both the speed and p.l.m. tests it may only be faulty with regard to speed. The solution here is to indicate long make + long break + slow speed as a slow dial that passes the p.l.m. test, and similarly short make + short break + fast speed as a fast dial that passes the p.l.m. test. This gives the technician the option of readjusting fast or slow dials in the field, but distinguishes all other types of impulsing faults, for which current policy is to replace the dial in the field, returning the faulty unit to a central point for repair.

Another facility at present lacking is a test for foreign battery. However, in nearly all cases, this condition will be detected as an insulation resistance test failure.

Speed 20 i.p.s. dials will not be used by the A.P.O. for some considerable time to come, if ever. The speed test for 20 i.p.s. dials is therefore redundant and the test code digit 2 could be allocated to some other test facility. A temporary use for this redundant test could be to provide a single robot in hybrid exchanges, accessible from both step-by-step and crossbar subscribers' services, but offering different dial speed test limits for each category of service. The former 20 i.p.s. dial speed test could be easily modified to suit step-by-step limits. The other test standards, i.e. those for loop and insulation resistance, would have to be common to step-by-step and crossbar services.

Another test facility that seems unnecessary is the full ring voltage test. A number of other robot conditions apply full ring voltage to the line.

There are several conditions where a test facility is faulty but a good test result may be indicated. These are: failure of h.t. supply to insulation resistance test, failure of 50 c/s supply to dial speed test and less than ten impulses in dial speed test train. An alarm system to detect these conditions would be desirable.

CONCLUSION

The robot test desks at present in use offer only a limited range of facilities. However, they have demonstrated that such devices are a practical proposition. Furthermore it is obvious that their usefulness can be greatly enhanced by providing additional test facilities.

If centralised testing schemes are to be successful a worthwhile reduction in local exchange test desk work is a necessary outcome. Here the robot test desk should prove a useful ally.

The application of the robot test desk to quite small exchanges, e.g. R.A.X.'s, should be considered. Here one technician is required to handle both exchange and area work. Since he cannot be in two places at once the robot would provide a facility not available before.

Finally, to obtain the fullest use of robot test desks, an education programme for potential users is necessary. Such users would be area maintenance technicians, fault linemen, and substation installers (technicians or linemen) making preliminary tests on new services.

ACKNOWLEDGMENTS

The writer is indebted to various engineers and technicians in the Metropolitan Equipment Service and Installation Sections (New South Wales) for many useful suggestions concerning the robot test desk and helpful criticisms of this article. The writer also wishes to acknowledge the helpful guidance provided by the Headquarters Telephone Exchange Equipment Section on this project.

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LETTER TO THE EDITOR

P.M.G. Research Laboratories,
59 Lt. Collins Street,
Melbourne, C.1.
20th August, 1964.

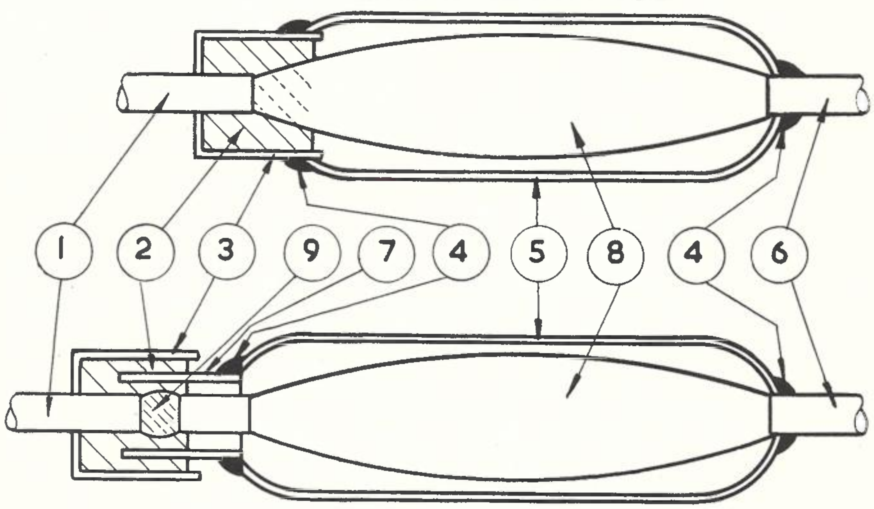
Dear Sir,

The purpose of this letter is to comment on certain historical matters arising out of R. D. Johnston's article "Installation of an 1,800 Pair Polythene Insulated and Sheathed Cable" in the June, 1963, issue of the *Journal*, particularly in relation to the sheath jointing method described. An essential feature of this jointing method is the use of a lead mould for an epoxy resin casting and the incorporation of a lead sleeve wiped on to this mould at one end and on to a lead sheathed cable at the other end to provide a reopenable joint between polythene and lead sheathed cables.

As far as I am aware, this type of joint was first put into service by South Australian engineers in 1959 (Fig. 1). However, this joint, in common with that described by Mr. Johnston, has the following weaknesses: —

(a) During the curing period the epoxy resin may shrink away from the mould, particularly so when this is made of lead, to which epoxy resins show little adhesion.

(b) During the "wiping-on" of the lead sleeve to the lead mould the latter tends to expand away from the cured resin. After repeated joint openings, any adhesion between the resin and the lead remaining after the curing period may be broken.



1. Polythene insulated and sheathed cable.
2. Epoxy Resin compound.
3. Metal cup.
4. Wiped joint.
5. Lead sleeve.
6. Paper insulated, lead covered cable.
7. Lead tube.
8. Conductor joint.
9. Water barrier.

Fig. 1.—Modification of an Epoxy Resin Based Joint.

In 1960 Headquarters engineers suggested a modification which overcame this difficulty (Fig. 1): a lead tube is cast into the epoxy resin at one end and the main joint sleeve is wiped on to the exposed end of the tube. The epoxy resin is re-formulated to produce a material capable of absorbing the stresses set up during the resin cure and the lead wiping operations. The length of tube between the resin and the wiped joint aids the dissipation of heat applied during the wiping operation.

In 1960 the use of epoxy resins by field staff was considered inadvisable and this technique was only used on special cable tails prefabricated in the Postal Workshops. The design used on these tails provided for resin penetration into the conductors to produce a water barrier in the plastic insulated cable (see W. H. Walker, "Some Aspects of External Telephone Plant in Australia" in the *Journal* for October, 1963, particularly Fig. 7). Hundreds of these tails, known as "Prefabricated Water Barriers" were used at joints between plastic and lead sheathed cables, but because they required an extra joint in their installation, their use was discontinued when epoxy resin field packs were introduced to enable resin castings to be safely and readily made in the field.

The next development, which followed on logically from the preceding events, was described by F. Herbstreit in the June, 1964, issue of the *Journal* ("Epoxy Resin Based Joint for Large Size Cables"). Many such joints have been made in experimental 100, 200 and 400 pair plastic insulated, plastic sheathed cable and five of particular interest were installed in Sydney during August, 1961, on the same shipment of experimental 1800/4 plastic cable from which the installation described by Mr. Johnston was supplied.

Modifications of the joint described by Mr. Herbstreit are at present being considered by Headquarters as a result of experimental work in the P.M.G. Research Laboratories to enable it to be used as a branch joint as well as a straight joint.

Yours faithfully,
H. J. Ruddell, A.M.T.C.

A TRANSMISSION LEVEL TRACER

L. N. JACKSON, B.E.E., A.M.I.E.Aust.*

INTRODUCTION

The ever increasing growth in the number of telephone channels and the better quality demanded of these circuits due to the introduction of multi-frequency calling has created the need for quick and accurate measuring methods in the V.F. band. Data transmission and the increased demand for teleprinter channels have further accentuated this need, which can be best satisfied by the application of sweep frequency techniques.

An instrument which can fully satisfy the requirements is the so-called Level Tracer Rel 3 K 211. This unit was developed in Western Germany by Siemens and Halske A.G. and is used by the Australian Post Office. Although its original development was commenced as early as 1941, numerous improvements have been made, and many new applications discovered during the last ten or so years.

GENERAL DESIGN ASPECTS

With reference to the development, one should perhaps first recognise that two major solutions to the problem of measuring sweepwise across the V.F. band exist. Firstly, one can transmit a tone whose frequency is varied either electronically or mechanically across the band of interest. The tone excites the circuit under test and the resulting signal is received by a flat gain receiver.

As a second alternative a wide spectrum of noise may be generated followed by bandwidth limitation as required. This signal may then be applied to the circuit under test. At the output, a selective receiver periodically scans the resulting frequency spectrum. This method, although sometimes used at radio frequencies, has one major disadvantage when applied to the problem in question. For sufficient resolution in the voice band, the bandwidth of the receiving section must be extremely narrow. This involves a very long measuring time, since the time constant of the narrow band filter used necessarily must be long. The first alternative therefore, at least for normal applications, presents the better solution.

Following the question of design still further a decision must be made whether to use an electronic or mechanical sweep (i.e., with a rotary capacitor). Swept band operation is possible electronically with reactance tubes, magnetically biased coils, voltage dependent capacitances, etc. The principal disadvantage with such presently available electronic sweep methods is that manual selection of a particular frequency is difficult. Since the electronic sweep technique generally requires complicated circuitry, this can also be cited as a disadvantage. With future development of electronic sweeps, these difficulties will probably be overcome. On the other hand, a mechanical sweep using a simple, rotary, variable capacitor can be made accurate and robust, and constructed so that little maintenance is required.

The above problems which were solved in the development of the instrument are naturally only some of those encountered. Other aspects of development have been discussed by Niedereder and Sanders (1).

Finally it can be said that design emphasis has been placed on simplicity of calibration and operation so that technicians with normal training can perform accurate and reliable measurements with speed and ease.

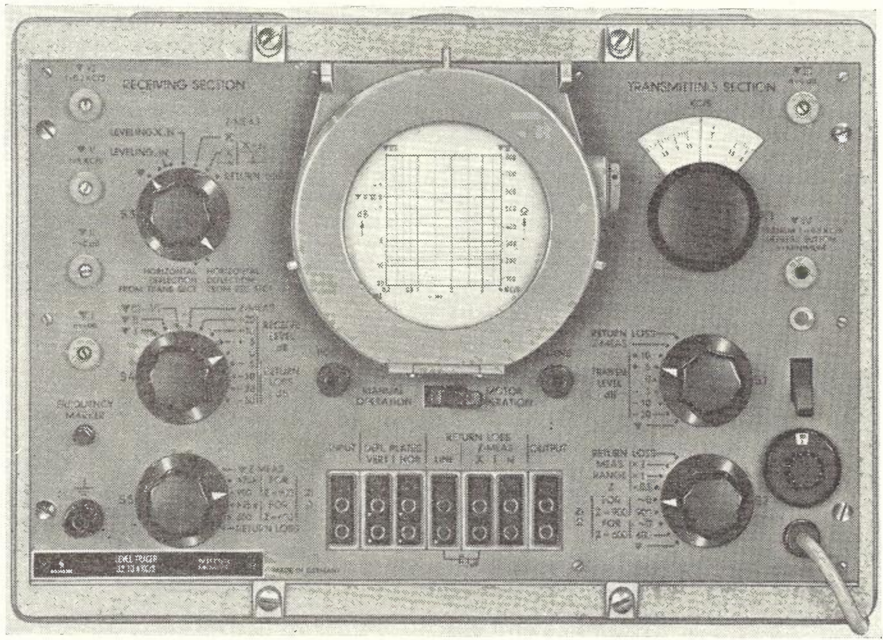


Fig. 1.—Panel View of the Level Tracer Rel 3 K 211gla.

DESCRIPTION OF THE INSTRUMENT

The instrument described hereunder has a frequency range of 0.2 to 4 Kc/s (Rel 3K211 gla); another model is also available with a frequency range extending to 6 Kc/s, but with db calibration only.

Referring to Figs. 1 and 2 it can be seen that the instrument is composed of a transmitting, a receiving and a switching section. The controls (i.e., Level Selector and Impedance Selector) for the transmitting section and the scale of the rotary capacitor can be seen on the right hand side of Fig. 1. On the left-hand side are further control knobs, including the function selector knob. An engraved plexiglass graticule with vertical scale limits of +3 and —20 db is provided directly in front of the Cathode Ray Tube (C.R.T.) face.

In the transmitting section, the variable frequency test signal is produced by beating the variable oscillator output (which varies between 70.2 Kc/s and 74 Kc/s) with the output of the fixed frequency oscillator (70 Kc/s). The variable oscillator frequency is varied by a rotating variable capacitor driven by a synchronous motor. This motor can be switched off at will and any transmitted frequency between 0.2 and 4 Kc/s set by hand. Hence special points of interest within the swept band can be investigated more accurately. The normal rate of sweep with motor operation is approximately 2 secs., a period which is long enough to ensure that even very sharp spikes in the attenuation curves of filters, etc., are measured correctly. In fact, one can check that the sweep rate is long enough (i.e., that the specimen is measured under steady state conditions) by observing if the go and return traces on the C.R.T. are coincident.

The transmit signal, after passing through the filter and amplifier as shown, is available at the output jacks with a level variable between —20 and +10 dbm.

The receiving section is composed basically of amplifier, detector, frequency meter (discriminator) and a C.R.T. The cathode ray display of received signal (y axis) against frequency (x axis) is of course the heart of the instrument. A flat faced cathode ray tube with electrostatic deflection and having a long persistent phosphor is used; the screen diameter is 3½ ins.

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*Mr. Jackson, previously a member of the Staff of Siemens Halske Siemens Schuckert (A/asia) Pty. Ltd., is Engineer Gr. 4, State Electricity Commission of Victoria. See page 83.

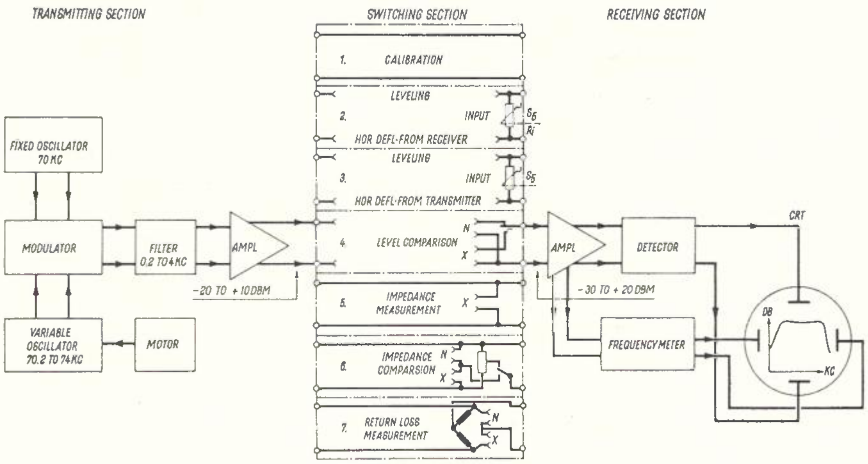

Fig. 2.—Block Diagram of the Level Tracer Rel 3 K 211gla.

The input level is switchable between —30 and +20 dbm, and as shown in Fig. 2, the resulting signal at the detector output is applied to the vertical plates of the C.R.T.

The frequency meter is so designed that, providing the input signal is large enough, i.e., not smaller than about —50 dbm, sufficient level is available for the discriminator to enable a correctly frequency dependent voltage to be applied to the X plates of the C.R.T. Should the receiver input signal not be large enough for the discriminator, due to the specimen having too much attenuation in certain parts of the frequency range, a signal voltage for the frequency meter alone can be obtained direct from the transmit section. This is achieved by correct selection of the function switch.

It may be noted that a scale spread amplifier can be built-in to secure expansion of the reading range such that the vertical scale limits become +0.5 and —5 db, i.e., the reading accuracy is improved about threefold. This facility is not provided in the instrument described. Such accuracy can be very helpful for level comparison tests; a special graticule is available.

Referring to the switching section it is to be noted that the following functions can be selected. Calibration of instrument, level measurement (with horizontal deflection from receiver), level measurement (with horizontal deflection from transmitter), level comparison, return loss, impedance measurement, and $\frac{X+N}{2}$ measurement. Each of these functions will be briefly described under the heading, "Instrument Applications".

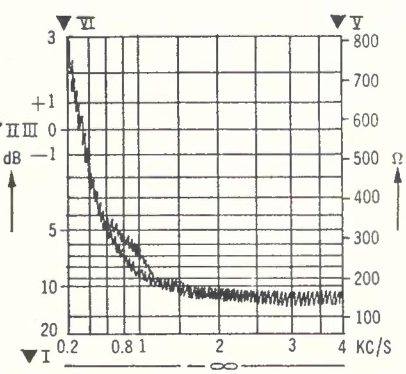

Fig. 3.—Curve of the Impedance of a Noisy, Nonloaded Pair. Impedance scale x 2.

SETTING-UP PROCEDURE

Calibration of the C.R.T. trace against the engraved gratitude is to be considered as the first step in the operation, so that full accuracy is ensured. No auxiliary calibrating instrument is required. Accurate internally generated calibrating voltages ensure correct level calibation, while a very sharp 800 c/s band stop filter provides accurate frequency calibration (see Step 4 below). All calibration positions and controls on the instrument are clearly marked in red on the front panel, the tuning capacitor dial, and the graticule. The symbol ▼ designates a calibration function or position. The instrument being described provides screw driver calibration controls recessed behind the front panel. The calibration is carried out in the following six steps. Steps 1-3 ensure calibration in the vertical direction, while the correct horizontal (i.e. frequency-wise) calibration is attained in the last three steps.

For Steps 1, 2 and 3 the drive switch is to be in the position MOTOR OPERATION.

Step 1. With the switches S1, S2, S3, S4 and S5 in their extreme anti-clockwise positions, adjust the ▼ I screwdriver control until the trace coincides with the — ∞ line designated ▼ I on the graticule.

Step 2. Operate S4 to its ▼ II position and adjust the ▼ II screwdriver control until the trace coincides with the 0 db line designated ▼ II ▼ III.

Step 3. Operate S4 to the position ▼ III . . . . . VI and then adjust the ▼ III screwdriver control until the trace again coincides with the 0 db line.

For Steps 4, 5 and 6 the drive switch is to be in the position MANUAL OPERATION.

Step 4. Rotate the tuning capacitor manually to the 0.8 Kc/s line designated ▼ IV and then depress and turn the screwdriver control ▼ IV until the trace is at a point of minimum deflection.

Step 5. With the tuning capacitor set at the 4 Kc/s position designated ▼ V, turn the ▼ V screwdriver control until the spot coincides with the 4 Kc/s (▼ V) line on the graticule.

Step 6. Rotate the tuning capacitor to the 0.2 Kc/s position (▼ VI position) and then turn the screwdriver control ▼ VI until the spot coincides with the 0.2 Kc/s (▼ VI) line on the graticule.

Since there is some interaction between steps 5 and 6, these steps should be repeated a few times to ensure accurate calibration.

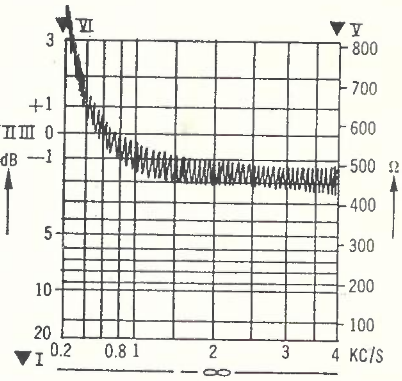

Fig. 4.—Impedance of a Noisy, Nonloaded Pair—Tip to Ground. Impedance Scale x 2.

INSTRUMENT APPLICATIONS

Level Measurement

The instrument lends itself ideally for the measurement of the overall equivalent (i.e., attenuation of the circuit terminated in 600 ohms) of a voice channel.

The transmitting level may be controlled by means of an attenuator from —20 to +10 dbm in 5 and 10 db steps. Should 1 db steps be required an external attenuator may naturally be used. Full scale sensitivity of the receiving section may be adjusted over the range from —30 to +20 dbm. Within the sweep range of 200 c/s to 4 Kc/s, the output e.m.f. of the transmitting section remains constant within ± 0.1 db, and the sensitivity of the receiving section within ± 0.2 db.

A typical application is the testing of individual VF channels of broadband or other multi-channel carrier systems during installation. As an initial test on a channel modem rack, a loop would be made from the group amplifier output (transmit side) via a fixed gain amplifier to the distributing hybrid on the receive side. Each of the 12 corresponding V.F. channels would then be tested for frequency response at the test jack field on the rack itself.

A further application is the maintenance of V.F. channels. In this case when go and return circuits are not looped, two instruments are required,

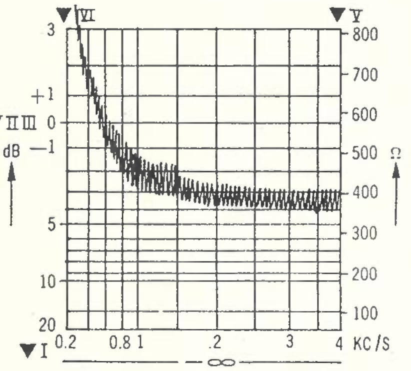

Fig. 5.—Impedance of a Noisy, Nonloaded Pair—Ring to Ground. Impedance Scale x 2.

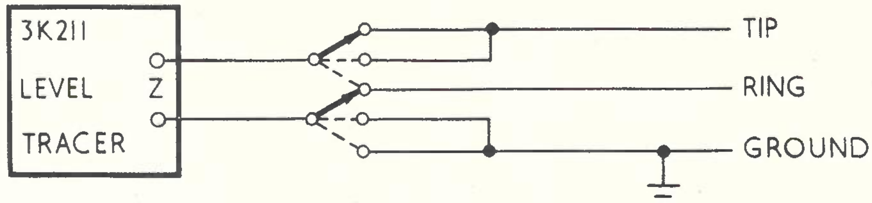

Fig. 7 (a).—Simple Switch for Aiding Noise and Unbalance Impedance Measurements.

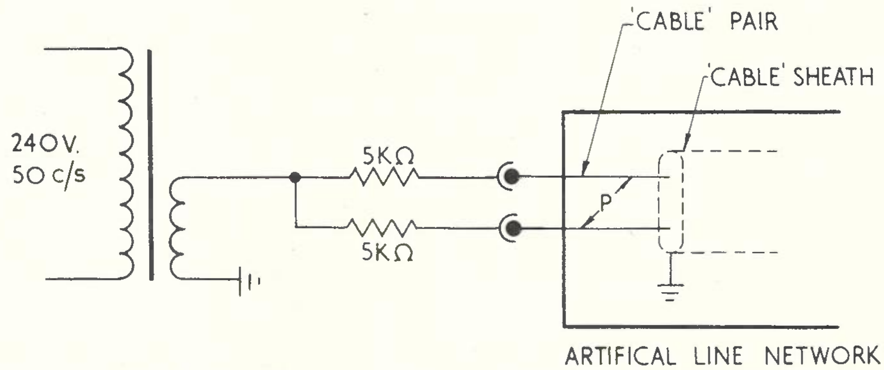

Fig. 7 (b).—Simple Circuit for Producing Noise on a Deliberately Unbalanced Artificial Line.

one serving as transmitter at one end, and one as receiver at the other end. As the receiver incorporates a frequency meter, no special synchronisation is required between the two instruments. To facilitate this test in practice, a Dialling and Holding Device should be used to guard against the seizing of the channel under test.

When the overall equivalent of a V.F. channel having in-band signalling is to be measured, the sweeping signal may disturb the measurement or even release the connection when it sweeps through the signalling frequency. To prevent this the following facility can be utilized. A small capacitor is switched across the tuned circuit of the variable oscillator in the transmitting section and this causes a sudden frequency shift. Hence the electron beam traces out the display up to the critical frequency, jumps back about 300 c/s, corresponding to the frequency shift, and then proceeds again towards the critical frequency. The small capacitor is then disconnected and hence the electron beam is deflected quickly to the position in which it then would have been had the capacitor not been switched in. In other words a frequency gap of approx. 300 c/s is left in the transmitted frequency spectrum. This gap occurs for both the "go" and "return" sweeps.

A pair of contacts actuated by a cam on the shaft of the variable capacitor is used to switch the small capacitor in and out of circuit. The position of the cam relative to the shaft is adjustable so that the suppressed band can be matched to the signalling frequency. This facility allows level and return loss measurements over V.F. circuits using in-band signalling or it may be adjusted for use with out of band signalling.

In addition to terminated level measurements utilizing the switched internal terminations, high impedance bridging measurements are possible, i.e., the position "> 25K" of switch S.5 (see Fig. 1) is used.

Level Comparison

Contacts provided in the drive of the sweep oscillator and a transfer relay at the input of the receiving section permit a direct inter-comparison of the levels from two specimens or from a specimen and a standard.

This function mainly proves useful to the manufacturers of telecommunications equipment. A typical application is the alignment of VF channel filters by relatively unskilled personnel. The attenuation characteristic of the filter being aligned ("X") is traced in the forward direction, and the characteristic of a standard filter ("N") is displayed by the return trace. The outputs from the specimen X and standard N are switched with the abovementioned transfer relay. It should be noted that this function is not suitable for route measurements.

Return Loss Measurement

This facility permits direct measurement of the reflection co-efficient. The measurement circuit uses a bridge incorporating a 0 db loss hybrid coil mounted within the instrument. The range of measurement extends from 0 to 40 db corresponding to reflection coefficients of 100% to 1% respectively; however a 50 db return loss can also be determined with some reduction of accuracy.

The standard, i.e., balancing network, compromise network, etc., is connected to the N jack, while the line under test is normally connected to the X jack. Should however battery or ringing current be present on the line, connection

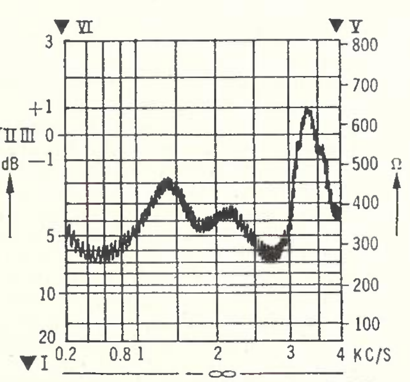

Fig. 6.—Impedance of a Noisy Loaded Pair. Impedance Scale approx. x 7.

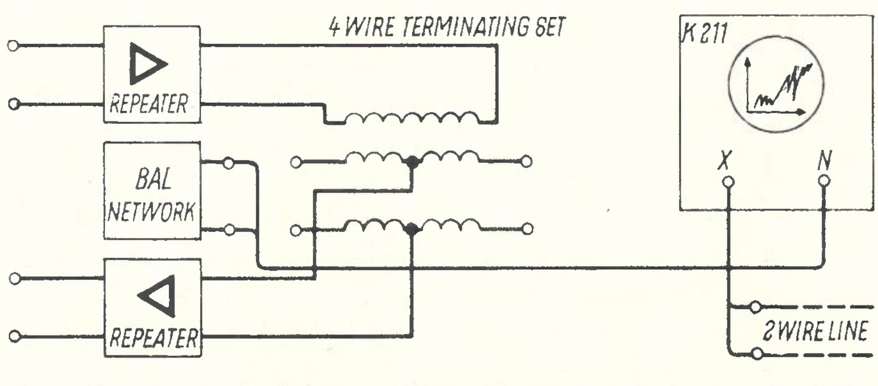

Fig. 8—Measuring Setup for the Alignment of the Balancing Network of a 4-wire Terminating Set.

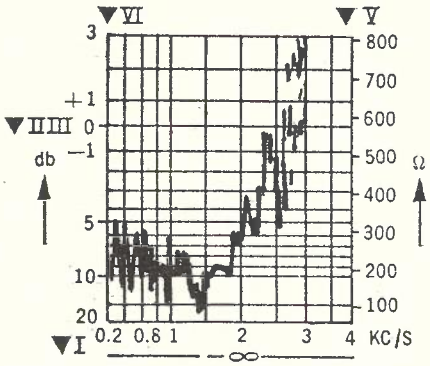

Fig. 9.—Return Loss Curve of Balancing Network against 2-Wire Line.

should be made to the LINE jack which places a blocking capacitor in series with the hybrid.

Use of the swept band technique for a return loss measurement provides the big advantage that the effect of any adjustments is seen immediately over the whole frequency range. Hence the risk of improving the return loss at a single frequency while degrading it at other frequencies is removed.

Impedance Measurement

For this measurement the output of the transmitting section is switched to present a high source impedance, i.e., operates as a constant current generator. A current is passed through the specimen; the magnitude of the current being effectively independent of the impedance under test. Hence the voltage drop across the specimen is proportional to the magnitude of the impedance (R ± jX). The impedance magnitude is read directly on a scale calibrated from 100 to 800 ohms, a range which can be expanded with switch S_2 upward and downward by the ratios 2 and 0.5 respectively.

Where the magnitude of the impedance under test exceeds 1,600 ohms, the transmitted level may be reduced in 5 db steps by means of S_1 or the sensitivity may be increased in 5 db steps with S_4. Each 5 db step results in an additional multiplying factor of 1.78. Consider the following example:—

Scale Reading:— 600 ohms
Switch S_2 at:— Z MEAS. x 2
Switch S_1 at:— + 5

Z equals 600 x 2 x 1.78 ohms.

No additional calibration of the Level Tracer is required for the measurement of impedance. Usual applications for this feature include the fault location on many types of VF cables (both loaded and unloaded).

Impedance Comparison

This facility is available in two versions:—

(a) A Measurement is made of the quantity $\frac{X+N}{2}$ so that both the magnitude and the phase of the unknown impedance "X" can be determined. Both X and N are assumed to be complex for this test.

(b) A straight out comparison "X" against "N" (analogous to the "Level Comparison" facility).

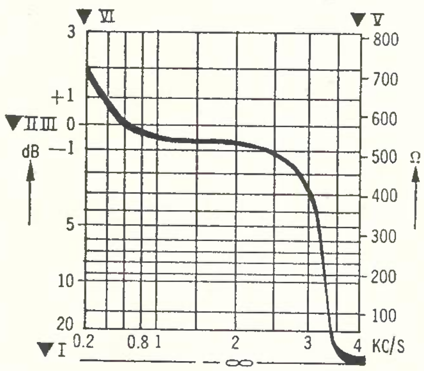

Fig. 11.—Insertion Loss of Correctly Loaded and Terminated Cable.

Facility (a) is always provided whereas facility (b) is only available as an alternative to "Level Comparison". Facility (b) is sometimes required by telephone administrations since it can be very useful for locating faults on loaded cables.

The use of the function $\frac{X+N}{2}$ to determine both the magnitude and phase of the unknown impedance "X" will be understood from the following. On the forward trace the magnitude of X is displayed and on the return trace the magnitude of $\frac{X+N}{2}$. By varying the magnitude and phase of N one tries to achieve coincidence of both traces. At the points where this is attained N equals X both in magnitude and phase.

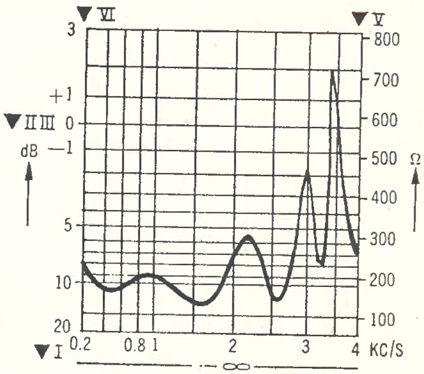

Fig. 12.—Impedance of Loaded Pair with the Fifth Loading Coil Omitted. Impedance Scale approx. x 7.

This function offers perhaps an advantage over the return loss function in that the sense of the impedance variation may be determined by observation, whereas with the return loss measurement only the magnitude of the difference between the impedances is displayed. On the other hand the return loss measurement is much more accurate.

The decision to use the Return Loss or Impedance Comparison functions is dictated by the particular requirement. As an application example for the type (b) impedance comparison facility ("X" against "N"), consider the location of faults on a loaded cable using an artificial line (2) as a fault simulator. Although more will be said later about faults on loaded cables, it suffices to say here that the fault could be a defective or missing loading coil, an incorrect joint or perhaps incorrect coil spacing. Usually the fault can be simulated with the artificial line by comparing the two impedance curves, which although alternately traced on the

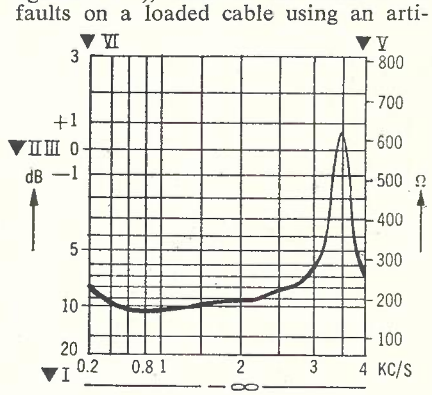

Fig. 13.—Impedance of a Correctly Loaded and Terminated Pair. Impedance Scale approx. x 7.

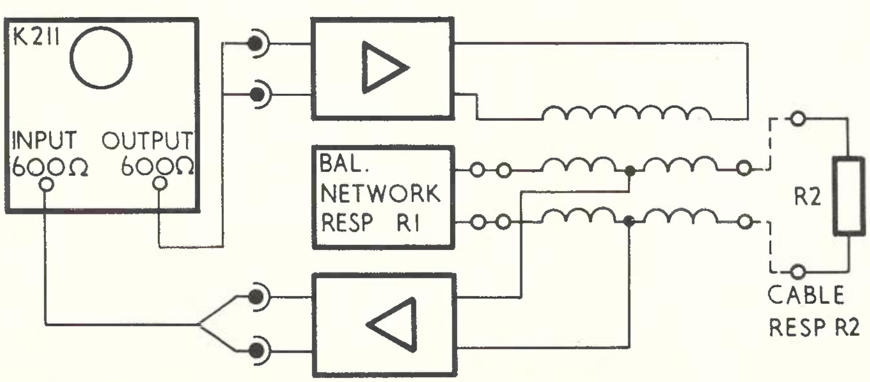

Fig. 10.—Return Loss Measurement on the 4-Wire Terminating Set by Measuring the Trans-hybrid Loss with the Level Tracer Used as a Conventional T.M.S.

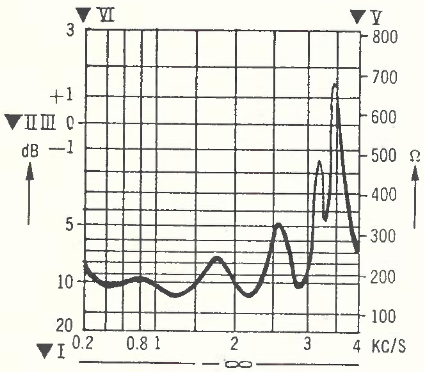

Fig. 14.—Impedance of Loaded Pair with the Sixth Loading Coil Omitted. Impedance Scale approx. x 7.

screen can be compared simultaneously because of the long persistence CR. screen. Such a method of fault location, using relatively unskilled technicians, can quite often result in big cost savings.

Special Applications

Repeater Line-up: Apart from the measurement of Overall Equivalent as described previously, the Level Measurement function of the Level Tracer is of great use for lining up VF repeaters, e.g., negative impedance or hybrid type repeaters.

Noise and Unbalance on Subscribers' Lines: Using the Impedance Measurement facility interfering voltages which may appear as a result of power induction, crosstalk noise, etc., can be shown up. Figs. 3 to 6 illustrate the impedance curves for both loaded and non-loaded pairs with a noise voltage (e.g., 50 c/s power induction) present.

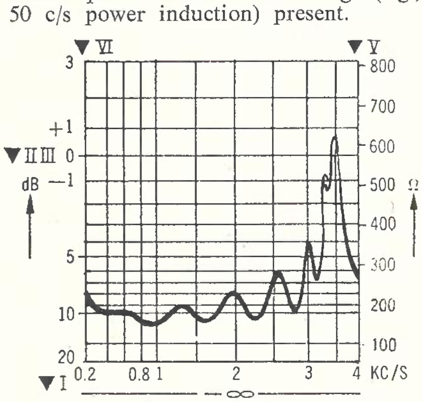

Fig. 15.—Impedance of Loaded Pair with the Eighth Loading Coil Omitted. Impedance Scale approx. x 7.

Such a noise voltage is usually induced because the cable pair is unbalanced with respect to ground (capacitance and/or resistance unbalance). This can be confirmed by firstly measuring the tip to ground impedance (see Fig. 4 as example) and then the ring to ground impedance (see Fig. 5). The vertical displacement of one curve with respect to the other is proportional to the amount of unbalance of the pair. The three position double pole switch shown in Fig. 7 (a) proves useful in practice for the measurement.

When noise due to an unbalance fault is to be simulated using an artificial line a simple noise source as shown in Fig. 7 (b) would be sufficient.

The presence of a noise voltage on a cable pair is apparent much more readily when displayed on a C.R.T. than when indicated on a pointer type instrument. The integrating characteristics of the pointer type instrument frequently fail to reveal the presence of such noise voltages, whereas the C.R.T., with its rapid writing rate, shows them quite clearly.

Aligning Four Wire Terminating Sets: In a typical alignment procedure (see Fig. 8) the initial balance is made

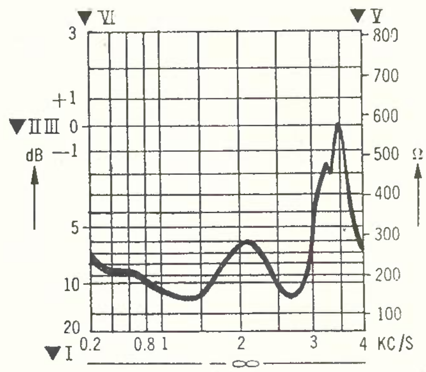

Fig. 16.—Impedance of Loaded Pair with Extra Loading Coil at Half Section between the Third and Fourth Loading Coils. Impedance Scale approx. x 7.

with the Level Tracer switched to "Impedance Comparison—X against N". The fine alignment is then made in the position "Return Loss"; a typical trace is shown in Fig. 9. The line under test and the balancing network each comprise one arm of the bridge in the Level Tracer.

When the balancing network is already installed in a four wire repeater or when the return loss of a trunk hybrid in a distant office is to be determined via a 4 wire line, the frequency response of the trans-hybrid loss can be displayed. In this case the Level Tracer is connected as a conventional transmission measuring set. (See Fig. 10.)

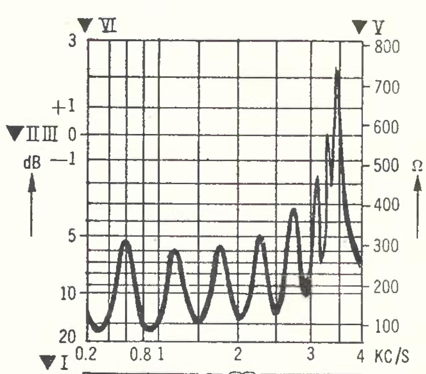

Fig. 17.—Impedance of Loaded Pair with Double Loading at the Ninth Loading Coil. Impedance Scale approx. x 7.

Acceptance Testing of Trunk and Exchange Cables: The Level Tracer provides an additional facility on new or repaired cables beyond the normal tests for Opens, Shorts, Crosses and Resistance Unbalance (possibly caused by faulty jointing). The following tests with the Level Tracer may be very useful:

(a) Measurement of Transmission Loss versus Frequency. This test can be made either as a loop or a route measurement. In both cases the cable must be terminated correctly. Fig. 11 shows a typical curve of the insertion loss characteristic for a correctly loaded cable.

(b) Measurement of Impedance versus Frequency. This test is particularly important for loaded cable since it allows the quick and accurate determination of faults such as: variation in coil spacing, missing or defective loading coils, erroneously installed coils, wrong type of coil (i.e., incorrect inductance or even wire gauge) and faults in the cable itself.

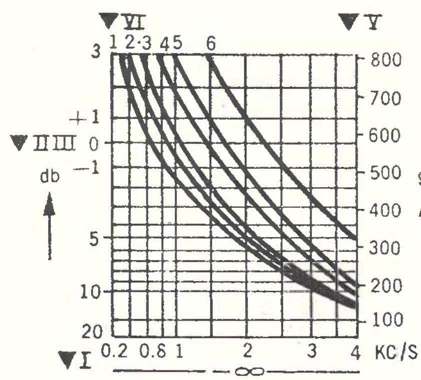

Fig. 18.—Impedance Characteristics of Non-loaded Pair when Unterminated. Impedance Scale x 2.

Curve 1	6,000 yards
Curve 2	5,000 yards
Curve 3	3,500 yards
Curve 4	2,500 yards
Curve 5	2,000 yards
Curve 6	1,300 yards

As an example of one of the above faults consider a loaded cable pair in which, say, the fifth loading coil is omitted. Using the Impedance test the trace shown in Fig. 12 results. One may note that the trace has four separate and distinct peaks. This is in accordance with the well known formula:—

No. of Significant Peaks = N — 1

Where N = The no. of the missing loading coil (as counted from the input end).

This formula evolved from the original point by point method of measuring impedance versus frequency. Another useful formula which evolved from the original method is:—

$$d = \frac{V}{2 \Delta f}$$

where d = distance to the irregularity
V = velocity of propagation
Δ f = frequency spacing between adjacent peaks.

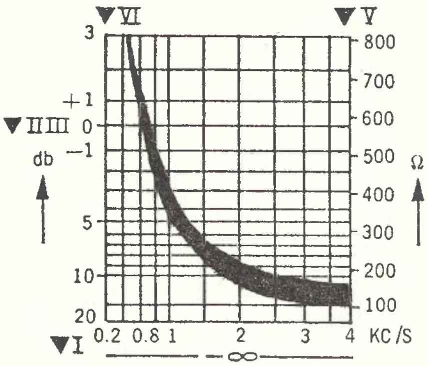

Fig. 19.—Impedance of Nonloaded Pair with Excessive Noise.

For comparison Fig. 13 shows the impedance characteristic of a loaded cable pair in good condition.

Figs. 14 and 15 illustrate further how the position of missing loading coils can be determined easily. Although quite an amount of experience is necessary before a technician can recognise complex faults, the use of an artificial loaded line can simplify matters a great deal. The curves shown in Figs. 16 and 17 are examples of more complex types of faults, which however can be usually simulated by an artificial cable kit (2) and hence still located.

As a note on the practical application of the impedance test to loaded cables, it should be said that the end section (normally half the length of a loading section) usually requires building out with a capacitance to about 0.8 of a full section. Measurement from both ends of a faulty pair naturally will add to the accuracy.

As further aids to fault finding on loaded cables the following tests may also be useful:—

(i) Measure the Return Loss of the cable input against the input of an artificial line. By adjusting this line for minimum return loss the fault can be quite often determined.

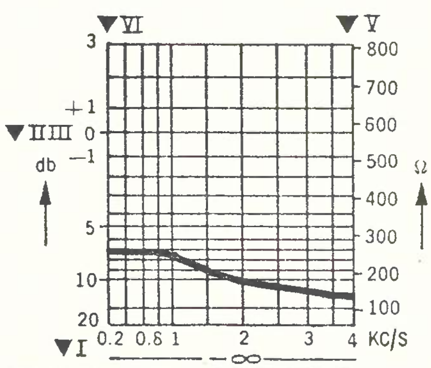

Fig. 20.—Impedance of Long Subs. Pair with Short at Subs. End.

(ii) Structural Return Loss Measurement. This is representative of the homogeneity of the cable pair and is defined by the difference between the input impedance of the actual line and the characteristic impedance of an ideal line.

Fault Finding on Subscribers' Lines with the Open Circuit Impedance Test: This test is often termed a "One Man Test" or a subscribers' "On Hook" test. As the heading implies this test is made without terminating the line at the subscriber's premises (i.e., telephone set remains on hook).

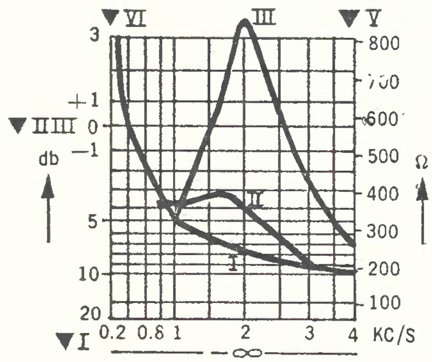

Fig. 21.—Effect of Loading Coils Left in a Nonloaded Cable Pair of Various Locations. Cable is unterminated.

Curve I—10,000 yds. of nonloaded cable.

Curve II—Loading coil at 5,000 yds. from measuring end.

Curve III—Loading coil at 2,000 yds. from measuring end.

Some administrations supervise subscribers' lines by measurements at a single frequency. However, since lines must increasingly be capable of data transmission, measurements throughout the transmission range have become necessary in many cases. Because of the large number of subscribers' lines, and the large related amount of work in making normal measurements, rationalized methods for fault tracing and locating have been developed. The essential problem is to detect and locate non-standard conditions.

Faults involving poor design, noise, crosstalk, etc., can be detected and located by matching displayed impedance curves with typical sample curves, such as:—

(i) the impedance characteristics of various lengths of non-loaded cable in the unterminated condition. (Fig. 18).

(ii) the impedance curve of a non-loaded line with excessive noise. Crosstalk has a similar appearance but will be highly intermittent. (Fig. 19).

(iii) the impedance curve of a long subs. line with a short at the subs end. If the short is nearer to the testing point, the impedance will decrease but the same general shape will remain. (Fig. 20).

(iv) the effect of loading coils left in a de-loaded cable at different locations. (Fig. 21).

CONCLUSION

This paper summarizes some important points in the development, the functions and many applications of a general purpose transmission measuring set featuring visual display of the quantity to be measured as a function of frequency.

ACKNOWLEDGEMENTS

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The permission to publish this paper given by the management of Siemens Halske Siemens Schuckert (Australasia) Pty. Ltd., is also acknowledged.

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NEGATIVE IMPEDANCE REPEATERS – PART II

*M. O'CONNOR, B.E.E.**

STABILITY OF NEGATIVE IMPEDANCE REPEATERS

It was shown, in Part I, that the following five factors prevented the hybrid 2-wire repeater from operating at a zero equivalent:—

(i) Reflections from the line terminations.

(ii) Irregularities of the equivalent over the pass band.

(iii) The "precision return loss factor".

(iv) The "structural return loss factor".

(v) The "image return loss factor".

It was also shown that by good design of equipment and layout, (i) and (ii) might be reduced to small proportions. (iii), (iv) and (v) are closely related to the care taken in designing and constructing the line, but even if the line construction is excellent even small deficiencies in these factors may be amplified by the bi-directional repeaters.

In the preceding sections, the negative impedance repeater was examined in sufficient detail to show that (iii) is not related to them. The other four items will remain (but sometimes to differing degrees) and another instability contributor is introduced which will be called the "difference image impedance factor". The implications of these various factors will now be discussed.

Reflections From Line Terminations: In the particular application where a line is to be amplified at a point remote from either end, no distinction can be drawn between the stability of negative impedance repeaters and hybrid repeaters. However, if the amplification is to be provided at the end or ends of a line then the hybrid repeater is less prone to instability. This is because the matching of a negative impedance repeater to the line termination cannot be as good as for the hybrid repeater since its image impedance is governed principally by the line characteristics rather than by the termination.

Irregularities of Equivalent over the Pass Band and Structural Return Loss: The variation of line insertion loss, structural return loss and amplifier gain are dependent upon the same considerations in circuits amplified by either negative impedance repeaters or hybrid type repeaters, and no distinctions can be drawn between these factors in their influence on the two types of circuit.

The Image Return Loss Factor: It was observed earlier that this factor arose in the case of 2-wire hybrid repeaters when a signal incoming to the repeater suffered a reflection due to the difference in the impedances of the line and the repeater, and that it would normally be a major cause of instability when more than one repeater is in a line. For the negative impedance repeater, where the concept of a precision return loss factor lapses, the image return loss also occurs for a signal outgoing from the repeater. In fact, in the latter regard, it has the same kind of effect that the precision return loss factor has in the hybrid repeater, but to a more pronounced degree owing to the absence of 'precision' networks accurately constructed to match the actual impedance of the line. Series or shunt repeaters suffer the disadvantages of this factor to a greater extent than series-shunt repeaters since the image impedance of these repeaters cannot be matched even approximately to the impedance of the line.

It has also been mentioned that the frequency characteristics of the image impedance and gain can be controlled by proper design of the networks and converters of the repeater. Fig. 17 (a) shows a typical network (Series type) and Fig. 17 (b) shows a typical frequency response of a converter (Series-type) when it is terminated in a non-reactive impedance.

It can be seen that a certain measure of matching of line to image impedance is obtained (it may be preferable to call this equalization), but this is largely in the hands of the manufacturer of the amplifier and not the installation or maintenance Engineer. As a rule, the manufacturer specifies settings of the networks for certain line facilities, and these settings accommodate both the gain response and the impedance characteristic. Consequently if it is thought that the impedance characteristic of a certain amplifier in a certain location could be improved, any adjustments must be done at the risk of upsetting the gain response, and possibly rendering the circuit unstable.

It can be concluded, then, that the image return loss factor would generally be worse on a negative impedance repeater than on a hybrid type repeater.

The Difference Image Impedance Factor: In a hybrid amplifier, the hybrid networks allow the impedance on one side to be controlled or "balanced" independently of the other side. Thus, in a terminal amplifier, one network is a compromise network for the various terminating impedances which may be switched to that end, while the other network is a precision network accurately tailored to match the line impedance at that point. In an intermediate amplifier, both hybrid networks become precision networks. There is consequently no reason why the transmission lines on either side should not differ in type and impedance.

However, the series-shunt negative impedance repeater is a perfectly symmetrical quadripole and its image impedance is the same looking from either side. Therefore, if it is wished to place the negative impedance repeater at the junction of two dissimilar transmission lines, a compromise image impedance will need to be devised which will not exactly match the impedance on both sides simultaneously at all frequencies. This limitation will not generally be serious, since probably the only differences in transmission lines that will be met will be changes of gauge and the impedance discontinuity in this case is not serious.

This factor is not really applicable to series or shunt repeaters since no attempt is made to match these repeaters to the line.

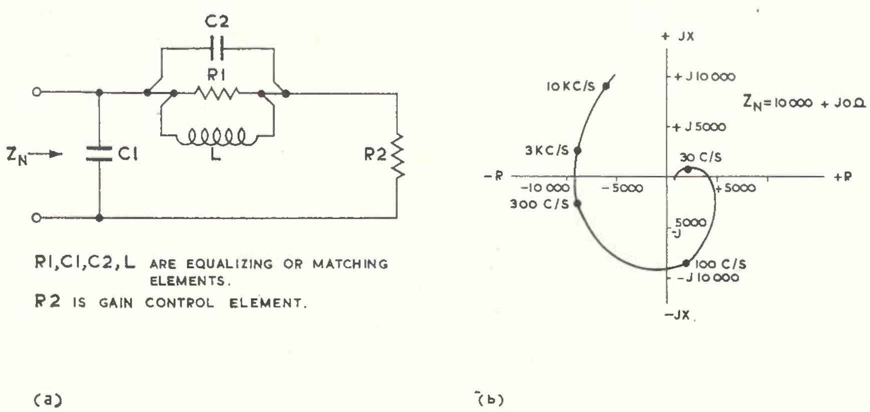

Fig. 17.—(a) A Typical Network for Terminating a Series Negative Impedance Converter. (b) A Typical Frequency Response for a Series Negative Impedance Converter Terminated by Z_N.

HYBRID OR NEGATIVE IMPEDANCE REPEATER?

The preceding sections have shown that there is little difference in the transmission performance of 2-wire hybrid repeaters and negative impedance repeaters; in fact, if the engineering practicalities are ignored, there is no theoretical difference in the transmission performance of these repeaters.

* Mr. O'Connor is Senior Engineer, Overseas Telecommunications Commission. See Vol. 14, No. 5/6, page 422.

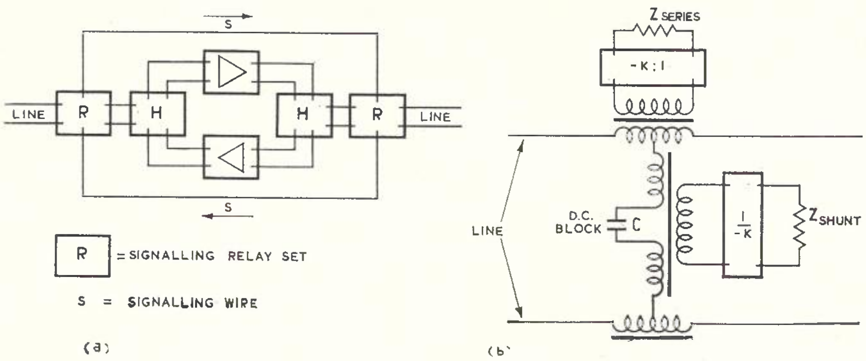

Fig. 18.—(a) 2-Wire Hybrid Repeater Equipped for Signalling. (b) Negative Impedance.

Generally, a circuit will provide a larger margin of stability if it employs hybrid type repeaters rather than negative impedance repeaters, assuming the amplified equivalent is identical in each case.

Despite this, no new 2-wire hybrid-type repeaters are being purchased for the Australian telephone network and their place is being filled by negative impedance repeaters. Furthermore, because negative impedance repeaters have advantages to offer, which were not inherent in hybrid repeaters, the former are being installed in locations where a hybrid repeater would never have been used. The reasons for this are discussed below.

Signalling: DC holding loops, D.C. signals (dial impulses, battery reversals, etc.) and low frequency signals are used on the great majority of the trunks and junctions which can employ 2-wire repeaters.

In the hybrid repeater, D.C. and low frequency continuity is disturbed firstly by the hybrid coils and secondly by the VF amplifiers which do not transmit any signals below about 100 c/s. This means that relay sets are required on both sides of the hybrid repeater to split the system into 2 talking wires and 2 signalling wires, the latter by-passing the actual VF repeater. See Fig. 18 (a).

In the negative impedance repeater, a typical schematic being shown in Fig. 18 (b), the signalling loop is only affected by the insertion of the series transformer winding and by the shunting effect of the condenser C. A typical value of DC resistance of the transformer winding is 80 ohms, and if C is kept low enough no serious impulse distortion will occur.

Fig. 18 (b) shows the more commonly encountered form of the negative impedance repeater (c.f. Fig. 9). The transformers are introduced mainly to enable more acceptable components to be employed.

Costs: Using present day prices as a guide, the cost of a hybrid repeater and its associated signalling relay sets would be approximately 50% more than a negative impedance repeater. The signalling relay sets represent the main price difference.

Installation: The installation cost of 2-wire hybrid repeaters is swelled by the need for precision networks. The design and assembly of these units is generally beyond the scope of the regular equipment installers and specialists in transmission measurements are usually required. The work normally entails taking impedance measurements of each section of every pair from both ends, devising a network of resistors, capacitors and inductances to exactly balance the measured impedance, and then checking and trimming the result by individual return loss measurements.

By comparison, negative impedance repeaters are usually supplied with their networks already tailored to a particular type of line without the means of adjustment, or alternatively, some manufacturers supply a range of components with each repeater, ready for strapping. This makes the installation of these units a relatively simple procedure.

Maintenance: Reference again to Fig. 18 will show that power failures have the effect of completely disrupting communication over a hybrid repeater. When the power to the negative impedance repeater fails, communication is not lost since the circuit continues to function but without amplification. Actually, there is usually a slight increase in loss over that of the passive line. Furthermore, the fact that the hybrid type repeater employs conventional one-way amplifiers with conventional screw driver or knob-type gain control is itself a hazard. Human error in routine line-ups, and the ease by which the need to fix a small line or relay circuit fault may be obviated by reducing the amplifier gain are two instances of this. In the negative impedance repeater, there is usually no simple provision for varying the gain after installation, and consequently human error would normally be a factor only on installation (where rigid checks are usually made anyway). Thus, maintenance of negative impedance repeaters is intrinsically easier and more reliable than that of hybrid repeaters.

PLANNING OF NEGATIVE IMPEDANCE REPEATER INSTALLATIONS

In view of the fact that negative impedance repeaters have only recently been introduced into the Australian network, it is premature at this stage to establish firm rules for the planning of circuits amplified with this type of repeater. It will be necessary to wait some years to gain experience and to see what advances in design of the equipment are made. Nevertheless, by adopting a policy which possibly errs on the cautious side, the principles discussed in the following paragraphs have been established.

Maximum Permissible Gain

Crosstalk: As with all VF repeaters, the crosstalk attenuation obtainable after a specified degree of capacitance (or admittance) unbalance elimination between all combinations of pairs in a cable is a necessary consideration regarding maximum gain. The usual minimum crosstalk attenuation obtained in a cable used for the provision of amplified trunks or junctions is 75 db. If a signal to crosstalk ratio of 55 db is allowable (this figure would generally be accepted) then the maximum VF power level difference which can be tolerated between two pairs in a cable is 20 db.

In Fig. 19, formula (a) is obtained showing the maximum permissible gain of a repeater for crosstalk reasons. Applying this formula to a 15 db line:—

(i) with the repeater in the centre, the maximum permissible gain is 20 db, and

(ii) with the repeater at one end, the maximum permissible gain is 5 db.

Therefore, from the crosstalk point of view it is always preferable to place the repeater as near as possible to the centre of the line.

Noise: The VF power level on the line cannot be allowed to approach the ambient noise level present on the line. In nearly all cables where negative impedance repeaters are used, dialling impulses will be transmitted which will bring the ambient noise level up to an average figure of about —60 dbm. Then allowing a minimum signal to noise ratio of 50 db, formula (b) is derived in Fig. 19, which shows the maximum line length permissible. Applying this formula:—

(i) with the repeater at the centre, the maximum line loss is 20 db, and

(ii) with the repeater at one end of the line, the maximum line loss allowable is only 10 db.

Therefore, from the noise point of view it is always preferable to place the repeater as near as possible to the centre of the line.

Stability: It has been shown above how an expression for obtaining the stability margin of a two wire repeater can be obtained as a function of image impedance and image attenuation of the amplifier and the line, and the impedance of the terminations. This expression would be rather complicated

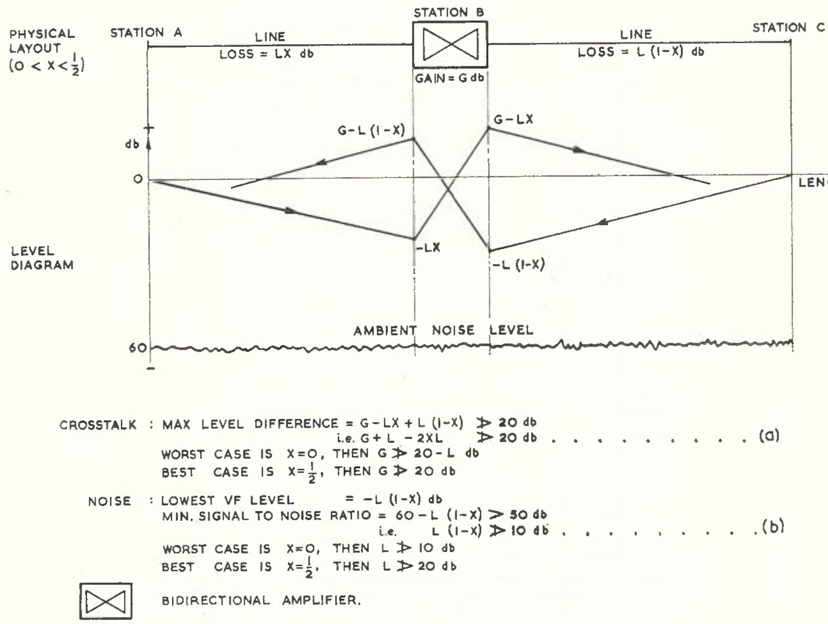

Fig. 19.—Crosstalk and Noise Restriction on Repeater Gain.

and it is possible to visualize the stability margin more clearly by considering simply the insertion gain of the repeater and the actual impedances seen by looking both ways from the repeater terminals. See Fig. 20.

It is easily seen that the repeater in Fig. 20 will oscillate when the sum of the return loss of Z_2 against Z_1, and the return loss of Z_3 against Z_4 is equal to or less than twice the gain G. Using the same symbols as before, this can be denoted as follows:—

Instability occurs when

$$R(Z_2/Z_1)+R(Z_3/Z_4)-2G \leqslant 0$$

If a margin of stability of 1 db is allowed when the worst terminating conditions are applied (open or short circuits), then for stability:—

$$R(Z_2/Z_1)+R(Z_3/Z_4)-2(G+1)>0$$

i.e. $G<\frac{1}{2}R(Z_2/Z_1)+\frac{1}{2}R(Z_3/Z_4)-1$ ....(9)

(Under talking conditions, when the terminating impedances are reasonable, this stability margin would be sufficiently great to ensure freedom from hollowness.)

Formula (9) will now be applied to a 15 db line equipped with standard relay sets, etc., (open or short circuit terminations could occur).

With the repeater in the centre: Under good conditions it could be expected that $R(Z_2/Z_1) \approx R(Z_3/Z_4) \approx 14$ db over all of the pass band except the fringes, and assuming that the gain of the repeater is reduced at the fringes such that the return loss at these frequencies is not controlling, then for stability:—

$$G < 13 \text{ db}$$

With the repeater at one end (say side A): It would be normal to expect $R(Z_2/Z_1) \approx 0$ (to allow for short circuits and open circuits from impulsing contacts or switchboards, say,) and $R(Z_3/Z_4)$ would undergo some modification but would still be approximately equal to 14 db as before. In this case, for stability:—

$$G < 6 \text{ db}$$

Therefore, from the stability point of view, it is always preferable to place the repeater as near as possible to the centre of the circuit.

Fig. 21 shows a typical manufacturer's claim for maximum gain. Since these curves would not allow much margin of stability and would assume excellent lines, the full gains shown would not be implemented. At present, the local practice is to provide circuits with an equivalent equal to approximately 1 db less than the allowable loss (i.e., a "6 db equivalent circuit" would be amplified to approximately a 5 db equivalent) provided that:—

(i) the gain does not exceed 0.6 times the passive loss, (when the repeater is to be situated near the centre of the circuit, this figure may be increased to about 0.7); and

(ii) none of the conditions previously formulated relating to Crosstalk, Noise and Stability is violated. The conditions relating to Crosstalk and Noise are easily enough accomodated but standards for return loss are difficult to assess.

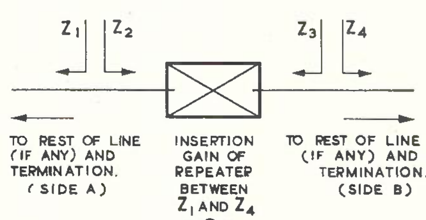

Fig. 20.—Repeater Under General Working Conditions.

To appreciate the implications of the return loss aspect, the nature of the impedances Z_1, Z_2, Z_3, Z_4 in Fig. 20 must be understood. The line impedances Z_1 and Z_4 will be similar to Fig. 11 (d) except that the terminating impedance can no longer be taken as 1,200 ohms. Allowance must be made for short or open circuit terminations, which, depending on the length of the line, will modify the impedance characteristic by introducing hills and dales (and in the worst case — terminal repeater — will make Z_1 or Z_4 zero or infinite). Z_2 and Z_3 would need to be the same as Z_1 and Z_4 under ideal conditions (cf. Equation (7)). These ideal conditions are that Z_1, Z_4 and the square root of the product of the series and shunt negative impedances are all equal throughout the pass band. This, of course, is impossible to achieve in practice and it is difficult to estimate by how much Z_1 and Z_4 will differ from the nominal image impedance of the repeater. Knowing these conditions and equipped with a set of return loss curves a reasonable guess can be made to determine return loss values to substitute in Formula (9). Unfortunately, it is this ill-defined return loss factor rather than the crosstalk or noise factors which is, in most cases, controlling.

Fig. 22 shows the unamplified and amplified insertion loss response of a typical series-shunt repeater installation. The bearer consisted of 20 miles of 20 lb. QL cable.
The aggravation of the hills and dales by the negative impedance repeater is fairly common. The overall flatness over the frequency band is a measure of how well the networks have been set up.

Line Construction

Types of Line: An examination of the costs of cable, open wire routes and amplifying equipment will show that, for economic reasons, negative impedance repeaters should only be used on loaded cable lines. Nevertheless, by providing the appropriate networks, it is possible to accommodate any kind of line; e.g., open wire, unloaded cable. (It should be observed, however, that temperature changes, wet and dry weather, dew, etc., make the operation of 2-wire repeaters impractical over open wire lines). Equations (5) and (7) demand that:—

$$Z_{series} \; Z_{shunt} = Z_o^2$$

where Z_o is the impedance of the line on both sides of the repeater. This places a theoretical limitation on the use of the repeater in that a break in the continuity of line impedance will upset its operation. However, since the design of the repeater installation can be engineered to accommodate even short or open circuits, it is also possible to accommodate minor breaks in the line impedance continuity and still have an echo free circuit.

In Victoria, the repeaters have only been used on loaded cable, the impedance of which is reasonably independent of conductor gauge. No experience has

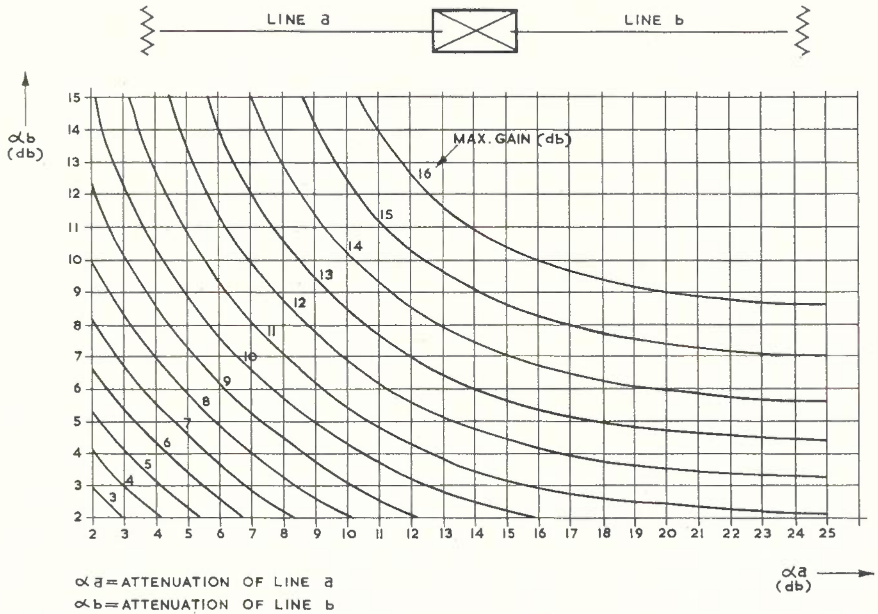

Fig. 21.—A Typical Manufacturer's Claim for Maximum Possible Gain Obtainable from a Negative Impedance Repeater under Various V.F. Loaded Line Conditions.
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been gained to date on what variations can be tolerated in coil spacing, capacitive or resistive building-out, mutual capacitance, etc., and therefore a cautious policy has to be adopted.

Coil spacing variations are being limited to 150 feet in successive sections within the range 5,700 feet to 6,300 feet and deficiencies of cable in full sections greater than 1,500 feet are being built out with both resistance and capacitance. (c.f. C.C.I.T.T. IInd Plenary Assembly, New Delhi, 1960. Recommendation G.543. "The nominal loading coil spacing in a repeater section shall be equal to the theoretical value within ± 2%. The actual loading coil spacing measured along a repeater section may differ by 10 metres from the nominal spacing.") The repeaters are being presented with a half loading section of line to the same percentage tolerances. For the time being, linear measurements of capacitance (i.e., based on .072 mircofarad/mile) are being used for line design purposes rather than electrical measurements, since it is expected that variations in mutual capacitance in cables will not influence the operation of the repeaters to any marked degree. These requirements should not place a large restriction on cable laying practices since cable is available in drum lengths of 500 or 1,000 yards. Consequently, in rural areas at least, by commencing laying operations from a loading point, almost exact 6,000 feet sections can be achieved.

Emergency or interim line arrangements such as using double loading to reduce loss or parallel pairs to reduce loop resistance must be treated with caution. The mid-section impedance of double loaded cable (i.e., 88 millihenry per 3,000 feet section of parallel pairs) is almost the same as the mid-section impedance of a normal loaded pair and therefore these circuits may be amplified in the normal way. However, a repeater placed in a line consisting of two parallel loaded pairs would see only half the required line impedance and therefore would not function properly. Paralleling two amplified loaded pairs, with the two amplifiers near the centre of the lines, does give a reasonable circuit.

City Junctions

A crossbar network provides an excellent field for the use of negative impedance repeaters in that first choice routes are generally direct junctions having a loss requirement of about 10 db. These could well consist of very light gauge conductors with a passive loss of about 20 db. For late choice crossbar junctions and step-by-step network junctions where the loss is generally required to be smaller than 6 db., the use of negative impedance repeaters becomes more difficult. This follows from the earlier discussion above where it was shown that return losses obtainable at the terminals of the repeater will be worse due to the shorter line length. The main effect of this is to exclude negative impedance repeaters from the trunk exchange to main exchange links which usually require to be not more than 2 db. (This is to the advantage of the trunk network since 4-wire circuits terminating at the Main Trunk Exchange will not be switched to circuits with a low margin of stability which would induce echo and hollowness into the overall connection.)

CONCLUSION

The attractive cost of a trunk or junction equipped with the two-way 2-wire voice frequency amplifier called the negative impedance repeater makes it likely that many thousands of these units will be installed in Australia over the next few years. The following summarises the more important properties of negative impedance repeaters.

Planning:

(i) The repeaters have instability characteristics similar to the hybrid 2-wire repeater (e.g., 'type 22') and in like installations are probably slightly inferior to them. By careful engineering, and using the repeaters only on circuits for which they are intended, these instability characteristics can be overcome.

(ii) It is preferable to locate the repeater as close as possible to the centre of the line to obtain optimum gain, crosstalk, signal to noise ratio and freedom from hollowness. If this is not possible, the repeaters should be located towards the end of the circuit distant from the switching centre. If the repeaters are located at the switching centre two repeaters could be connected next to each other in tandem when two amplified trunks are switched together. Crosstalk would be the limiting factor in this case but in some circumstances such an installation may be acceptable.

(iii) Although they are suitable for most types of transmission lines, economic factors limit their use to loaded cable. Therefore, there will probably be no application for the use of the repeater in the subscribers' network. However, the presence of continuous DC through a repeater (e.g., transmitter current) would not affect its performance.

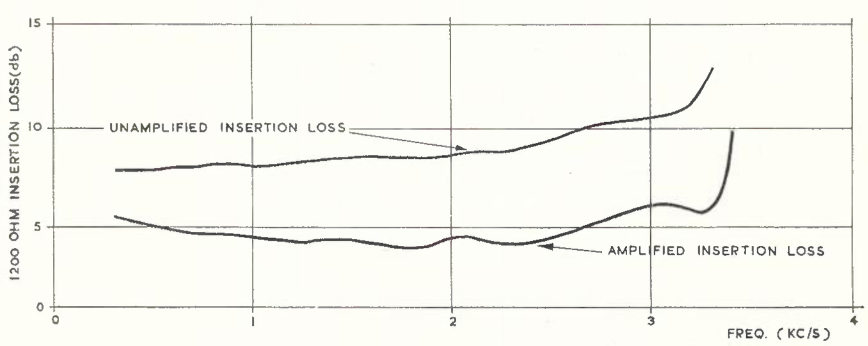

Fig. 22.—A Typical Response of a Line Amplified with a Negative Impedance Repeater (Wentworth-Mildura).

(iv) The repeaters have little effect on the DC loop resistance, but since they are employed to advantage on long light gauge cable pairs, the limitations of DC signalling equipment restrict their use to a certain extent. Voice frequency signalling systems, if introduced, would partially eliminate this restriction.

(v) Negative impedance repeaters are used in tandem overseas and more experience will be required locally to see whether such a scheme can be used in Australia to advantage.

(vi) When allocating pairs in a cable which is to provide both amplified and unamplified circuits, crosstalk will be minimised if two amplified circuits are not allocated to the one quad. (In 4-wire amplified working, the four wires of each circuit are contained in the one quad so that the within quad crosstalk, whch is about 10 db worse than quad to quad crosstalk, will only appear as echo.)

(vii) The maximum gain which can be obtained from a negative impedance repeater while still retaining a circuit free from hollowness is, in general, about 0.6 times the passive loss. If the amplifier is placed near the centre of a well constructed line, the gain could be increased to about 0.7 times the passive loss. If the amplifier must be operated at the end of a circuit the gain should be reduced to about 0.5 times the passive loss.

Installation:

(i) The repeaters are physically very small (typically mounting 8 repeaters to a 3¼" x 21" panel) and they require no auxiliaries such as dial round relay sets, etc.

(ii) The power supply for transistorized repeaters is usually 12 volts DC, eight repeaters requiring typically 1.5 watts. Power feeding along a cable pair can be accomplished easily.

(iii) The repeater must be installed on a well constructed line. The quality of the line is best checked by ensuring that the insertion loss (1,200 ohm) versus frequency characteristic is free from hills and dales. The installation staff should check this point before attempting to "line up" the repeaters since if the line is faulty (e.g., loading coil errors, split pairs, etc.) the repeaters will almost invariably oscillate.

(iv) Specialised transmission staff is not required to set the repeater networks.

Maintenance:

(i) Routine line-ups are eliminated to a large extent since the gain is controlled by internally fixed connections when the units are installed. However a system whereby hollowness, power failure, etc., could be regularly checked would have to be instituted since the lines would still be workable under these fault conditions.

(ii) Being DC operated, power failures would seldom be a problem. However, in the event of a break in the power supply, transmission is not interrupted but suffers an increase in loss of about 5 db.

ACKNOWLEDGEMENTS

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[**Editorial Note:** Part I of this article appeared in Vol. 14, No. 5/6 of the *Journal*. The author has advised that the use of the term "real part of" in the derivation for the gain of the series—shunt repeater on page 382 is an error. The correct term is "modulus of".]

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STRAIN GAUGES IN MATERIAL TESTING AND DESIGN

D. MACQUEEN, A.M.I.Mech.E., A.M.I.E.Aust.*

INTRODUCTION

Electrical resistance strain gauges were invented in 1930 and have been improved and cheapened to such an extent that they are now common engineering tools. With them it is possible to directly measure the strain, and therefore the stress, at any required point on almost any item. They have been used in gas turbines at 1,000°F, in rocket engine fuel tanks containing liquid oxygen, inside concrete dams and even on machinery rotating at 60,000 r.p.m. Doctors, investigating strain in bones, have bonded gauges to human skulls and other bones. Their application to any problem in the measurement of strain is limited only by the imagination and skill of the experimenters.

The following is an outline of the theory of the gauges and of the application to recent problems in the Postmaster-General's Department. Readers requiring extra information on strain gauges are recommended to study Reference (1).

STRAIN GAUGES

General

In many engineering design calculations, the relationship between load and stress can be determined with reasonable accuracy by well known formulae. However, cases often arise where the loads themselves are only known approximately and/or where the theoretical relationship between load and stress is either very difficult or even impossible to calculate accurately. In these cases empirical designs embodying large factors of safety are normally applied. Such designs are likely to range from ultra conservative to inadequate and, either way, result in high costs. These deficiencies would, in some measure, be eliminated if means could be devised to check the stress at any point in an article under its service or simulated service load. A complete solution to the problem is not available but strain gauges provide an extremely useful means of measuring the strain at any point on the surface of an article and thence, if the Tensile Modulus (E) of the material is known the stress can be calculated. Experimentally determined values for E for most materials are readily available.

A strain gauge contains a very fine wire looped backwards and forwards to form a flat grid. The grid is cemented to a thin paper base. In use the gauge is itself cemented to the required area on the surface of the article being tested and the strength of the cement in the gauge and between the gauge and the surface is such that when the article is loaded in any way the wire of the gauge is stretched or compressed exactly the same amount as the surface. This requires high quality adhesives, carefully applied. The straining of the wire changes it electrical resistance; the change is proportional to the change in the length of the gauge and therefore to the strain at the surface below the gauge.

Gauge Factor

The gauge factor (F) is defined as the ratio of the change in resistance to initial resistance divided by the ratio of the change in length to the initial length i.e.

$$F = (r/R)/(l/L)$$

where R and L are the initial resistance and length and r and l are the changes in resistance and length respectively.

F is therefore a dimensionless quantity and it varies for different wires; it may even be negative. It is determined experimentally by the gauge manufacturer and is stamped on the gauge. The most common general purpose gauge uses "Advance" wire, a nickel-copper alloy, and has a gauge factor of 2.1.

In using the gauge we are determining the strains, which is, in fact, the ratio l/L and therefore,

$$S = r/RF$$

The strain is always very small and is usually expressed as microstrain.

$$S = (r/RF) \times 10^6 \qquad (1)$$

Instrumentation

A typical gauge has a resistance of 100 ohms, a gauge factor of 2.1 and the microstrain may be as low as 100. Then the resistance change from equation (1) is 0.021 ohms. Measurement of this change must be accurate to within ± 0.001 ohms for the strain, and therefore the stress, to be accurate to ± 5%.

This order of accuracy is readily achieveable by using a Wheatstone bridge. The bridge is balanced with the gauge unstrained and when the gauge is strained the output voltage is proportional to the strain. For rapidly changing (dynamic) strains, the output can be amplified and displayed on a cathode ray oscilloscope or recorded directly by a pen recorder. In all cases it is usual to calibrate the output display or record to show the microstrain directly.

Temperature Compensation

Strain gauges, by virtue of their construction, are temperature sensitive as well as strain sensitive. It is only necessary to touch a gauge for a few seconds with the hand when the bridge has been balanced, for the indicator to record an apparent strain of several microstrain. To cancel any temperature effect on the strain gauge, two similar gauges are used in adjacent arms of the bridge. One of these, the active gauge, is mounted on an unstressed piece of the same material. The two gauges are located close together so that both are subjected substantially to the same temperature, the net effect of temperature changes being zero.

Type of Gauge and Application

There are several hundreds of different types of electrical strain gauges on the market to cater for specific conditions. They are easily installed on either flat or curved surfaces, are almost without mass when compared with the test material and are linear in response. They are made in various lengths down to as small as 1/16 in. long and a few thousandths of an inch in thickness. Those most used in the Department are about 1 in. long, ½ in. wide and 1/32 in. thick. Various bonding agents are available but the most easily obtained are the epoxy resins which, with suitable hardeners, enable a gauge to be used one hour after being attached to a specimen.

Determination of Stress

When the output of the bridge is calibrated to read the strain directly, the only additional information required is the Tensile Modulus (E) of the test specimen then:—

$$\text{Stress} = \text{Strain} \times E$$
$$= \text{Microstrain} \times E \times 10^{-6}$$

Thus for steel,

$$E = 30 \times 10^6 \text{ lbs./sq. inch}$$

and therefore,

$$\text{Stress} = 30 \times \text{Microstrain.}$$

For measurement of stresses under static conditions, manually balanced bridges calibrated to read the percentage resistance change are used and, from equation (1), the relationship becomes:—

$$\text{Microstrain} = (10^6/F) \times (\text{Percentage Resistance Change}/100)$$
$$= (10^4/F) \times (\text{Percentage Resistance Change}).$$

Strain gauges only allow stress *changes* occurring after the gauge is installed to be determined. They give no indication of the stress in the specimen prior to the attachment of the gauge.

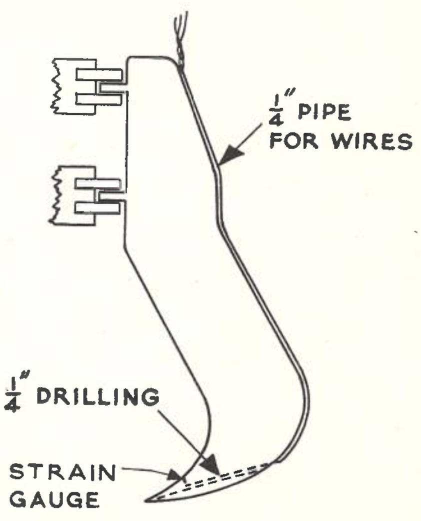

Fig. 1.—Strain Gauge Attached to Cable Plough Tine.

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*Mr. MacQueen is Engineer Class 2, Automotive Plant Section, Sydney. See Vol. 13, No. 6, page 501.

APPLICATION OF GAUGES

Some examples of the way strain gauges have been used in the Australian Post Office are described below.

Impact Loading on Ploughing Tines

There is no accurate method of calculating impact loading. Direct recording of the value with dynamic recorders is the only satisfactory measure. An ideal application for dynamic strain gauge tests is the determination of the value of impact loads on tines used for cable ploughing when the tine or tractor is suddenly brought to rest by the tine hitting a buried rock. According to the information available at the design phase, two tractors of 30,000-40,000 lb. drawbar pull used in tandem, with a ploughing speed of about 2 mph., required a tine about 3 in. wide and 3 ft. to 4 ft. deep (2).

Even using an ignorance factor for impact as high as 10, this presented no stress problems in the main body of the tine. However, at the change of section, where the tine comes to a point, it was impossible to find a steel to carry the theoretical stresses. To test the theory, however, and to discover exactly the stresses set up in use, the best available steels were used to build a test tine. A recess was ground on the face of the tine and a gauge attached (Fig. 1); a cover plate was placed over the recess and lead wires brought through the tine in a previously drilled hole and then up the back in conduit to the recorder.

This tine failed on test by twisting before impact tests could be carried out. It was found that this was due to stress relieving not having been carried out properly during manufacture. Repaired and tested again, this tine performed satisfactorily. With two tractors used in tandem, each with a drawbar pull of between 30,000 and 40,000 lbs. travelling at 2 m.p.h. and the combination brought suddenly to rest by the tine striking a buried rock, the impact load measured was between 170,000 and 200,000 lbs. Repeated tests confirmed these figures which were a far cry from the factor of 10 considered in the theoretical study.

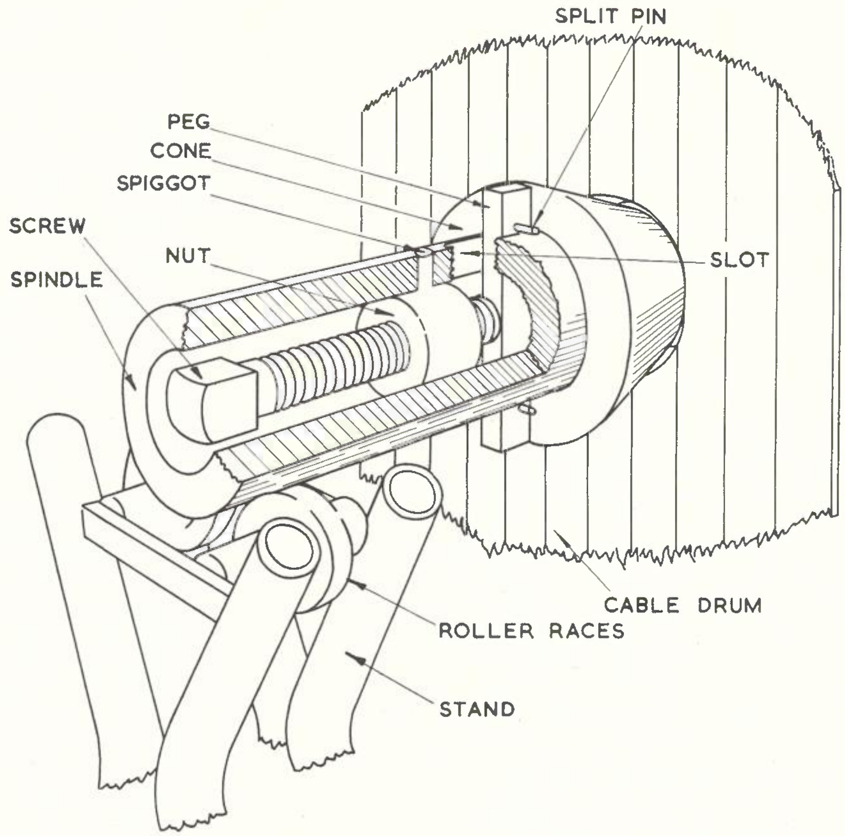

Fig. 3—Tubular Spindle for 8 Ton Cable Drum.

The stresses encountered could be covered by commercial steels, and there have been no tine failures in any of the tines subsequently built for cable ploughing.

Chassis design for Cable Carrying Vehicles

Static stresses in regular sections of vehicle chassis are among the simplest of engineering calculations. The dynamic stresses, however, are a different matter for not only is there the load transfer from side to side when cornering, but there is the flexing of the members because of the changing load distribution through the spring hangers all the time the vehicle is in motion.

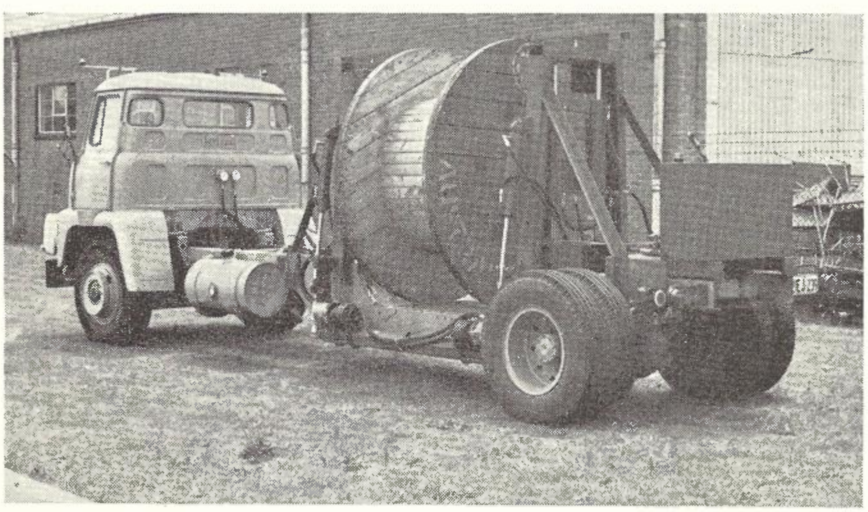

Fig. 2.—7 Ton Capacity Cable Drum Transporter.

Until recently, the heaviest cable carrier specifically designed for this purpose had been the 3½ ton cable trailers. With the advent of larger cables, longer lengths of cable haul and heavier drums, the need has arisen to design and build 7 ton special purpose cable handling vehicles (Fig. 2). The requirements were for a vehicle under 25 feet in length, with a tare weight of approximately 5 tons, to enable a seven ton load to be carried within the Road Traffic Act requirements of a maximum load of 8 tons on the rear axle and 4½ tons on the front. A standard vehicle of the required load carrying capacity was used but it was necessary to lengthen the chassis to give the correct load distribution over the axles when carrying full load; at the same time the centre section of the chassis had to be lowered to give the lowest possible centre of gravity.

Because of the compound stresses at the change of level of the chassis, strain gauges were used for the stress analysis in the various planes. The tests were carried out in three parts.

(i) With the bare, unreinforced chassis lengthened and dropped, and then placed under load to discover the stress figures and indicate the reinforcing required.

(ii) With the chassis reinforced as indicated by test (i).
(iii) Dynamic tests on the road under full load and overload.

In the first test an eight ton load was used supported on rolled steel joists extending over the width of the vehicle, these in turn being carried on jacks. By means of the jacks the load could be lowered and raised gradually, giving any desired loading on the chassis up to eight tons. The elastic limit of the steel used in the chassis extension was 48,000 lbs./sq. in. and when the load was finally placed on the chassis the maximum stress recorded was 45,000 lbs. From the stress diagram now drawn up, reinforcing was carried out as indicated on them and the maximum static stress brought down to 8,000 lbs./sq. in. in the chassis when carrying an eight ton load. Following this, dynamic tests were carried out using the same load, and at a speed of 30 m.p.h. the stress was 14,000 lbs./sq. in. which is well within the limits for the steel used.

Cable Drum Spindles

The cable drum spindles used for many years in the Department were made from 2½ in. and 3 in. diameter shafting screwed at one end. In use the spindle is pushed through the centre hole of the drum, a tapered collar pushed over the spindle and locked to it close to the drum cheek, and a second collar screwed up the spindle thread until the drum cheeks are locked to the collar and spindle. The external screwed spindle has disadvantages in use:—

(i) The external thread is subject to damage caused by careless handling.
(ii) Because of the comparatively narrow mountings for the drums, dictated by statutory vehicle widths, accurate placing of the cable drum in the mounting is essential to avoid damage to the "tail" of the cable. When a crane is used to lift the cable drum into the mounting, or the trailer is backed on to the drum, a time consuming process is necessary to adjust the position of the drum to within an inch or two of a desired position.
(iii) A 3 in. diameter mild steel shaft spindle about 6 ft. long is difficult for a man to handle, particularly as it has to be pushed through two holes, each less than 4 in. in diameter and 4 ft. apart.
(iv) Spindle mountings are between 5 ft. and 6 ft. apart. The stresses set up in a 2½ in. diameter mild steel spindle carried between centres 5 ft. to 6 ft. apart become excessive if cable drums weighing much over 4 tons are carried on them. The problem of stress could be overcome by using high carbon steels, but as a safety measure, mild steel is used wherever possible to lessen danger of metal fatigue.

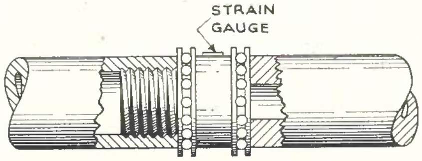

Fig. 4.—Drill Rod Test.

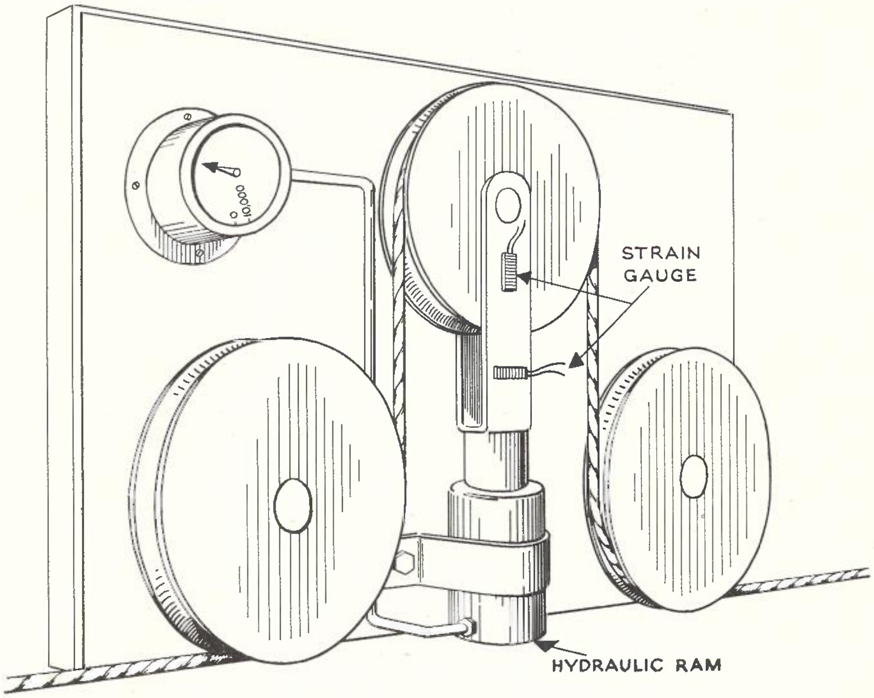

Fig. 5.—Strain Gauge Attached to Cable Hauling Dynamometer.

The design finally reached is the spindle shown in Fig 3. This is a 3 in. diameter mild steel hollow spindle, screwed internally which has none of the disadvantages of the old spindle. It can be handled by one man and is suitable for 7 ton drums. Accurate placing of the drum in the mounting can be carried out by slackening and tightening the screws by turn, allowing the cable drum to slide along the shaft.

Calculation for the design was straightforward except for the stress concentration round the slots. The stress analyses here were carried out using strain gauges. The maximum stresses recorded were 12,000 lbs./sq. in. static and 18,000 lbs./sq. in. dynamic when paying off cable and 28,000 lbs./sq. in. when the load was carried by the spindle in a vehicle travelling at 30 m.p.h. Normal practice, however, when transporting 7 ton drums, is to carry them on the tray of the vehicle, with the spindle used only as a locking device. This keeps the stresses within safe limits and allows an ample margin for careless usage.

Drill Rods

Among the first problems encountered when designing horizontal drilling machines was that of failure in the drill rod threads. Because the weight of the rods has to be kept to a minimum for manhandling, it is essential that the lightest drill rod and coupling thread be used. Although torque testing of the rods themselves is comparatively simple for the static torque, the determination of the screw thread stress involved the measurement of the friction on the inclined plane of the screw thread, thus:

Compressive load in screw coupling

$$= \frac{2 \pi T}{P + 2 \pi \mu r_s}$$

Where T = Applied torque
P = Screw thread pitch
μ = Coefficient of friction
r_s = Radius of thread

The method involved a collar made to slip over the male thread, with strain gauges bonded to it, thrust races being inserted at each end of the collar (Fig. 4). From the strain gauge readings, the ring up force, or the compressive load to which the threads were subjected, was measured and eventually the stress calculated.

Surging in Cable Hauling

The term 'surging' in this context is the sudden intermittent rise and fall in the tension required to haul a length of cable into a duct over and above that tension which is due to friction between the cable and the duct. It has four sources:—

(i) Uneven running of the engine driving the winch.
(ii) Because the co-efficient of friction is not uniform along the length of the duct, a changing tension results. At slow speeds the cable can be seen momentarily starting and stopping. However, above a critical velocity, yet to be determined, this can be more or less eliminated.
(iii) Misaligned ducts, where a surge is generated when the end of the cable strikes the end of the misaligned duct. This surge can be practically eliminated by having a tapered guide over the end of the cable.

(iv) The non uniform co-efficient of friction between the winch capstan and the hauling rope. This comes about in two ways:—
 (a) From the capstan design itself.
 (b) From the changing co-efficient of friction of wet and muddy ropes, the co-efficient of friction changing as the water and mud are forced out.

In practice the surging can be seen in the rope itself as well as on the hydraulic tension meters fitted to cable hauling winch trucks, but the magnitude of it and the sources generating it are difficult to assess from a visual examination.

For the preliminary tests, pressure transducers were used and then a differential transformer both associated with a short persistence screen cathode ray oscilloscope. These proved unsatisfactory and finally electrical strain gauges were used attached to the standard hydraulic tension meter, the meter having been drained of oil for the initial tests to ensure that there was no cushioning effect from air trapped in the oil chamber (Fig. 5). A single channel dynamic strain recorder and paper tape were used for recording measurements. The assumption made here was that for practical purposes, the strain in the pulley support was directly proportional to the rope tension. The tests carried out were as follows:—

(i) Conventional cable hauling, i.e. hauling lengths of cable through ducts, using a winch capstan driven from the engine, the winch rope taken up on a hand operated take up spool. The total surge from all sources was recorded, as well as the engine surges which were recorded separately by a tachometer.

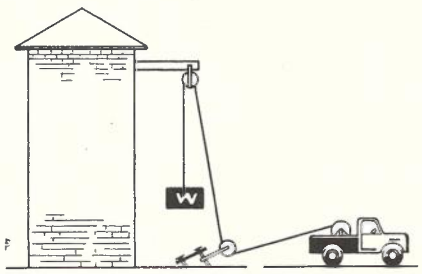

Fig. 6.—Test of Surge-free Load.

(ii) Using the same winch as in the first test, a weight on the winch rope was suspended from a pulley and the surge due to the capstan and mechanical drive measured (Fig. 6). By using this method a surge free load was provided, the surges being generated by the engine and capstan only.

(iii) Using a test similar to (ii) but using a hydraulic winch, which for all practical purposes eliminated surges generated by the engine.

(iv) Using the centre drum of the winch, cables were again hauled through ducts and the surge and tension recorded. This was to determine if, when hauling above a determined critical speed, all surges except those due to faulty running of the engine were eliminated.

Although some of the results from the surge tests have still to be evaluated, the immediately available information shows conclusively that the largest single source of surging is the use of the hand operated take up spool. When this had been highlighted, further tests showed that a minimum tension of between 200 and 300 lb. was necessary between the capstan and take up spool to sustain a practically surge free pull of 5,000 lb. from the capstan. This is a far higher tension than can be sustained on a manually operated spool.

CONCLUSION

For mechanical and civil engineering design work and inspection, electrical strain gauges are becoming as common engineering tools as slide rules and mathematical tables and their advantages cannot be over-rated. Their use, as has been mentioned, is not confined to the direct measurement of strain and they can be incorporated in other devices such as transducers. The application of the bonded filament strain gauge to any problem is limited largely only by the imagination of the experimenters.

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ARTICLES BY P.M.G.'s DEPARTMENT STAFF APPEARING IN OTHER JOURNALS

Progress in Planning a World-wide Automatic Telephone System*

By I. A. Newstead, D.I.C.(Lond.), B.A., B.Sc., A.M.I.E.Aust., and G. E. Hams, B.Sc., A.M.I.E.Aust.

The completion in December, 1963, of the Commonwealth submarine cable, COMPAC, linking Australia, New Zealand and Canada marks another milestone in the rapid development in international communications. Recognizing the pace of these developments, the International Telecommunication Union has for the past few years been actively engaged in developing plans for a world-wide automatic telephone system. This paper reviews the progress made in this work.

Use of Electronic Computers in Telephone Traffic Simulation Studies*

By J. Rubas, Grad.I.E.Aust.

Many traffic engineering design problems arise in the more complex telephone switching systems, which cannot be solved analytically, and "Monte Carlo" simulation methods must be resorted to. The development of large, high speed electronic computers has provided a new and powerful tool for traffic simulation, largely superseding earlier simulation techniques. The paper describes the essential elements of a computer telephone traffic simulation study employing 7090 FORTRAN compiler, and discusses some of the results obtained.

* These are abstracts of articles appearing in the Nov., 1964, issue of the Electrical and Mechanical Engineering Transactions of the Institution of Engineers, Australia.

DRAFTING ASPECTS OF CROSSBAR SWITCHING

C. J. WALKER, C. L. DALTON* and W. H. FREEMAN***

INTRODUCTION

In presenting some aspects of the impact on the Drafting Sections of the Postmaster-General's Department of the introduction of crossbar equipment, it is considered preferable, owing to the divergence of drafting requirements between the Headquarters Drafting Section and State Drafting Sections, to differentiate between the two areas. Accordingly, this paper is presented in two parts, Part 1, the Headquarters contribution by Messrs. C. J. Walker and C. L. Dalton, and Part 2, that of the State Drafting Section, by Mr. W. H. Freeman, Drafting Section, Sydney.

PART 1.

HEADQUARTERS CONTRIBUTION

Introduction

At the outset, discussions were held between engineers of the Australian Post Office Telephone Equipment and Drafting Sections and L M Ericsson company representatives with the intention of establishing a satisfactory method of producing circuit drawings, on a suitable transparent medium, for distribution to all States in unprecedented numbers and in a minimum of time. Transparent prints are supplied by L M Ericsson and as an interim measure it was decided to use these transparencies as A.P.O. drawings in the 'CE' and 'CEA' series by adding 'change' and 'issue' columns, etc. Such a practice is really only suitable where the transparencies have been taken from new or like new originals. As this is not always possible a number of transparencies, which are only considered to be of minimum standard, are being distributed to the States. Doubtful transparencies are sent to the print room where a test portion is printed on to transparent paper and a dyeline made from the transparent paper. By this means, the probability of the States being sent transparencies from which it is not possible to obtain satisfactory prints is reduced to a minimum.

All crossbar drawings are marked indicating that they are subject to a more restricted distribution than is normally the case.

The two Drafting Sub-sections mainly affected by the introduction of the new equipment are the Circuits Sub-section and the Telephone Equipment Sub-section.

Circuits Sub-Section

Circuit drawings are allotted numbers in appropriate categories in the CE-14000, 15000 and 17000 series.

L M Ericsson circuit drawing practice provides for the circuit drawing and the corresponding Technical Data drawing to have the same number. From an A.P.O. point of view such a practice has many disadvantages and a new drawing prefix CEA has been introduced. The CEA drawing proformas were devised to follow the L M Ericsson pattern with spacing suitable for insertion of typewritten data. The sheet numbering provides for a sheet No. 0 which is a Drawing List with issue numbers and history of changes. Technical Data for relay sets is mostly provided by L M Ericsson together with circuit diagrams, but in cases such as rack circuits and some locally developed relay sets the necessary information must be compiled by the A.P.O.

Minor mounting assemblies are included on Technical Data sheets to enable circuit drawings to closely control all modifications. Thus the circuit draftsman with his knowledge of the components involved is able to complete the drawing requirements for most circuit modifications and the corresponding structural drawings need only be affected by circuit changes which involve major structural alterations.

Circuit diagrams presented by L M Ericsson are mostly shown in "semi-attached contact" form in contrast to the "detached contact" system used by the A.P.O. and do not provide the same information found on routed schematic circuit drawings. To obtain wiring information for each unit it is necessary to consult Technical Data sheets, terminal diagrams and running lists. Component positioning is provided by coding on the Technical Data sheets and in the case of racks and wall frames, by layouts on the circuit diagram. Technical Data sheets include the component descriptions and quantities per unit. Terminal appropriations and jack wiring are catered for on rack and installation wiring diagrams.

Redrawing of many circuit drawings to conform with A.P.O. circuit drawing standards would have taken more time than could be allowed and was not justified in view of the time and expense involved and the likelihood of error. Fortunately, the interest displayed in the new equipment by technical staff at all levels following the introduction to crossbar equipment at Templestowe, Toowoomba, etc., confirms the opinion held by many that the change in circuit drawing language to the L M Ericsson standard would not present a major problem.

Telephone Equipment Sub-Section

The metric system of dimensioning was adopted by the A.P.O. to ensure that the basic L M Ericsson dimension (Metric) is maintained on the equipment.

Initially the sub-section produced assembly drawings for ARF and ARK type racks, associated equipment and rack superstructure. These drawings are not intended to be used as manufacturing drawings, but primarily for acceptance, identification and purchasing purposes.

The possibility of using L M Ericsson drawings as A.P.O. originals was considered and discarded. L M Ericsson rack drawings with specification sheets are intended for international use and therefore are a general presentation to cover a wide variation in positioning, size, quantities, etc. Showing a number of variants on one drawing can be confusing because the drawing is not representative of any particular rack of equipment. L M Ericsson rack specification sheets were of course automatically excluded from the A.P.O. system when it was decided not to use L M Ericsson rack assembly drawings. Instead, data extracted from the L M Ericsson specification sheet appears on the A.P.O. assembly drawing and Technical Data sheets.

The sub-section has adopted the following procedure regarding preparation of Technical Data sheets. A Technical Data sheet in draft form is prepared from the L M Ericsson documents and forwarded to the Supervising Engineer, Telephone Exchange Equipment Section, together with the check print of the rack assembly drawing for initial inspection. When approved, the draft is returned to the Drafting Section for further subdivision by the Circuit Subsection. Ultimately this portion of the Technical Data Sheet is included with the CEA drawing. Subsequent amendment affecting mechanical components appearing on the Technical Data sheets is done by the circuit draftsman as previously mentioned.

To speed the production of rack assembly drawings which would have been delayed considerably if A.P.O. drawings of crossbar piece parts were to be issued first, reference is made to L M Ericsson numbers. These L M Ericsson numbers will gradually disappear from subsequent issues of the A.P.O. drawings and will be replaced by a reference to the equivalent CE drawing.

Drawings have been produced which are intended to facilitate the calling up and identification of various sub-assemblies and electrical components on Technical Data sheets. These sub-assembly drawings are intended as an interim measure, and give L M Ericsson reference only. Ultimately they will be included in the Minor Equipment group of CE drawings as individual drawings.

Although the preceding paragraphs have dealt with rack assembly drawings, it is anticipated that a similar system of drafting procedure will be adopted when preparing relay set assembly drawings and other minor equipment drawings. Relay set Technical Data sheets already issued with the circuit could be supplemented by the addition of further sheets referring to mechanical components.

Minor equipment items for which drawings have been prepared are mainly associated with racks, with the excep-

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*Messrs. Walker and Dalton are Senior Drafting Officers, Headquarters. See page 83.
**Mr. Freeman is Assistant Chief Drafting Officer, N.S.W. See page 82.

tion of drawings which require the adaptation of L M Ericsson equipment for the production of units that are not included in the L M Ericsson system such as wall-mounted racks and BCH relay sets fitted with "3000" type relays.

Drawings of piece parts have, in the main, been confined to items dealing with superstructure. Crossbar piece part drawings do not present a drafting difficulty as they can mostly be copied from the L M Ericsson drawing where the use of first angle projection is in line with A.P.O. standard drawing practice.

Allocation of Drawing Numbers

CE drawings of crossbar equipment have been allocated the following groups of numbers:—

Circuit Sub-Section	
ARF & ARK Circuits	CE-14000—14299 CEA-14000—14299 CE-14800—14999 CEA-14800—14999
ARF & ARK Operational and Installation Wiring Diagrams	CE-14300—14799
ARM Circuits	CE-15000—15299
ARM Operational and Installation Wiring Diagrams	CE-15300—15999
P.A.B.X. Circuits	CE-16000—16999
Telephone Equipment Sub-Section	
ARF & ARK Major Equipment Drawings	CE-44000—44499
ARM Major Equipment Drawings	CE-45000—45199
Exchange Equipment other than ARF, ARK and ARM Major Equipment Drawings	CE-45200—45999
ARF and ARK Minor Equipment Drawings	CE-64000—64999
Exchange Equipment other than ARF and ARK Minor Equipment Drawings	CE-65000—65999
ARF and ARK Piece Part Drawings	CE-84000—84999
Exchange Equipment other than ARF and ARK Piece Part Drawings	CE-85000—85999
Miscellaneous Exchange Installation Drawings	CE-94000—94999 and some were included in the CE-90000—90999 group before the special series for Crossbar was allocated.

PART 2—STATE CONTRIBUTION

Introduction

Within a State Drawing Office, a substantial proportion of the output of staff of Equipment Sub-Sections has always been directed towards the provision of drawings necessary for the installation of telephone exchange switching equipment. In fulfilling this function, it is necessary to develop a somewhat different approach to that adopted by engineers and other technical staff and, whilst a thorough comprehension of the detailed operations of each type of equipment encountered is essential, emphasis, for a draftsman, is placed on aspects directly related to his work.

Since the introduction of automatic switching, several major changes in equipment types have been made and each development has required a study of all inherent variations in installation practices from the viewpoint of determining the best basis for detail design and drafting procedure in the new circumstances. With regard to this, the decision to adopt L M Ericsson Crossbar equipment as the new A.P.O. standard is, from the draftsman's viewpoint, progression of some significance. A greater problem, however, is the immediate volume of work associated with its simultaneous introduction for extension of a considerable number of exchanges and the consequent abandonment of all existing drawings prepared on the basis of previously planned development by use of 2000 type equipment. Relatively minor extensions, therefore, are demanding considerably greater drafting effort at a time when staff are adjusting their approach to this new equipment.

The following has been prepared on the basis of presenting in outline some aspects of the draftsman's work in connection with the implementation of the crossbar installation programme.

Staffing

In the New South Wales Drafting Section there are, at present, four Sub-Sections that are primarily concerned with telephone exchange installations. Comprising one Country and three Metropolitan, these Sub-Sections are functioning on a parallel basis and the total intake of work is divided on a reasonably stable regional allocation. In addition, there is some overflow of trunk telephone exchange installation work into the Transmission and Telegraphs Sub-Section but this has not, to date, included any work on crossbar equipment.

With the introduction of crossbar equipment, it was clear that this staff would be required to cope with the preparation of drawings for an extensive installation programme whilst gaining a thorough understanding of the completely new system. It was also evident that the more experienced staff would be required to establish a basis for this work and each would have to undertake the preparation of drawings for several exchanges simultaneously in order to meet the installation requirements.

Because of the specialised nature of this work, only limited assistance could be obtained from other drafting staff and time did not permit any significant help by way of recruitment and training of additional staff. In the main, therefore, the existing organisation was required to re-adjust for this task by endeavouring to simplify and reduce, wherever possible, the drafting effort associated with each individual installation.

In order that an early appreciation could be gained of the new equipment, informal group discussions were encouraged and any useful information about the system was made available for reference. With all the staff of these Sub-Sections located within the one office, little difficulty was experienced in achieving a free exchange of ideas or information and attention was directed primarily towards providing a satisfactory service with a maximum economy of drafting effort. A basic principle that has been applied throughout was that of avoiding unnecessary duplication of investigation and, wherever possible, all derived data of a directly useful nature was summarised for the use of all drafting staff. Careful consideration was given to the establishment of useful standards of presentation for each aspect of an exchange installation and, although some modifications are still being introduced, a general pattern of requirements for each installation has been adopted by the Drawing Office.

Technical Aspects

It is desirable that telephone equipment drafting staff have a complete appreciation of all details of crossbar exchanges but particular attention must naturally focus on those aspects that are directly related to the preparation of the necessary installation drawings. Generally, these items of major interest may be classified under the following headings:—

(i) I.D.F. Design
(ii) Equipment Layout
(iii) Overhead Ironwork — Troughing — Runway
(iv) Main Cabling
(v) Trunking
(vi) Suite Control
(vii) Service Control.

In the following comments on each of these items, an attempt has been made to convey something of the draftsman's approach to the problems of providing a satisfactory service for installation staff.

I.D.F. Design

This is one of the first steps towards the preparation of drawings for a particular installation and corresponds, generally, to the T.D.F. appropriation of a pre-Francis 2000 type exchange. The main difference lies in the greater number and variety of circuits that must be interconnected, but common to both systems there is the need for a reliable forecast (by way of trunking diagram) of the exchange capacity requirements. In this respect, it is clear that the heavy cabling associated with these I.D.F.'s must be carefully planned since this is an area where future re-arrangement could prove difficult. It appears, at this stage, desirable to favour layouts that provide at least a small proportion of distributed unallocated I.D.F. space to permit, say, a change in the size ratio of the different group selector stages.

Consideration of the manner of grouping of I.D.F. racks is another matter in which careful consideration must be given to the future development of the exchange. Economy of cabling may be effected by locating "cells" of I.D.F. racks on the floor area convenient to the devices to be interconnected but care should be take to ensure that this divided arrangement provides adequately for growth and makes some allowance for unforeseen development. The alternative "continuous" suite of I.D.F. racks may be satisfactory in some circumstances but generally requires more cable and may present development problems associated with the concentration of cabling in the I.D.F. suite.

The change from the BAB948 to BAB970 type I.D.F. for A.R.F. installations was of major importance since it varied the circuit terminations and layout in addition to affecting most drawings of an installation. From a drafting viewpoint, this involved some loss of effort on exchanges that had been planned for BAB948 racks and, until the supply position was clarified, there was uncertainty regarding the exchanges that would employ the earlier type of rack. Since no specific guide was available concerning the circuit terminations on the BAB970 rack, a set of reference drawings was urgently prepared for this purpose to meet the requirements of the Installation Divisions and this now provides a basis for I.D.F. planning.

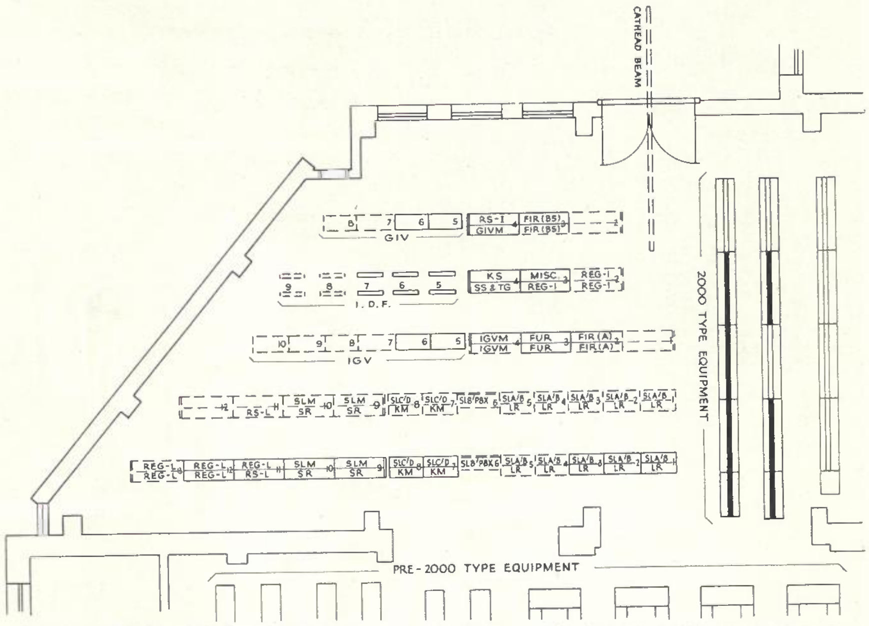


Fig. 2.—ARF Crossbar Equipment Extension of Composite 2000 and Pre-2000 Type Exchange.

Equipment Layout

Crossbar exchange equipment layouts are prepared initially for planning engineers to demonstrate the feasibility of a scheme and to provide the basis for submission of the associated proposal. Later, at the instigation of installation engineers, these plans are revised or amended, as required, to meet the more detailed conditions that become apparent at the commencement of each particular project and further changes are also effected throughout the design period to refine or improve earlier plans. This does not vary, in principle, from the methods used with earlier types of equipment and most problems have centred on the following:—

(i) The physical dimensions and relative placement of equipment racks.

(ii) Introduction of metric measurements.

(iii) Integration of extensions with existing equipment.

The main difficulty posed by the use of metric measurements is associated with crossbar extensions of exchanges that have existing equipment layouts drawn to a scale of $\frac{1}{4}$ inch to a foot (i.e. a ratio of 1:48). This has necessitated the production of special metric scales for drafting use graduated to this ratio and, because of the desired accuracy, the Workshops Sub-Section of the Drawing Office was requested to make an original plastic negative on a precision chart scribing machine for printing the necessary copies. Considerable use has now been made of these scales and they have proved most satisfactory.

The problems of integration with existing equipment are, perhaps, best illustrated by reference to the typical layouts shown in Figs. 1 and 2. Here it may be seen that double sided racks are required to extend suites of existing single sided equipment and the irregular suite lengths can cause the separation of inter-related groups of racks. In each of these examples the I.D.F. has been made continuous and in Fig. 2 all the crossbar suites have been located at right angles to existing suites to facilitate close association of the more conveniently grouped racks.

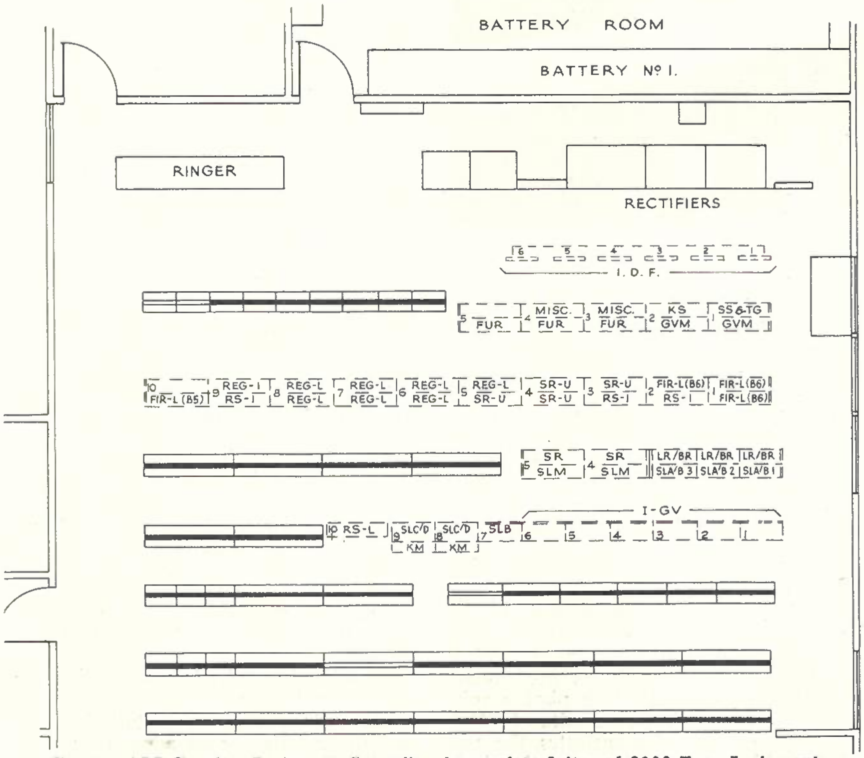


Fig. 1.—ARF Crossbar Equipment Extending Incomplete Suites of 2000 Type Equipment.

Overhead Ironwork—Troughing—Runway

Little comment appears necessary with respect to the ironwork, troughing and runway requirements of the Ericsson crossbar equipment. Similar to most systems, this new equipment must be supported by overhead ironwork and provided with a means of conveying cables between racks. There are changes in the supporting steel sections employed

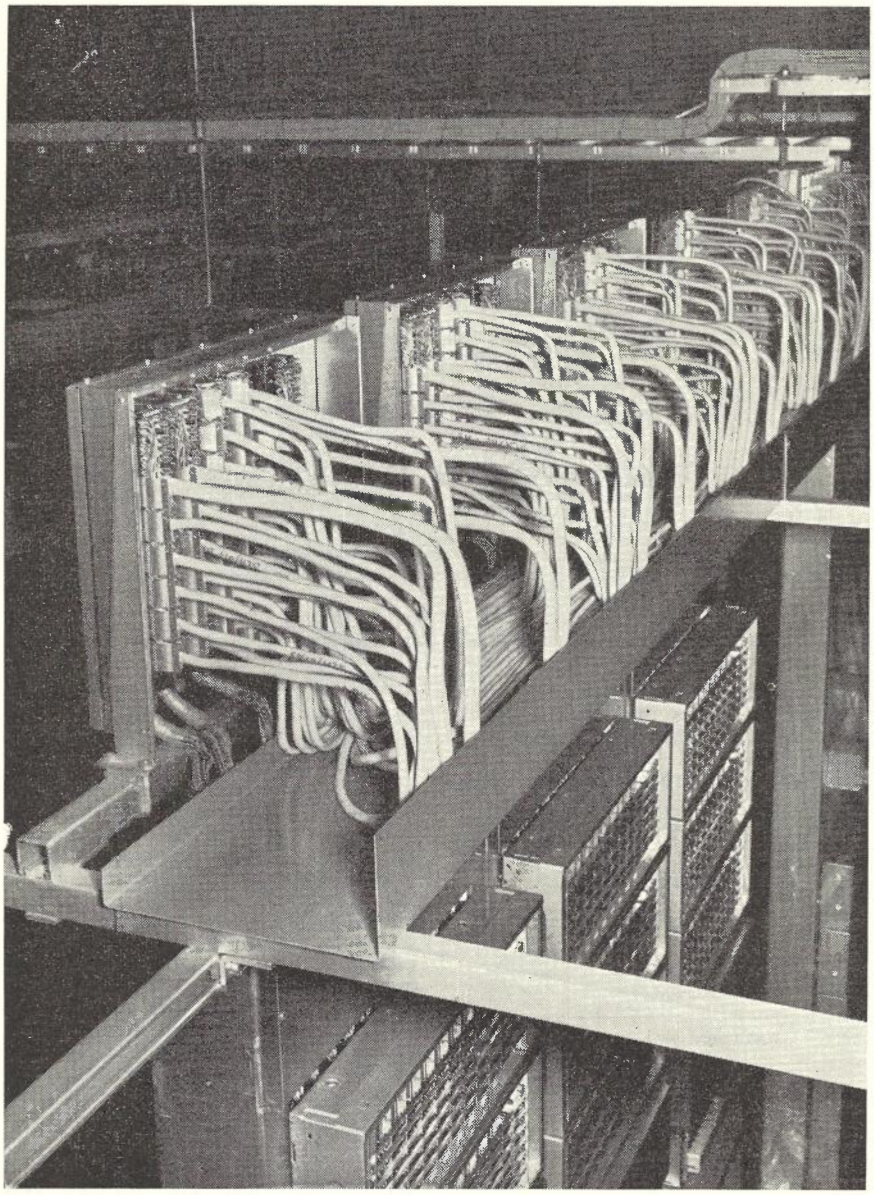


Fig. 3.—Cabling of BDD Type Racks.

and their conventional spacing is different to the familiar 2000 type practice, but these matters only cause some concern when problems of integration with existing equipment are encountered and such situations have not, to date, presented much difficulty. The only significant change associated with the use of troughing is its effect on the cabling details of exchange installation drawings and, generally, the structural arrangement is quite straightforward. The drafting requirement for each installation is, in most cases, confined to the diagramatic representation of standard items on a transparent copy of the floor layout.

Cabling

A substantial proportion of the work of preparing installation drawings for telephone exchanges is associated with cabling and, in this matter, L M Ericsson crossbar equipment has introduced different methods of access to racks and a completely new approach to the whole problem.

The three types of rack that are most frequently encountered in A.R.F. installations are the selector rack (BDD), the relay set rack (BDH) and the I.D.F. (BAB948 or BAB970). All main cabling to the BDD rack is plug-ended and each cable must gain access to the appropriate jack unit associated with the rack. Runway may be employed for conveying cables to these jack fields, but experience to date suggests that the greater flexibility of a troughing installation would merit its preferment for this type of rack. The photograph, Fig. 3, shows portion of a suite of BDD racks and clearly demonstrates the use of troughing for cabling to the jack fields. It may also be noted that cabling for this type of installation lacks the neatness and precision associated with earlier types of equipment and the troughing assists in maintaining a tidy appearance when viewed from floor level.

With the B.D.H. rack, cabling has limited access via a formed metal side member and the main sheathing is removed at the top of the rack with the wires extending as a common laced form. Either runway or troughing may be effectively employed in conjunction with these racks and the photograph, Fig. 4, shows a substantial bulk of cable converging into a common form to feed the jack units of an SS-TG rack. In this example, runway has been used to convey the cables to the drop point and it may be clearly seen that the area for cable access to each rack is specifically located and, in this case, almost fully occupied.

The I.D.F. in use for the majority of current installations is the BAB970 and the photograph, Fig. 5, gives some impression of the method of feeding cables down the rack and to the grading strips. The rack is, in effect, a vertical cable duct and the box section of approximately 15" x 2¾" enclosed by the formed sheet metal and rear removable rods contains all the cables for the rack. These cables are then given access to the grading strips in a predetermined sequence through plastic grommets on the left hand side of the rack. From this photograph it is evident that, similar to the B.D.H. rack, only a limited specifically located area is available for cable drops and, whilst any necessary manipulation of cables within the rack is effectively concealed, it is necessary to exercise care in planning the initial and ultimate build up of cables requiring entry to the rack. These racks are usually grouped and the resultant concentration of cabling can present some difficulty. As an aid to the effective placement of cables and with a view to permitting some flexibility of development, short lengths of transverse high level runway may be employed to advantage in a manner similar to that shown in the photograph.

When some appreciation was gained of the physical factors associated with gaining access for inter-rack cabling of this new equipment, major considerations for drafting staff were:—

(i) Determining methods of presentation necessary for cabling drawings.
(ii) Compiling basic cabling data in a suitable form for ease of reference.
(iii) Minimising the drafting effort per individual installation whilst maintaining the desired service.

With regard to these matters, it was important that a broad policy should be established quickly to ensure that all drawings would be prepared in a similar manner throughout the office and a desirable measure of standardisation introduced.

In achieving this, it was necessary to anticipate the type of service that would be directly useful to installation staff and to provide for an adequate amount of detail to meet present and future needs. Less detail was clearly permissible for cabling plans of troughing installations, but consideration also had to be given to projects making partial or full use of runway. A further important consideration was that of attempting to achieve a balance between available drafting resources and the essential demands of the installation works programme.

Generally, in the matter of presentation, it was decided that past practice of providing cable plans and sections would be maintained wherever runway was used, but a simpler line diagram would be introduced to meet the needs of troughing installations. With this line diagram, the desired relative location of groups of cables would be shown, but detailed cable sections would only be given where essential (i.e. I.D.F. drops, main cable runs, etc.). Plans for current installations have been prepared on this basis for the full or combined use of either runway or troughing and these methods have proved satisfactory.

From a drafting viewpoint, one of the more important effects of the introduction of crossbar equipment was the need to establish a directly useful source of basic data for the preparation of individual cabling plans. Ideally, this information should not include supplementary irrelevant detail and for each of the conventional groups of equipment racks a single reference should provide all the necessary inter-rack cabling data. This would assist in ensuring that no cables were overlooked and overcome the need for each drafting officer to compile these details independently.

Installations of previous types of step-by-step equipment did not present any great difficulty in this matter of inter-rack cabling, since few cable runs had to be considered and details of these were readily committed to memory. For example, a 1000 line group of primary equipment with its associated penultimate selectors would involve only four main cable runs if composite 2000 type equipment were used and experienced drafting staff would have no need to check the quantity and size of cables required. A similar installation of L M Ericsson crossbar equipment would involve approximately 20 inter-rack cable runs, and since these are varied for the different quantities of SR's and subscriber's multiple (or "m") values, the urgent need for cabling data reference plans was soon evident.

As an aid to drafting staff, therefore, a series of cable analysis plans were drawn for each of the commonly inter-cabled groups of racks and a typical example is shown in Fig. 6. In this case, all the cables for a developing group of primary equipment are shown and their progressive extension to provide for an equipment capacity of 200 to 800 lines is clearly evident. A total of two racks of SR's have been provided for, and the subscribers multiple or "m" value is 6. Plans of this type have been prepared for each new condition that has been encountered and retained for future reference. This has overcome much of the individual detailed examination of separate rack wiring diagrams and, following the initial effort by the officer who first encounters a new requirement, all staff have benefited from the use of these basic reference diagrams. Plans, similar to the example, have now been prepared for the following conditions:—

1. **Primary Equipment.**
   (a) m = 6A & B with 80 SR's
   (b) m = 6B with 100 SR's
   (c) m = 8A with 100 SR's
   (d) m = 8C with 120 SR's
   (e) m = 8D with 120 SR's
   (f) m = 10A/B/C with 150 SR's.
2. **Group Selector Equipment.**
   1GV and GIV.
3. **Other Inter-Rack Cabling.**
   REG/SS/TG & KS.

An examination of Fig. 6 and its associated diagram, Fig. 7, serves to demonstrate the following principles which have been used as a basis for the preparation of these drawings:—

1. Complete cabling details for conventionally coupled racks of equipment are shown on a single sheet.
2. Each inter-rack cable is, where possible, drawn as a separate line.
3. Size of cable and method of termination at each end are indicated.
4. Jack field locations of plug ended terminations are designated.
5. Any progressive cabling development is shown.
6. Reference letters are provided for cable run identification on individual cabling plans.

This example provides, at a glance, an overall impression of the cabling interconnections and a closer examination reveals the purpose of each cable run. From a drafting viewpoint, the

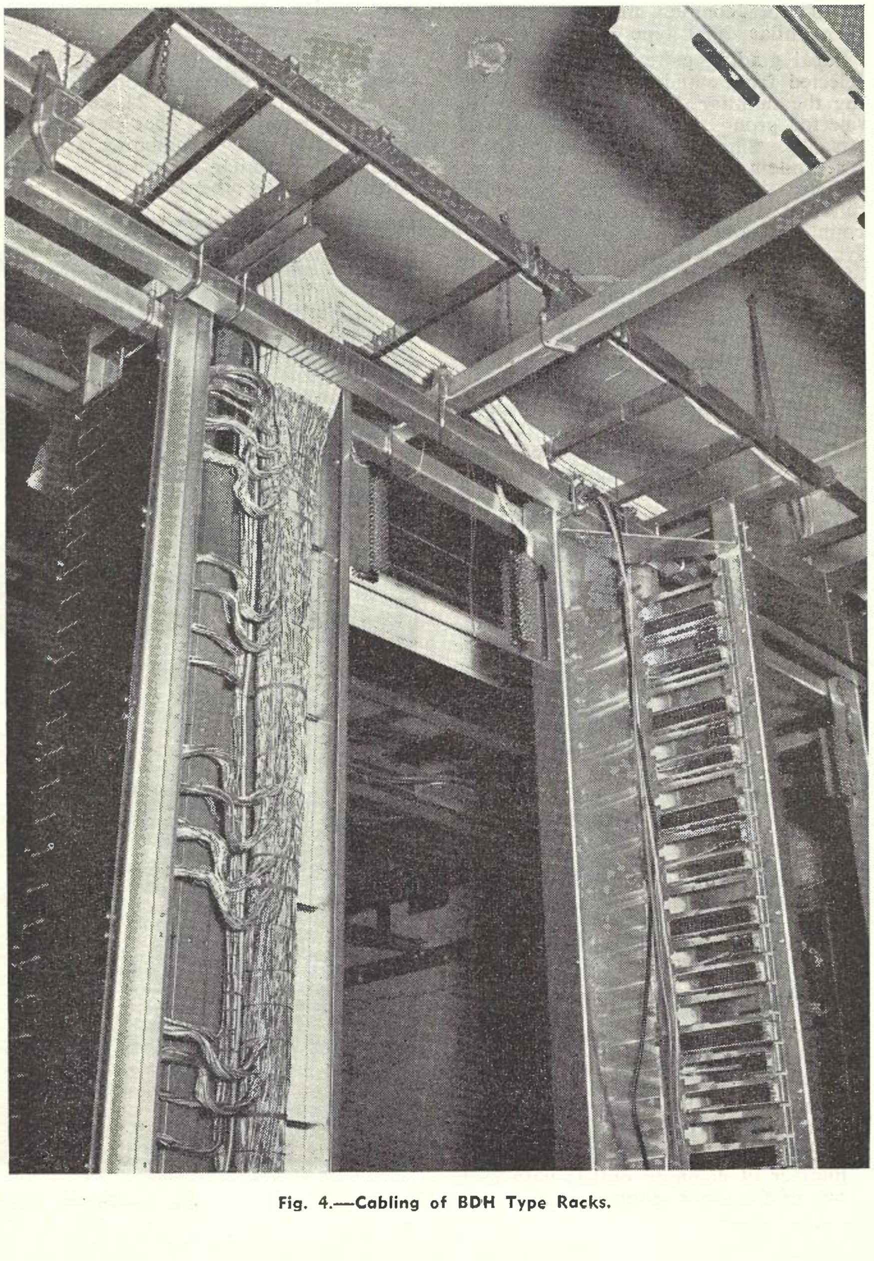


Fig. 4.—Cabling of BDH Type Racks.

practical use of this information necessitates its re-arrangement to suit the alternative rack placements of specific installations and its integration with other initial or future groups of intercabled racks. The usual consideration must here be given to methods of conveying cables, designed growth of the exchanges and any special planning considerations.

Trunking

Comments on this aspect have been based on impressions gained from the limited experience associated with early installations that are now progressively coming "into service". No attempt has been made to present this topic comprehensively and these thoughts are given to some items selected at random.

The same basic functions of grading and outlet allocation still apply and, although different criteria are used to determine the ideal solutions, this work is no more complex than that required for similar 2000 type installations.

Ideal grading patterns can usually be selected from standard tables by applying the familiar data of availability (k) selector groups (g) and number of outlets (N). Since the equipment provides for random testing and selection of free outlets, the basic gradings are of a different form to that previously encountered and consist of a series of symmetrical interconnected fields. Each of these fields is a self-contained cell and provides for a defined section of the total availability of the grading. Total outlets of a standard symmetrical grading are therefore a multiple of the number of grading groups and any "in between" requirement is obtained by adjustment.

The range of grading tables currently available is shown in Fig. 8 and, from this, selection of the more routine requirements is merely a matter of reference. Further questions remaining, however, are how to provide a grading for an "in-between" number of outlets not specifically quoted and what action should be taken with problems outside the scope of the grading tables. For the former, the usual practice involves the insertion of additional outlets into the closest basic pattern and this can obviously be effected in many different ways. Whilst the effect of these alternative arrangements on the commoning between groups can be readily checked, only a subjective assessment may be made of the relative lack of symmetry of such schemes. The latter problem, of determining unlisted grading patterns, has generally been undertaken in the manner outlined by L M Ericsson and the following practical example demonstrates this method.

Assuming that an equal quantity of similar traffic is offered to each grading group, the following objectives are sought in the preparation of a satisfactory grading pattern.

1. Symmetry of the interconnection pattern with reference to grading groups.
2. Each grading group to have the same number of common outlets with each one of the other groups.
3. A maximum of two availabilities to be used for the separate fields employed. Where two availabilities are necessary they should be consecutive numbers (e.g., pairs and threes).

For this example, 24 outlets are to be provided from a 12 group grading with an availability of 9 and it is evident, from the above objectives, that the complete pattern should consist of two symmetrical fields using availabilities of 4 and 5.

The first step to be taken requires the preparation of comprehensive tables of symmetrical fields for 12 grading groups with availabilities of 4 and 5. This is achieved by a simple systematic numerical process which automatically generates all the valid patterns for tabulation with details, in each case, of the commoning of the first grading group. In this case, 39 and 66 possibilities were listed for availabilities 4 and 5 respectively and the full table for the former is shown in Fig. 9.

It is evident that, for the purpose of designing new gradings, this list may be reduced from 39 to 24 entries by discounting any fields that duplicate a previously quoted commoning arrangement and a similar reduction was also applicable to the other table.

By a process of selection and matching, the ideal combination of commonings for this example was obtained from fields 1-2-4-6 and 1-2-5-6-11. Fig. 10 illustrates this grading and its detailed analysis.

It is apparent from this example, that the number of patterns and combinations to be prepared and examined can be large and, in order to relieve some of the tedium of this work, tables similar to Fig. 9 may need to be prepared for a comprehensive range of grading groups and field availabilities. Information in this form is more basic than the full grading patterns and seems to have greater value for re-trunking or assessing the merits of different schemes.

In the matter of presentation of gradings, the methods employed by L M Ericsson have been adopted and basic forms of a similar type are being used. Whilst there is no doubt that these proformas will be satisfactory, it has been noted that the methods used convey the necessary information in a significantly different manner to the familiar 2000 type practice. In the latter technique, it is customary to quote the succeeding group selector, etc., directly on the grading, with the method of connection via I.D.F., etc., being determined less readily. The new procedure, on cross-

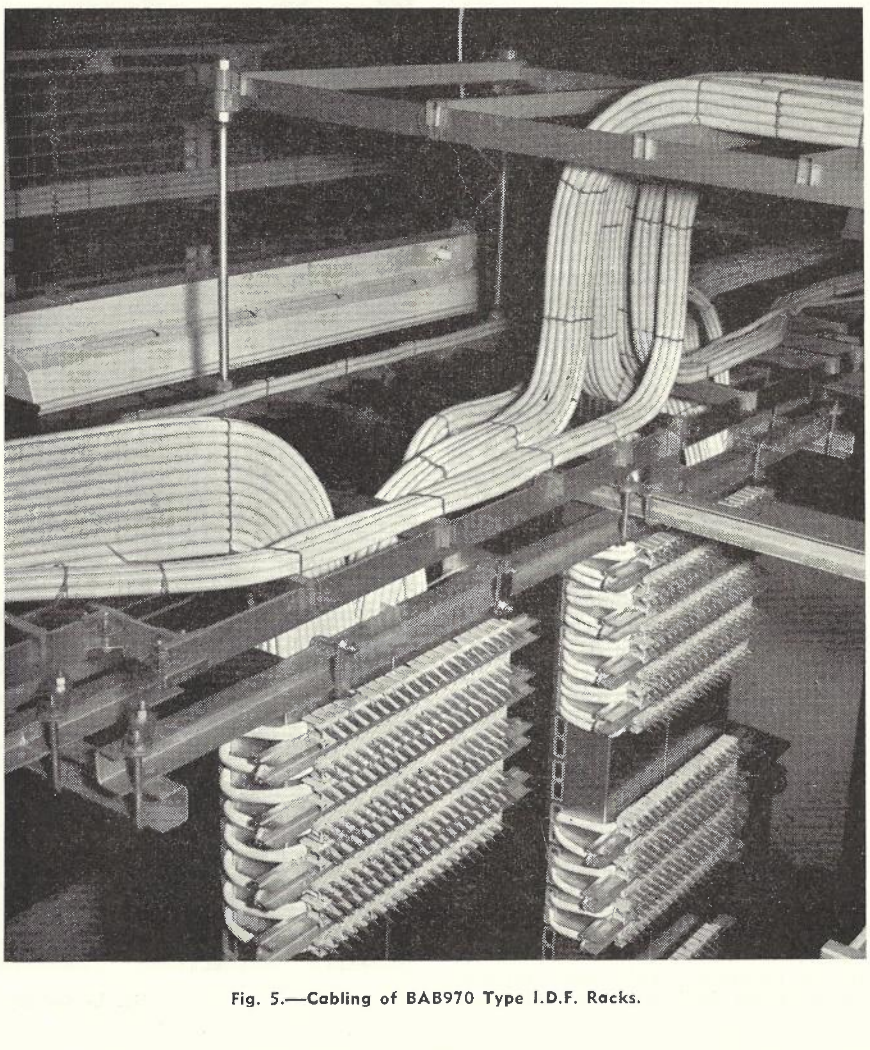


Fig. 5.—Cabling of BAB970 Type I.D.F. Racks.

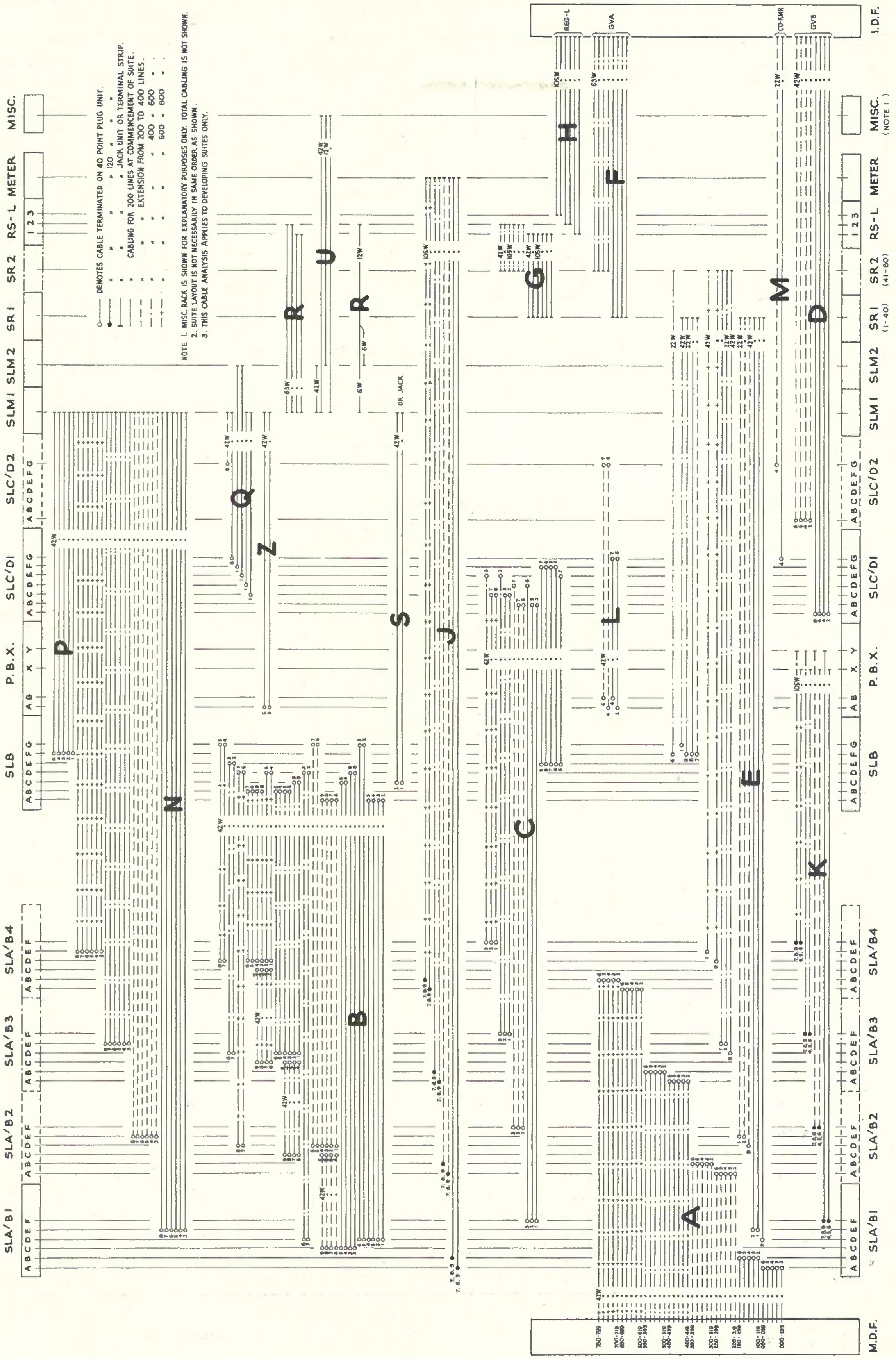


Fig. 6.—Typical Cable Analysis Plan ("m" = 6 — 200 to 800 Lines).

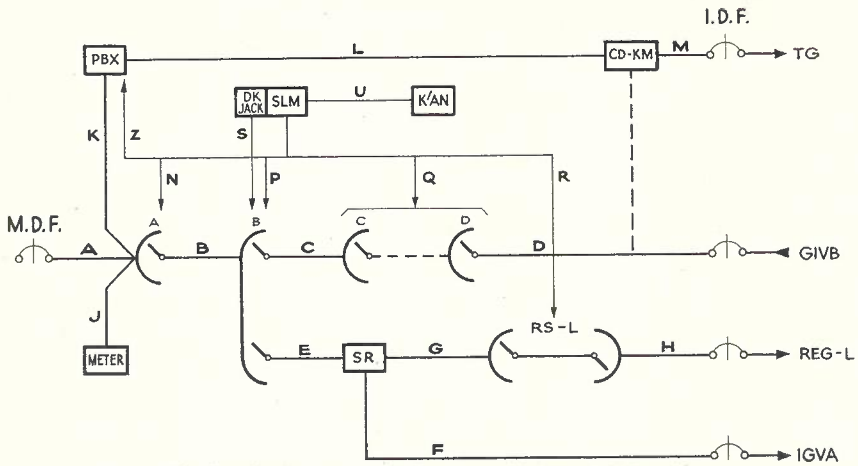


Fig. 7.—Cable Run — Key Diagram. (For use with Fig. 6.)

bar gradings, gives outlet numbers which, generally, provide for a systematic progress to the succeeding device through a series of references (i.e. suite and rack, grading strip and terminal group, etc.) which are listed adjacent to the grading and on supplementary I.D.F. jumpering sheets. This method is undoubtedly straightforward for installation staff, and, although some modification may be warranted for maintenance records, such changes will probably be effected gradually as more experience is gained with this equipment.

As a final thought on the subject of trunking, comment is made on the problem of determining which SR's should be left "out of service" when the traffic requirements show a lesser figure per 1000 lines than the cabling pattern provides. Although there is evidence that a degree of flexibility is permissible in this matter, a lead has been taken from the method employed by L M Ericsson for cabling of SR's in developing subscriber's equipment groups. Consideration has here been given to providing a balanced availability of SR's to each 200 line group at all stages of development and this same principle has been applied in determining which SR's should be used to meet the trunking requirement for a specific installation. In addition, some thought has been given to offering balanced traffic to register-finder groups and retaining, where possible, the SR's associated with the 5th vertical of SLB switches in order to maintain the advantage of delayed selection associated with these outlets.

Suite Control

Essentially, suite control equipment consists of one or more control boxes mounted at the end of each suite for the purpose of distributing the alarms and common services (i.e., rings, tones, alarm battery supply, etc.) to individual racks within the suite. Test points are provided at these boxes for rings, tones, etc., together with push buttons for isolation of individual feeds and there are mountings for protector strips, alarm lamps and alarm relays. Additionally provision is made for the extension of alarm, fault and subscriber blocking conditions to the Service Centre via the I.D.F.

Using the pilot installation at Petersham as a guide, a comprehensive suite control and alarm survey drawing was compiled with a view to including every possible circuit element that any rack may require. This was then used as a basis for design of the individual suite wiring which was originally drawn in a similar manner to the L M Ericsson plans for Petersham, with full details of each suite individually presented on a single sheet. More recently, an adaptation of a method developed by the Victorian State Office has been employed with a view to providing a faster and more efficient drafting service. This method provides for a partially tabulated presentation making use of a series of foolscap proforma sheets for each suite and has generally proved more suitable for installation purposes.

In considering the individual suite control layout, appropriation of the boxes is dependent on the types and quantity of racks contained in the suite and, as some racks, particularly the REG-L, require a much larger proportion of equipment in the suite control box, variation of floor layout could be of advantage in eliminating the need for an additional box at some suites. On the other hand, where an ultimate layout of a particular suite is indefinite, it may be convenient to connect an isolated initial rack to the suite control box of an adjoining suite. Positioning of these boxes should, of course, be arranged for the ease and convenience of viewing by service staff.

Service Control

To maintain an acceptable grade of service from any automatic telephone exchange it is necessary to keep a close check on each element of equipment to ascertain whether it is operating efficiently. With the Ericsson ARF crossbar system, use is made of fault counters and alarm lamps to ensure that malfunctions are automatically recorded in the service centre. Some early installations in N.S.W. will make use of locally available components, wired and assembled to provide the desired functions, and drafting staff have been required to assist in the design of this equipment.

In order to provide a directly useful reference to all the service control cabling requirements, a comprehensive survey drawing was prepared. The cabling needs of each type of rack were clearly shown together with the I.D.F. interconnections. In addition, a series of drawings have been prepared for the revised terminations associated with the new BAB970 I.D.F. and, in conjunction with the survey drawing, these are useful in determining I.D.F. appropriations, etc., for service control installations in individual exchanges.

ARK Rural Automatic Exchanges

The Ericsson Crossbar RAX's to be used in Australia consist of two types —the ARK511 and the ARK521 systems.

Initially, in New South Wales, it was planned to install ARK511 and ARK521 exchanges in portable buildings and it was therefore necessary to prepare drawings showing the layout and specifications for the construction of suitable buildings. Additional drafting requirements were ironwork and troughing layout and detail drawings, structural drawings for special racks, test equipment, battery cabinets, M.D.F.'s, etc., modifications to Ericsson equipment racks and cable terminating details. Drafting work is still in progress to provide for further modifications and the preparation of suitable grading and strapping sheets.

Circuits—Signalling Relay Sets, Etc.

With the introduction of crossbar equipment into country areas, it was evident that, due to line conditions, long distances and different types of existing equipment (i.e., magneto, SxS automatic, C.B., etc.), various types of conversion signalling circuits would be necessary for use in conjunction with the ARF and ARK installations. Since

		NUMBER OF GRADING GROUPS g							
		3	4	5	6	7	8	9	10
OUTLETS	AVAIL. OF 5	6	8	10	6 & 12	7 & 14	8 & 16	9 & 18	10 & 20
	" " 10	12 & 15	12 TO 20	15 TO 25	12 TO 30	14 TO 35	16 TO 40	18 TO 45	20 TO 50
	" " 20	21 TO 30	24 TO 40	25 TO 50	24 TO 60	21 TO 70	24 TO 81	27 TO 90	30 TO 100
	" " 40	42 TO 60	44 TO 80	45 TO 95	42 TO 120	42 TO 140	48 TO 160	45 TO 180	50 TO 200
	" " 60	63 TO 90	64 TO 120	65 TO 145	66 TO 180	63 TO 210	64 TO 240	63 TO 270	70 TO 300

Fig. 8.—Range of Standard Grading Tables.

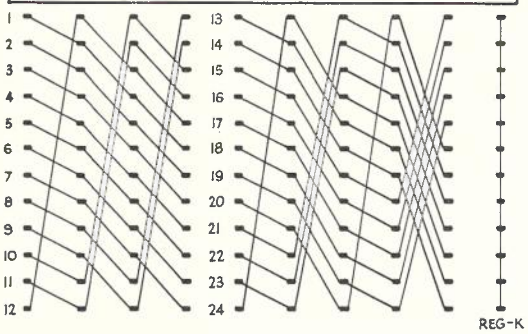
many of these circuits were already working satisfactorily in pre-crossbar installations, the new requirement was largely a matter of re-locating the components in the most convenient manner on various sized BCH plates specially punched for 3000 type relays and suitable for mounting on Ericsson type BDH racks. Drafting staff of the Country Sub-Section were required to assist in this work and prepare the necessary drawings.

It was proposed, generally, that the same components be used and a supply of BCH type plates was procured with the necessary mounting facilities for rows of 12 relays of the 3000 type in the space designed to accommodate 14 Ericsson relays. To differentiate between these two plates on the component layout of a circuit, the usual designation has included an explanatory suffix, e.g., BCH131 (3000 type). For various practical reasons it has been necessary to use this modified BCH type mounting in other situations and, as the need has arisen, drawings have been prepared on this basis for complaints (service desks), information, observation circuits, etc.

In addition, other circuits have been prepared, as required, using components that are currently available to provide such facilities as SR tester, REG-L tester, wire tester and traffic route tester. Each of these circuits made use of 3000 type relays and associated structural designs were prepared for the mounting of all components in suitable portable cabinets.

FIELD	COMMONING WITH GROUP										
	2	3	4	5	6	7	8	9	10	11	12
1,2,3,4.	3	2	1						1	2	3
1,2,3,5.	2	2	1	1				1	1	2	2
1,2,3,6.	2	1	1	1	1		1	1	1	1	2
1,2,3,7.	2	1		1	1	2	1	1		1	2
1,2,3,8.	2	1			2	2	2			1	2
1,2,3,9.	2	1		1	1	2	1	1		1	2
1,2,3,10.	2	1	1	1	1		1	1	1	1	2
1,2,3,11.	2	2	1	1				1	1	2	2
1,2,4,5.	2	1	2	1				1	2	1	2
1,2,4,6.	1	2	1	1	1		1	1	1	2	1
1,2,4,7.	1	1	2		1	2	1		2	1	1
1,2,4,8.	1	1	1	1	1	2	1	1	1	1	1
1,2,4,9.	1	1	1	1	2		2	1	1	1	1
1,2,4,10.	1	1	2	1		2		1	2	1	1
1,2,4,11.	1	2	2		1		1		2	2	1
1,2,5,6.	2		1	2	1		1	2	1		2
1,2,5,7.	1	1	1	1	1	2	1	1	1	1	1
1,2,5,8.	1		2	1	1	2	1	1	2		1
1,2,5,9.	1		1	3	1		1	3	1		1
1,2,5,10.	1		2	2	1		1	2	2		1
1,2,5,11.	1	1	2	1		2		1	2	1	1
1,2,6,7.	2			1	2	2	2	1			2
1,2,6,8.	1	1		1	2	2	2	1		1	1
1,2,6,9.	1		1	2	2		2	2	1		1
1,2,6,10.	1		1	3	1		1	3	1		1
1,2,6,11.	1	1	1	1	2		2	1	1	1	1
1,2,7,8.	2				2	4	2				2
1,2,7,9.	1	1		1	2	2	2	1		1	1
1,2,7,10.	1		2	1	1	2	1	1	2		1
1,2,7,11.	1	1	1	1	1	2	1	1	1	1	1
1,2,8,10.	1	1	1	1	1	2	1	1	1	1	1
1,2,8,11.	1	1	2		1	2	1		2	1	1
1,2,9,11.	1	2	1	1	1		1	1	1	2	1
1,3,5,8.		2	1	1	2		2	1	1	2	
1,3,5,10.		2	1	1	2		2	1	1	2	
1,3,6,8.		2	1		3		3		1	2	
1,3,6,9.		1	2	1	1	2	1	1	2	1	
1,3,6,10.		1	2	1	2		2	1	2	1	
1,3,7,10.		1	2	1	1	2	1	1	2	1	

Fig. 9.—Commoning of 12 Grading Groups—Availability of 4.



COMMONING WITH GROUP											
1	2	3	4	5	6	7	8	9	10	11	12
●	3	3	3	3	3	2	3	3	3	3	3
3	●	3	3	3	3	3	2	3	3	3	3
3	3	●	3	3	3	3	3	2	3	3	3
3	3	3	●	3	3	3	3	3	2	3	3
3	3	3	3	●	3	3	3	3	3	2	3
3	3	3	3	3	●	3	3	3	3	3	2
2	3	3	3	3	3	●	3	3	3	3	3
3	2	3	3	3	3	3	●	3	3	3	3
3	3	2	3	3	3	3	3	●	3	3	3
3	3	3	2	3	3	3	3	3	●	3	3
3	3	3	3	2	3	3	3	3	3	●	3
3	3	3	3	3	2	3	3	3	3	3	●

Fig. 10.—Typical Grading and Analysis.

Because of the type of components involved, all the above circuits were prepared in the conventional A.P.O. detached contact wiring-schematic manner and, therefore, varied from the method employed for the associated crossbar equipment. This, of course, is a circumstance that will soon be common to all combined installations of crossbar and step-by-step equipment and will require some additional interpretation from technical staff. The L M Ericsson technique of attached contacts, different symbols and extensive "abbreviation" is most certainly a departure from past practice and drafting staff have taken a lively interest in considering the relative advantages of each system.

Some appreciation of one aspect of the different methods may be gained from the comparative diagram, Fig. 11. In this example an element of the circuit of the K.S.R. relay set has been drawn in the following ways:—

(a) Ericsson "attached contact" method.
(b) A.P.O. standard for other than Ericsson equipment.
(c) Bell System of "detached contact" schematics (1).

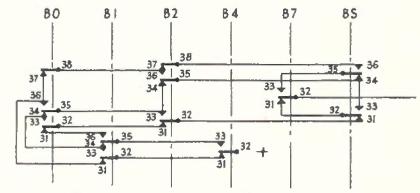
In the Ericsson method much of the advantage of the fully "detached contact" presentation has been achieved together with a significant improvement over the earlier "attached contact" circuit drawings. Location of relay contacts is simple with this presentation and the relay designation usually appears only once on the circuit. With the A.P.O. standard developed for step-by-step equipment, the function of the circuit element is clear but there is repetition of the relay designation at each contact unit. The third illustration has been included merely to demonstrate that other techniques are currently in use and this method, which is employed by the Bell System (1), appears to have been developed on the same basis as the A.P.O. standard but has progressed further with symbolic abstraction. Under the present circumstances, in Australia, it is difficult to envisage any significant change being effected in the matter of circuit presentation, but it is important that development towards simpler techniques and clearer circuits should at all times be encouraged.

CONCLUSION

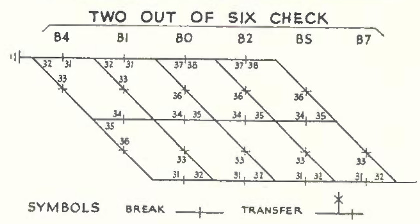
The work of the Drafting Section in connection with the introduction of Ericsson crossbar equipment into the automatic telephone network has really only commenced. Much remains to be done by way of providing drawings for specific installations and, in this matter, the Drawing Office has as its primary objective the provision of the best possible service for engineers and technical staff.

REFERENCE

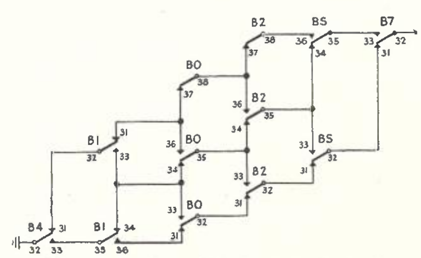
1. J. W. Gorgas, "Detached Contact Schematics"; Bell Laboratories Record, July, 1954.



(a) Ericsson Attached Contact Method.



(b) A.P.O. Standard Presentation for Step-by-Step Equipment.



(c) Bell System of Detached Contact Schematics.

Fig. 11.—Element of KSR Relay Set Circuit.

THE MEASUREMENT OF INTENSE RADIO FREQUENCY RADIATION

*P. E. BROWN**.

Editorial Note: This article has been offered to the Telecommunications Society of Australia, for publication in this country, by Marconi Instruments Ltd. of St. Albans, England. It deals with the measurement of intense radio frequency radiation and, in view of the interest in the subject and the scarcity of relevant literature, it is included in the Journal as a service to readers. With the trend over recent years towards the use of higher powers in both broadcasting and telecommunication equipment, the possibility of exposure of operating or maintenance personnel to a high level of radio frequency energy has been the concern of the Postmaster-General's Department for several years. In 1960 the Headquarters Radio Section undertook a complete investigation of this subject and issued Radio Design Notes No. 2/1960 "Health Hazards of Microwave Radiation".

The following article surveys the problem of measurement of radio frequency power densities throughout the radio spectrum from the lowest to the highest frequencies and describes a simple portable practical instrument which has been developed commercially for this purpose.

INTRODUCTION

It has been long known that radio frequency (r.f.) energy can have beneficial effects on the human body when properly administered. Equally, it is a long established fact that excessive power densities can have harmful and at times fatal results. With the increasing use of powerful radio sources the risk is no longer an academic one.

Large scale research into the effects of over-exposure started in 1956 in the U.S.A., where many universities have carried out work in conjunction with the Defence Department. At the same time work has been carried out in Great Britain by various bodies, the most prominent being the Medical Research Council and the British Post Office.

Experiments on animals and animal tissue show that symptoms caused by excessive r.f. power densities may be due to thermal effects such as overheating of tissue, blood and internal organs. In addition symptoms may arise that are not directly due to thermal effects but are of a more complex nature. The reader is recommended to study the extensive literature on the subject, but a few of the facts discovered in recent years are summarised below.

BIOLOGICAL EFFECTS

The ability of r.f. energy to penetrate the human body is dependent upon frequency. Frequencies in the 200 to 400 Mc/s range reach tissue deep in the body, while higher frequencies such as 3,000 Mc/s and above do so to a lesser extent. Since the human nervous system is comparatively insensitive to heat deep within the body it is possible to sustain serious internal overheating produced by r.f. energy at the lower frequencies and yet be conscious only of a warm internal glow.

The eye will develop a permanent opacity (cataract) following over-exposure. A rabbit's eye will develop an opacity if subjected to a 2.45 Gc/s r.f. source having a power density of 120 mW/cm², provided the exposure is 35 minutes or more. If the exposure time is only 20 minutes and the same power density is used, then an opacity is unlikely. On the other hand a 20-minute exposure to a power density of 180 mW/cm² or more will bring on an opacity. This and many other results demonstrate that the threshold for a single cataractogenic dose of r.f. radiation is determined by the power density and the duration of the exposure. Increasing either will give a greater risk of eye damage.

Although the eye temperature rises when subjected to r.f. radiation it is thought that this is coincidental with, rather than the cause of, opacities. There appears to be no clearly defined temperature threshold above which opacities occur as evidenced by the following (1):—

A 2.45 Gc/s r.f. source applied to a rabbit's eye.

5 minutes at 280 mW/cm², causes opacity, eye temperature 49.3°C.

3 minutes at 280 mW/cm², no opacity, eye temperature 47.2°C.

35 minutes at 120 mW/cm², causes opacity, eye temperature 44.0°C.

Repeated sub-threshold doses can cause opacities in cases where one such dose would not. This cumulative effect is demonstrated by the following results (1):—

2.45 Gc/s, 280 mW/cm²,
3 minute single dose, no opacities.
3 minutes daily or every fourth day, caused opacities.
3 minutes weekly for five consecutive weeks—no opacities.

The seven-day interval seems to allow time for the eye to recover from the previous dose. It is thought that over-exposure to r.f. power may affect the lens protein directly and affect the metabolism of the eye. After a cataractogenic exposure a marked reduction in ascorbic acid level occurs some 18 hours or so later.

Evidence exists that the brain may be affected by smaller power densities than those needed to produce similar effects in the eye. Temporary paralysis of a chicken's legs results when a low power density beam of r.f. energy is directed at the back of its head. Immediately the beam is shut off the chicken regains the use of its legs and is quite unharmed in any way. Science fiction writers can undoubtedly envisage an invading army immobilising their opponents by r.f. means but keeping them healthy in order to work for their new masters at switch-off time.

General agreement has been reached in the U.S.A. and Great Britain on the maximum continuous daily exposure allowable in respect of human beings, namely, 10 milliwatts/cm². This figure has a built-in safety margin which is larger at some frequencies than others; as further knowledge is gained this level may be modified in order to allow higher power densities over part of the spectrum.

POWER DENSITY DISTRIBUTION

The maximum power density is usually assumed to occur at the Rayleigh distance from the transmitter aerial. The Rayleigh distance is given by $D^2/2\lambda$ where D = dish diameter and λ = wavelength of transmission, D and λ being measured in the same units of length. The power density at the Rayleigh distance is approximately (2) $2.3\ P/D^2$ where P is the total radiated power. In the near-field or Fresnel region (between aerial and Rayleigh point) diffraction occurs due to phase differences between constituent (non-parallel) parts of the beam emanating from the dish. This results in fluctuations in power density (with distance) about a mean level which is higher than that existing at the Rayleigh distance. At one point the power density can be 3 to 5 db higher than that existing at the Rayleigh distance, falling off again to a small degree as the aerial is approached. Despite this, it is generally valid to take the power density as having its maximum at the Rayleigh distance provided that the radiating dish is elevated above the general ground level. This follows from the fact that the field between Rayleigh distance and aerial is largely confined within an imaginary cylinder (2) whose base is the aerial dish. The field below this cylinder is generally about the same as that existing at the same height at the Rayleigh distance.

At twice Rayleigh distance (D^2/λ) and beyond (in a direction away from the aerial) the power density decreases in accordance with the inverse square law, this being known as the Fraunhofer region. For most practical purposes power density in the region between $D^2/2\lambda$ and D^2/λ may also be considered to follow the inverse square law, the error being insignificant in most cases.

From the above information it would seem a simple matter to calculate the power density at any given point and thus obviate the need for a measuring instrument. In fact the formulae given above only hold good for free space;

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multiple reflections from the ground and local buildings may modify the power flux pattern; it is often difficult to know the total power transmitted with sufficient accuracy. Aerial subsidiary lobes and leakage from faulty feeder connections could give rise to hazardous power densities in some unexpected places, behind the aerial dish for instance. Modern radar installations in aircraft can be both compact and powerful; when equipments are tested in a signals workshop various precautions have to be observed if tests under normal working conditions are required. The dish must be placed within or opposite a radome let into the workshop wall and a suitable area outside the building must be roped off to exclude all other personnel. If the radome is not properly radio-transparent or the beam is at an abnormal angle relative to it then hazardous radiation levels may be back-scattered into the workshop. These and other conditions demand the use of specialised equipment to check that personnel and public are not subjected to power densities in excess of 10 mW/cm².

BRITISH POST OFFICE RECOMMENDATIONS

In 1960 the British Post Office issued a series of recommendations (3) based on consultations with various government and civil bodies. A few of these recommendations are briefly summarised below:—

(a) The upper permissible limit for continuous daily exposure is 10 mW/sq cm over the frequency range 30 to 30,000 Mc/s.

(b) In pulse modulation systems the radiation should be averaged over complete trains of pulses including any intervals between pulse trains.

(c) To meet requirements in (b) measuring equipment must average the intensity of pulse trains occurring in any period of 1 second.

(d) Initial measurements should be made and any danger area fenced off to exclude locally employed personnel and members of the general public. These measurements should be repeated at least once per year and in any case whenever any change is made in the radio-frequency equipment or in the environmental conditions, e.g., erection of new buildings. Where conditions are subject to frequent change a radiation protection officer should be designated, this officer to advise on frequency of measurement and other precautions.

(e) Where a number of transmitters operate in the same region the sum of radiation intensities must not exceed 10 mW/cm² in areas open to personnel and public.

GENERAL SPECIFICATION OF MEASURING EQUIPMENT

The B.P.O. recommendations included the following specifications of measuring equipment:—

(a) Equipment frequency coverage should be appropriate to the radiated spectra at the station, establishment or factory concerned. The equipment should be relatively insensitive outside its declared frequency band.

(b) Measurements to be possible over at least the range 1 to 20 mW/cm² with an error between minus 0 and plus 2 db under plane-wave propagation conditions, at power levels in the range 5 to 20 mW/cm², i.e., the equipment is allowed to be too sensitive by up to 2 db but must never err on the insensitive side.

(c) The equipment must be suitable for the measurement of the average radiation intensity of unmodulated, modulated and pulse emissions and should have rise and decay time constants of 1 second.

Fig. 1.—A Radiatron Power Meter in Operation with S Band Aerial.

(d) The equipment must be capable of measuring intensity at a point irrespective of direction or polarization of incident radiation.

(e) Remote reading facilities shall be provided.

(f) Overloads of up to at least 200 mW/cm² shall be accommodated without affecting accuracy as laid down in (b).

METHODS OF MEASURING HIGH INTENSITY R.F. FIELDS

A power density of 10 mW/cm² is equivalent to a field strength of 1.94 v/cm and can be measured by a comparatively insensitive detector. The four main methods of detection are as follows:—

Method **A**. Black body. A substance, preferably having the same characteristics as human tissue, is placed in the field and its temperature rise measured.

Method **B**. Crystal diode detector. Measures voltage across a known load connected to a receiving aerial.

Method **C**. Thermocouple. Measures power output of receiving aerial.

Method **D**. Thermistor. Measures power output of receiving aerial.

Methods B., C. and D. are capable of measuring power density in accordance with the formula

$$Po = \frac{4\pi \, Pr}{\lambda^2 \, Gr} \quad \ldots\ldots (1)$$

where

Po = Power density = watts/cm²
Pr = Received power in watts
Gr = Absolute gain of receiving aerial with respect to isotropic case
λ = Wavelength in centimetres

the only requirements being an accurate power meter and an aerial of known gain together with an accurate wavemeter if wavelength is unknown.

Method A has the prime disadvantage that its calibration can only be checked by placing it in an accurately known field of near-hazardous level; such a field is difficult to provide for obvious reasons and as yet no such standardising service is made available by any British organisation. The method is cumbersome in use because the most suitable materials have a long time constant, and furthermore, accuracy can be affected by ambient temperature variations. A single black body can be made to have equal response to all or most of the 30 to 30,000 Mc/s band, but while this may be advantageous under some circumstances it nevertheless fails to comply with the Post Office requirement given in (a).

Methods B and C utilise components that can be fairly easily damaged by electrical overloads or by mechanical shock whereas the mechanically rugged thermistor (Method D) can handle 20 times its normal working power level without affecting its accuracy as a r.f. to d.c. transducer. This overload handling capacity is partly due to the reflection of power which occurs as the thermistor resistance decreases. Additionally, the thermistor responds to r.m.s. power regardless of waveform or any type of modulation which is likely to be encountered, unlike Method B which can give appreciable error on some types of signal. The thermistor detector accuracy can be made virtually independent of ambient temperature variations by maintaining the thermistor bead at a high temperature by means of a suitable bias current.

INSTRUMENT DESIGN AND OPERATION

The thermistor appears to possess the most desirable characteristics and may be used in various ways. One approach is to use the thermistor as an insensitive detector directly connected to an aerial of suitably small aperture or alternatively several thermistors connected to a combination of slot aerials may be utilised in a wide-band arrangement. Again there is the disadvantage that performance checking can only be carried out in an accurately known high level field and the wide band arrangement fails to meet the requirements in (a).

It would appear that the best and most flexible arrangement is to use a sensitive thermistor detector in conjunction with a separate aerial of larger aperture, with an attenuator inserted between them. This allows the use of classic design procedures in regard to the aerials, and their testing is more easily and accurately accomplished. The complete equipment can be dismantled into its separate building bricks, each of which can be tested by conventional laboratory equipment.

This approach has been adopted in the R.F. Radiation Power Meter Type OA 1430 designed and manufactured by Marconi Instruments Ltd. of England. This instrument will be used by various armed forces and in general meets the British Post Office requirements listed previously. It utilises thermistors in a 50 ohm coaxial power meter of high accuracy (± 0.25 db at mide-scale) over the frequency range 10 Mc/s to 10 Gc/s. The aerials supplied as part of the equipment cover X band (8.73 to 10 Gc/s), S band (2.7 to 3.3 Gc/s) and L Band (700 to 1,400 Mc/s). Aerials for other parts of the 10 Mc/s to 10 Gc/s band can be designed; those for low frequency use may be of the loop type. The X and S aerials are waveguide horns of the sectoral variety with built-in waveguide-coaxial transformers, and the L band aerial is of the discone type whose output connection is of course coaxial, the device being in effect a broad band dipole.

The OA 1430 is shown in Fig. 1, the operator is holding an S Band horn aerial which is connected to the main instrument (TF 1396A) (Fig. 2) by virtually lossless coaxial cable. A detachable coupler unit inside TF 1396A provides the necessary (pre-set) attenuation by means of lossy coaxial cable, the output end of which feeds r.f. power to the thermistor mount. Each of the X, S and L band aerials has its respective colour-coded coupler unit which is quickly placed in position inside TF 1396A whenever a different frequency range is required. In the case of X and S bands the aerials have a constant aperture throughout their respective frequency ranges and therefore the couplers are required to provide constant attenuation. The L Band aerial however has an aperture which decreases with increase of frequency, and for this reason the coupler unit contains an R.C. filter (in addition to the lossy coaxial cable) whose attenuation also decreases by the required amount.

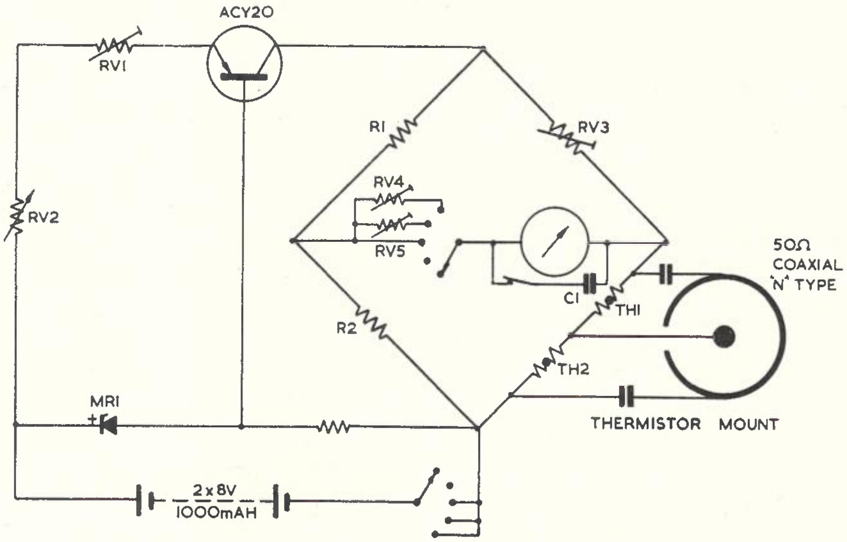

Fig. 3.—Functional Diagram of Marconi Instruments R.F. Radiatron Power Meter, Type TF 1396 A.

A functional diagram of the power meter is shown in Fig. 3. It can be seen that the two thermistors are in series to d.c. and in parallel to r.f. Thermistors tend to be unstable when fed from a constant voltage source, and so a transistor is used to provide a constant current bridge supply. Zener diode MR 1 and set zero controls RV 1 and RV 2 determine the transistor base current and therefore the current through the collector load which is formed by the bridge. With zero r.f. input, RV 2 is adjusted until the thermistor current is such that the resistance value of TH 1 + TH 2 provides a good match to the 50 ohm system; RV 3 has previously been set to equal this value, and since $R_1 = R_2$ the meter will read zero in these conditions. Application of r.f. power will slightly lower the resistance of TH 1 and TH 2, and the meter is deflected by the resultant unbalance current giving an indication of power density over the range 0 to 20 mW/cm^2; a db scale is also provided, and the scale is marked with red and green sectors representing power densities above and below 10 mW/cm^2 respectively. Although zero setting has to be readjusted with changes in ambient temperature the circuit is so designed that absolute sensitivity is hardly affected over the temperature range of 0 to 50°C.

The aerials supplied are all of the linearly polarised variety, and the instrument may be switched to its LIN (linear) range and used on both vertically and horizontally polarised incident fields by suitable rotation of the aerial for maximum indication. In a circularly polarised field the output of each aerial is reduced by 3 db. Consequently the CIRC (circular) switch position doubles the power sensitivity of the power meter thus allowing the same 0 to 20 mW/cm^2 scale to be used. A further increase in sensitivity of about 3 db is provided on the H.S. (high sensitivity) range which allows initial

Fig. 2.—Marconi Instruments R.F. Radiatron Power Meter, Type TF 1396 A.

search and aerial alignment to be carried out at a point more remote from the transmitter aerial. The instrument may be tripod mounted and a remote meter connected to a socket provided on the front panel.

The thermistor mount is designed to provide a good match to the 50 ohm system, a VSWR of 1.3 or better is achieved over most of its frequency range. The thermistors are physically tiny in order to reduce stray reactances to a minimum, low-loss dielectric materials being used to preserve proper resistive matching up to 10 Gc/s. The whole unit is mounted inside a type N socket.

The complete instrument is shower-proof, dielectric windows being used in the X and S horns. The polystyrene sheet used must be thin in order to avoid upsetting the aerial electrical characteristics, and in the S aerial the sheet is given mechanical support by filling the waveguide with expanded polystyrene which has a dielectric constant close to unity. In the X aerial the window is of sufficiently small area to be self-supporting.

Sources of Error

With the aerial/pre-set attenuator/power meter configuration, tolerances of component parts of the system must be kept small because the total maximum error is assumed to be equal to the sum of the errors of individual parts. This assumption is made, even though it is statistically improbable that all errors will have the same sign, in order to err on the side of safety; for the same reason the pre-set attenuators are adjusted so that the reading of power density is correct or on the high side when on the extremes of the total tolerance band. The design must be such that the following parameters have errors which are either insignificant or allowed for in the overall accuracy claim; aerial aperture V frequency; mismatch loss V frequency at aerial/attenuator junction; pre-set attenuation V frequency; mismatch loss V frequency at attenuator/power-meter junction; power meter sensitivity V frequency.

Aerial Aperture

$$\text{Aerial gain} = Gr = \frac{4\pi A}{\lambda 2} \quad \ldots (2)$$

where A = aerial aperture in cm^2
λ = wavelength in cm,

substituting in Eqn 1 gives

$$Po = \frac{Pr}{A} \quad \ldots (3)$$

It is obviously desirable that the aerial should be designed to have a constant known aperture throughout the frequency band under consideration. In order to check that this requirement is met by a particular design, two identical aerials must be directed towards each other to achieve maximum transmission then

$$A = R\lambda \sqrt{\frac{Pr}{Pt}} \quad \ldots (4)$$

where R = distance between aerials (in same units as λ)
Pr = Power received
Pt = power supplied to transmitting aerial

$\frac{Pr}{Pt}$ can be most accurately determined by means of a substitution technique involving the use of a precision attenuator. It is vital that the aerials are mounted well clear of all objects including the ground, distance R must be sufficiently large to ensure absence of near field effects and connections, sources and loads must have a V.S.W.R. close to unity. Identity of aerials can be established by means of the three aerial method. With care it should be possible to determine aerial aperture to an accuracy within ± 0.25 db. In cases where it is impossible to design an aerial of constant aperture throughout the relevant frequency band, a suitable filter/attenuator must be inserted between aerial and power meter such that a constant effective aperture exists at the power meter input terminals.

Mismatch Losses

If a source with a V.S.W.R. of Ss is coupled to a load with a V.S.W.R. of SL, then the resultant V.S.W.R. can be as good as $\frac{Ss}{SL}$, as bad as Ss SL, or at some intermediate value. In the $\frac{Ss}{SL}$ case the mismatch loss will be at a minimum value Mmin,

$$Mmin = 10 \log_{10} \frac{(Ss/SL + 1)^2}{4\ Ss/SL} \text{ db} \quad \ldots (5)$$

In the Ss SL case the mismatch loss will be at a maximum value Mmax,

$$Mmax = 10 \log_{10} \frac{(Ss\ SL + 1)^2}{4\ Ss\ SL} \text{ db} \quad \ldots (6)$$

Power in the load will be less than the available power by the amount shown in equations 5 and 6. Equation 6 shows the worst case and is the only one considered when calculating power loss at any junction. It is obvious that careful design is necessary so that Ss and SL are each as close to unity as possible in order to make Mmax small.

Pre-set Attenuator

With an aerial of defined aperture and a power meter of known sensitivity it is a simple matter to calculate the necessary attenuation figure, and great care must be taken to procure an attenuator frequency response that is complementary to the aerial aperture, e.g., if aperture decreases with increasing frequency then attenuation must decrease in the same proportion.

Power Meter Sensitivity

By careful attention to detail the Marconi OA 1430 power meter realises an accuracy of ± 0.25 db in terms of actual power dissipated within the thermistor mount. A further error arises due to finite V.S.W.R., this is allowed for when considering mismatch losses.

CONCLUSION

Power densities above 10 mW/cm^2 can give rise to harmful effects in humans and animals; a few of these are briefly discussed. British Post Office safety recommendations are summarised and some suitable measuring methods considered.

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1. R. L. Carpenter et al, "Biological Effects of Microwave Radiation With Particular Reference to the Eye"; U.S.A. Paper No. 30, Third International Conference on Medical Electronics, 21st-27th July, 1960.
2. D. H. Shinn. Letter to Editor, Nature, 27th December, 1958.
3. British Post Office; "Precautions Relating to Intense Radio Frequency Radiation"; H.M. Stationery Office Code No. 43-182.

FURTHER READING

1. Marconi Instrumentation, Vol. 8, No. 7, pages 147 and 150.

AUTOMATIC TRUNK TRANSMISSION TESTING

*C. FLETCHER, A.R.M.I.T.C.**

INTRODUCTION

The planning of a Commonwealth-wide scheme of Subscriber Trunk Dialling (S.T.D.) has been in progress for several years and progressively greater numbers of subscribers are being given direct access to trunk lines. As these circuits are not monitored by skilled operators, greater importance is being placed on the stability of the transmission equivalents and improved testing methods had to be devised. As a result of this a number of circuits have been designed which allow semi- or fully automatic transmission checks to be made.

THE TESTING SYSTEM

The testing system adopted (See Fig. 1) follows the principle of a method described by Missen (1). A special relay set called a Self Answering Relay Set (S.A.R.S.) is connected to a test number. The relay set is seized from the testing exchange by dialling the appropriate number over the trunk line. This can be done by means of an automatic routiner (in larger centres) or by means of a manual tester (in smaller exchanges) The principle of the test is based on the fact that the S.A.R.S. responds to a predetermined level of test tone applied via the trunk circuit. A relay will operate in the S.A.R.S. when the tone level at its input exceeds a certain fixed value. This causes the relay set to return test tone of fixed level to the testing end. In this way channel equivalents can be checked in both directions of transmission by one testing officer or automatically where routiner access is available.

As a first step a fairly simple relay set had been designed which was connected to a 2VF receiver as trigger unit. It was soon realized that the operate point of such a receiver was not as stable as was hoped. For this reason the transistorized relay set (See Fig. 2) described below was developed. Two types of tests can be carried out with the above set-up.

Limit Testing: In this case the sending device will send two tone levels, e.g. —7dbm followed by —2dbm. The distant S.A.R.S. is adjusted to operate to a level of —6dbm applied at its line jacks. If 0.5db is allowed for switching loss on either side of the trunk (i.e. a total of 1db), S.A.R.S. should not operate when —7dbm is sent and should operate on —2dbm send level. If S.A.R.S. operates to the lower send level the channel equivalent is more than +2db. If the trigger circuit does not respond to the —2dbm sent, the channel equivalent will be less than —3db.

Level Testing: In this case a measure of the actual transmission equivalent can be obtained. In the sending device an oscillator is connected to the trunk line through a variable attenuator. Attenuation is switched out in 0.5 or 0.25db steps and after every step it is ascertained if the distant S.A.R.S. has operated. This type of testing is not included in the circuits to be described later. However, it has been tried experimentally (2) and would be of value if the automatic routiner circuit, to be described later, was equipped with "Telegraphic Read Out".

Besides achieving rapidity in testing, and saving at least a technician at the remote end, the method involves all equipment associated with the trunk line including relay sets and hybrid coils. A particular fault found on a number of occasions will illustrate the importance of testing through relay sets. If an earth fault exists on one side of "HYB LINE", it would not normally be detected if testing is done between "HYB LINE" and "HYB LINE" using a transmission measuring set. However, testing through the relay set results in one half of the A relay in the relay set being short-circuited by the "Earth" fault as far as AC is concerned. Severe attenuation is caused by this condition.

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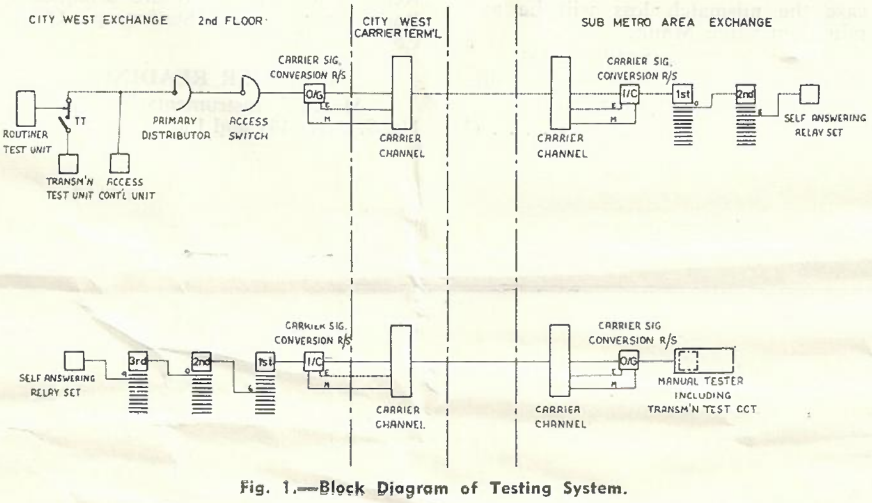

Fig. 1.—Block Diagram of Testing System.

CIRCUITRY

From what has been said, it will be realized that in this testing system we have a requirement for—

(a) an oscillator circuit with an output level stable over long periods and under varying temperature conditions; and

(b) a receiver circuit which will receive V.F. tone and operate a relay if the input exceeds a certain fixed level. This trigger point must also remain constant over long periods.

Furthermore a suitable test frequency had to be selected. As the C.C.I.T.T. recommended standard test frequency is 800 c/s. this frequency was approached as closely as possible without causing interference to the 2VF system. 820 c/s. ± 5 c/s. was adopted. Furthermore the stability of both the oscillator and the receiver circuits had to be better than ± 0.2db over long periods and under varying temperature conditions.

Oscillator

The basic oscillator was designed in the P.M.G. Research Laboratories (3) and this circuit was followed by a Class AB amplifier stage so that sufficient output could be obtained (See Fig. 3). Total harmonic distortion of the output does not exceed 4 per cent at any level.

From Fig. 4 it can be seen that NL, NR, LP and R form the four arms of an impedance bridge. The oscillator output voltage is virtually applied between points A and B by means of the tuning winding NC + NT. The signal voltage developed across C and D will depend on the unbalance of the bridge. The more nearly the bridge is balanced the less voltage is developed across C and D. This voltage is the feedback voltage of the oscillator applied between base and emitter of the transistor. On switching on, the lamp filament is cold and its resistance small (5 ohms approx.). The feedback voltage across CD is large and oscillation builds up. As the output voltage across AB increases so does the current through the lamp increase. The filament temperature rises and with it the resistance. The bridge becomes more nearly balanced and the feedback voltage across CD is reduced. Finally with approx. 1 volt applied across the lamp the filament resistance will be approx. 29.8 ohms. LP almost bears the same ratio to R as does NL to NR (2 : 1). The voltage across CD is very small and just enough to maintain oscillations. If the gain of the transistor increases the output voltage would tend to increase. This would increase the current through the lamp. The filament resistance of the lamp would increase

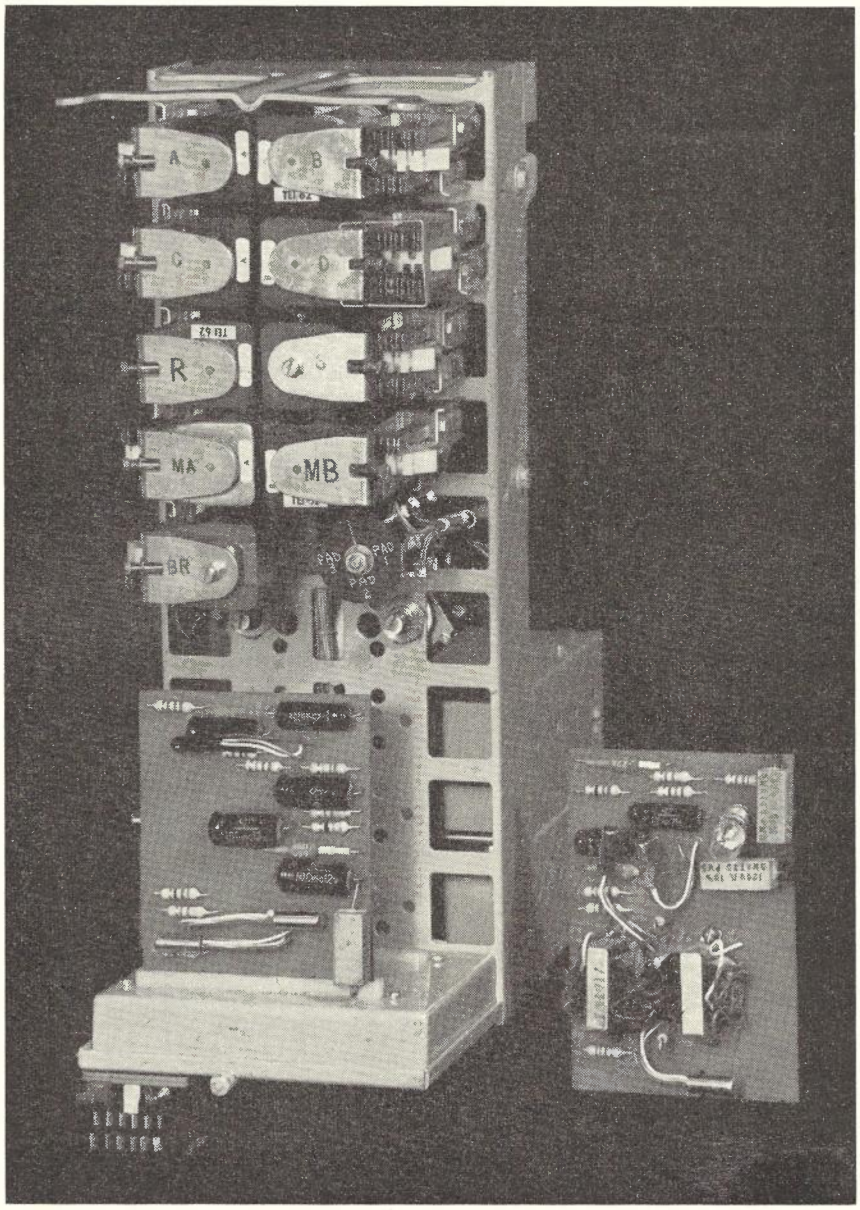

Fig. 2.—Self Answering Relay Set with Oscillator Board Removed.

further, thus balancing the bridge more perfectly. The feedback voltage across CD is more reduced and thus the output voltage is maintained constant. If the gain of the transistor decreases the opposite takes place and the feedback voltage is increased.

Receiver

This circuit (See Fig. 5) consists of a two-stage transistor amplifier followed by a rectifier which rectifies the signal output and a Schmitt Trigger circuit which operates to this rectified signal voltage. To maintain the circuit gain constant, voltage as well as current feedback are applied to the two stage amplifier. The Schmitt Trigger circuit functions as follows:—

With no signal applied the voltages in the circuit are as shown in Fig. 6. VT1 is conducting and its collector potential is nearly the same as its emitter potential. As the emitters are common a very small voltage is only applied between base and emitter of VT2 and VT2 is cut off. The S relay is released. When a signal is applied to the receiver circuit a DC voltage will be developed across the rectifier bridge, i.e. UV. As the potential of U is fixed by the Zener Diode so must the potential of V drop towards earth, i.e. the potential VW decreases with increasing signal level. This potential drops from 12.8 volts to 5.4 volts. The voltage Y-W is dependent on the voltage V-W and therefore also drops from 5.4V to 4.7 volts. The potential X-W also is decreased from 5.2 volts to 4.5 volts as the current through VT1 is reduced. Point Y becomes less and less negative with respect to point X and VT1 is more and more driven to "Cut Off". Finally when the potential developed across the rectifier is 32.6 volts Y is so little negative with respect to X that VT1 cuts off. The potential ZW rises towards 36 volts approx. This applies a negative potential between base and emitter of VT2 which starts to conduct. The voltage across X-W jumps to 19 volts due to the large current (19mA) flowing through VT2. The emitter of VT1 is now very much more negative than its base and VT1 is completely driven into "Cut Off". VT2 is held conducting and relay S operates. When the signal applied to the receiver is reduced the opposite process takes place and S releases.

Self Answering Relay Set

Facilities: From what has been said before, the facilities this circuit must provide can be deduced. They are:—

(a) On seizure to provide a holding and guarding earth on the P wire.

(b) To provide for three complete reversals at standard intervals (750 m. secs.) the last reversal being a permanent one.

(c) After the last reversal to connect a level sensitive receiver to the line which will operate a relay if the tone level on the line exceeds a specified limit e.g. —6dbm.

(d) When the receiver is triggered, to connect a stable level oscillator to the line which sends a constant tone level, e.g. +1dbM.

(e) To provide a break in the tone sent after 5 seconds and to reset the circuit ready for retriggering.

Operation: The circuit operation is shown in Fig. 7 and details are set out below:—

(a) When the relay set is seized A operates to the loop condition. A1 connects earth to the P. wire. A2 connects R to the interrupted earth lead and R commences to pulse and continues to do so as long as the relay set remains looped. A3 prepares the operate path of MA and MB.

(b) To ensure that three complete reversals are returned in every case the first "ON" and "OFF" period of interrupted earth are disregarded by means of the MA and MB relays.
Earth on: R operates. R2 operates MA via MB3 but keeps MB short circuited. MA1 completes the operate path of MB in series with MA. MA2 operates BR via S3.
Earth off: R releases. R2 removes the short circuit from MB which now operates in series with MA. MB3 prevents R from having any further effect on MA and MB which remain held as long as the relay set remains looped.
MA2 and MB1 have now connected the counting circuit and the next three pulses of R are counted.

(c) R operates again. Earth at R1 via MB1, C3, D5 operates B. B1 prepares the operate path for C, but C remains shortcircuited as long as R is operated. B3 and B5 reverse the line potentials.

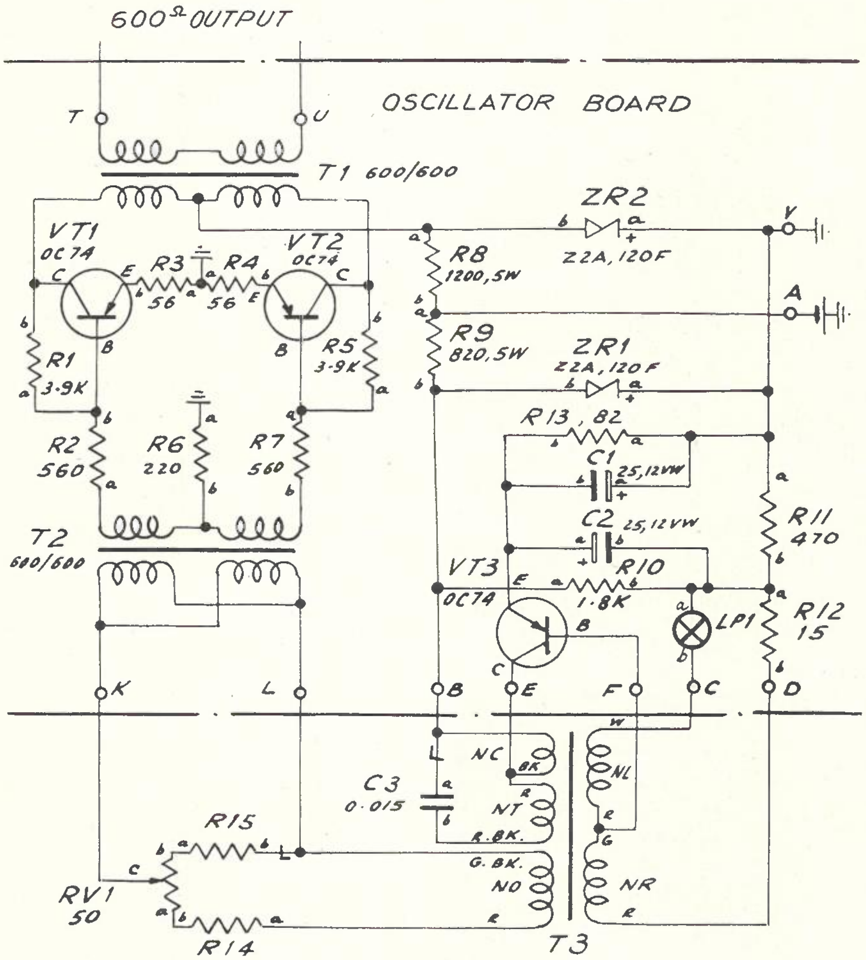

Fig. 3.—Oscillator Circuit.

(d) R releases and C operates in series with B via MA2, D3 and B1. C3 prepares the operate path for D. C1 and C2 restore the original line potentials.

(e) R operates again. D operates via R1, MB1, C3, and MR1 and locks via MA2 and D7. D1 and D2 reverse the line potentials again. D3 opens the locking path of C and thus puts C back under control of R1.

(f) R releases. C releases but B is held via D6, R2 and B1. C1 and C2 restore original line potentials.

(g) R operates. B is shortcircuited via MB1, C3, D5 and released. B3 and B5 reverse the line potentials once again and B2 connects the receiver to the line via S2 and S4, BRI and BR3 and D4. D remains operated while B and C stay released as long as the relay set is seized. R continues pulsing but has no effect. During the transit time of the reversal contracts of B, C and D, A will be released and re-operated momentarily but the connection is held as MA3 guards the P wire and MA for this reason has a long release lag (180 mS approx.)

(h) If the level on the line exceeds the preset operate level S will be operated by means of the Schmitt Trigger circuit on its first winding. S locks on its second winding to the earth on the P wire via BR2 and S1. S3 opens the circuit of BR, S2 and S4 connect the oscillator to the line.

(i) BR takes 5 seconds to release due to C3 and R4. After this period BR1 and BR3 disconnect the line thus providing a break in the tone. BR2 releases S. Due to C4 and R3 S has a release lag of approx. 300 MS.

(j) S3 causes BR to re-operate and the circuit is ready to be retriggered again. The release lag of S ensures a minimum break before retriggering of the circuit is possible. This ensures that any 2VF circuit connected to this circuit will be able to clear down when the tone is broken.

(k) When the holding loop is broken, A releases, releasing MA and MB. MA2 releases D and all relays are then released again. A1 and MA3 remove the earth from the P wire so that the preceding train of switches is able to release.

APPLICATION

Manual Testing

The transmission test circuit can be built up as a separate unit and used in conjunction with an existing relay set tester (Fig. 8). The relay set tester is connected to the trunk relay set through this circuit. Normal testing is carried out on the relay set, but a Self Answering Relay Set (S.A.R.S.) is dialled up as distant test number. Before releasing the call a transmission test is carried out.

If the circuit is provided with a switchboard type jack, it can be used in manual exchanges without further addition. The S.A.R.S. is dialled up from the switchboard and the Answer Cord inserted into the jack on the transmission tester.

Also future relay set test circuits can be designed to incorporate the transmission test circuit.

Facilities: (a) The circuit provides a through connection until the "Transmission Test" key is operated. Dialled impulses etc. pass through the circuit without interference.

(b) On transmission testing a holding loop is extended to the trunk relay set.

(c) The circuit allows monitoring of the level of its own oscillator by operating the "Measure Send" key.

(d) On operation of the "Send Low" key low level tone is sent to line which should not trigger the distant S.A.R.S.

(e) On operation of the "Send High" key higher level tone is sent to line which should trigger the receiver in S.A.R.S.

(f) The tone being sent by the distant S.A.R.S. is measured on the db meter provided by operating the "Measure Receive" key.

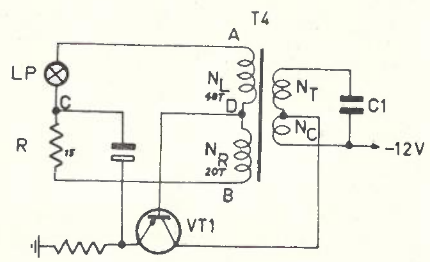

Fig. 4.—Oscillator Operation.

Operation: The operation of the testing circuit is described below:—

(a) With all keys normal the test jacks are connected through to the test plugs via KTT.1 and KTT.2. All parts of the transmission test circuit are disconnected at KMR.1, KMR.2, KSH.1, KSH.3, KSL.1, KSL.2, KTT.1, and KTT.2.

(b) When operating KTT the "Through" connection is broken and the transmission test circuit connected to the line.

(c) Operating KMS connects the meter circuit across the oscillator output while all other parts of the circuit are disconnected. The output level of the oscillator is read on the meter.

(d) On operating KSL the oscillator is connected to the line via KMS.2, KMS.4, HSH.2 and KSH.4, the 6 db pad, KSL.1, KSL.2, and the 4 mF capacitors. If the oscillator level is adjusted to —0.75 dbm then —7dbm

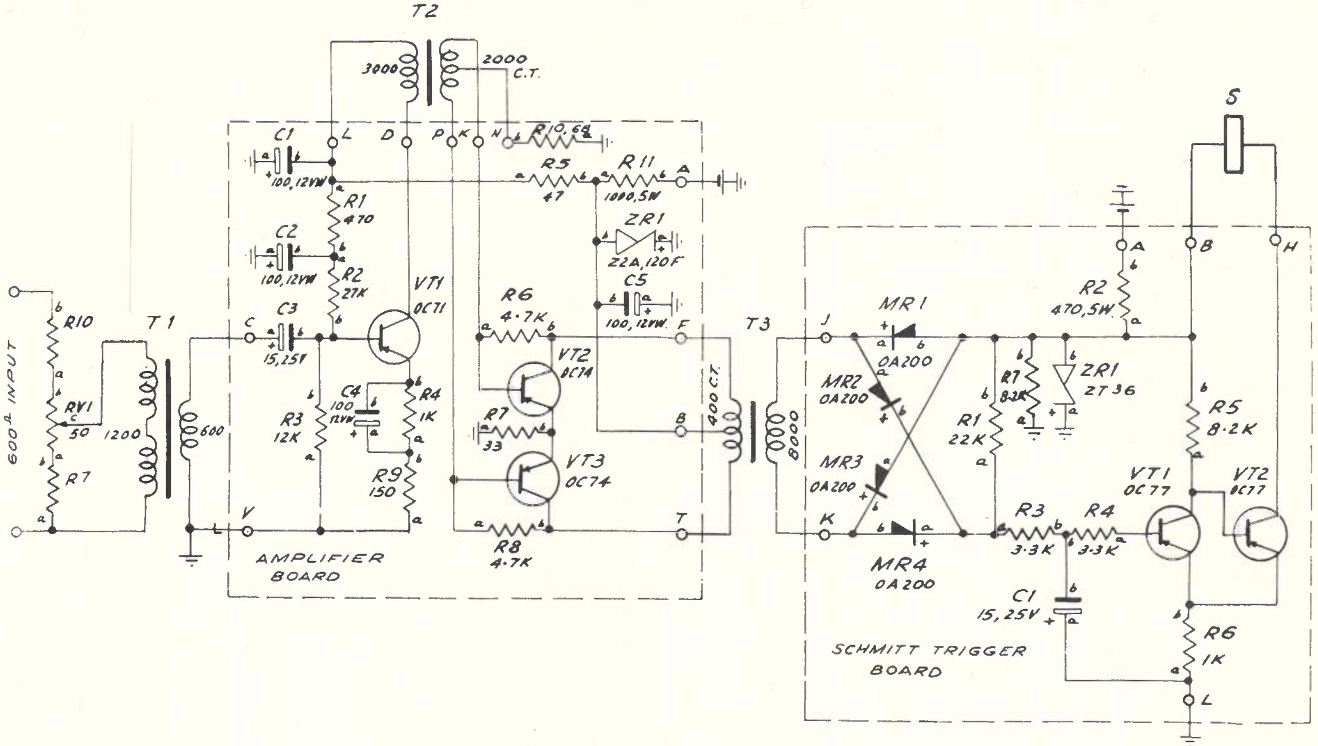

Fig. 5.—Receiver Circuit.

will be sent to line (0.25 db is lost in the transmission bridge).

(e) On operating KSH the pad is switched out via KSH.1, KSH.2, KSH.3, KSH.4, —1 dbm is sent to line.

(f) When tone is received from the distant S.A.R.S. and KMR is operated the meter circuit is connected to the line via KMS.1, KMS.3, KMR.1, KMR.2, KSH.1, KSH.3, KSL.1, KSL.2, C.1, C.2 and KTT.1, KTT.2. The incoming level in dbm is read on the meter.

Automatic Testing

The circuit shown in Fig. 9 was designed to operate in conjunction with the Test Unit of the Signalling Conversion Relay Set Routiner at City West Exchange. However, it can be built into any routiner circuit provided a start condition can be signalled to the unit

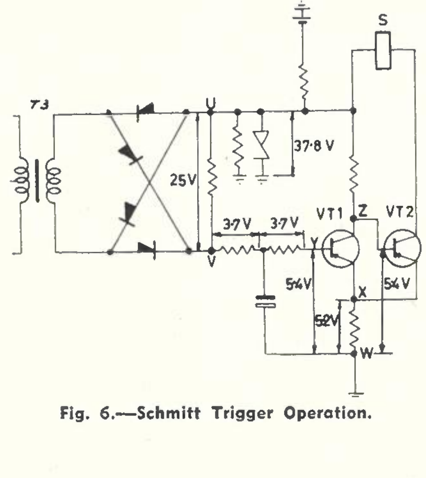

Fig. 6.—Schmitt Trigger Operation.

(operation of TT) and its own "Step On" condition is accepted.

Facilities: (a) Circuit sends low level tone to line (e.g. —7dbm). If distant and triggered, this could be due to—

(i) False operation due to howling of the channel during reversals.

(ii) The channel equivalent is above specified limits (e.g. +2db).

(b) The circuit ascertains whether the distant end has operated and to remove possibility (a) (i) applies low level tone again.

(c) If distant end triggers again possibility (a) (ii) exists which is a fault condition. The circuit ceases to test any further.

(d) If the above test is passed high level tone e.g. (—2dbm) is sent to line and the circuit again ascertains if the distant end has operated. If the distant S.A.R.S. does not return tone this time the channel equivalent is below the specified limit e.g. —3db, and the routiner stops, as a fault condition exists.

(e) If the 2nd Test is passed the circuit provides for two further tests to check that the tone level returning from the distant end is within specified limits. The routiner stops if either of the two tests fails.

(f) If channel is passed OK a "Step On" signal is sent to the Routiner Test Unit.

(g) Suitable limit changing for different classes of trunks is provided by the LCA and LCB relays which are to be operated from the access equipment.

Operation: (a) When the Test Switch in the Routiner Test Unit reaches position 15 (Transmission Test) TT operates in the RTR Test Unit. TT 1 signals a "Start" condition to the Transmission Test Circuit. TT 4 and TT 5 disconnect the RTR Test Circuit and connect the Transmission Test Circuit. The oscillator is connected to the line via a specified pad e.g. 8db if —7dbm are to be sent to line.

(b) I is operated slowly on its 550 ohm winding by earth at TT1 via II. II opens the operate circuit of I and connects A to earth at TT1. I holds due to the charge on C4. A operates and A1 connects the local receiver to the line.

(c) If tone is received from the distant end S operates and earth at S1 via D6/1, A3 holds I operated on the 400 ohm winding. I holds A operated at I1. Earth at S1 also operates H via D8/1. H locks to the main control earth at TT1 via H2. H1 prepares the operating path for R.

(d) The tone from the distant end breaks after 5 seconds, S releases, Earth at S1 (released) operates R via A2, L1, H1 and D2/1. R locks via R1. R2 operates L which locks via L2 and R3 releases H, and A. R4 prevents energizing of the stepping magnet. A2 releases R.

(e) I re-operates slowly to earth at TT1, Steps (a) and (b) are repeated.

(f) If the distant end triggers again H operates and locks as in (c), I and A are again held operated. However when the tone breaks and S releases L1 prevents R from re-operating. H, I and A remain locked and the "SEND" and "HIGH" Lamps are alight.

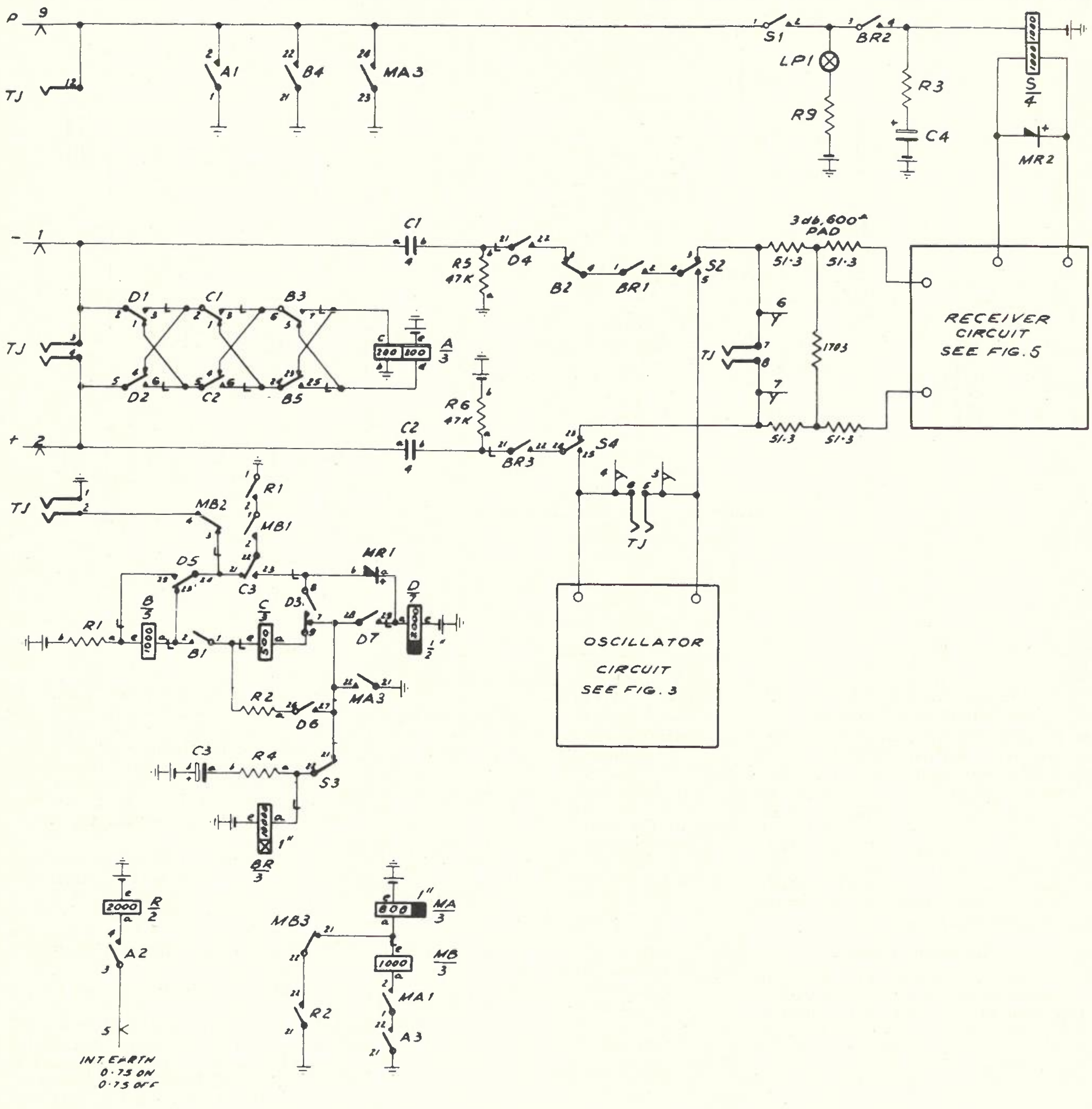

Fig. 7—Self Answering Relay Set Circuit.

(g) If no tone was received from the distant end after (b) or (e) I releases slowly when the charge on C4 decays followed by the slow release of A.

(h) During the time I is released and A still holding the magnet of the digit switch is energized via A4, I2 and R4. The switch steps when A finally releases.

(i) Higher level tone is now sent to line by connecting the oscillator to the line via a smaller pad e.g. 3db if —2dbm are to be sent to line. The distant end should now trigger unless the transmission equivalent in the outgoing direction is below standard.

(j) I1 operates A and A2 reconnects the receiver to the line. S will not operate if the distant end has not operated. S1 holds I on the 400 ohm winding via DM/2, A3. I1 holds A operated. The "SEND" and "LOW" Lamps are alight.

(k) If the S.A.R.S. at the distant end did operate in (i) the Switch steps as in (h), as I and A are not held by earth at S1.

(l) SR operates to earth at A3 via D6/3 and SR3 and locks via SR3. SR4 extinguishes the "SEND" light and "REC" lights. SR1 and SR2 connect the switch operated Pad system between the line and the local receiver.

(m) The switch steps to contact 4 and tone at a fixed level e.g. +1dbm is being sent by the distant S.A.R.S. The local receiver is set to operate also at a predetermined level e.g. —6dbm. The large pad e.g. 8db is connected between line and receiver and S will operate only if the channel is high in the receive direction.

(n) If S operates, H will operate and lock itself as well as A, I as in (c) the "REC" and "HIGH" Lamps are alight.

(o) If S did not operate in (m) the switch steps to contact 5. S should now operate unless the channel is low in the receive direction.

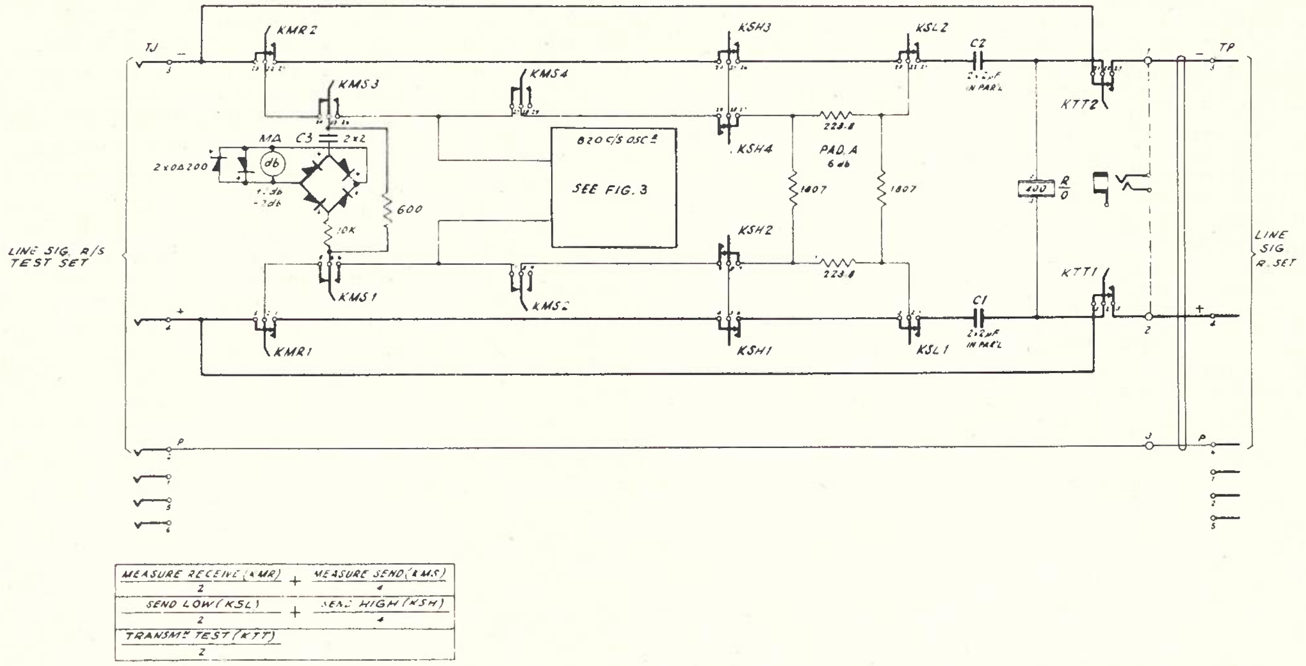

Fig. 8.—Manual Testing Circuit.

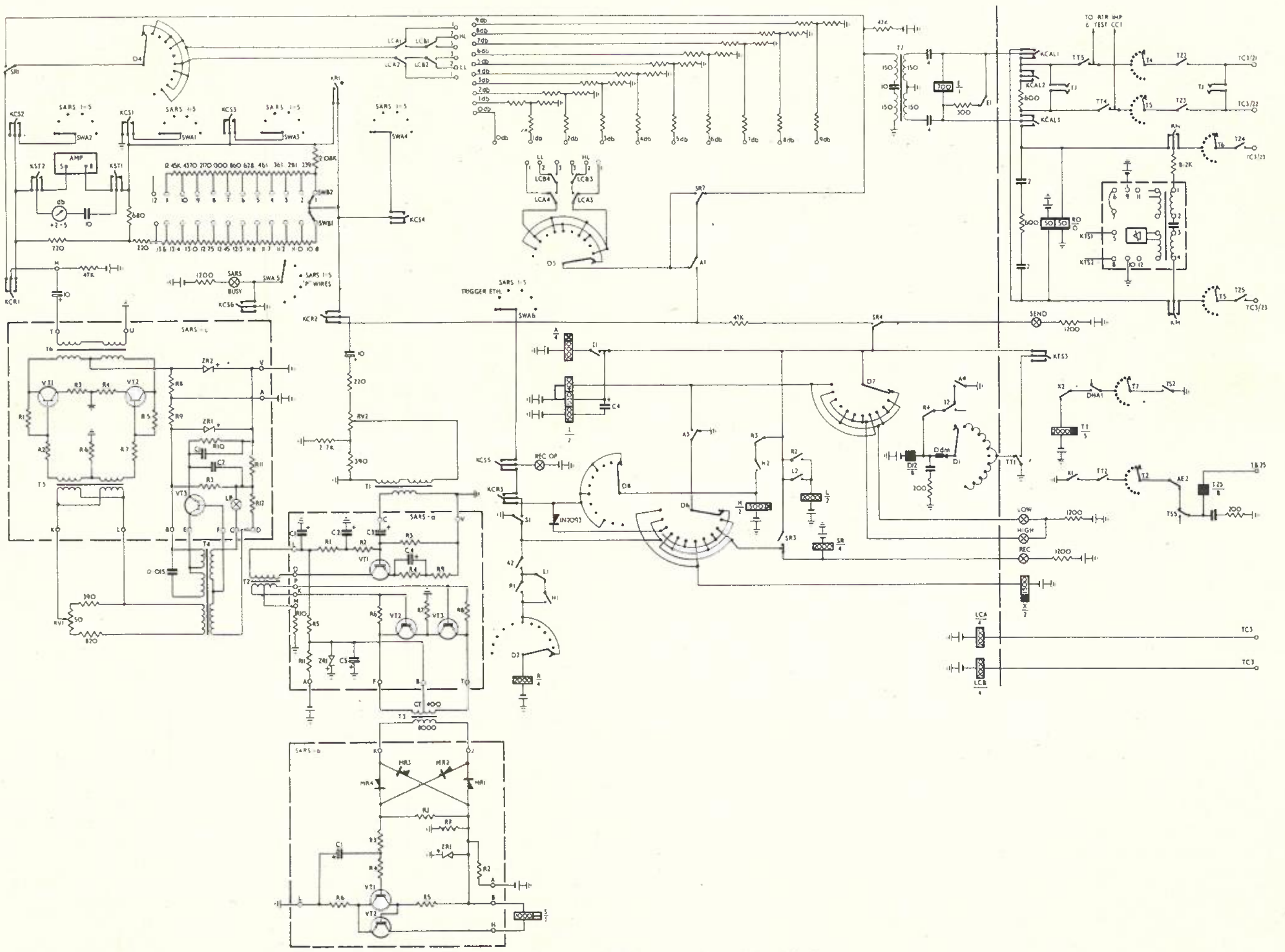

Fig. 9.—Automatic Transmission Test Unit.

(p) If S did not operate I and A are held operated as in (j). The "REC" and "LOW" Lamps are alight.
(q) If S did operate in (o) the switch is allowed to step to contact 6. X operates via D6/6 to earth at A3.
(r) X1 energizes the T switch magnet via TT2 and X2 releases TT slowly.
(s) TT2 breaks the T switch magnet circuit and the switch steps on to the next test in the cycle after "TRANSMISSION".
(t) TT1 (released) completes the homing circuit of the digit switch via D1. The switch homes to contact 1 or 7.

CONCLUSION

The circuits described have been in service in the Melbourne E.L.S.A. Area for approximately nine months. The initial fault incidence was very high. A large number of faults were found to be in the drop equipment. These included incorrect pad settings in 4 Wire Terminating Sets, the already mentioned "Earth" faults on "Hybrid Line", short-circuited turns on "A" relay coils, bunched "E" relay contacts in i/c trunk relay sets causing terminating resistors to be left across the speech wires after the "Answer" condition and lastly open circuited transmission capacitors. These faults were found very quickly and rectified. A number of intermittent faults were however also located in the carrier equipment including repeaters. These could only be isolated by carefully analyzing fault repetition. In most cases "Dry" joints were located in some items of equipment. Today each trunk in the E.L.S.A. Area is checked once daily and an average of 1% of all circuits is found to be faulty per day, i.e. their equivalents are found to be outside the specified limits. Further development of the testing system is at present being undertaken. The aims are to achieve even greater stability of the electronic circuits as well as greater receiver sensitivity, to develop equipment for "Level" testing as well as "Limit" testing, and to incorporate the method in traffic route testing.

ACKNOWLEDGMENTS

The author wishes to acknowledge the assistance received from the many colleagues who contributed to the design of the various circuits described in this article and particularly Mr. W. Hockley's contribution in designing and manufacturing the printed circuit boards.

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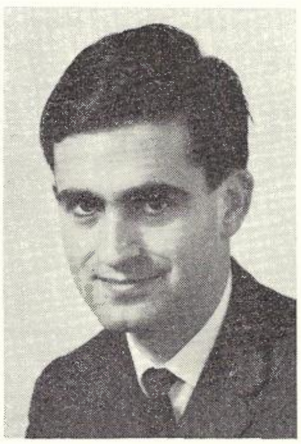
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After joining the Postmaster-General's Department as a Junior Mechanic in 1939 he was promoted to Cadet Draftsman in 1941, progressed through the positions of Draftsman and Sectional Draftsman and has occcupied his present position since 1961.

His cadetship was interrupted by 3½ years' war service with R.A.A.F. and a further absence from the Drafting Section occurred during the period 1950 to

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E. J. WILKINSON, co-author of the article, "Expansion of Transmitting Station Facilities for the National Television Service", was educated at University High School and Melbourne Technical College. Mr. Wilkinson joined the Postmaster-General's Department as a Junior Mechanic in Training in 1937 and qualified for appointment as Engineer in 1944.

After five years in the Radio Section of the Victorian Administration engaged on duties associated with broadcasting studios, medium frequency transmitting stations, and the high frequency transmitting sations at Lyndhurst and Shepparton, he was promoted as Divisional Engineer to the Headquarters Administration in October 1949.

With the exception of a six months' period in 1961 when he returned to the Victorian Administration, Mr. Wilkinson has been engaged at Headquarters since 1949 on the plant provision aspects of radio equipment, formerly on radiotelephone equipment, but more recently on television and broadcasting station equipment.

Mr. Wilkinson is an Associate Member of the Institution of Engineers Australia, and a Member of the Institution of Radio and Electronics Engineers (Australia).

Mr. Wilkinson served for some years on the Board of Editors of the *Journal* prior to his transfer to the Victorian Administration in 1961. Since 1962 he has undertaken a series of lectures on Television for the Society, in Melbourne and throughout the country areas of Victoria. His "Television" lecture to the Ballarat branch on 13th November, 1962, was the inaugural country lecture of the Society.

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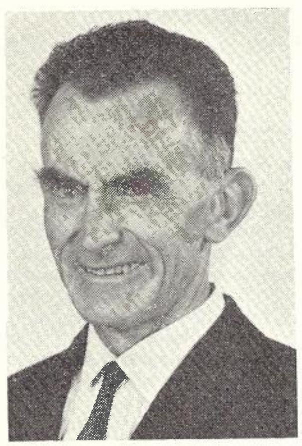

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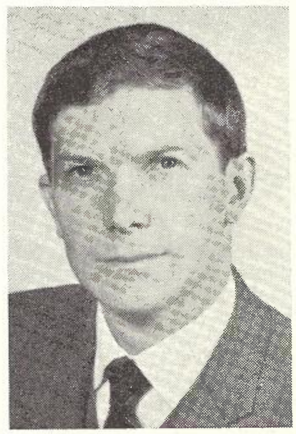

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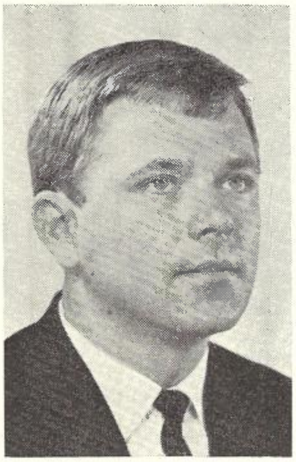
L. N. JACKSON, author of the article, "The Transmission Level Tracer", completed a Diploma of Electrical Engineering at Bendigo Technical College in 1956. After graduating B.E.E. from Melbourne University in 1958 he joined Austral Standard Cables Pty. Ltd. where as Cable Engineer he was responsible for the design, testing and quality control of communication cables, especially coaxial cables. In September, 1960, Mr. Jackson joined Siemens Halske Siemens Schuckert (Australasia) Pty. Ltd. where he was a Sales Engineer for communication test equipment. At the end of 1962 he visited Siemens & Halske A.G. in Munich, Western Germany, to gain information on carrier telephone equipment and test gear. On returning to Australia he became responsible for the contract administration for Coaxial Cable Broadband Carrier Systems and the sale of test equipment. Mr. Jackson has recently taken up a position as Engineer Grade 4, Communications Section, with the State Electricity Commission of Victoria.



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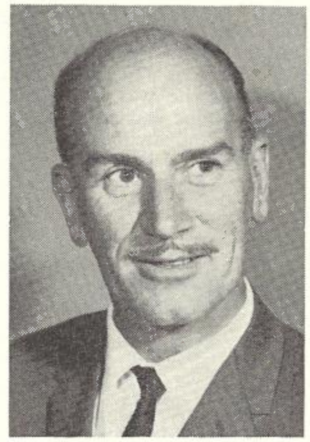
I. T. HAWRYSZKIEWYCZ, author of the article "Computer Compilation of Summaries of Technical Assistance Reports", joined the Department in 1959 as a Cadet Engineer. He completed the Degree of Bachelor of Engineering with first class honours at the University of Adelaide in 1961. From 1961 to 1962 he was a post-graduate student at the University of Adelaide, and carried out work related to analog simulation on digital computers.

In August, 1962, he was appointed Engineer Class 1, in the Transmission Lines Division at the Research Laboratories. In this position he has been associated with the CDC-160A computer at the Laboratories and has carried out research work on the applications of this computer. A major portion of this work has been concerned with the study and development of methods which can be used to process subscriber reports.

He is a student Member of the Institution of Electrical Engineers, London.



J. D. ROBERTSON

J. D. ROBERTSON, co-author of the article on the "Expansion of Transmitting Station Facilities for the National Television Service", received his B.Sc. (Engineering) Degree with Honours in Electrical Engineering from Edinburgh University and is an Associate Member of the Institution of Engineers Australia. After working with the B.B.C. and Imperial Chemical Industries Limited in their Research Engineering Section, he joined the Australian Post Office in 1950, coming to the Radio Section in N.S.W. He has been associated with most of the activities of the section in N.S.W. since then; firstly in the rapid expansion and equipment modernisation of the National Broadcasting Service in the '50s and secondly, in the even greater expansion of the National Television Service in N.S.W. in the early '60s. He became Divisional Engineer, Broadcast Stations in 1955, then Divisional Engineer, Radio Telephone Installation, followed by Divisional Engineer, Television in 1961, since which time he has been closely associated with the expansion of television transmitting facilities throughout N.S.W.

ANSWERS TO EXAMINATION QUESTIONS

Examination No. 5147—6th July, 1963, and subsequent dates. To gain part of the qualifications for Promotion or Transfer as Senior Technician (Telecommunications) Telephones (Postmaster-General's Department Section 2 —Long Line Equipment, (Answers to Section 1 were given in Vol. 14, No. 5/6.)

Answers by *J. M. WALKER*

QUESTION 1.

List the equipment you would require to measure the characteristic impedance of an open wire line in the range 1 kc/sec to 3 kc/sec and show by means of a schematic diagram how the equipment would be connected.

What arrangements would be necessary at the distant end of the circuit?

ANSWER 1.

See Telecommunication Journal of Australia, Vol. 9, No. 4, page 222 (amplifier detector is not required).

QUESTION 3 (a).

Draw in block schematic form, the arrangement of the units of equipment which make up a vibration test set. Include in the diagram the block representing an item to be tested.

ANSWER 3 (a).

See Telecommunication Journal of Australia, Volume 13, No. 4, page 311, figure 2, diagram (a).

QUESTION 3 (b).

Describe briefly the method of making the test. Give examples of typical faults you would expect to find.

ANSWER 3 (b).

The equipment to be tested is connected between the output and input terminals of the fault detector.

The frequency of the oscillator of the fault detector is set to a value within the pass range of the equipment and at a level of at least 10 db below the normal operating value of the equipment.

The input attenuator and noise suppressor are adjusted for maximum sensitivity. A test of sensitivity may be made by introducing an artificial fault or by tapping a suitable resistor across the input of the equipment being overhauled.

Disturb all external leads between the test set and the equipment to ensure that these are satisfactory. Before removing any covers test external "U" links or connections by gently disturbing them and listening for clicks or crackles from the set.

Remove panel dust covers as gently as possible to prevent disturbance and temporary clearance of any intermittent faults.

Using a light rubber headed hammer vibrate all components, wiring, cable forms and connections by gently tapping them. The force applied is appropriate to the component, etc., and is not so great as to damage it. Using pliers or tweezers coated with an insulating material or film, all wiring connections are pulled very gently to ensure that a bad connection does not exist.

A slight turning and rocking motion is applied to some components, e.g. valves to check socket connections.

A careful and systematic visual examination is made at the same time and any faulty conditions repaired before completing the test.

Faults discovered by vibration testing include bad connections of all types, potentiometer wipers, loose electrodes in valves, faulty carbon resistors, faulty mountings in crystal element filters, broken wires in forms, loose grid caps and loose fuses.

QUESTION 4 (a).

Why is it necessary to synchronise the oscillators of carrier telephone systems?

ANSWER 4 (a).

Differences in the frequencies of modulator and demodulator oscillators at the ends of a circuit result in similar differences in the output and input signal frequencies. These differences increase as circuits are connected in tandem. These changes in frequency result in distortion of speech and voice frequency signals.

Since oscillators vary with time in their output frequency it is necessary to synchronise them periodically, i.e. reduce the differences to a small value.

QUESTION 4 (b).

Describe in detail the method of synchronising the oscillator of the two terminals of a three-channel carrier system of the older type not employing crystal control.

ANSWER 4 (b).

See Telecommunication Journal of Australia—Volume 10, No. 5, page 160.

QUESTION 5 (a).

What are the functions of an amplifier detector in an amplitude modulated voice frequency telegraph system?

ANSWER 5 (a).

(i) To amplify the voice frequency signals as received from the channel receive filter.
(ii) to compensate for changes in the bearer circuit loss by varying the amplifier gain to deliver a substantially uniform level to the detector with a given range of input levels.
(iii) to ensure the automatic gain control does not operate so rapidly as to vary the gain during the absence of signal when spacing signals are applied.
(iv) to rectify the voice frequency signal so as to reproduce the D.C. signals from a telegraph relay.

QUESTION 5 (b).

List the steps you would take to adjust the gain of an amplifier detector in any system with which you are familiar.

ANSWER 5 (b).

The following is the method for adjusting the gain for systems which are adjusted on a mark signal.

(i) Connect a 600 ohm, 5 db pad between RECEIVE LINE and RECEIVE EQUIPMENT or at a suitable point individual to each channel.
Caution: Care must be taken to ensure that a balanced pad is not inserted at a point where the circuit is unbalanced with respect to ground; at such points an unbalanced pad must be used.
(ii) Adjust the amplifier-detector gain control on each channel to the point of minimum gain.
(iii) Apply a Mark signal to all channels at the far terminal.
(iv) Observing the plate current of the detector stage, increase the gain of the amplifier-detector of channel 1 until the point is reached where the plate current ceases to rise.
(v) Repeat for the remaining channels in turn.
(vi) Remove the 5 db pad.

QUESTION 6 (a).

At the control station of a 12-channel open wire carrier telephone system equipped with automatic gain control a pilot fail alarm occurs. Examination of the system shows that both the flat and slope pilots have failed. At the same time all telephone channels on the system are reported as "off no voice" by the telephonist. One channel of the system is used as a bearer for a 24-channel V.F.T. system which is also reported as faulty. State briefly what action you would take to restore service to both the telephone and telegraph channels and to localise the fault.

ANSWER 6 (a).

Assuming that the A station of the system is the control station the indications show that the system has failed in
(a) both directions or
(b) in the B-A direction only.

The following action should be taken.
(i) Patch the V.F.T. system to its regular patch bearer
(ii) Ascertain the pilot alarm indications at the repeater stations. If it is a system with a large number of repeaters it would be desirable to commence at a station in the middle.

If it is a bearer failure then the alarm indicators will be "B-A pilot fail" at all stations between the faults and the A Station and "A-B pilot fail" at all stations between the fault and the B station.

If it is a failure in the B-A direction only then "B-A pilot fail" alarms will occur at all stations between the faulty repeater station and the A station and dependent on the faulty equipment a similar alarm will occur at the faulty repeater station. The latter condition can be checked by measuring the incoming and outgoing B-A pilot levels.

(iii) After locating the faulty repeater section or repeater arrange for a bearer patch between repeater stations in the case of a faulty repeater section, or for patching spare equipment in the case of a faulty repeater. If a "J" patch bearer or spare repeater equipment is unavailable, then subject to the approval of the Traffic Officer in charge at the control station a less important "J" system could be sacrificed.
(iv) Check that all circuits are satisfactory.

QUESTION 6 (b).

Give the limits of variation of the level of the pilot from its nominal value before the pilot fail alarm is operated.

ANSWER 6 (b).

+ 3 db and — 5 db.

QUESTION 8.

You are required to install a valve equipped 3-channel carrier telephone terminal at an established country L.L.E. office with battery supply busbars.

QUESTION 8 (a).

Name the types of cable you would require.

ANSWER 8 (a).

1. Switchboard Cable. 20 wire.
2. Screened Cable Twin Twisted. 1 pair.
3. Power Cable. Thermoplastic Insulated 3/.029.

QUESTION 8 (b).

Briefly outline the reasons for the use of each cable type.

ANSWER 8 (b).

1. Switchboard cable required to extend Hybrid Line and Net or in some cases Mod In and Demod. Out to the I.D.F. (6 pairs). Also used for patch trunks, order wire connections and alarm extension.
2. Screened Cable required for connection between bearer circuit, line filters and carrier terminal. Screened cable used to reduce noise and crosstalk interference to the system.
3. Power cable for connection between busbars and system power terminals. 3/.029 has current rating of 10 amps which is sufficient for 24 Volt supply to most 3 channel terminals.

QUESTION 8 (c).

List the testing instruments you would require to test the completed system.

ANSWER 8 (c).

1. Combined Volt ohm Milliammeter.
2. A.P.O. Transmission Measuring Set or similar.
3. Variable frequency oscillator covering range at least 200-4000 cycles.
4. Noise measuring set with speech weighting network.

QUESTION 8 (d).

Name three tests which would be performed and the instrument to be used.

ANSWER 8 (d).

1. Measurement of filament and anode supply voltages. Measurement of anode currents. Check of cabling for continuity or grounds (Volt ohm milliammeter).
2. Adjustment of terminal send levels. Adjustment of receive levels. Measurement of channel frequency responses (A.P.O. Measuring Set and Variable Oscillator).
3. Noise measurement on each channel. (Noise measuring set.)

Examination No. 5240.—4th July, 1964. To gain part of the qualifications for promotion or transfer as Senior Technician (Telecommunications), Telegraphs, Postmaster-General's Department.

Answers by *J. R. KROL*

QUESTION 2.

(a) Explain clearly what is meant by—
(1) A transmission speed of 50 bauds.
(2) A receiving margin of ± 35 per cent.

(b) A DXD4 test transmitter is in fact running 5 per cent fast. It is being used to check the margin of a 50 baud teletype Model 15 page printer which is running at correct speed. Show by means of a timing chart the effect of the DXD4 speed error on the measured margin of the Teletype when the teletype has a true margin of ± 35 per cent at 50 bauds.
(15 marks)

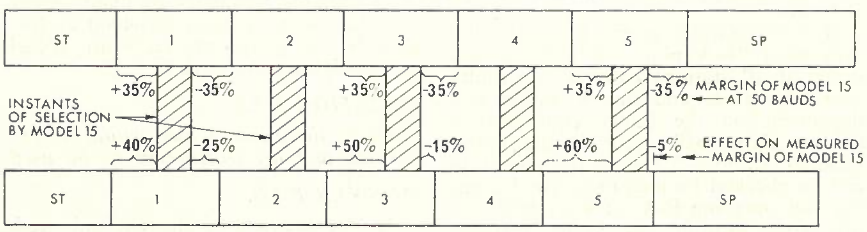
ANSWER 2.

(a) (1) A transmission speed of 50 bauds means that 50 units of equal length can be sent per second. A unit in this case is 1/50 second long, i.e. 20 milliseconds.

(2) A receiving margin of ± 35 per cent. means that the receiving mechanism of a telegraph machine can tolerate signals with 35 per cent marking distortion and 35 per cent spacing distortion without incorrect translation of the received signals.

(b) As DXD4 test transmitter is running 5 per cent fast, each signal element transmitted from it will be shorter by one millisecond, i.e. it will be 19 milliseconds instead of 20. The effect on the measured margin of the Teletype Model 15 which is running at correct speed of 50 bauds is shown below by means of a timing chart. This margin will be + 40 per cent. and — 5 per cent.

50-BAUD SPEED OF MODEL 15 PAGE PRINTER



SPEED OF DXD4 5 PER CENT FAST

QUESTION 6.

(a) What does T.R.E.S.S. stand for?

(b) Describe in full the message preamble necessary for the transmission of messages in the system—from the "beginning of message" signal to the "message separation" signal, inclusive.

(c) What are the functions of the following items of Tress Exchange equipment—
(1) register
(2) marker
(3) sequential start and number bulletin printer.

(d) Two types of lines which may be terminated in a Tress exchange are Simplex Linefinder and Duplex. Explain the differences between the exchange termination for each of these types.

(e) A message is sent from a simplex linefinder outstation of one Tress exchange to a duplex outstation of another Tress exchange. What form of record of the message is kept in each exchange.

(20 marks)

ANSWER 6.

(a) T.R.E.S.S. stands for Teleprinter Reperforator Switching System.

(b) The message preamble necessary for the transmission of messages in the TRESS system is as follows:—
It starts with "space" (combination 31) which the system recognises as a "beginning of message" signal. This must be followed by three characters, the first character representing the destination State, and the second and third identifying the office of destination. Then follows space, three more characters representing the State and office from which the message is originated, the message route serial number and the message separation signal "=".

(c) The functions of the following items of TRESS Exchange equipment are as follows:—

1. Register.
 (i) Recognizes when one of its ten transmitters has a message to be handled.
 (ii) Connects itself to one of its calling transmitters.
 (iii) Reads the first routing character and determines whether the message is interstate or intrastate.
 (iv) If an interstate message, regards the State letter and blank as the routing code.
 (v) If an intrastate message, it ignores the State letter and reads the next two characters as routing code.
 (vi) Calls for marker when routing information has been stored.
 (vii) Ignores multple "space" (combination 31) characters at the beginning of a message.

2. Marker.
 (i) Recognizes calls from registers.
 (ii) Connects registers in strict preference order.
 (iii) Tests leads between register and marker.
 (iv) If test faulty it changes over to another marker.
 (v) If test correct it reads routing code.
 (vi) Marks the required outlet.

3. Sequential start and number bulletin printer.
 (i) Recognizes when one of its transmitters has a potential call set up.
 (ii) Searches for and finds a calling transmitter.
 (iii) Connects to the calling transmitter.
 (iv) Tests outlet with a test pulse.
 (v) If outlet is busy it awaits a release pulse and then examines other transmitters to see if they need service before returning to the original transmitter.
 (vi) If outlet is free it completes the connection and starts auto numbering.
 (vii) After auto numbering has been completed it starts the transmitter.
 (viii) Records details of outgoing line code and message number.
 (ix) Records details of originating line code and message number.
 (x) For interstate messages it first records the destination code of the message (State letter from A.N.), two letter destination from transmitter, then remainder of (viii) and (ix). Hence all messages are completely logged and message tracing facilitated.

(d) (i) Exchange termination for simplex linefinder. In this case simplex lines from lightly loaded offices are arranged in groups to connect to a smaller number of incoming reperforator transmitter (R/T) stores via line finders. Each line finder group has an alloter which allots a free line finder and its associated R/T to wait for a call from an outstation. Up to 25 simplex linefinder lines may share 10 R/T's.

(ii) Exchange termination for duplex lines. Each duplex line is connected to a terminal relay set with which are associated two R/T's. One R/T receives messages from the outstation and retransmits them via a cross office circuit to a selected outlet. The other R/T receives messages via its cross office circuit and retransmits them to line.

(e) The TRESS exchange which receives a message from a simplex L/F outstation and re-transmits it to a duplex outstation of another TRESS exchange will have the following record:
 (i) Tape record on the incoming L/F suite R/T.
 (ii) Number bulletin printer record.
 (iii) Tape record on the outgoing duplex suite R/T.

The TRESS exchange which receives the message from a distant TRESS exchange and retransmits it to a duplex outstation will have the following record:—
 (i) Tape record on the incoming duplex suite R/T.
 (ii) Number bulletin printer record.
 (iii) Tape record on the outgoing duplex suite R/T.

TECHNICAL NEWS ITEM

AUSTRALIAN POST OFFICE TO USE ALUMINIUM CONDUCTOR TELEPHONE CABLE

The Australian Post Office is currently using up to 15,000 tons of copper annually, a large proportion of which is used as fine conductors for underground telephone cables. In the financial year 1964/65 it is expected that approximately 2,000,000 miles of conductors will be added to a network which already contains over 14,000,000 miles.

For some years the Post Office has been interested in the use of aluminium conductors to replace copper, but previous investigation and use was limited as it was generally shown that aluminium was uneconomic compared with copper on the previous ruling prices of copper of around £(A)305 per ton. Rapid rises in the price of copper, the possibility of an actual copper shortage and improved technology in the aluminium industry has caused the Post Office to reconsider the position at present prices. Aluminium conductor telephone cables in a large range of sizes affords substantial saving in cost compared with copper conductor cables

Trial orders have been placed for aluminium conductor cable for two specific projects, one each in Sydney and Melbourne, to re-evaluate the economics, and to ensure that some technical difficulties known to exist have been overcome. Delivery of these first lengths of cable will be made early in 1965, and subsequent installation will be effected. Present indications are that manufacturing problems have been overcome by an Australian cable manufacturer who has successfully manufactured a trial length of 200 pair cable.

The cables being purchased are in sizes 600, 800 and 1,200 pairs, with aluminium conductors 0.0256 inch in diameter. This size was selected as it gives equivalent cable characteristics, particularly resistance, to the 0.020 inch (6½ lb./mile) copper conductors already used in parts of the network, yet is almost identical in diameter to the .025 inch (10 lb./mile) conductors used elsewhere in the network. This will enable the cable manufacturers to employ existing factory equipment without undertaking developmental work other than that associated with the different metals. This, in turn, will allow an assessment to be made of the use of aluminium in the shortest time and at the lowest cost.

Jointing of aluminium conductors and, in particular, the jointing of aluminium conductors to copper conductors already in the network is known to be a difficult problem because of the aluminium oxide film. However, several jointing techniques have been investigated by the Post Office and two of the most promising ones capable of ready use by field staff have been developed to a satisfactory stage for the field trials. Aluminium to aluminium conductor joints will be made using a tip weld on the end of a normal twist joint (see Fig. 1), and aluminium to copper conductor joints will be made by crimping an aluminium press sleeve onto the conductors (see Fig. 2). In this latter technique, the wires must first be tightly twisted together, and the pitch of the twist must be less than the width of the crimping tool.

The specific type of aluminium conductor to be used has been selected, and is a compromise taking into account sufficiently high tensile strength for manufacturing and cable hauling purposes, ductility for field jointing and twisting operations, and high conductivity.

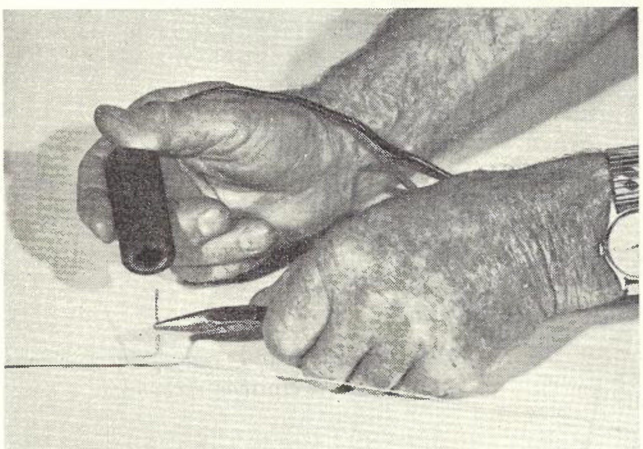


Fig. 1.—Paper-insulated aluminium to aluminium conductors about to be tip welded. The carbon rod is connected to the negative 24 Volt battery terminal.

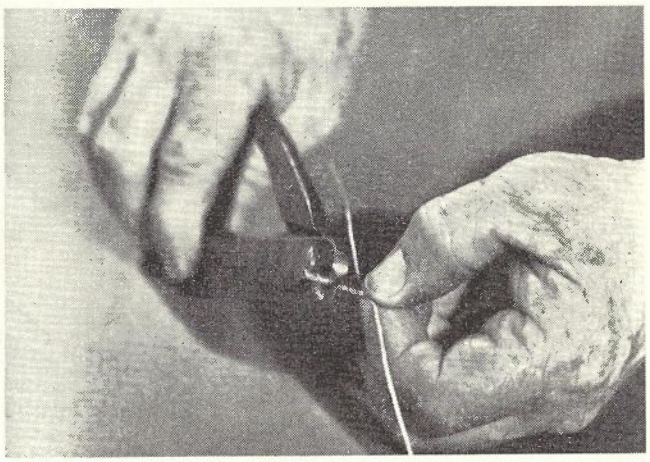


Fig. 2.—Jointing aluminium to copper paper-insulated conductors using an aluminium press type sleeve and a standard 40 lb. conductor jointing tool. One crimp has been made, and the second is about to be inserted.

Junction radio equipments, operating in the VHF and UHF bands with capacities of 5 or 9 speech circuits, are supplied.

Public Telephone Exchanges

The Company manufactures telephone exchanges for public service ranging from rural automatic exchanges having only a few subscribers connected to them, to main exchanges having many thousands of lines, and trunk switching centres. The exchanges are particularly suitable for subscriber trunk dialling systems and equipment for these can easily be installed either with the initial exchange or at a later date and are compatible with future electronic exchange. The exchanges at present in service use electro-mechanical switching devices. Today, however, development resources are directed towards the efficient application of electronic switching devices to automatic telephony. Progress in this direction has greatly accelerated recently. Prototype exchanges have already operated in public service and the experience gained is being applied to the development of an economical exchange that will provide many more facilities than are at present available.

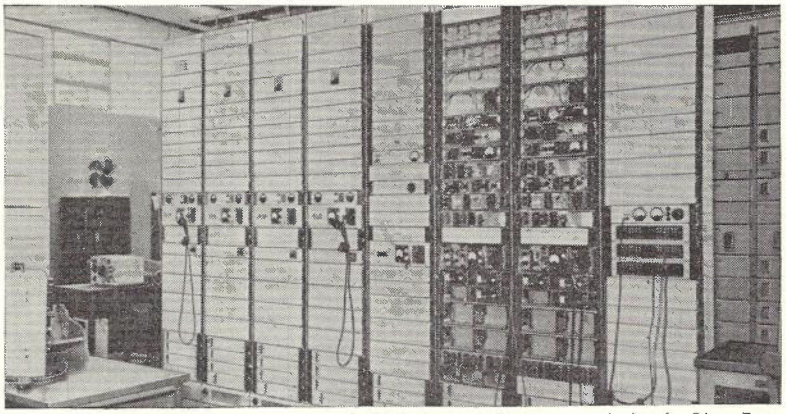
Private Systems

A similarly wide range of telephone exchanges is manufactured to provide private telephone communications within a factory, office block, hospital or other organisation. This range includes purely internal systems (PAX) and those having connexions to public exchanges (PABX). In either case the exchange can vary in size from as few as ten extensions to many hundreds of extensions in a large organisation.

An alternative system when only a few extensions are required is the pushbutton intercommunication system. This is suitable for up to twenty-one stations and a connexion is established by pressing a pushbutton.

Telephones

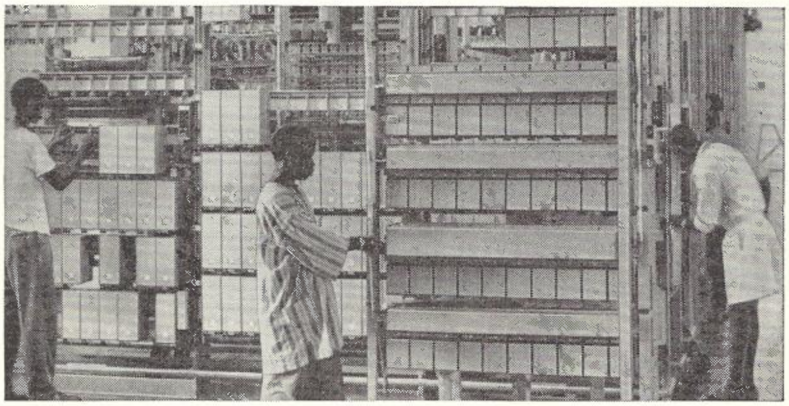
The Company produces a wide range of high-quality telephone instruments suitable for use on any telephone system. This includes telephones for wall or table mounting in a wide range of attractive colours as well as instruments for special application such as secretarial and extension systems, railways, ships, etc.



3-circuit & 12-circuit carrier terminal racks, Lima, Peru.

G.E.C. 706 Telephone.

V.H.F. Radio Racks at Kerewan repeater Station, The Gambia.



Automatic telephone exchange equipment at Ibadan, Nigeria.

Test desk and exchange apparatus at Hung Hom Exchange, Hong Kong.

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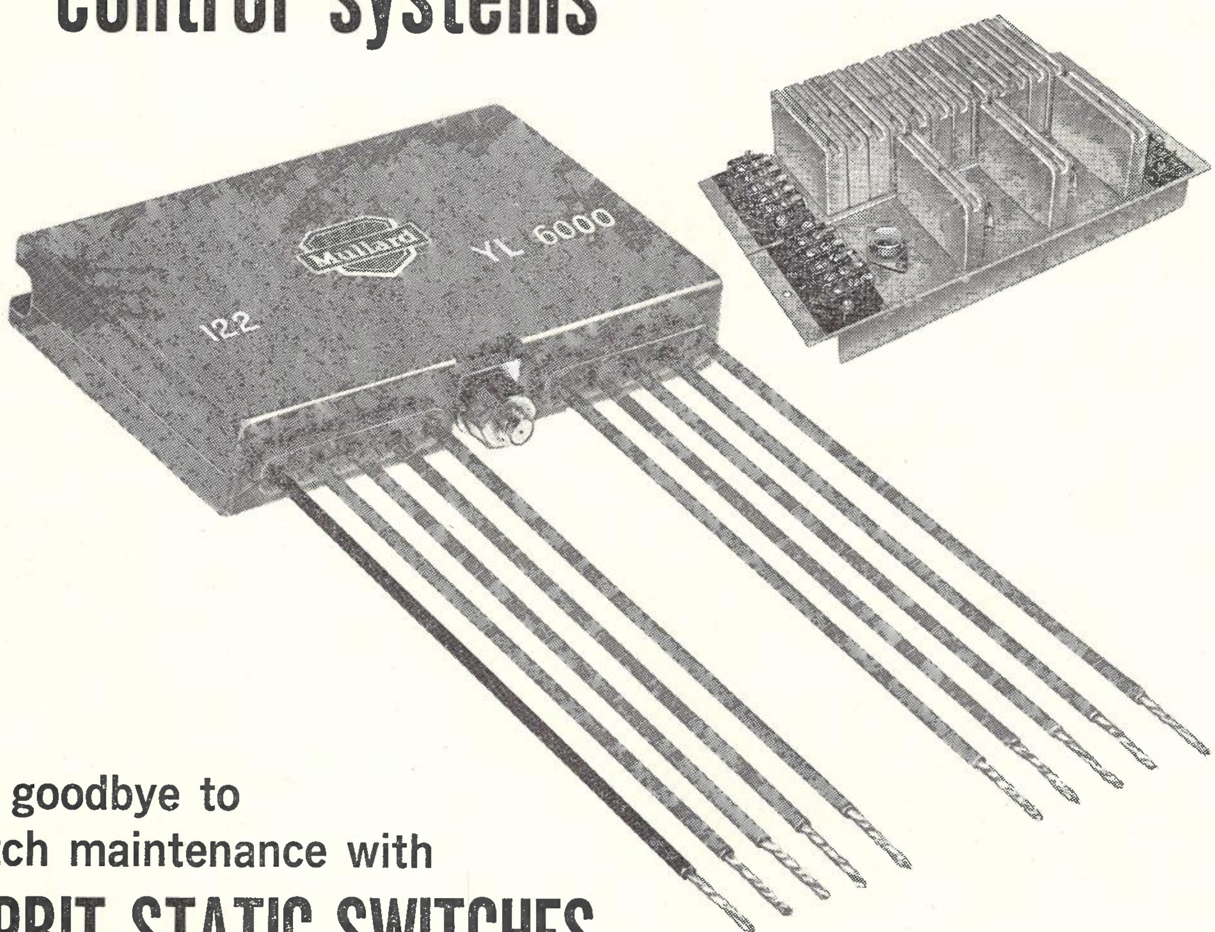
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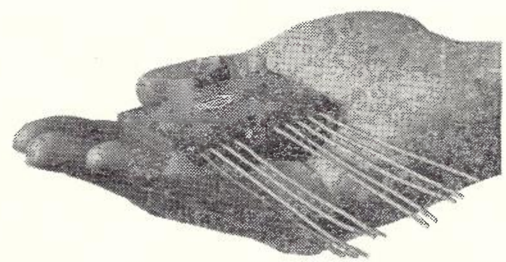

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