THE

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IN THIS ISSUE

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THE TELECOMMUNICATION JOURNAL OF AUSTRALIA

VOL. 20 No. 1
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The TELECOMMUNICATION JOURNAL of Australia

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DESIGN ASPECTS OF THE PERTH-CARNARVON COAXIAL CABLE SYSTEM

A. HANNAH, Assoc. I.E.E., F. J. HARDING, M.I.E.E.***

INTRODUCTION.

Between the end of 1959 and the end of 1967 the Australian Post Office installed some 2000 miles of coaxial cable, the bulk of it being in the south-eastern portion of the continent. While all the cable was designed and laid out for ultimate 12 MHz operation, the initial equipment operated up to 6 MHz only, employed thermionic valves and a high voltage, alternating current, remote power feeding system.

The heavy power requirements necessitated the use of continuously running power plant at main stations, which had the capability of accepting mains power failure and changeover to diesel prime mover without interruption to the power feeding conditions.

The large size of line equipment units required a building at each dependent repeater position (approximately 5.7 miles apart), which also housed cable termination units, gas reservoirs and control equipment for the cable protection system, emergency power units and many other items of equipment—all in a controlled environment.

Overseas developments in transistorised line equipment had been under study for some years, and the economic advantages to cable systems was clear at an early stage. This led to the decision to purchase only transistorised line equipment after mid-1967. Since then some 2000 miles of coaxial cable have been laid or are in course of construction, all being specifically designed to exploit the economic potential of all-transistorised, all-underground construction. This paper is the first of a series on this new equipment.

BROADBAND EQUIPMENT.

General.

So far transistorised coaxial line equipment of two different types has been installed in the Australian Post Office network. These are pilot-controlled and temperature-controlled, each of which has its characteristic advantages and disadvantages. This article is confined to the systems installed on the Perth-Carnarvon cable, which are of the temperature-controlled type manufactured by Siemens A.G., Munich, West Germany. The coaxial cable is 4-tube (2.6/9.5 mm) throughout, and two separate systems were installed, a 12 MHz (V.2700) on tubes Nos. 1 and 2 and a 4 MHz (V.960) on tubes Nos. 3 and 4.

TABLE 1.

Item.	Systems	
	12 MHz	4 MHz
Terminals	2	2
Main repeaters with drop out facilities	9	9
Main repeaters without drop out facilities (u.g.)	2	nil
Temperature-controlled repeaters (u.g.)*	197	87
Temperature-controlled, last-fed repeaters (u.g.)*	2	12
Partially regulated repeaters (u.g.)*	8	2
Capacity	1200 telephone circuits and one both-way T.V. relay.	960 telephone circuits (standby system)

*"**Dependent" repeaters**

Route Layout.

The layout of the route, which is 603.7 miles (971.5 km) long, is shown in Fig. 1.

Outline data on the quantities of line transmission equipment installed and the capacities of the two systems are shown in Table 1.

Family of Systems.

The C.C.I.T.T. (International Telephone and Telegraph Consultative Committee) recommends two types of coaxial cables for transmitting large voice circuit capacities over long-haul routes. These are the small diameter, 1.2/4.4 mm coaxial tube for medium capacity systems (300 to 960 voice circuits) and the 2.6/9.5 mm coaxial tube for larger systems (960 to 2700 and more voice circuits). Development of carrier equipment for these coaxial tubes has led to three co-ordinated systems known as V.300 V.960, and V.2700, which provide respectively for 300, 960 and 2700 voice circuits to be transmitted on a 4-wire basis over two coaxial tubes. Fig. 2 shows in simple straight line form the layout of the three co-ordinated systems.

Due to the progress made in the transistor field and miniaturisation of components, the volume of dependent repeaters has been reduced from about 210 cu. dm to 9 cu. dm, and resulting from this, virtually maintenance-free repeaters can be accommodated in containers installed underground like the cable itself. The repeater sets of all three systems are of uniform dimensions and their gain is so selected that expansion to the next larger system (V.300 to V.960 or V.960 to V.2700) only requires halving the repeater sections and changing the repeater sets.

Power is fed to the dependent repeaters from a power-feeding terminal or main repeater over the d.c. looped inner conductors of the two coaxial tubes. The d.c. feeding current is constant, irrespective of how many dependent repeaters are fed. Remote feeding filters on the line sides of each dependent repeater separate the d.c. feed current from the signal current.

Three types of dependent repeater are used: temperature-controlled, temperature-controlled last-fed, and partially regulated. The function of each of these will be described later in this article.

The terminal and main repeater equipment is transistorised and is mounted on racks for installation in conventional buildings but may, exceptionally, be mounted in underground containers if necessary. In summary, the main features of the line equipment are:

(i) Low power consumption, high reliability, long service life and negligible maintenance.

(ii) Reduction in space and weight by use of printed-circuit sub-assemblies and plug-in, slide-in chassis.

* Mr. Hannah is Engineer Class 4, Long Line Equipment, Headquarters. See Vol. 13, No. 3, P.271.

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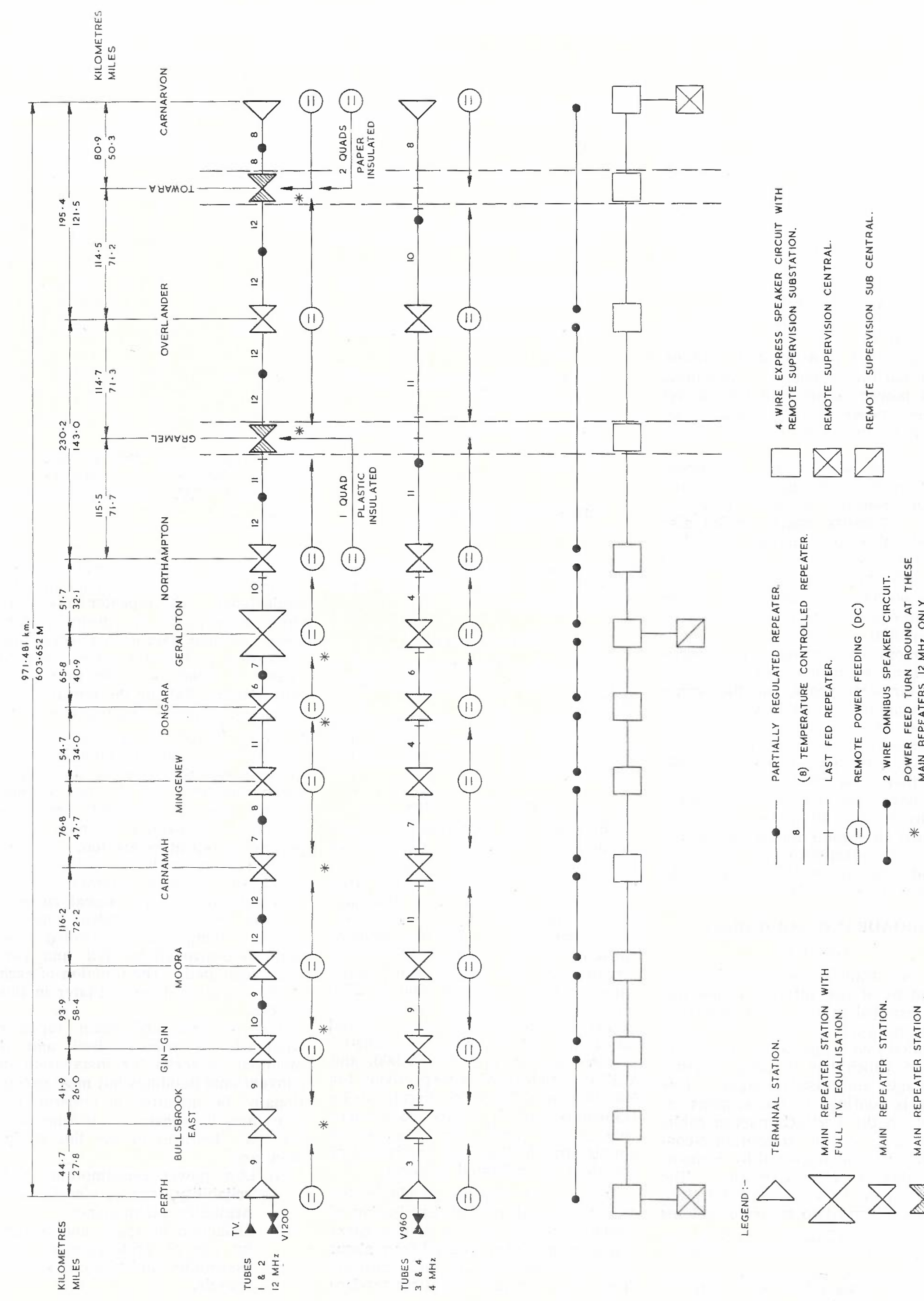


Fig. 1.—Perth-Geraldton-Carnarvon Coaxial Cable System.

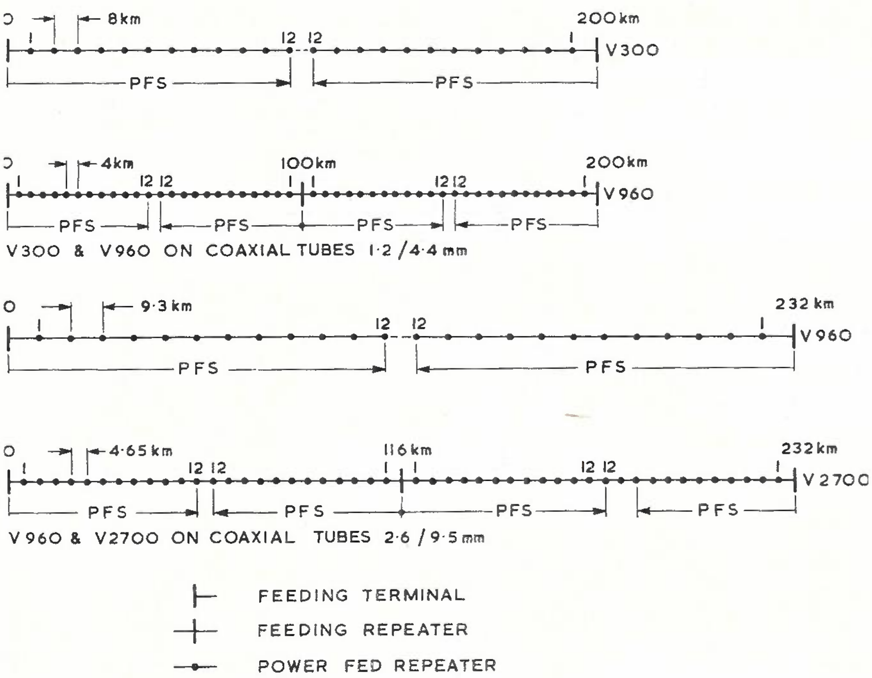


Fig. 2. — Family of Co-ordinated Systems.

(iii) In all dependent repeaters except 1 in every 12, control of the gain is by means of a temperature-sensitive element (indium antimonide) connected in the feed-back circuit of the amplifier.

(iv) Minimal noise power; on the average 1 pW/Km at zero relative level point.

(v) No special test wires are needed for supervising the operation of the system. A remote supervision system is operated over the 4-wire order wire and location of a faulty dependent repeater is made by means of an outband pulse signal.

System Elements.

The coaxial system consists of combinations of the following main elements:—

(i) **Terminals.** The terminal provides amplification for the adjacent minor repeater section, mop up equalisation for the main repeater section, and connects the line transmission band to the frequency division multiplex equipment. This equipment is rack-mounted and accommodated in surface buildings.

(ii) **Main Repeaters.** Main repeaters are provided at intervals along the coaxial cable route as demanded by power feeding, gain regulation and equalisation limitations or the need to extract one or more supergroups. This equipment is also rack-mounted, is generally accommodated in surface buildings, but may exceptionally be accommodated in underground chambers at locations where neither supergroup drop out nor power feeding facilities are required. Main repeaters provide a greater degree of regulation and equalisation than do dependent repeaters.

(iii) **Dependent Repeaters.** These repeaters are accommodated underground and provide amplification of the signal at regular intervals along the route to maintain an adequate signal to noise ratio and also to provide equalisation and gain regulation.

(iv) **Ancillary Facilities.** These comprise power feeding systems, remote supervisory system, pulse fault location equipment and order wire facilities.

Fig. 3 shows the block layout of terminal and main repeater stations

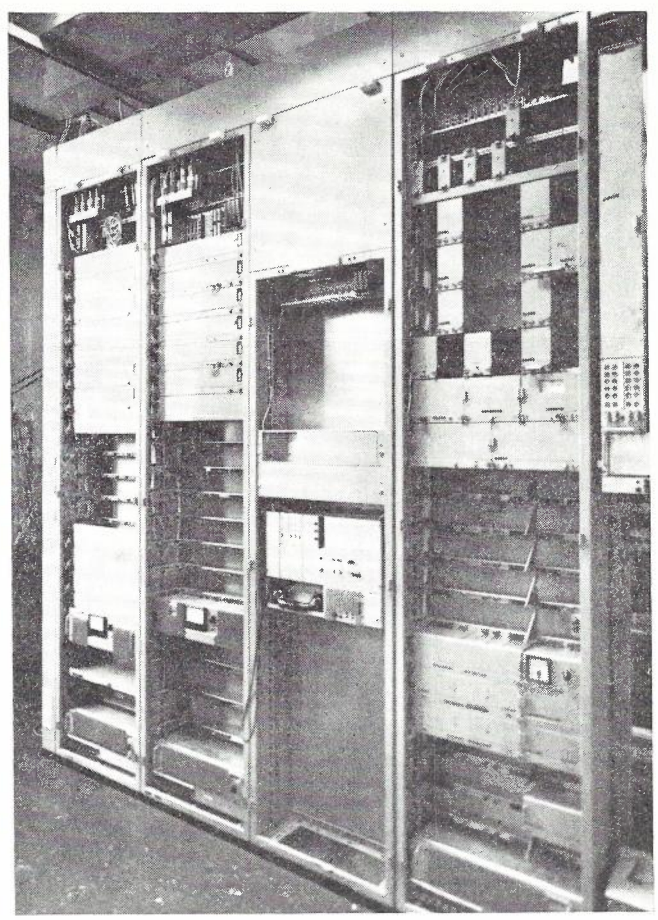
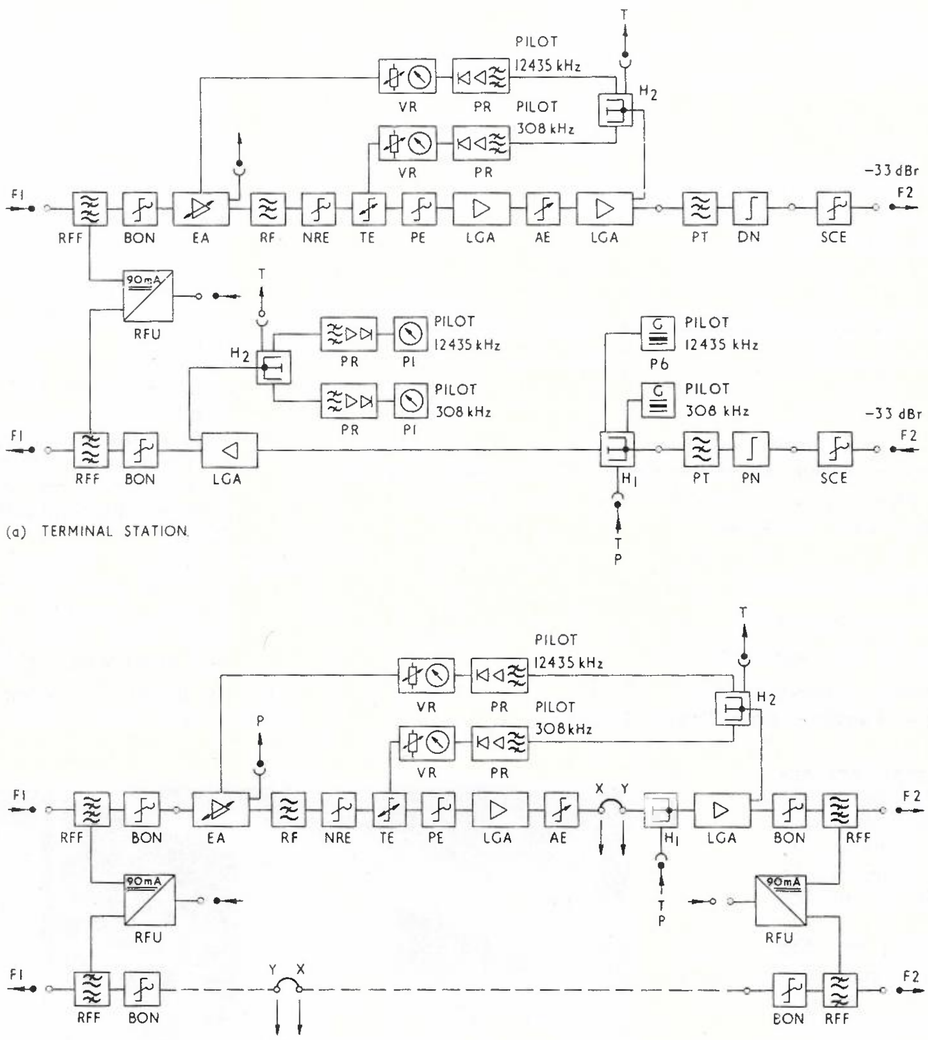
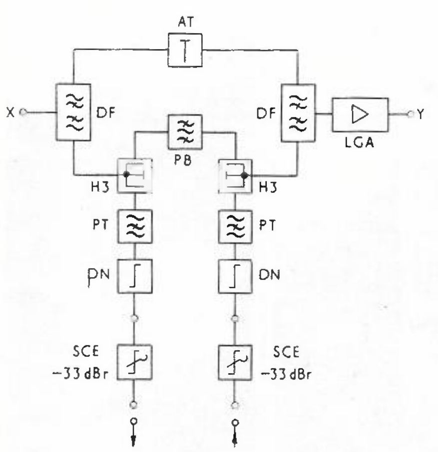


Fig. 4. — Arrangement of Racks at Gin Gin Main Repeater Station.



(a) TERMINAL STATION.

(b) MAIN REPEATER STATION



(c) DROPOUT EQUIPMENT.
(CONNECTS, IF NEEDED, TO TERMINALS X AND Y OF INTERMEDIATE STATION).

AE	ATTENUATION EQUALIZER (ECHO EQUALIZER).
AT	ATTENUATOR.
BON	BUILDING-OUT NETWORK.
DF	DROPOUT FILTER (HERE FOR SUPERMASTER GROUP 1).
DN	DEEMPHASIS NETWORK.
EA	EQUALIZER AMPLIFIER.
H_1, H_2	HYBRIDS FOR INJECTION OR EXTRACTION OF PILOTS.
H3	HYBRID
LGA	AMPLIFIER WITH FREQUENCY INDEPENDENT (FLAT) GAIN.
NRE	EQUALIZER FOR NON-RANDOM ERRORS.
P	SOCKETS FOR INJECTION OR EXTRACTION OF LOCALIZING PULSES.
PB	PASSBAND FILTER FOR BYPASSING PILOT (HERE FOR 308 kHz PILOT).
PE	PILOT EQUALIZER.
PG	PILOT GENERATORS.
PI	UNIT FOR INDICATION AND SUPERVISION OF PILOT LEVEL.
PN	PREEMPHASIS NETWORK.
PR	PILOT RECEIVER.
PT	PILOT TRAP.
RF	REJECTION FILTER FOR LOCALIZING PULSES.
RFF	REMOTE FEEDING FILTER.
RFU	REMOTE FEEDING UNIT.
SCE	STATION CABLING EQUALIZER.
T	SOCKETS FOR INJECTION OR EXTRACTION OF TEST PILOTS.
TE	TEMPERATURE EQUALIZER.
VR	VARIABLE RESISTOR WITH UNIT FOR INDICATION AND SUPERVISION OF PILOT LEVEL.

Fig. 3. — Block Layout of Fully Regulated Repeater Stations.

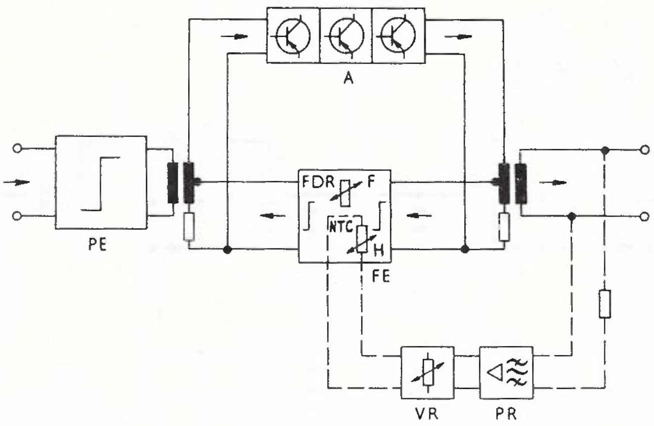


Fig. 5. — Basic Circuit Diagram of Dependent Repeater.

for the 12 MHz system. The 4 MHz system is similarly arranged and has been described in Ref. 1.

Fig. 4 shows the arrangement of racks in a typical main repeater station (Gin Gin). Reading from left to right the racks shown are:—12 MHz system, 4 MHz system, remote supervisory and order wire equipment, supergroup modem equipment (partially equipped).

The Underground Repeater.

The dependent underground repeater is the most significant development in the design of transistorised coaxial line systems. The bi-directional repeater provides amplification, equalisation and level stabilisation every 4.65 km (2.8 miles) for 12 MHz systems and every 9.3 km (5.7 miles) for 4MHz systems.

The basic circuit diagram of the dependent repeaters is shown in Fig. 5, which indicates the arrangement for both temperature-controlled and partially regulated underground repeaters.

Fig. 6 shows a 12 MHz dependent repeater with the lower portion of the outer case removed. The components visible in the photograph are those comprising the amplifier for one direction of transmission, the other half of the bi-directional repeater is the same. Visible also inside the lower portion of the outer case are the two bags of silica gel which are replaced each time a repeater is opened.

The schematic arrangement of the three types of dependent repeater (temperature-controlled, partially regulated and temperature-controlled last fed) used on the Perth-Carnarvon route is shown in Fig. 7.

Each bi-directional repeater consists of two line amplifiers for the two directions of transmission, power separation filters, and a band pass filter for the remote supervision system. The only distinctive feature in the last fed repeater is that the d.c. power feed loop is terminated at this repeater. The power separating filters for the ongoing route are replaced by two high-pass filters and transformers which separate two adjacent power feeding sections, and a stop filter for terminating the pulse fault locating section. A 'partially regulated' repeater, the gain-frequency response of which is automatically varied in step with the 12,435 kHz pilot (4287 kHz for 4 MHz systems), is used at approximately every 12th repeater position. Variations in cable attenuation, which are not fully compensated for by the temperature-controlled repeaters, are thus equalised. The operation of the temperature-controlled repeater has been described in Ref. 1, and in this article only a brief recapitulation of the principle is given with later reference to the problems that arose in the particularly high temperature conditions encountered on the Perth-Carnarvon route.

The underlying principle is to cause the gain frequency response of the temperature-controlled repeater to vary in step with the variation in attenuation of the coaxial cable due to changes in the temperature of the cable. The cable temperature varies in the same direction and degree as the temperature of the soil surrounding it i.e., as the temperature rises the cable attenuation increases and conversely, as the temperature falls the cable attenuation decreases. Included in the feed back path of each amplifier, and mounted within the repeater case, is a temperature-dependent, magnetic-flux-dependent resistor ('Field Plate') consisting of semi-conducting material (indium atimonide, with additions of nickel antimonide), whose resistance is a function of both temperature and a magnetic field. The temperature dependence of the resistor is used for temperature control, while its flux dependence serves for the continuous and contactless adjustment of the amplifier gain, and consequently the length of the repeater section. The resistance of the element and thus the

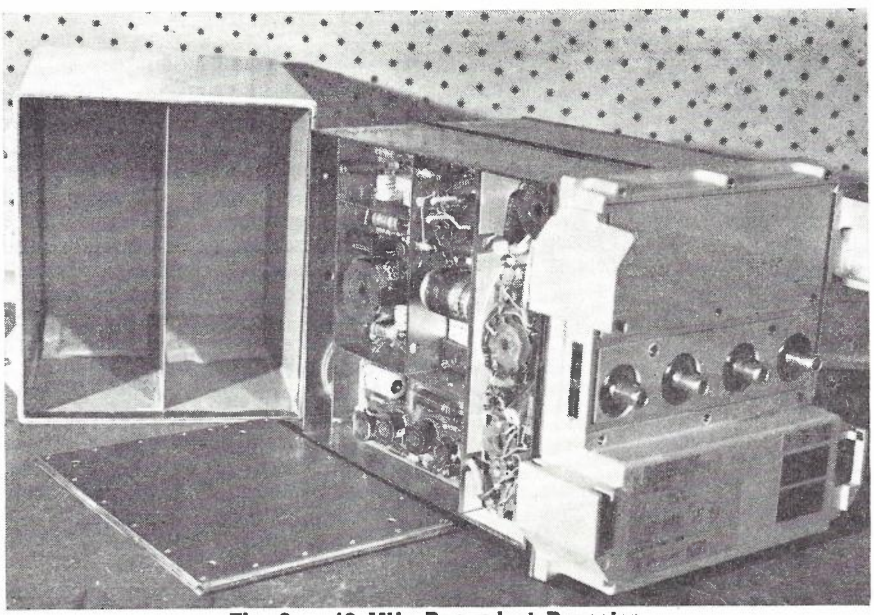


Fig. 6. — 12 MHz Dependent Repeater.

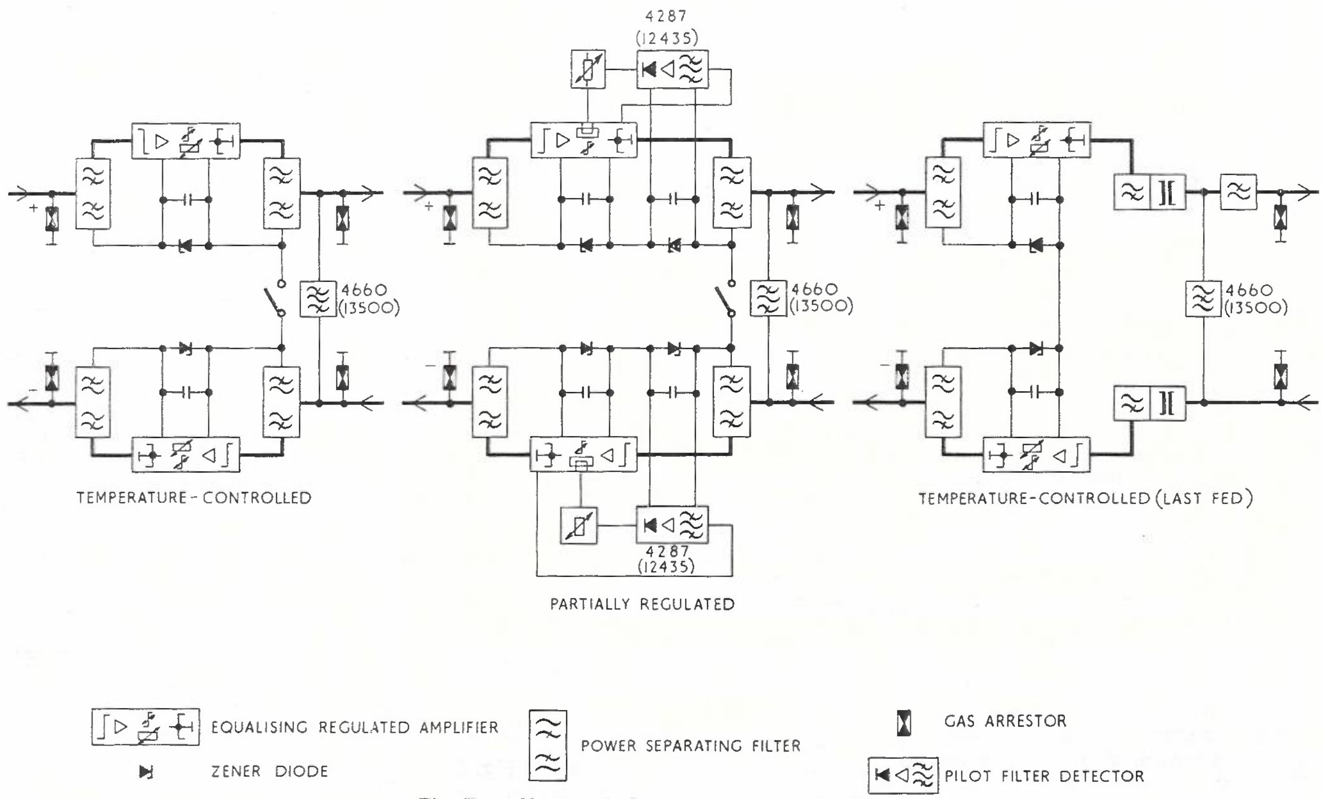


Fig. 7. — Unattended 4 MHz Repeater Stations.

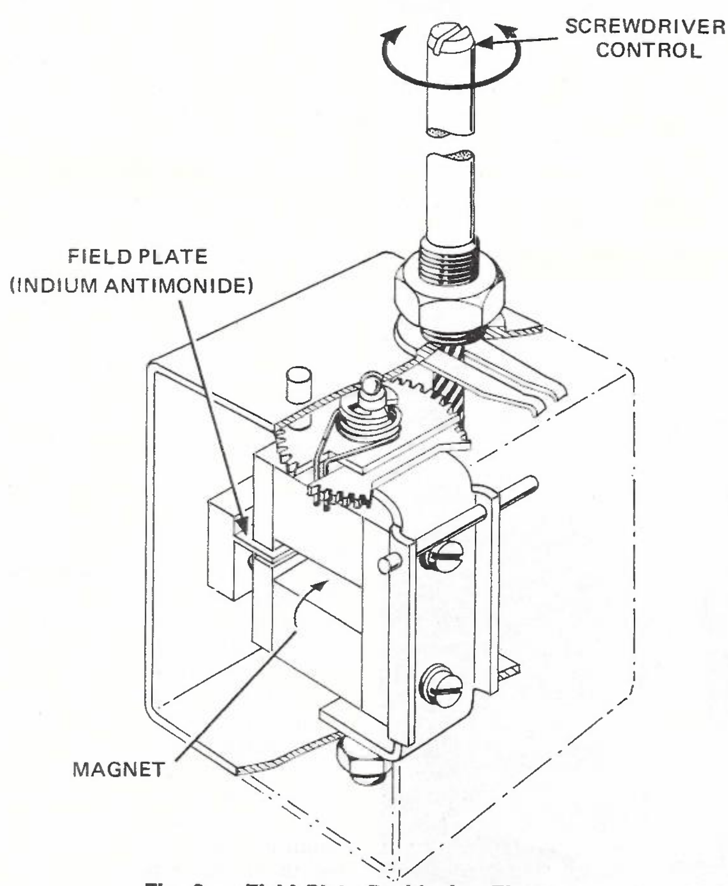


Fig. 8. — Field Plate Positioning Element.

amplifier gain are so adjusted (by means of a screwdriver control) that the field of a permanent magnet penetrates the flux-dependent resistor to a greater or lesser extent. Fig. 8 shows the element and its control.

The range of resistance of the Field Plate under the influence of the magnetic flux is approximately 14 to 47 ohms, which permits gain adjustment of the amplifier of about 3.5 dB.

Equalisation.

It will be seen from Fig. 5 that two equalisers are included in the amplifier circuit, a pre-equaliser which is a 2-network, bridged-T and the equaliser in the feed-back path. The latter is a 5-section equaliser, the first three sections are bridged-T circuits, the fourth is an R-L-C combination, which is connected in series either to the 'Field Plate' for temperature-controlled repeaters or to a negative temperature coefficient (n.t.c.) resistor fed by the electronic regulator assembly for partially regulated repeaters. The fifth section is a bridged-T circuit. These two equalisers offset the loss/frequency response of the coaxial cable section preceding the amplifier.

Power Feeding.

Dependent repeaters are power fed by applying d.c. voltage at constant current to the centre conductors of the two coaxial tubes forming the signal transmission circuit. The system used on the 4 MHz system, namely, 'single-voltage' power feed, where the power feeding voltage is greater than or equal to 600V. d.c. at 60 mA plus or minus 2 per cent. has been described in Ref. 1. In the case of the 12 MHz system, however, where it was necessary to power feed more than 12 underground repeaters, a 'double-voltage' power feed is provided by connecting two power feed units in series to provide greater than or equal to 1200V. d.c. The stable current feed is 90 mA and up to 25 dependent repeaters are supplied with power by this means. The northern section of the route, Northampton to Carnarvon, a distance of 425.6 km (264.5 miles), is sparsely populated, and it was uneconomic, as well as unnecessary from a circuit drop out point of view to provide more than one main repeater station building, that at Overlander. The problem of locating the main repeaters at Gramel and Towara was overcome by using underground chambers for the accommodation of the rack-mounted equipment. Their location was selected to permit remote power feeding. In the case of Gramel a polyethylene insulated 40lb. (0.9 mm) interstitial quad was used which permitted a sufficiently high voltage to be used to power feed the main repeater itself, plus a load of about 25 watts for remote supervision and 4-wire order wire equipment. In the section of cable between Towara and Carnarvon only paper-insulated quads were available, which limited the d.c. voltage that could be applied between wires. It was necessary, therefore, to use two paper insulated quads to power-feed the remote supervision and 4-wire order wire equipment at Towara. Over-voltage protection and fault location design details have been described in Ref. 1.

Supervision.

Two separate voice frequency service channels (order wire) and a gas pressure alarm circuit are provided throughout the system. These occupy the four 20 lb./mile (0.9 mm) paper insulated centre unit pairs which are laid up in multiple twin formation. One of the order wires is a 2-wire passive circuit linking dependent repeaters and main stations. It is terminated in a waterproof jack mounted in an accessible position in each manhole and a portable telephone is connected to provide local communication between manholes and from manholes to the nearest main station.

The second order wire is 4-wire amplified and equalised at each main station. It functions as a long-haul circuit inter-connecting all main stations at which it can be switched to the 2-wire order wire.

The 4-wire circuit also provides the bearer for the transmission of supervisory signals from all main repeater stations and the distant terminal to a 'remote supervision central station,' which is Perth. The indications of unstandard conditions are conveyed by pulse trains transmitted by the start-stop method and the system provides for ultimate extension to serve up to 200 separate stations, each of which can supply up to 200 different indications and receive up to 100 double-control signals. The supervisory signals are transmitted at up to 200 bauds in a 400 Hz slot (2800 to 3200 Hz) of the 4-wire order wire. The part-system installed on the Perth-Carnarvon route is designated 'F.U. 16/20' and does not provide for the transmission of any control signals over the system. It is limited at present to the continuous interrogation of the main stations and the transmission of signals back to the central station to indicate faults or non-standard conditions at the main stations. The initial capacity provides for the transmission of 20 different indications from each of sixteen remote stations. The indications are encoded for transmission and decoded at the central station to appear finally as a lamp display.

This installation is the first of its kind in the Australian network. Its performance in the brief period it has been in service has been satisfactory, and it is intended to use similar equipment for the remote supervision and control of all broadband systems. More experience of the operation of the system is necessary before its expansion can be put in hand.

Circuit Derivation.

The derivation of telephone circuits from the broadband system follows orthodox practice of frequency division multiplex technique, which assembles voice channels through successive stages of modulation for transmission to line. The equipment is fully transistorised and is operated from standardised 48V. d.c. power supplies comprising rectifier/battery combinations normally driven from public mains (a.c.) with standby diesel/alternators, which are automatically started in the event of mains failure. This equipment has been described in Ref. 2. The frequency scheme used on the Perth-Carnarvon 4 MHz and 12 MHz systems conforms to the C.C.I.T.T. recommendations.

Television Bearer.

A notable feature of the 12 MHz system is that the top half of the signal band (6.3 to 12.3 MHz) is used for 625-line T.V. relay. This facility was intended in the original engineering of the system to provide for T.V. programme relay in one direction only, from Perth to Geraldton, a route distance of 307 miles (494 km).

The arrangement of the T.V. modem and equaliser equipment is shown in Fig. 9 and completely satisfactory performance was achieved in its original installation between Perth and Geraldton. An unexpected demand arose on the occasion of the Apollo 11 moonshot to provide a television relay from the satellite ground station at Carnarvon to Perth, a total distance of 603.6 miles (971.5 km). The 'Perth-Geraldton' T.V. modem and equaliser equipment was hastily re-arranged and re-installed to provide this T.V. relay with complete success. This unexpected opportunity to test the capabilities of the equipment proved that permanent extension of the T.V. relay facility to Carnarvon, and in the 1970/71 year further northward another 529 miles to Port Hedland, is well within the system capability.

Television Modem.

Referring to Fig. 9 the video signal reaches the station line equaliser, where a patching panel allows conventional measurements to be made. Built-in pads can be cut in so that the modulator and demodulator can be measured under short circuit conditions with conventional measuring equipment. A high-impedance video signal alarm amplifier precedes the modulator.

A low pass filter at the input of the modulator rejects noise components above the video band. The d.c. restorer stabilises the depth of modulation and suppresses noise voltages at low frequencies. After equalisation in the video range the signal is modulated with a ring modulator and a 6.799 MHz crystal oscillator. The carrier band is boosted in a flat-gain amplifier and then passed through filter networks, which suppress modulation products above 12.3 MHz; reject the lower sideband and form the sloping flank of the vestigial sideband. The level is then again boosted in a flat gain amplifier.

In the transmitting equaliser the attenuation and envelope delay distortion that develop during modulation are eliminated. A further flat

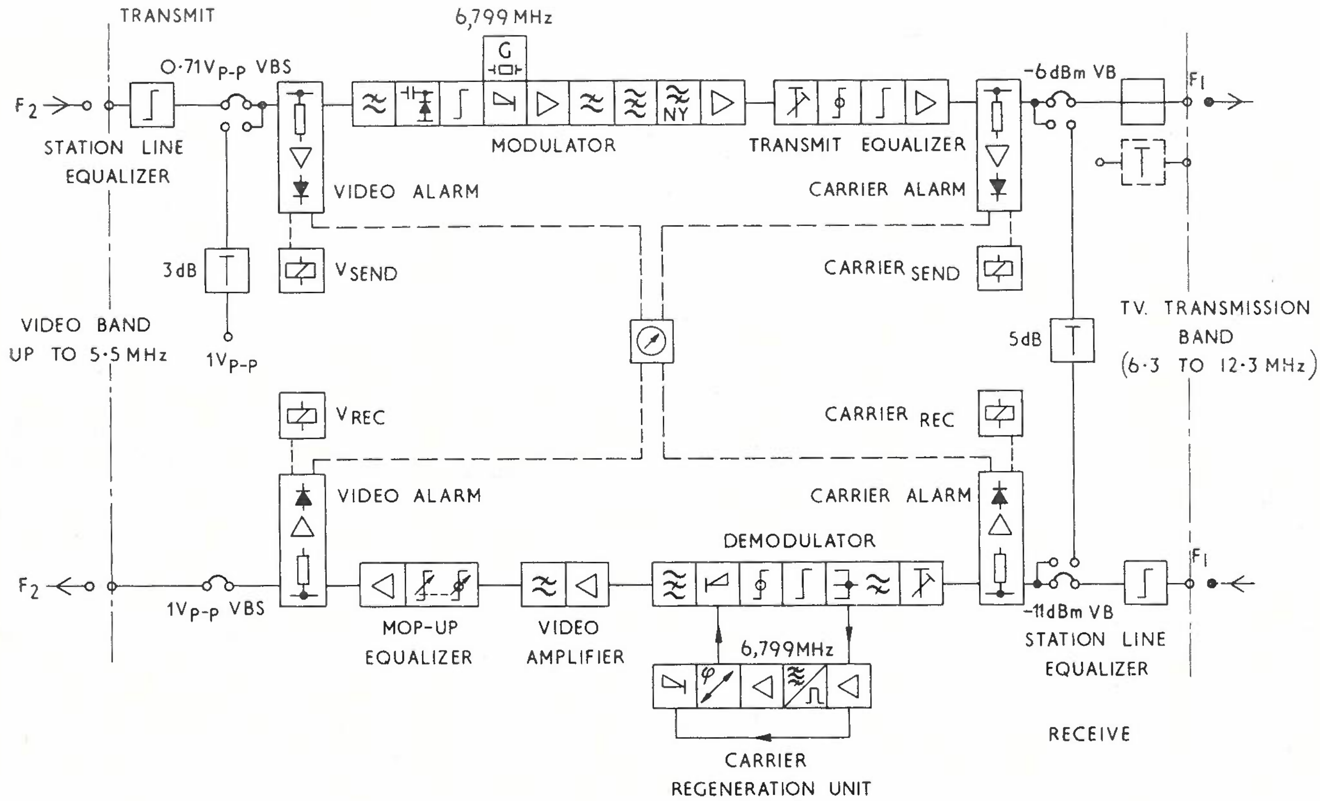


Fig. 9. — Block Schematic of Television Modem Equipment of 12 MHz System.

gain amplifier gives an output level which can be varied by ±3 dB. The output, level is —6 dBm for the VB level, i.e., without sync pulses. As this level is 2 dB higher than recommended by the C.C.I.T.T., a reserve of 5 dB instead of only 3 dB is available for the following station line. A carrier signal alarm amplifier and a patching panel provide operational supervision and measurements.

A station line equaliser is similarly connected to the carrier input of the demodulator, where the signal amplifier at the input and output match those of the modulator. The incoming carrier level can be regulated ±3 dB at the input to the demodulator. A hybrid following a high-pass filter branches off a portion of the signal and applies it to the carrier regeneration circuit. The main portion passes through attenuation and envelope delay equalisers, which eliminate the distortion resulting from the demodulator; the signal with the 6.799 MHz carrier delivered by the carrier regeneration circuit is then demodulated back to the video band. The following stop filter suppresses the upper sideband and the residual carrier. A video amplifier with associated low pass filter boosts the level again and suppresses the higher modulation products. The mop-up equaliser equalises the residual distortion of the overall route.

BALANCED PAIR CARRIER SYSTEMS.

Background.

The planning of earlier coaxial cable routes invariably included a number of multi-pair, paper insulated, voice frequency minor trunk cables to cater for the trunk outlets from switching centres to rural exchanges along and adjacent to the main cable route (Ref. 3), or alternatively, by providing one or more layers of voice frequency pairs laid up over the coaxial core of the cable. The trunk circuits so provided were generally short in length and small in group size with relatively low growth rates. The circuits were short in length mainly due to a relative abundance of trunk switching centres which were a carry over from the days of the trunk aerial network and manual switching centre operation. The minor routes were, therefore, in general too short and too small to justify carrier operation by the available means. At that time (circa 10 years ago) the carrier line systems were valve operated, high gain devices which had to be powered from local sources (either mains or prime mover generators), were expensive and had to be housed in expensive buildings some 15 to 20 miles apart. The only cables available were multi-pair, paper insulated, carrier types, which came in 14 pair and 24 pair sizes of either 20 lb. or 40 lb. per mile gauge. Such systems were economically superior to voice frequency cables and open wire plant only when route distances and circuit group sizes were favourable to them. During the past decade the processes of trunk network automation, combined with the development of low cost transistorised carrier systems, have brought about a significant reduction in the number of trunk switching centres. This has been aided by the flexibility with which 60 channel super groups can be dropped from broadband systems, plus the development of remote power fed 12 channel repeaters suitable for operation on the interstitial quads of coaxial cables. At the same time a small, low cost, single quad rural carrier cable has been developed which is eminently suitable for linking main cable routes with rural exchanges some tens of miles away.

At the time when the Perth-Carnarvon system was being designed, all the above developments were simultaneously becoming available and this was the first system to exploit all these capabilities to the full.

Thus the number of trunk switching

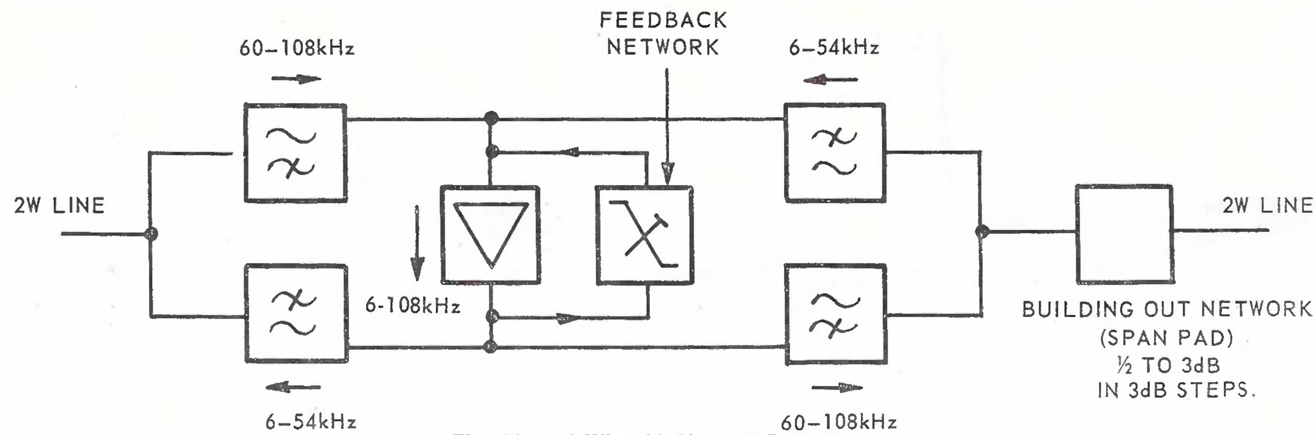


Fig. 10. — 2-Wire 12-Channel Repeater.

centres was greatly reduced, the provision of voice frequency minor trunk cables (or voice frequency layer pairs on the main cable) eliminated, and a high percentage of wayside and adjacent exchanges served by carrier systems with a minimum of modulation processes.

The developments above are estimated to have saved some $300,000 compared with the most economical methods previously available to suit this project.

The Transistorised System.

Two-wire 12-channel systems use the frequency ranges 6 - 54 kHz and 60 - 108 kHz for the two directions of transmission and the type of repeater developed in Australia uses a single amplifier covering the bandwidth 6 - 108 kHz. Fig. 10 shows the way in which directional filters control the two directions of transmission through the common amplifier.

For correct operation it is essential that cable sections on either side of a dependent repeater be matched closely to the repeater and to one another in regard to both insertion loss and slope characteristics. Limited adjustments are available on each repeater, but every effort is made in plant layout to ensure electrically uniform cable sections, apart from those adjacent to terminals where rack mounted built-out units and equalisers are available.

The maximum repeater gain is 29 dB, but the maximum permitted length of repeater section is 25 dB at 108 kHz. This gives a nominal repeater spacing of 8000 yards of 20 lb. P.I.Q.C. (interstitial quads) or 12,000 yards of 40 lb. S.Q.C. (single quad carrier cable).

Power Feeding and Line Regulation.

A constant current of 40 mA is supplied by the power feed unit in the terminal repeaters and fed via a phantom circuit derived from the bearers of two systems. The d.c. path of the line and repeaters for two systems forms a completely balanced, series connected chain with power turn around at the fourth repeater position out from the feeding station.

At present only the rack mounted terminal repeaters are regulated, dependent repeaters being entirely unregulated. This limits the distance between rack mounted equipments to 9 dependent cable sections, i.e., a power feed chain of 4 repeaters from each terminal. This is equivalent to a distance of about 40 miles of P.I.Q.C. or 60 miles of S.Q.C. bearers. So far these distances have been found adequate for the type of application described.

Fault Location and Supervision.

Each terminal station is provided with a selective test set, which is able to identify a faulty repeater by checking for the presence or absence of an identification signal which is unique to each repeater position. This is generated by means of a common fixed frequency oscillator, which generates an out-band signal whose frequency is unique to each repeater location. The out-band signal is transmitted to line via all of the repeaters at each particular location.

The local order wire is terminated at each 12-channel repeater position along the main cable route. On spur routes, however, no speaking facilities are provided. For either the main or spur routes equipment faults are dealt with by substituting replacement repeaters, repairs being done only at centralised service locations.

CABLE PLANT.

The Main Coaxial Cable.

The centre unit consists of 4 twin paper insulated pairs, 20 lb. per mile gauge and 0.095 mF per mile mutual capacitance. Four standard coaxial tubes (2.6/9.5 mm) are laid around the centre unit and in each of the interstitial spaces remaining, one 20 lb. per mile carrier type quad, 0.053 mF per mile mutual capacitance is located. The sheath is lead alloy 'E' (0.4 per cent. tin. 0.2 per cent. antimony) of reduced thickness (compared with old standards), coated with a bonding compound and then provided with an outer polyethylene jacket 0.08 inches in thickness.

Lead-sheathed plastic - jacketed cables are now the common form of finish for all trunk cables, but other varieties of finish are available for special applications. Survey of the Perth-Carnarvon route showed no need for special cable finishes, and the full 604 miles is of the lead-sheathed plastic-jacketed type.

Feeder Balanced Pair Carrier Cable.

The single quad feeder cables employ 40 lb. per mile copper conductors, each insulated with pure solid polyethylene, the quad being laid up over a solid polyethylene centre string. The inner sheath is a pure polyethylene extrusion which holds the quad in formation. A longitudinal copper tape is laid over the inner sheath and an outer jacket of nylon is extruded over this tape.

The result is a high performance balanced pair cable, lightning proof

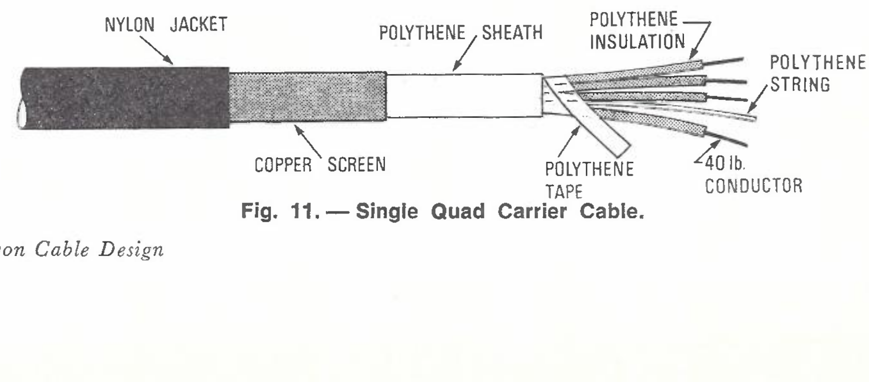


Fig. 11. — Single Quad Carrier Cable.

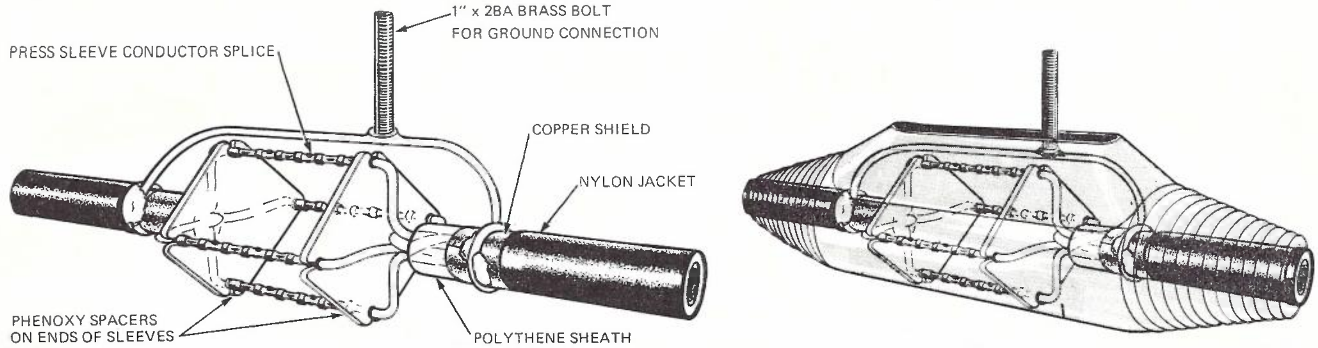


Fig. 12. — Precision Splicing Method for Single Quad Cable. Left: Details of Components. Right: Epoxy Resin Encapsulation.

and insect proof, which has an ultimate capability of carrying 120 telephone channels to serve medium capacity trunk routes at very low cost. An alternative application, made attractive by the very low cost of the cable, is that of feeder cable linking rural exchanges to their switching centres and doing this via nearby broadband cables where appropriate. In this application each single quad cable carries a limit of two 12-channel systems at present. Fig. 11 shows the components of a single quad cable and Fig. 12 shows the high precision method of splicing, which is necessary to avoid transmission problems at the upper frequencies for which the cable is designed.

Both the main cable and the feeder cables have been laid in long lengths at 48 inches depth by direct burial using newly-developed mole ploughing equipment and work methods. These aspects of the project are described in detail in Ref. 4.

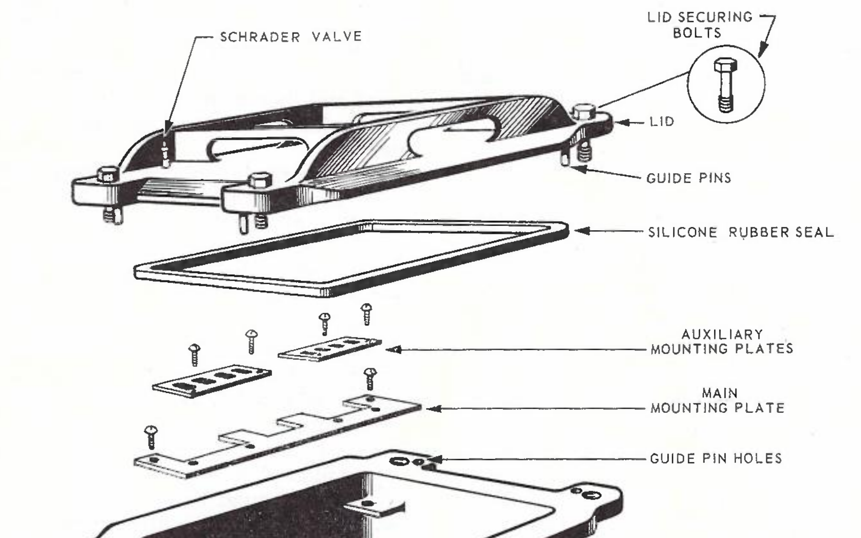


Fig. 13. — Repeater Housing.

Repeater Housings and Connections.

The standard Australian Post Office underground repeater housing is designed to accommodate two bothway coaxial line repeaters (4 MHz or 12 MHz) or 8 two-wire, 12-channel repeaters. In either event it is designed to be installed in an underground chamber at approximately the same depth as the cable to which it is connected. When used on coaxial cables the housing is maintained under gas pressure up to 15 p.s.i.g., the same as the rest of the cable systems. It is, therefore, required to be strong, corrosion resistant airtight, compact and yet versatile. Fog. 13 shows an exploded view of the housing and its lid, which are made from grey cast iron, but dip galvanised after machining. The lid is secured to the body by four stainless steel bolts, and locating guide pins ensure correct location of lid in regard to body.

A silicone rubber gasket, fitted in a groove in the lid, provides the sealing medium, the faces of both lid and body having been machined. Two schrader valves are provided in the lid so that pressurisation and accurate pressure measurement can be done simultaneously. There are three cable entry holes, one at one end of the housing and two (situated vertically one above the other) at the opposite end of the housing. The spare cable entry hole (normally sealed by a cover plate) permits the two tail cables to enter from the one end of a housing where this is enforced by congested underground plant situations. Normally one tail cable is connected to each end of the housing. The only other aperture in the body is a threaded hole to accept the gas pressure inlet pipe.

Mounting lugs are cast inside the body to hold a main mounting plate to which coaxial connector plates are subsequently fitted. Alternatively a variety of equipment chassis can be mounted in the body to accept a range of line equipments, e.g., 12 channel

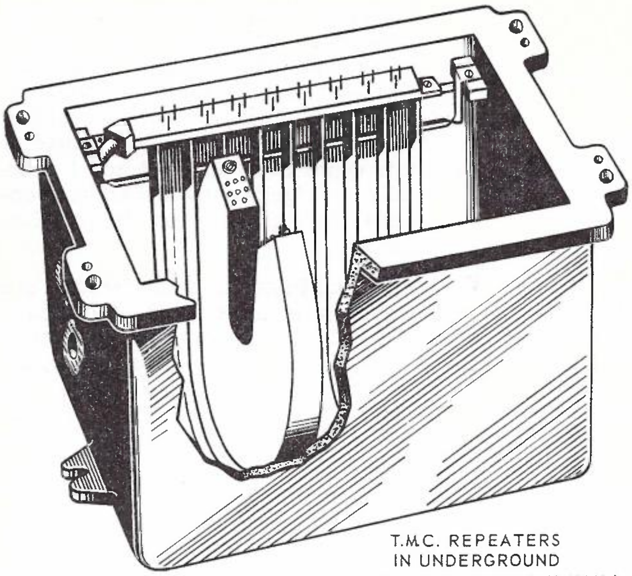


Fig. 14. — 2-Wire 12-Channel Repeater Accommodation.

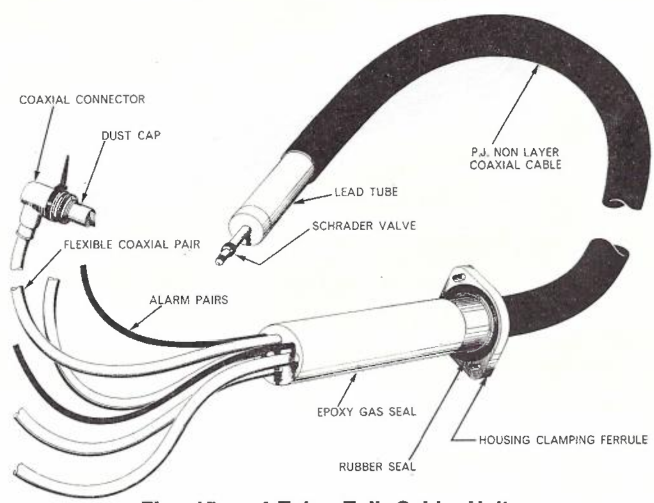


Fig. 15. — 4-Tube Tail Cable Unit.

repeaters (as in Fig. 14), video repeaters, etc.

Despite its weight of about 200 lb. the complete repeater housing could tend towards buoyancy and external securing lugs have been provided to enable it to be bolted to a manhole floor or other structure.

The coaxial tail cables are as shown in Fig. 15 and each consists of a 10 ft. length of standard 4-tube cable. At one end the four air-spaced tubes are jointed to semi-flexible, solid dielectric tubes, each terminated in a male coaxial connector.

A tinned gunmetal securing flange is soldered to the cable sheath and an epoxy resin block encapsulates the whole of the transitional joint. The gunmetal flange is slotted to accommodate an "O" ring seal which isolates the housing body from the atmosphere. The epoxy block isolates the inside of the housing body from air pressure in the tail cables. In this way air pressure inside the housing can be controlled independently of the air pressure in the main and tail cables, and the lid removed safely after closure of appropriate stop valves and release of pressure from the housing.

For balanced pair carrier repeaters, the tail cables are as in Fig. 16. Each consists of a length of regular 14 pair 20 lb. P.I.Q.C. cable, of which 8 pairs are spliced at a transitional joint to 8 plastic insulated, flexible pairs. The transitional joint is epoxy resin encapsulated in a similar manner to the coaxial tail cables shown in Fig. 15, and the same type of securing flange is soldered to the lead sheathed cable to seal it to the repeater housing.

The plastic insulated pairs are terminated in an epoxy resin moulded terminal strip for subsequent wiring to individual repeaters. The tail cables are supplied in pairs, each pair consisting of a left hand and a right hand terminal strip—the 8 pairs being terminated in opposite sequence in the two strips. For clarity one strip only is shown in Fig. 16.

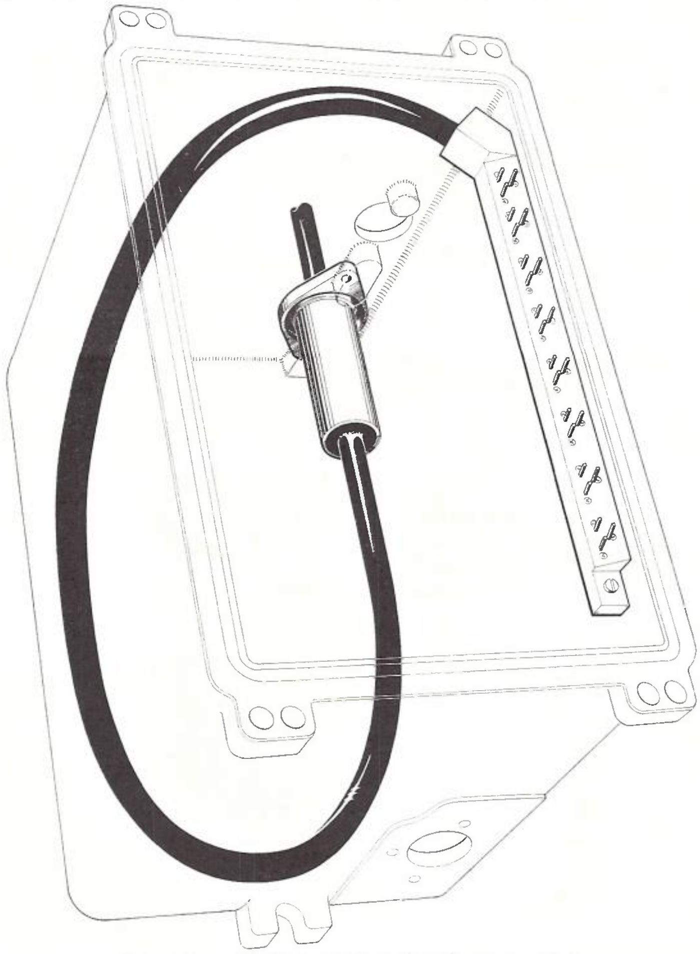


Fig. 16. — Eight-Carrier Pair Tail Cable Unit.

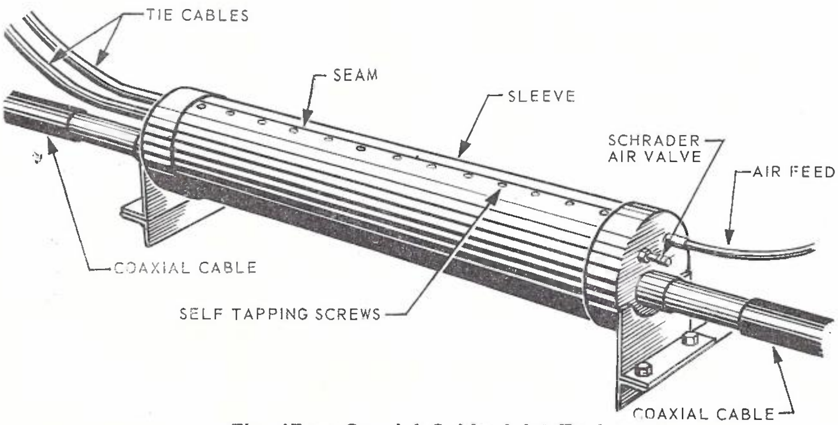


Fig. 17. — Coaxial Cable Joint Enclosure.

Carrier repeater housings are not connected pneumatically to the main cable. They are pressurised independently to 8 p.s.i.g. after installation is completed and the residual pressure left in them. This is done to eliminate the risk of air pressure loss from the main cable via any leaking 12-channel housings; the 12-channel housings being of secondary importance to the main cable.

Cable Protection.

The principal hazards to trunk cable plant are:—

(a) Chemical and electrolytic corrosion.
(b) Mechanical damage.
(c) Animal pests.
(d) Heavy ground currents.
(e) Poor quality splicing.
(f) Inter-crystalline fatigue fractures.

Cable plant design has progressed steadily over the last decade to combat the above hazards and to minimise their effects when they cannot be totally eliminated.

Corrosion: Lead is still a preferred material for underground environments due to its relatively high position in the electrolytic scale of metals and due to the ease with which it can be worked. Given a continuous jacket of 0.080 inches of polyethylene, the sheath corrosion rate is reduced to zero for most of the length of a buried cable. At splices, branching points and places where auxiliaries are connected to the cable, the polyethylene continuity is broken. The careful application of corrosion inhibiting pastes and protective coverings minimises the corrosion risks at such locations. Cable accessories which cannot be wrapped or coated are made of corrosion resistant materials, e.g., copper, brass, gunmetal, stainless steel, cast iron, and plated with either tin or zinc to minimise mutual electrolytic couplings.

Mechanical Damage: The primary cause of catastrophic failure of trunk cable plant is mechanical damage to cables, usually through earth moving, excavating, drilling, boring or probing processes being carried out by other persons or authorities. Total protection is unattainable except at prohibitive cost, but a reasonable depth of burial, say 48 inches, can be achieved at moderate cost and cables buried at this depth have been subjected generally to significantly fewer interruptions than older plant buried less deeply.

Animal Pests: Ants and termites are prevalent in most areas of Australia and will attack polythene and, to a lesser extent, lead. Growing experience suggests that such pests are rarely present at a depth of 4 feet in undisturbed soil, thus depth of burial is a significant safeguard to cables provided pests can be kept away from disturbed soil until it reconsolidates. For some years now the practice of introducing insecticide into the ground together with the cable, has been done

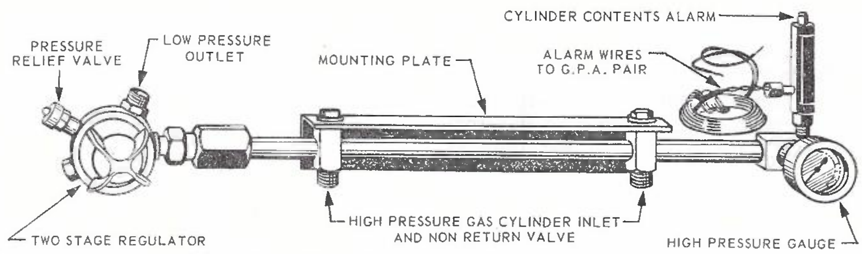


Fig. 18. — High Pressure Manifold Assembly.

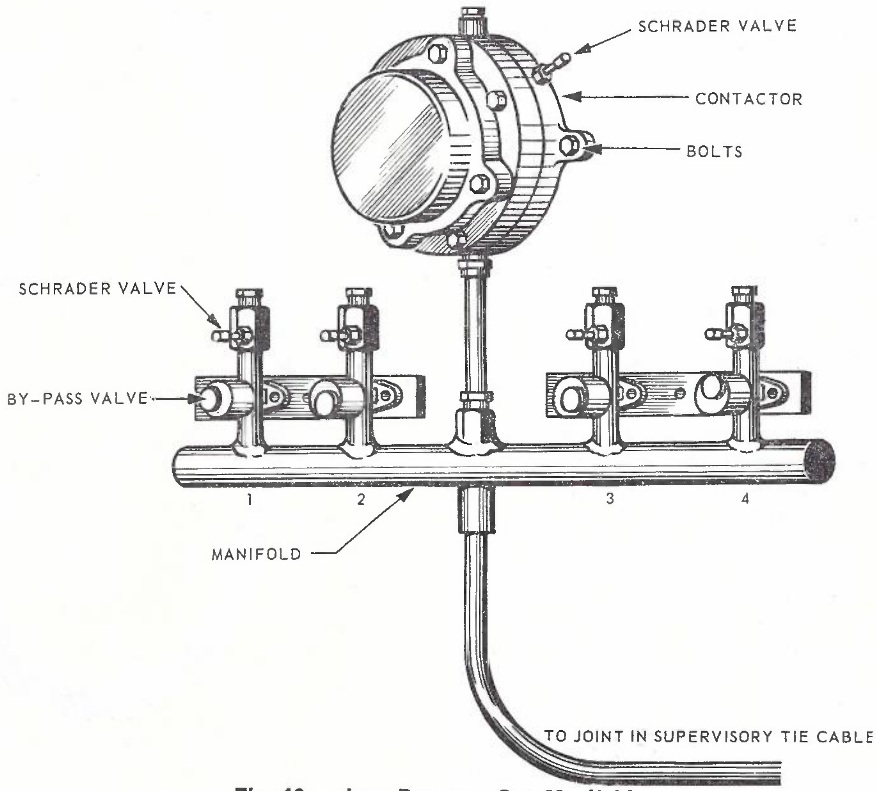


Fig. 19. — Low Pressure Gas Manifold.

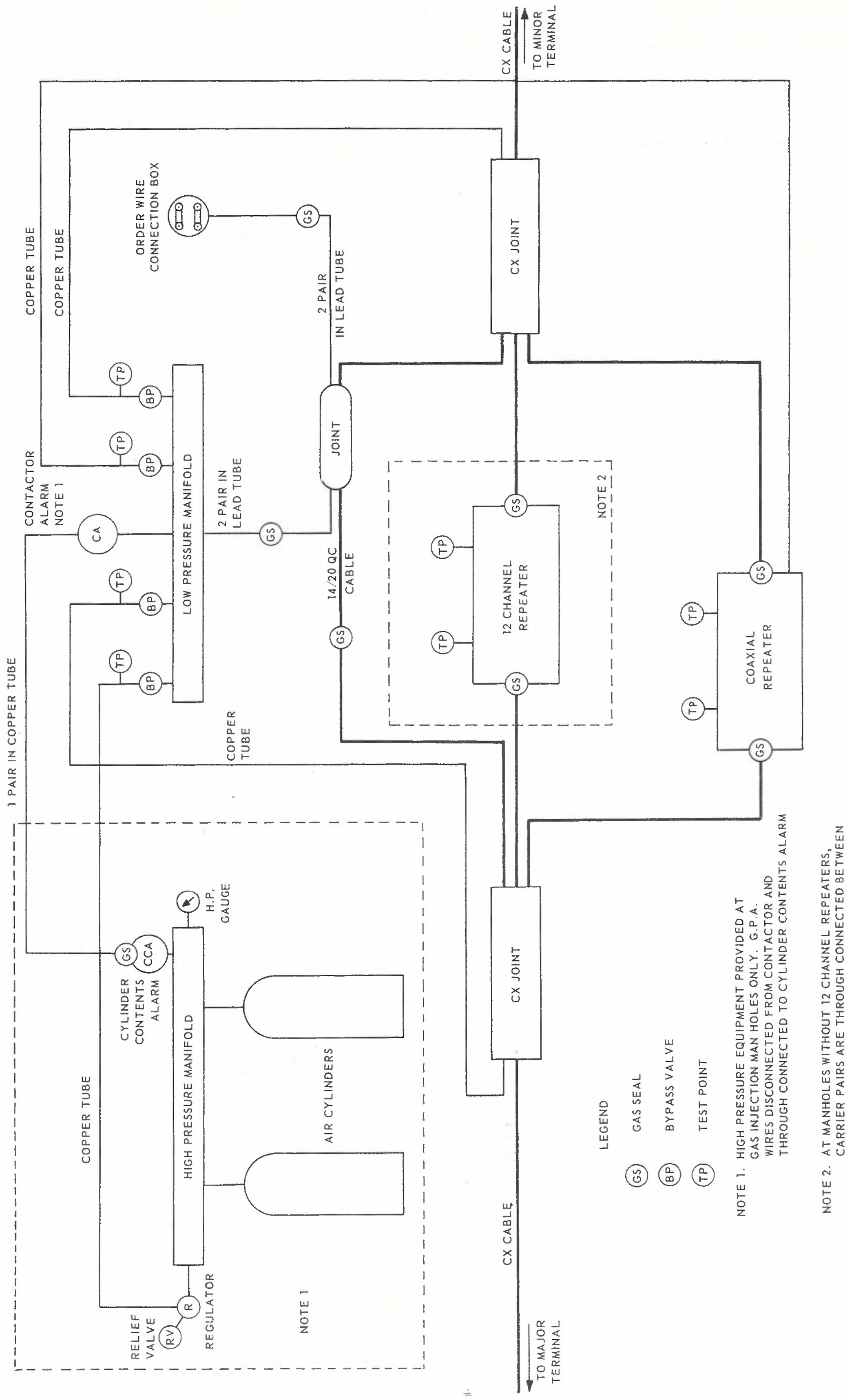


Fig. 20. — Manhole Gas Pressure Arrangements.

in infested areas with apparent success.

Heavy Ground Currents: Lightning discharge and power line fault currents can be a serious hazard to cross country cables (Ref. 5). However, the survey of the Perth-Carnarvon route indicated that the probability of damage due to these causes was slight and regular types of cable would be adequate.

Poor Splicing: Cable splices are often a source of trouble, particularly where complex branching joints have to be made with a multiplicity of cables or pipes at one end of the joint. The old method of forming splice cases from sheet lead at the work site and beating it into shape often resulted in unsatisfactory soldered joints. Current practice includes prefabricated joint components, designed to suit a variety of splicing requirements, which are made of tinned brass. They are designed to be re-openable, yet firmly bolted to supports, and at the same time require only straightforward soldering processes (Fig. 17).

Inter-crystalline Fatigue Fractures: The worst incidence of failure due to this cause arises from overland transportation of cable over long distances. Road haulage up to 620 miles has been necessary on the Perth-Carnarvon project, but no fatigue failures have been observed. However, the presence of the plastic jacket and bonding compound over the lead sheath at once makes it difficult to detect fatigue failure and greatly reduce the effect of any failure. The other cause of this class of failure may arise where cables are installed on vibrating structures. No such situation has arisen on this project.

Gas Pressure System.

The foregoing discussion brings out the point that cable protection starts with good design. Even so, faults will occur; they must be anticipated and action taken to minimise their effects. This has been the philosophy guiding the development of gas pressure systems for cables of major importance during the past 15 years or more in Australia. The basic principles of continuous flow systems are long established (Refs. 6 and 7), but modification to some plant items was required for the "all underground" environment of the Perth-Carnarvon cable, together with a strategem for reducing the flow of gas from underground gas cylinder reservoirs.

The general arrangement of high pressure and lower pressure manifolds is shown in Figs. 18 and 19 respectively, from which it will be seen that under water type gauges, regulators and pressure switches have been modified for cable applications. Also complete control is provided, by means of stop valves and gas seals, over the gas pressure and gas flow conditions in all parts of the system. Fig. 20 shows schematically the gas control arrangements at a repeater manhole.

Very small air leaks from the cable and its appendages are usually very difficult and expensive to locate. It is preferred, therefore, to allow air pressure to leak out from the system to atmosphere in the certain knowledge that water entry at such leaks cannot occur. However, with repeater buildings far apart on transistorised cables, compressor dehydrator units, as compressed dry air sources, are far apart on a long distance cable. Air cylinder reservoirs are also now increased in spacing from 5.7 to 11.4 miles maximum and located underground. To reduce the effort of frequently replacing underground gas cylinders, the stratagem has been adopted of operating the compressor supplies at 15 p.s.i.g. and the cylinder supplies at 12 p.s.i.g. after the system has initially stabilised. Thus minor gas flow via small leaks is supplied from the compressor units, the cylinder reservoirs are not thereby depleted and remain available to increase the flow rate should a serious leakage occur.

Manhole Arrangements.

The type of manhole installed at repeater positions in cross country locations is shown in Fig. 21. It is six feet in diameter and six feet deep, constructed from reinforced concrete pipe 3 inches thick for the walls, and having prefabricated base and top sections. The internal diameter of six feet is the minimum practical dimension which will permit satisfactory bends in the coaxial cable tails, house all the equipment and leave a reasonable working space. Important design details include the provision of a sump hole cast into the base section to facilitate de-watering and cast-in holes for cable entries and various securing bolts for the joint supporting frame and air cylinder mounting frame. All such holes are designed to provide a locking facility for associated bolt heads.

The joint supporting frame is fabricated from angle iron and hot dip galvanised after assembly. As well as supporting the main cable joints, it also supports tie cables, low pressure air manifold and faultmans speaking jack.

A basic feature of the design philosophy has been to prefabricate as many of the structures and components as possible in base workshops in Perth and Melbourne, to limit field

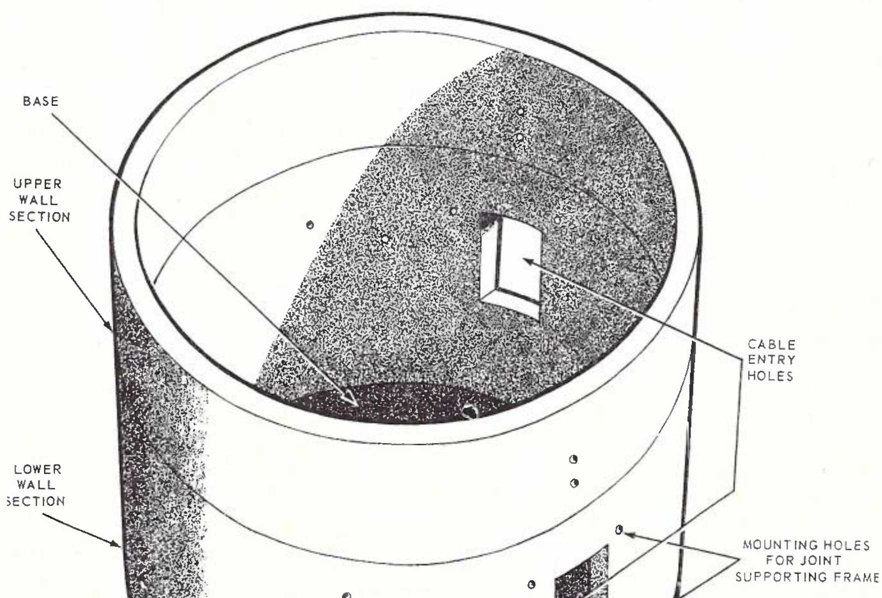


Fig. 21. — Precast Concrete Manhole.

work to the final stage of an assembly line process, to reduce field manhours to the minimum (thereby minimising field supervision, accommodation and support problems) and to attain a uniform repetitive quality of finished product.

Thermal Insulation Problems.

Perth lies in latitude 32 deg. south and Carnarvon in latitude 25 deg. south, which is only some 100 miles south of the Tropic of Capricorn. Ambient temperatures ranging up to a maximum of 116 deg. F. (46.5 deg. C.) are experienced in the summer months and the design range of the difference in variation of temperature of underground cable and dependent repeater has been exceeded on days of high ambient temperature.

Data on the temperature conditions observed by measurements in the form of continuous chart recordings will be published in a later issue of this journal. In the meantime the thermal environment conditions experienced will be explained, together with the measures taken on the Perth-Carnarvon route to overcome the difficulty.

The temperature of the underground cable, buried at a depth of four feet, is virtually unaffected by daily air temperatures and the cable temperature follows the seasonal climatic cycle. There is a lag of about 6 to 8 weeks in the cable temperature, i.e., the cable does not reach its highest temperature until nearly two months after the highest (seasonal) air temperature. On the other hand, the temperature of the dependent repeaters as installed in manholes on the Perth-Carnarvon route was affected by daily air temperature changes. All of the manholes are positioned in the area cleared for cable laying, and the top of each manhole is in full sunlight. The repeater housing is exposed to heat radiation from the underside of the manhole top, which includes a ¼ in. thick iron checker plate hatch measuring 2 ft. x 4 ft. Under the worst conditions the repeater temperature did not follow the cable temperature.

The temperature of the repeater is higher by up to about 5 deg. C., than the cable, due to heat dissipation within the repeater housing. This varies depending on whether one 12 MHz only or one 12 MHz plus one 4 MHz repeater are accommodated in the housing. In the former case 3.8 Watts are dissipated and in the latter case almost 6 Watts. The condition is shown simply in Fig. 22, which also shows the permissible variation of ± 1.6 deg. C. per repeater in the difference between repeater and cable temperatures.

The cable had been laid and all manholes constructed some time before the underground repeaters were installed, and it was not until about end-November, 1968, that the inadequacy of the thermal environment of the repeaters became apparent. Fortunately it was possible to make a rapid assessment of the relative effectiveness of three forms of thermal insulation: about 2 ft. of earth cover over the top of manholes, a 4 in. thick, 4 ft. x 2 ft. slab of closed-cell foamed polyethylene insulating material fixed to the underside of the ¼ in. iron plate entry hatch to manholes, or a 4 in. thick, 6 ft. diameter circular slab of the same insulating material fixed to the whole of the underside of the top of manholes. The rapid assessment was carried out by measuring the gain of a chain of 5 repeaters (10 amplifiers) by means of the pulse teletester at frequent intervals over a 24-hour period and arriving at the average temperature change by relating the measured gain change to the known temperature coefficient of 0.2% per degree Centigrade. This inexact method was fast and sufficiently accurate to:

(a) Confirm in practical terms that the thermal environment of uninsulated manholes was inadequate, and
(b) Establish the performance of the three methods of thermally insulating manholes.

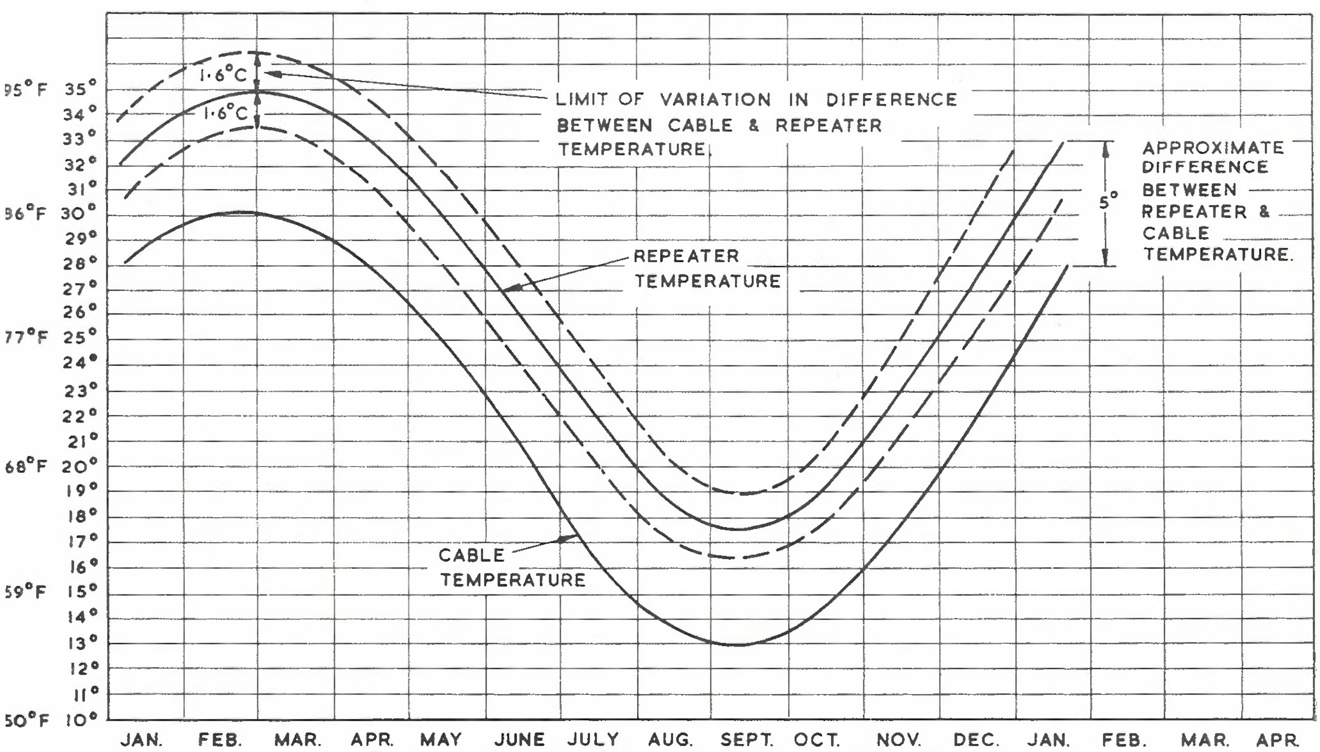


Fig. 22. — Limit of Variation in Temperature Differences.

As expected, the earth cover of manholes was the most effective. Partial insulation, i.e., of the underside of the checker plate entry hatch was inadequate, but full insulation of the whole of the underside of the top of the manhole kept the temperature differential between cable and repeater within the prescribed limits of plus or minus 1.6 deg. C. It was therefore decided to thermally insulate in this manner all 200-odd manholes throughout the route and this work was completed in about two weeks.

It will be appreciated that the validity of the conclusion reached as a result of the tests described applied only in the air temperature conditions obtaining at the time of the tests. In the presence of air temperatures higher than those measured, the thermal insulation may be inadequate; this condition may be experienced in the northern third of the route for some days in the hottest part of the summer.

Arrangements have been made to secure continuous chart recordings of temperatures of cable, repeater housings and manholes throughout a full seasonal cycle, and these recordings will be available for study about March, 1970.

The long-term solution to providing a fully adequate temperature environment for underground repeater housings probably lies in a choice between:

(a) direct burial of the housing, or
(b) the provision of a partially buried manhole with two feet of earth cover and an insulated surface access trunk.

Development work is now proceeding along these lines.

CONCLUSION.

The overall design for the Perth-Carnarvon communications system has successfully combined modern developments in transistorised coaxial line equipment, transistorised balanced pair line equipment, the new single quad carrier cable and specially designed external plant components. The result is a high capacity, flexible, low cost, high reliability system which caters for the full trunk and subscriber needs of the route, down to and including nearby rural exchanges and isolated wayside subscribers.

Experience so far has shown that the television bearer, occupying the upper half of the bandwidth, and the first in the world to operate over transistorised equipment, has been an outstanding success. Furthermore, the flexibility of the combined line plant and equipment has resulted in significant savings in trunk switching equipment. The technical and economic advantages anticipated some years ago for this integrated design concept have been realised in full.

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TECHNICAL NEWS ITEM

MEETINGS OF THE INTERNATIONAL CONSULTATIVE COMMITTEE ON TELEPHONY AND TELEGRAPHY (C.C.I.T.T.) IN MELBOURNE

The Australian Post Office will act as host for a meeting of international telecommunication experts, to be held in Melbourne, 16th February 1970 to 11th March 1970.

The meetings are held under the auspices of the C.C.I.T.T. which is a permanent organisation of the International Telecommunications Union (I.T.U.), which itself is the specialised agency of the United Nations in the field of telecommunications. The I.T.U. and the C.C.I.T.T. maintain and extend international co-operation for improved national and international use of telecommunications. They also have a responsibility for promoting the development of technical facilities with the view to increasing their usefulness to the public and to standardise facilities and services on an international basis.

The Melbourne meetings will be concerned mainly with transmission problems relevant to telephony, but will also consider other transmission problems, for instance those related to data transmission.

This is the third time that the Post Office will act as host for such meetings. On the previous occasions the topics for discussion were telephone switching and telegraph operations respectively.

THE PERTH-CARNARVON CABLE PROJECT: PLANNING ASPECTS

*L. A. JONES, M.I.E. Aust.**

INTRODUCTION.

The Perth-Carnarvon broadband system, which entered service during 1969, comprises a four-tube coaxial cable, just over 600 miles long, fitted with 12-MHz equipment to provide up to 1200 telephone circuits and a television channel. In addition, there are a 4-MHz standby system and numerous 12-circuit peripheral systems.

This article deals with the planning of the system and its utilisation to meet the needs of the community. As the Perth-Carnarvon system is but the first link in a chain extending to Wyndham in the far north, some attention will be devoted to regions well beyond Carnarvon.

HISTORICAL.

Ever since Western Australia was first settled, most of its population has been concentrated in the south-western corner. However, during the nineteenth century some agricultural, pastoral and mining development did occur in the northern districts. This gave rise to demands for rapid communication with Perth and overseas. In 1874 (the year that the Perth-Adelaide line was established), a single iron telegraph wire was provided from Perth to Geraldton.

Extension northwards followed fairly quickly, so that, by the turn of the century, the line had reached Wyndham, in the far north of Western Australia, approximately 2200 route miles from Perth. Over most of its length, this route followed the coast quite closely; a second telegraph route through Meekatharra and Marble Bar was subsequently provided to serve the developing inland centres. Trunk telephone service, where it existed, relied on voice-frequency circuits superimposed on the telegraph wires.

Gradually, copper wires were erected on the old telegraph routes from Perth to Geraldton and Meekatharra, and in 1950 a new trunk telephone route was built from Mullewa to Carnarvon. The application of carrier telephone and telegraph systems yielded adequate facilities to meet requirements in the mid-northern region, but high costs inhibited the further extension of the trunk network. Not until 1958 did it become opportune for a start to be made on the extension of copper wires northwards from Meekatharra—a phase of development that culminated late in 1967, when a copper pair was completed between Derby and Wyndham.

Open-wire line systems were supplemented by H.F. radio telegraph and telephone links, with some application of short-haul V.H.F. and U.H.F. systems, e.g., between Wyndham and Kununurra.

Such was the development of northern communications up to 1968. Fig. 1 shows the main routes as they then existed. Additional information is available in Refs. 1 - 3.

RECENT DEVELOPMENTS.

In the early nineteen-sixties, with all of the significant centres of population in the north about to be connected to the national network, it seemed reasonable to look forward to a period of consolidation. But several factors have conspired to bring about an enhanced rate of industrial development and hence of traffic growth, namely—

(a) Improved agricultural methods, leading to the farming of a big area of land between Perth and Geraldton previously thought unsuitable.

(b) The application of irrigation in the Kimberley area.

(c) An intensive search for oil and gas, already yielding substantial results.

(d) The rapid surveying and exploitation of several large deposits of iron ore, especially in the Pilbara region.

Among other recent activities are the establishment of a large United States naval radio station at North-west Cape (Exmouth) and of a spacecraft tracking and control station at Carnarvon, with which is associated a major earth station for satellite communication across the Pacific Ocean.

FUTURE DEVELOPMENTS.

The continued rapid growth of the iron-mining industry over a long period seems assured, with eventual production of steel a strong possibility. Firm proposals exist for the large-scale extraction of salt by solar evaporation of sea water, and for the production of alumina from big deposits of bauxite near Admiralty Gulf, in the Kimberleys. The recent Commonwealth-State agreement to provide a large dam on the Ord River will lead to irrigated farming on a bigger scale and may be but the first of several such projects. Mineral development generally is regarded as having barely begun: a recent decision to proceed with a big copper-mining venture at Whim Creek is an indicator to the future.

INITIAL PLANNING.

By 1965 it was apparent that the orderly development of the established open-wire lines could not long continue to meet the demand. Forecasts showed requirements amounting to some hundreds of telephone circuits in the Perth-Geraldton section, with reduced but still substantial quantities further north.

Over the long distances involved, the cost of each added open-wire bearer is very high in proportion to the number of extra circuits it affords. Moreover, the expansion of subscriber trunk dialling and telex facilities calls for trunk circuits of a quality and reliability not readily obtained on long open-wire routes through inhospitable, cyclone-prone country. In any event, the routes from Perth to Geraldton and Mullewa were already close to saturation.

Other kinds of plant that might conceivably have supplemented or superseded the open-wire routes were examined, e.g.: carrier cable, V.F. four wire cable, and 24 channel U.H.F. radio. None could have yielded more than short-term relief and then at excessive per-circuit cost.

A further factor now entering calculations was the rising public demand for the extension of the National Television Service to Geraldton and places further north. Coupled with the expected telephone development, this directed attention at a broadband system as the only one able to meet the requirements.

Consequently, a planning decision was made, early in 1966, that a broadband route should be developed as soon as possible from Perth to Geraldton, Carnarvon and Port Hedland, a distance of nearly 1200 miles. Authority was obtained during 1966 for the Perth-Carnarvon section to be provided as the initial phase. The Carnarvon-Port Hedland section has since been approved and construction is proceeding.

ALTERNATIVE SYSTEMS.

Broadband systems have been developed to meet impressive standards of quality and reliability, as well as large circuit capacity (Ref. 4). Their capital costs are high, but the ultimate cost per circuit is low, especially if

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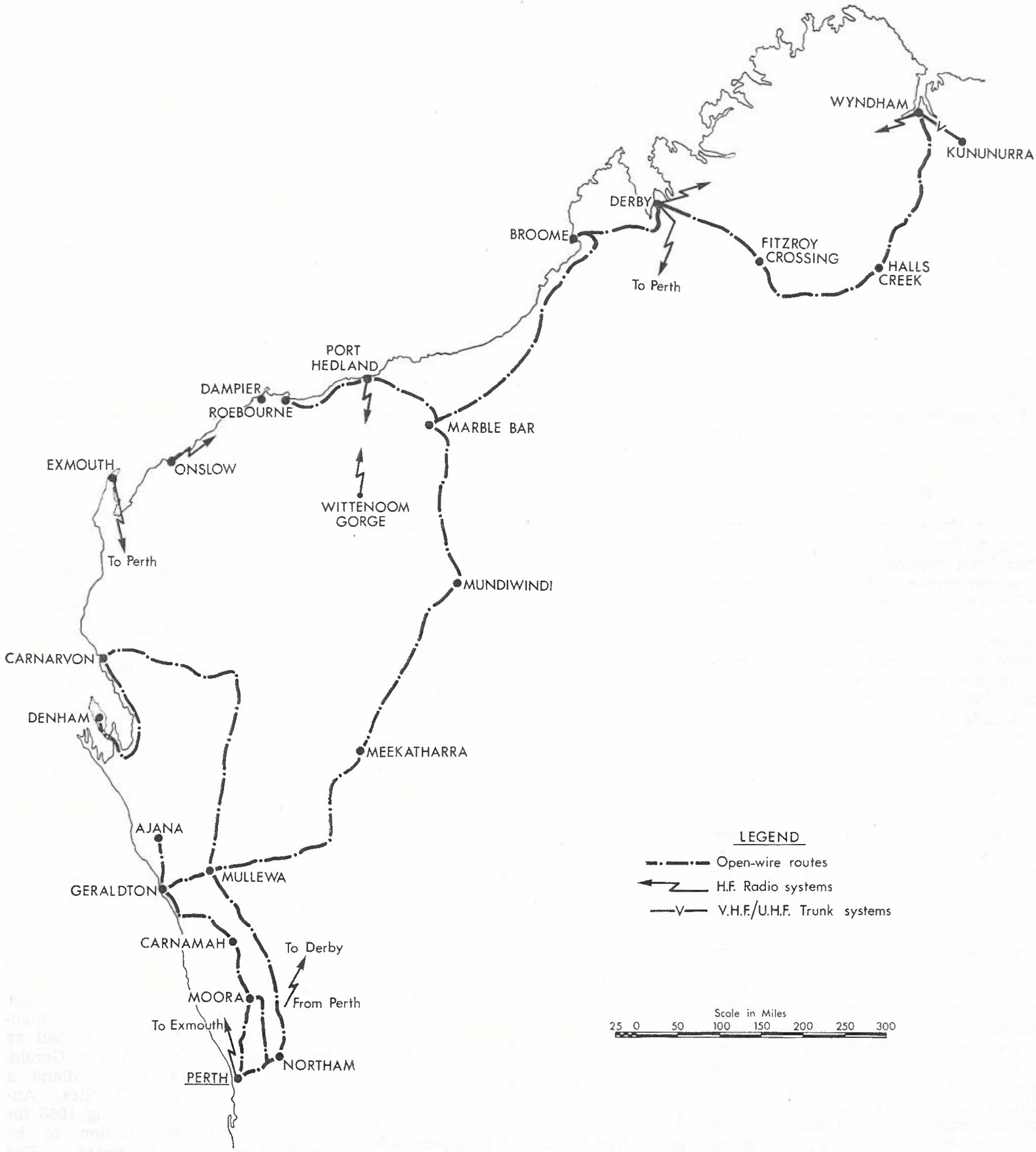

Fig. 1. — Trunk Routes to the North of Western Australia, 1968.

the growth of traffic is rapid; moreover, most of the cost of adding to the initial circuits is independent of distance. Thus, apart from the heavy initial investment, this class of system is especially well adapted to the Perth-Carnarvon requirement.

The available alternatives are coaxial cable and microwave radio. The results obtainable are generally similar, except that radio systems are less easily able to cater for the dropping out of small or moderate-sized groups of circuits at intervals along the route. Radio systems tend to have lower first cost but higher operating costs. In any case, the relative costs of coaxial and radio systems are strongly influenced by the nature of the terrain, which determines tower heights, access-road costs and the readiness with which cable can be buried.

For the Perth-Carnarvon system the economic study favoured coaxial cable. Two factors were especially important:

(a) Recent developments in the design of coaxial line equipment had substituted transistorised, buried repeaters for valve-operated equipment in surface buildings. The new equipment promised better performance with higher reliability at lower cost.

(b) Impending improvements in mechanical plant and methods offered the prospect of direct burial by mole plough, instead of dropping the cable into a prepared trench. A reduction of installation costs could be expected.

THE ADOPTED SOLUTION.

Having decided on a coaxial system, it was necessary to select the type and size of cable. In view of the distance and circuit quantities involved, it was easy to determine that standard 0.375 in. coaxial tubes should be used, rather than the 0.174 in. type, especially as the latter had not been used in the Australian network.

Either two-tube or four-tube cable could have been adopted for the whole route, or a combination giving, say, four-tube between Perth and Geraldton, and two-tube beyond. Previous experience had shown that a standby system on a second pair of tubes was needed to ensure adequate dependability; the anticipated high reliability of transistorised repeaters could not yet be regarded as well enough proven to engender complete faith in a single pair of tubes. So four-tube cable was chosen, with the added advantage of greatly-enhanced ultimate circuit capacity.

It was clear at the outset that a television relay would be needed from Perth to Geraldton in 1969, and the opinion was held (since confirmed) that its extension northwards would not long be delayed. Of the available transistorised systems (Table 1) only the 12-MHz system could furnish a wide enough band to accommodate the Australian standard television signal. Rather than try to procure a system especially to suit Australian conditions (like the 6-MHz valve system) it was decided to purchase 12-MHz line equipment.

For the standby system it was considered that 960-circuit capacity would be enough to meet emergencies (although the television relay would be lost), and so a 4-MHz system was adopted for the second pair of tubes. Up to the present the Perth-Geraldton section of the standby system has been placed in service: the repeaters for the Geraldton-Carnarvon section have been temporarily diverted.

SELECTION OF THE ROUTE.

The route adopted is shown in Fig. 1 of Ref. 5. Comparison with Fig. 1 (above) will show that between Perth and Ajana (60 miles north of Geraldton), the cable follows closely the old open-wire trunk route. As well as offering a convenient route for cable laying, this choice afforded the possibility of serving all of the established towns and adjacent rural exchanges by circuits provided from the cable system. This in turn enabled the complete recovery of the open-wire route to be contemplated. Advantage could also be taken of the equipment buildings, mains power supplies and maintenance facilities already in existence.

Between Ajana and Carnarvon, the main road forms the shortest and the only reasonable route. Very few people live in this section, but the route was planned so as to give telephone service where possible and to take advantage of such roadside facilities as exist.

THE MAIN AND STANDBY SYSTEMS

Line Equipment.

The equipment selected for this route is of Siemens Industries Ltd. manufacture (Ref. 6, 7).

Most of the repeaters are located in manholes and are temperature-controlled. At intervals, rack-mounted repeater equipment must be installed to take care of such functions as equalisation, pilot regulation and the feeding of D.C. power to the buried repeaters. At these points known as main repeater stations, facilities can readily be provided to allow one or more supergroups to be dropped out of the broadband system.

Co-ordination of the line equipment design with the more important blocks of circuit requirements yielded the layout depicted in Fig. 1 of Ref. 8. Of the eleven main repeaters, eight are equipped as branching stations. The remaining three are Bullsbrook East, which can be so equipped when needed, and Gramel and Towarra, where there is no requirement for circuits.

F.D.M. Processes.

The translation of individual telephone circuits by frequency division multiplex (F.D.M.) to form 12-channel basic groups and 60-channel basic supergroups follows well-established procedures (Ref. 4, 9). Coaxial systems of various bandwidths differ in the manner of assembling supergroups to utilise the available spectrum. The usual arrangement for a 4-MHz bandwidth is simply to stack 16 supergroups in the frequency range 60-4028 kHz to form a 960-channel system. With a 12-MHz band, further translation is necessary. Of several possible methods, that selected for Australian systems (Fig. 2) entails the translation of a SG2-16 assembly into the range 4404-8120 kHz, with another similar assembly in the range 8620-12336 kHz. This process, known as supermastergroup modulation, allows in all 45 supergroups (2700 circuits) to be derived. Supergroup 1 does not figure in this scheme, since its retention would impose an unacceptable ratio of highest to lowest frequency to be handled by the line amplifiers.

Television transmission on the 12-MHz system is arranged by modulating the video signal with a 6799-kHz carrier. The resultant upper sideband and a vestigeal lower sideband occupy the region from 6300 to 12300 kHz. This means that SMG3 and most of SMG2 are lost. The design of the Perth-Carnarvon system provides for the remnant of SMG2 (five supergroups) to be utilised; equipment for this purpose is due to be added in 1971.

The FDM equipment, which is completely transistorised, conforms to the general pattern of recent purchases for Australian broadband systems.

WAYSIDE AND PERIPHERAL SYSTEMS.

Before 1966, the exchanges on and adjacent to the cable route had been served by physical lines and open-wire rural, three or twelve-circuit carrier systems, and in most cases circuit relief was badly needed. The newly-developing farming communities between the main route and the coast

TABLE 1: TRANSISTORISED LINE EQUIPMENT.

Nominal Bandwidth.	Frequency Range (kHz	Capacity		Repeater Spacing	
		S.G.	Ccts.	Km.	Yd.
4	60 – 4028	16	960	9.3	10,000
12	312 – 12336	45	2700	4.65	5,000
12	312 – 12300	20	1200 + TV	4.65	5,000

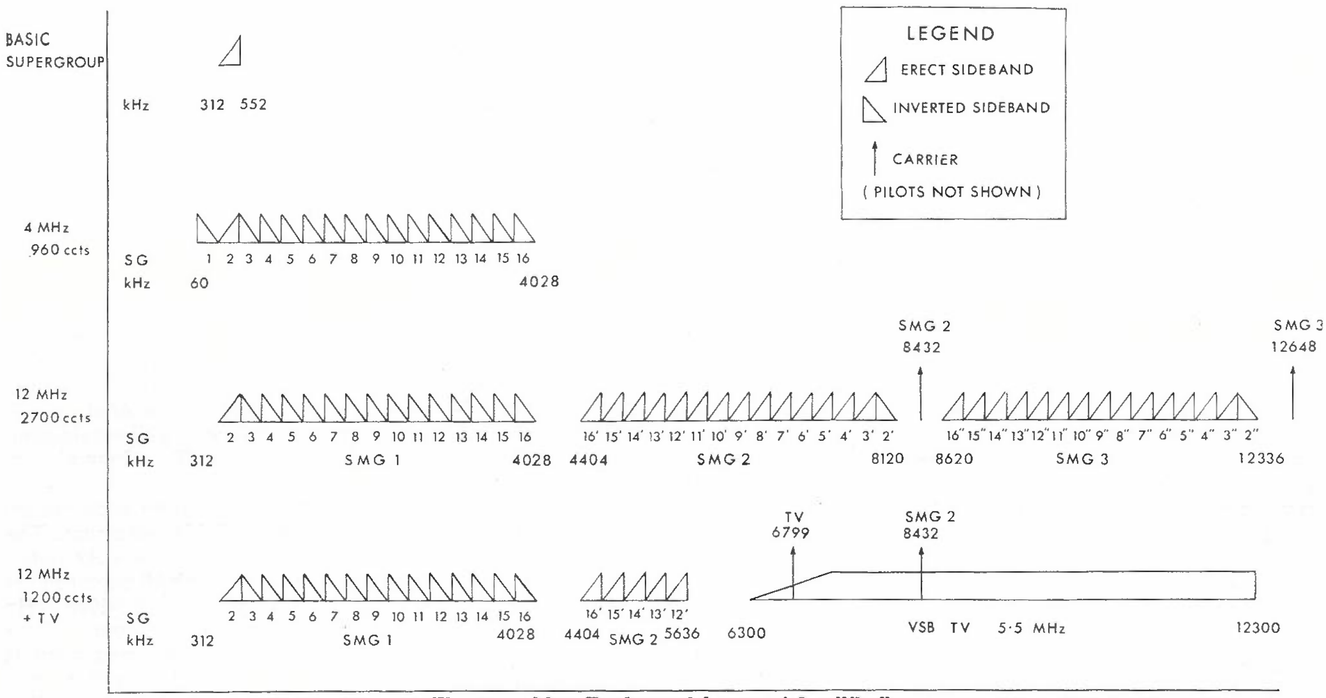

Fig. 2. — Line Equipment Layout (simplified).

were also calling for telephone service.

The locations of broadband dropouts at the more important centres having been determined, there remained many smaller exchanges that could not be served in this way.

In the past, it has been common practice to meet wayside requirements by adding a layer of V.F. paper-insulated quads within the coaxial cable sheath. Two difficulties in the way of adopting this procedure in the Perth-Carnarvon case were that, first, direct burial of the thickened cable might not prove practicable; and secondly, production of the cable in time to meet the laying schedule might be prejudiced.

The Carrier Solution.

The possibility of using layer pairs was therefore abandoned and a study was made of the alternatives, namely:

(a) Retain most of the open-wire route.

(b) Provide separate V.F. or carrier cables along with the coaxial cable.

(c) Make maximum use of the four carrier-type interstitial quads that are provided as a matter of course in four-tube cable. This was attractive because of the low cost of obtaining carrier bearers. Its adoption was assisted by two opportune developments: transistorised, power-fed, underground repeaters for 12-channel cable carrier systems, and a new type of single quad, plastic-insulated and sheathed carrier cable suitable for spur routes.

The two-wire, 12-channel cable carrier equipment (type Z12N) selected for these minor systems accepts the standard basic group at 60-108 kHz; a frequency translation gives 6-54 kHz for one direction of transmission on the line. At the terminals, either channel modems may be provided, or a through group connection may be effected into some other system that will accept the basic group. If one terminal of Z12N system is at a broadband dropout station, the group may readily be extended to another broadband station. In the planning of the Perth-Carnarvon route, this feature assumed significance in relation to the economics both of circuit provision and trunk switching.

Influence on the Trunk Switching Pattern.

The former trunk switching scheme for the Perth-Carnarvon region was based on open-wire lines and manual exchanges. Under these conditions numerous switching centres were prescribed in the plan. Some modification was to be expected as automatic switching, with subscriber trunk dialling, gradually took over. Much more radical changes, however, arose from an examination of the effect of the coaxial cable and its dependent carrier systems.

The former scheme proposed, for example, an automatic trunk exchange at Moora. Such an exchange would have entailed a heavy outlay in equipment and a building extension. Much of this money could be saved by connecting the outlying terminals and the Moora local exchange straight to Perth. Such a procedure would require more circuits to be provided between Moora and Perth than for a switched link. Nevertheless, the cost of circuit provision would, on the whole be less. This apparent paradox arises from the facility for through group connection, already discussed. A major part of the cost of F.D.M. carrier systems resides in the channel modems. Considering a terminal exchange near Moora, served by a Z12N system: one set of channel modems is necessarily provided at the small exchange. The remote set of modems may be either at Moora or Perth. If at Moora (implying that the traffic is switched there) then other modems must be provided at Moora and Perth to allow traffic to flow to the capital city, and so the cost of circuit provision increases.

The new trunk switching scheme allows only one switching centre along the broadband route—the secondary centre at Geraldton. All other exchanges are to be treated as terminals, with direct circuits either to Perth or Geraldton.

The economics of terminating all the exchanges on Perth or Geraldton depend on the prevailing pattern of traffic dispersion and on the existence of surplus capacity in the 12-MHz system. They will not necessarily be favourable on other routes or at all future times on this route; as the system approaches

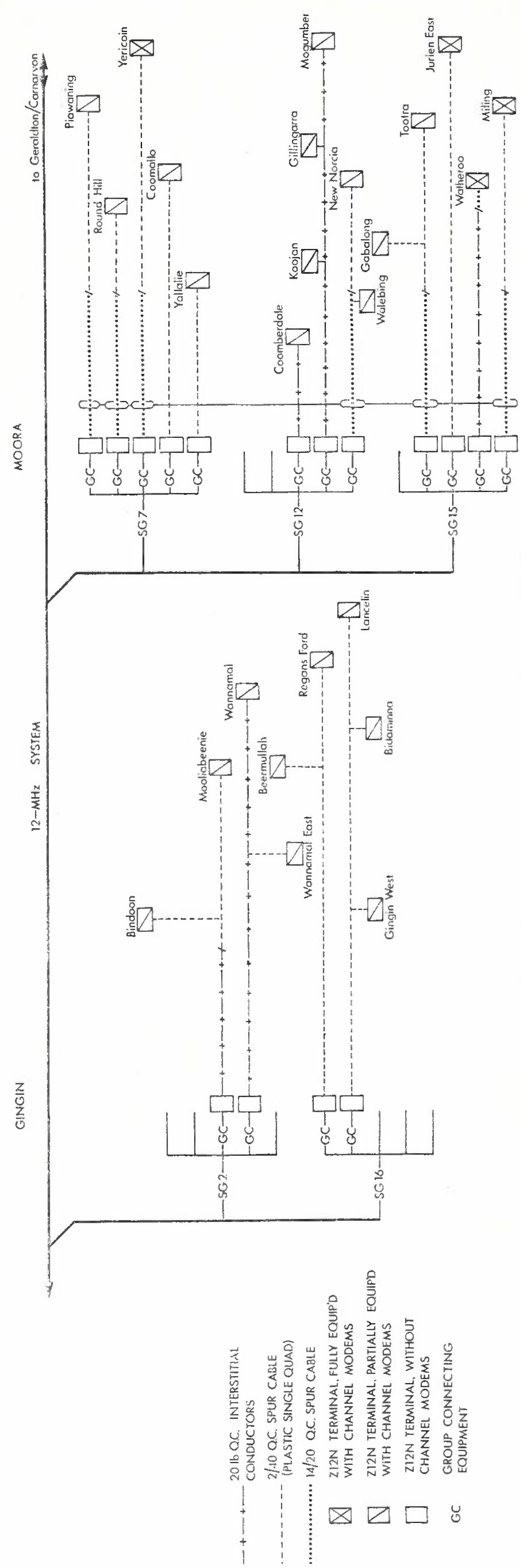

Fig. 3. — Minor Carrier Systems, Gingin and Moora.

saturation, it may prove worth while to postpone relief by installing automatic trunk exchanges. Nevertheless, the scheme adopted has produced a very substantial saving in capital cost and will accelerate the provision of S.T.D.

Some of the smaller exchanges do not warrant a full 12-channel system, at least for several years. A novel approach in these cases is the combination of two or even three exchanges into one 12-channel system, so conserving repeaters, modems and the 12-MHz spectrum.

Part of the planned minor system provision is shown in Fig. 3. This represents the situation late in 1970, by which time relay sets allowing direct connection of terminal exchanges to the Perth switching centre are expected to be supplied.

V.F. Circuits.

In the section from Ajana to Carnarvon, telephone subscribers are few and scattered: so much so that the provision of new exchanges along the broadband route could not be justified. The problem of providing service in a reasonably economical way has been resolved by establishing several virtual exchanges at which subscribers are collected into small groups. From these points, circuits are being established by means of V.F. amplified core and interstitial pairs to the nearest broadband dropout or 12-channel carrier terminal (Fig. 4). The design of these facilities has led to some interesting problems in cable protection and signalling.

THE COAXIAL SYSTEM: CIRCUIT PLANNING.

Television signal transmission on a 12-MHz system poses some difficult technical problems for the equipment manufacturer, but from the systems planning viewpoint is quite straightforward: it merely entails the application of a modulator at the sending end (in this case Perth) and of an equaliser and demodulator at the receiving end (Geraldton). The planning of the telephony facilities, on the other hand, calls for close attention if all requirements are to be met at the least cost.

As a first step, it is necessary to forecast the trunk circuit requirements at each station. Allowance must then be made for through-connected groups, which in most cases will be incompletely filled, and for miscellaneous circuits such as programme channels, telegraph bearers and leased circuits. Supergroups may then be allocated within the constraints of the system's capacity and the facilities available for dropping and replenishing.

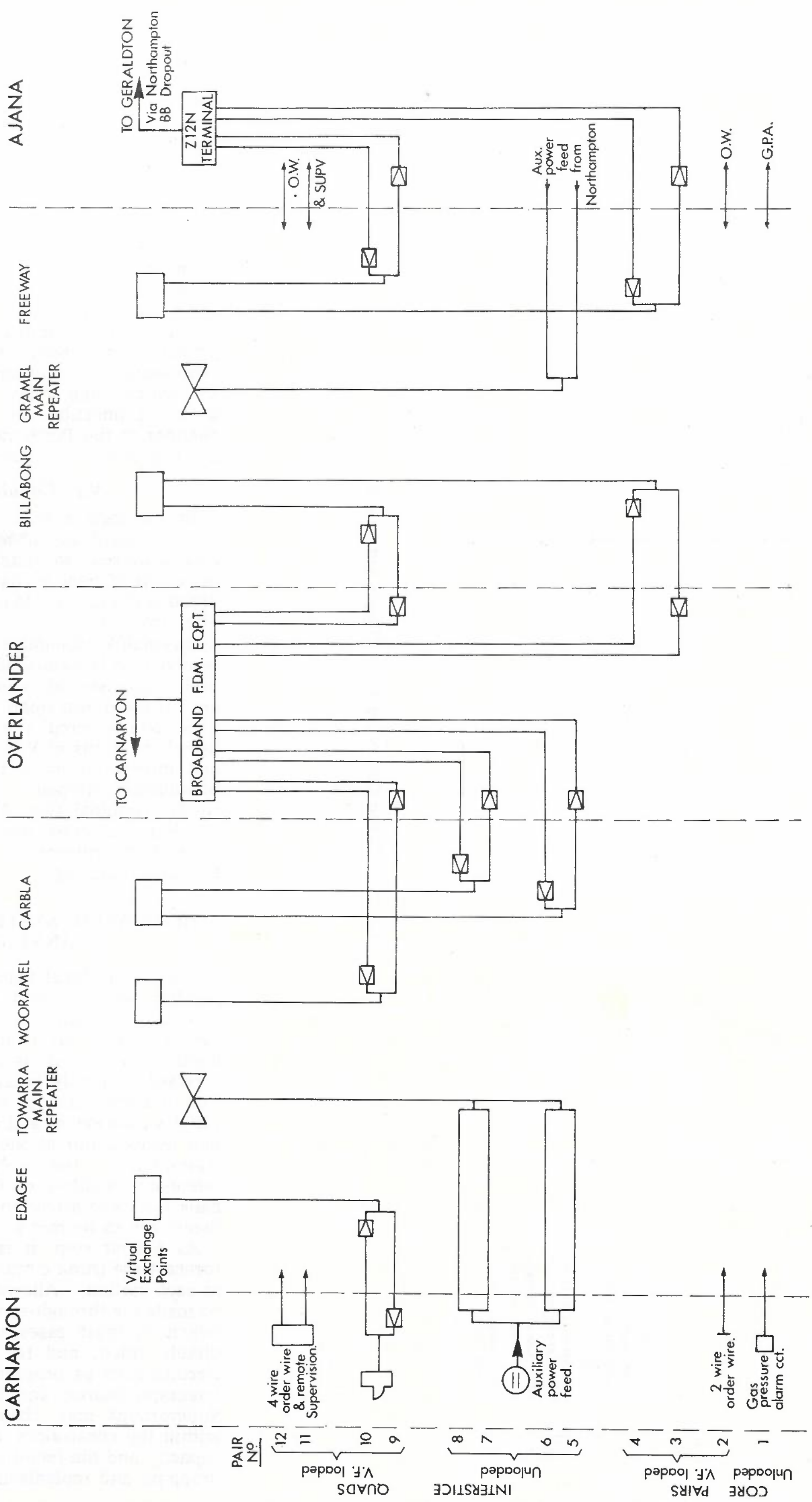

Fig. 4. — V.F. Circuits in the Ajana-Carnarvon Section.

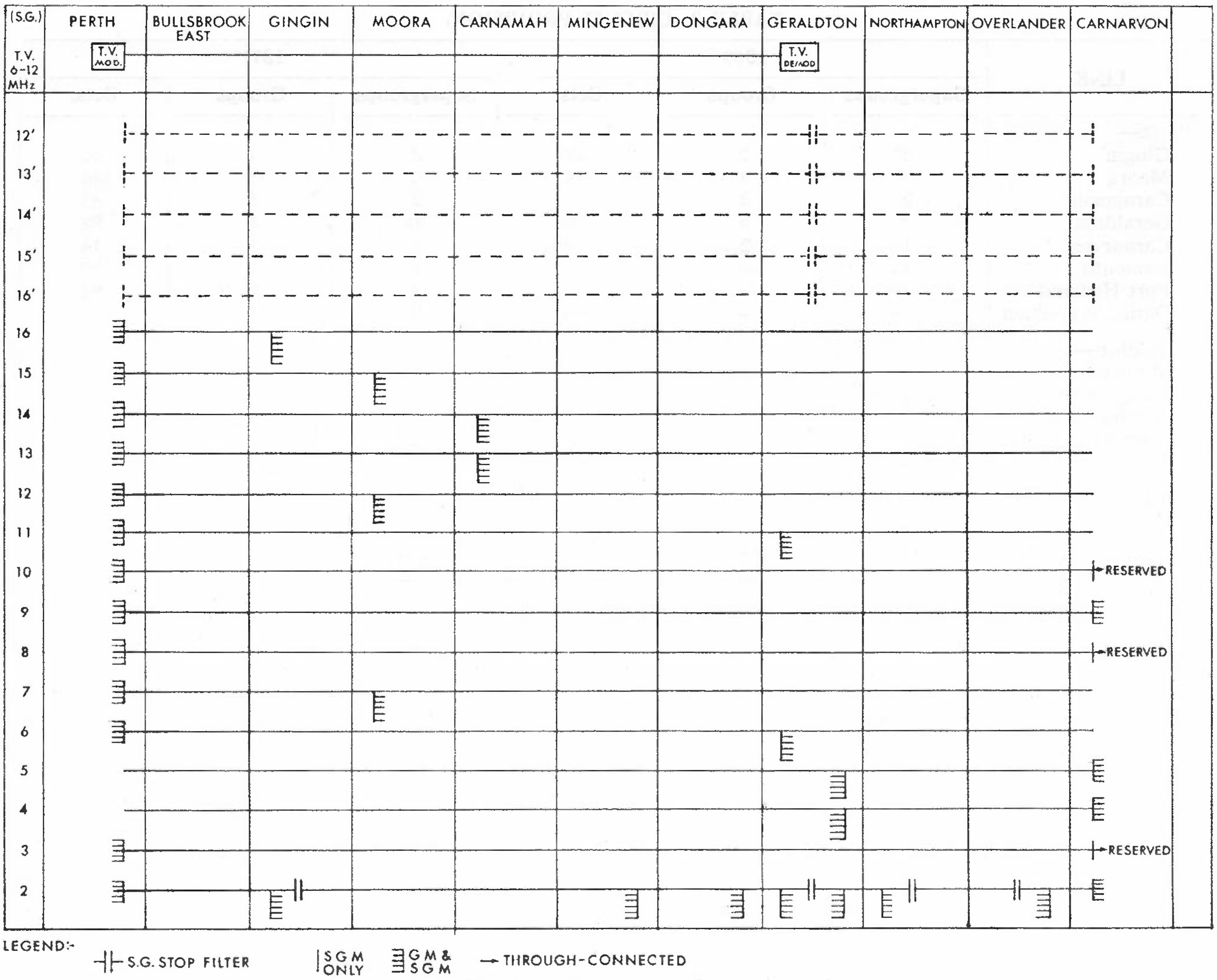

Fig. 5. — Supergroup Allocation, 1969.

The 12-MHz system has an initial capacity of 15 supergroups, to be extended to 20. As the five supergroups to be provided in the SMG2 range will be lost when a patch is made to the 4-MHz bearer, each station ought to have at least one supergroup in the SG2-16 range.

At a given station, a supergroup may be derived either by simple branching (in which case it cannot be re-used further along the route) or by dropping and replenishing. Replenishing can be done in two ways: either by back-to-back working or by inserting stop filters (Ref. 10).

Back-to-back or through-supergroup working is expensive and introduces noise into the through supergroups. Stop filters are available in the Siemens 12-MHz system for SG2 or alternatively SG2 to 5 or 7 to 16; in the latter two cases, the filter characteristics make SG6 unusable.

Generally, the requirements of the Perth-Carnarvon route are best met by simple branching, together with SG2 stop filters. Through-supergroup operation will be adopted at Carnarvon for the extension to Port Hedland and is also proposed at Geraldton for the five extra supergroups to be derived in the SMG2 range.

Fig. 5 shows the initial supergroup allocation. Some modification will occur when the Carnarvon-Port Hedland extension is connected, and again after the SMG2 supergroups come into use.

The quantities of working supergroups and circuits at cutover in 1969 are summarised in Table 2, along with the probable situation in 1971.

BUILDINGS.

Completely new buildings have been provided at only three stations: Dongara (Fig. 6), Northampton and Overlander. A building extension was undertaken at Geraldton to house broadband and switching equipment. All of the other branching stations already possessed equipment buildings which, with some re-allocation of floor space, proved adequate for the broadband system, other long-line equipment and local exchange plant. The Perth terminal fitted readily into the existing broadband equipment suites in the Pier exchange building.

The main repeaters at Gramel and Towarra are necessary for the operation of the 12-MHz system, but as no circuits are dropped out, the amount of rack-mounted equipment required is small. Sufficient power can be fed over the coaxial tubes, with assistance from the interstitial quads. As these stations are remote from settled localities, sealed underground containers were adopted rather than surface buildings.

FUTURE EXTENSIONS.

Early in 1969, approval was obtained for a four-tube coaxial cable to be laid from Carnarvon to Port Hedland, with a 12-MHz system (1200 circuits plus

TABLE 2: CIRCUIT PROVISION.

LINK	1969			1971		
	Supergroups	Groups	Ccts.	Supergroups	Groups	Ccts.
Perth—						
Gingin	2*	2	20	2*	7	55
Moora	3	3	34	3	15	136
Carnamah	2	2	20	2	9	83
Geraldton	2	5	60	4‡	9	98
Carnarvon	1	2	9	1	2	14
Exmouth	—	—	—	1	3	25
Port Hedland	—	—	—	3	9	92
Derby, Wyndham	—	—	—	3	4	48
Geraldton—						
Mingenew	½*	2	10	½*	3	25
Dongara	½*	1	11	½*	2	13
Northampton	1*	3	17	1*	4	34
Carnarvon	2	5	14	2‡	7	54
Port Hedland	—	—	—	1‡	2	14
Carnarvon—						
Overlander	1*	2	10	1*	2	16
Total working	12*	27	205	10*‡	78	707

‡SG12'–14' are used twice.
*SG2 is used four times.

television) on one pair of tubes. This work has been in progress since April, 1969, with a view to gaining circuit relief to Port Hedland by December, 1970. Included are single quad cable spurs to Exmouth and Onslow (Fig. 7).

At the same time, provision will be made for the television channel to be extended from Geraldton to serve prospective transmitters at Carnarvon, Port Hedland and in the Dampier-Roebourne district. All of these tele-

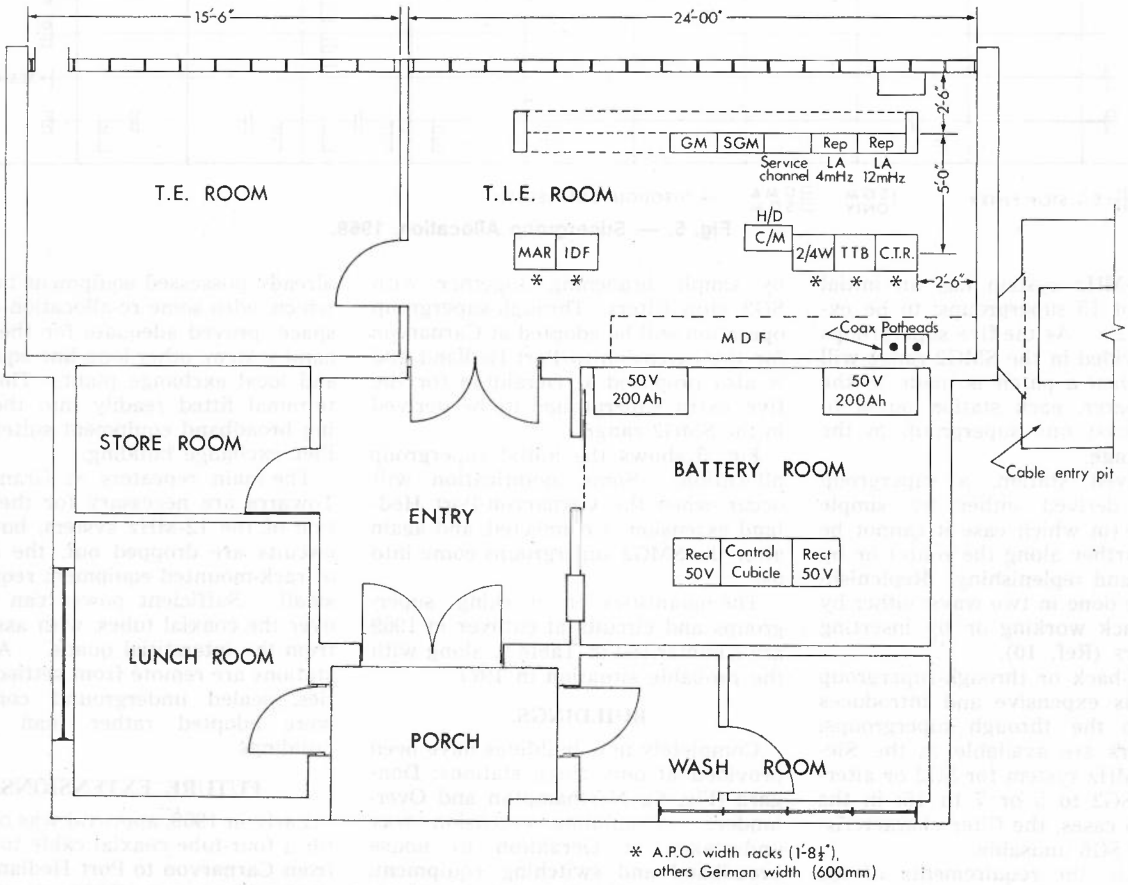

Fig. 6. — Dongara Equipment Building: Layout of Coaxial Equipment and Power Plant.

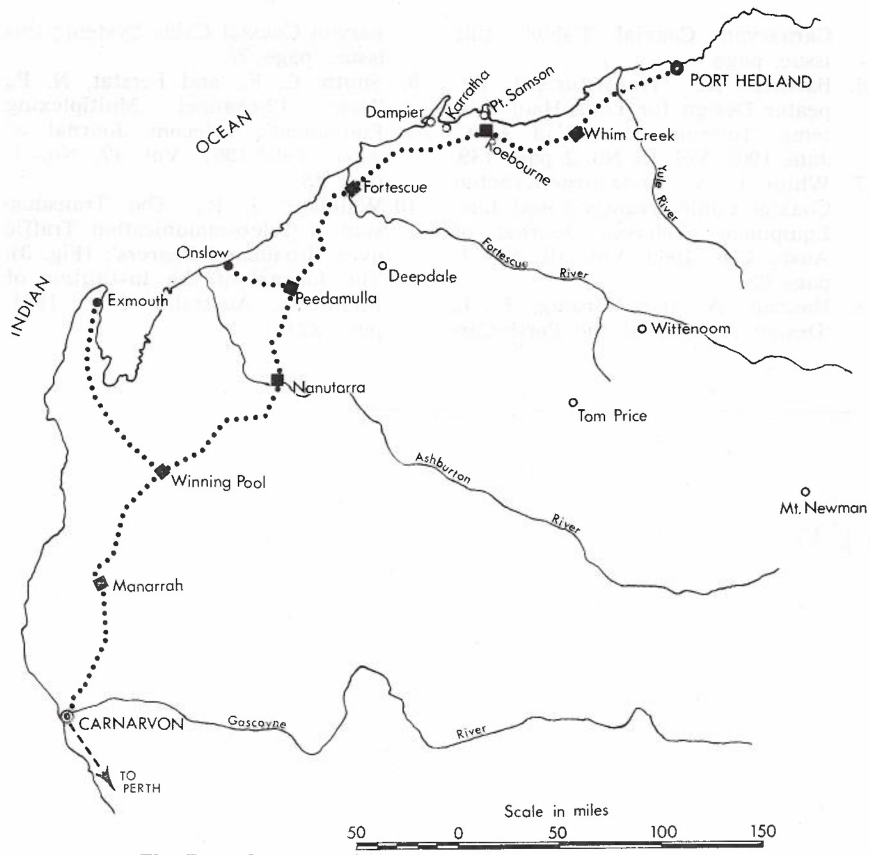

Fig. 7. — Carnarvon-Port Hedland: Proposed Cable Route.

vision stations are to be supplied with the same programme, and hence can share the same television programme channel.

The town of Exmouth, with which is associated a high-powered V.L.F. radio station of the U.S. Navy, is served by a low-capacity H.F. radio system terminating at Perth. Because of a pressing need for more circuits for both civil and defence purposes, means were sought to obtain relief out of the new main and spur cables ahead of the completion of the 12-MHz extension.

Twelve-channel systems could be provided on the spur, but could not be expected to operate properly all the way back to Carnarvon on an interstitial quad. A solution was found in the temporary provision of a 4-MHz system from Carnarvon to Winning Pool, with a Z12N extension to Exmouth. The temporary system uses some of the equipment originally provided for standby purposes in the Geraldton-Carnarvon section.

Other spurs from the Carnarvon-Port Hedland system are expected to develop as new towns, associated with mining ventures, develop at such places as Karratha, Tom Price, Parraburdoo and Deepdale.

Beyond Port Hedland it is possible to foresee the eventual extension of the broadband system all the way to Darwin, thus completing a broadband chain right around Australia and establishing an alternative route from Perth to the eastern capitals. For the present, open-wire lines must continue to carry the trunk traffic to and from the far north of Western Australia.

SPECIAL USES.

The power and versatility of the 12-MHz coaxial system as part of a broadband network have already been demonstrated in two quite unexpected ways:

(a) The provision at short notice of a temporary Carnarvon-Perth video link to all Western Australian television viewers to participate in the international relay (via the Pacific INTELSAT 3 repeater) of the first lunar expedition.

(b) The inclusion of two Perth-Carnarvon broadband groups in a chain of systems linking Perth to Sydney through the INTELSAT 3 satellite. The resultant circuits, as well as helping to carry the fast-rising transcontinental telephone traffic, afford valuable experience in the operation of a domestic satellite system.

EXPANSION OF CAPACITY.

The long-term forecasting of trunk circuit requirements is notoriously difficult. On this route, prediction is even more hazardous than usual because the extent of industrial development, even ten years hence, is quite uncertain. However, by the mid-nineteen-seventies, progressive exhaustion of supergroup capacity is expected to occur, starting in the section closest to Perth. Relief could readily be obtained by providing F.D.M. equipment on the four-MHz standby system. Alternatively, the 4-MHz repeaters could be replaced with 12-MHz, starting with, say, the Perth-Moora section and progressing northwards as the demand increases. The latter procedure, while initially more costly, would better exploit the cable's inherent capacity in the long run. On the other hand, it is possible that a second broadband system following a different route(e.g., through Northam and Mullewa) to Geraldton will eventually be provided. In this case, the full capacity of a second 12-MHz bearer on the original cable might never be exploited.

This question will need to be resolved soon.

CONCLUSION.

The Perth-Carnarvon coaxial cable system, a project comparable in length and capacity with the Sydney-Melbourne cable, was planned in 1966 and successfully entered traffic in 1969. New ground was broken in three main respects:

(a) Direct burial of the cable by mole plough.

(b) Long-haul application of 12-MHz line equipment (1200 circuits plus television).

(c) New methods of dealing with wayside requirements, and the exploitation of broadband capacity to reduce trunk switching costs.

With its extension northwards, already in progress, the system will form the backbone of the telecommunication network in a vast and rapidly-developing region.

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TECHNICAL NEWS ITEM

ELECTRONIC TRUNK EXCHANGE FOR PITT, SYDNEY

The Postmaster-General (Mr Hulme) announced in September 1969 that Standard Telephones and Cables Pty. Ltd., the Australian subsidiary of International Telephone and Telegraph (I.T.T.), would supply and install a large electronic trunk exchange in the new Pitt exchange building, Sydney. The exchange will be of about 10,000 lines with potential to expand beyond 50,000. It will control 200 manual assistance positions for both national and international calls as well as providing 'a changed number and redirection' service, which is both more efficient than the present interception methods and has potential for providing new services such as 'absent subscriber call redirection' and 'telephone answering'. The 17-storey Pitt exchange building under construction at present is due for completion in 1970 and it is planned to have the exchange in service by 1973.

The present Post Office trunk switching equipment, the L. M. Ericsson ARM 20 crossbar type, has a maximum installed capacity of 8,000 lines. Exchanges requiring a larger capacity employ multiple ARM installations. With the current rate of growth of trunk traffic Sydney would require a fully equipped unit every two or three years in the 1980s. This would lead to substantial inefficiency in the use of the trunk network.

The new exchange, known as the I.T.T. 10C System, will be electronic processor controlled and is similar to other systems being installed in countries faced with similar problems, notably the United States, Belgium, The Netherlands, Sweden and Japan. The first 10C exchange in public service is a subscribers exchange of 1,000 lines capacity which has been operating in the Brussels suburb of Wilrijk since September 1967. In its initial size the Pitt exchange will be operated by two I.T.T. 3200 telephone switching computers, each of which is capable of connecting 290,000 calls per hour and of carrying the full load of an exchange about twice the size of Pitt. The extra computer is provided to ensure reliability and the design specification calls for a 'mean time between failures' of greater than 50 years. In operation, both computers share the exchange load and in the event of one failing, the other assumes full control without loss of calls. The 10C system is capable of expansion to a maximum of 6 computers and over 200,000 trunks and junctions.

As well as permitting high switching capacity, electronic control allows for the provision of new services and maintenance facilities, simplifies line relay set design, reduces space requirements and prepares the way for automatic network management techniques to be used. A more advanced type of manual assistance switchboard will be introduced which will provide more information to the operator and is expected to yield a more efficient operation. In addition the exchange computers will calculate the call charges and record these on magnetic tape which will be processed in the Post Office Telephone Accounting A.D.P. System. Hence the handwritten trunk docket may not be necessary at all in the Pitt manual trunk centre. A further feature made possible by the use of computers is that the switchboards may be located remote from the trunk exchange, thus easing staffing problems now evident with metropolitan manual assistance centres.

The further application of 10C trunk equipment and 10C local exchange equipment is at present being evaluated. Articles for the Journal giving a system description are in preparation.

INSTALLING THE PERTH-CARNARVON COAXIAL CABLE

*J. A. HUSTON, B.A., B.E., M.I.E. Aust**

INTRODUCTION.

Authority to commence this 602-mile extension of the Australian broadband communications network was given in September, 1966. The target dates set for the completion of cable installation were to Geraldton by the end of May, 1968, and to Carnarvon by the end of December, 1968. To meet these dates the rate of cable installation had to exceed any previous achievements and it was therefore very satisfying to reach both towns ahead of schedule.

The cable as planned became the first fully transistorised 12-MHz cable system capable of transmitting both television and telephone traffic simultaneously over a pair of coaxial tubes, besides introducing the concept of a totally buried system. Its use in this capacity, to transmit live, the first landing on the moon by man, early in 1969 was consequently a fitting finale to the project as a whole.

In this paper an attempt is made to describe what was done, with the emphasis on new developments rather than repeating what has been adequately described elsewhere. (See further reading list.)

THE CABLE PATH.

Route Selection.

The route is shown in Fig. 1 and it will be seen that between major repeaters there were minor repeaters at 5000-yard spacing, housed in buried 6 ft x 6 ft. circular concrete manholes.

Between Perth and Geraldton the route selected depended to some extent on nominated towns where relief was required or where new exchanges were to be provided. Wherever possible the railway reserve was utilised to obviate damage to property, and to take advantage of the naturally good grades and lightning protection offered. Access to the route was always considered paramount because of the problems that would otherwise be encountered in placing 1000-yard, 4¼ ton drums of cable on peg, and also for maintenance purposes.

The route selection was performed by an engineer assisted by an estimating foreman and two linemen. The latter carried out test borings and soil resistivity measurements as directed. During this operation, conduit requirements, together with special provision at major rivers, were decided upon. Only four rivers, viz., Moore, Chapman, Murchison and Wooramel, were placed in this category.

Survey.

Two survey parties then pegged the route in accordance with normal practice, from which 8 chains to the inch base plans were prepared. Using these plans, drum length advices were produced within the limits specified by the overall system design. A standard allowance for snaking, rippling, and loss of alignment was applied to each drum length. This was initially set at 20 feet, subsequently reduced to 12 ft., and now to 9 ft. per 1000 yds. The actual joint and repeater positions were then pegged and marked on the drawings. The plans also set out the type of soil that would be encountered, besides recording other surface information such as gates, clearing and levelling required.

The speed and accuracy with which these surveys were carried out and plans produced are a credit to the drafting office. The average rate for a survey field party was 10 miles per week.

A close liaison was maintained with the drafting office and from the experience gained on the project certain changes have resulted.

Reference marks which were placed at 5000 feet are now located at 3000 ft. intervals. These marks then became the joint and repeater positions in the majority of cases. The initial strip plan virtually becomes the drum length advice except for minor altera-

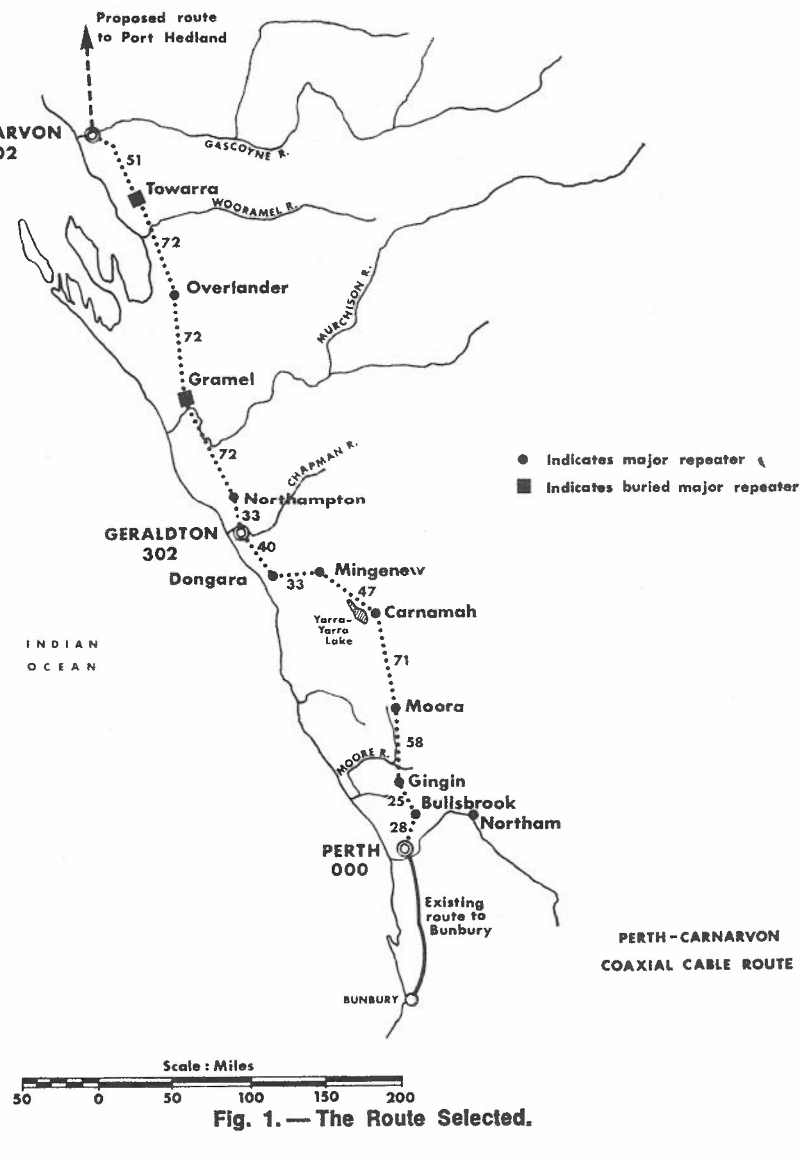
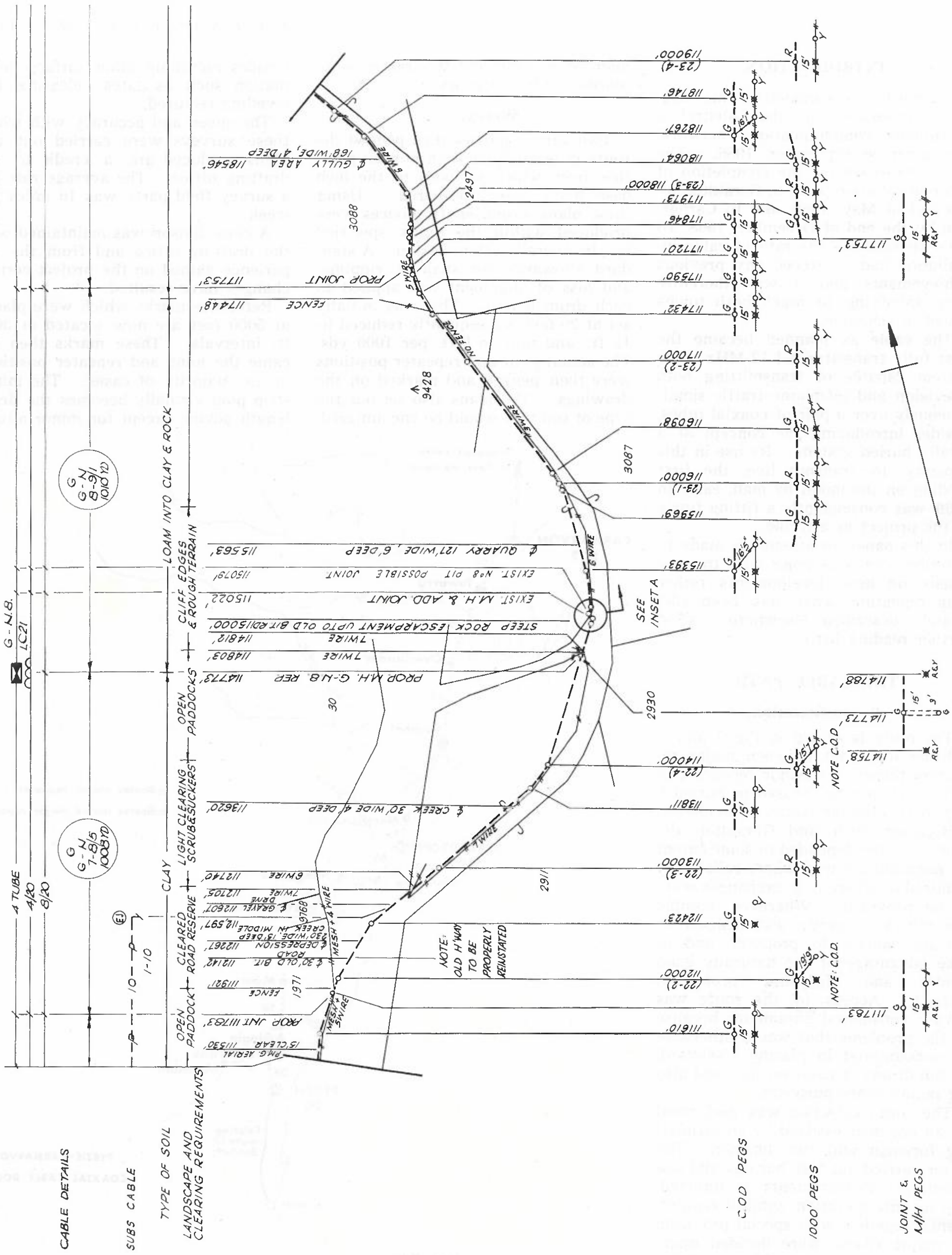


Fig. 1. — The Route Selected.

* Mr. Huston is Engineer Class 3, Coaxial Cable Division, W.A.


CABLE DETAILS
SUBS CABLE
TYPE OF SOIL
LANDSCAPE AND CLEARING REQUIREMENTS
C.O.D. PEGS
1000' PEGS
JOINT & M/H PEGS
4 TUBE
LOAM INTO CLAY & ROCK
CLIFF EDGES & ROUGH TERRAIN
OPEN PADDOCKS
LIGHT CLEARING SCRUB&SUCKERS
CLAY
CLEARED ROAD RESERVE
OPEN PADDOCK
SEE INSET A

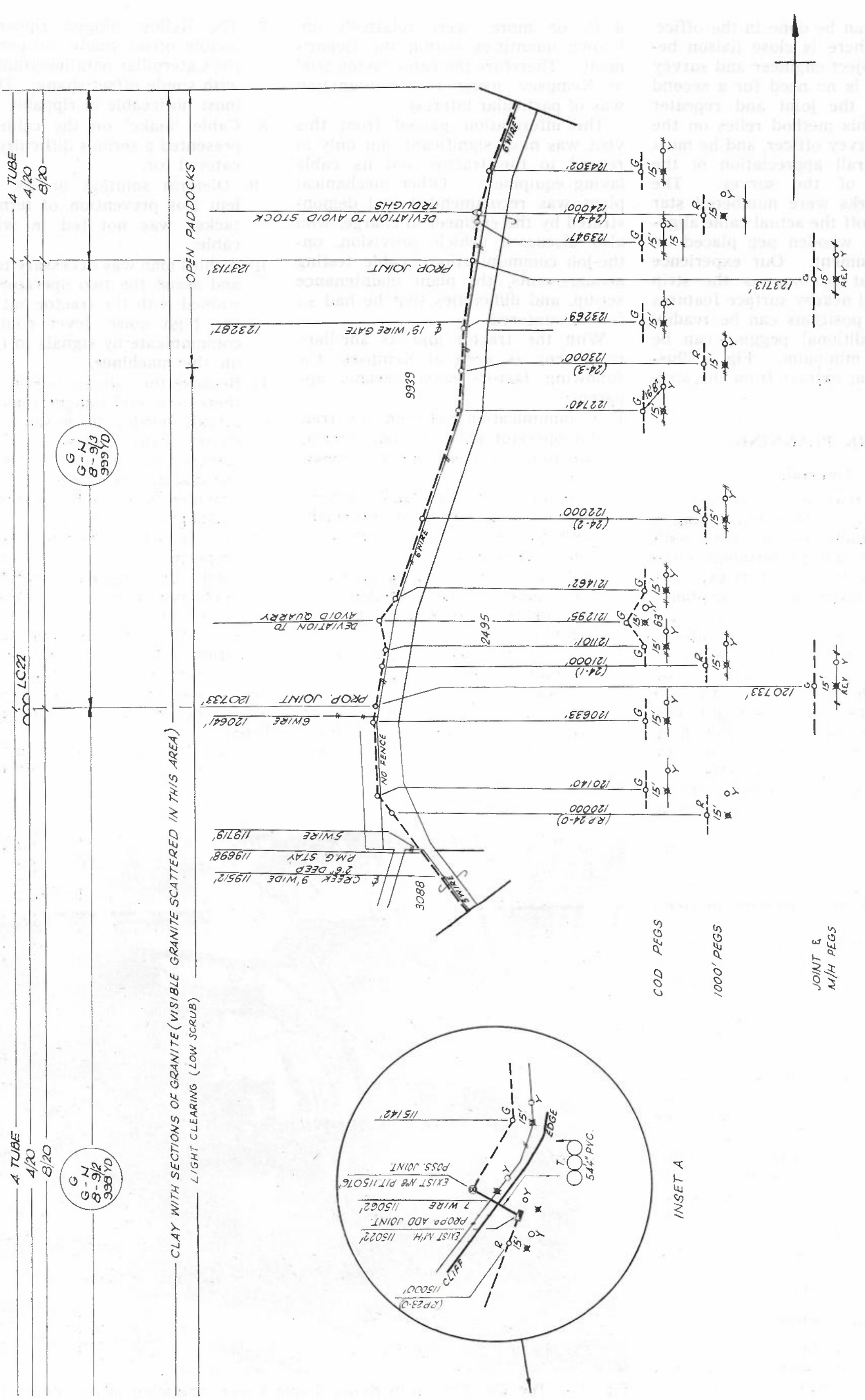


Fig. 2.—A Typical Example of the Strip Plans Used.

tions which can be done in the office.

Providing there is close liaison between the project engineer and survey officer, there is no need for a second pass to peg the joint and repeater positions. This method relies on the skill of the survey officer, and he must have an overall appreciation of the end purpose of the survey. The reference marks were numbered star pickets 20 ft. off the actual cable alignment, with a wooden peg placed on the true alignment. Our experience has been that so long as the strip plans tie in all nearby surface features so that joint positions can be readily identified, additional pegging can be reduced to a minimum. Fig. 2 illustrates a typical extract from the strip plans.

WORK PLANNING.

General.

One of the reasons for opting for a cable solution on this route was a calculated gamble on the speed with which cable could be installed, commissioned and put into service. The gamble was based on the acceptance of an unproven mole plowing technique, which was considered capable of installing more than 10 miles of polythene-jacketed non-layer lead sheathed cable in a week. The big worry, of course, was the fragility and bedding of the unarmoured cable in an unseen environment that would often contain rock. Subsequent events vindicated this decision. Once committed to the proposed new method, installation techniques had to be finalised as quickly as possible so that suitable plant could be ordered and supplied in time. Visits were made to a trial installation of 10 miles of steel-sheathed coaxial cable on the Geelong/Warrnambool route and later to a more extensive trial, conducted with polythene-jacketed lead - sheathed cable on the Kempsey/Coffs Harbour route. On the basis of this information, plus local knowledge and advice from headquarters, initial orders for mechanical plant, vehicles, and camp accommodation were placed by December 1966. These were later slightly modified after further field trials in the West during March 1967. The modifications were mainly in regard to vehicles and mechanical aids to maintain a 4 ft. depth of cover through heavy rock. At about the same time bulk orders for material were placed and a first approximation work schedule drawn up.

Plant Selected.

The D9G Caterpillar tractor and Kelley ripper cable layer, which make cable plowing possible at depths of 4 ft. or more, were relatively unknown quantities within the Department. Therefore the cable laying trial at Kempsey using this combination was of particular interest.

The information gained from this visit was most significant, not only in regard to the tractor and its cable laying equipment. Other mechanical plant was recommended and demonstrated by the engineer in charge, who also discussed vehicle provision, on-the-job communications, cable testing arrangements, the plant maintenance set-up, and difficulties that he had so far encountered.

With the tractor and its ancillary equipment as seen at Kempsey, the following factors soon became apparent:

1. Communication between the tractor operator and the man steering the Kelley cable layer was essential.
2. Visibility from the tractor driver's position was very poor, especially with a drum of cable carried on the dozer blade.
3. With a drum of cable carried on the blade the tractor tended to be unbalanced, especially in soft ground.
4. In the set-up used it took as long or longer to change a drum as it did to install a drum.
5. Only one drum of cable could be carried and plowed in at a time.
6. The Kelley cable layer worked very efficiently.
7. The Kelley hinged ripper with double offset shank out-performed the Caterpillar parallelogram ripper with single offset shank. This was most noticeable in rippable rock.
8. Cable 'make' on the cable drum presented a serious difficulty unless catered for.
9. Dieldrin solution or its equivalent (for prevention of termite attacks) was not fed in with the cable.
10. A third man was necessary to direct and assist the two operators. He walked with the tractor but due to the high noise level could only communicate by signals to the men on the machines.
11. Because the cable is buried unseen, there is a real danger that due to a fault developing, in say the layer chute, many miles of damaged cable could be innocently installed.
12. Excavating the buried cable ends provided a situation where cable damage could occur.
13. Provided the ground had been properly ripped, then adequate cable depth could be maintained.
14. Personnel safety would have to be looked into.

Following this visit and a trial installation of a 15-mile section of our cable near Gingin in March 1967 a design was evolved which eliminated or minimised most of the problems listed.

Items 1 and 10 were resolved by providing an intercom on the tractor

Fig. 3. — The Cat D9G, with Kelley Cable Layer, operating in the Moora Region.

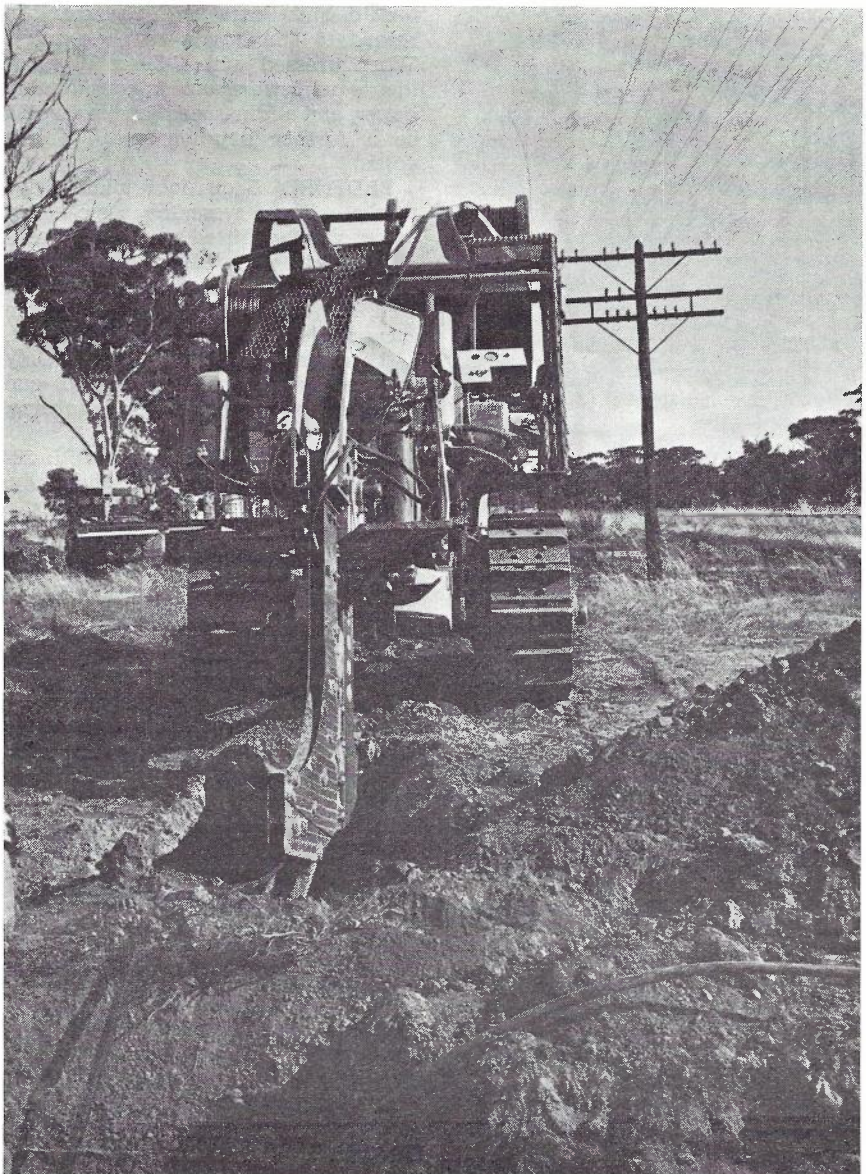


Fig. 4. — A Rear View of the Cable Layer Illustrating Shute and Cable Box Detail.

with the third man mounted on the operator's platform. The intercom system employed noise cancelling microphones with the receiver enclosed in earmuffs. A complete standby circuit with amplifier and attention given to vibration problems, was incorporated in the design.

Items 2, 3, 4, 5 were significantly improved by designing a special set of cable drum handling forks in lieu of the dozer blade. Drum changes could be effected in less than ten minutes and the co-ax plus another drum could be carried simultaneously on separate spindles riding on bearings. Overrun on both drums was controlled by disc brakes on the spindles.

Item 8 is dependent to a large degree on the way the drum is constructed and the smoothness of the laying operation. The make was catered for by holding the inner end under continuous tension by means of spear gun rubbers. Other methods were tried, but this proved the most effective.

Item 9 was taken care of by mounting a 60-gallon tank on the tractor on the opposite side to the hydraulic tank. The dieldrin solution was mixed in this tank using special pumps and pourers designed around a "no touch" technique. This tank was replenished at every second drum change. A gravity feed from the tank to the cable laying chute was employed with the air cylinder injection point controlled by the layer operator. The latter also had a simple visigauge to indicate that dieldrin was being applied.

Items 11 and 12 were covered in the tray, chute and fairlead design and by having an advance test group moving with the tractor about two drum lengths behind.

Item 14 was tackled by engineering safety into every operation, and emphasising safety at all times. Films, lectures, stickers, and a generous attitude on personal safety wear helped considerably in this regard.

A set of local drawings was produced, and the tractor in its eventual form is shown in Figs. 3, 4, 5.

Besides this unit the following major items of plant were purchased:

JOY 500RR Air Track Drill with Ingersoll Rand 600c.f.m. trailer mounted compressor (Fig. 6)—a good reliable combination, although the compressor power unit tends to overheat on hot, still days. The very high noise level demands ear protection and there is a dust hazard on still days. The dust problem could be alleviated by conversion to damp drilling. This is still under investigation. (Two units.)

HYMAC 580 crawler mounted 5/8-yd. hoe plus clamshell attachment (Fig. 7). This low ground pressure high capacity hoe proved invaluable in service. Besides digging and installing the 6 ft. circular repeater manholes, where it doubled as a crane, it was used on river crossings, across swamps, and for rock removal rigged as a grab. The only drawback was the need to permanently associate it with a 17-ton low loader; in this case with a Dodge prime mover, because of its low travelling speed. (One unit.)

JOHN DEERE 95 tractor equipped with JD 400 ⅝ yd., back hoe—a high capacity robust unit which would have been vastly improved with high flotation front wheels. A fair degree of maintenance was required, which was made more difficult by this model being the first of its kind in this State at the time. (Four units.)

CATERPILLAR D9G crawler tractor with 9S tilt blade. Fig. 8 shows two of these machines operating in tandem on ripping. It was some time before both ripping machines were equipped with Kelley gear and this was a major factor in the workface not being well north of Geraldton when an abnormally wet winter set in. The machines have tremendous power available; the problem is to deliver the power. As supplied, they were fitted with standard 24 inch tracks. These were rapidly cut down on the rock sections or where a handicap in soft standing. At present the tractors are being converted to 27 inch extreme service tracks. (Three units, including the cable-laying tractor).

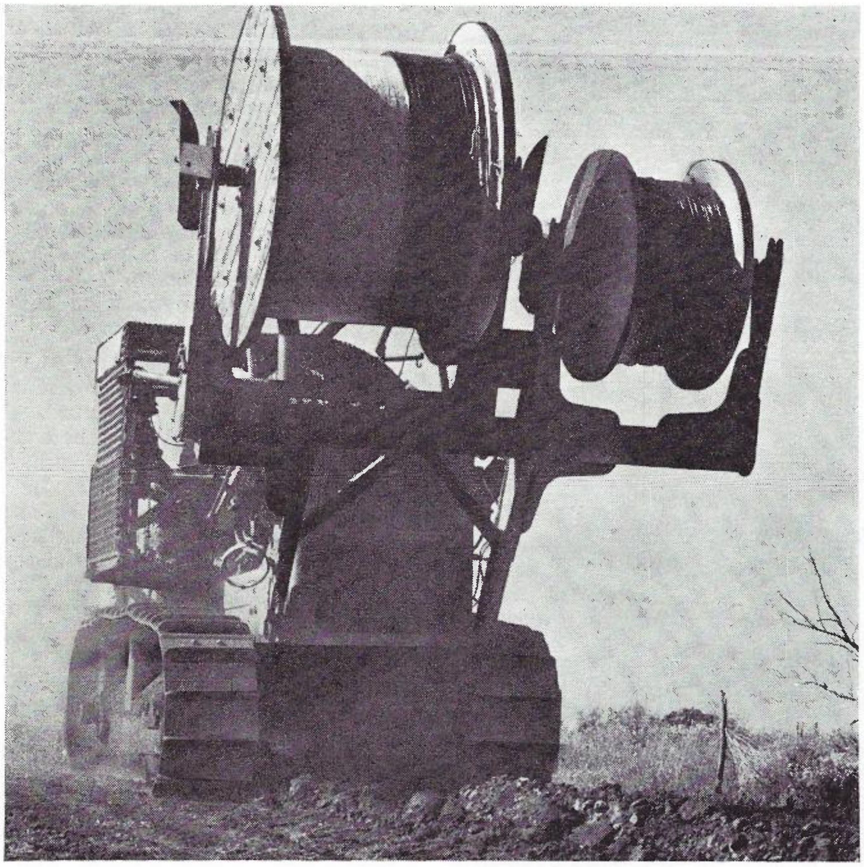


Fig. 5. — A Front View of the Cable Layer Illustrating the Drum Carriage Arrangement.

tory, despite limitations in sand and in regard to stability in rough country. When dressed with 7-50 x 16 tyres their sand performance is considerably better, and a four-speed gearbox would be a further improvement. (Thirty units.)

BEDFORD 5-ton four-wheel drive trucks. These were the basic heavy truck, whether fitted as mobile workshops, test vans, Hiab equipped or straight flat tops. They have done well, only demonstrating weakness in the transfer case chassis attachment, and fuel tank holding brackets. Only five trucks were Hiab equipped, and this has since been increased to nine. (24 units.)

KENWORTH prime mover with 50-ton capacity quad axle float plus dolly. These trucks were fitted with sleeper cabs and air-conditioning, with a view to long distance heavy haulage. They have performed superbly, especially after conversion to Michelin tyres. (Two units, see Fig. 11.)

LEYLAND prime mover with 25-ton capacity triple axle float. Intended for cable transportation and the movement of any mechanical aids other than the D9s. However, this unit proved to be slower and less reliable than the Kenworths. In retrospect it would have been more flexible and economical in the long run to have had a third Kenworth prime mover with quad axle float and no dolly, rather than the Leyland.

CATERPILLAR D7E crawler tractor with 7A Straight blade. These proved to be very useful and reliable machines. Their only drawback was again the original fitting of standard tracks instead of extreme service; also their flexibility would have been vastly improved had they been supplied with 7S tilt blades. (Two units.)

CHAMBERLAIN/CRANVEL 5 - 8 ton crane. This is a fairly well-known combination in our department. In this case the load-bearing wheels were fitted as duals to improve flotation. The unit did the job it was intended for, but with some difficulty. The unit originally requested was a crane with 360 deg. slew, all wheel drive, power shift boom, and capable of a 10-ton lift. It would have been ideal for the purpose. The Austen Weston is a crane of this type. Both machines are illustrated in Figs. 9 and 10. (Two units.)

TOYOTA 1-ton four-wheel drive trucks. These were selected as the basic light truck for the project because of their power and good maintenance record in the State. Their overall performance has been satisfac-

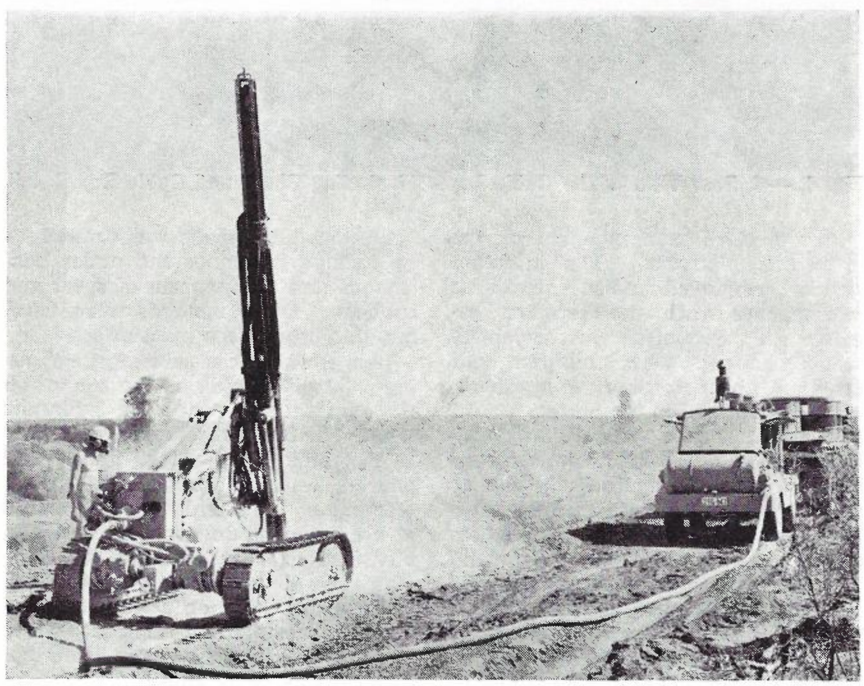


Fig. 6. — Joy 500 RR Air Track Waggon Drill and Ingersoll Rand 600 c.f.m. Compressor.

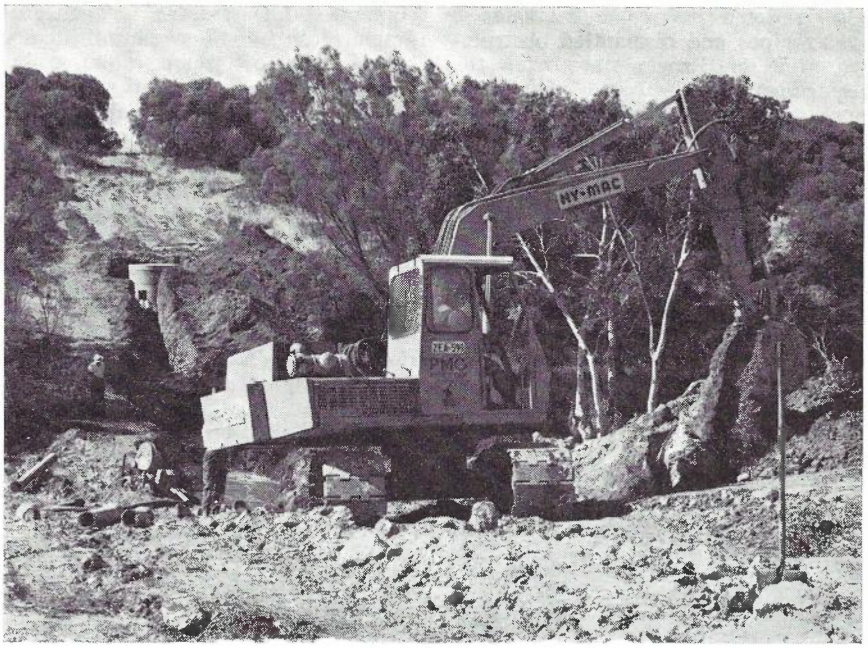


Fig. 7. — The Hymac 5/8 yd. Excavator.

One camp based on 32 ft. x 8 ft. caravans capable of housing 50 men. This includes diner kitchen, office, ablutions, storage, amenities and sleepers. (14 vans plus two 35 K.V.A. trailer mounted power generators.) (See Fig. 12.)

Three camps based on 20 ft. x 8 ft. caravans capable of housing a total of 60 men. Similar facilities to those listed above were provided (30 vans plus one 35KVA one 12.5KVA, and one 6KVA power generators, either trailer or truck mounted.)

One two-way radio telephone system, including 25 mobiles and 4 talk through repeaters with associated 1½KVA power generators. Good on-the-job communication is essential to a project of this nature, and although the system purchased could be improved upon, it served the purpose intended. The nominal range with all repeaters in service was 120 miles.

PRELIMINARY ACTIVITIES.

General.

In January, 1967, using plant on loan from the State fleet or hired from contractors, the preparatory phase of the project got under way. The activities undertaken consisted of installing gates, conduits and ducted river crossings, track preparation, test ripping and blasting rock that could not be ripped.

The men recruited were all voluteers from within the State organisation. They were selected with a view to their eventual roles for cable installation, and every opportunity was utilised to train them accordingly. A maximum staff of 46 men were in the field at the conclusion of this stage, with a skeletal divisional structure consisting of two engineers, a line inspector, two foremen and one clerk supporting them.

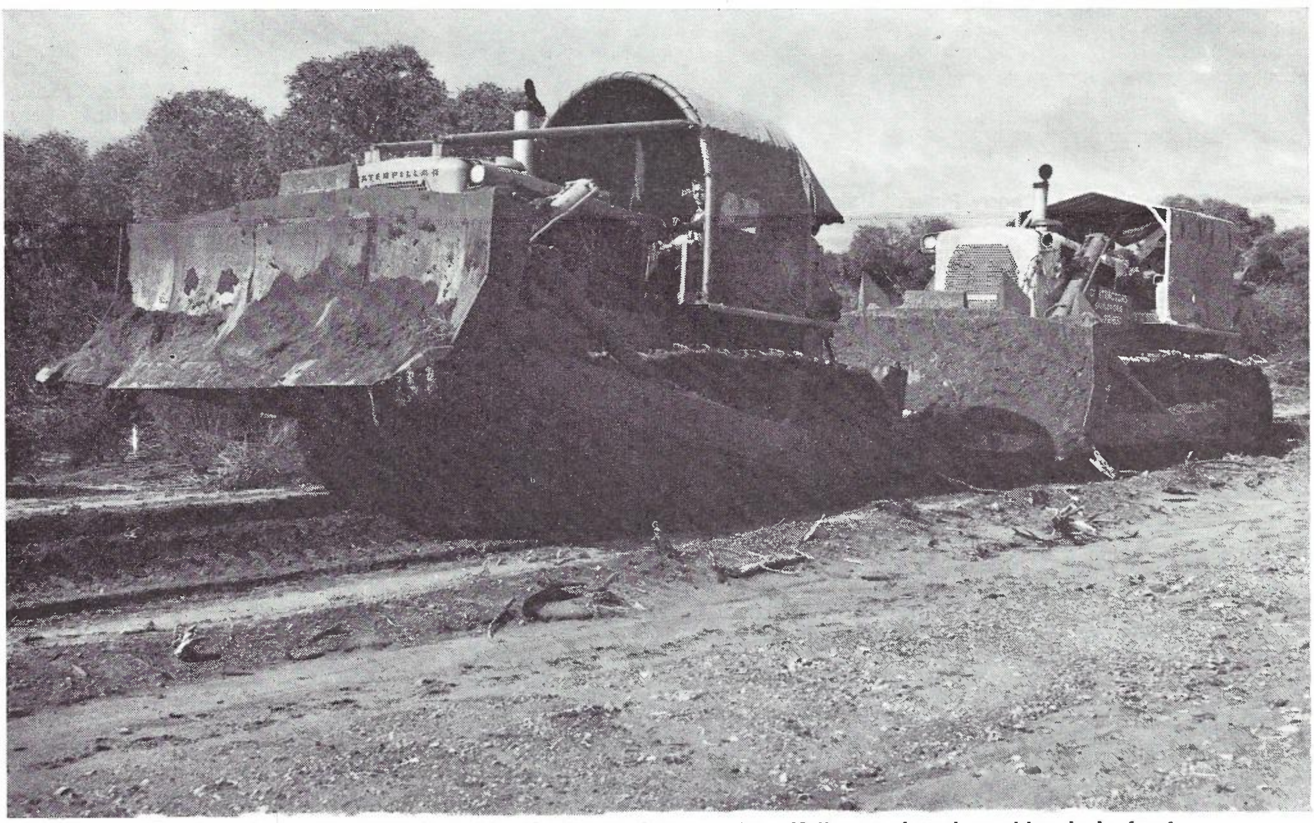


Fig. 8. — Caterpillar D9G Tractors Ripping in Tandem. The Kelley equipped machine is in front.

Gate Erection and Ductwork.

There was nothing particularly novel about these tasks except for the economies achieved by the Hymac on the river crossings compared with tendered prices, and the adaptation of the tractor mounted piledriver used on the East/West route, for gatepost installation. The posts, either pipe or railway iron, thus installed proved to be very stable and strutting was only necessary on permanent M braced 16 ft. gates.

Track Preparation.

A grader and D7E crawler tractor were used for this purpose. The party also inserted removable sections in water pipes and dismantled obstructing wind and angle stays from the departmental pole route where this occurred. In place of angle stays a 2 in. pipe strut was inserted.

Their main function, however, was to provide a clear level path for ripping and cable laying. In deviations they also provided an access track alongside the actual cable path, i.e., a clear level strip 30 ft. wide in lieu of the usual 20 ft.

Ripping.

Test ripping commenced in February 1967 with the arrival of the first Kelley equipped D9G tractor. The programme ran into immediate difficulty because only one shank, point, collar and fixing pin came with the unit. These parts are only available ex the United States with a lead time of about twelve weeks. The average usage rate for these items was later established as 17 off 308 short blue points, 5 collars, and 10 flex pins per hundred miles of ripping. It was also found that the original design Kelley double offset ripper shank, fitted with wear pads, lasted for 100 to 125 miles of ripping before fatigue failure occurred through the wear pad locating pin holes. At this stage, whether the shank had failed or not, it was beyond repair. As a result all future orders have been for the shank with wrap around style protector, but their life has not been evaluated yet.

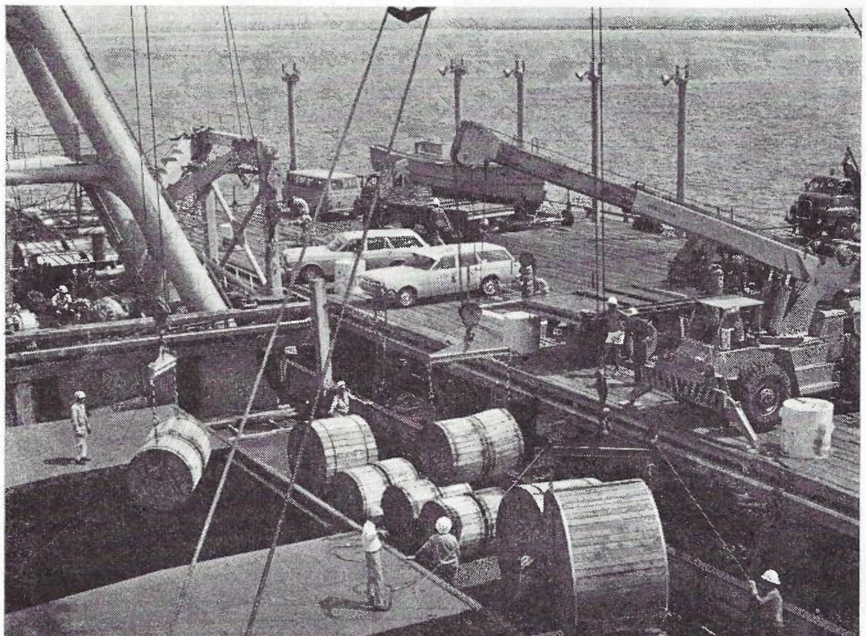


Fig. 9. — The U.S. Navy "Cherry Picker" Unloading Cable at Exmouth. Illustrating the Preferred Type of Crane.

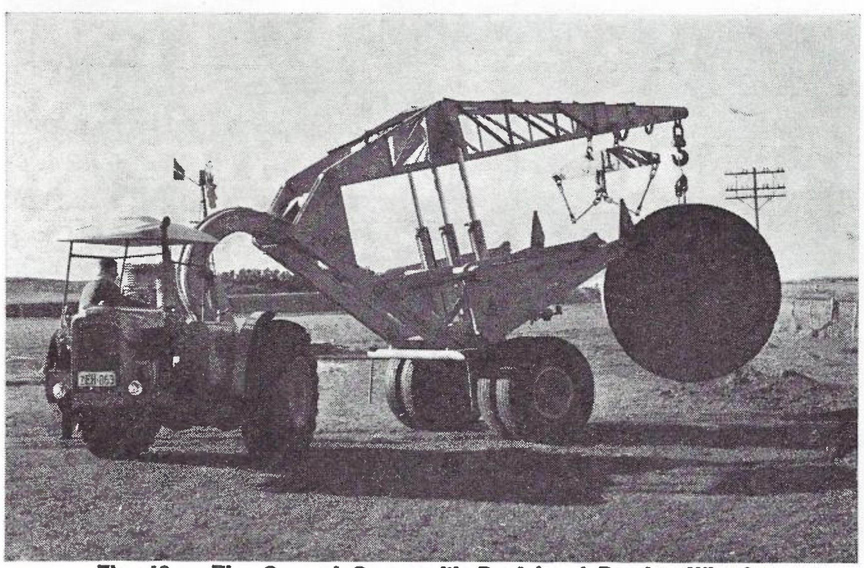


Fig. 10. — The Cranvel Crane with Dual Load Bearing Wheels.

With what was available, and after the cable laying trials near Gingin, selected rock areas at Coorow, Dongara, Murchison, and Overlander were test ripped. Records were kept of performance through various soil conditions of wear, progress rates and failures, corresponding to the configuration used. The opportunity was also taken to evaluate ripping through blasted rock in the Murchison River area. We found that very little was known about deep ripping for cable laying, even by well-known contractors.

The recorded results were carefully analysed and it was possible to set down guide lines on how to go about the ripping function. These results also indicated that the blasting operation would now be critical because the limestone in the Dongara and Overlander areas proved to be unrippable. This nearly doubled the blasting originally allowed for.

Pertinent points from the ripping instruction are listed below:—

1. To lay cable at 4 ft. the minimum ripping depth must be 4ft. 6 in. In moderate going every inch of ripping depth beyond 5 ft. costs 50 per cent more than the preceding inch.
2. The ripped slot must be at least 3 in. wide all the way down. Consequently the final pass must be carried out with a ripper point that is in good condition. This ensures passage for the cable laying box.
3. Except in sand, loam or loose clay the ripping machines should be worked in tandem.
4. After 9 tandem or 20 single passes the ground is either unrippable, or the loose surface causing loss of traction must be bladed off before further ripping.
5. After blading off use one machine for a maximum of 7 passes, and if

Fig. 11. — A Kenworth 50 ton Low Loader. On the rear is a tracked cable drum trailer capable of handling the 5 ton, 7ft. x 5ft., coaxial cable drums.

still unsuccessful, clean up the surface and leave it for blasting. If successful, fill in, and proof rip with a minimum of three passes.

6. In ground that has been blasted, level off and proof rip with a minimum of 5 passes. This ensures sufficient 'fine' generation to safely bed the cable.
7. All large rocks brought to the surface (over 15 in. diameter) in the rip line or track path must be removed.
8. In a 10-hour day, with two Kelley equipped D9G tractors, the following approximate production figures should be achieved. For Cat equipped machines the figures should be reduced by 20 per cent.

Pure sand—16 miles.
Loam—8 miles.

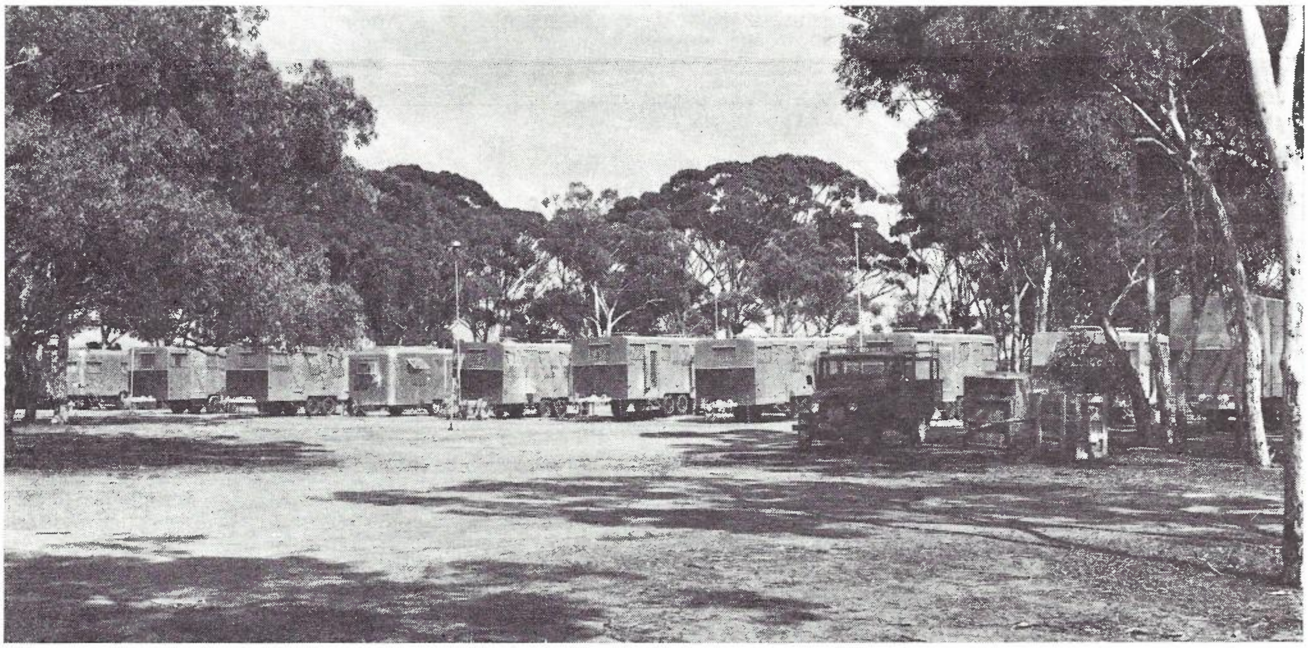
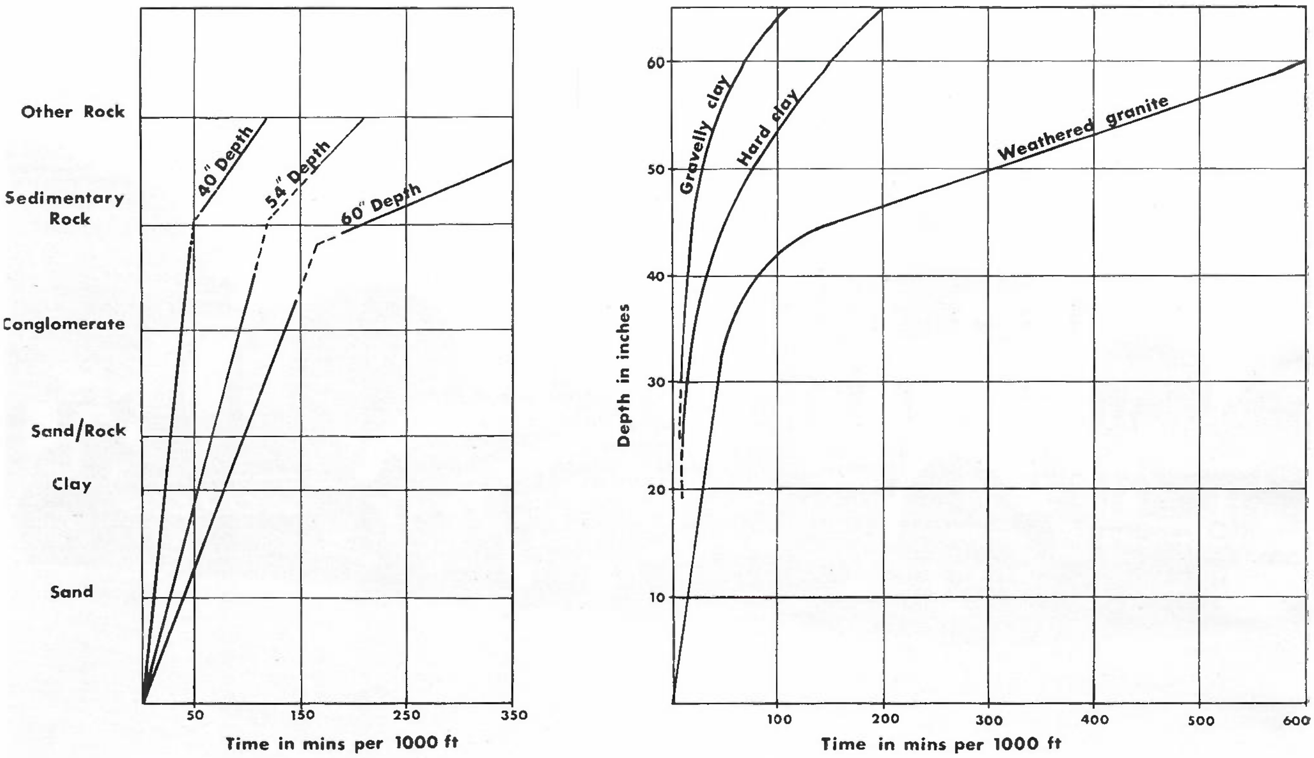


Fig. 12. — A view of the Jointing and Testing Camp then Situated Near Moora.



Single D 9 G, Kelley Ripper — Tandem D9Gs, Kelley Ripper.

Fig. 13. — Two of the Charts Used in Scheduling Ripping Operations.

Loose gravelly clay—4 miles.
Tight packed hard clay—3 miles.
Sand into conglomerate at 36 in. — 2 miles.
Ironstone or conglomerate at 12 in.—1½ miles.
Limestone or weathered rock—1 mile (assuming it is rippable).
Pre-blasted granite or limestone—1 mile.

Rock at a depth of 3 ft. with a loose surface is one of the most difficult soil conditions to contend with. Fig. 13 shows two of the charts produced in the ripping analysis. From the data compiled the ripping effort required for Perth/Geraldton called for two D9G tractors, and if Kelley equipped would take 5 months. In fact it took 6 months because the second set of Kelley gear did not arrive till midway through the fifth month.

The characteristics of the Kelley and Cat rippers are compared in Fig. 14. An Esco shank was also observed and found to be 10 per cent. worse again than the Cat.

Ripping and its associated techniques have proved to be most critical on a cable-laying project, and much could still be done to improve the economics in this area.

Blasting.

The original estimate for blasting was 40 miles, but this was increased to 75 miles when it was found that the limestone and caliche occurring in the Dongara and Overlander areas could not be ripped. One Joy drilling rig could only complete about one mile per week, so it became necessary to double our resources in this direction. The other areas where unrippable rock occurred was mainly in the Northampton/Murchison mineral

KELLEY RIPPER	CAT. 9B RIPPER
Fixed beam hinged tool bar with forged steel shank. Depth adjustment mainly by altering shank length.	Fixed beam parallelogram action, with forged steel shank. Depth adjustment by using the parallelogram and by altering shank length.
With 60" penetration, shank can be completely withdrawn.	Cannot be cleared.
Hydraulic pin puller very fast, operating 10-15 seconds.	Slow 30-40 seconds.
Hanging up characteristic is good.	Poor.
Penetration in rippable rock is good.	Fair.
Angle of attack is 25° and with double offset profile good speed, cutting and breakout is achieved.	Angle of attack is 37° with single offset profile giving only fair cutting, speed, and breakout characteristics.
Performance in soil containing floaters is only fair.	Good.
Average point life 24 hours, but cost approximately double Cat.	8 hours.
Service and parts poor.	Good.
Shank not repairable if fatigued.	Repairable.

DG9 RIPPER COMPARISON

Fig. 14. — A Comparison of the Main Advantages and Disadvantages Between the Kelley and Caterpillar Rippers.

belt and on the fringes of the Darling Escarpment nearer to Perth.

Again methods that would be appropriate to ripping rather than trenching had to be evaluated. Basically our equipment was suited to in line firing, and it was a question of determining optimum hole spacing, hole diameter, hole depth and type of explosive. Other factors such as hole angle, delay firing, and electrical firing were also explored. The end result was a basic 12 ft. spacing in the less homogeneous rocks and 8 ft. spacing in the very dense rocks. A 3 inch bit was used and the holes set at an angle of 12 deg. - 15 deg. and down to a depth of 7 ft. The most effective, safe and economical explosive was found to be prilled ammonium nitrate primed with diesoline. Depending on spacing either 9 lb. or 6 lb. of explosive was the recommended quantity, and an instruction for the guidance of field staff was produced. There has been very little variation from this instruction except for the limestone areas, where successful blasting depended to a large extent on liaison between the drillers and shot firers, and therefore on the experience of both. Initially many of these firings had to be repeated two and three times before the right recipe was found.

Electrical firing was not adopted, mainly for the sake of simplicity and safety.

From figures taken out during the evaluation period, the chart shown in Fig. 15 was produced. It illustrates the expense involved with blasting, since ripping must still be carried out. In fact, the hole spacings settled on were maximums in order to get the job done in time. It would have taken less subsequent ripping time, but more drill and shoot time if spacings of 10 ft. and 6 ft. could have been nominated. The only other trick employed on the rare occasions where blasting was required but could not be performed (e.g., across a road) was to drill 3 in. holes, 5 ft. deep, 9 - 12 in. apart, and then rip through.

CABLE INSTALLATION.

General

At full strength the Division consisted of 105 men. The supervisory and clerical group numbered 15 men, comprising 3 engineers, 3 clerks, 1 supervising technician, 4 line inspectors, 1 plant, inspector, and 3 foremen. Amongst the field staff there were 2 senior technicians, 1 trainee technician, 5 mechanics, 10 party leaders and 12 jointers. By this stage instructions had been written covering the following topics and the key men were fully briefed.

1. General information sheet.
2. Ripping for cable laying.
3. Blasting prior to ripping.
4. Cable laying.
5. Reinstatement and advance testing.
6. Circular manhole and repeater installation.
7. Cable jointing.

By late October 1967, as soon as ground conditions permitted a full-scale dress rehearsal was carried out in a sand plain north of Gingin. Finally on November 22, 1967, the installation of the 602 miles of coaxial, plus 270 miles of subscribers' cable, began at a point some 70 miles north of Perth. A start here was necessary due to wet ground conditions further south.

The cable in all the long conduit sections was hauled in by the staff of the Primary Works Division to fit in with the cable laying schedules. Their co-operation was also appreciated in completing the duct runs at Geraldton and Carnarvon.

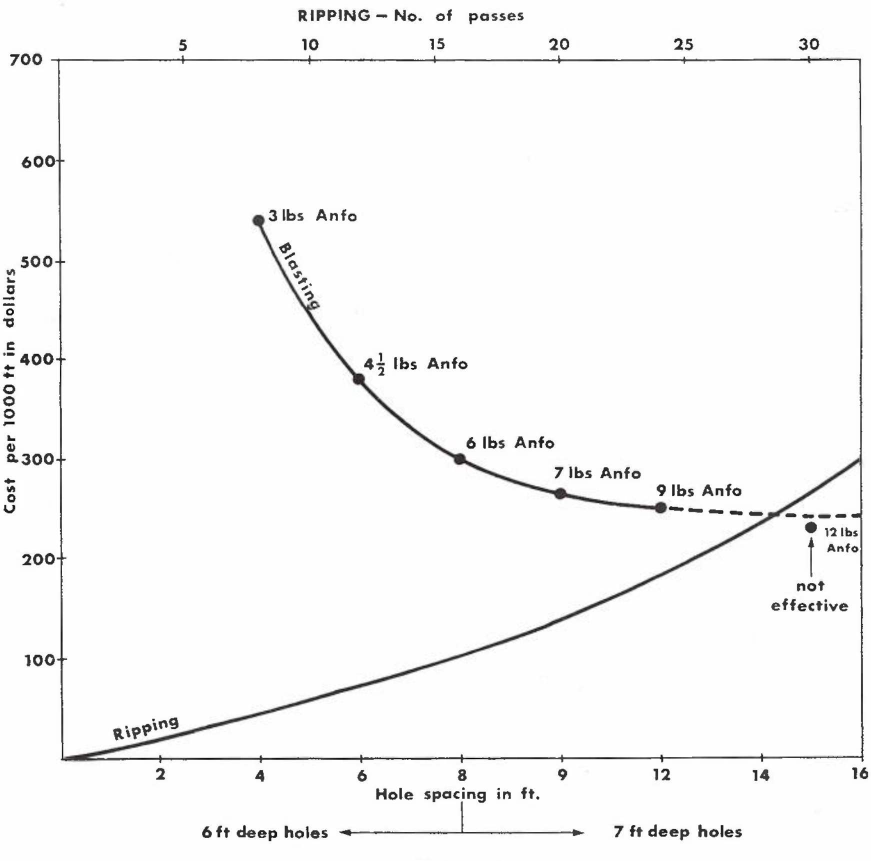


Fig. 15. — A Cost Comparison Chart Depicting the Break Even Point of Ripping vs. Blasting.

Cable Laying.

This group comprised 38 men, excluding engineers and inspectors. They were divided into parties taking care of circular manhole and repeater installation, cable laying, route reinstatement, and camp duties.

The success and speed achieved by the new method depended on the design work that went into the tractor and its ancilliary fittings. It is a considerable advance on the plowing techniques that have been used in the Department for many years.

One aspect not overcome till about 150 miles of cable had been installed was the practice of lashing the tail end of one drum to the start end of the next and plowing continuously. The backhoes, which then excavated the ends and joint position had great trouble in avoiding a hit on the cable. Besides this, due to the way in which the ends are made up in the factory, one cable tended to crush and damage the other. Hence we changed to a fresh start with each drum of cable in a backhoe excavated slot alongside the end that had been run out of the ground. Thus if the backhoe does strike the old end the joint position can be moved back slightly to avoid the dented cable, and crushing of lashed ends, of course, does not occur.

Besides checking the cable, the advance test group also coupled the cable ends together by means of Beverage tu-

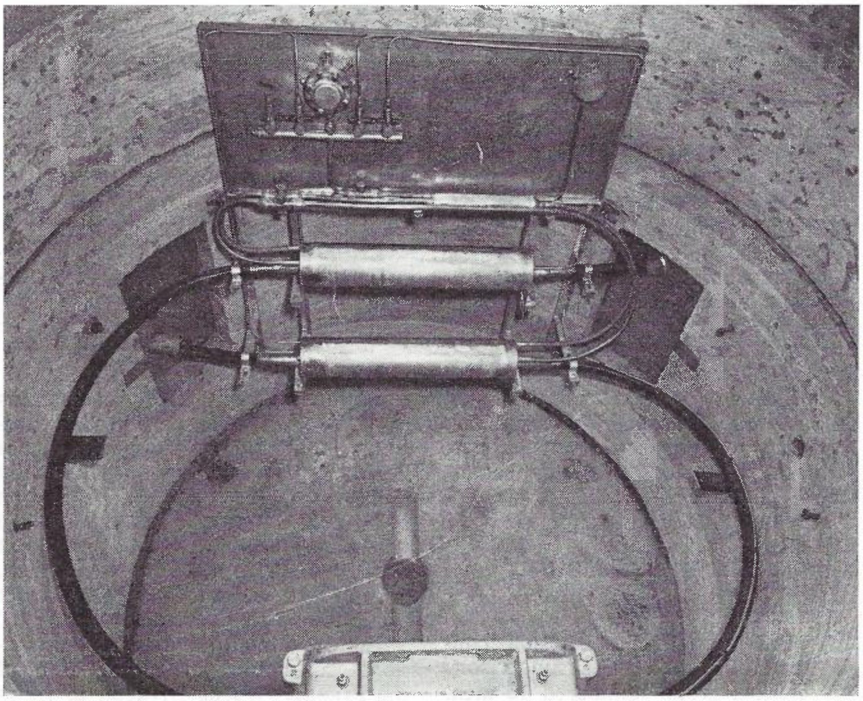


Fig. 16. — Looking down into a Minor Repeater Circular Manhole.

bing to feed air through from cylinders located at 11-mile intervals. Dieldrin was applied at the tractor, at the rate of 20 gallons of 1.1 per cent. concentration per 1000 yards. Consequently these men and others handling the cable had to observe a high degree of cleanliness.

Circular manholes and repeaters were placed in position ahead of the cable layers, and the route, apart from joint positions, was reinstated behind them. The reinstaters also erected cable markers at a nominal rate of 4 per drum length.

Cable installation averaged 16 miles per week, with the best performance on one day being 12 miles.

Jointing and Testing.

Jointing, testing and hole reinstatement employed a total of 30 manipulative staff. Their progress rates were tailored to coincide, and be about the same as cable laying. In the beginning this camp was about 100 miles behind the layers, but at Carnarvon the ripping, laying and jointing activities concluded in the same week a fortnight ahead of schedule.

The standard rolled sleeve method of tube jointing was used throughout and each jointer's target was two joints completed, flash tested, and wrapped with denso tape in a day. Fig. 16 shows a complete minor repeater manhole, jointing of cables, and a section of the repeater container. With practice this proved no problem and only the two minor-repeater joints took slightly longer. Several jointers consistently completed three joints in a day (Figs. 17 and 18.)

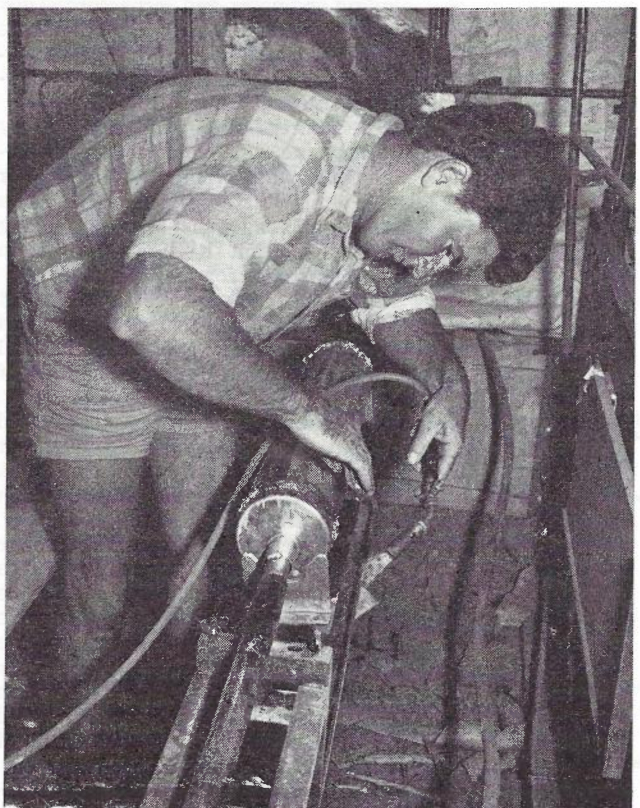


Fig. 17. — Jointer Completing a Straight Joint in an Open Hole Protected by Tent and Frame. The special jointing jig and seating arrangement can also be seen.

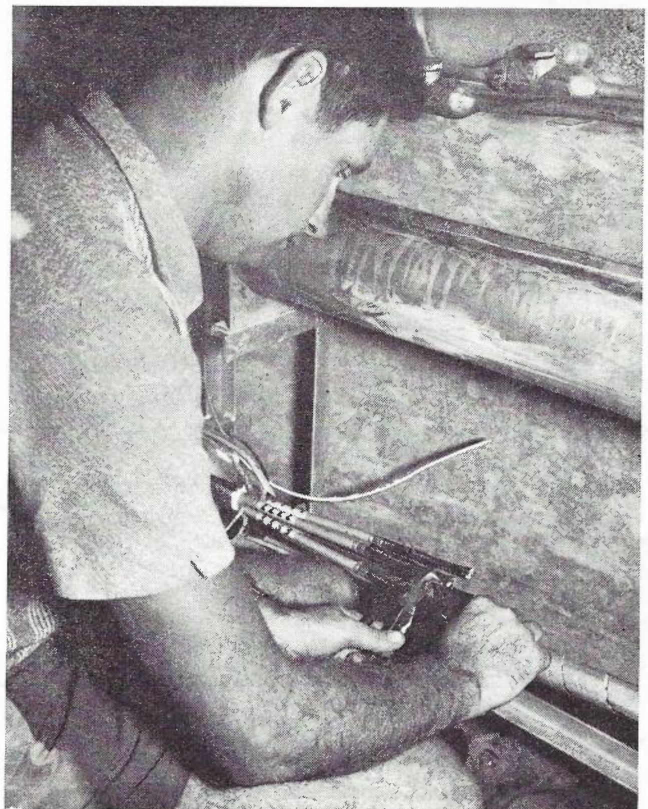


Fig. 18. — Jointer Working in a Minor Repeater Circular Manhole.

After testing and acceptance, the joint positions were filled in, paving slabs being left about 6 in. above the joint canister as a warning for future excavators. A pipe cable marker was also erected at each joint position. Thus only the concrete lids of minor-repeater manholes every 2.8 miles, and the yellow markers in between will indicate the presence of buried cable joints.

The jointing canister used was an improvement on previous designs and has now become standard for this class of work. Instead of a lead slip sleeve a preformed tinned bronze sheet was used to wrap around the end caps. It is held against the internal pressure by self-tapping screws so that the plumbing merely seals the canister.

The testing crews used the Kieler Howaldswerke pulse echo test set (P.E.T.S.) to accept or reject the tubes in each minor repeater section and a Siemens complex level tracer with X - Y locus plotter to test and admittance balance each Z12N minor repeater section on the interstitial pairs. On the core pairs chosen for supervision it was essential to have a cut-off frequency not lower than 3.04 kHz. This was not possible with standard loading and their high 0.95 microfarad/mile, mutual capacity. (Fig. 19.)

Special rearrangements of pair allocations were therefore made, and in future similar cables 88 millihenry loading at 3000 ft. spacing has been specified. Fault location was generally carried out with the P.E.T.S. and verified by means of the S.T.C. high voltage bridge. Wherever possible a ratio calculation was employed since this was found to be more accurate than an absolute measurement based on the cable characteristics. Fault locations to within a few inches were usually made.

The subject of testing both pairs and tubes in coaxial cables is fully treated in engineering instructions, and reference is made to these in the list of further reading.

A problem arose from the thermal behaviour of the circular manholes. This is described in an associated journal article.

Gas Pressure System.

Three men installing the continuous flow gas pressure system were the last project people through the route. They had the invidious task of working with a newly-conceived system capable of operation when totally immersed. It had many shortcomings, and is still under development so will not be further described here. Suffice to say that a basic contactor alarm principle is used, with compressor fed gas injection points at every major repeater station. (Fig. 20).

Costs.

The overall external plant cable installation cost per mile for the project was $8350, excluding administration charges. Of this the cable cost per mile amounted to $5830, and miscellaneous material to $780 per mile. The figure of merit, or installation cost per mile, then becomes $1740. Conduit work amounted to $120790 vote, for 20.5 duct miles, i.e., a cost of $5890 per duct mile.

In Retrospect.

This article would not be complete without mentioning some of the more important lessons learnt.

1. The time spent on trials, analysis, training, planning, scheduling, safety, public relations and just critical thinking, was amply rewarded.
2. The weather is a major factor, and job scheduling must give full consideration to precipitation/evaporation data. In the doubtful months the study must get down to weeks and even days in allotting time slots to various activities.
3. Test boring to evaluate soil conditions is a waste of time and money. An engineer with some

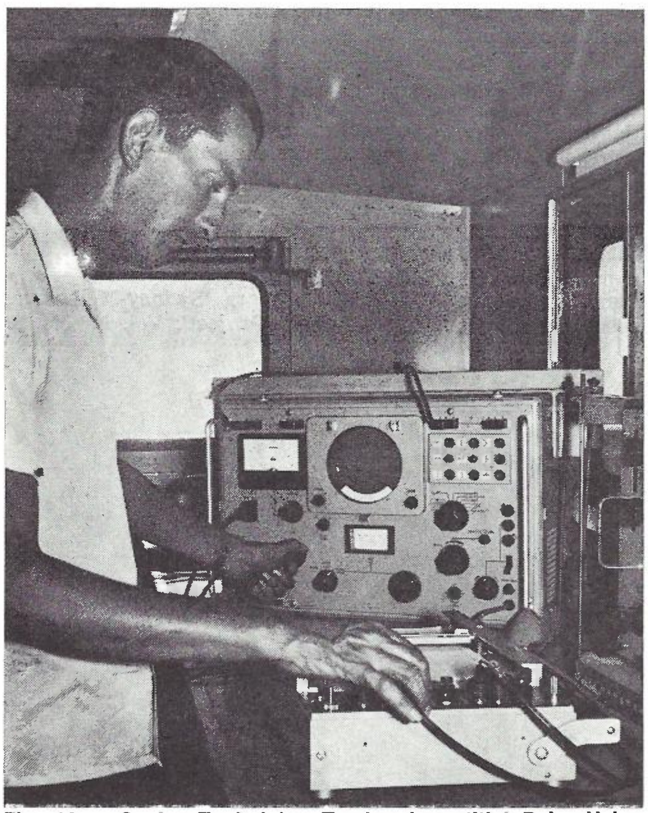


Fig. 19. — Senior Technician Testing Interstitial Pairs Using the X-Y Locus Plotter.

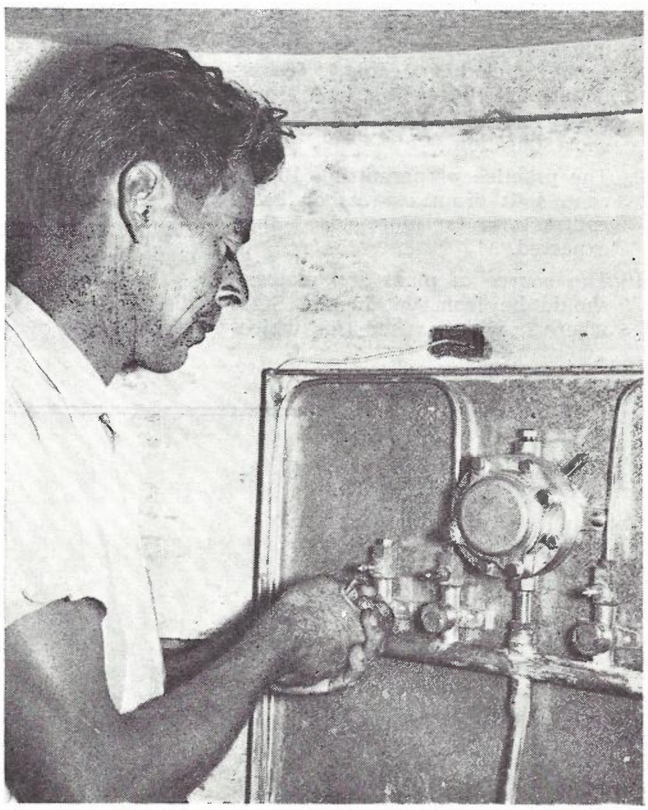


Fig. 20. — The Low Pressure Manifold and Contactor Arrangement on the Joint Frame in a Minor Repeater Manhole.

knowledge of geology, coupled with a lot of experience on ripping, can predict soil conditions from surface indications with 90 per cent. accuracy. In the 10 per cent. area of doubt there is no substitute for ripping the whole track with a D9G tractor.

4. Engineers must have a very close familiarity with the route, but the often stated necessity to walk the route should be forgotten.
5. It is always better and cheaper to rip first and shoot afterwards than the other way round.
6. The preparatory functions of track preparation and gate erection can readily be absorbed into the ripping function without increasing staff numbers.
7. Ripping will take at least twice as long as cable laying, even with two ripping machines. It is therefore essential on a large project to have at least two ripping machines, and to programme the cable laying machine, as an additional ripper, for as long as possible before beginning to lay cable.
8. A substantial stockpile of materials is essential before commencing cable laying. A minimum of 50 per cent. of the year's job requirement should be on hand with the balance coming forward. In our case we at some time or other ran out of every item of Interstate material, including cable. Fortunately the latter occurred only once, and then only for a very short duration.
9. The practice of permitting 10 per cent. split drum lengths on cable contracts is far more costly than expected.
10. The source of plant and material should be from within the State where it will be used (for whichever items this is possible). The advantage of local control of material supply in a project of this size and nature permits overall economies greater than those resulting from a collective schedule.
11. Small size plastic cable is not a proposition for installation in long drum lengths. Stick to 1000-yard lengths, and then regard 6/20 as the minimum acceptable size for this application.
12. In allocating times for any activity work on the basis of 50-minute hours, and besides this allow 10 per cent. down time on all mechanical plant.
13. Do not stint on engineers, supervisors or mechanics. In the long run basic engineering, supervision, plant maintenance and morale will determine the success or failure of a project.
14. Relief vehicles are essential if the mechanics are to ever cope with the maintenance problem.
15. The difficulties involved with matching cable ends and fault location have been very much exaggerated in the past.
16. There is a very substantial penalty involved in experimenting with a project while it is in progress.

CONCLUSION.

It would not be fair to conclude without paying tribute to the rank and file of the project. Staff morale was always excellent, with a healthy competitive spirit between the various groups. This was highlighted when the cable reached Carnarvon, and all camps, set up within yards of each other, celebrated the occasion. The engineers and field supervisors also made a major contribution.

The people in support, principally the Perth workshops and automotive division, and the transport and supply, branches, should also not be forgotten. Without their assistance and the outposted blacksmith situated in the project depot, the targets could not have been achieved.

The senior line inspector on the project, near its completion, confidently asserted to Mr. C. J. Griffiths, then F.A.D.G. Works, that given another chance the high performance figures already achieved could be bettered by at least 15 per cent. He and the division were given the chance on the extension of the cable from Carnarvon to Port Hedland and are keeping that promise.

FURTHER READING.

'Acceptance Testing of Coaxial Cable'; A.P.O. External Plant Information Bulletin No. 40.

'Gas Pressure Systems'; A.P.O. External Plant Information Bulletins Nos. 31 and 35.

'Acceptance Testing—Carrier Cables'; A.P.O. Engineering Instruction, Lines, Cables, T2401.

'Acceptance Testing—Tubes'; A.P.O. Engineering Instruction, Lines, Cables, T2431.

'Coaxial Cables, Systems, Design and Plant Layout'; A.P.O. Engineering Instruction, Lines, Cables, SY3902.

And the following articles from The Telecommunication Journal of Australia:—

F. T. Harding and T. N. Pimm 'Lightning Protection for Buried Cables'; Vol. 16, No. 1, page 56.

F. J. Harding, 'Cross Country Cable Construction—Installation Programming Based on Predictable Climatic Conditions'; Vol. 14, No. 1, page 36.

D. MacQueen, 'Some Aspects of the Design and Use of Cable Ploughs'; Part I, Vol. 13, No. 6, page 459; Part II, Vol. 14, No. 1, page 52.

Various authors, 'Sydney-Melbourne Coaxial Cable Project'; Vol. 13, No. 3.

COMMUNICATION SATELLITES

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INTRODUCTION

In October 1945 an historic article appeared in the British periodical 'Wireless World'. Writing at a time before the development of rockets with orbital power and even before the possibilities of radio transmission outside the atmosphere were completely established, the physicist Arthur C. Clarke declared that the use of radio repeaters in orbiting satellites would be the only satisfactory answer to the problem of world-wide communications. He further suggested that the best method of providing world coverage was by locating three equally spaced satellites in an orbit 22,300 miles above the equator, travelling from west to east, so that they appeared stationary when viewed from the ground. Considering that the international communicators have only concluded that this was practicable in the past decade, after carefully examining the system characteristics of other orbits, this was foresight indeed.

Communication satellites essentially represent the answer to the problem of conveying high capacity, high quality radio transmission around the curvature of the earth and are effectively microwave repeaters in a two-hop line-of-sight system. The satellite corresponds to a tower some thousands of miles high.

Facilities

Apart from the wide coverage, facilities which a satellite system can make available are thus similar to those which can be derived from any microwave system, with a significant modification. Instead of providing the facilities basically in a point-to-point manner, the system can be accessed by any earth station established within radio sight of the satellite, giving substantial flexibility in station interconnection.

The types of communication facilities which a satellite could provide include trunk telephony, subscribers' telephone services (fixed or mobile), TV point-to-point relays for retransmission, TV distribution to multiple points for retransmission, TV transmission direct into domestic receivers, aircraft and marine navigation signals, data, facsimile etc. Direct transmission of TV into domestic receivers appears unlikely to be achieved for another decade although a form of direct TV broadcasting into special 'community' receivers for collective viewing is likely to be tested in India by 1972.

The realisation of subscribers' telephone services by this medium presents strong attractions to the Australian Post Office by virtue of its potentiality for giving service, both fixed and mobile, to the many remote locations in the continent, which it is not practicable at present to serve other than by high frequency radio. Individual subscribers' service by satellite presents substantial problems however in both costs and network integration compared with high calling-rate trunk circuits. Very limited attention has been paid to this problem internationally and the Post Office regards it as an appropriate area on which to concentrate its satellite research. A series of experiments are currently directed to this question using NASA's Pacific satellite ATS-1 and the Cooby Creek earth station in conjunction with a prototype small earth station suitable for a single subscriber's circuit developed in the Post Office Research Laboratories.

THE SPACE SEGMENT

Launching and Positioning in Geostationary Satellite Orbit.

As indicated earlier, a satellite travelling from west to east in the plane of the equator and 22,300 miles above the surface of the earth will have an orbital period of 24 hours and since it is moving with the earth's rotation will appear to be stationary when viewed from the earth. This is known as a geostationary satellite.

The advantages of this orbit are primarily associated with the simplification of earth station equipment. Other orbits require expensive tracking, and steering arrangements and for continuity of service (particularly in the case of telephony) call for more than one satellite and at least two antennas at each earth station to change rapidly from contact with a disappearing satellite to one coming into view. Geostationary satellites also minimise problems arising from the Doppler effect.

On the other hand geostationary systems result in significantly greater transmission delays than will result from lower altitude satellites. This aspect is discussed at the end of the paper. Despite this factor and the necessity for more accurate placement and maintenance of a geostationary satellite in orbit, it has now been generally accepted that the balance of advantages lies with this type of system for commercial communications except in special cases. This exception essentially relates to the difficulty of covering widespread areas at high latitudes from the equatorial plane.

Launching is normally achieved by first placing the satellite into 'transfer' orbit. This is an elliptical orbit and the highest point, or apogee, is approximately 22,300 miles from earth. It is also in the plane of the equator and, since the launching vehicle has to be turned into this plane, launching sites near the equator yield payload advantages. During separation of the final rocket from the satellite in transfer orbit a spin of some 100 r.p.m. is imparted to the satellite around an axis in the direction of travel to maintain stability.

After a suitable number of passes in transfer orbit, the orbit is changed to a circular geostationary one by applying thrust at the apogee. This is currently achieved by firing an 'apogee motor' which is integral to the body of the satellite. The fuel consumed in this manoeuvre is approximately half of the total satellite weight in transfer orbit and hence the final payload is only half the payload which the launch vehicle can put into transfer orbit. Once in the geostationary orbit the satellite is turned so that the spin axis is across the equatorial plane (i.e. parallel to the earth's axis) and then 'drifted' into its required position. This latter operation may take several weeks. A typical launch sequence is shown in Fig. 1.

There are other methods of stabilising a satellite such as the gravity gradient principle but all the commercial communication satellites launched to date employ the spin stabilisation method described.

Placement and maintenance of the satellite in position is achieved by gas (normally hydrazine) jets in the top and sides of the satellite. The spin axis passes through the top of the satellite and, since this axis is across the equatorial plane, latitudinal errors can be corrected by gas bursts from the top jet. This jet is normally offset from the axis so that wobbles can be corrected by pulses

* Mr. Kellock is Engineer Class 4, Planning Branch, Headquarters. See Vol. 18, No. 3 p. 286.

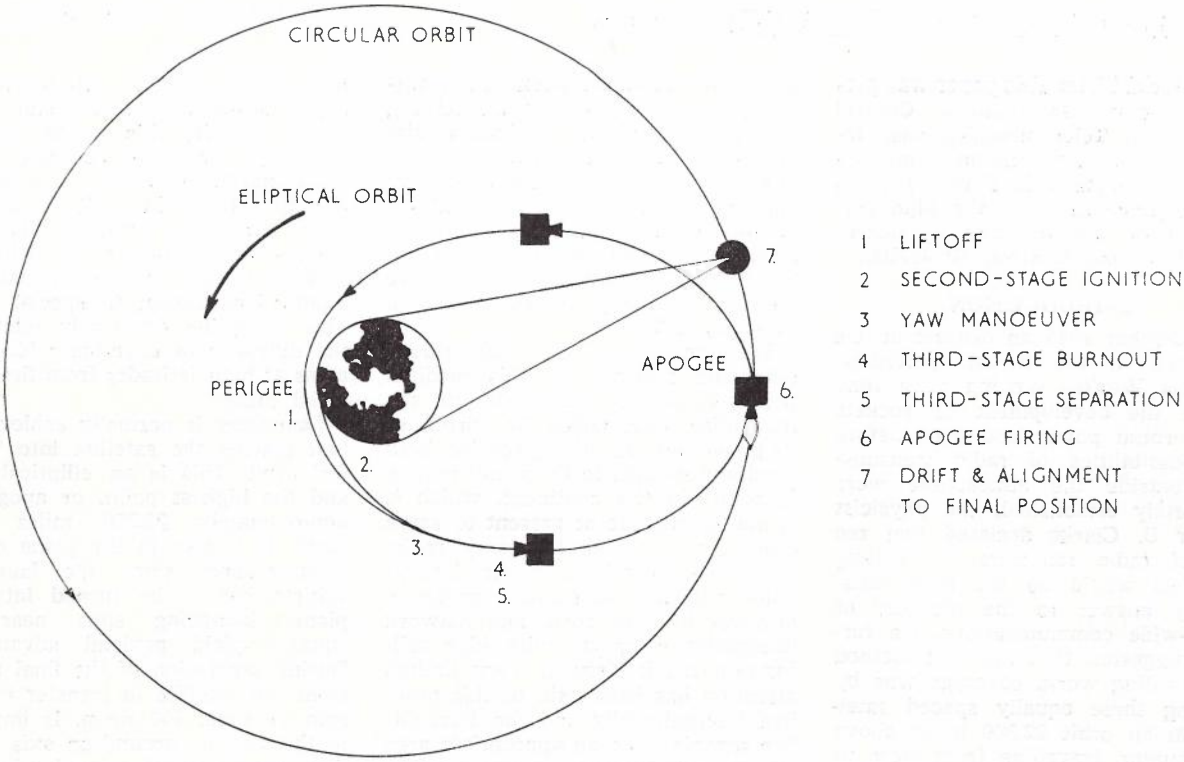


Fig. 1 — Typical Launch Sequence.

of gas in synchronism with the spin, while the latitudinal correction is made by a steady burst. The side jet corrects for longitudinal errors by pulses in synchronism with the body spin.

The satellite orbit is subject to continuous perturbation due to

(a) 'tri-axiality' or lack of symmetry in the earth's gravitational field which induces longitudinal movement; and

(b) the influence of the sun and moon which tend to drag the satellite into an inclined orbit with respect to the equator.

Viewed from the earth, a small inclination angle appears as a thin figure 8 with top and bottom on opposite sides of the equatorial plane. As the inclination angle increases apparent height of the '8' increases and remedial action is fundamentally one of latitude correction.

Successive generations of satellites have been controlled with progressively tighter limits. Proposals for

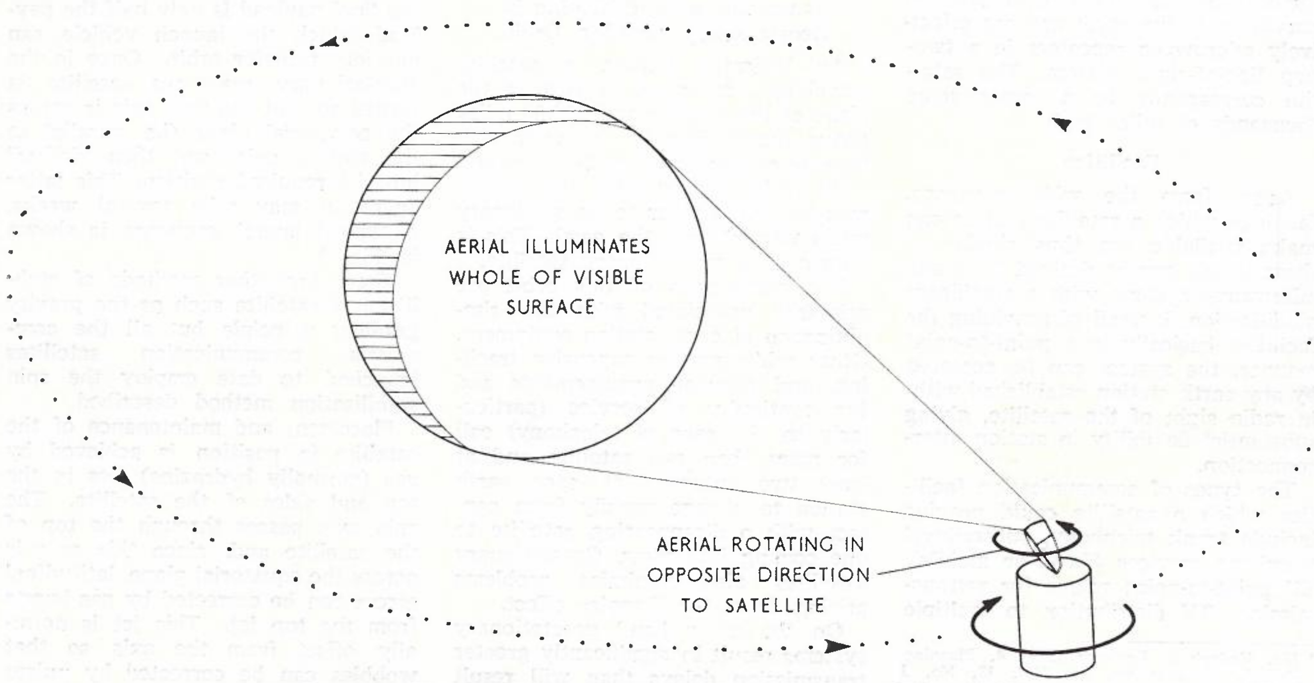


Fig. 2 — Mechanical Despun Antenna for Directional Transmission.

several future systems envisage maintenance of position within plus or minus 0.1° in both longitude and latitude, although some are more relaxed with respect to latitude since this control in this direction requires more gas to maintain the same tolerance.

The effective life of the satellite is determined by the amount of gas for position control since this is the critical life-determining parameter in the payload tradeoff. The optimum economic point in tradeoff analysis of recent satellites has called up a design life of 5 years but analyses of some of the larger satellites to come has resulted in specifications of 7 years.

The early commercial communication satellites such as Intelsat I (Early Bird) and II radiated over 360° in the equatorial plane from linear arrays along the spin axis. In order to increase the Effective Isotropic Radiated Power (E.I.R.P.) however, later generations commencing with Intelsat III have employed more directional antennas with approximately earth coverage (about 17° beam). Intelsat IV and proposed domestic systems will have even smaller beams of the order of 5°. To maintain orientation of the directional antenna beam with a spin stabilised satellite it is necessary to de-spin the antenna by either electrical or mechanical means. The Intelsat systems have been designed for mechanical de-spinning, that is the antenna platform is spun in the reverse direction to and at the same rate as the body of the satellite (Fig. 2).

Electronic Aspects

The galactic noise arriving from outer space increases rapidly below approximately 1GHz while atmospheric noise and atmospheric attenuation rises markedly above 10GHz as indicated in Fig. 3. Satellites radiating to the earth must co-exist with existing terrestrial services and the desirable 'window' between 1 and 10GHz is already extensively assigned.

Commercial communications satellites have so far shared the 4 and 6GHz band used by terrestrial microwave links for commercial communications. The band 5.925-6.425GHz is used for the uplink and 3.7-4.2GHz for the downlink from the satellite. Although increased E.I.R.P. from the satellite would ease the receiving requirements and hence the cost of earth stations, criteria for frequency sharing with other services impose a limit to the power flux density arriving at the earth's surface. International agreements prescribe that this shall not exceed -152 dBW/sq. metre per 4kHz/band although this may be increased, depending on the angle of arrival by up to 6 dBW/sq. metre/4kHz for vertically incident radiation. In addition earth stations must be kept away from terrestrial microwave systems operating in the same bands. The potential interference paths are indicated in Fig. 4.

These limitations and the restriction of 500MHz available bandwidth provide a strong incentive to develop into bands where co-ordination is a less serious problem or where greater bandwidth may be available. There has been some interest in the bands between 11 and 13GHz as well as 16-18GHz and 28-31GHz. The allocation of frequencies for space radio services will be considered again at a World Administrative Radio Conference in 1971. In any event equipment development must occur and problems arising from variable rain attenuation must be met before the higher frequencies can be exploited.

Various modulation techniques have been used in non-commercial satellites but commercial systems have so far been limited to frequency division multiplex and frequency modulation (normally designated as FDM/FM/FDMA where the latter refers to the method of multiple access). The transponders basically comprise frequency translating amplifiers receiving at 6GHz and transmitting at 4GHz. The two transponders in Intelsat I had bandwidths of 25MHz each and incorporated hard-limited output stages.

It was only practicable to link at any time two earth stations, each transmitting its own carrier. The European stations operated in turn on a scheduled basis to the U.S. station.

Intelsat II transponders operated with 126MHz bandwidth and the Intelsat III series have two transponders with 230MHz each.

These satellites are not hard-limited and hence multiple access between a large number of earth stations has become practicable. However, the travelling wave tube output stage is operated in a limiting mode for maximum efficiency and the nonlinearity of the transponders necessitates accurate control of the power-level of all carriers arriving at the satellite from each earth station transmitter. In practice the limits are of the order of plus or minus 0.5dB variation from all sources. Considerable backoff in output power is required with multi-carrier working and this can severely reduce circuit capacity.

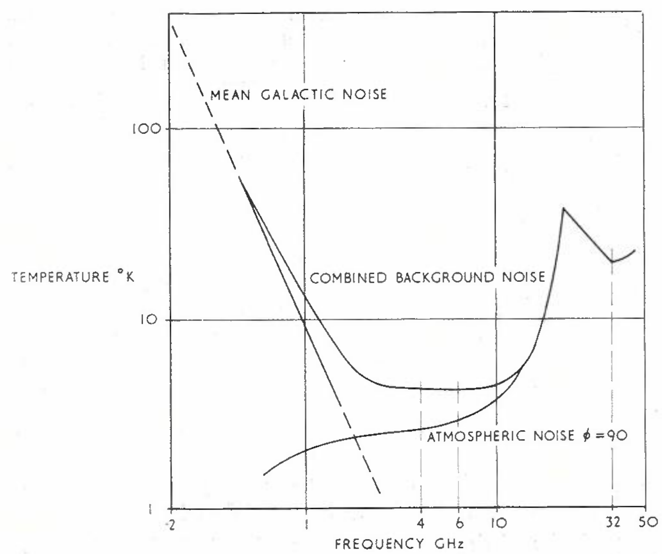


Fig. 3 — Relationship of Sky Noise to Frequency (Vertical Incidence).

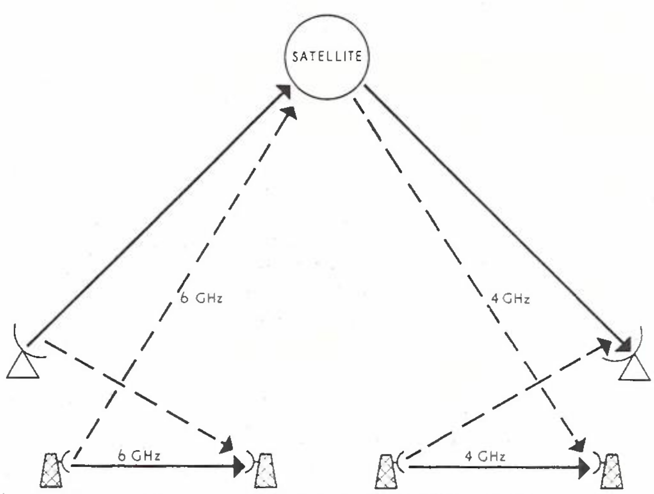


Fig. 4 — Potential Interference Paths.

It is proposed with Intelsat IV and a number of domestic satellite projects to divide the 500MHz band between a number of transponders each handling about 40MHz bandwidth. Although this is primarily motivated by the allocation of a convenient band to each of the 8W travelling wave tubes, it also has the advantage of easing the problem of carrier interaction and improving redundancy aspects.

The provision of multiple access by frequency division involves some lack of flexibility particularly when additional accesses are required after carrier allocations have been made. Time division multiple access has advantages from this point of view as well as from its capability to maintain transponder capacity when required for access by many earth stations. A number of future satellite systems including Intelsat IV are therefore being designed for time division multiplex using pulse code modulation with multiple access being given by time division. The International Telecommunications Satellite Consortium (INTELSAT) is considering bit rates of over 600Mb/s for Intelsat IV global-coverage, and over 140Mb/s for spot-beam (4.5°) communications. Intelsat IV is also intended to employ pulse code modulation on a single-channel per carrier, frequency division multiple access basis (PCM/PSK/FDMA). This is the form taken by the Communications Satellite Corporation (COMSAT, which manages INTELSAT) system of demand assignment known as SPADE. This will be discussed later.

There are numerous other possible modulation and access combinations among which spread spectrum (or RADA) technique is of particular interest for military communications because of its added secrecy facilities, but it makes inefficient use of frequency spectrum for civil applications.

Power Supplies

The primary sources of power in the communications satellites flown to date are solar-cell arrays. The capacity of these has been steadily increasing and Intelsat IV will employ an array generating about 500 W. Recent announcements have indicated that 'roller blind' type arrays can generate some 1500 W.

Nuclear power sources will undoubtedly increase the amount of primary power available in a satellite but considerable development will be necessary before this can be realised for communications satellites.

The earlier Intelsat series were power limited but as a result of the increases in available power, Intelsat IV will be effectively limited by the 500MHz of bandwidth available in the 4 and 6GHz bands rather than by power.

A geostationary satellite suffers periods of eclipse of the sun by the earth for periods of up to 20 minutes a day during the equinoxes. During the era of use of solar cells, on-board batteries are required to cover the lack of solar-generated power for services which must be maintained during these periods. Batteries represent a significant payload penalty and for a national satellite system, measures can be considered to minimise the cover required from them. The eclipse occurs around local midnight at the longitudinal position of the satellite but the apparent time would be later for a country farther east. Hence a country operating a national service for television purposes may be able to avoid battery cover for television channels by locating its satellite slightly to the west.

The INTELSAT System

Arthur C. Clarke's vision has now been realised by the International Telecommunications Consortium (INTELSAT). This is a joint venture by 68 nations for international satellite communications. Operations commenced in 1965 through Intelsat I over the Atlantic. This satellite had an orbital weight of 76 lbs., E.I.R.P. of 15dBW, a design life of 1.5 years and a circuit capacity of about 240 telephone circuits. It was however only designed for single access between two earth stations.

A series of Intelsat II's were launched in 1966 and 1967 to positions over the Atlantic and Pacific Oceans. These had 165 lbs. orbital weight, 17.5dBW E.I.R.P., a design life of 3 years and a capacity of over 240 circuits using multiple access.

There is now one Intelsat III satellite over each of the Atlantic, Pacific and Indian Oceans and another is to be placed over the Atlantic. This series has 322 lbs. orbital weight, 24dBW E.I.R.P., a design life of 5 years, and a capacity of about 1200 telephone circuits (or 4TV channels) using multiple access.

The first of the Intelsat IV series is expected to be launched by early 1971. It will have an orbital weight in excess of 1250 lbs., 23dBW E.I.R.P. from its global coverage antenna, and 34.7dBW from its 4.5° antennas. Circuit capacity will be of the order of 5000, multiple access, and the design life will be 7 years.

The Overseas Telecommunications Commission earth stations at Moree (N.S.W.) and Carnarvon (W.A.) are operating to the Pacific satellite and the earth station at Ceduna to the Indian Ocean satellite.

ATS Series

The U.S. National Aeronautics and Space Administration has been launching, since 1966, a series of Applications Technology Satellites (A.T.S.) in which developmental elements of communications satellites have been tested. These programmes include new methods of satellite stabilisation, experiments in modulation and multiplex techniques, operation of frequency bands other than 4 and 6GHz and developments in antenna arrays. Most have been located in geostationary orbit and they have tended to indicate characteristics of future generations of commercial communications satellites.

EARTH STATIONS

Since the E.I.R.P. of a satellite is limited, and the free space attenuation is of the order of 196dB at 4GHz between a geostationary satellite and earth, the most critical factor of an earth station is its receiving characteristic. Earth stations are designated by a figure of merit known as the G/T ratio, where G is the gain of the antenna and T is the equivalent noise temperature of the receive system. (The essential elements of an earth station are shown in simplified schematic form in Fig. 5.)

Most earth stations in the INTELSAT system are designed to meet a standard G/T ratio of 40.7dB at 5° elevation. This standard ratio requires antenna diameters of at least 85ft. For this size of antenna, the receiving system noise temperatures must be less than about 50°K, achieved principally by use of a cryogenic pre-amplifier close to the antenna feed. The pre-amplifiers are usually helium-cooled paramps with a noise temperature of about 20°K.

The need to operate receivers close to the noise threshold under power limited conditions has dictated the use of threshold extension techniques in detection, such as dynamic tracking filters, phase lock loops and frequency feedback demodulators. Effectively these reduce the bandwidth and hence the noise by using a narrow-band filter whose frequency follows the modulated carrier.

The international stations typically include a tracking system operating from the satellite beacon and an an-

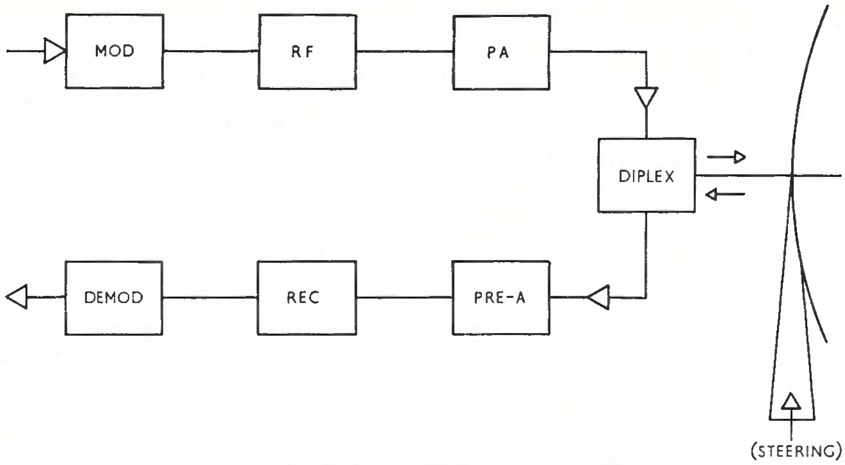


Fig. 5 — Earth Station — Skeleton Block Diagram.

tenna with steering mechanism linked by servo to the tracking receiver.

The cryogenics, tracking and steering systems are a significant section of the costs of these large earth stations.

It is possible to use smaller, cheaper earth stations with lower G/T ratios but this means some reduction in circuit capacity of the satellite. In the case of power-limited satellites of the Intelsat I and II series, a trade-off of satellite power for antenna gain has the result that an earth station with G/T of the order of 32dB (e.g. 42 ft. antenna, pre-amplifier with a noise temperature of 100°) requires 6.5 times more satellite utilisation than a 40.7dB station to establish a circuit of comparable quality. A station with a G/T ratio of 26dB (e.g. 30ft. antenna and uncooled paramp with 200°K noise temperature) would require 27.6 times the utilisation required by an 85ft. antenna. This is the reason for the standardisation of the large antenna for international operation.

With the advent of bandwidth limited satellites, however, the penalties associated with lower G/T ratios are smaller and this could result in smaller antennas becoming economic. Under these conditions an optimum, economic system would allow for smaller antennas at locations where total circuit requirements are likely to be low.

The close position control of the classes of satellites proposed for future domestic operation, in conjunction with a wider beam subtended by smaller stations, will obviate the need for tracking and steering systems. As a result the cost of earth stations in domestic satellite operation is likely to be substantially less than the $4-5m required to establish a major international station This would have added significance in domestic operation since an administration would normally provide a large number of earth stations to justify a national satellite and the space segment costs would be heavily outweighed by those of the ground segment. There may be a limit to the reduction in size of antennas, however, since the side-lobes limit the number of satellites, radiating in the direction of the earth station in the same frequency band, which can be located in the geostationary orbit.

Multiple Access and Demand Assignment

The fact that only two earth stations were connected at any one time through Intelsat I has been mentioned. Commencing with Intelsat II a number of stations were interconnected by access to the same transponder.

The normal method of implementing this in Intelsat III is for each station to transmit a carrier with a number of specific channels intended for various destinations at the far-end. The designated receiving stations demodulate the carrier and extract those channels from the multiplex which are exclusively assigned to them. A station receiving these channels is also transmitting its own multi-destination carrier and by association of the appropriate assigned channels in the reverse direction, a group of circuits are assembled between two stations. These circuits are pre-assigned to the two stations and if they are not being used, the satellite capacity which they occupy cannot be employed to accommodate overflow traffic from temporarily busy circuits between other stations.

It would be more flexible and economic of satellite capacity to place the satellite circuits into a pool so that they can be assigned between earth stations on demand. Various forms of demand assignment have been proposed although none are operating regularly as yet. INTELSAT has successfully laboratory tested its SPADE system and proposes to introduce it in the operation of the Intelsat IV series. SPADE is a single channel per carrier system of frequency division multiple access providing demand assignment without central control. PCM is used for channel encoding and four-phase coherent PSK is used for modulating each carrier. Each earth station uses a Demand Assignment Signalling and Switching Unit (DASS) for self-assignment of channels based on continuously-updated, channel-allocation-status data provided on a TDMA common signalling channel with a bit rate of 128 kilobits per second. Access to 800 circuits per transponder can be provided to 50 stations.

Since demand assignment equipment has its own cost, it is not economic to apply it to the basic circuits on a heavy traffic link. These will remain pre-assigned. Demand assignment however can be profitably employed for handling both light traffic links and overflow from heavy traffic links. Calculations by COMSAT have suggested that the system will cut down the channel requirements by a factor of 2 and 3 to 1 in some of the light traffic links considered.

SATELLITE SYSTEMS FOR DOMESTIC COMMUNICATIONS

Overseas Proposals

Canada, the United States and Japan have proposals to establish satellite systems for domestic communications and there are two regional proposals within Europe.

One country, the Soviet Union, has a domestic satellite system operating. This system, known as 'Orbit', does not use the geostationary satellite orbit because of the difficulty of covering the wide expanse of Russian territory in the high latitudes. It consists of a number (constantly being added to, but currently about 10) of satellites known as 'Molnya-I' in eliptical orbits inclined at 65° to the equator with periods of about 12 hours. The apogees above Russia are approximately 24,500 miles and the perigees of the order of 300 miles on the other side of the earth so that each satellite is in view of Russia for some 8 to 10 hours. The system is used to distribute television programmes from a central earth station to 24 regional earth stations with 40 ft. antennas which must follow the path of the satellite and, as it moves lower, switch to a succeeding satellite.

The frequency band 800 to 1000MHz is employed.

The next national system to be established is likely to be Canada's. Contracts have been let for a system which is intended for operation in 1971. Initially one satellite with six transponders operating in the 4 and 6GHz bands will be placed in geostationary satellite orbit. At the outset, two transponders will be used for television relays, one for point-to-point trunk telephony from east to west and one for trunk circuit distribution to the remote north. A second satellite will be established later. As well as a main, steerable, control station, there will be three main operating stations with non-steerable 60 ft. antennas for telephony and television, two special stations with 30ft. antennas designed for telephone and television in the extreme northern climate and some twenty stations with antenna diameters from 23 to 30 ft. for TV reception only.

Japan has announced plans for a domestic satellite system to be established in 1973, primarily for the purpose of TV relays.

The U.S. Federal Communications Commission (F.C.C.) has received a number of proposals for a U.S. domestic system, some of which are for television only. The American Telephone and Telegraph Co. proposed an ambitious project for telephony and television. Initially only two satellites would operate in the 4 and 6GHz bands each with a capacity of 9,600 voice circuits or 12 TV channels. Beginning in 1972, it was proposed to launch a new generation of large satellites, each including a large number of transponders receiving pulse code modulated telephony signals of 30GHz and transmitting them at 18GHz. Narrow beam antennas on the satellite would illuminate areas 50 to 150 miles across at the earth's surface for telephony signals. Four satellites launched between 1972 and 1976 would afford capacity to meet the estimated 1980 requirement of 83,000 telephone circuits, 27 full-time TV channels and 61 occasional TV channels. Over 100 earth stations were proposed.

Subsequently however, COMSAT submitted a more limited proposal for a 'pilot programme' to obtain experience in establishing and operating a domestic satellite system with only limited commitment. This includes two satellites with 12 transponders each, operating in the 4 and 6GHz bands, to provide 4,400 telephone circuits and 8 TV channels. It could be established within 2 years of approval and COMSAT would place ownership in trust pending a later decision by the F.C.C. on the appropriate operating entity.

The F.C.C. has not yet announced its decisions on the various proposals but the Chairman recently indicated that it would decide shortly on the makeup and management of the system.

The two European projects are the Franco-German "Symphonie" to provide two TV channels in a satellite by 1972, and the European Conference for Telecommunications by Satellite (C.E.T.S.) proposal. The latter would provide two TV networks for the European Broadcasting Union by 1975.

India has been actively developing proposals for the distribution of TV programmes direct to high quality 'village' or 'community' receivers by satellite. It will carry out pilot studies using the ATS-F satellite in 1972 with a view to establishment of a full national system. Brazil is developing a similar programme and UNESCO is co-operating in similar studies in Pakistan and Argentina.

Australian Studies

Despite some early publicity about the cheapness of satellite communications the studies of most administrations have shown that even over long distances, satellite circuit costs are at best only marginally competitive with terrestrial systems such as microwave radio at this stage.

The early studies of the Australian Post Office showed that on the cost structure and technology, then existing, a satellite system would not be as economic for the provision of selected facilities as terrestrial systems would be. However, development in technology and costs now appear to indicate that there may be advantages in establishing a system in the late 1970's.

The establishment of a national system may afford the possibility of services which cannot be practically provided by any terrestrial system. The example has been mentioned of the problem of provision of telecommunication services with network connection in remote areas and, in particular, single channel telephony to individual subscribers or small settlements.

As mentioned in the introduction, the Post Office Research Laboratories are now experimenting with a small earth station for this purpose through ATS-1 over the Pacific to NASA's earth station at Cooby Creek, Queensland. The purpose of this series of experiments is to evaluate a preliminary system study and to obtain engineering data concerning aspects which, as far as is known, have not been considered overseas. However besides coping with several technical problems, it remains to be seen whether sufficiently-cheap earth stations can be developed for this purpose. Among other special requirements will be the equivalent of demand assignment for the relatively low calling rate of subscribers' lines (compared to trunk circuits). Network integration, a problem with satellite circuits (see below), is especially difficult in the case of subscribers. Problems of signalling, charging, switching and points of entry into the terrestrial network are being worked through.

Discussions have been proceeding with other Commonwealth authorities to determine whether other facilities which can be incorporated in communications satellites, such as air and marine navigation systems and meteorological cameras, should be included in an initial satellite.

Time Delay

It would not be appropriate to conclude a discussion of communications satellites without referring to a particular difficulty of geostationary satellites. A transmission delay of 240-280 milliseconds (depending on the relative locations of satellite and earth stations) is characteristic of the height of this orbit. When it is added to the delay in the tails between earth station and the network and the total is doubled, the round trip delay is commonly of the order of 600ms. All telephone circuits require high quality echo-suppressors for this order of delay. Since echo-suppressors employ switching devices which either disconnect or heavily attenuate the return channel, a new type of echo canceller is being developed in the Post Office Research Laboratories and in several overseas countries to overcome the disadvantages of the echo-suppressor principle. It is based on the concept of generating a signal of the same waveform as the echo but of opposite polarity so that when added they cancel each other. Although the development of the principle of adaptive echo cancellation is promising, cost reduction to levels appropriate for domestic communications remains a difficult problem.

Delays significantly in excess of the order quoted above are likely to give rise to difficulties in conversation and it has been internationally agreed that it is undesirable to include more than one geostationary satellite link in a complete circuit connection. Signalling systems for automatic switching must carry forward information that a link has been set up over a satellite so that the switching machine may avoid satellite circuits on later links.

For greatest flexibility, this requires some balance to be maintained between the number of circuits by satellite and by terrestrial systems on any particular link, but it obviously presents some problems with circuits to remote centres.

The long round trip delay also excludes the use of many existing signalling systems. In some instances special signalling treatment is required for the satellite link, with a conversion interface to the national system at each end.

The effect of time delays of this order on telephone conversations has been the subject of some controversy. It has now been demonstrated that the effect on international calls has, at most, been marginal. There has been some speculation that delays due to satellites may not be so acceptable, over internal links, to users who are accustomed to alternative, high quality, terrestrial circuits where the psychological conditioning of an 'international call' is not present. Until recently the only domestic circuits operated over a geostationary satellite were between Hawaii and mainland U.S.A. The 24 circuits between Sydney and Perth which the Post Office has been operating since November 1969 using Overseas Telecommunications Commission's earth stations at Moree (N.S.W.) and Carnarvon (W.A.), and capacity in Intelsat III over the Pacific, represent the first case of regular commercial operation within a country's continental borders. (See Fig. 6.)

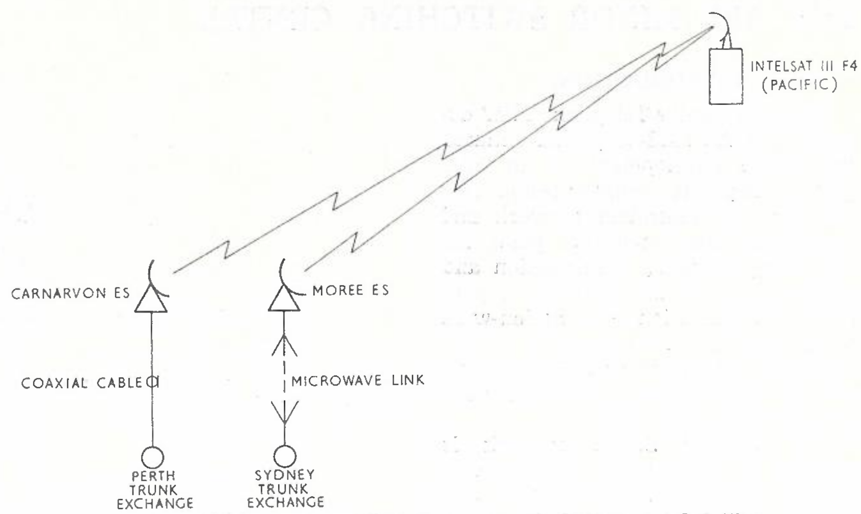


Fig. 6 — Method of Providing Sydney-Perth Circuits by Satellite.

This operation is not only providing valuable experience to the Post Office in the development of its proposals for a national system, but the results of a detailed survey of customer reaction may be of considerable interest overseas.

ACKNOWLEDGMENT

Acknowledgment is made of the assistance provided by colleagues at Headquarters, notably Mr. E. R. Craig of the Post Office Research Laboratories, during the preparation of the Paper.

FURTHER READING

1.—F. P. O'Grady, 'Artificial Satellites for Telecommunications, Internal and External'; Paper presented at I.R.E.E. (Aust.) Radio and Electronics Engineering Convention, Canberra, 22nd-26th March, 1965.

2.—F. A. O'Nians and J. L. Blonstein, 'Some Aspects of the Economics of Satellite Communications'; (I.T.U.) Telecommunications Journal, Vol 35 — xii/1968.

3.—R. E. Knightley, 'Developmental Trends in Communications Satellite Earth Stations'; Proc. I.R.E.E. (Aust.) July 1969.

4.—F. P. O'Grady and E. R. Craig, 'Radio Communication by Artificial Satellites'. Telecom. Journal of Aust., June 1961, Vol. 13, No. 1.

CHANGE IN BOARD OF EDITORS

Mr. E. R. Banks has resigned from the Board of Editors after ten years service. The Council of Control of the Society has approved the appointment of Mr. R. M. Lennon to fill the vacancy.

Mr. Banks joined the Board in February, 1960, to represent the internal equipment area. In these vital early years of the change to common control equipment, he contributed significantly to the planning and publication efforts required to bring crossbar to Journal readers. Subsequently he ably represented Planning Branch interests in the Journal, and continued to make a valuable contribution to the general planning and presentation of the Journal.

The appointment of Mr. R. Lennon to represent Planning Branch on the Board in this new decade is particularly appropriate. As Engineer Class 4 in the Switching Facilities Section, he will bring to the Board a close association with the momentous change to electronic switching which will dominate the equipment scene during the 1970's. Mr. Lennon graduated from the University of N.S.W. with Honours in Engineering, and after extensive experience in equipment planning in N.S.W., joined the Headquarters Planning Branch in July, 1967.

THE ARF MINOR SWITCHING CENTRE

*D. F. BERGMAN, B.E.**

INTRODUCTION.

The 'Community Telephone Plan' developed in the 1958-60 period outlined the future development of an integrated telephone communication system for the Australian network and established basic national plans for switching, charging, transmission and numbering. It also outlined a plan for the introduction of a nation-wide S.T.D. system. The objective of this system is to have at least 66 per cent. of the total trunk calls subscriber dialled by the year 1975.

The national S.T.D. network is planned to consist of 48 four wire ARM20 exchanges and about 300 minor switching centres. The minor switching centre will be capable of providing complete minor switching and national charging facilities, and will play an important role in achieving the target of 66 per cent. of all trunk calls to be subscriber dialled by 1975. To illustrate the importance of this role, in 1966/67 71 per cent. of the trunk calls originating in Australia came from provincial areas. In the future, the bulk of this traffic will be handled by minor switching centres.

The first bulk deliveries of the new ARF minor switching equipment will be made in 1969/70, and this represents a major breakthrough in the expansion of the automatic trunk system. The new ARF minor switching equipment will allow the future development of switching plans, so that a larger proportion of trunk traffic will be switched clear of the ARM trunk exchanges. This will result in reduced capital expenditure on trunk switching equipment.

* Mr. Bergman is Engineer Class 4, Telephone Exchange Equipment, Headquarters.

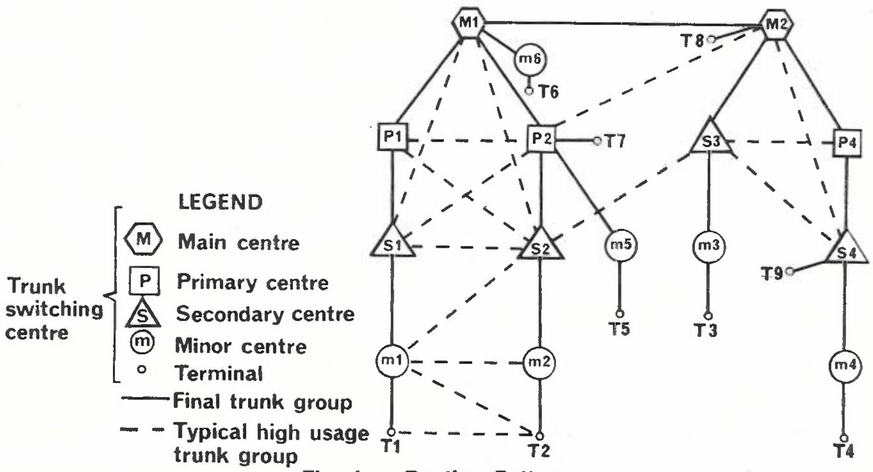


Fig. 1. — Routing Pattern.

THE SWITCHING PLAN.

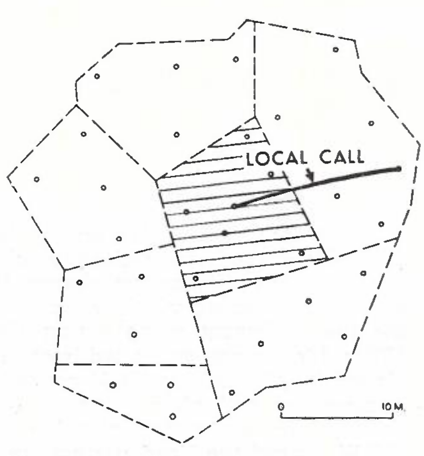
The switching plan for the Australian network was laid down by the 'Community Telephone Plan' for Australia and the routing pattern chosen for the A.P.O. network is shown in Fig. 1. The foundation of the plan is a network of final routes which interconnect all exchanges. These are shown as full lines and are routes for which no later choice alternate routes are provided. The switching centres were classified and the classifications chosen are shown at the side of the figure. Classification of an exchange is independent of whether the exchange is in the country or metropolitan area. It will be seen from the figure that five classes of switching centre were provided, but only the three lowest order centres are of immediate interest.

These centres are:

Terminal Exchange: An exchange that performs no through-switching of inter-exchange circuits.

Minor Switching Centre: An exchange that switches final routes for terminal exchanges only.

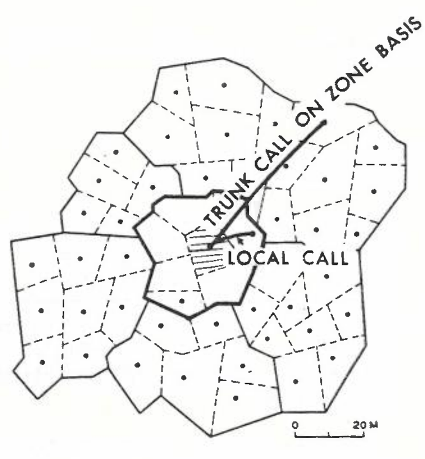
Secondary Switching Centre: An exchange that switches the final routes



LOCAL CHARGING

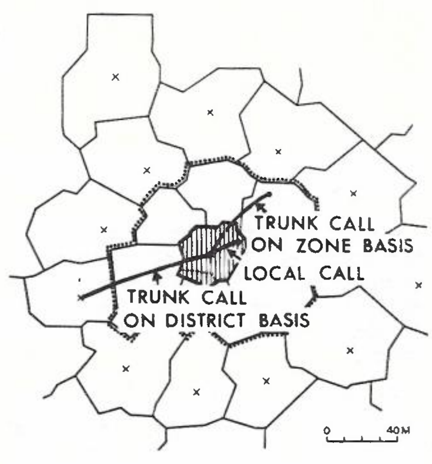
EXCHANGES ARE GROUPED TO FORM ZONES.
CALLS WITHIN A ZONE AND TO ADJACENT ZONES WILL BE TREATED AS LOCAL CALLS.

THE DIAGRAM SHOWS THE LOCAL CALL RANGE FOR SUBSCRIBERS IN THE SHADED ZONE.



TRUNK CHARGING ON ZONE BASIS.

ZONES ARE GROUPED TO FORM DISTRICTS.
CALLS (OTHER THAN LOCAL CALLS) WITHIN A DISTRICT OR TO ADJACENT DISTRICTS WILL BE CHARGED AT TRUNK RATES BASED ON THE MILEAGE BETWEEN ZONE CENTRES.



TRUNK CHARGING ON DISTRICT BASIS

CALLS BETWEEN DISTRICTS WHICH ARE NOT ADJACENT WILL BE CHARGED AT TRUNK RATES BASED ON THE MILEAGE BETWEEN DISTRICT CENTRES.

Fig. 2.

for minor switching centres, and, if required, to terminal exchanges also.

The basic network on which numbering plan areas are developed is the secondary switching network and a typical example is shown in Fig. 2.

In general, the numbering area or switching centre consists of a number of zones, which are grouped together to form a charging district. Calls within a zone or to adjacent zones are charged as local calls. Calls within a district or to adjacent districts are charged at trunk rates based on the distance between zone centres. Calls between districts which are not adjacent are charged on the distance between district centres.

Following the development of the switching plan consideration was given to the type of switching equipment that was needed to meet the requirements of these centres. It was decided that the secondary switching centre would be provided with four wire ARM201 equipment. ARM 503 equipment was examined for use at the minor switching centre and was rejected. It was then decided to use standard two wire ARF102 equipment for the minor switching centre.

The functions to be performed by the minor switching centre are essentially identical to those of the well-known metropolitan tandem exchanges. The minor switching centre switches circuits to and from the secondary switching centre and to and from the terminal exchanges. However, the other role which must be performed is that of determining the trunk fee for the 71 per cent. of trunk calls originating in provincial areas.

Trunking.

The basic trunking diagram for the minor switching centre is shown in Fig. 3. It will be seen that the following types of circuits must be provided for at the minor switching centre:

(a) incoming circuits from higher order centres, e.g., secondary centres, and direct routes from other minor exchanges, etc. Generally these circuits will not require register access. However when they are incoming from foreign secondary centres an entry point register (Y1/LP) will be required on these routes.
(b) Incoming circuits from dependent ARF exchanges. These will not require register access.
(c) Incoming circuits from dependent RAX's and ARK exchanges. These will require access to a register ELP.
(d) Outgoing circuits to terminal exchanges, ARF, Step-by-Step, ARK and RAX. These may be to either unit fee or trunk rate destinations.
(e) Outgoing circuits to trunk destinations for which a single trunk rate applies from the whole minor switching area, or, in other words, fixed fee multimetering circuits, i.e., calls to non-adjacent secondary areas.
(f) Outgoing circuits to trunk destinations for which several different rates would apply from various zones in the minor switching area or variable rate multimetering, e.g., route to the parent secondary centre or adjacent secondary switching centre.

The one other route needed to complete the basic trunking diagram for the minor switching centre shown in Fig. 3 is discussed in the following paragraphs, but at this point it is necessary to consider the traffic dispersion in the minor switching area. This dispersion is shown in Fig. 4 and shows the dispersion figures current when the initial study for the minor switching centre was made in 1965/66. Since then the changed role of the minor switching centre brought about by a reduction in the number of ARM exchanges has modified these figures, but the figures shown are indicative of the nature of the problem.

The general impression gained from the traffic dispersion figures shown in Fig. 4 is that in a typical minor area, 75 per cent. of the traffic is local fee traffic and 25 - 30 per cent. is trunk fee traffic, the bulk of which is destined for areas outside the minor switching area. However, there is an important 1 to 2 per cent. of trunk fee traffic, which originates in the minor switching area and is going to destina-

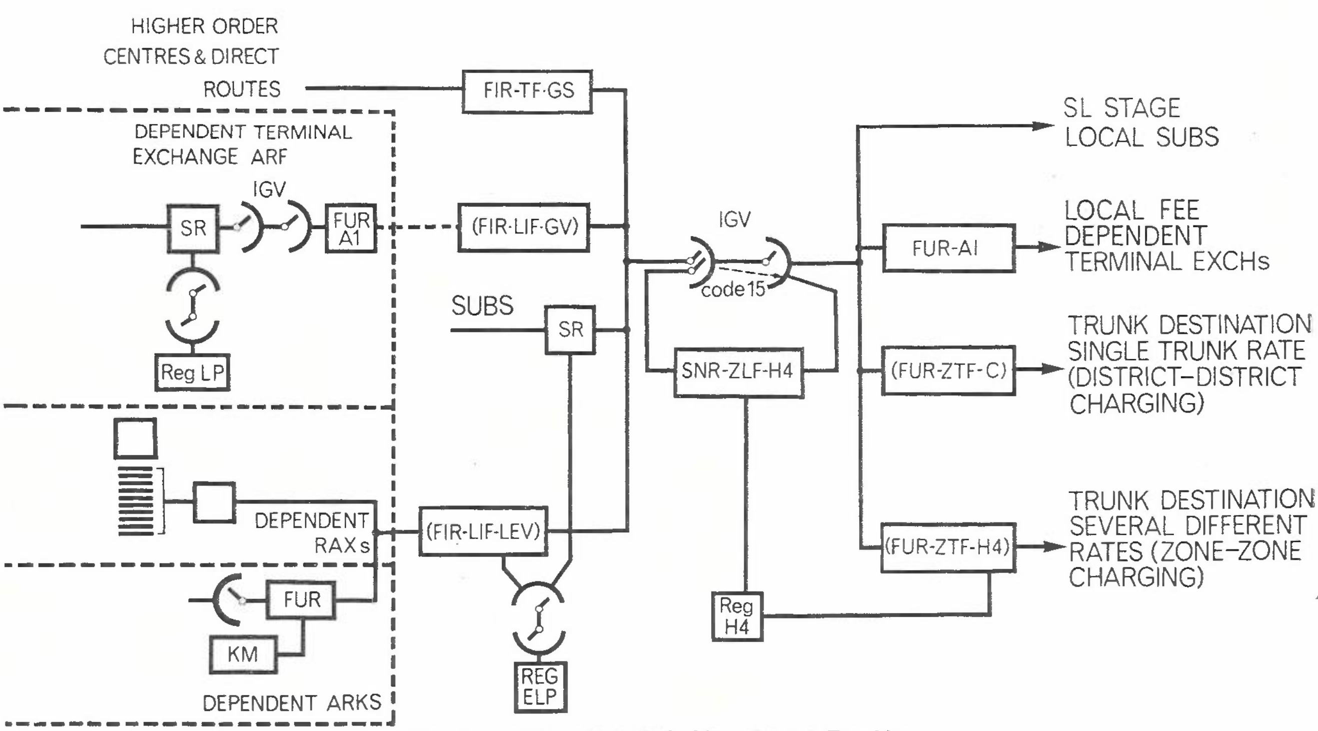


Fig. 3. — ARF Minor Switching Centre Trunking.

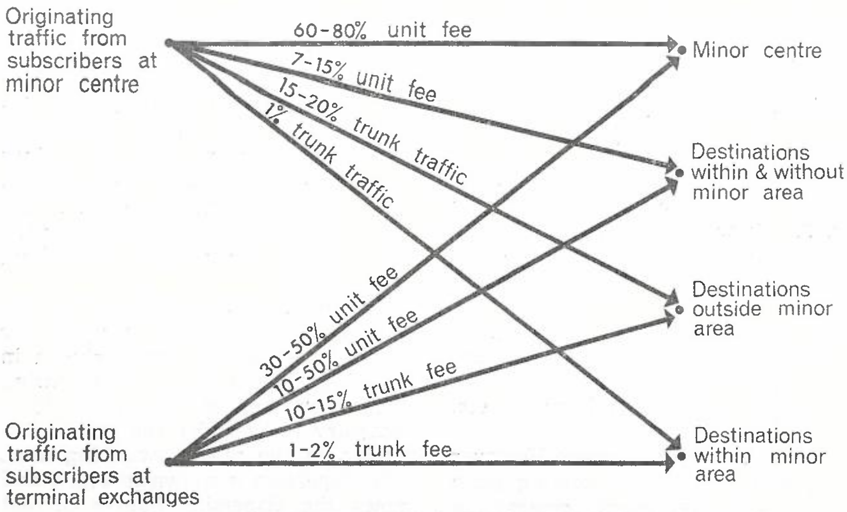


Fig. 4. — Traffic Dispersion in Minor Switching Areas.

tions within the minor switching area. The handling of this traffic presented some problems. The simple solution would have been to equip the outgoing routes to terminal exchanges with variable rate multimetering equipment. This was considered undesirable for two reasons:

(a) It is expensive; the traffic dispersion figures showed that the bulk of the terminating traffic to terminal exchanges was unit fee and this unit fee traffic could be handled by an FUR-A1 at the minor switching centre. This is a much simpler and cheaper relay set than a variable rate multimetering relay set.

(b) Circuits incoming from higher order centres or direct routes from other minor centres expect B party supervisory line signals to be returned from the exchange equipment, whereas the variable rate multimetering FUR would return modified Karlsson line signals to incoming circuits.

A different method of handling the 1-2 per cent. of intra minor area trunk fee traffic was required and it was decided that the most economical method of handling this traffic was by a method of re-entrant trunking. This trunking is shown in Fig. 3, and consists of connecting an outlet of the GV stage via a re-entrant variable rate multimetering relay set SNR-ZLF-H4, to an inlet of the 1GV stage.

The types of traffic which are routed via this re-entrant trunking are:

(a) trunk fee calls which originate and terminate in the minor switching area;

(b) trunk fee calls via a direct route to a terminal exchange in another minor switching centre where the bulk of traffic is unit fee, but which in some cases requires the application of a trunk fee.

For calls to local subscribers the re-entrant relay set SNR-ZLF-H4 provides ring and battery feed facilities.

With this method of trunking the originating register examines the zone of origin, together with the destination code, and if a trunk fee is required, MFC code '15' is inserted in front of the dialled digit. The GV marker on receiving code '15' selects an outlet which is connected to a GV inlet via the variable rate multi-metering relay set, SNR-ZLF-H4. The GV vertical is set and the same digit is left on line until the rate setting register H4, which is coupled to the SNR, calls for the zone of origin from the originating register. Digits of the destination code are then called for one at a time by REG-H4 until sufficient have been received to determine the appropriate trunk rate. This rate is then set in the SNR-ZLF-H4 by REG-H4. A restart signal 'A2' is returned to the originating register, REG-H4 releases, and the call proceeds in the normal fashion.

Line Signalling.

The minor switching centre presented some problems in line signalling, but before considering these problems it is necessary to briefly review the types of line signalling used by the A.P.O. (Ref. 1). Two types of line signalling on d.c. circuits are used by the A.P.O. These are:

(a) B party supervisory line signals (Fig. 5), where the 'on hook' and 'off hook' condition of the B party are transmitted from the B party to the A party by means of line reversals.
The answer and metering condition is conveyed by the first line reversal.

(b) Modified Karlsson type line signals (Fig. 5), which are returned from a charging relay set towards the A party. They not only convey the 'on hook,' 'off hook' condition of the B party line, but also meter pulses at the appropriate rate.

Karlsson signalling is named after its inventor and consists of a system of line signalling where an answer signal is a reversal of line potential. A metering signal is signalled by restoring the line potential to normal for 150 mS. The B party release is signalled by a forced release signal, i.e., by opening the line towards the A party for a nominal 600 mS and then restoring the line potential to normal. The term 'modified Karlsson signalling' arises from the fact that a meter pulse is returned on answer and the first subsequent meter pulse is then absorbed. The effect of this is to provide a period following answer of 1-2 pulse intervals for identification of

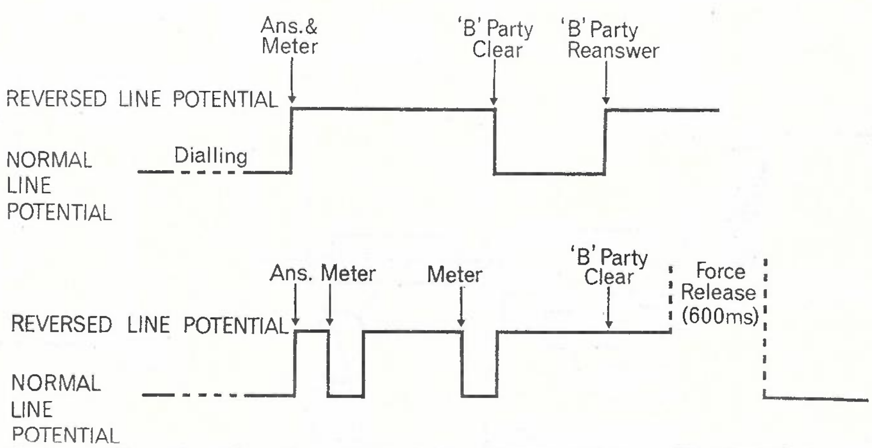


Fig. 5 — Line Signalling. Top: 'B' Party Supervisory. Bottom: Modified Karlsson.

the B-party. The A.P.O. has adopted modified Karlsson signalling for use in its network.

It is important to note that B party supervisory line signals are not returned past the charging relay set. This is necessary to prevent flicks of the B party switch hook being interpreted as meter pulses. Also the B party clear is not returned direct but following a time out interval, which is initiated by A party release, a forced release signal is returned to the A party. This is also necessary to prevent temporary restoration during transfer of the call at the destination, e.g., switchboards, from metering the A party.

The types of line signalling required for the various types of circuits connected to the minor centre are as follows (see Fig. 6):—

Circuits to Dependent Terminal Exchanges: These circuits will receive from line, and return to the A Party, B party supervisory signals.

Routes Serviced by Variable Rate or Fixed Fee Multimetering Equipment: These circuits receive B party supervisory signals from line and return modified Karlsson signals towards the A party.

Circuits incoming from higher order Centres or Direct Routes from Other Minor Exchanges: These circuits expect to receive and re-transmit B party supervisory signals and as they only require access to the circuits to dependent exchanges or to the local SL stage this requirement is met.

Circuits Incoming from Dependent Exchanges: The circuits from dependent ARK's and RAX's require access to both unit fee and trunk fee circuits. This means that the FIR will receive from the exchange both Karlsson type and B party supervisory line signals. If these are merely repeated to line, expensive discrimination equipment must be provided at the terminal exchange. This equipment would examine the code dialled. determine the appropriate line signalling mode and arrange the FUR at the dependent exchange accordingly.

To avoid this it was decided that the line signals between minor centres and dependent exchanges would always be in the Karlsson mode. A further reason for this is that the MFC ARK (ARK-M) (Ref. 2) is designed to receive only Karlsson type line signals. REG-ELP is arranged to examine the destination code and determine which type of line signals, Karlsson or B party supervisory, will be received by the FIR from the exchange and to then arrange the FIR to repeat them in the Karlsson mode.

However, where the incoming circuit is from a dependent ARF terminal exchange no register is available to set the FIR in the appropriate mode and another method must be used to advise the FIR which type of signalling, i.e., Karlsson or B party supervisory, will be received by the FIR from the exchange.

When considering the various types of FIR's and FUR's that are used at the minor switching centre it was recognised that as the minor switching centre provided tandem facilities, i.e., it switches circuits originating from dependent exchanges, FUR-LN cannot be used on circuits over 2000 ohms due to the fact that it does not provide for decadic pulse repetition. This left FUR-A1 or FUR-PABX, which could be used to terminate the outgoing d.c. circuit and with a view to its relative cheapness it was decided that FUR-A1 would be used.

This means that the FIR on the incoming side of the exchange must provide a battery feed and hold forward on the 'c' wire. These requirements are identical to those of the metropolitan tandem exchange. Also, like the tandem exchange, facilities must be provided to ring subscriber if the call teminates on the local SL stage. In the tandem exchange this is done by providing an LVR relay set on the outlets to the SL stage. However, a study showed that in the minor switching centre it would be more economic to provide ring facilities in the FIR because:

(a) the majority of calls originated via SR's which were already equipped with ring facilities.

(b) the cost of providing a separate stage for test access to the SL stage was avoided.

It was therefore decided that the minor switching centre FIR should provide junction supervisory facilities in the normal conditions and switch to the B party ring condition when the normal 700 ohm negative battery on the B party 'c' wire was encountered.

It was found that a satisfactory solution to the problem of setting the FIR in the correct line signalling mode would be provided if the GV stage was to superimpose a flash of positive battery on the earth potential of the 'c'

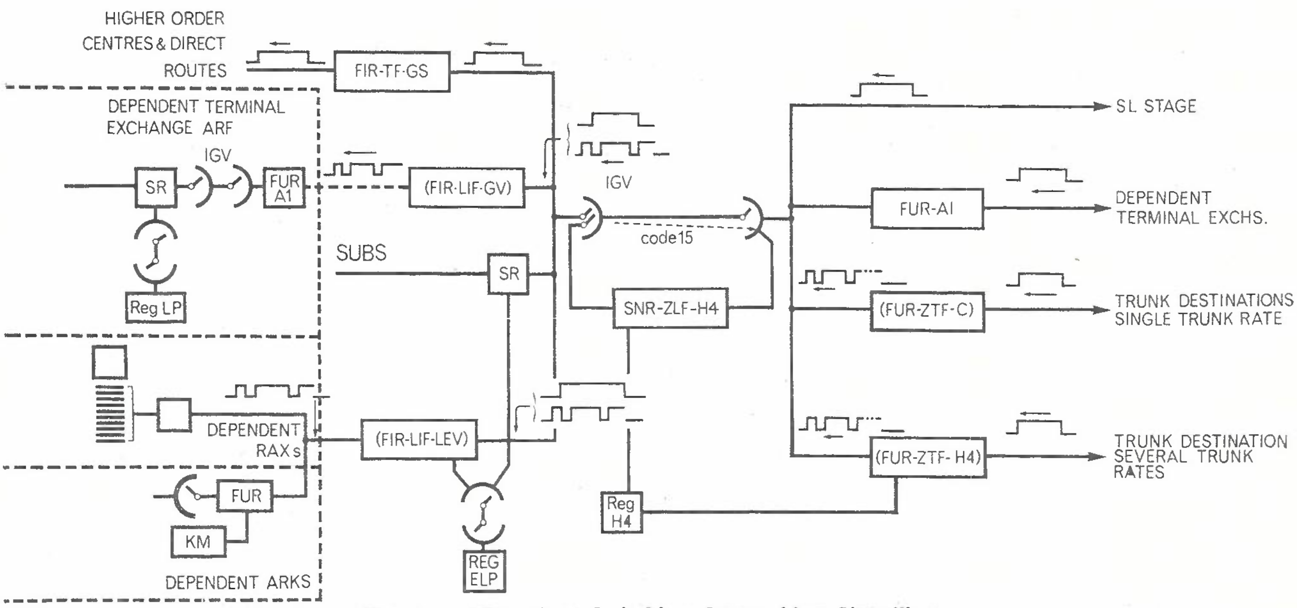


Fig. 6.— ARF Minor Switching Centre Line Signalling.

wire when an outgoing multimetering circuit was selected. This flash would then set the FIR in the correct mode of operation.

The positive flash was also used to solve another problem. In the case of calls routed via the SNR-ZLF-H4 to a dependent exchange the multimetering rate is initially set in the SNR. However, if the call encounters congestion on the direct route and overflows to the backbone route a situation is created where two sets of multimetering equipment are connected in series. This gives rise to difficulties in supervisory line signals. To overcome this, the positive flash returned by the GV stage towards the SNR when the backbone route is selected is used to through switch the SNR. Multimetering signals returned from the backbone route FUR are then passed directly to the FIR.

REG-H4 OPERATION.

REG-H4 (Fig. 7) is used in a minor switching centre as the charge determining register. It can also be used in metropolitan tandem exchanges.

The register is designed to work in association with two types of relay sets; these are:

(a) the variable charge rate relay set FUR-ZTF-H4, which is used on the outgoing routes to parent trunk centres or to distant exchanges or to other minor switching areas;

(b) the register is also used in association with the variable charge rate relay set SNR-ZLF-H4. This relay set is used for variable rate trunk fee calls which are connected over a unit fee route.

It should be noted that REG-H4 should not be connected to FDR's as the circuit cannot be seized forward until REG-H4 has determined the charge. The outgoing circuit at the distant end is not busied until such time as a pick up pulse is received and the risk of dual seizure of the circuit is thus increased to an unacceptable level.

The REG-H4 is designed to receive numerical forward MFC signals from REG-L and can return only MFC signals A1 'Next Digit', A2 'Restart' and 3A5, 'Send Zone of Origin.' It is installed as a single rack of equipment which will cater for up to 120 FUR or SNR. If an installation is less than 120 FUR or SNR no reduction of equipment is possible except for the XY-H4 which is provided on the basis of 1 per 40 FUR.

The connecting equipment uses relay sets GV-XY (1 per 2 REG-H4); XY-REG-H4 (1/40 FUR); 1K-REG-H4 (1/2 REG-H4).

These relay sets give full access between the 120 inlets and 2 REG-H4. A connection is made on an eight wire circuit.

The REG-H4 relay set is capable of receiving and storing up to 15 zones of origin. It can also receive up to 6 digits (0 + 5 digits) of the called number as required for charge analysis. This information is passed to the REG-H4 AN relay set, which determines the charge rate. REG-H4 sets the tariff rate relays in the FUR or SNR, sends a restart signal A2 to the originating register, and then ready connects the FUR or SNR. REG-H4 can apply any one of eight trunk rates plus unit fee plus no fee charge. On calls to certain destinations (international codes) it can also arrange the FUR-ZTF-H4 to repeat the Karlsson line signals received on the line side.

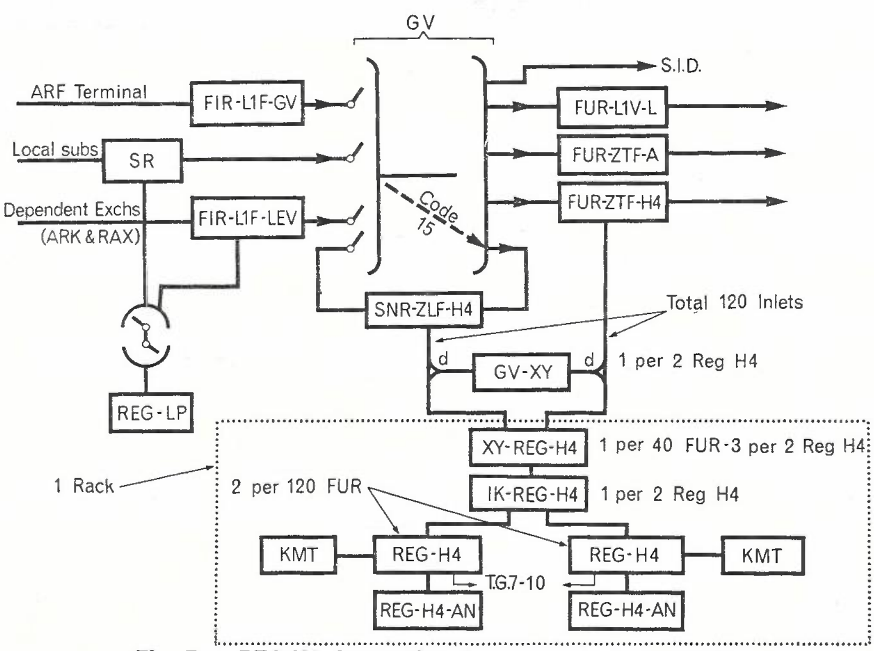


Fig. 7. — REG-H4 Connecting Arrangements in Network.

REG-ELP.

Space does not permit a full description of the operation of REG-ELP, but its basic functions are as follows:

The relay sets comprising REG-ELP (Fig. 8) can be divided into five functional groups:

(a) The basic register consisting of DIR
relay set REG-LP Part 1.
REG-LP, Part 2.
REG-E.
AN REG

(b) The MFC code sender KS consisting of—
relay set KSR;
relay set KSP;
relay set KSE;
relay set AN-KS.

(c) The decadic pulse sender DS consisting of—
relay set DSR;
relay set DSP.

(d) The connecting equipment between the three units SS.

(e) The miscellaneous relay sets required in a REG-ELP installation.

It should be noted that relay sets REG-E and KSE are add-on relay sets which are required to convert REG-LP to REG-ELP.

The Basic Register.

The DIR relay sets is an 'add-on' relay set to the RSM. While RSM is connecting a calling FIR to an idle register, DIR connects a 24 wire multiple to the register and tranfers information for digit insertion, mode of operation, i.e., REG-L or REG-I operations, zone of origin (stored in REG-E) and the 'A' subscriber classification.

Digits dialled by the subscriber are received in Part (I) and stored on relays in Part (II)—transfer of the digits is by 2/5 code. If the subscriber connected is using a push button telephone the appropriate subscriber classification causes a code receiver to be connected. The voice frequency signals received from the telephone are then transferred from the code receiver to the register on wires by a two out of five code.

AN REG is called when 0 + 2 digits are stored in Part (II) or, if the first digit is not 0, when a prestrapped number of digits has been received. This is usually the 'E' digit. The AN-

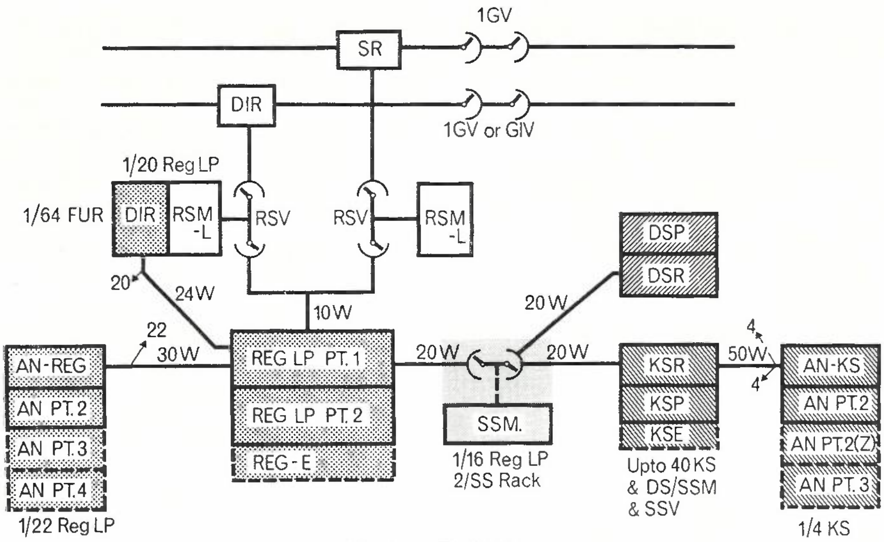


Fig. 8. — REG-ELP.

REG has associated with it a number of Part (II) relay sets—the number depending on digit analysis requirements. The analysis capacity is 0 + 5 digits and the resulting analysis information is passed back to, and stored in, the basic register.

The information provided by the AN-REG comprises:

(a) when to call the KS;
(b) the direction in which the call should be set up if it originates from an ARK-M;
(c) number length of the destination; this is provided at a later stage of the call.

KS-Code Sender and Receiver.

The code sender and receiver comprises relay sets KSR, KSP and KSE and is provided on the basis of 40 KS per SS.

When KS is seized by REG-LP (Part (I), the zone of origin information is tranferred from REG-E to KSE and the following information is transferred to KSR:

(a) type of originating exchange;
(b) 'A' subscriber classification - rectifier in line.

When AN-KS has completed its functions the following information is passed to the KS:

(a) type of signalling, i.e., Karlsson, switch hook or local ring;
(b) routing, e.g., interception NUT, SNR;
(c) special conditions, e.g., non-metering, congestion tone, no time out, last party release, cyclic storage, etc.

The type of signalling and special condition information are transferred to the basic register at the appropriate time, while the routing information is used by KSR to control the call.

The KSR performs these control functions:

(a) Call of AN-KS and the transfer of information from the basic register and KSR to AN-KS.
(b) Call of DS and the transfer of 'P' chain setting and other information.

Relay set KSP controls MFC sending and receiving and interprets the backward signals so that:

(a) the appropriate 'P' chain shifts are made, e.g., shift back to P1 on restart;
(b) signals KSR when action in basic register is required, e.g., busy, ready connect, etc.
(c) when required changes the interpretation of backward signals, e.g., transfers from 3A to the 'B' series if 3A9 is received.

In sending forward signals KSP:

(i) reads out the dialled digits from the basic register;
(ii) sends special codes, e.g., code 11, 15 and zone of origin.

AN-KS is shared between 4 KSR's and on seizure, AN-KS transfers from the basic register or KSR:

(a) the dialled digits—0 + 5 digits can be analysed;
(b) 'A' subscribers' classification;
(c) zone of origin.

The information is analysed and the previous mentioned three types of information are transferred to the KSR, i.e., type of signalling, routing and special conditions.

Decadic Sender DS.

The decadic sender DS consists of two relay sets DSR and DSP. When KS receives a send decadic signal it calls DS via the basic register and SS, then connects the DS, KS and basic register together over a 20 wire connecting circuit and while this connection exists KS transfers to DS:

(a) the 'P' chain position;
(b) the type of line signalling (for use at ready connection);
(c) the signal series (3A or 4A), in which the decadic request was received.

When this transfer has been completed DS releases KS and calls for the AN-REG. The AN-REG then transfers to DS the number length and number shift information (required for cross boundary calls).

DS then releases AN-REG and commences decadic outpulsing.

EXISTING 3A SERIES
1 Send next digit MFC
2 Restart MFC
3 End of selection Change to 'B' series
4 Send decadic 1st digit
5 " 2nd "
6 " 3rd "
7 " 4th "
8 " 5th "
9 " 6th "
10 Send previous digit MFC

PROPOSED 3A SERIES
1 Send next digit MFC
2 Restart MFC
3 End of selection - Change to 'B' series
4 Congestion
5 Send zone of origin
6 Send 'A' party's category - change to 'C' series
7 Spare
8 "
9 Send decadic - change to 4A series
10 Send previous digit MFC

PROPOSED 4A SERIES
1 Spare
2 "
3 "
4 Send decadic B digit
5 " C "
6 " D "
7 " E "
8 " F "
9 " G "
10 Spare

Fig. 9 — Portion of Proposed New Signalling Series.

Outpulsing is controlled by DSP, which contains:

(a) The 'P' chain for control of digits to be sent;
(b) a decadic sender;
(c) time supervision for NLU calls;
(d) premature reversal detector.

OPERATION ON TYPICAL CALLS.

In describing the typical signalling cases which follow, the signals used are those contained in the new signalling scheme which is to be introduced into the A.P.O. network. The full signalling scheme is set out in Ref. 3, but the changes which are of immediate concern are shown in Fig. 9. It will be seen that the send decadic signals have been moved into a new series of signals called 4A and new backward signals have been allocated to the signals thus freed in the 3A series.

The signalling cases shown are self-explanatory provided it is remembered that:

(a) Determination of the charge rate for a trunk call depends upon two things:
(i) The zone in which the call originates. This is ob-

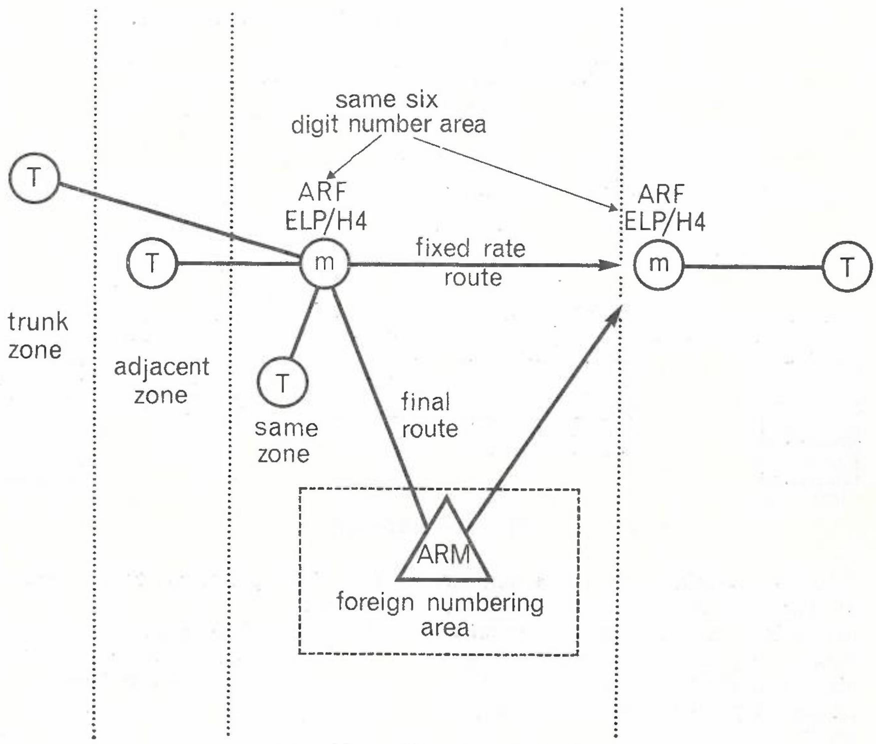


Fig. 10. — Signalling Case 1.

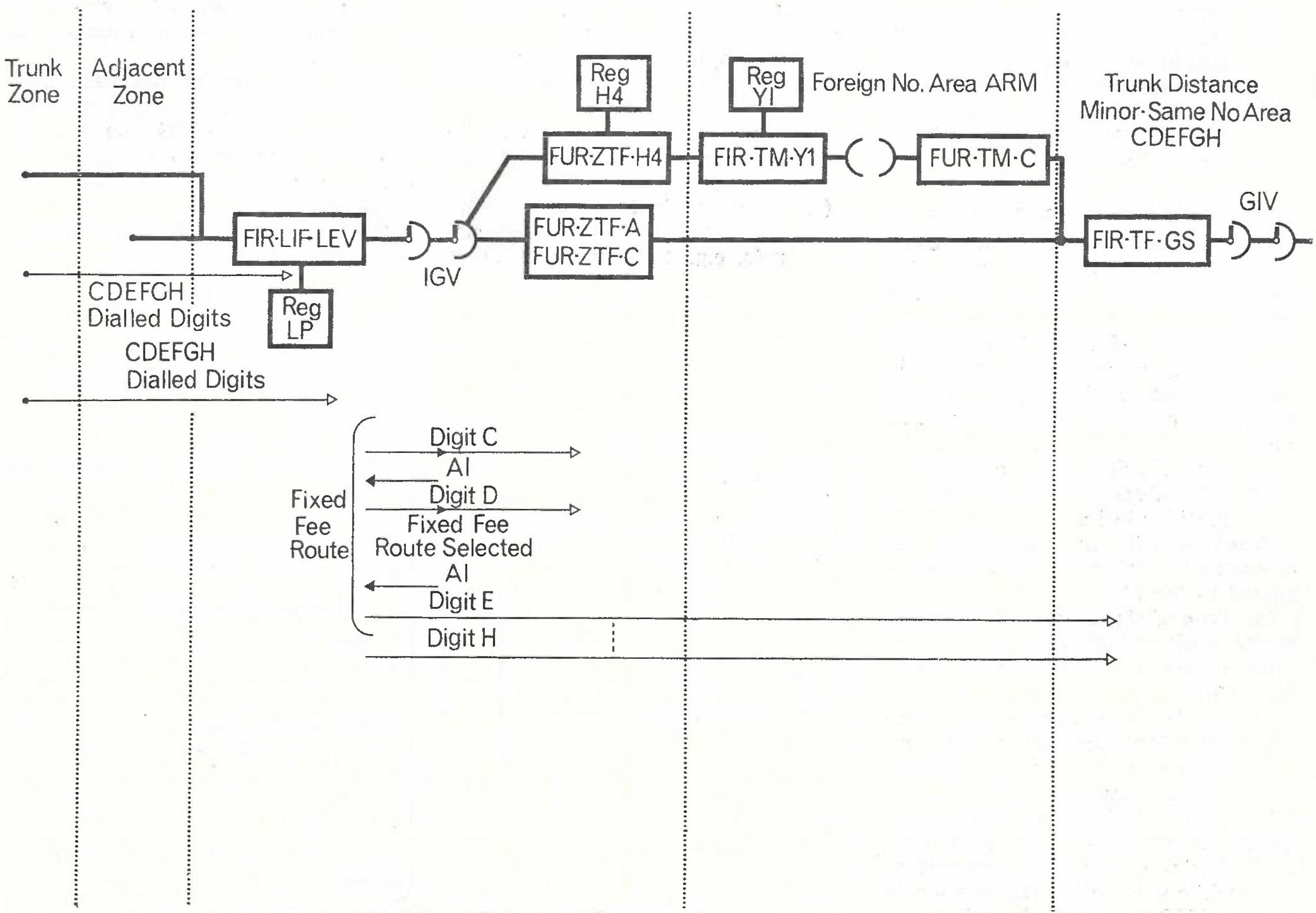


Fig. 11. — Signalling Case 1 — Call via the direct route.

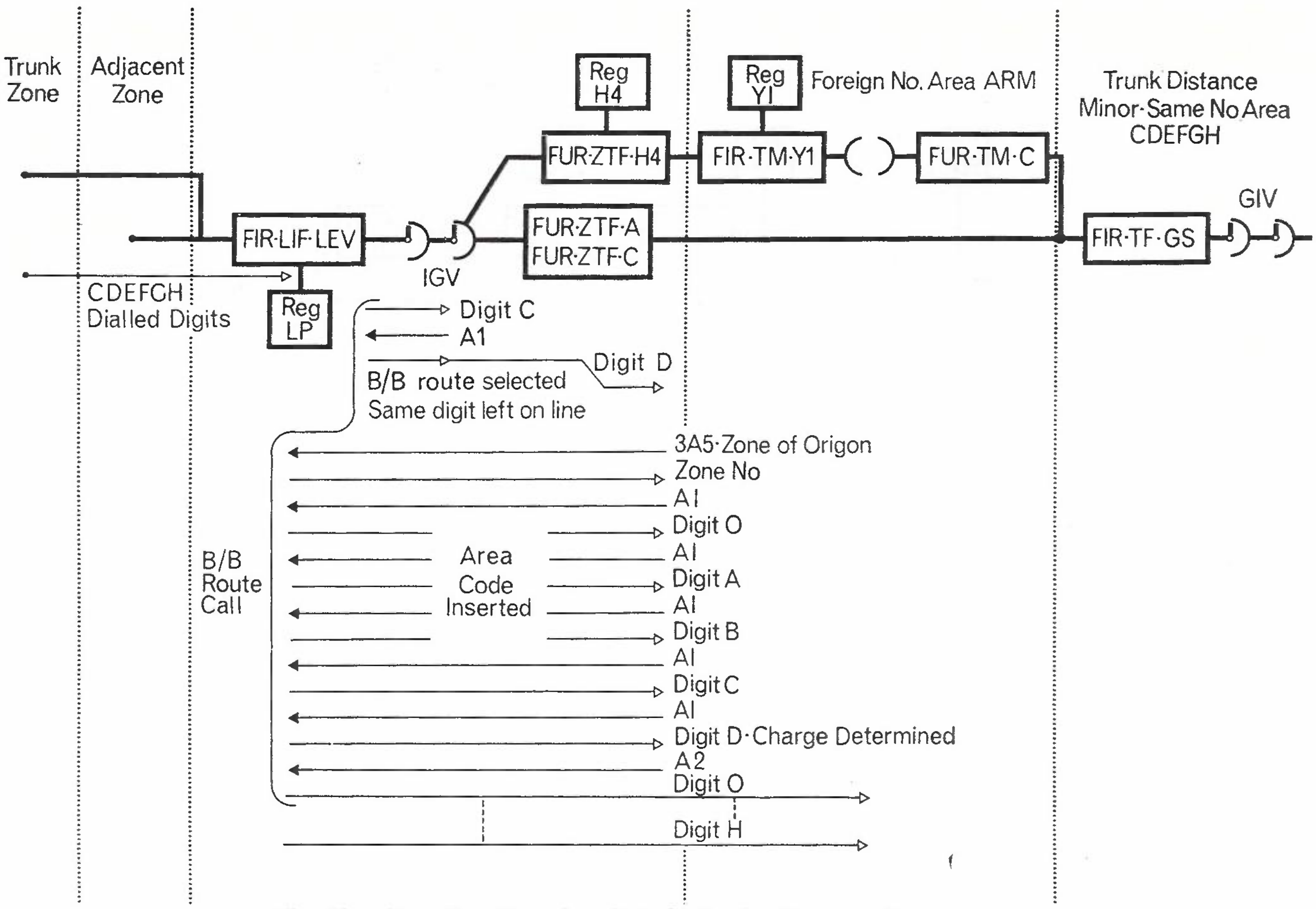


Fig. 12 — Signalling Case 1 — Call via the backbone route.

tained by the charging register returning a request for Zone of Origin (3A5) to the originating register. The originating register responds by sending the appropriate signal from one of a group of 15 forward signals. Up to 15 Zones of Origin can be identified by REG-ELP.

(ii) The charging register analyses the destination code in conjunction with the Zone of Origin and determines the appropriate charge rate.

(b) Where a Minor Switching Centre has a parent secondary centre which is located in a foreign numbering area, it is necessary for all calls routed via the ARM to contain the area code of the destination. If this were not so, calls destined for a zone within the local numbering area could be wrongly connected to a zone within the foreign numbering area.

If REG-ELP does not contain the area code as part of the dialled digits the register has been arranged to insert the area code in front of the dialled digits on receipt of the first A1 backward signal which follows a request for Zone of Origin.

Signalling Case 1: The first signalling case is shown in Figs. 10, 11 and 12 and is that of two minor switching centres in the same six digit numbering

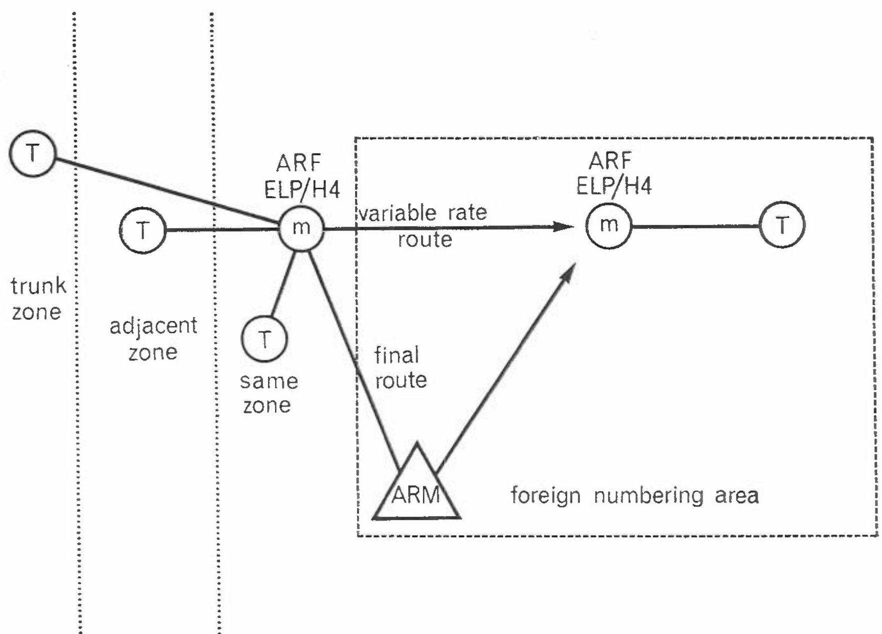


Fig. 13. — Signalling Case 2.

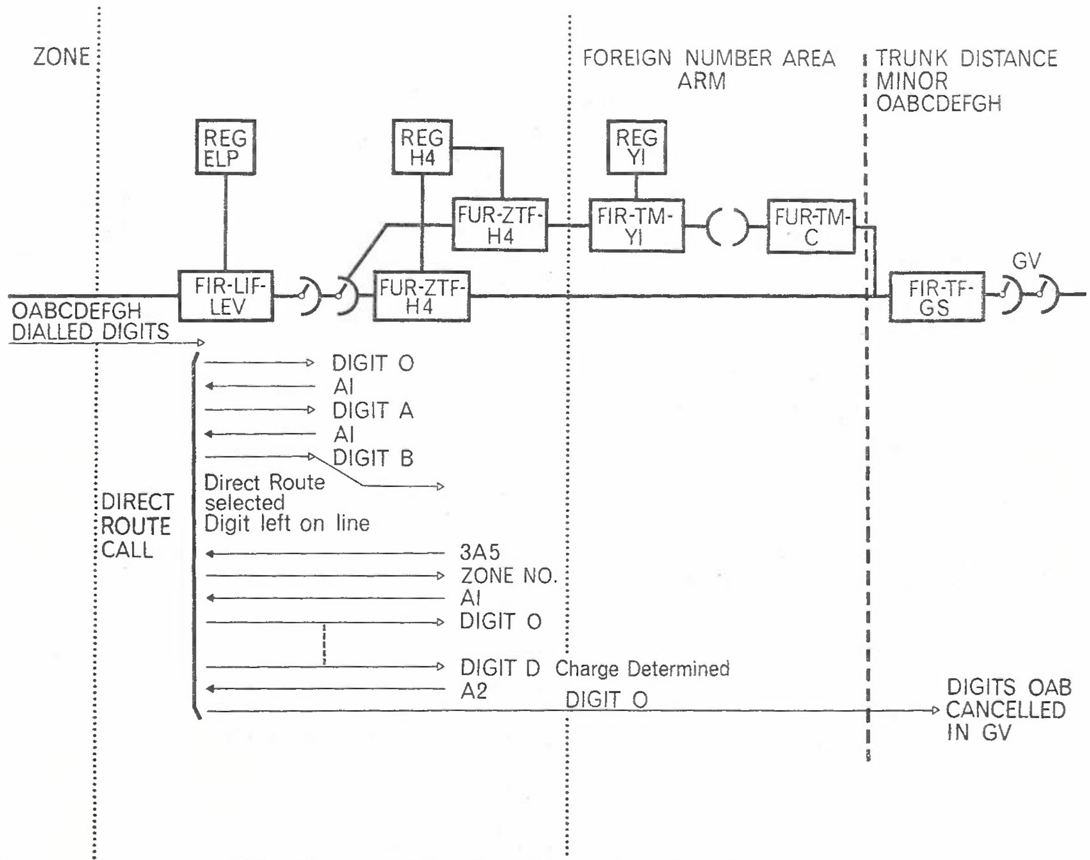


Fig. 14. — Signalling Case 2 — Call via the direct route.

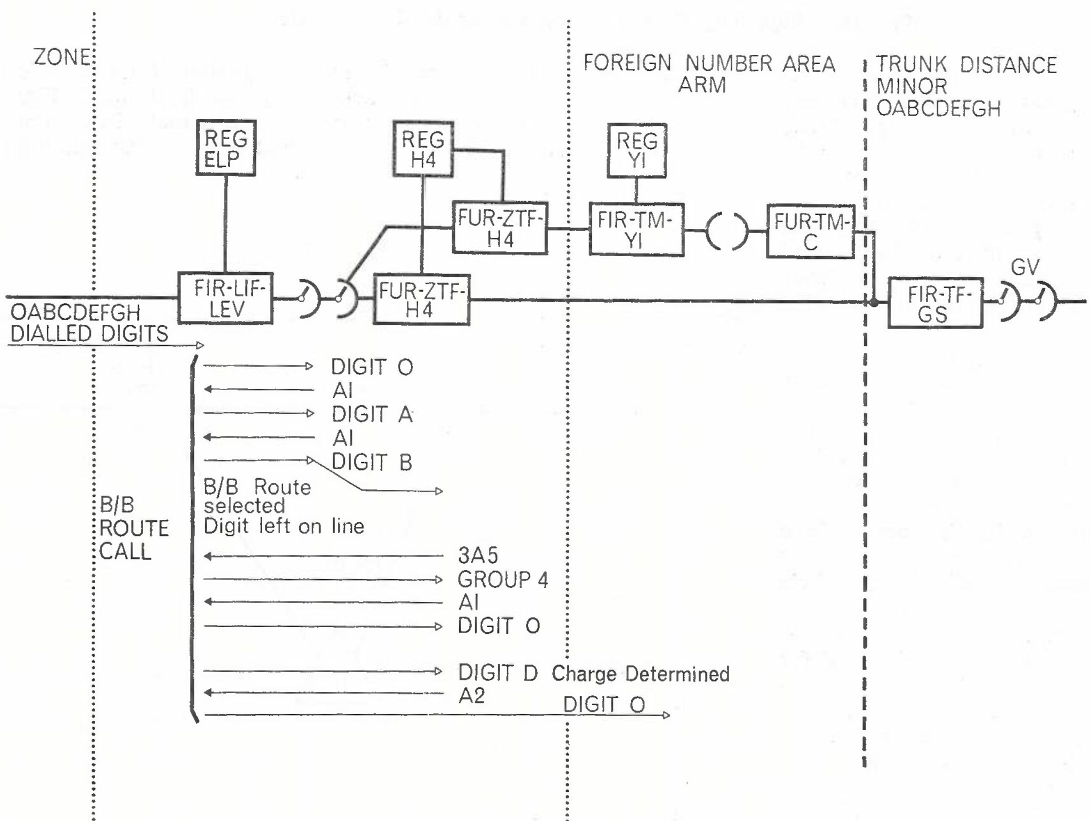


Fig. 15. — Signalling Case 2 — Call via the backbone route.

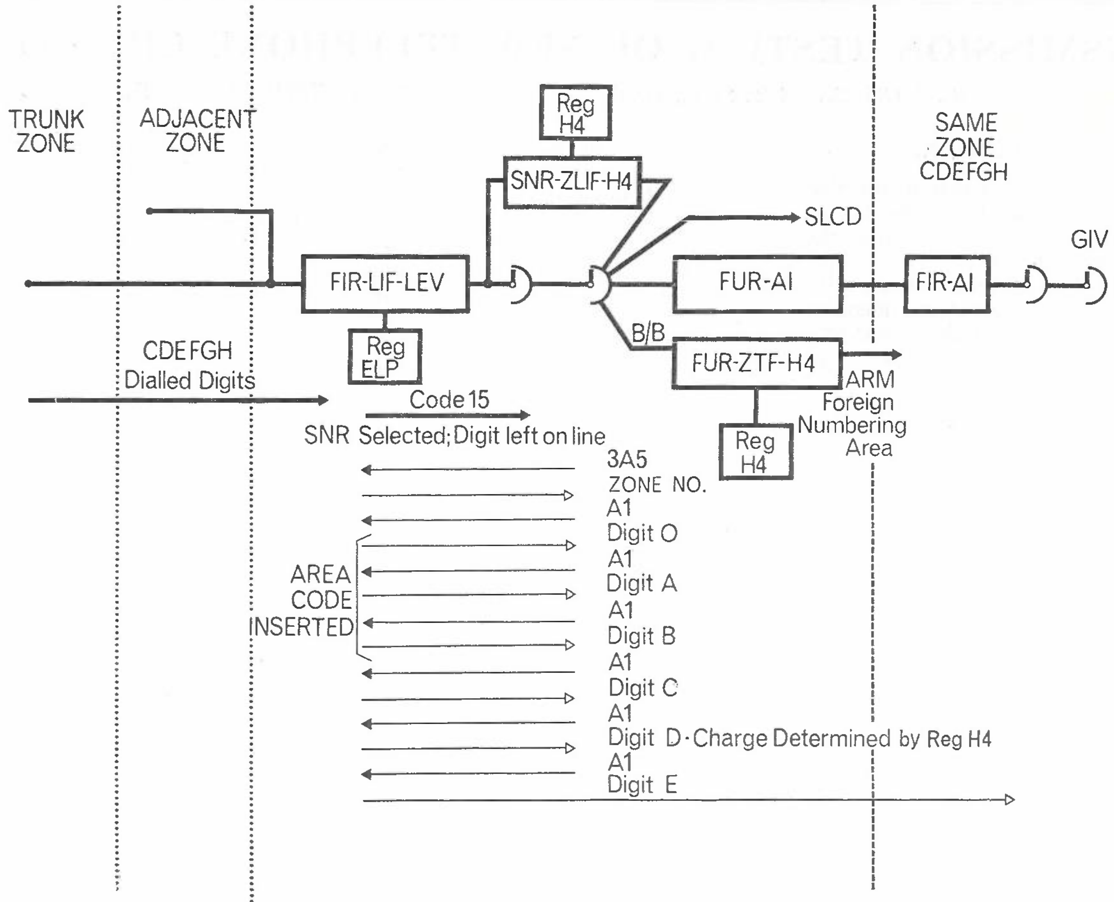


Fig. 16. — Signalling Case 3 — Trunk fee call within the same numbering area.

area where both are parented on a secondary centre located in a foreign numbering area (Fig. 10).

The minor centres are linked together via a fixed rate multimetering relay set (FUR-ZTF-A or FUR-ZTF-C) and the B/B route to the ARM is via a variable multimetering relay set (FUR-ZTF-H4). Fig. 11 shows a call via a variable route, while Fig. 12 shows a call via the B/B route.

Signalling Case 2: The second signalling case is shown in Figs. 13, 14 and 15 and is that of two minor switching centres which are trunk distance from one another and located in different numbering areas. Both minor switching centres are parented on a secondary centre, which is located in either of the numbering areas (Fig. 13).

The minor centres are linked together via a variable rate multimetering relay set (FUR-ZTF-H4) and the B/B route to the ARM is via a similar FUR-ZTF-H4. Fig. 14 shows a call via the direct route, while Fig. 15 shows a call via the B/B route.

Signalling Case 3: The third signalling case is shown in Fig. 16 and is that of a call originating in a zone which is trunk distance from the minor centre and terminating at a terminal exchange in the same zone as the minor centre (Figs. 10 or 13). Unit fee traffic between exchanges in the same zone is connected via FUR-A1 (Fig. 16). Trunk fee calls between the non-adjacent zones are connected via SNR-ZLF-H4.

CONCLUSION.

The minor switching centre has been developed from performing pure tandem functions, i.e., switching unit fee intra-minor traffic via the local GV stage into providing national charging functions.

The gains made by providing charging functions at the minor switching centre are:

(a) Network security is improved by allowing all intra-minor local and trunk calls to be handled at the minor switching centre.

(b) The trunk requirement between the minor and parent secondary centres are reduced.

(c) As national charging will be carried out at the minor switching centre the link from the minor will terminate on REG-Y1 equipment at the ARM, which is less expensive and less complex than REG-H1 equipment.

(d) As the charging function is completed at the ARF minor switching centre the Zones of Origin associated with that minor will not have to be forwarded to the parent ARM, thus considerably reducing the analysis requirement at the ARM.

(e) By performing the charging function at an early stage, there is an increased freedom of ability to direct route in the most economical manner. Routing will then be independent of numbering and charging.

ACKNOWLEDGMENTS.

The basic principles of the minor switching centre were developed jointly by members of the Exchange Equipment Switching Design Sub-section and the Switching and Facilities Planning Section in A.P.O. Headquarters. The detailed design was undertaken by L. M. Ericsson Pty. Ltd.

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3. Australian Post Office Drawing No. CP2123.

TRANSMISSION TESTING OF NEW TELEPHONE CIRCUITS

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INTRODUCTION.

With the increasing rate of installation of trunks and junctions in the A.P.O. telephone network and the requirement that transmission testing be carried out on all telephone circuits, it is essential that correct and adequate telephone circuit commissioning procedures be used. During the period of the establishment of the ARM Grid in 1967 (Ref. 1 and 2), the methods of commissioning telephone circuits had to be clearly specified in an effort to obtain a uniform approach to the commissioning of all types of telephone circuits. A brief resume of the types of tests and methods used during the commissioning of the first ARM Exchanges has been given in a previous issue of the Journal (Ref. 2).

This paper outlines the present methods in use in Victoria to commission telephone circuits, both two wire and four wire, in regard to transmission. The commissioning procedures are based on the telephone circuit as defined in this paper, and have been prepared in close co-operation with the Headquarters Long Line Equipment Section. A series of engineering instructions treating this subject in more detail, both from the installation and service points of view, is presently being prepared by Headquarters. These should be available early in 1970.

Summary of Activities

Broadly, the activities involved in commissioning new telephone circuits are as follows:—

(a) Specification of transmission details for particular telephone circuits by the Transmission Planning Section.
(b) Selection and preparation of the appropriate transmission commissioning procedure based on (a) above by the Project Exchange Installation Engineer.
(c) Strapping of pads to obtain correct end section loss at both near and far ends of the telephone circuit by field staff.
(d) Functional testing of relay sets over the line circuit by field staff.
(e) Overall loss measurement of the telephone circuit by field staff.

The functional tests mentioned in (d) above were referred to in detail in a previous issue of the Journal (Ref. 2) and will not be discussed in this paper.

To ensure that these activities are carried out in a uniform manner on all types of telephone circuits and to provide readily comparable results it is necessary that detailed testing procedures be set down for use by technical staff engaged in this type of work. Many of these procedures have been prepared for use in the Victorian Administration and some examples are referred to in this paper.

TELEPHONE CIRCUITS.

A.P.O. Engineering Instructions have defined a telephone circuit as one which includes the line and line signalling relay sets at each end of the line. For each type of telephone exchange a reference point has been defined and ideally transmission commissioning tests should be carried out between the exchange reference points at each end of the telephone circuit. Fig. 1 shows the elements of a typical telephone circuit and defines the exchange reference points. On Fig. 1 the circuit is shown as extending between exchange reference points. This includes some switching equipment which is not strictly part of the telephone circuit but is shown this way because circuit losses are specified and measured as between exchange reference points. However in most cases the exchange reference point is an inaccessible test point, that is, a jack point is not available. In most cases the nearest jack access point to the exchange reference point has been selected and defined as the transmission test point (TTP). Typical TTP's are shown in Fig. 1. Therefore, from the view-point of commissioning it is the TTP with which testing officers should become familiar and not the exchange reference point. All circuit loss measurements are made between defined TTP's and provided the loss between the exchange reference point and the TTP at an exchange is not greater than 0.25 dB the measured results are taken as the actual circuit loss. If the loss between the exchange reference point and the TTP at an exchange is greater than 0.25 dB, then that loss is added to the measured loss to give the overall telephone circuit loss.

In the early ARM projects attempts were made to establish the TTP at the FIR-M relay set instead of at a test FUR-H relay set. This procedure required that certain relays in the FIR-M relay set be operated manually to set up the test condition. Since testing instructions state that overall transmission tests are to be performed with the telephone circuit in the switched and answered condition, electrical operation of relays is preferred. Pending the manufacture and installation of the ARM trunk test access and console facilities (Ref. 3), an interim transmission test position was developed for use in ARM exchanges to ensure that all overall test conditions were set up electrically. Access to the test position is via an FUR-M relay set as shown in Fig. 1. The interim test

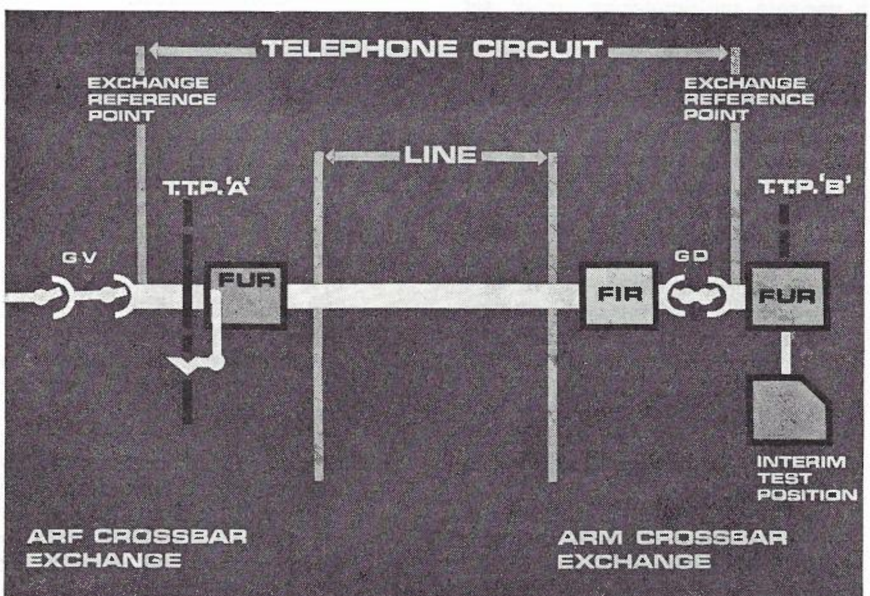


Fig. 1. — Typical Telephone Circuit — Showing Location of Exchange Reference Points and Transmission Test Points.

* Mr. Larsson is Engineer Class 2, ARM Design and Coordination, Victoria. See Vol. 19, No. 1, P. 77.
** Mr. Reid is Engineer Class 1, ARM Design and Coordination, Victoria.

Fig. 2. — Interim Test Position in Use at the Geelong ARM Exchange.

position provided an easier and quicker testing method as well as producing more reliable and consistent results. Fig. 2 shows an interim transmission test position and transmission measuring set in use at the Geelong ARM exchange.

In exchanges other than ARM exchanges, test positions at which transmission tests can be made are not available. A transmission test console is at present being developed for use in ARF minor switching centres, and will provide facilities similar to those offered by the ARM test console. The lack of fixed transmission testing positions means that TTPs at these types of exchanges are established at defined jacking points generally in line signalling relay sets. Because of the variation of the position of the TTP from one type of telephone circuit to another the need to specify the location of TTP's for each type of telephone circuit is obvious. Consideration is being given to the provision of a transmission test relay set from which transmission tests can be performed in smaller exchanges.

COMMISSIONING ACTIVITIES.

The commissioning of a telephone circuit from a transmission point of view is carried out in 4 main activities which are illustrated in Fig. 3. The first activity is the lining up of the carrier equipment or other line equipment, such as amplifiers or negative impedance repeaters (NIR). At the time of commissioning of a new telephone circuit it is assumed that the line equipment has been correctly lined up and, in the case of carrier equipment, is under control of the Group Control Station (Ref. 4). The Group Control Station is responsible for the correct functioning of the group of circuits between the channel modulator input and channel demodulator output points. For systems employing 12 circuit groups these will be the 'Chan Mod. In' (—13 dBr) and 'Chan. Demod. Out' (+4 dBr) points. Before the overall telephone circuit commissioning tests are made, the line equipment should be checked to see that, in the case shown in Fig. 3, the —13 dBm and +4 dBm points are in correct adjustment on all circuits to be commissioned. If the levels are out of adjustment, the Group Control Station should be asked to check the line equipment.

It may happen that the line equipment is, for example, 2dB low at the +4 dB point and the condition may take some time to rectify. If this is the case, overall telephone circuit measurements can be made, but must take into account the 2 dB difference in level. If, for example, the overall loss from TTP 'A' to TTP 'B' is specified as 2 dB, then a —3 dBm signal transmitted at TTP 'A' should give a reading at TTP 'B' of —5 dBm. But since in this case the line equipment is 2 dB low, a reading of —7 dBm at TTP 'B' would result. Thus, later when the unstandard level condition of the line equipment has been restored to normal, the correct reading of —5 dBm at TTP 'B' will result. In no case must adjustments be made to channel gain controls simply on the basis of isolated measurements. If the line equipment varies from nominal by 3dB or more, commissioning tests should not be performed until the line equipment is restored to normal.

The second and third activities consist of setting the end section losses between the TTP's and the Carrier Reference Points (CRP's) at each end of the telephone circuit. Generally, the end sections consist of passive components, including strappable pads, hence once end section losses are set they should not vary unless a fault condition occurs. When setting and measuring end section losses care must be taken to ensure firstly, that the pads are strapped correctly, and secondly that any VF terminations normally across the circuit in the idle condition are removed by manually operating the appropriate relay contacts during this test. Experience to date has shown that a considerable amount of time can be lost in the setting of end section losses if these two points are not carefully observed.

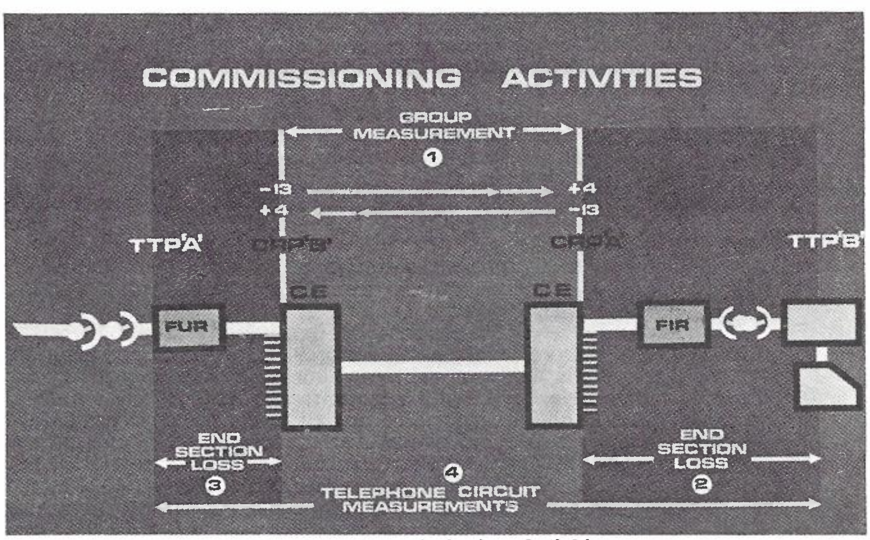


Fig. 3. — Commissioning Activities.

Setting of end section losses is covered in more detail later in this paper.

The fourth activity consists of between 3 and 5 measurements, depending on the type of telephone circuit being commissioned. In the particular case shown in Fig. 5 the following measurements make up the fourth activity:

(i) Variation of receive levels with respect to 820 Hz.

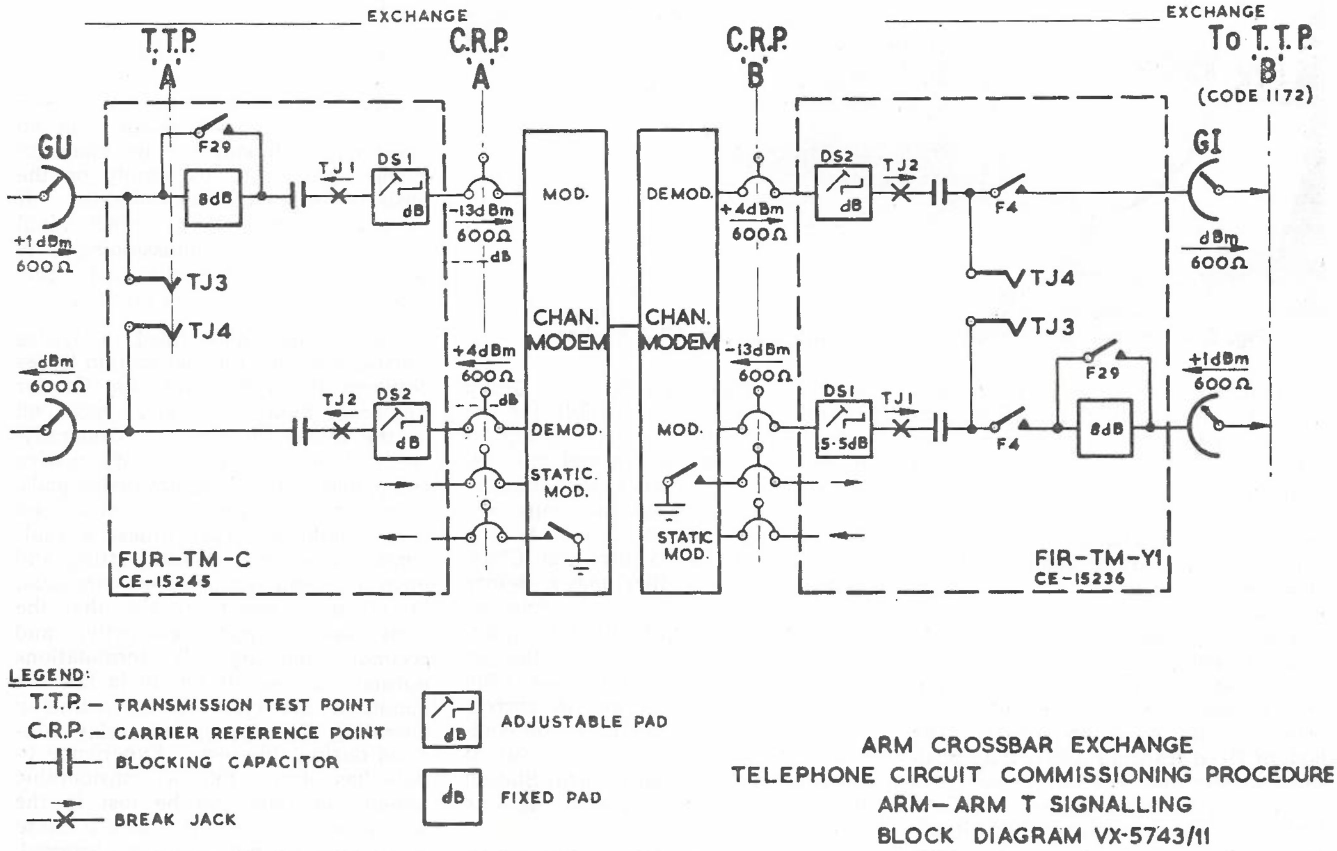
(ii) Noise measurement.

Tests are also performed to check for talker echo and stability of the circuit. In most cases, however, these tests are not strictly a circuit test, but are performed to test the effect of two circuits connected together via a two wire transit exchange. Therefore, these tests are not included in this paper. Figs. 4, 5 and 6 detail the measurements involved for the three types of telephone circuits shown.

The activities listed above outline the basis on which all telephone circuit commissioning procedures have been prepared in Victoria and are consistent with engineering instructions at present being prepared by Headquarters.

COMMISSIONING PROCEDURES.

Figs. 4, 5 and 6 show examples of commissioning procedures. The block



Prior to commissioning tests, all adjustable pads in relay sets at both ends should have been set to:—

(i) values shown on Drawing VX. 5743/11.

(ii) values not shown on VX. 5743/11 but derived from

(a) the send and receive levels specified on VX. 5743/11,

(b) the measured loss between CRP 'B' and TTP 'B.'

(c) the average error in levels at CRP 'A' as specified on VX. 5743/11 (refer Drawing VSK-X-22 for pad strapping).

(iii) strap up all pads to determined value, measure end section loss of each circuit and record on CID. 205, Pt. III.

It is assumed that the carrier systems are lined up correctly and no adjustment should be made to the carrier system levels except under direction from Group Control.

(1) Cross-calibrate all instruments to be used for the same purpose in any one station.

(2) Connect Automatic Exchange Tester (AET) to TJ3 and TJ4 in FUR and call distant manual Test Position (code 1172).

(3) Ask distant end to apply answer condition.

(4) Send 820 Hz at + 1 dBm/600 ohms from TTP 'A' and distant end should read .... dBm/600 ohms at TTP 'B.' Record level on CID. 205, Pt. I.

(5) Ask distant end to send 820 Hz at + 1 dBm/600 ohms from TTP 'B' and .... dBm/600 ohms should be read at TTP 'A' TJ4. Record level on CID. 205, Pt. I. The Supervising Technician in charge of the project, under the guidance of his engineer, will examine the results recorded on CID. 205 and decide further action.

(6) **Variation of Receive Levels with respect to 820 Hz:**—At both ends, send the following spot frequencies at a level of + 1 dBm/600 ohms and record all levels received on CID. 205, Pt. II. Where possible, use sweep equipment and graticule and sweep over the range — the reference point being 820 Hz. Spot frequencies: 300 Hz, 400 Hz, 820 Hz, 1.6 kHz, 2.4 kHz, 2.7 kHz, 3.0 kHz, 3.4 kHz.

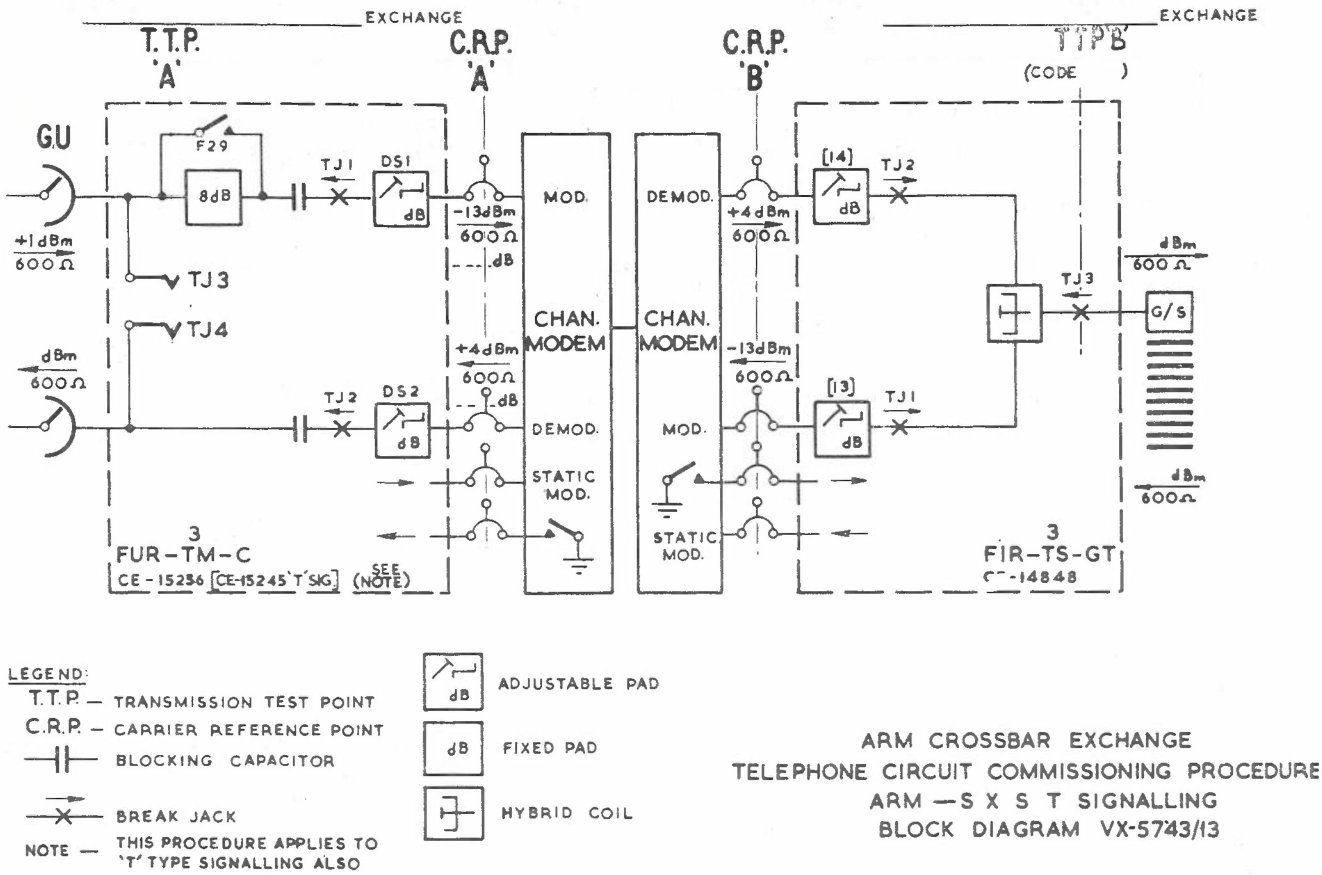
(7) **Noise Test:** At both ends, terminate the 'send' direction at TJ3 in 600 ohms and apply a psophometer in the speech weighted position to the receive direction at TJ4. The reading shall not exceed .... dBm at either end of the circuit.

Fig. 4. — Telephone Circuit Commissioning Procedure ARM to ARM T Signalling.

diagrams show the basic transmission elements and jacking points for each type of telephone circuit. This information indicates to the Testing Officer the location of pads and hybrids in relation to the jacking points, the appropriate send and receive test levels and measuring impedances.

It will be noted that all test levels are given in dBm and the term relative level is not referred to in the procedures. The authors consider that by specifying test levels in terms of dBm and not in terms of relative levels, the Testing Officer is left in no doubt as to the setting of his test instruments. Another advantage gained by using dBm is that all test result sheets from any ARM exchange, for example, will be immediately comparable.

Referring to the block diagram in Fig. 6, it can be seen that the type of relay set at each end of the telephone circuit is specified by its symbol and



Prior to commissioning tests, all adjustable pads in relay sets at both ends should have been set to:—

(i) values shown on Drawing VX. 5743/13.

(ii) values not shown on VX. 5743/13 but derived from
  (a) the send and receive levels specified on VX. 5743/13,
  (b) the measured loss between CRP 'B' and TTP 'B'
  (c) the average error in levels at CRP 'A' as specified on VX. 5743/13 (refer to Drawing VSK-X-22 for pad strapping).

(iii) strap up all pads to determined value, measure end section loss of each circuit and record on CID. 205, Pt. III.

It is assumed that the carrier systems are lined up correctly and no adjustment should be made to the carrier system levels except under direction from Group Control.

(1) Cross-calibrate all instruments to be used for the same purpose in any one station.

(2) Connect Automatic Exchange Tester (AET) to TJ3 and TJ4 in FUR and call distant Test Number (code ....).

(3) Ask distant end to apply answer condition.

(4) Send 820 Hz at + 1 dBm/600 ohms from TTP 'A' TJ3 and distant end should read ....dBm/600 ohms at TTP 'B' TJ3. Record level on CID. 205, Pt. I.

(5) Ask distant end to send 820 Hz at ....dBm/600 ohms from TTP 'B' and ....dBm/600 ohms should be read at TTP 'A' TJ4. Record level on CID. 205, Pt. I. The Supervising Technician in charge of the project, under the guidance of his engineer, will examine the results recorded on CID. 205 and decide further action.

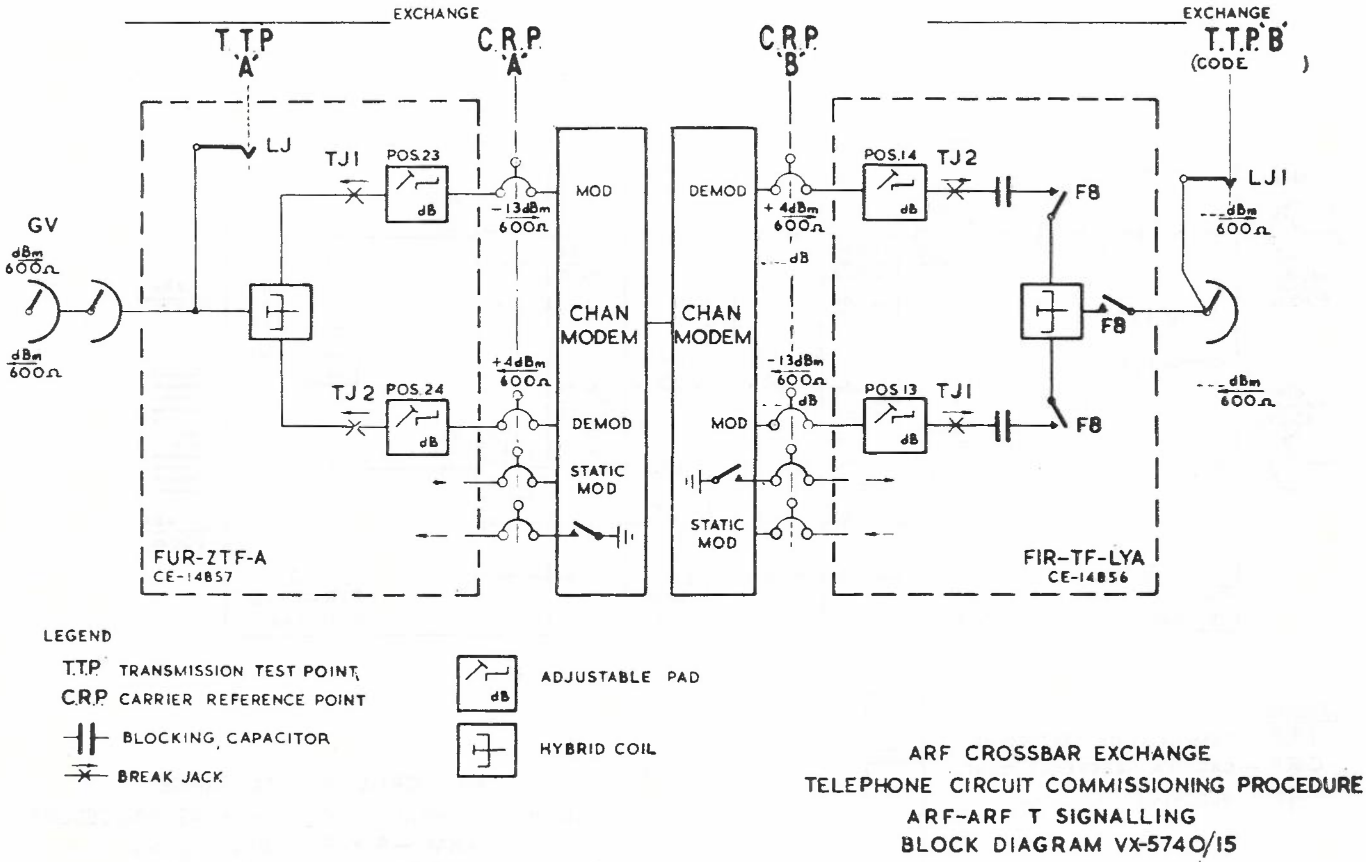
(6) **Variation of Receive Levels with respect to 820 Hz:** Repeat steps (4) and (5), but send the following spot frequencies at a level of + 1 dBm/600 ohms and record all levels received on CID. 205, Pt. II. Where possible, use sweep equipment and graticule and sweep over the range — the reference point being 820 Hz.
Spot frequencies: 300 Hz, 400 Hz, 820 Hz, 1.6 kHz, 2.4 kHz, 2.7 kHz, 3.0 kHz, 3.4 kHz.

(7) **Noise Test:** At the local end terminate the 'send' direction at TJ.3 in 600 ohms and apply a psophometer in the speech weighted position to the receive direction at TJ4. At the distant end the psophometer terminates the 2W line. The reading shall not exceed .... dBm at the TTP 'A,' TJ4 and ....dBm at TTP 'B,' TJ3.

Fig. 5. — Telephone Circuit Commissioning Procedure ARM to Step-by-Step T Signalling.

CE drawing number, that is, FUR-ZTF-A, Drawing CE 14857, at the outgoing end and FIR-TF-LYA, Drawing CE 14856, at the beginning end. This block diagram and associated procedure can only be used for this specific telephone circuit. If a commissioning procedure is to be used for one or more types of telephone circuits, the alternative relay sets also should be marked on the block diagram as shown in Fig. 4.

When preparing telephone circuit commissioning procedures, it is important to show on the block diagram all relay sets included between the two TTP's. In some instances two relay sets in tandem at one or both



Prior to commissioning tests, all adjustable pads in relay sets at both ends should have been set to:—

(i) values shown on Drawing VX. 5740/15,

(ii) values not shown on VX. 5740/15 but derived from

(a) the send and receive levels specified on VX. 5740/15.

(b) the measured loss between CRP 'B' and TTP 'B.'

(c) the average error in levels at CRP 'A' as specified on VX. 5740/15 (refer to Drawing VSK-X-22 for pad strapping).

(iii) strap up all pads to determined value, measure end section loss of each circuit and record on CID. 205, Pt. III.

It is assumed that the carrier systems are lined up correctly and no adjustment should be made to the carrier system levels except under direction from Group Control.

(1) Cross-calibrate all instruments to be used for the same purpose in any one station.

(2) Connect Automatic Exchange Tester (AET) to LJ in FUR via Interface Unit and call distant end Test Number (code ....).

(3) When Distant End Test Number telephone bell rings, Distant End Technician is to plug Interface Unit into LJ1 in the unanswered condition. **Do Not Answer the Telephone!**

(4) Ask distant end to apply answer condition and insulate contacts 37 and 38 of relay F8.

(5) Send 820 Hz. at .... dBm/600 ohms from TTP 'A' and distant end should read .... dBm/600 ohms at TTP 'B.' Record level on CID. 205, Pt. I.

(6) Ask distant end to send 820 Hz at .... dBm/600 ohms from TTP 'B' and .... dBm/600 ohms should be read at TTP 'A.' Record level on CID. 205, Pt. I. The Supervising Technician in charge of the project, under the guidance of his engineer, will examine the results recorded on CID. 205, Pt. I, and decide further action.

(7) **Variation of Receive Levels with respect to 820 Hz:**—Repeat steps (5) and (6) but send the following spot frequencies at a level of .... dBm/600 ohms and record all levels received on CID. 205, Pt. II. Where possible, use sweep equipment and graticule and sweep over the range — the reference point being 820 Hz. Spot frequencies: 300 Hz, 400 Hz, 820 Hz, 1.6 kHz, 2.4 kHz, 2.7 kHz, 3.0 kHz, 3.4 kHz.

(8) **Noise Test:** Information in brackets indicates test from distant end, i.e., FIR. At FUR (FIR) terminate TTP 'A' (TTP 'B') in .... and apply a psophometer in the speech weighted position to TTP 'B' (TTP 'A'). The reading shall not exceed ....dBm at either end.

Fig. 6. — Telephone Circuit Commissioning Procedure ARF to ARF T Signalling.

ends of the telephone circuit may be required, and the transmission elements of all relay sets should be shown. It would be pointless trying to achieve accurate results unless full details of the transmission path are known.

Before the telephone circuit commissioning procedures are sent to field staff for implementation, send and receive levels as well as limits for stability balance return loss, echo balance return loss and noise should be included on the commissioning procedure in the blank spaces provided for this information.

At the present time in ARM exchanges, outgoing transmission tests are being performed with the aid of an ARM automatic exchange tester (AET) fitted with an extension unit into which is placed the transmission measuring set and interface unit. Fig. 7 shows an ARM AET being used to commission telephone circuits. The unit which houses the interface equipment also contains an Automatic Transmission Test Unit (ATTU) (Ref. 5, 6 and 7). The purpose of the interface unit is to provide DC isolation and circuit holding facilities during the commissioning tests.

Exchanges other than ARM exchanges require another type of interface unit which is referred to in Step 3 of the commissioning procedure shown in Fig. 6. The purpose of this interface unit is to provide DC isolation for the transmission measuring set, as well as an appropriate termination for the measurement being made. Fig. 8 shows the schematic circuit of the interface unit at present in use in Victoria. The unit, which has been more commonly known as a link loss test set, can be used with an automatic exchange tester, buttinski or telephone when originating outgoing tests, and when used on incoming tests provides answer, reversal and hold conditions. In both cases the interface unit can switch an oscillator or level meter across the circuit for carrying out transmission measurements.

Fig. 7. — ARM AET and Extension Unit in Use at Geelong ARM Exchange.

SETTING OF PADS.

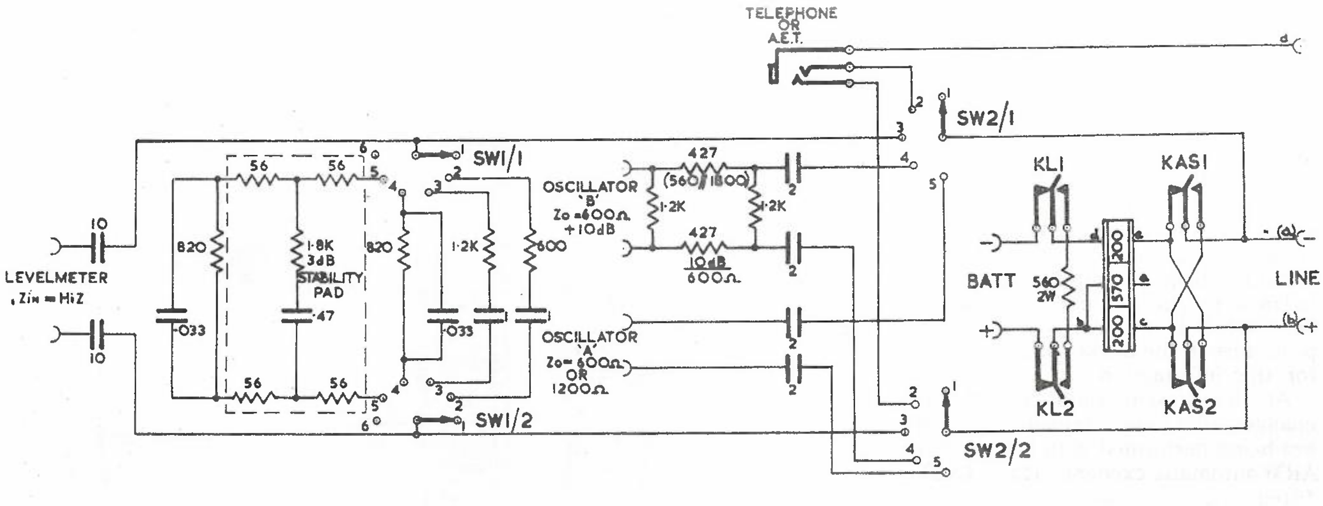
Since the end sections of telephone circuits in general are passive and include pads, considerable care should be taken when calculating and setting pad values. It is important to remember that end section loss measurements must be made between the CRP and TTP at each end of the circuit and not just across the relay set. Cabling losses between the CRP and the line signalling relay set are an integral part of the end section loss.

To set pads for telephone circuits on a given route a series of measurements is made on a sample of 3 relay sets at each end of the telephone circuit to determine the cabling and relay set wiring losses. Taking, for example, the type of telephone circuit shown in Fig. 4 and referring specifically to the outgoing end, the links at CRP 'A' should be removed before the end section measurements are made. In the FUR-TM-C relay set, 8dB pads should be inserted in the DS1 and DS2 positions and relay F29 operated manually to short circuit the 8dB pad. TJ3 of sample relay set 1 is connected by plug and cord to TJ3 of sample relay set 2. The loss of the two relay sets on their send sides is then found by measuring the loss between the two, —13 dBm carrier reference points for relay sets 1 and 2. Similar measurements should then be made with circuits 1 and 3 paired and 2 and 3 paired. If any of these measured losses vary by more than 0.3 dB from each other, a new sample of three relay sets should be chosen.

The results of the three readings taken are totalled and divided by six to give the mean loss from TTP 'A' to CRP 'A.' The value of the pad required to provide the correct loss between TTP 'A' and CRP 'A' is then calculated. For example, if the specified loss from TTP 'A' to CRP 'A' is 14dB and the measured cabling and relay set loss is 0.3 dB, then:

DS1 = Specified loss — (8dB + measured cabling and relay set loss).
= 14 — (8 + 0.3).
= 5.7 db, nearest pad value is 5.5 dB.

LARSSON & REID — Transmission Testing



SW2 FUNCTIONS

POSN.	FUNCTION
1	—
2	TELEPHONE OR A.E.T.
3	RECEIVE
4	SEND 600Ω
5	SEND 600Ω OR 1200Ω

SW1 FUNCTIONS

POSN	FUNCTION
1	REC. IMPED. -HiZ (OR ALT. SPECIFIED IMPED.)
2	" " 600Ω + 1uF
3	" " 1200Ω + 1uF (TANDEM)
4	" " 820Ω // ·033 (SUBS EQV.)
5	" " 820Ω // ·033 + 3dB PAD
6	" " -HiZ

$$\frac{\text{LOOP (KL)}}{2} + \frac{\text{ANSWER (KAS)}}{2}$$

Fig. 8. — Schematic Circuit of Interface Unit.

DS1 pads should therefore be set to 5.5 dB in all the FUR-TM-C relay sets on that particular route.

With the pad DS1 set to 5.5 dB, the loss from TTP 'A' to CRP 'A' should measure:

8 dB + 0.3 dB + 5.5 dB = 13.8 dB, that is, 0.2 dB less than the specified loss of 14 dB, but within the accepted tolerances of ± 0.25 dB. Loss measurements between TTP 'A' and CRP 'A' on all circuits of that route are made and the results should be within 13.8 ± 0.2 dB for all circuits. A similar procedure is carried out for the receive side of the circuit between TTP 'A' and CRP 'A' and the DS2 pad set accordingly.

The DS1 and DS2 pad values in the FIR-TM-Y1 relay sets at the incoming end of the telephone circuit are calculated and set in a similar manner. However, when calculating the pad values at the incoming end an effort should be made to compensate for the difference between the specified loss and the measured loss at the 'A' end of the circuit. As stated in the example above, the specified loss between the TTP 'A' and CRP 'A' is 14 dB, but the measured loss is 13.8 dB, that is, 0.2 dB difference. Therefore, to correct for this difference the loss between CRP 'B' and TTP 'B' should be increased by 0.2 dB to compensate for end 'A.' Assuming the specified loss from CRP 'B' to TTP 'B' is 3.5 dB, this should be increased to 3.7 dB to compensate for end 'A.' This value of the DS2 pad would then be found from:

DS2 = Specified loss + 0.2.
— Measured cabling and relay set loss.
= 3.7 — Measured cabling and relay set loss.

Summarising,

Specified loss, end 'A', 14 dB
+ Specified loss, end 'B', 3.5 dB
= 17.5 dB.

Measured loss, end 'A,' 13.8 dB
+ Compensated loss, end 'B,' 3.7 dB.
= 17.5 dB.

It is important that the end sections of telephone circuits are set as precisely as possible and checked to close tolerances, as these are subject to little change of loss in service.

It will be noted also that all setting and measuring of end sections is carried out independently of the carrier system.

CONCLUSION.

The essence of successful commissioning of telephone circuits, especially in regard to transmission requirements, in the authors' opinion, is the preparation of appropriate commissioning procedures for each type of telephone circuit installed. Field experience to date has shown the need for these procedures, which, when prepared and used on the job, enable the work to be completed quickly and accurately. However, as the automatic access trunk testing positions become available and are installed in ARM and ARF minor switching exchanges, some commissioning procedures will be simplified.

Another important aspect in the preparation of commissioning procedures and the successful introduction of this method of commissioning, is the need for constant communication between field staff using the procedures and the officers responsible for the preparation of procedures. Good communication, that is, feed-back of problems or errors on the procedures will ensure that assistance or corrective advice can be given to the originator of the problem as well as sent to all other teams that may be engaged in the commissioning of similar telephone circuits.

With the increasing penetration of S.T.D. Telephone Traffic via the 4 wire ARM and 2 wire ARF transit exchanges, it is essential that proper attention be given to commissioning techniques, together with the supply and installation of adequate testing and measuring equipment.

ACKNOWLEDGMENTS.

The authors wish to acknowledge the initial work done in this field by the Headquarters ARM Transmission Measurements Working Party and the Long Line Equipment Installation and Transmission Testing Study Group of Victoria.

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TECHNICAL NEWS ITEM

VALUE ANALYSIS LEADS TO NEW PUBLIC TELEPHONE CABINET

The Australian Post Office has successfully applied value analysis techniques to the design of public telephone cabinets with a saving of some $140,000 on the first order of 2,500 cabinets. Deliveries of the cabinets began in December, 1969 and the order is to be filled over 15 months. Manufacture is taking place in Postal Workshop at Melbourne and Brisbane.

In 1967, the Post Office engaged a value engineering consultant, Denis Carroll Associates, to advise on the application of value analysis techniques Subsequently, a Post Office team of five drawn from design, customer, manufacturing, industrial engineering and procurement groups studied each component of the standard cabinet and several major and minor parts were eliminated or re-designed.

The re-designed model is aesthetically pleasing and some $56 cheaper than the CW505 model now in use. With about 2,000 cabinets going into service every year, substantial savings are expected.

Basically, the investigating team went for more glass and less aluminium in the new design, reduced the gauge of some aluminium sheeting from 10 to 16, and eliminated several braces and stiffeners. Big savings were effected by replacing anodised aluminium bottom panels with drawn sheet glass. (See Figs. 1 and 2.)

Overall manufacturing and installation costs are expected to be in the region of 25% less than for the old model, while annual maintenance costs are expected to be lower.

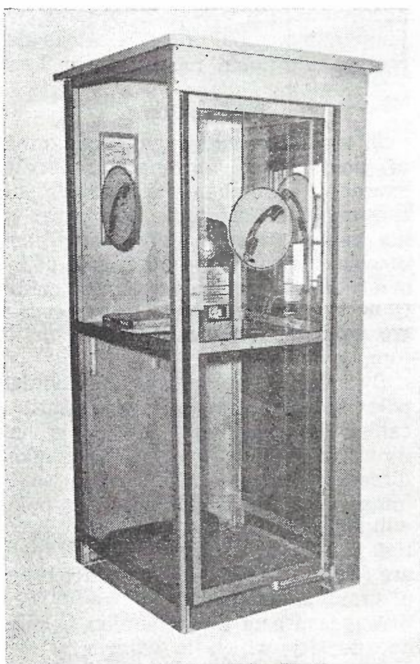

Fig. 1 — New Design

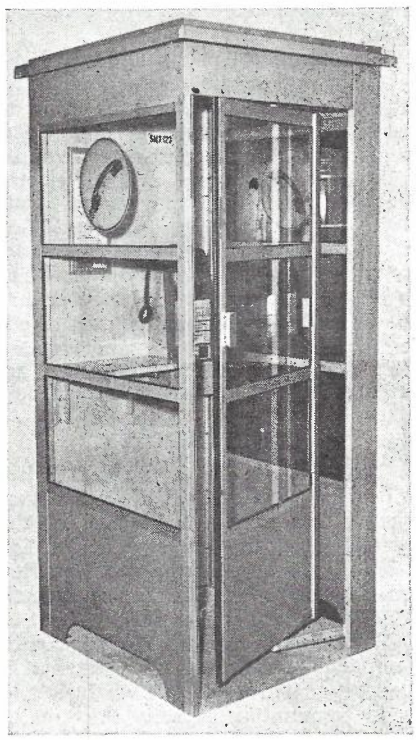

Fig. 2 — Previous Design

DEVELOPMENTS IN MAIN DISTRIBUTING FRAMES

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

INTRODUCTION.

In planning for the new Lonsdale subscribers' exchange in Melbourne, Victoria, the main distributing frame necessary to serve this building was seen to present many problems. The estimated future requirements of external and internal cable pairs to be terminated were far in excess of that of any existing m.d.f., as were also the number of jumper cross-connections. This led to an extensive study of m.d.f.'s in general, and an examination of the problems that had arisen on existing m.d.f.'s, with a view to adopting any improvements possible in the design of the Lonsdale m.d.f. to ensure that it shall remain satisfactory in the future.

FUNCTIONS OF M.D.F.

The m.d.f. serves an essential and important role in the telephone exchange. It provides for the termination of external and internal cables, and for all required inter-connections of the terminated pairs by means of jumpers.

The terminations on the m.d.f. include an opening point which facilitates testing, cutovers, and connection to recorded announcements, etc. The m.d.f. also accommodates any required protective equipment against electrical hazards which may arise from lightning discharge or fault condition in the external plant, such as contact with commercial power lines. The need for this protection, however, has now greatly diminished as most of our external plant is wholly underground (u.g.) and where aerial lead-ins are used, insulated drop wire is provided.

JUMPER DENSITY.

The construction of the m.d.f. provides for a horizontal side and a vertical side, so named because of the direction that the jumpers are run. External cables are normally terminated on the horizontal side and equipment cables on the vertical side.

Because the horizontal side carries jumpers between verticals of the m.d.f., the larger the number of verticals and their terminating capacity the greater the density of jumpers, and this becomes the greatest problem on large m.d.f.'s. Jumper density on the vertical side, however, is limited per vertical to the number of terminations on that vertical, plus some jumpers which are changing from one horizontal tray to another, such jumpers terminating both ends on the horizontal side. These would not increase on a large m.d.f. because the extra verticals would accommodate their share of such jumpers.

In the absence of any measures being adopted to reduce jumper density in the horizontal trays, and with random distribution of external cable terminations along the m.d.f., the greatest density of jumpers will occur near the mid point of the m.d.f., where half the total jumpers would be expected. A count of jumpers on existing m.d.f.'s has proved this to be correct.

The number of jumpers on each horizontal tray should be approximately the same if proper jumpering practice is applied. A count of jumpers on some m.d.f.'s has shown, however, that the more accessible trays carry more than their share of jumpers. This is due to favouring the accessible trays, where a choice exists, and this applies to u.g. to u.g. jumpers which terminate on a different tray at each end. It would also apply to jumpers terminating at both ends on the equipment side of the m.d.f., as any horizontal tray can be selected for these jumpers. Jumpers which terminate one end on the equipment side and the other end on the horizontal side have no option but to use the horizontal tray on which they terminate. These jumpers are fairly evenly distributed on all horizontal trays.

On the Melbourne City West m.d.f., which probably has the greatest jumper density in Victoria, the number of jumpers on the more accessible trays is much greater than the less accessible trays. A count of jumpers on the most congested tray showed a total of 4000 on that tray with a maximum density of 2000 jumpers crossing near the mid-point of the m.d.f. This density of jumpers is no problem and a much higher density would be quite tolerable.

The fact that all of the old type jumpers which were of large cross section and of rough surface fabric insulation, have been replaced over recent years with present-day p.v.c. insulated jumpers, has greatly minimised the jumper congestion. The removal of early type jumpers was a result of extensive re-jumpering in connection with the re-termination of existing cables on 50 pr. link mountings in lieu of 20 pr. and 25 pr. fuse mountings. This was necessary to clear the upper portion of the m.d.f. to provide terminations for new u.g. cables.

CONTROL OF JUMPER DENSITY.

It is estimated that with existing p.v.c. insulated m.d.f. jumper wire a maximum density of 3000 jumpers per horizontal tray at the most congested point would be quite tolerable. There are a number of ways by which the jumper density can be minimised and some of these measures can, with advantage, be applied even to m.d.f.'s where future jumper congestion is not likely to present any problem. The less the jumper density the better for running new jumpers, tracing of existing jumpers and removing of cancelled jumpers. In addition, most of the measures adopted to reduce jumper density will also result in shorter jumpers.

Tie Cables.

The use of tie cables within the m.d.f. is a ready means of preventing jumper congestion. These tie cables bypass the points where congestion would otherwise arise. However, in addition to the cost of providing tie cables and the terminating space that they occupy on the m.d.f., cross connections which use them require two jumpers instead of one. Tie cables also require additional records to be kept.

Segregation.

In a tandem exchange, the number of junction pair terminations usually exceeds the number of subscriber pair terminations. If these two types of u.g. cables are separately grouped and of course also on the other side of the m.d.f. the appropriate equipment cables (junction and subscriber) are located, we gain a very large reduction in jumper density.

By selecting an appropriate dividing point between junction and subscriber cables the m.d.f. can develop in one direction for junctions and in the other direction for subscribers. The only jumpers to cross this dividing point will be those which cross connect junction pairs to subscriber pairs, and these are few compared with the other types of cross-connections.

A measure of the reduction in jumper density which is gained by this arrangement of segregating the junction and subscriber portions of the m.d.f. can best be demonstrated by taking an ideal example where the number of junction cross-connections and of subscriber cross-connections are equal. It this case maximum jumper density appears near the midpoints of both the junction portion and the subscriber portion, where half of each type of jumper crosses. On an

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m.d.f. with mixed subscriber and junction cables the maximum density of jumpers is expected to be near the mid-point of the mixed frame, where half the total jumpers is expected to cross. The density of jumpers at this point will thus be double that of the segregated m.d.f.

In the past, there have been objections on the external plant side, to segregating subscriber and junction cables. This was mainly because of some lack of flexibility in the cable well when the cables are supported on shelves each accommodating three or four cables. To avoid crossing over cables on a shelf, the inner cable must terminate first, then the next one, and so on.

The current method used in supporting cables in the cable well is fully flexible. Shelves are not used and the cables are run one above the other to form a single vertical layer, so that any cable can terminate on any position.

Preferential Allotment.

By providing for equipment development in more than one group, and allotting the equipment in the group nearest to the u.g. cable termination, the cross connecting jumpers between equipment and u.g. cable terminations can be greatly reduced in length. With two groups of equipment the average jumper length is halved and the jumper density reduced. Instead of a maximum jumper density of half the total jumpers appearing at the midpoint of the m.d.f., the maximum jumper density would be one-quarter of the total jumpers appearing at both the quarter and three-quarter points along the m.d.f. This assumes, of course, that the equipment terminations for each of the developing groups are suitably located along the m.d.f.

For subscriber equipment a possible arrangement would be that the odd hundreds appear on one half of the m.d.f. and the even hundreds on the other half. This arrangement would, however, probably increase the length of the cable run from the equipment to the m.d.f.

A more suitable arrangement is to provide the subscriber equipment terminations at the second point only at the later stage of development when the need arises. At that time the m.d.f. has grown in length towards its ultimate, and the need, or not, to minimise future jumper congestion by preferential allotment will be more apparent.

The adoption of preferential allotment has the disadvantage that the subscriber's number has to be allotted to suit the location of the u.g. cable pair. However, the person allotting the number could be supplied with each of the two groups of u.g. cables and their optimum number ranges for allotment.

Preferential allotment may be taken further by selecting not only the group of numbers but allotting the nearest spare number within the group. This will further reduce jumper length and jumper density, but is more difficult to practise as it may require inspection of the m.d.f. to decide upon the most suitable number for allotment in each instance.

To avoid number change when a subscriber moves to another address in the same exchange area, the preferential allotment practice need not be adhered to under these or other special circumstances.

For junction equipment, a similar scheme of two groups of terminations may allow preferential allotment of junction pairs to junction equipment. The provision of two developing groups of FUR and FIR racks is then required. These can be combined into a single group at the i.d.f.'s on which the equipment side of the relay sets are terminated.

Jumper Cables.

A large proportion of the jumpers on a tandem exchange m.d.f. are for cross-connecting pairs between two junction u.g. cables. This is also the case at many terminal exchanges, especially those near a main junction route which serves other exchanges. It is the usual practice in such cases to not provide 'through' cables, but to route them all via the m.d.f. and provide through jumpers. This gives maximum flexibility in meeting development on the many junction routes which are now necessary with crossbar, and it also facilitates dispersion of junctions throughout the various junction cables so that a junction cable failure does not cause the loss of all circuits on one route.

If the cross-connected pairs are allotted in groups which conform to their link mounting terminations, the use of jumper cables is facilitated. These jumper cables are used in lieu of separate jumpers to cross-connect groups of pairs between two link mountings. The size of cables used conforms to the capacity of terminating blocks, so that with 100 pair link mountings, 100 pair cables are used. Cross connections in this form cost less in material and less in labour than with 100 separate jumper pairs.

The jumper cables occupy less space than jumpers, but more importantly they do not occupy jumper space in the horizontal tray. These jumper cables can be accommodated beneath the tray either by tieing beneath the horizontals or by providing auxiliary trays as proposed on the Lonsdale m.d.f. These auxiliary trays do not impede access to the jumper trays because they are shorter and only three inches below the horizontal above them.

Cross-Connections in External Plant.

Where large groups of pairs on junction cables require cross-connecting for long-term periods, they can be jointed from one cable to the other in the cable well, cable tunnel, or a manhole. This eliminates these cross-connections from the m.d.f. Such pairs should not have a multiple appearance on the m.d.f. but should be cut away from it where they are through jointed. This removes a fault hazard and also avoids shunt capacitance, resulting in transmission attenuation, which increases with frequency.

With MFC signalling, where two frequencies constitute each code, increased attenuation of the higher frequency must be minimised, as the code receivers will not respond if the received levels of the two frequencies differ by more than 3dB.

In addition to eliminating m.d.f. jumpers for pairs, which are cross-connected externally, other advantages are the simplification of cross-connection records and greater security from fault conditions.

Direct Junction Cables.

The practice of terminating all junction cables on the m.d.f.'s of intermediate exchanges has a number of advantages. It is, however, expensive in cross-connecting labour, m.d.f. size, and building costs, including the larger cable chamber capacity which is necessary. It also increases the route distance of cable.

The provision of some 'through' junction cables reduces these costs, and gives greater security of service in the event of damage to an m.d.f. by fire or other hazard. There are already some examples of this practice in the Melbourne network, and more may occur in future.

This provision of through cables is merely taking the previous jumper reduction method a step further. It could be applied to some existing cables, in which case the m.d.f. terminations become spare for new cables.

Thinner Jumper Wire.

The present standard jumper wire for m.d.f.'s is of .028 inch diameter conductors. Field trials of the thinner jumper wire of .020 inch conductors have proved quite satisfactory and its use is proposed for Lonsdale m.d.f. and on other m.d.f.'s where jumper density is expected to be high.

This smaller jumper wire weighs less and occupies little more than half the space in the jumper tray as compared with the larger size, and is expected to greatly increase the maximum number of jumpers that can be tolerated before jumper congestion problems arise. As its cost is much less than that of present standard m.d.f. jumper wire, large savings will result if the smaller jumper wire becomes the new standard for all m.d.f.'s, and experience to date has shown no reason why this should not be so.

Damage to the insulation of jumper wire has been fairly prevalent in the past. The main cause was abrasion through feeding the jumper wire through the small jumper ring and dragging it across existing jumpers. This is avoided by running the jumper clear of the m.d.f., and after terminating one end, laying the jumper in the horizontal tray. This method of running jumpers is described later. Another cause of damage was the softness of the p.v.c. insulation, where on some i.d.f.'s the pressure against the jumper ring due to the weight of jumpers had bared some of the conductors. Investigation showed that the hardness of the p.v.c. insulation on samples tested varied from 'Barcol' hardness of 50 down to as low as 12 (Ref. 1). The hardness factor has since been added to the specification for p.v.c. insulation. A 'Barcol' hardness of 50 has been specified and this should avoid similar failures in the future.

The minimum thickness of insulation specified for thin jumper wire is 0.007 inches compared with 0.010 inches for the thick jumper wire. The thin jumper wire is therefore slightly more prone to damage to the insulation, but this should not occur with proper jumpering practices.

TERMINATING CAPACITY PER VERTICAL.

Thirty years ago the u.g. cables were terminated on 20 pair fuse mountings, and equipment cables were terminated on 20 pair protector mountings. Soon afterwards, the 20 pair fuse mounting was superseded by one having 25 pairs capacity.

The introduction of 50 pair link mountings approximately 15 years ago gave a very large increase in terminating capacity per m.d.f. vertical for u.g. cables. At the same time a 50 pair link mounting for the equipment side of the m.d.f. became available, and this was used for terminating junction equipment. More recently this link mounting has been used extensively for terminating subscriber equipment in lieu of the 20 pair protector mounting. In suburban exchanges where a small proportion of lines include bare aerial construction, the 20 pair protector mountings are also provided on a sufficient scale to allow these lines to be jumpered in and out of the protectors (using only the heat coil).

The 50 pair link mounting has enabled many existing m.d.f.'s to cope with development, and has greatly reduced the number of verticals which would otherwise have been necessary. In many exchanges it has avoided the need for building extensions to accommodate additional m.d.f. verticals and has also avoided costly cable well extensions.

Recently developed is the 100 pair link mounting, and this will undoubtedly solve many future m.d.f. problems in the same way as the 50 pair link mounting has done in the past. It is expected that the 100 pair mounting will be used exclusively in future for all new u.g. cable terminations, and to replace fuse mountings and 50 pair link mountings on m.d.f.'s where space problems arise.

The 100 pair link mounting is also available for the equipment side of the m.d.f., and although the 50 pair mounting seems quite adequate in capacity on this side of the m.d.f., it is prudent not to waste space which could be of value in the future, say, for terminating u.g. cables on that side. The cost per pair with the 100 pair mounting is also less than that of the 50 pair mounting.

Summarising on the terminating capacity on m.d.f.'s, for terminating u.g. cables on the line side, we require only one-fifth of the number of verticals using 100 pair mountings, than we required thirty years ago when the

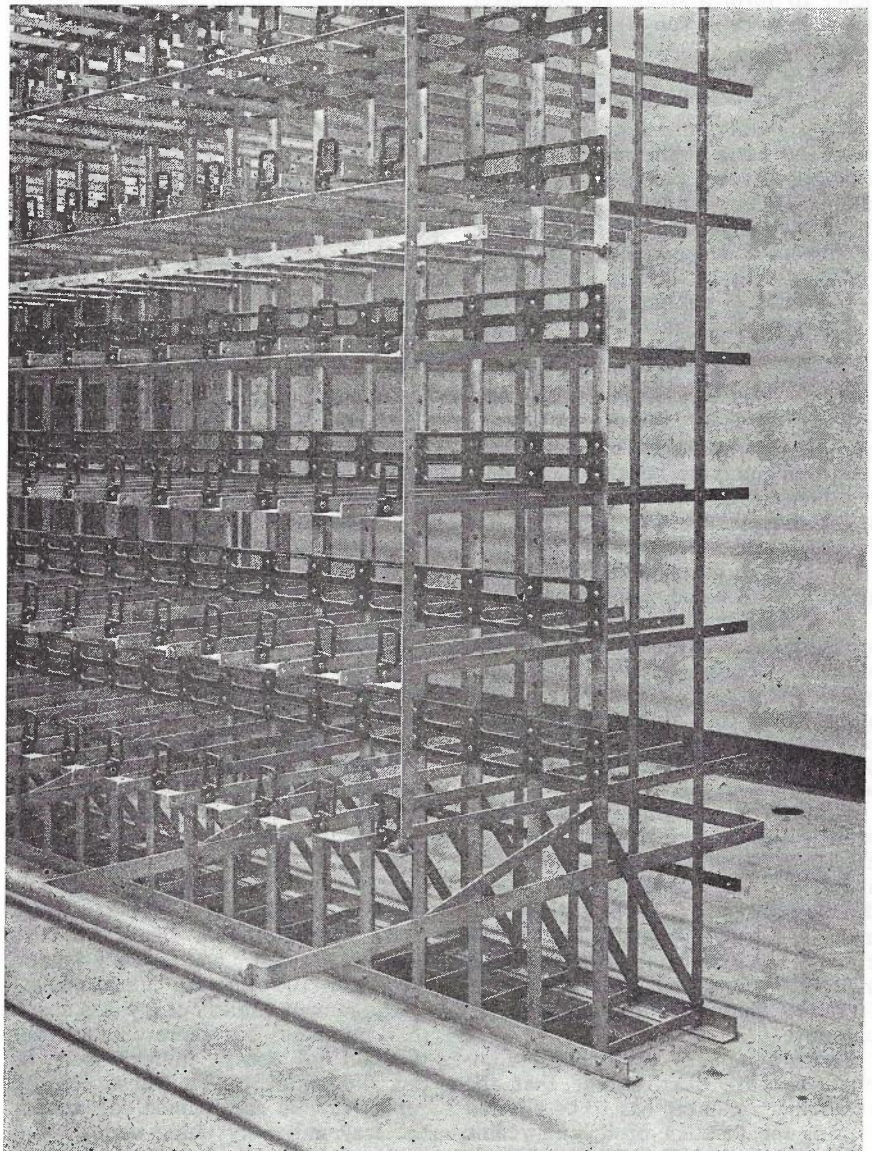

Fig. 1.— Details of the Lonsdale M.D.F.

PROVAN — M.D.F.'s

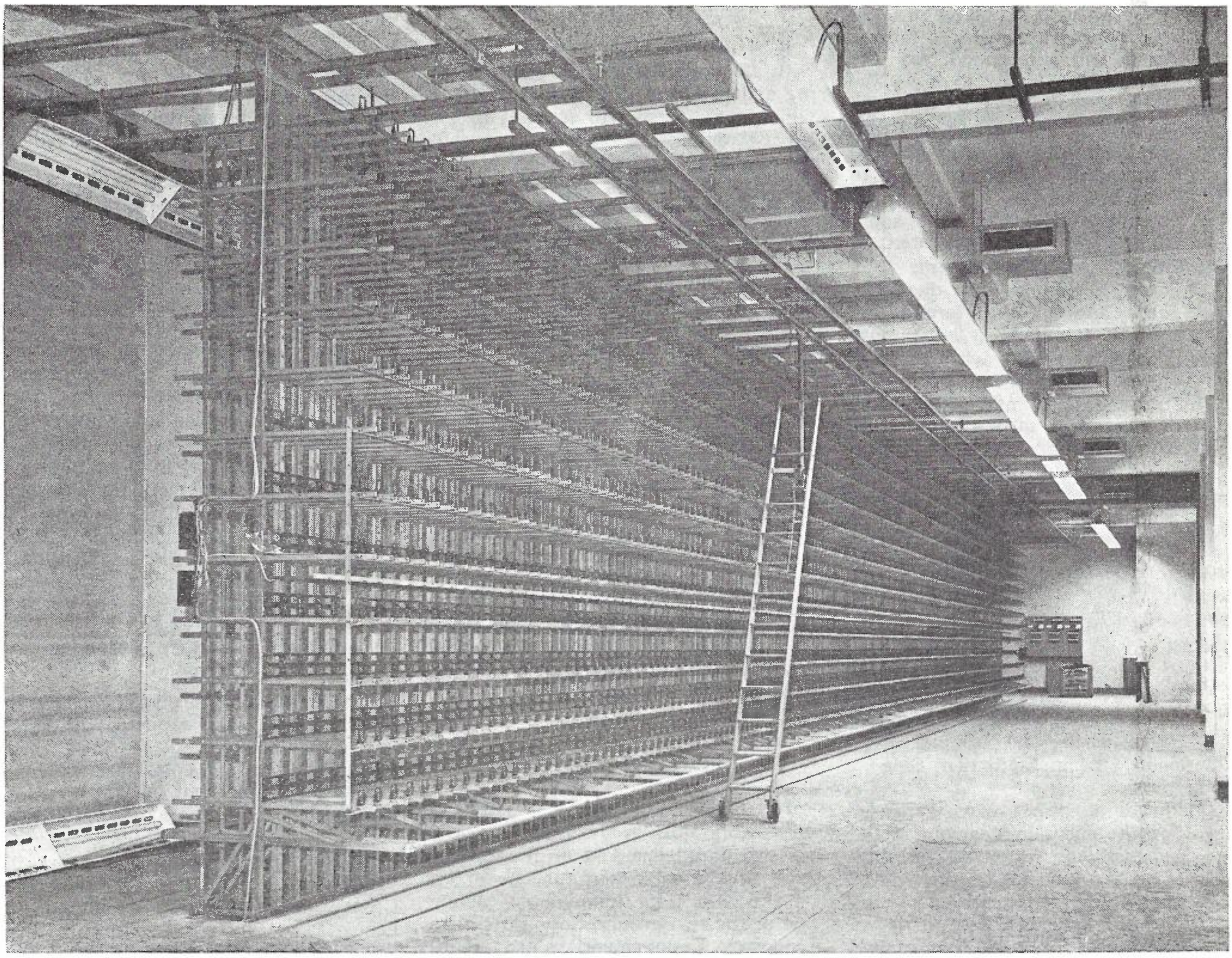

Fig. 2. — View of the Initial 200 Verticals at Lonsdale.

twenty-pair fuse mounting was used. Similar increased terminating capacity can be gained on the equipment side with 100 pair link mountings in lieu of 20 pair protector mountings.

CONSTRUCTIONAL CHANGES.

The m.d.f. has had only minor changes to its construction over the last few decades, and this must be an indication that it was very well designed. One change was the use of 1 in. x ⅛ in. angle iron for the horizontals in lieu of 1 in. x ⅜ in. channel, which became unavailable. The angle section is inferior to the channel because the jumpers are supported on a comparatively sharp edge of the angle compared with the ⅜ in. wide channel section.

Some of the changes that have been adopted for the Lonsdale m.d.f. can be seen in Figs. 1 and 2. The horizontals are constructed from 1 in. x ¼ in. bar, which gives a wider support for jumpers than did the 1 in. x ⅛ in. angle. The base is widened to enable it to straddle the 8 in. wide cable slot in the floor. In providing the wider base the construction is simplified by extending the fanning strip mounting bar down to the base.

The auxiliary tray for carrying jumper cables can be seen below the fifth horizontal (counting from the bottom). Although only the one tray is fitted, it is proposed that the same arrangement be provided below all horizontals within the junction portion of the m.d.f.

Both the large and small jumper rings are of new design, both being of moulded polyprophelene. The purpose of the two holes in the large jumper ring is to avoid upgoing jumpers rising in the tray and wasting jumper space. The lower hole is used exclusively until the depth of jumper blocks it. Then the upper hole is used.

JUMPERING PRACTICE.

Damage to the insulation of existing jumpers can occur when new jumpers are dragged across them. The friction causes the insulation to be bared owing to the resultant heat and wear. Tests have proved that a jumper drawn for only a few yards across the same point on another jumper will remove the insulation at that point. Inspection of existing m.d.f.'s showed that bared insulation on jumpers was very prevalent because of the practice of drawing the new jumper for its full length over existing jumpers. This method of running jumpers has now been abandoned.

An improved method of running jumpers which requires no additional effort and minimises the possibility of damage, because the jumper is not dragged along the horizontal tray, is described for various types of jumpers in the following paragraphs:

Line Side to Equipment Side Jumpers:

(a) From a jumper wire dispenser near the termination point on the line side, the end of the jumper wire is carried to the vertical where it is to terminate.

The end is then poked through the appropriate large jumper ring, and terminated on the vertical side.

(b) From the horizontal side, the jumper is then laid in the horizontal tray back to the line side terminating point, and cut to required length. The end is then poked through the small jumper ring and terminated.

Line Side to Line Side Jumpers:

(a) From a jumper wire dispenser near one of the termination points, the end of the jumper wire is carried to within two or three verticals of the other termination point. The end is then poked through the large jumper ring. On the vertical side, the end of the jumper is taken up or down as required and poked through the large jumper ring at the appropriate horizontal level. The end is then terminated on the horizontal side.

(b) The jumper is then laid in the horizontal tray back to the other termination point, and cut to required length. The end is then poked through the small jumper ring and terminated.

Equipment Side to Equipment Side Jumpers:

(a) From a jumper wire dispenser on the line side, near one of the verticals on which the termination is to be made, the end of the jumper is carried to the other vertical, where it is to terminate. It is then poked through the large jumper ring and terminated on the vertical side.

(b) From the horizontal side, the jumper is then laid in the horizontal tray, back to within two or three verticals before the one on which it is to terminate. The jumper is then cut to adequate length, taken through the small jumper ring, then across the tray and poked through the large jumper ring on the vertical where it is to terminate. It is then terminated on the vertical side.

To facilitate this method of running jumpers, jumper wire dispensers should be located on the line side near each end of the m.d.f., and also at intermediate points on long m.d.f.'s. The dispenser should be suspended from the tie bars so that the jumper wire is not dragged along the floor.

Jumpering congestion can be caused if, where there is a choice of horizontal trays, the more accessible trays are selected. The lightly loaded trays should be given preference, even though they may be less accessible.

Slack in Jumpers.

It is essential that jumpers remain with adequate slack to facilitate tracing and to ensure that future jumpers which cross them will lay flat in the tray. Otherwise, the underneath jumpers become tight, and also jumper space in the tray is wasted, because of air space underneath the jumpers. When terminating jumpers, therefore, as much slack should be left as can be tidily accommodated on the horizontal tray. This will vary from a minimum of six inches on the very short jumpers to several feet on long ones.

Removal of Cancelled Jumpers.

Care should be exercised when removing old jumpers, to avoid damage to existing jumpers. All bare wire and all wire which has been bent or kinked should be cut off before withdrawing. Its length should not be pulled through the small jumper ring. It should be gently withdrawn, and by pulling in line with the jumper along the horizontal tray. If excessive force is necessary, the jumper should be traced, cut, and removed in two or more lengths. Dead jumpers must always be removed.

LONSDALE M.D.F.

The Lonsdale building was provided with cable slots in the floor to allow for two parallel m.d.f's on the ground floor and a cable slot for one m.d.f. on the first floor immediately above one of the two ground floor slots. The proposed arrangement, since abandoned, was that the m.d.f. on the first floor would terminate all equipment cables on its vertical side, and have no terminations on its horizontal side, which would consist only of jumper trays which were to be doubled to reduce jumper density. The spacing of the horizontals was to be half that of the normal $11\frac{1}{4}$ in. centres to gain the additional trays. The m.d.f. immediately below on the ground floor was to terminate u.g. cables on both the horizontal and vertical sides.

Jumpers between u.g. cable pairs were to be confined to the ground floor m.d.f., but jumpers from u.g. pairs to equipment cable pairs were to rise and pass through the floor slot in the first floor and then run horizontally to the required equipment termination. Jumper density on the ground floor m.d.f. was to be minimised by eliminating horizontal running of equipment jumpers, which would have the extra jumper tray capacity for this purpose on the first floor m.d.f.

This arrangement had the disadvantage of jumpers having to be run between the ground and first floors, and jumper density seemed a problem on the horizontal trays of the first floor m.d.f. Although the number of jumpers per tray was halved by doubling the number of trays, the small spacing between trays would have impeded access to them.

A number of other m.d.f. arrangements were examined. These included two m.d.f.'s on the ground floor using one for subscribers and one for junctions. The advent of the 100 pair link mounting made a single m.d.f. the final choice. To reduce jumper density and jumper length, the junctions and subscribers must be segregated. The arrangement proposed was for subscriber u.g. cables and subscriber equipment cables to occupy ultimate verticals 1 to 100, and for junction u.g. cables and junction equipment cables to occupy verticals 101 onward.

The initial m.d.f. consists of 200 verticals occupying vertical positions 31 to 230, allowing for future growth in both directions.

Terminations and Cross-Connections.

The Lonsdale m.d.f. design was based upon the following expected ultimate requirements:

Subscriber u.g. pairs, 124,000 having 56 per cent. occupancy ...... =	69,400
Junction u.g. pairs, 211,000, having 78 per cent. occupancy ...... =	164,500

Cross-connections were estimated to be:

(a)	Junction u.g. cable to Junction u.g. cable	42,000
(b)	Junction u.g. cable to Subscriber u.g. cable	20,000
(c)	Subscriber u.g. cable to Subscriber u.g. cable ...	4,000
(d)	Junction u.g. cable to Equipment	60,580
(e)	Subscriber u.g. cable to Equipment	41,440
	Total cross-connections	168,020

The total of u.g. pairs to be terminated is 335,000. With 100 pair link mountings the line side capacity of the m.d.f. is 1200 pairs per vertical. The number of verticals required is 335,000/1200 = 280. There is space for the one m.d.f. to grow to 350 verticals so that it is unlikely that a second m.d.f. will ever be required.

With u.g. subscriber and junction cables terminated along the m.d.f. in the order in which they are provided, we would have a mixed m.d.f. with a total of 168,020 cross-connections. Assuming no tie cables, there would be 168,020 jumpers. The average number of jumpers per horizontal tray would be one-twelfth of this total, and the maximum jumper density would be near the mid-point of the m.d.f., where half the jumpers would be expected to appear. The average density per tray at this point would be 168,020/24 = 7001. This would be far in excess of a tolerable density.

By separate grouping of subscriber u.g. cables and junction u.g. cables along the m.d.f., and of course terminating the subscriber equipment cables and the junction equipment cables on the appropriate portion of the m.d.f. the jumper density is greatly reduced. We then have divided the m.d.f. into two adjoining portions, one for subscribers and the other for junctions.

With this arrangement, the only jumpers not confined to the one portion of the m.d.f. are those in item (b) above, which is 20,000 cross-connections between subscriber u.g. pairs and junction u.g. pairs.

The subscriber portion of the m.d.f. will have jumpers in items (b), (c) and (e), a total of 65,440. Half of these jumpers will cross near the mid-point, where the greatest jumper density will occur. The average per horizontal jumper tray at this point will therefore be one-twenty-fourth of 65,440, which is 2727. This is quite a tolerable jumper density.

The junction portion of the m.d.f. will have jumpers in items (a), (b) and (d), a total of 122,580. Half of these jumpers will cross near the mid-point, where the greatest jumper density will occur. The average per horizontal jumper tray at this point will therefore be one-twenty-fourth of 122,580, which is 5107. This jumper density is much too great as a maximum of something like 3000 is all that should be tolerated.

Although it is necessary to further reduce jumper density on the junction portion of the m.d.f., our calculations to this point show what a large reduction in jumper density is gained by separating subscriber and junction terminations. The single mixed m.d.f. would have had an expected jumper density per tray of 7001. The separated subscriber and junction terminations reduce the jumper density to 2727 on the subscriber portion of the m.d.f. and 5107 on the junction portion.

Reduction of jumper density on the junction portion of the m.d.f. seems best achieved by attention to cross-connections in items (a) (junction to junction 42,000) and (b) (junction to subscriber 20,000).

Item (a) is confined to the junction portion of the m.d.f. and half of the 42,000 would be expected to cross its mid-point, thus constituting 1750 per jumper tray of the maximum density of 5107. The use of jumper cables is expected to be practicable for a large proportion of these cross-connections, and the remainder can use a comparatively small number of tie cable pairs, which would be provided, if necessary, within the junction portion of the m.d.f. This would reduce maximum jumper density per tray on the junction portion of the m.d.f. from 5107 to 3357.

Item (b), junction to subscriber cross-connections, would constitute part of the maximum jumper density on both the subscriber and the junction portions of the m.d.f. Of the total 20,000, approximately 10,000 would cross the points of maximum jumper densities.

The provision of 10,000 tie pairs terminating beyond the mid points of both the subscriber and junction portions of the m.d.f. can eliminate these jumpers from the most congested areas, thus reducing maximum jumper density per jumper tray on both subscriber and junction portions of the m.d.f. by 833. Maximum jumper density per jumper tray is then reduced from 2727 to 1894 on the subscriber portion, and from 3357 to 2524 on the junction portion. These maximum jumper densities are quite modest, so that the need for reduction by other means such as preferential allotment of equipment seems unnecessary.

Future requirements of u.g. cable terminations, junction equipment, subscriber equipment and the cross-connections may differ greatly from present predictions. By using 100 pair link mountings for all terminations on the equipment side of the m.d.f., there will remain a large reserve of terminating space for unforeseen requirements, including additional tie circuits.

TIE CABLES TO CITY WEST M.D.F.

In the previous calculation of jumper density, etc., for Lonsdale m.d.f. the estimated ultimate requirements when City West m.d.f. is eliminated have been taken. This will not take place for thirty years, but Lonsdale m.d.f. will progressively take over the function of City West m.d.f. During this period the need for tie cables between the two m.d.f.'s is expected to rise fairly rapidly to a maximum of 21,000 pairs and then reduce gradually as each m.d.f. becomes less dependent on the other and a larger proportion of cross-connections are confined to the one m.d.f.

About 70 per cent of the total tie pairs will be used for cross-connecting u.g. pairs between the two m.d.f.'s. The next largest number will be required for Lonsdale u.g. pairs to City West equipment pairs. Tie pairs would be also required for connections between Lonsdale equipment and City West equipment, and for connections between Lonsdale equipment and City West u.g. pairs.

Consideration was given to providing four separate groups of ties such that all terminations would appear on the opposite side of each m.d.f. from the pair to which they were jumpered. All tie jumpers would then cross from one side of the m.d.f. to the other side.

Although this may be the best for jumpering, it was decided that all of these tie pairs should terminate on the equipment side of the Lonsdale m.d.f. This will suit the majority of jumpers and there is really no problem with jumpers that terminate at each end on the same side of the m.d.f. The advantages of this arrangement are that surplus terminating capacity exists on the equipment side, requirements for all ties is provided in one group, and selection of a suitable tie pair is simplified.

The tie pairs on the Lonsdale m.d.f. will terminate as required in groups of 2000 pairs at a number of points along the m.d.f. On the City West m.d.f. 1000 of each group from Lonsdale will terminate near the quarter point and the other 1000 near the three-quarter point along the m.d.f. This arrangement will minimise jumper length and congestion on both m.d.f.'s. Selection of a tie pair at Lonsdale will be determined by the nearest 2000 pair termination group and its 1000 sub-group, which best allows the shortest jumper at City West m.d.f.

CONCLUSION.

Many of the developments resulting from the study of the problems associated with the design of Lonsdale m.d.f. are applicable to some existing and future m.d.f.'s, especially the larger ones. Jumper density in the horizontal tray can become the greatest problem on large m.d.f.'s and much of this article is devoted to an examination of a number of ways in which it can be controlled. The practices to be adopted in running jumpers, which minimise damage to the insulation of existing jumpers, are of importance on all m.d.f.'s. With the use of thinner jumper wire, which should become the standard in future, this method of jumpering is of even greater importance.

The new 100 pair link mounting has enabled a single conventional m.d.f. to provide, with a fair margin of reserve, for all of the predicted terminations necessary at Lonsdale. It has solved many problems at this exchange, and will undoubtedly reduce many future problems at other exchanges.

REFERENCE

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MANAGEMENT CONTROL SYSTEMS

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INTRODUCTION.

Engineers may experience considerable frustration in performing day to day management functions. This can be partly attributed to difficulty in making accurate assessments as to the most effective plan for work allocation consistent with the normal resource limitations of capacity, capability and time. Hence accurate and detailed information concerning work performance is essential.

In developing information systems the industrial engineer aims to provide the engineering manager with accurate information to assist in more effective management and control of his domain. Technological developments have, in general, overshadowed advances in application of management techniques and too little emphasis has been given to developing the engineer as a manager.

On the job the technical complexity of the engineer's work continues to increase and time saved by providing him with improved management techniques will enable him to give greater attention to technical problems. In essence, engineering management should ensure that available resources are allocated most efficiently to the various activities, such that staff are operating at optimum effectiveness and the service objectives of the organisation are being attained at minimum cost. The high cost of labour resources in relation to other expenditure suggests that management decisions should warrant at least the same degree of cost-benefit analysis as that currently being expended on technological decisions.

Engineers must also recognise the increasing complexity of their role as a manager and take advantage of the more recent developments in management science to further their efforts towards productivity improvement. One of the most important of these developments is the management control system, which can provide timely and accurate control information.

The dimensioning and measurement of work being performed in each plant (subscribers' equipment, exchange equipment, external plant, etc.) operation is the best starting point towards the selection of plant areas for future improvement studies, having due regard to the most profitable expenditure of resources in competition with plant or overhead activities.

THE MANAGEMENT PROCESS.

Management seeks to utilise and co-ordinate available resources and to maximise productivity consistent with the corporate objectives. The first need for any manager is to identify his position in the organisation and to set targets in accordance with the objectives to be achieved. Before a particular project commences he must determine the group to whom responsibility for certain activities will be assigned, define the working relationships that will exist, and assemble resources in accordance with a planned sequence. Measurement of progress, effectiveness, quality and cost must be carried out during performance of the work so that an evaluation can be made of the overall performance and compliance with the original plan. Evaluation of job progress will permit immediate reallocation of resources and provide information for the planning of future work. This return to the planning of future objectives completes the cycle in the information flow process, a pattern commonly identified with the classical school of management and said to occur at all management levels. Fig. 1 illustrates the general form of the management cycle and emphasizes the cyclic dependency of the different activities.

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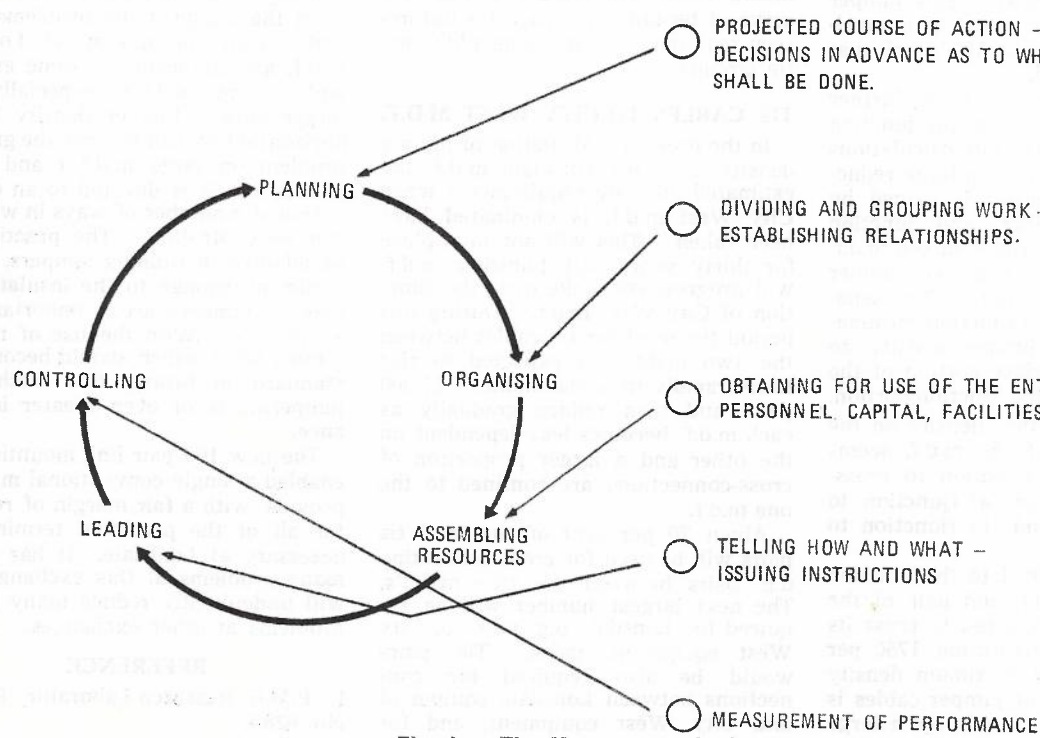

Fig. 1. — The Management Cycle.

A close examination of this cycle will reveal a system with similarities to other fields. If we consider a feed back amplifier, a thermostat or a governor, we note that their function is illustrated by the same pre-planning of output requirements, the setting of a standard, the sampling of an output and comparison of this sample with with the present standard and subsequent adjustment of the input to reduce any variance detected. The feed back amplifier, the thermostat and the governor all belong to different engineering sciences, but all are commonly called control systems. It is fitting, therefore, that a system devised to employ all the activities of the management cycle should be called a Management Control System. Management control systems enable managers to ensure that resources are obtained and used effectively towards the attainment of the objectives of the organisation (see also Ref. 1).

MANAGEMENT CONTROL SYSTEMS

The activities of the management cycle can be combined into three functions: programming, scheduling and control.

The Programming Phase.

Programming is the strategy of employment. It is the fitting of the required work to the planned available resources with due regard to:

(i) Identification of work.
(ii) Priorities of tasks.
(iii) Capacity and type of resources.

A programme becomes a listing of work, in priority order, to broad groups of facilities or resources for a reasonable period in the future and is designed to achieve certain objectives by the optimum use of available resources. Programming is a technique which is appropriate to top and middle management levels because it provides a 'picture' of the work load ahead, and a broad indication of the resources which will be required.

The basic requirement in the programming phase is the accurate determination of resource capacities on one hand and work load contents on the other. The capacity of a resource may, in general, be expressed in manhours or equivalent manhours and must take into account total available working hours, leave requirements, training and supervisory commitments, performance and overhead efficiencies, lost and waiting times. Work contents of a job need incorporate only the estimate of times to perform discrete activities, thus reducing the number of variables in this function. Unless capacity and work content are determined accurately, it will be found that the work is not allocated efficiently to the staff and will quickly fall out of step with the planned rate of progress, necessitating frequent reviews and costly reprogramming.

Programming must provide for advance ordering of resources and systematic allocation of work. The programme must incorporate categories of available resources according to the type of work, and as such, has the following advantages:

(i) an overall picture is provided relating to work to be done;
(ii) the state of work preparation is indicated succinctly.
(iii) controlled issue of resources to the work situation in accordance with the programme.
(iv) a basis is provided for measurement of the effectiveness of work performed.

The Scheduling Phase.

Scheduling is the assigning of work to specific resources at a specific time. Whereas programming is the strategy of allocation, scheduling is the tactics of disposition of resources. Scheduling consists of two functions:

(i) the distribution of resources to specific jobs, or conversely, the allocation of work to various skills or specific facilities.
(ii) the assignment of start and finish times to individual jobs.

Scheduling is designed to assist the controlling officer to have a complete knowledge of the work and the sequence in which it is to be performed. Critical areas are highlighted and progress can be planned for the efficient allocation and reallocation of scarce resources to achieve maximum utilisation. Every effort can be made to ensure that material is available when and where it is needed.

Scheduling can take several forms and is often designed to suit organisational or operational specifications. The short duration scheduling performed by the despatcher of a Fault Despatch Centre in the A.P.O. is based on the requirement to optimise service to the subscriber, whilst the sophisticated PERT scheduling employed in telephone exchange installation work optimises the efficiency of allocation of resources and the flow of material. Irrespective of the format, scheduling is best performed by the work supervisor. It acquaints him most closely with the work flow, assists with his later assessment of progress, and enables work balancing to be effected.

When assigning work from a schedule, the amount of work allocated to any particular unit must be:

(i) sufficient to enable reasonably efficient allocation of skills;
(ii) not so great as to require too much re-scheduling; and
(iii) sufficient to allow some flexibility in the change of programmed work.

Limited supervision work would be divided into short duration activities and an allocation of twice the daily capacity of the working group may be typical. For close supervision, longer duration tasks are generally established and a work allocation of twice the weekly capacity of the unit may be in order with weekly reallocation of new work after review of progress.

A schedule should be reviewed frequently, and, if it is to be fully effective, updated or, if necessary, a new schedule produced. This is one of the important features of scheduling which emphasizes its difference from the programming phase. Whereas the programme should remain fairly static over its period of usefulness, the schedule provides the flexibility to account for the constant changes that inevitably occur in any multi-resource work. For this reason the mechanism of the schedule should be carefully selected to ensure easy operation and simple updating procedures. Various types of boards and charting systems can be used (Ref. 2); a built in control should be employed with each mechanism to ensure that the scheduling action is being carried out. Often, because of lack of training or incorrect choice of the scheduling mechanism, the process becomes a burden to the supervisor and too often represents only a pictorial record of how a job might have been done.

Summarising, scheduling should be adequate for the project, sufficiently flexible to account for changes, easy to operate, and easy to understand.

The Control Phase.

Control, in an Industrial Engineering sense, and indeed in most engineering and management situations, is the assurance that the desired results are obtained and refers to the following:

(i) the measurement of performance
(ii) comparison of actual performance with planned or standard; and
(iii) instigation of corrective action to adjust any variance determined.

The control step of a management system is vital in that if omitted it renders the scheduling pointless and deteriorates the effectiveness of programming. Effective control implies an effective reporting system of critical data from the field which is summarised for progressive use up the line of management. Control is needed to ensure that targets are met, resources are used as planned and productivity is maximised.

Control is one of the major functions which should be used by management in the pursuit of improved productivity and is essential to further economic growth of any business undertaking. Emphasis on responsibility accounting will undoubtedly cause technically oriented engineering managers to rethink the areas of greatest profit and assess the need for increased financial and administrative control at the expense of technical perfection. This will lead to the maximisation of business opportunities and the optimum use of available resources consistent with the restraints of the organisation.

INTEGRATED CONTROL SYSTEMS.

Programming, scheduling and control have been reviewed above as isolated functions of management and in many situations these functions can be separately applied. However, as illustrated in Fig 1, there is a cyclic dependency in the total function of management that demands the integration of the three functions. At each management level, an interdependency also exists between these steps in that control action and scheduling will be influenced by the requirements of the programme, while the achievements measured during the control phase may be influenced by the content of the programme and schedule. In addition, formal and informal lines of communication exist in any organisation between the various management levels. The full management system of an organisation, therefore, is said to be integrated by the information flows within the system.

The integrated system designed for engineering management requires the passing down from top management of the objectives, plans and policies of the organisation, which can be progressively developed in greater detail at the lower levels of the organisation, such that achievements can be measured and compared against the targets and programmes set at each organisation level. This same information must be capable of summary for use by top management in policy making and top level planning. Such a system is illustrated in Fig. 2 and this diagram can be used as a basic model for the creation of management control systems.

Several characteristics of this system warrant particular comment as follows:

(i) The system consists of a major information cycle with a series of sub-cycles at each level of management and displays the interdependency of one level of an organisation on another. The breakdown or cessation of communication at any level will affect the total system.

(ii) Source data for the upward information flow is achieved from the operative level.

(iii) Information is processed and acted upon at each level.

(iv) Information is provided to successive levels of management by systematic processing and summarising.

(v) Management and administrative action occurs as a result of specific information provided to each level.

(vi) At the supervisory level, progress information is generated in terms of achieving target performance. As the information is further processed and forwarded up the line of control, in combination with information from other areas as appropriate, it is converted progressively into the desired measures of effectiveness and efficiency for each level.

Accordingly, an integrated control system should conform to the following principles:

Furnish timely, adequate and accurate information: As previously point-

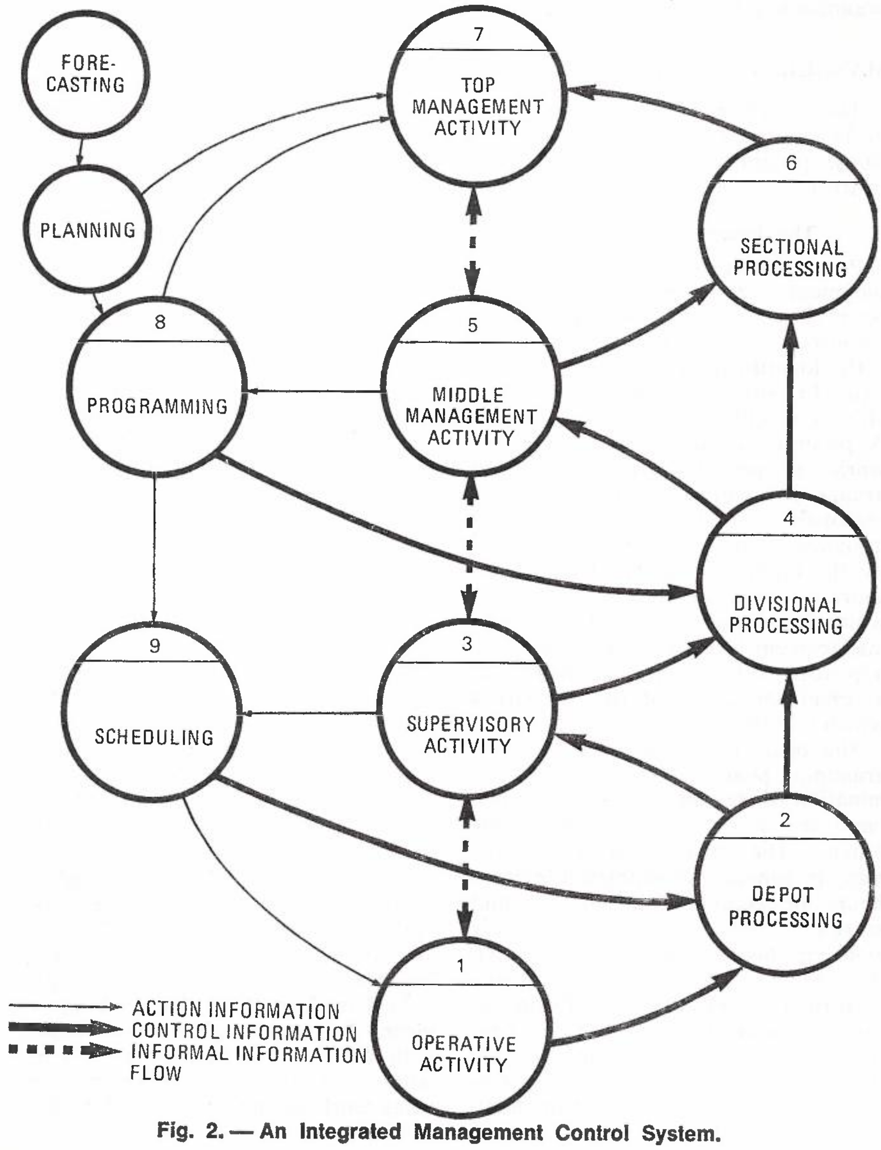

Fig. 2. — An Integrated Management Control System.

ed out, communication or information flow is the basis of any control system for management, and information generated within the system must be timely, adequate and accurate if it is to be useful.

Flexibility: The system must be capable of modification to accommodate changes in the operation or the conditions that exist in the activity. In addition, the system is required to adjust to variation in the workload.

Simplicity: The system must be designed in such a manner as to be clearly understandable to everyone connected with it.

Economic Justification: The fundamental reason for the development of a control system is to improve operating economies. In all cases, therefore, tangible profit returns must be anticipated to be in excess of costs expended in planning and control. The fact that many of the benefits accrued by control systems are intangible and therefore difficult to evaluate in monetary terms emphasizes the complexities experienced with such analysis. Only by comparing the cost effectiveness of operations when no formal system of control was used against the cost effectiveness when a control system is used, could the total benefits be measured accurately.

Force Prior Planning and Corrective Action: The system should, by its inherent features, ensure forward planning and facilitate corrective action.

Permit Management by Exception: A system which permits management by exception is one which reports to management only those things which require action by management. The system must also assure management that the unreported events are proceeding according to plan.

DESIGN OF MANAGEMENT CONTROL SYSTEMS.

The analytical approach to design of management control systems is ideally suited for the initial inquiry phase of the system survey function and has the objective of establishing the critical design parameters with minimum effort. The approach has been formalised by the authors from experience with analytical problem-solving techniques, well known to all engineers and managers, and the system approach to computer system design. The progressive steps enable the designer to reach an understanding of the organisational requirements for information and the action involved in obtaining and effectively utilising such information. The systems approach incorporates the following procedural steps:

State the Situation: A brief statement should outline the conceptual framework of the business functions and operating environment in which the proposed systems will be situated.

State the Aim: The objectives of the proposed systems should be developed and explanations outlined for any decisions likely to affect subsequent detailed development of the system. Following implementation of the system, the procedures should be analysed in retrospect to ensure that the original aims have been achieved.

State the Limitations of the Study: The terms of reference, qualifications, boundaries and degree of accuracy should be highlighted and subsequently related to the decision factors. For example, it may be considered necessary, for policy reasons, to exclude staff loading from the system and/or to tolerate less than complete accuracy in the interests of simplification.

Problem Analysis: This step requires the study of the organisation concerned in the operation of the proposed system. Business organisations can be studied by analysing the following structures:—

(i) The functional structure which concerns how and by whom the business functions are performed.

(ii) The authority structure which constrains the formal control system design and stems from the need to keep an orderly operational situation.

(iii) The status structure which provides the system of personal satisfaction, rewards and incentives so that personnel perform their work effectively.

The functional and authority structures complement each other in that the organisation achieves its objectives through the functional structure whilst the authority structure allows this to happen in the best possible way. The importance of the status structure is not to be underestimated, particularly during the design and implementation phases, and is of particular concern during system analysis. A system that affects the status relationships of working groups will also affect motivations.

The functional structure originates in the need for the division of labour and is analysed in accordance with two different analytical approaches:

(i) The identification of principal work items and the grouping of the detailed activities at the work face into a hierarchal model of the work.

(ii) The analysis of the work flow from the top down and the determination of the interrelationships and interdependencies.

The authority structure is essential within an organisation to direct and control expenditure of resources, consistent with the business objectives. This structure preserves the existence of the functional structure by a system of rewards and penalties and is in fact conjoined to the status structure in the form of the contract of employment. The contract of employment virtually says that certain people in the organisation have the right to direct and that employees will receive certain rewards for compliance to these directives. This command structure is of interest during systems analysis and extends to both the formal organisation and the informal (committees, working groups, etc.) organisation.

The purpose of studying the authority structure is to determine the degree of control that is exercised over decisions and actions within the functional structure and therefore the influence the authority structure has on the work flow. In this way the responsibility areas can be identified within the authority structure.

This step may lead to a recommendation for organisational change to increase the effectiveness of the proposed system. Such recommendations should probably be limited in the short term to minor staff re-arrangements as organisational changes do not, in general, eventuate rapidly. Long term recommendations relating to organisational changes would warrant proposals for phased involvement.

Decision Factors: The factors influencing the aim are analysed in detail, in accordance with the limitations of the proposed system as follows:—

(i) An organisational model is developed from the problem analysis phase which combines the work flow with the responsibility levels.

(ii) Functions at each level are defined in broad terms such as 'programme annual works' 'establish staff level,' etc. These functions must be related to the aim; unrelated functions should not be considered.

(iii) Objectives of each function are stated separately with a view to finding out why and how the function is performed.

(iv) The information required for each function is established and listed.

(v) The data required to provide each informational element is established.

(vi) The input required to achieve the data output can then be found by aggregation, identification and regrouping to form logical reporting elements to the various levels of the organisation.

These steps complete the system survey phase and at this point, from an analysis of the survey data, the type of scheduling arrangement may be selected, the scale of the desired control and informational elements being known.

A fairly wide range of programming and scheduling arrangements exists and these should be assessed carefully in accordance with the complexity of the workflow. For instance, if the control is basically related to the completion of project steps, the precise scheduling will result in effective control being achieved. Conversely, if the control is related to the completion of total jobs, then detailed scheduling would probably be wasted.

Work Measurement: The requirement for job estimating, scheduling and control information will dictate that standard times be established for work elements, dimensioned by rationalising the need for accuracy (small work elements) and convenience of recording (large work elements). Standard times are established by work measurement techniques and the one most often used in the A.P.O. at present is the Agreed Time technique, which finds favour because of its economical function with reasonable accuracy. The initial requirement for work measurement is to define the work in elements that are dimensioned to suit the technique employed. The work elements will invariably be of a different size to those selected for scheduling and control, particularly as the agreed times technique becomes more accurate as the size of the work element decreases. Work measurement should be commenced before the detailed system design is completed because it is often time consuming and the derived times are required during the design phase in order to optimise the combinations of basic activities for estimating, scheduling and control.

Design the Programming and Scheduling Systems: The scheduling arrangement would have been selected in a previous step, but the detailed design of the procedures for programming (estimating) and scheduling would need now to be finalised, so that they are integrated and appropriate for the type of work flow.

Design the Information System: The survey would have provided the information requirements for effective management in the area concerned. Some of this information may not directly relate to the functions of a management control system (programming, scheduling and control), but opportunities often exist to integrate these additional information flows. For example, cost of operations can be derived when all work performed is to be reported. The recording procedures are a natural derivation of the output requirements and a great deal of care should be placed in their design to minimise clerical effort and develop accuracy. The object of this step, which is closely associated with the previous, is to gather all the output information elements, including inherent system control requirements, and the input or reporting procedures into a specification that can be employed for creating the data processing, whether automatic or manual.

Simulation: The design should be simulated in a model or workshop situation prior to finalisation of the system design to ensure that all steps and interactions are covered.

Documentation: The analytical or systems report should be documented as the outcome of the system analysis/design function. This report should form the framework of the ultimate system design and be used to obtain top management acceptance prior to the development of the various detailed specification and user manuals.

The following advantages result from this system design approach:—

(i) The definition of functions and responsibilities at each level of the organisation identifies the information required for successful completion of that function.

(ii) The objectives and information required at each level can be related back to the input data required.

(iii) The fact that input data has been expressed in relation to the objectives ensures that only useable information items are measured.

(iv) The full effect of informal functional structures such as committees, co-ordinating group, etc., can be observed.

(i) The effect of power and personal relationships which may have a bearing in the final system design, are considered progressively.

CONCLUSION.

The principles of management have been reviewed and related broadly to the current problems of field engineers of the A.P.O. The concept of management control and an approach to the design of management control systems has been discussed as an introduction to subsequent descriptions of systems that have been introduced into the work situation.

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DUAL TELEPHONE JACKS FOR MANUAL SWITCHBOARDS

*F. M. SCOTT, A.M.I.R.E.E. (Aust.)**

INTRODUCTION

Dual telephone jacks are required on most manual trunk exchange operating positions. The second jack on a trunk assistance or special services position enables a monitor or supervisor to plug in a handset and assist the telephonist with the handling of a call. The facility is particularly useful when trainee telephonists are receiving practical instruction. The transmitter and receiver of the second handset (or headset) are electrically connected to those of the first, via the jack springs, so that both outfits may be used for speaking or listening on a connect circuit. The second jack also enables a relief telephonist to take over from another operator without disrupting the continuity of traffic handling.

A number of circuit arrangements have been employed to interconnect the first and second telephone jacks ranging from the very simple to the more complex. This article reviews some of the methods used in the past and gives details of an improved circuit provided in System AFM402. (Ref. 1.)

EARLY METHODS

The simplest method of connecting the two telephone jacks is to wire the four springs of Jack 2 in parallel with the corresponding springs of Jack 1. This method is illustrated in Fig. 1,

* Mr. Scott is Engineer Class 3, Internal Equipment, Queensland. See Vol. 19, No. 1 P. 77.

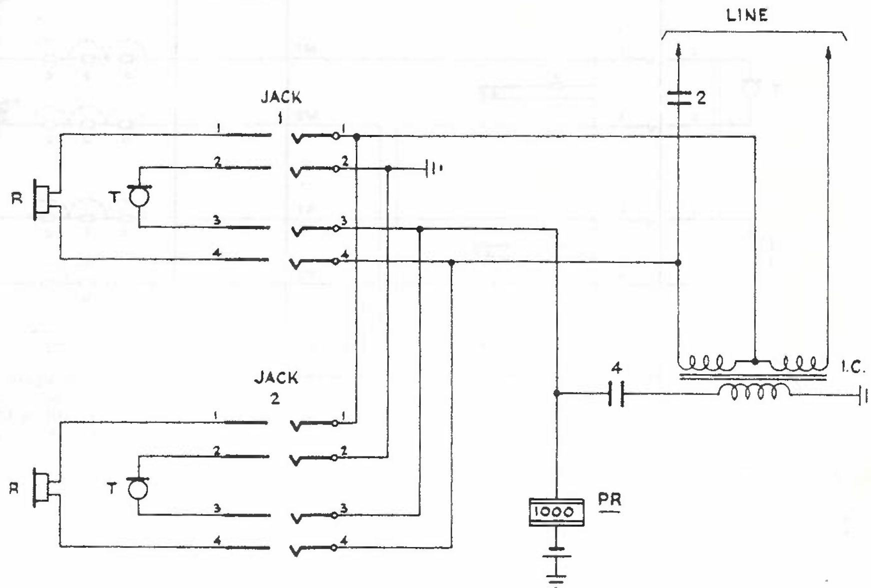

Fig. 1. — Dual Telephone Jacks, Method 1 — Circuit Diagram.

and was popular on earlier switchboards because it could be applied using the existing 4-pole jacks without the necessity for auxiliary jack springs. The large 4-pole concentric jack, the miniature concentric jack and the 4-pole flat jack were used in this manner. While simple to apply, this method resulted in unsatisfactory transmission performance both to operators and to subscribers. With the two transmitters connected in parallel, the current in each is approximately halved. Furthermore, the second transmitter imposes a low impedance shunt on the first, thus reducing the A.C. power available for sending to line. The received level in the first receiver is reduced when the second receiver is connected in parallel. Other changes in transmitted, received, and side tone levels occur due to the lowering of terminating impedances in the induction coil circuit.

A refinement of this method was introduced at a later stage when jacks with an auxiliary springset containing a changeover contact unit became available. Fig. 2 shows how the auxiliary springs are used to modify the transmitter circuit so that when two outfits are plugged in, the transmitters of each are placed in series instead of in parallel. With only one headset plugged in, the auxiliary springs place a short circuit across jack springs 2 and 3 of the other jack to maintain continuity in the series circuit. When the second headset is plugged in the auxiliary springs have no effect in the circuit and the two transmitters are connected in series. This method improves the sending efficiency as the transmitter current with two headsets connected is not appreciably less than when only one transmitter is in circuit. A fairly serious disadvantage is that during insertion and removal of the second plug momentary open circuits are introduced in the PR relay circuit causing it to release and re-operate. If the PR relay is used to perform position staffed functions, i.e., acts as a start relay for the position, these mo-

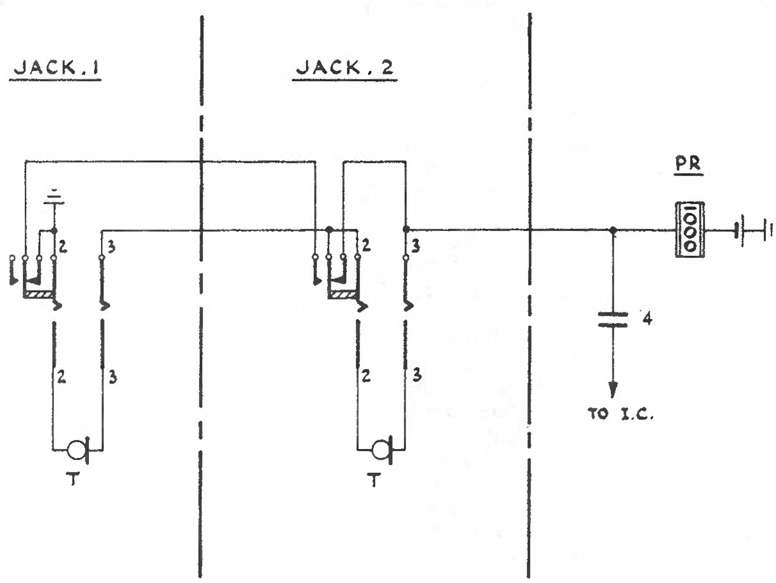

Fig. 2. — Dual Telephone Jacks, Method 2 — Circuit Diagram.

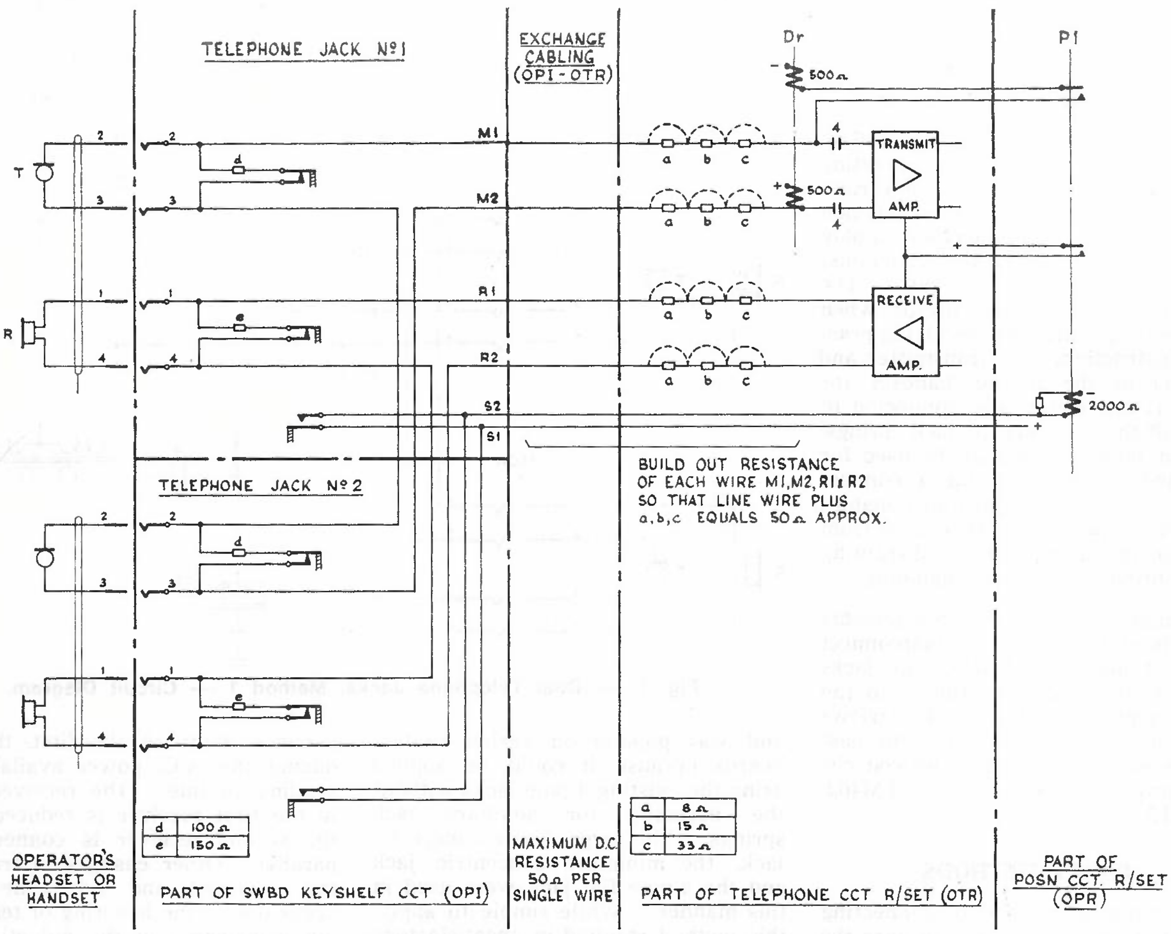

Fig. 3. — Dual Telephone Jacks, Method 3 — Circuit Diagram.

mentary breaks may cause circuit misoperation in the position relay set and associated circuits. No improvement in the received speech level results from this arrangement as the two receivers are still connected in parallel.

DESIRED FACILITIES

The following facilities are desirable in a dual telephone jack circuit:—

(i) The transmitter current should remain approximately the same irrespective of whether one or two headsets are plugged in.

(ii) The impedance of the V.F. termination on the transmit pair should be approximately the same with either one or two transmitters connected.

(iii) The received speech level in the first receiver should not vary noticeably when the second receiver is connected.

(iv) The V.F. termination provided on the receive pair should remain approximately constant with either one or two receivers connected.

(v) Insertion or removal of the second plug should not introduce momentary breaks in the position staffed relay circuit.

(vi) The jacks should be capable of being taken into use in any order.

(vii) No current should flow when the circuit is idle.

These conditions have been met in the circuit shown in Fig. 3. The design is based on the transmitter having a nominal impedance of 100 ohms and the receiver having an impedance of 150 ohms. The terminating impedances of both the transmit and receive pairs remain virtually constant over the three circuit conditions of idle, one headset and two headsets. Series connections are used for the transmitters and the receivers. With one headset in circuit its transmitter and receiver are placed in series with dummy loads equivalent to the nominal impedances of the second headset transmitter and receiver. When the second headset is plugged in, its transmitter and receiver are substituted for the dummy loads.

Interruptions to the position staffed relay are avoided by connecting it to auxiliary make springs on each telephone jack. These springs are wired in parallel. The transmitter current is supplied from a separate retard. Losses in the sending and receiving direction introduced by the dual telephone jack connecting circuit are made up by suitable gain adjustment in the directional speech amplifiers. Building-out resistors are provided to optimise transmitter current, series losses and amplifier terminating impedances.

This circuit could be modified for use with a two-wire unamplified telephone circuit relay set as follows:—

(i) Omit the building-out resistors.

(ii) Retain the existing arrangement on the transmit pair.

(iii) Retain the existing arrangement for operating the position staffed relay and supply transmitter current via a separate relay.

(iv) Connect the receivers in parallel instead of in series and omit the dummy load resistors.

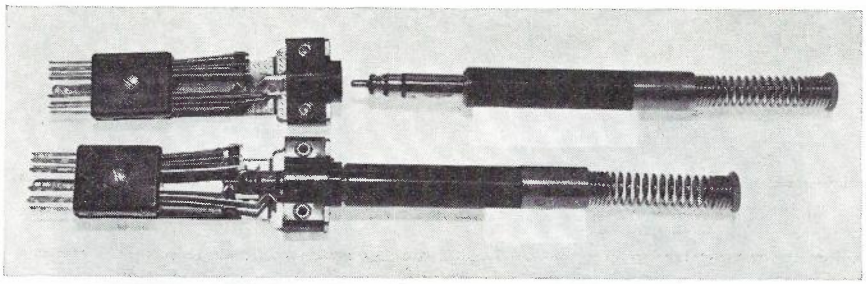

Fig. 4 — Four Pole Plugs and Jacks.

These circuit arrangements are dependent on the use of a jack with up to three auxiliary contact units. Fig. 4 shows the four-pole plugs and jacks employed in manual switchboards associated with A.P.O. Systems AFG201 and AFM402.

CONCLUSION

The circuit arrangement described here was specifically designed for use on a four-wire switchboard. Transmission performance is maintained at a uniform level, with one or two headsets connected. Some improvement to telephone circuits on two-wire switchboards may also result by adapting the circuitry to meet individual requirements.

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TECHNICAL NEWS ITEM

A.P.O. CALLS TENDERS FOR A COMMON USER DATA NETWORK

The A.P.O. has recently called tenders for the supply and installation of equipment to form a nationwide message and data transmission and switching network, referred to as a common user data network (C.U.D.N.).

The provision of this network will expand and improve the facilities that the Post Office now offers in the fields of message switching and data transmission. Advanced facilities of the type to be provided on the network are required for some major Australia-wide organisations which have been long-standing users of private message relay networks and have a need for various improvements in message services. The network will also provide facilities for the transmission of data between data stations and computers, a special case of which permits data stations to interrogate a centralised on-line computer and to receive a rapid response.

The C.U.D.N. will provide a common grid on which separate customer sub-networks may be derived and arrangements will provide that the traffic of each customer is secured against intrusion from other customers. Facilities will also be available to allow a customer to supervise the flow of traffic on his sub-network and interfaces with the public telegram and telex networks will also be provided.

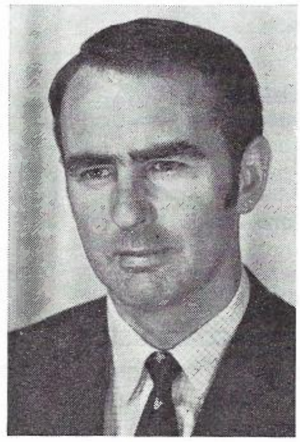
In addition, the possibility will also be explored of utilising C.U.D.N. switching plant to improve service for some classes of public message traffic, notably printergram and registered telegraphic address messages.

Establishment of the network may involve installation of computer based switching equipment in all States and interconnection of these centres by data links. It is expected that the initial customer service will be available on the network during 1971. The number of customers' lines connected to the network in the early stages is expected to include about 500 low speed (less than 200 bits/sec.) lines, 20 medium speed (up to 2,400 bits/sec.) data lines, which would connect customer data stations, and provide inter-connection to customers' computers. By 1980 the number of lines on the network would be up to three times the numbers currently quoted.

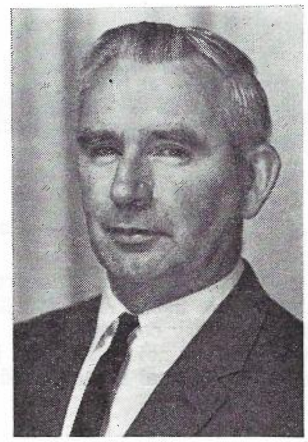
The C.U.D.N. will provide a basis for the modernisation and improvement of services offered by the A.P.O. in data communications and will maintain Australia's position among the technically advanced telecommunication nations. Similar programmes are being carried out in the United States and Sweden.

OUR CONTRIBUTORS

P. J. HIGGINS



R. KEIGHLEY



D. F. BERGMAN

P. J. HIGGINS, co-author of the article 'Management Control Systems', joined the Postmaster-General's Department as a Cadet Engineer in 1959. He graduated Bachelor of Electrical Engineering from Melbourne University in 1962, and completed a post-graduate Diploma of Engineering Management at Melbourne University in 1964. From 1963 he was Engineer Class 1 in Metropolitan Service Section, Victoria and was involved both with exchange maintenance activities and the development of the fault despatch centre and centralised testing at Ivanhoe. In May 1967, Mr Higgins was appointed Engineer Class 2 in the Industrial Engineering and Training Section, Headquarters where he has been closely associated with the development of management control systems for subscribers installation and exchange maintenance activities.

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L. A. JONES, author of the article, 'The Perth-Carnarvon Cable Project: Planning Aspects'; joined the Postmaster-General's Department in 1937 as a telegraph messenger. Subsequently he became a technician-in-training and, after war service, in the Australian Corps of Signals, worked as a technician and senior technician before qualifying as an engineer in 1951. Since then he has been engaged in a wide range of the Department's activities in Western Australia, where he now occupies the position of Divisional Engineer, Bearer Utilisation, in the Planning Branch. Mr Jones is a member of the Institution of Engineers, Australia.

R. KEIGHLEY, co-author of the article 'Management Control Systems', joined the Postmaster-General's Department as a technician-in-training in 1950. After working as a technician on telephone exchange maintenance he qualified as senior technician and was appointed trainee engineer during 1957. He completed the Diploma of Communication Engineering in 1959 and was with the Victorian Metropolitan Installation Section until 1961. From 1961 to 1966 Mr Keighley was engaged at Headquarters, as an Engineer Class 2, in the design of telephone instruments and P.A.B.Xs. In February 1967 Mr Keighley was promoted to his present position as Engineer Class 3, Industrial Engineering, where he has been responsible for the design and development of management control systems as well as the co-ordination and development of computer applications within the Engineering Works Division.

★

L. A. JONES

D. F. BERGMAN, author of the article 'The ARF Minor Switching Centre', joined the Postmaster-General's Department as a junior mechanic in 1940. He completed his training and qualified as a senior technician in 1948 after four years service in Army Signals. Subsequently he qualified as an engineer at the Open Examination for Engineers held in 1952.

In 1949 he commenced as acting engineer in the Telegraph Division, N.S.W. In 1951 he was appointed as an engineer in the Long Line and Country Installation Section, N.S.W. While in that section he was engaged in the installation of switching equipment in the northern areas of N.S.W. In December 1960 he transferred to the Internal Plant Planning Section (Country) where he took part in the planning aspects of internal plant in country areas. He was promoted in 1962 to the position of Engineer Class 3, Switching Systems Design, Telephone Exchange Equipment Section, Headquarters. In that position he was responsible for co-ordinating the development and interworking of switching and signalling equipment used in metropolitan and provincial telephone exchange networks. During that period he was associated with development of the minor switching centre. In 1969 he was appointed as Engineer Class 4 Exchange Installation Standards Sub-Section, Telephone Exchange Equipment Section.

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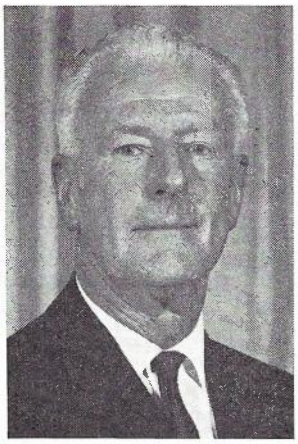
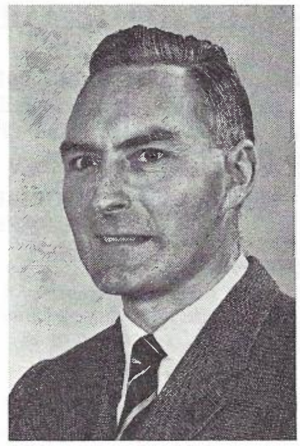


G. A. PROVAN

J. A. HUSTON



D. M. REID

G. A. PROVAN, author of the article 'Developments in Main Distributing Frames', joined the Postmaster-General's Department in Melbourne as a Junior Mechanic-in-Training in 1924, qualifying as a technician in 1934 and as a senior technican, Research in 1937 and Telephone Equipment in 1938. In 1941 he qualified for appointment as engineer by passing the Departmental examination.

His field experience included the initial installation at City West as a technician and after cutover was transferred to the maintenance staff where he acted as senior technician. In 1939 he was promoted to the position of senior technician at the Research Laboratories where he remained for one year. In 1940 he commenced as acting engineer, Metro. Lines, Victoria, and was promoted to engineer in 1942. In 1944 he was transferred to Metro. Equipment No. 3 and in 1950 was promoted to Divisional Engineer, Exchange Installation No. 1 Division. He was promoted to his present position of Supervising Engineer, Metro. Exchange Installation in 1964.

★

J.A. HUSTON, author of the article, 'Installing the Perth-Carnarvon Coaxial Cable'; joined the Postmaster-General's Department as a Cadet Engineer in 1951. After graduating as a Bachelor of Engineering from the University of Western Australia, he undertook a degree course in Arts and Economics while working in the Postal Workshops and Training areas. Subsequently as a group engineer he was attached to the Primary Works Country Division and was in the first batch of rotation engineers seconded to Headquarters. On his return to W.A. he took charge of the East/West open wire reconstruction project as divisional engineer. He then formed the Coaxial Cable Project Division, which is currently extending the coaxial cable link from Carnarvon to Port Hedland.

★

D. M. REID, co-author of the article 'Transmission Testing of New Telephone Circuits' joined the Postmaster-General's Department as an exempt technician in 1957, subsequently passed an examination for appointment as Technician (Radio and Broadcasting) and later qualified as senior technician. After field and technical office experience as technician and senior technician in the radio transmitter, studio equipment and microwave link areas he completed, in 1967, the Diploma of Radio Engineering at the Royal Melbourne Institute of Technology. In 1968 he commenced in Country Installation as Engineer Class 1 and is currently a member of the Long Line Equipment Installation and Transmission Study Group in Victoria. Mr Reid is a Graduate Member of the Institution of Engineers, Australia.

ANSWERS TO EXAMINATION QUESTIONS

Examination No. 5931, 5th July, 1969, and subsequent dates, to gain part of the qualification for promotion or transfer as Senior Technician (Telecommunications), Postmaster-General's Department.

TELEPHONE SUBSCRIBERS' EQUIPMENT.
WRITTEN PAPER NO. 2.

QUESTION 1 (a).

Fig. 1 is the schematic circuit of telephone 801. Redraw this circuit to include only those elements necessary for satisfactory transmission and reception of speech.

ANSWER 1 (b):

(i) Matches approximately the transmitter to the line impedance. Matches approximately the receiver to the line impedance. Separates the directions of transmission by connecting two-wire line to four-wire working in the telephone set to give sidetone control.

(ii) The line varistor produces the desired regulation of 'send' and 'receive' efficiency by shunting audio frequencies under the control of the d.c. voltage across the line terminals.

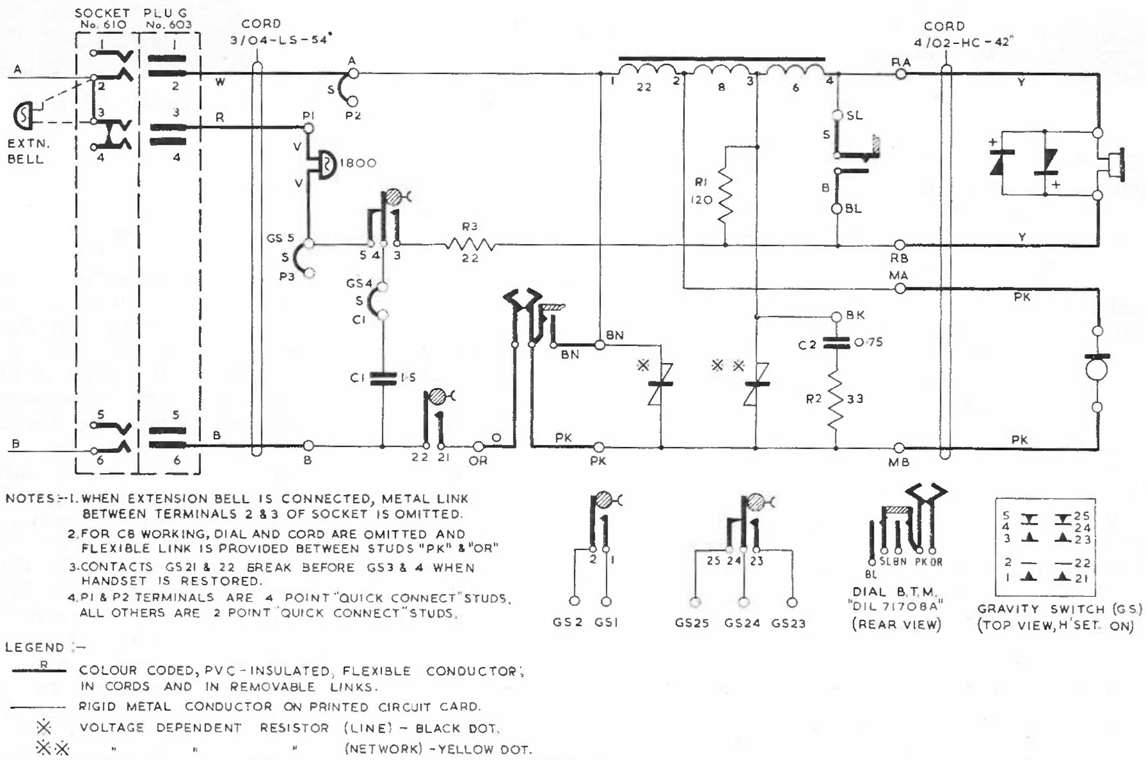
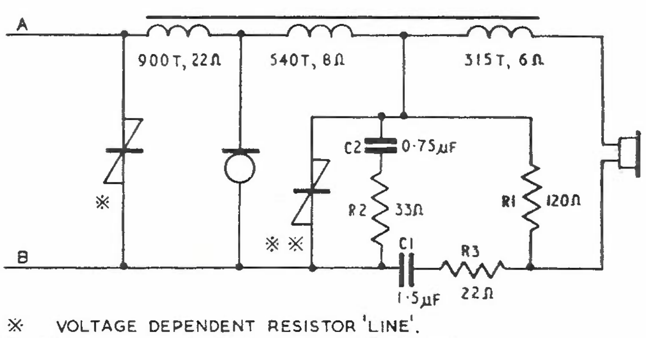


Fig. 1

ANSWER 1 (a).

See Fig. 2.



※ VOLTAGE DEPENDENT RESISTOR 'LINE'.
※※ VOLTAGE DEPENDENT RESISTOR 'NETWORK'.

Fig. 2

QUESTION 1 (b):

For the circuit you have drawn, briefly describe one function of the:

(i) Induction coil.
(ii) Line varistor.
(iii) 1.5 microfarad capacitor.

In combination with the network varistor, the line varistor helps shunt the feed voltage from the exchange on short loops. This reduces 'frying' by the carbon granules and increases the service life of the transmitter.

(iii) Provides low impedance path to speech signals but blocks d.c. from receiver.
Forms part of dial spark suppression circuit.
Forms part of gravity switch (contacts 21, 22) spark suppression circuit.
Forms part of balance network.
Blocks d.c. loop to exchange when phone 'on hook' but allows path for a.c. ring.

QUESTION 1 (c):

State two undesirable effects of excessive sidetone.

ANSWER 1 (c):

(i) It causes the speaker to lower his voice. This is equivalent to lowering the transmission efficiency of the telephone.

(ii) With excessive sidetone, loud room or background noises tend to mask incoming speech as they are fed into the receiver via the local transmitter circuit. This is equivalent to reducing the 'receive' efficiency of the telephone.

QUESTION 1 (d):

Why is some sidetone generally considered desirable?

ANSWER 1 (d):

Zero sidetone causes the telephone to sound 'dead.' Users generally prefer a small amount of sidetone.

QUESTION 2 (a):

You are a Senior Technician in charge of:

A Subscribers' Equipment Installation area.

or

A Subscribers' Equipment Maintenance area.

(Tick your preference and answer all of this question accordingly.)

You have, to assist you with your work in the area, a Technician and a Technician's Assistant.

(*i*) *Briefly describe in general terms the types of tasks you would expect the Technician's Assistant to be able to carry out.*

(*ii*) *Give one example of a task that a Technician's Assistant could carry out without pre-inspection or layout by yourself.*

ANSWER 2 (a):

(i) Subscriber's Equipment Installation or Maintenance. A Technician's Assistant should be capable of tasks requiring elementary electrical knowledge, have the ability to use hand tools, and possess a limited knowledge of Departmental methods.

(ii) Installation. Single point telephone installations (extension bells, control locks, etc.) plus less difficult multi-point installations. Any simple repetitive task such as terminating.

(iii) Maintenance. Rewiring subscriber's premises, change telephone instruments or other complete items of equipment, terminate on tag blocks.

QUESTION 2 (b):

(*i*) *Briefly describe in general terms the types of tasks you would expect the Technician to be able to carry out.*

(*ii*) *Give one example of a task that a Technician could carry out without pre-inspection or layout by yourself.*

ANSWER 2 (b)

(i) Subscribers' Equipment Installation or Maintenance. The main distinction between the Technician and the Technician's Assistant is his ability to carry out a variety of tasks on different types of equipment. He must possess basic electrical knowledge and manipulative skill. He may direct the work of a Technician's Assistant or direct the training of a Technician-in-Training.

(ii) Installation. Installs multi-point telephone installations other than those for the Technician's Assistant. Maintenance. Maintains all subscriber's equipment in an area with the exception of telegraph.

QUESTION 2 (c):

You have requested one of your staff to load several boxes of equipment on to a vehicle. The boxes contain small switchboards, and the weight is such that they can be lifted by one man one box at a time. It is necessary for you to give him basic instruction in the correct method of lifting the boxes. Name four key factors you would discuss.

ANSWER 2 (c)

(i) Obtain a proper hold of the box.

(ii) Maintain back straight during lifting.

(iii) Position the feet to obtain correct balance.

(iv) Make maximum use of leg muscles for the lifting.

QUESTION 3 (a):

Fig. 3 is the circuit of a two line telephone. What are the functions of:

(*i*) *Lamp LP1?*

(*ii*) *Zener diodes SC1 and SC2?*

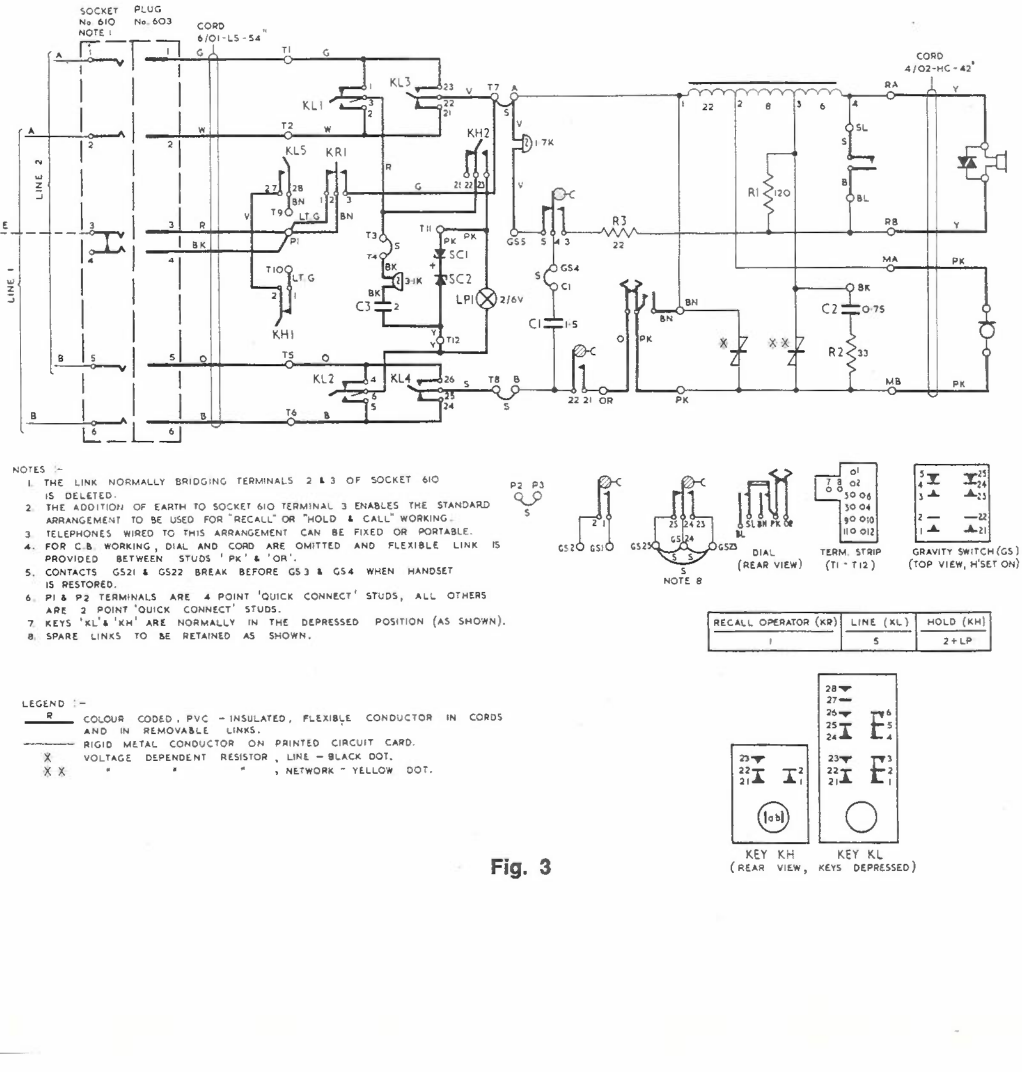


Fig. 3

ANSWER 3 (a):

(i) Lamp LP1 provides visual indication that hold key is operated.
The lamp provides part of the holding circuit together with Zener diodes SC1 and SC2.

(ii) Zener diodes SC1 and SC2 limit the voltage across LP1 (the voltage would be a function of line loop).
They are connected back to back to make the instrument insensitive to line polarity.

QUESTION 3 (b):

What limitations are there to the connection of an extension bell to this instrument?

ANSWER 3 (b):

An extension bell can only be connected in series with the buzzer and is therefore only available to one line at a time. An extension bell cannot be connected when a four-wire P.M.B.X. extension is one of the lines, or when push button recall is required.

QUESTION 3 (c):

What facilities can be provided by the push button KR1?

ANSWER 3 (c):

Recall on P.M.B.X.
Hold and call on P.M.B.X.

QUESTION 3 (d):

A subscriber with a two line telephone has an outgoing call established on each line. He is speaking on line 1 (line 2 is held). He finds it necessary to switch from line 1 to line 2 and back. Describe briefly what key operations are necessary.

ANSWER 3 (d):

As the hold key is already operated and the holding circuit is always applied to the line not in use by KL1 and KL2 under these conditions it is only necessary to release the line key to speak on line 1 and then re-operate it to speak on line 2.

QUESTION 4 (a):

Fig. 4 shows the basic trunking for an ARK 511 Rural Exchange equipped for 30 lines. Draw a grouping plan for this exchange.

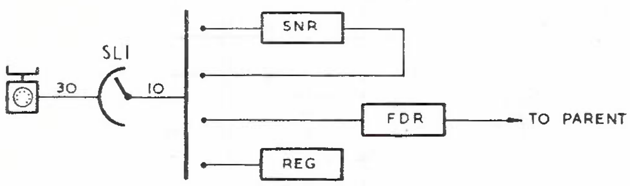


Fig. 4

ANSWER 4 (a):

See Fig. 5.

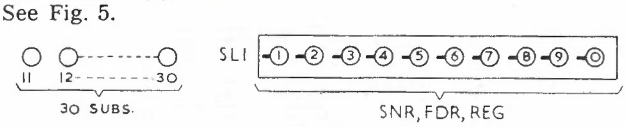


Fig. 5

QUESTION 4 (b):

You are tracing a call connected to this exchange. You are aware that SNR1 is being used for the call and that the A side is connected to vertical 1 of SL1 and the B side to vertical 2. If the called subscriber's number is 37, what horizontals and vertical would you expect to find operated for the connection between the SNR and the called subscriber?

ANSWER 4 (b):

Vertical 2 (B side of SNR for called sub.)
HB (M = 11 to 10, HA = 21 to 20. HB = 31 to 30).
H7.

QUESTION 4 (c):

The SNR relay set is used on a local internal call. List four functions of this relay set.

ANSWER 4 (c):

Any four of the following:

(i) Feeds ring tone to A Subscriber.
(ii) Feeds ring to B Subscriber.
(iii) Provides transmission bridge.
(iv) Applies meter pulse to A Sub's. meter.
(v) Provides time out facilities on ring.
(vi) Provides time out facilities if A party fails to clear after B party clears.

QUESTION 5 (a):

(i) Draw a circuit diagram showing the D.C. power distribution and fuse alarm circuit for a lamp signalling cord type P.M.B.X.
(ii) Name the type of power switch used and state its function.

ANSWER 5 (a):

(i) See Fig. 6.

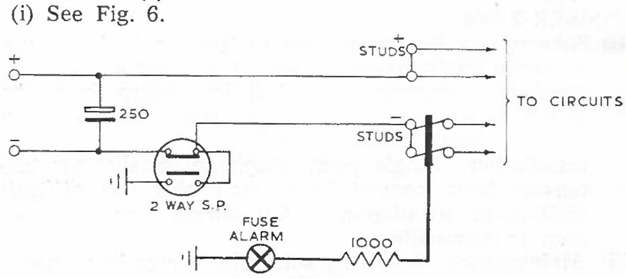


Fig. 6

(ii) The switch is single pole two-way. In the 'on' position it connects negative battery, via fuses, to the various circuits. In the 'off' position it earths the battery leads within the P.M.B.X. to prevent false operation of relays from charges stored in capacitors, etc.

QUESTION 5 (b):

What effect does an A.C. mains failure have on:
(i) Exchange calls on a type 2/3A (3 + 12) cordless P.M.B.X.?
(ii) The functions of an Intercom. System 1/3?

ANSWER 5 (b):

(i) Incoming exchange calls ring the bell in the operator's telephone.
Outgoing exchange calls can be made by the operator. Existing exchange to extension calls are not interrupted. The second and third exchange lines can be switched to selected extensions.

(ii) The following functions cease to work.
  (a) All local AC and DC signalling.
  (b) All local speech circuits.
  (c) 'Exchange to Extension' lamp supervision.
  (d) 'Exchange Call Held' lamp supervision.
  (e) Main cannot join in with 'Extension to Exchange' calls (when non-secrecy is used), but can monitor such calls.

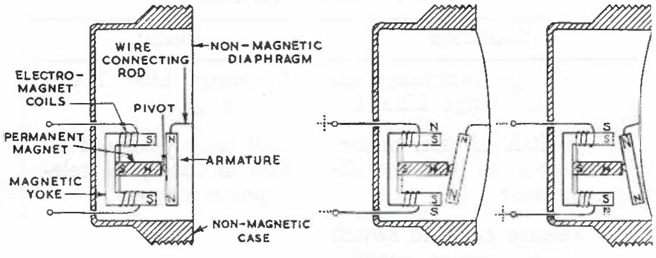
Also:
  (a) If extensions are 2-wire and 'Exchange to Extension' key is left operated, there will be no buzzer signal at the main when there is an incoming call.
  (d) Dialling outgoing calls will cause bell tinkling. There will be reduced transmission efficiency from 2-wire extensions.

QUESTION 6 (a):

With the aid of a labelled diagram, briefly describe the operation of a "rocking armature" receiver.

ANSWER 6 (a):

See Fig. 7.



(a) Diaphragm normal. (b) Diaphragm moves outwards. (c) Diaphragm moves inwards.

Fig. 7

In the normal condition (Fig. 7a), with no current in the coils, the two ends of the armature are equidistant from the tips of the pole pieces. The permanent magnet extends south magnetic poles of equal strength to each end of the magnetic yoke. The north poles induced into each end of the armature are, therefore, also of equal strength. As a result, the magnetic forces of attraction on each end of the armature are balanced, and there is no tendency for it to be attracted to either end of the yoke.

When a current flows in the coils, the electromagnetism strengthens one south pole of the magnetic yoke and weakens the other; and the armature is attracted to the stronger pole. Thus, when alternating speech currents flow, the armature is alternately attracted to either pole of the magnetic yoke and this movement is transmitted to the diaphragm (Figs. 7b and 7c).

QUESTION 6 (b):

State the advantages of this type of receiver over earlier types in use.

ANSWER 6 (b):

Is more sensitive than 1L and 2P.
Has a more uniform frequency response.

QUESTION 6 (c):

Briefly describe the action of an acoustic shock absorbing rectifier.

ANSWER 6 (c):

The acoustic shock absorber has electrical characteristics which are voltage dependant. At very low voltages of the level normally applied to the receiver the shock absorber is high resistance, so that only a very small portion of the incoming speech is shunted away. At high voltages, similar to that produced by transient noise, clicks, etc., the shock absorber is low resistance and therefore shunts a good portion of these signals away from the receiver.

QUESTION 6 (d):

If a receiver incorporating an amplifier is used in a telephone, what factors limit the amount of amplifcaton that can be provded?

ANSWER 6 (d):

The amount of amplification that can be provided is limited by the sidetone attenuation and the airpath attenuation between the transmitter and receiver. When the gain of the amplifier exceeds the total of these two attenuations the telephone will 'howl' due to feedback.

QUESTION 7 (a):

To prevent the possibility of A.P.O. facilities being used for illegal purposes, special precautions should be taken.

List four (4) conditions of installation which you consider would fall into each of the following categories:
(i) So serious that the installation should not proceed.
(ii) Where the installation may proceed.

ANSWER 7 (a):

(i) The installation will not proceed in the following cases:

1. The subscriber's name or address in the telephone order does not correspond with those where the service is actually required.
2. The service is required to be installed in a location on the premises which does not conform to the directions in the telephone order. The location of the telephone on the premises will be shown in all cases except that of the 'first in' service for a private residence. For example, in large buildings, guest houses, subdivided or sublet premises, the telephone order will include the floor number and flat, suite, office or room number(s).
3. Where the installation is desired in an unusual location and this location is not specified in detail in the telephone order.
4. Where the subscriber is found to have existing service(s) (including extensions giving access to exchange lines) in the same premises, and the telephone order does not contain the endorsement ALA.

In any of the above cases, the telephone order shall be returned to the Supervising Technician.

(ii) When any of the following cases are encountered, the installation will be completed, but a verbal report shall be given promptly to the Supervising Technician:

1. Where there is an existing service in the same premises in the name of another subscriber and the telephone order does not bear the endorsement: 'Installation Approved Same Premises—Existing Service........................'
   NOTE: The endorsement 'ALA' refers only to an additional line(s) for a particular subscriber.
2. Where, although a telephone order is endorsed 'Installation Approved Same Premises — Existing Service ....,' the new service(s) adds to a concentration of telephones in a small area, and this condition has not been shown in the telephone order.
3. Where there is reason to feel that the name and/or business of the subscriber shown in the telephone order is fictitious.
4. Where the layout of the premises or services suggests that they are used for an illegal activity or are intended for such use.

QUESTION 7 (b):

If you are a Senior Technician, and an installer on your staff informs you of any of the irregularities listed in (a), what information should be obtained to be passed on to the Telecommunications Division for investigation?

ANSWER 7 (b):

Telephone Order Number.
Telephone Number on the Order.
Depot concerned.
Name of Technician originating Report.
Details of the Report.
Sufficient information should be given in the report to enable the Telecommunications Division to investigate the matter, and, where appl'cable, to issue new orders acceptable to the field staff.

QUESTION 8 (a):

Draw a block schematic diagram showing the layout and cabling of a typical installation of a 1/2 intercom. system. Name all components and state the capacity of each connecting cord or cable.

ANSWER 8 (a):

See Fig. 8.

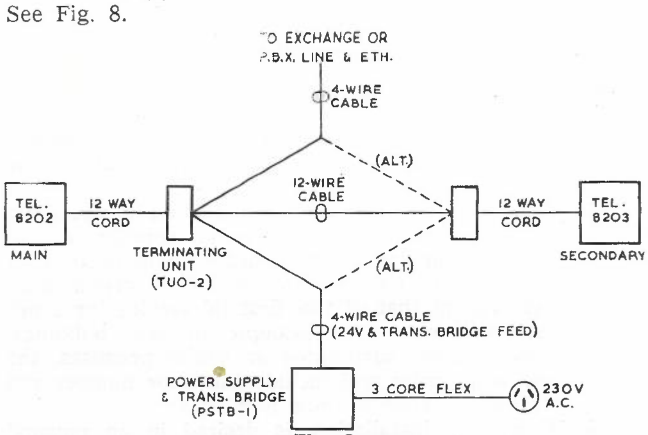


Fig. 8

QUESTION 8 (b):

When the telephones are supplied for such an installation, they are strapped to provide the monitoring facility.
List the variations of this facility which are possible and briefly describe them.

ANSWER 8 (b):

(i) Secrecy, where the main can have secret use of the line, or

(ii) Parallel operation, provided that the exchange line loop resistance does not exceed 400 ohm. When both parties are using the exchange line the L key lamp glowing in the main indicates the secondary's intrusion.

QUESTION 9 (a):

After havng installed a 2/3A P.M.B.X. and associated extensions, the installation is being functionally tested out.
State the procedure to be followed and the expected results if the equipment and cabling are in order, when testing the following functions:
(i) Exchange line and call trap circuit.
(ii) Power fail.

ANSWER 9 (a):

(i) See Table 1.

Table 1—Test Exchange Line and Call Trap Circuit.

Condition.	Result.
(a) Arrange incoming call on exchange line 1	Exch. line 1 call lamp Glows. N.A. buzzer operates.
(b) Operate 'Connext Exchange Line 1' and 'Connect Extn. 2' keys	Extn. 2 call lamp glows Extn. 2 telephone bell does not ring
(c) Answer call on operator's telephone	Exch. call lamp goes out.
(d) Ring Extn. 2 and restore operator's key	Extn. call lamp goes out and N.A. buzzer stops when extn. answers.
(e) Replace and remove extension handset	Relay interaction in swbd. indicates a reversed exchange line
(f) Release exchange call and restore keys to normal.	

(ii) See Table 2.

Table 2—Test Power Fail.

Condition	Result.
(a) Arrange incoming call on Exchange Line 1	Exchange Line 1 call lamp glows
(b) Switch off a.c. mains supply to battery eliminator	Call lamp goes out Bell in operator's telephone rings
(c) Release call and switch on a.c. mains supply	

QUESTION 9 (b)

Prior to testing the extensions on this installation with the exchange test desk, what is required to be carried out at the switchboard, and why is this necessary?

ANSWER 9 (b):

Operate the Night Service key. To disconnect the call trap in the exchange line circuit and provide a through circuit to any two-wire extensions.

QUESTION 10:

You are required to examine a room which has been prepared to accommodate a large P.A.B.X.

What important room features would you inspect to ensure that:

QUESTION 10 (a):

The P.A.B.X. equipment is protected against the possibility of damage or deterioration?

ANSWER 10 (a):

(i) Adequate Size Room. That the proposed room is of an adequate size to house the ultimate amount and type of P.A.B.X. required.

(ii) Gas, Water, Sewerage, Electricity Services. That gas, water, sewerage pipes and main electricity routes do not pass through the proposed P.A.B.X. room.

(iii) Floor Covering. The floor should be covered with high quality linoleum, vinyl or P.V.C. tiles or other approved material.

(iv) Finish of Walls and Ceiling. Walls and ceilings should have a smooth finish to minimise the settlement of dust and facilitate its removal.

(v) Ceiling. The ceiling of the proposed room should be lined, dustproof and watertight.

(vi) Doors. Doors should fit accurately and be capable of being securely locked.

(vii) Windows. Windows should fit accurately to prevent the ingress of dust and should generally be watertight. Windows should not permit direct sunlight to fall on the P.A.B.X. equipment.

(viii) Strength of Floor. The strength of the floor should be adequate to withstand the additional loading imposed by the P.A.B.X. equipment and maintenance activities.

(ix) Air Conditioning. The P.A.B.X. equipment will provide best service when it operates in a controlled environment of temperature and humidity. Room air-conditioning or forced draught ventilation will generally be required in P.A.B.X. equipment rooms.

(x) Vibration and Noise. The P.A.B.X. equipment should be placed in a position that will remain free from perceptible vibration and noise.

QUESTION 10 (b):

The P.A.B.X. equipment may be placed in the room and adequately accommodated?

ANSWER 10 (b):

(i) Adequate Room Dimensions. That the room dimensions, including the ceiling height, are sufficient for the handling and positioning of all of the P.A.B.X.

(ii) Entry of Equipment to P.A.B.X. Room. Doors through which it is necessary to transport equipment must be large enough or provided with false overhead panels to permit the entry of the largest equipment cabinets or racks.

(iii) Obstructions in Room. It is preferred that projecting ceiling beams, supporting pillars or other types of obstructions are not present in the proposed room. When these discontinuities do exist, the handling or positioning of the P.A.B.X. equipment should not be impeded or prevented.

QUESTION 10 (c):

Reasonable conditions will exist for the performance of maintenance activities?

ANSWER 10 (c):

(i) Room Lighting. The lighting of the equipment room should be sufficient to enable all parts of the equipment room to be examined by day or night.

(ii) Availability of Fresh Air. Fresh clean air at a reasonable temperature should be available for maintenance personnel, even though the P.A.B.X. room may be completely closed for long periods.

(iii) Provision of Power Outlets. Power outlets for portable electric tools and other appliances should be adequately supplied at suitable positions in the P.A.B.X. room.

(iv) Free Movement of Maintenance Staff. Proposed equipment layouts should be designed to ensure that the width of passageways permits the free movement of maintenance staff and their testing instruments, ladders, etc.

(v) Exclusive Use of the P.A.B.X. Room. The P.A.B.X. room must be exclusively used for the housing of P.A.B.X. equipment and for A.P.O. maintenance activities. It must not be used for storage of material or any other purpose.

QUESTION 11 (a):

Briefly describe the functions of the following parts of the both-way exchange line circuit of a C type PA.B.X.

(i) Each of the two relays (L and D) in series with the exchange line wires.

(ii) A.C. clearing signal.

ANSWER 11 (a):

(i) The L relay in the bothway exchange line circuit of the C type P.A.B.X. supervises the extension to exchange line to detect the presence or absence of a loop condition from the extension telephone.

(ii) Since the two coils of the D relay are differentially connected, D relay does not operate when the extension is connected to the exchange line. However, D relay will operate if the call back or inquiry button of the extension telephone is depressed, and initiate action to hold the exchange call and connect the extension to a call back or inquiry circuit.

(iii) A.C. clearing signal in the bothway exchange line circuit of a C type P.A.B.X. interrogates the public exchange equipment to ensure that the P.A.B.X. bothway exchange line circuit is released only after the public exchange equipment has completely restored to normal after release of an extension to exchange call.

QUESTION 11 (b):

With the aid of a simple schematic diagram, describe how an extension in a C type P.A.B.X. establishes a call back or inquiry call to another extension line.

ANSWER 11 (b):

See Fig. 9.

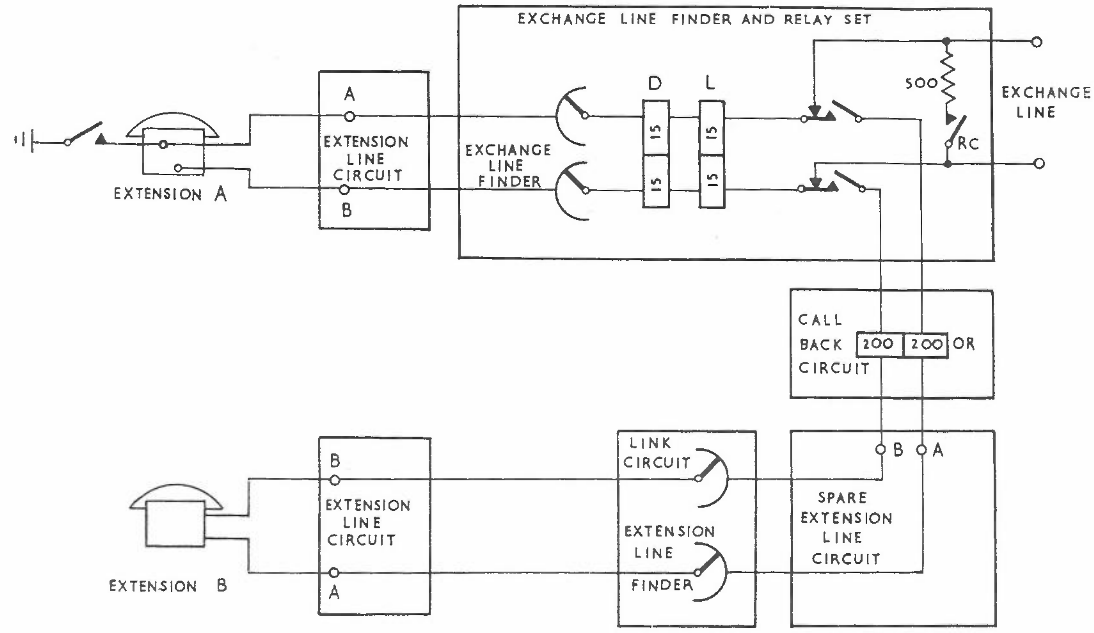


Fig. 9

(i) Extension A requiring the call back or inquiry connection presses the earth button in the extension telephone once.
(ii) Relay D in the exchange line circuit operates and extension A is connected to dial tone from a link circuit via the call back circuit and a spare extension circuit.
(iii) Extension A now dials the required extension number and establishes a connection to extension B.

QUESTION 11 (c):

Describe the rotary actions of a link selector in a C type P.A.B.X. when an extension dials:
(i) An outgoing exchange line code;
(ii) Another extension line number.
What technique is used to differentiate between the two general types of call nominated in (i) and (ii).

ANSWER 11 (c):

(i) When an exchange line code, 'O', is dialled by an extension of a C type P.A.B.X., the rotary magnet of the link selector steps the wiper assembly to the first contact of the tenth horizontal level of the bank.
(ii) The rotary magnet of the link selector is controlled by the dial of the calling extension and the wiper assembly steps horizontally to a bank position between 1 and 10, depending on the units digit of the called extension number.
(iii) A special vertical bank and wiper assembly is used to distinguish between the different switching actions required by single digit of the called extension number.

QUESTION 12 (a):

Briefly describe the following facilities provided in a Pentaconta crossbar P.A.B.X.:
(i) Group hunting.
(ii) Sequence or chain calls.
(iii) Operator's keysender.
(iv) Automatic night switching.

ANSWER 12 (a):

(i) Group Hunting—Calls to a group of extensions are made by dialling a common number. The first free line in the group always receives the next incoming call. The normal operation of the extensions in the group is not affected and calls to individual numbers in the group test only that particular extension line.
(ii) Sequence or Chain Calls—An incoming exchange call can be connected to an extension with provision for automatically recalling the operator when the extension clears. This feature enables an exchange call to be connected to a number of extensions in turn.
(iii) Operator's Keysender—The operator's keysender permits the operator to digit extension numbers by means of a set of ten keys so that incoming and revertive exchange line circuits may be switched to the required extension.
No dial pulsing is involved and the connection is established soon after the last digit key is released.
(iv) Automatic Night Switching—If the operator's position is left unattended or an incoming exchange call is not answered within approximately 60 seconds, the incoming call is automatically connected to the night-switch facility.
The night-switched condition remains until the telephonist resumes and operates the appropriate key to restore the switchboard to the attended mode of operation.

QUESTION 12 (b):

Name two Pentaconta P.A.B.X. facilities which include automatic recall of the operator after a fixed time period.

ANSWER 12 (b)

(i) If an incoming exchange call has not been answered by an extension within a fixed time period, the operator is automatically recalled to that circuit.
(ii) The operator may camp on incoming exchange call on a busy extension. If the busy extension does not restore within a fixed time period, the operator is automatically recalled.
(iii) An incoming exchange call may be held by the operator without affecting other operational features of the position. After the call is held for a fixed time period, the operator is automatically recalled.

QUESTION 12 (c):

Specify the type of relay set in a Pentaconta P.A.B.X. which would be used to terminate a tie line connected to an exchange line circuit of a lamp signalling P.M.B.X.

ANSWER 12 (c):

An extension line relay-set.

QUESTION 13 (a):

A cord type lamp signalling P.M.B.X. is to be installed with an outdoor extension located several miles distant and connected via the M.D.F. at the telephone exchange.
Describe the factors which you think should be considered prior to the approval of the installation.

ANSWER 13 (a):

Important factors to be considered are:
(i) The loop resistance between the extension and the switchboard must be such that sufficient current flows to satisfactorily light the extension lamp and operate the pilot relay. It is possible to strap out the 200 ohm resistor in the lamp circuit on long extensions and this allows a maximum loop, including the telephone of approximately 500 ohms.
(ii) The P.M.B.X. allows for through dialling (Exchange to extension) and therefore the total loop from extension through P.M.B.X. to exchange must not exceed the signalling limit for the exchange equipment, e.g., 1500 ohms for crossbar exchanges.
(iii) The allowable transmission loss between extension and exchange must not be exceeded, although in most cases this is less restrictive.
(iv) Where the transmission limit is satisfactory but either of the resistance limits is exceeded, consideration is given to provision of an intermediate relay set.
(v) The availability of cable pairs must also be ascertained.

QUESTION 13 (b):

In some cases this type of service requires the use of an intermediate relay set. Describe in general terms the functions this relay set should perform and show by block diagram where it would be installed. Give reasons for your choice of location.

ANSWER 13 (b):

The functions of the intermediate relay set would be:
(i) Provide a transmission bridge to the outdoor extension.
(ii) Provide a high impedance to loop on the P.M.B.X. side for supervisory purposes.
(iii) Repeat or pass around the set the ringing signals from the P.M.B.X. or exchange.
(v) Provide for earth unbalance or recall conditions to P.M.B.X.

The relay set could not be installed at the P.M.B.X. as very little gain could be achieved. As it requires power supplies it then would most conveniently be installed at the exchange. (See Fig. 10.)

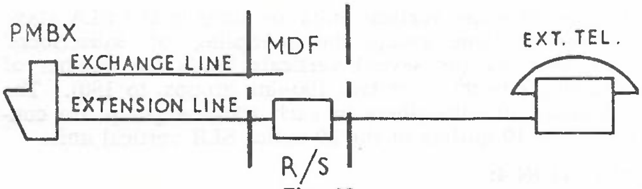


Fig. 10

QUESTION 14:

Use the circuit of the 2/3A (3 + 12) cordless P.M.B.X. to describe the following aspects of the circuit operation:

QUESTION 14 (a):

Indication of an incoming exchange line call.

ANSWER 14 (a):

For normal operation, relays NS and CT are operated. Incoming ring is received on A leg, negative half cycle passes through coil of relay AC, while the positive half cycle is shunted through diode, through CTA operated, capacitor C6, to B leg.

Because of shunting diode, AC operates to ringing current through its 1000 ohm coil.

AC1 lights the call lamp.

AC2 operates 'P' relay from battery 120 coil, NS8 operated, R3, AC2 operated, 1200 coil of AC, CT3 operated to earth.

The P relay when operated shunts its 120 coil with the 10 coil and thus provides a locking circuit for the AC relay. P1 will operate the buzzer if KA (key alarm) is operated.

QUESTION 14 (b):

Clearing indication after an exchange to extension call.

ANSWER 14 (b):

The gravity switch contact in extension telephone (A wire circuit) will operate extension lamp giving clearing supervision as follows:
From earth, GS operated, C wire, KX3 operated, extension lamp to battery via P relay.
P relay operates.
P1 operates audible alarm.
P2 connects 10 ohm coil of P relay in parallel with 120 ohm coil and the lamp will glow more brilliantly.

QUESTION 14 (c):

Incoming call on first exchange line under power fail conditions.

ANSWER 14 (c):

Under power fail conditions relay NS will release as well as all CT relays (on free lines).
Any incoming ring on the first line will now be diverted from A leg, SB4 normal, through the bell in the operator's telephone, KNS6 normal, SB3 normal, ST4 normal, capacitor C6 to B leg.
That is, the incoming ring will now sound the bell in operator's telephone and connection to the line is obtained by operation of keys as for a normal 'power on' call.

Examination No. 5932, 5th July, 1969, and subsequent dates to gain part of the qualification for promotion or transfer as Senior Technician (Telecommunications), Postmaster-General's Department.

TELEPHONE EXCHANGE EQUIPMENT. WRITTEN PAPER No. 2.

QUESTION 1 (a):

Describe briefly what is meant by the following terms when used in conjunction with maintenance methods:
(i) Preventive maintenance.
(ii) Corrective maintenance.
(iii) Qualitative maintenance.

ANSWER 1 (a):

(i) The action directed towards the discovery and correction of defects in equipment before they cause trouble in service.
OR
Action aimed at keeping equipment in a functional state with a view to preventing breakdowns.
(ii) The action of detecting and clearing faults which have actually occurred and are affecting service.
(iii) The balance between (i) and (ii) in order to regulate attention to plant and depends upon 'indicators.'

QUESTION 1 (b):

Explain briefly the difference between "scheduled" tests and "insurance" tests as applied to exchange maintenance.

ANSWER 1 (b):

Scheduled tests are applied according to service needs as revealed by indicators and expanded or curtailed in accordance with the number of faults found. Insurance tests are performed at a fixed frequency irrespective of the number of faults found.

QUESTION 1 (c):

Why is there a limited amount of "scheduled" tests still performed as part of maintenance operations?

ANSWER 1 (c):

To provide indicator information and to detect faults which are not revealed in sufficient time by other means and if allowed to remain would cause excessive service troubles.

QUESTION 1 (d):

Name the type of equipment most likely to be subject to "insurance" tests and give reasons for your choice.

ANSWER 1 (d):

Common service equipment such as alarms, power and service tone supplies, to help safeguard against major service breakdowns and damage to plant due to fire.

QUESTION 2 (a):

Draw, in the space below, the circuit principles of the two general types of transmission battery feed used in exchange apparatus.

ANSWER 2 (a):

See Fig. 1.

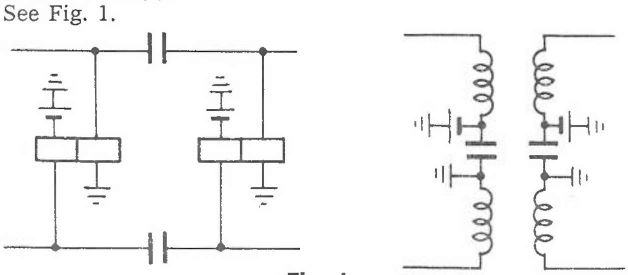


Fig. 1

QUESTION 2 (b):

Explain briefly why one of the transmission battery feed circuits is preferred for general application more than the other.

ANSWER 2 (b):

The Stone method is preferred because the inductance coils can be wound as relays and used for supervisory purposes

QUESTION 2 (c):
Define the term "Pulse Distortion" when used in connection with switching equipment.

ANSWER 2 (c):
The variation between the pulses produced by the dial contacts and the pulses received at the selector magnets.

QUESTION 2 (d):
Complete the following table of information concerning the general effects on the "PULSE BREAK RATIO" of dial pulses if the listed subscriber's line factor is increased.

ANSWER 2 (d):
See Table 1. The answers required are in bold type.

TABLE 1.

Subscriber's Line Factor Increased.	Effect on Pulse Break Ratio.
line resistance	increased
series inductance	**increased**
shunt conductance	**decreased**
shunt capacitance	**decreased**

QUESTION 3 (a):
Fig. 2 is part of a trunking diagram for an ARK 521 exchange serving 200 subscribers. Draw the corresponding grouping plan between SLB and SLC stages.

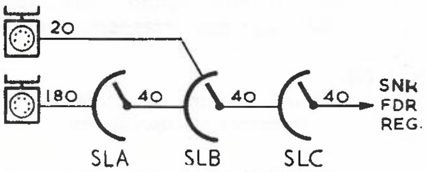


Fig. 2

ANSWER 3 (a):
See Fig. 3.

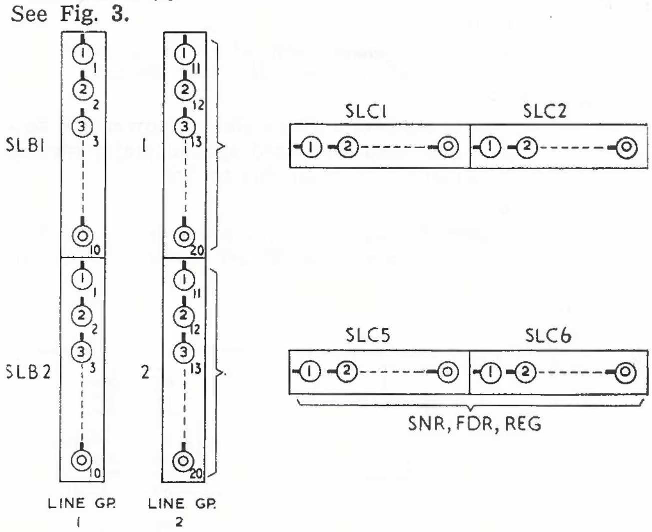


Fig. 3

QUESTION 3 (b):
What is the main function of the Reg. D device on outgoing calls from an ARK 521 exchange to an automatic step parent exchange?

ANSWER 3 (b):
REG obtains from the marker the subscriber category and analyses the digits dialled. If the category is prohibited from making the call, automatic disconnection follows.

QUESTION 3 (c):
Explain briefly why 180 subscribers are shown connected to the SLA stage and 20 subscribers are connected to the SLB stage.

ANSWER 3 (c):
Because 30-outlet vertical units are used in the SLA stage for each 100-line group, the multipling of subscribers' lines over six (or seven) verticals limits the number of subscribers to 90 (over two 100-line groups, to 180). The remaining 10 subscribers in each 100-line group are connected to 10 outlets of the 20-outlet SLB vertical units.

QUESTION 4:
Use the circuit of a 2000 type D.S.R. to answer this question.

QUESTION 4 (a):
State what straps are required for the D.S.R. to:
(i) Switch to an adjacent terminal exchange in the same closed numbering scheme
(ii) Switch to a local number.

ANSWER 4 (a):
Tag 'A' to the rotary contact corresponding to the first digit of the local and adjacent exchange numbers and then:
(i) Tag 'k' to the vertical contact corresponding to the second digit of the adjacent terminal exchange.
(ii) Tag 'H' to the vertical contact corresponding to the second digit of the local exchange number.

QUESTION 4 (b):
Explain, in detail, the electrical circuit operation of how the calling subscriber is metered on a call to an adjacent terminal exchange.

ANSWER 4 (b):
(i) When the called party answers, the direction of current over the junction is reversed (by the final selector), allowing relay D to operate in series with rectifier MRB. D2 closes the circuit to earth, BA1 of relay MD, which operates slowly. (MD is made slow operating so that it does not respond to flick operation of relay D due to line surges, etc.) The operation of relay MD reverses the current on the calling line at MD6 and MD3. MD4 removes the earth on the P wire and MD1 replaces it with positive battery via YA for operation of the calling subscriber's meter. MD2 opens the circuit of relay J, which releases slowly. Positive battery is connected to the P wire during the release time of relay J (about 300 mS), and when J releases, is replaced by earth at J2. Rectifier MRA maintains earth on the P wire during the transit time of MD and J contacts, but does not shunt the positive battery pulse. Relay MD locks via MD2 and J6 to earth at BA1, but when J releases, is again placed under the control of relay D.

QUESTION 4 (c):
Explain briefly why:
(i) The 25th contact of the junction hunter is not multipled.
(ii) Relay MD is made slow to operate.

ANSWER 4 (c):
(i) If all junction outlets to the tandem exchange are busy, the J.H. rotates to the 25th contacts. These are not multipled, so that the particular K. relay can operate in series with the J.H. drive magnet. This means dial tone can be connected to the calling line. Busy tone indicating junction congestion is only given if the call requires routing through the tandem.
(ii) So that it does not respond to flick operations of relay D due to line surges, etc.

QUESTION 5 (a):
Draw a block diagram showing the principles of how MFC signalling equipment is connected into the trunking of a typical ARF 102 exchange.

ANSWER 5 (a):
See Fig. 4.

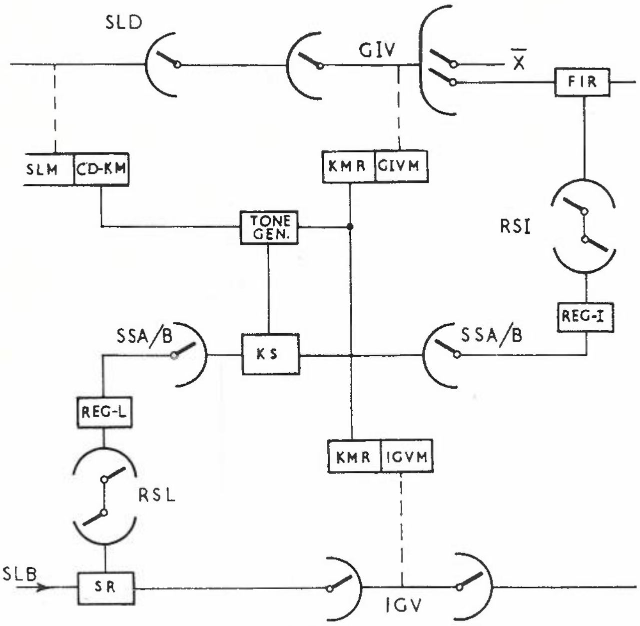


Fig. 4

QUESTION 5 (b):
Explain briefly what is meant by the terms "A terminal" and "B terminal" when using the MFC system of signalling in ARF 102 equipment.

ANSWER 5 (b):
The originating or register end is referred to for signalling purposes as the 'A terminal,' while the tone and marker equipment at each of the switching stages is referred to as the 'B terminal.'

QUESTION 5 (c):
Draw a trunking and MFC signalling diagram for a call commencing at a terminal ARF 102 exchange and trunking through a step tandem exchange into the GIV and SL stages of another ARF 102 exchange (assume 6-figure numbering).

ANSWER 5 (c):
See Fig. 5.

QUESTION 6 (a):
Complete the following table of information concerning 2000-type rack alarm equipment.

ANSWER 6 (a):
See Table 2. The answers required are in bold type.

TABLE 2.

ALARM	SHELF RELAY	RACK RELAYS	DELAY PERIOD
Release	RA	AR BR	9 Seconds
P.G. Supervisory	**LA**	**AB BS**	**6 minutes**
C.S.H. Supervisory	**LA**	**AS BS**	**3 minutes**
N.U. Tone Supervisory	**LN**	**AN BN**	**9 seconds**

QUESTION 6 (b):
Explain briefly with the aid of a sketch, the circuit principles used to operate the shelf and rack relay of the N.U. Tone Supervisory alarm circuit.

ANSWER 6 (b):
See Fig. 6.

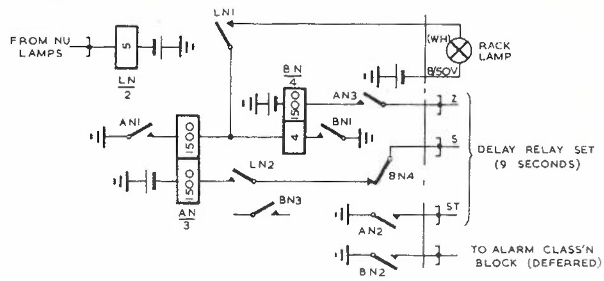


Fig. 6

In the event of a S/C or earth fault on any of the spare lines connected to the circuit, relay LN operates in series with the NU lamp (relay NU operated on MAR). Relay AN operates if the 9 second delay set is not stepping (via earth on S) and connects start earth to the delay set and prepares BN for operation. After 9 secs an earth pulse from lead Z operates BN; BN1 locks BN via the rack lamp, which glows because of the 4 ohm winding of BN.

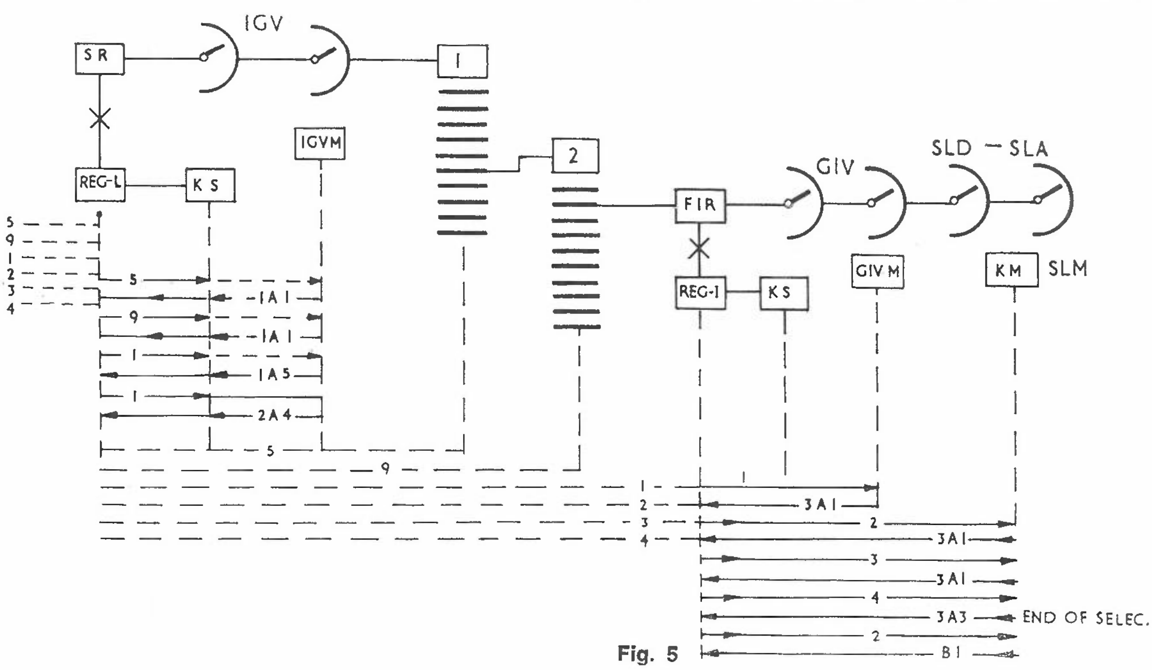


Fig. 5

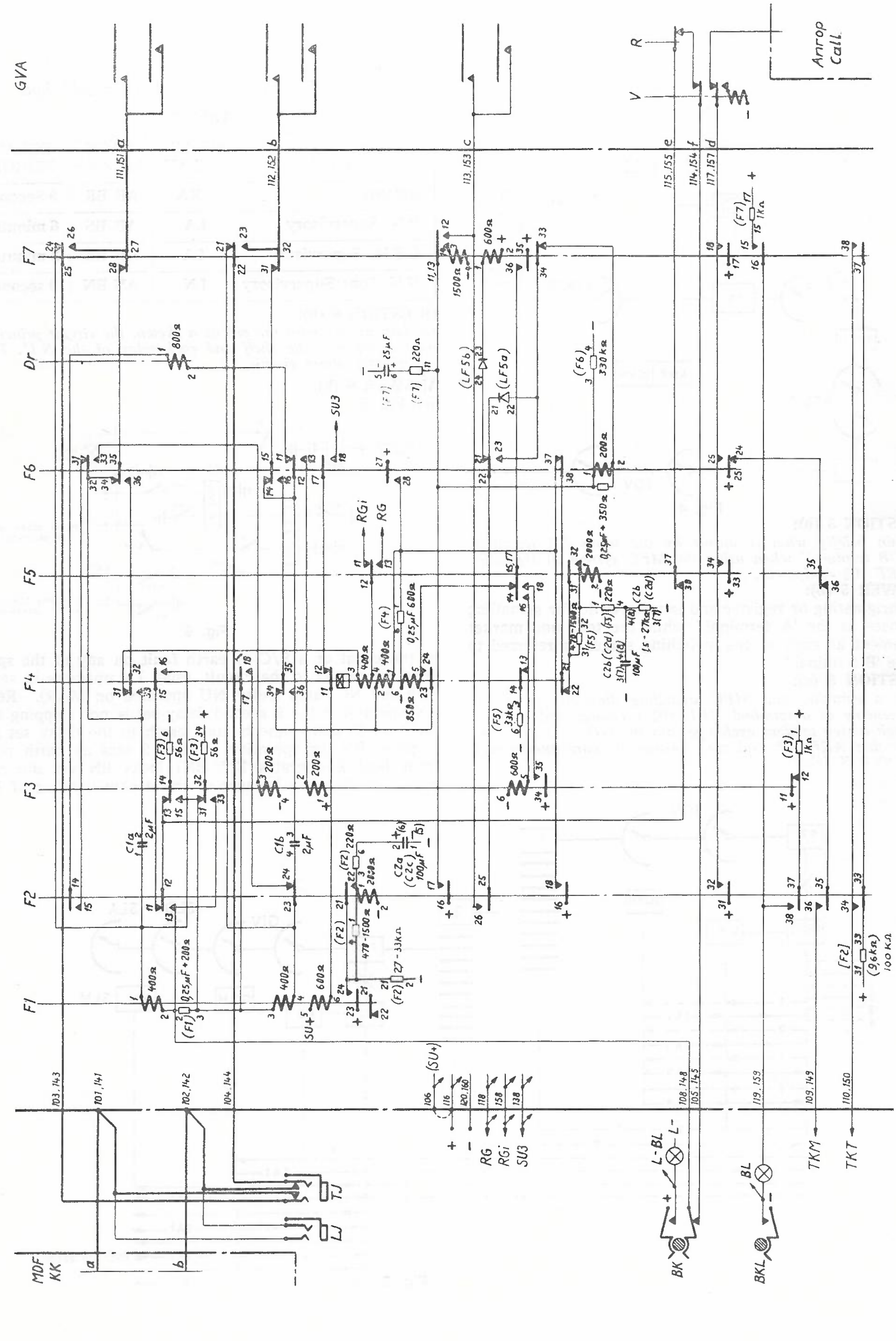

GVA
F7
Dr
F6
F5
F4
F3
F2
F1
MDF
KK
Anrop
Call
R
V
SU3
RGi
RG
L-BL
BL
BK
BKL
TKM
TKT
TJ
LJ

Fig. 7

This low resistance shunt causes AN to release (BN4 opens the original operate circuit and disconnects AN from the S lead). When the ST lead is opened AN2 releases. The delay set steps to the next normal position.

QUESTION 6 (c):
Explain briefly the purpose of the three connecting wires ST, Z and S used in alarm circuits.

ANSWER 6 (c):
ST is the start wire.
Z is pulse delay.
S is guard wire to ensure proper timing period and prevents seizure if the set is in use.

QUESTION 7:
Use the circuit Fig. 7 of an FIR-L(A1) to answer this question. The FIR-L(A1) relay set is in a Hybrid exchange and associated with a GIV inlet which has access to both crossbar and step primary equipment.

QUESTION 7 (a):
What are the functions of key BLK and its associated BL lamp?

ANSWER 7 (a):
Checks if circuit is free or busy. On calls to crossbar exchanges it gives 'Full Glow' if call is unanswered, 'Half Glow' if answered. On calls to step it gives 'Half Glow' if circuit is engaged (answered or otherwise).

QUESTION 7 (b):
State the electrical test-in path from the "a" leg of the MDF to the 56 ohm negative potential.

ANSWER 7 (b):
MDF 'a' leg, tag 101, TJ, tag 103, F7 24/25 F1 coil 1-2, tag 108, BK, tag 105, tag 114, f wire, V, R, e wire, tag 115, F5 37/38, F3 13/14, 56 ohms negative.

QUESTION 7 (c):
Name the relays which are operated during ringing conditions on a call to an idle crossbar subscriber connected to the exchange. (Assume the initial flash of ring has been sent.)

ANSWER 7 (c):
F1 F2, F6.

QUESTION 7 (d):
State the conditions received by the FIR on the "c" wire on calls to the step portion of the exchange.

ANSWER 7 (d):
++condenser discharge, followed by +.

QUESTION 7 (e):
Name the relay which arranges to re-charge the line during release, and explain briefly why this is necessary.

ANSWER 7 (e):
F4; to prevent flicks of F1 which would make spurious calls to the GV-M.

QUESTION 8 (a):
Explain briefly the principles used to modulate ringing tone in modern type ringing machines using permanent magnets in the tone generator.

ANSWER 8 (a):
(i) The rotor has 12 teeth removed, leaving two groups of six as shown in Fig. 8a.
(ii) The stator also has two corresponding groups and half the normal number of teeth. (24 teeth removed, leaving 2 groups of 12 (see Fig. 8b).
(iii) Tone winding is wound around the stator teeth.
(iv) This has the effect of producing the modulated 400Hz tone and ringing frequency in the stator winding.

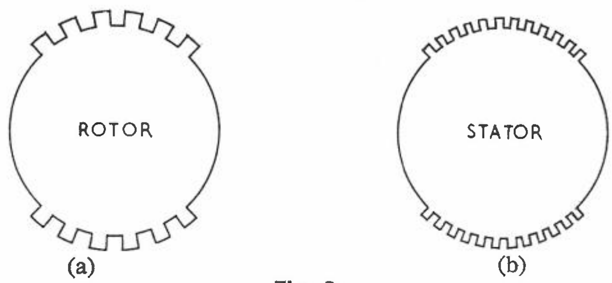


Fig. 8

QUESTION 8 (b):
Explain briefly, with the aid of a sketch, the principles used to automatically change over from a failed ringing machine to a second stand-by unit.

ANSWER 8 (b):
See Fig. 9.

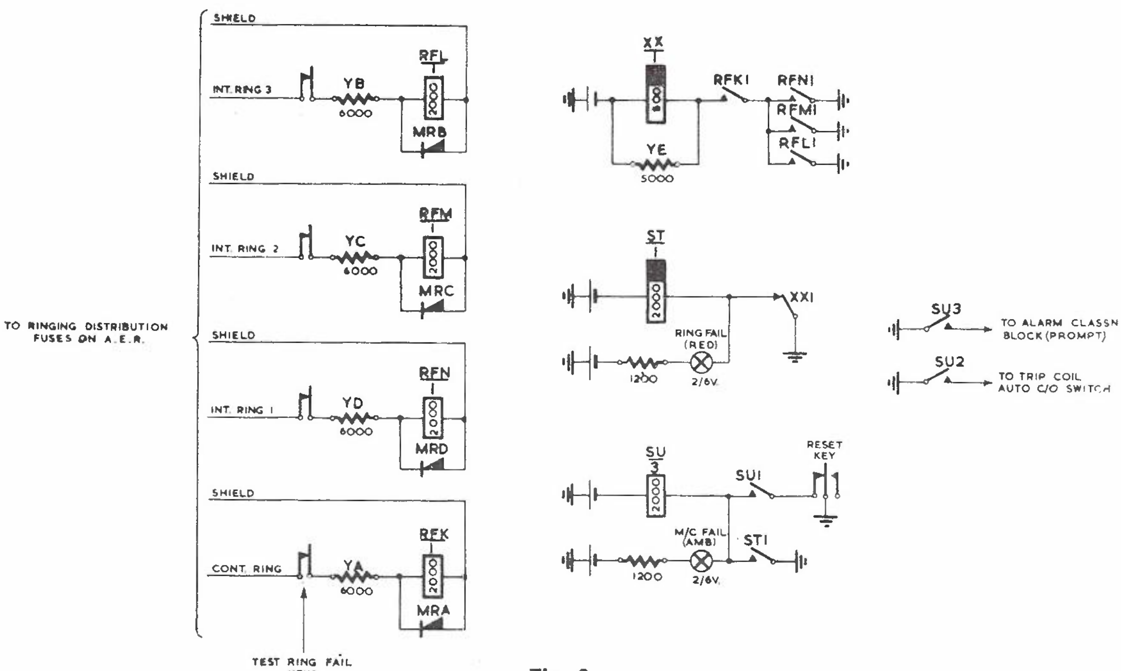


Fig. 9

(i) Relay RFK is operated by the continuous ring. RFN, RFM and RFL are operated in turn by the three interrupted ring supplies.
(ii) Relay XX is normally held operated by the contacts of these relays.
(iii) If a failure occurs, XX releases and XX1 operates relay ST and lights the 'Ring Fail' lamp on the power board.
(iv) ST operates relay SU and lights the 'Machine Fail' lamp.
(v) SU locks via SU1 to earth at the reset key, SU3 extends earth to operate the exchange alarm and SU2 extends an extra earth to the trip coil of the change over switch, which starts up the second ringer and connects it to the load.
(vi) If the ringing current is restored on all busbars, relay XX re-operates and releases relay ST. The alarm is maintained until the reset key is operated, thus ensuring a personal attendance at the power board.

QUESTION 9 (a):

Explain briefly what is meant by the following terms when used in conjunction with the National Telephone Plan.
(i) Trunk access code.
(ii) Area code.
(iii) Secondary switching centre.
(iv) Alternate routing.
(v) "C" digit.
(vi) Transit register.

ANSWER 9 (a):

(i) First digit '0.'
(ii) 2, 3 or 4 digits, including '0' and before the directory number.
(iii) Switches the final routes for minor switching centres and also, if required, terminal exchanges.
(iv) If all trunks are busy on a selected route, the call is automatically switched to a second route and so on until a final choice is made.
(v) 3rd digit of area code after 0.
(vi) One which calls for sufficient digits to allow the particular centre to perform its part in the connection (usually 0 ABC digits of the national number).

QUESTION 9 (b):

Explain briefly, the principles of call charging in the National Telephone Plan using charge zones and districts.

ANSWER 9 (b):

Exchanges are arranged in groups so that all exchanges within a group have a common charging basis. The charge for calls between any two exchanges is related to the distance between groups of exchanges to which they belong. Charging equipment need only discriminate on sufficient digits to identify a called group of exchanges and not an individual exchange.

The group charging plan depends upon the division of Australia into charging zones (about 200 sq. miles). About 8 to 15 zones are grouped into a charge district. Calls within a zone and to adjacent zones are untimed (unit fee). When a call is to a non-adjacent zone in the same district, it is charged at trunk rates based on the radial distance between the geometric centres of the two zones.

This same principle applies for calls between exchanges in any two zones which are in adjacent charge districts.

Calls between exchanges in adjacent zones which are in different charge districts are untimed. Calls between two exchanges which are in non-adjacent charge districts are based upon the radial distance between the charge district centres.

QUESTION 10 (a):

Draw the grouping plan for an RS-1 stage and show the main identification and test relays. (For simplicity, draw one RS switch, assuming 16 FIR's to 20 Reg. 1s.)

ANSWER 10 (a):

See Fig. 10.

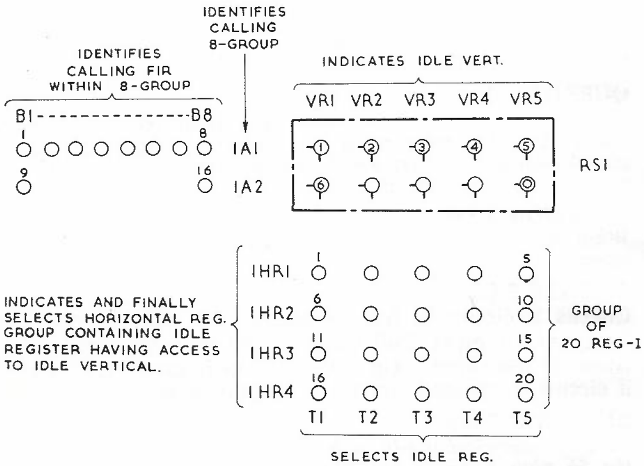


Fig. 10

QUESTION 10 (b):

Explain briefly, using your grouping plan, the method of connecting a particular Reg. 1 to an FIR.

ANSWER 10 (b):

Each group of 8 FIR relay sets is multipled over the horizontal springs H1-H8 on the five verticals to which they have access. For example, FIR1 is connected to H1 on verticals 1 to 5, similarly FIR2 is connected to H2, FIR9 in the second row of 8 FIR's is connected to H1 verticals 6 to 10 on switch RSV1, and so on. Each row of 4 registers is available from 8 verticals and connections from horizontal positions 9, 10, 11 and 12 are multipled over the 8 verticals from which the four registers are available. For example, register 1 is connected to H9 on verticals 1 and 6 on each of the four RS switches.

1. When an FIR is taken into use, it connects negative polarity on a call wire to the RSM controlling the register finder to which the relay set is wired. (For identification purposes, the 64 call wires from 64 FIR'S are considered as 8 groups each of 8 wires.) The identification is done in two stages:

(i) Identification of the 8-group containing the calling the calling FIR. The 8-group corresponds to a horizontal row in the grouping plan.

(ii) Identification of the calling FIR within its 8-group.

2. The selection of a register group containing a free register occurs.

3. Operation of one of the horizontal magnets H1-H8 and one of the magnets H9 to H12.

4. Selection of a free register from within the chosen group.

5. Operation of one of the vertical magnets V1 - V0 in one of the crossbar switches.

6. Extension of the calling subscriber class of service into the selected register.

7. Release of the RSM.

QUESTION 10 (c):

What are the functions of the following relay sets associated with a GIV marker?
(*i*) *GV-KMR part* 1.
(*ii*) *GV-KMR part* 2.
(*iii*) *KMT*.
(*iv*) *AB*.

ANSWER 10 (c):

(i) Sending of revertive backward control signals to the distant KSR.
(ii) Receives, counts, stores and analyses forward signals.
(iii) Provides filters, level regulators, channel receivers.
(iv) Two stage identifier and connector.

QUESTION 10 (d):

What information is indicated by the following leads which are wired out of a metro GIV stage?
(*i*) *SM lead*.
(*ii*) *TM lead*.

ANSWER 10 (d):

(i) Congestion.
(ii) Total time outs.

QUESTION 11 (a):

Explain briefly, with the aid of a sketch, the principles used in wiper switching for 200-*outlet* 2000-*type group selectors*.

ANSWER 11 (a):

See Fig. 11.

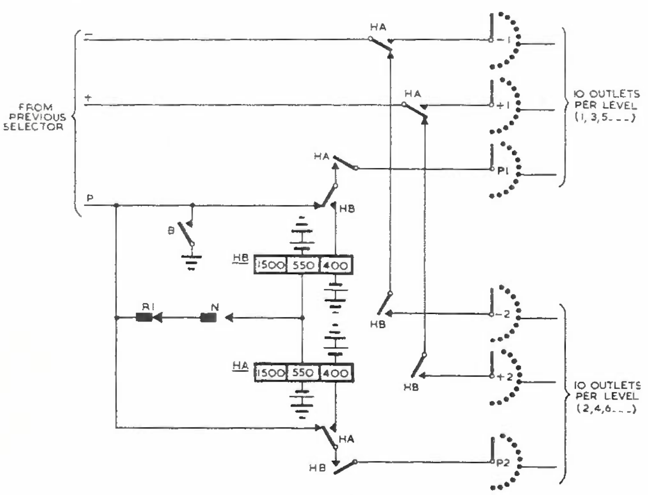


Fig. 11

Relay HA and HB are operated on their 550 ohm windings when the wiper carriage is stepped off-normal, but during stepping this circuit is opened at R1 each time the rotary magnet operates. If the outlets on which the wipers rest are busy, these relays hold on their 400 ohm windings to earth on the P1 and P2 wipers, respectively and the wipers are stepped to test the next outlet. If the odd-numbered outlet is free, relay HB releases, allowing relay C to reoperate and relay HA is held on its 1500 ohm winding. If the even outlet is free, relay HA releases and relay HB holds, switching the call to the even outlet. When the wipers reach a rotary step where both outlets are free, relay HB releases (through the design of the circuit) and the odd outlet is selected.

QUESTION 11 (b):

List four likely causes of "stop on busy" (triple connection) trouble in 200-*outlet* 2000-*type group selectors*.

ANSWER 11 (b):

1. Faulty alignment of the wipers on the bank contacts.
2. Faulty wiper adjustment.
3. Faulty adjustment of rotary interrupter contacts.
4. "Backlash" in the rotary magnet adjustment causing overshoot of wipers.
5. High resistance contact between wipers and banks (dirty bank).

QUESTION 11 (c):

Explain briefly what is meant by the following terms when used in conjunction with 2000-*type equipment and circuits*:
(*i*) 880-*point bank*.
(*ii*) *Fast guard*.
(*iii*) *Balanced transmission of tones*.
(*iv*) *Cut-drive principle*.
(*v*) *Step-off-open*.

ANSWER 11 (c):

(i) Four sets of 10 level standard banks each with 11 steps of twin contacts; usually a PBX Final selector bank.
(ii) A relay operates and applies earth conditions to the private wire.
(iii) Tone connected to a third winding of the battery feed relay. This 'tone' winding thus functions as the primary winding of a transformer, inducing the tone voltage equally into the line windings.
(iv) Self interrupted drive (actuated by a toggle action) causing the contacts to open when the armature nears the end of its operating stroke, and the contacts do not remake until the armature has almost completed its release stroke. The testing relay (a contact of which completes the rotary magnet circuit) remains operated while the P wire is passing over earthed contacts and releases and 'cuts' the drive circuit immediately a free outlet is reached.
(v) Step-off-open is the circuit feature which steps the switch on to the next outlet step if a holding earth is not returned after switching.

QUESTION 12:

Use the Mark 1 Common Services diagram (Fig. 12) *for crossbar exchanges to answer this question.*

QUESTION 12 (a):

Give the meaning of the following symbols:

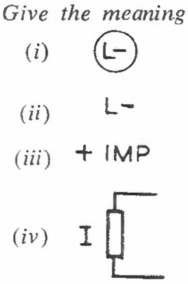


Fig. 13

ANSWER 12 (a):

(i) Negative battery from a 6 amp fuse on a discharge panel.
(ii) Negative battery from a fuse in the suite control unit.
(iii) 24 minute earth pulse which operates LK relays on the SLA/B rack. These relays are used for timing a subscriber on line-lockout (24-48 mins.).
(iv) Resistor.

QUESTION 12 (b):

Complete the following table of information concerning alarm lamp indications which glow when the named alarm relays operate.

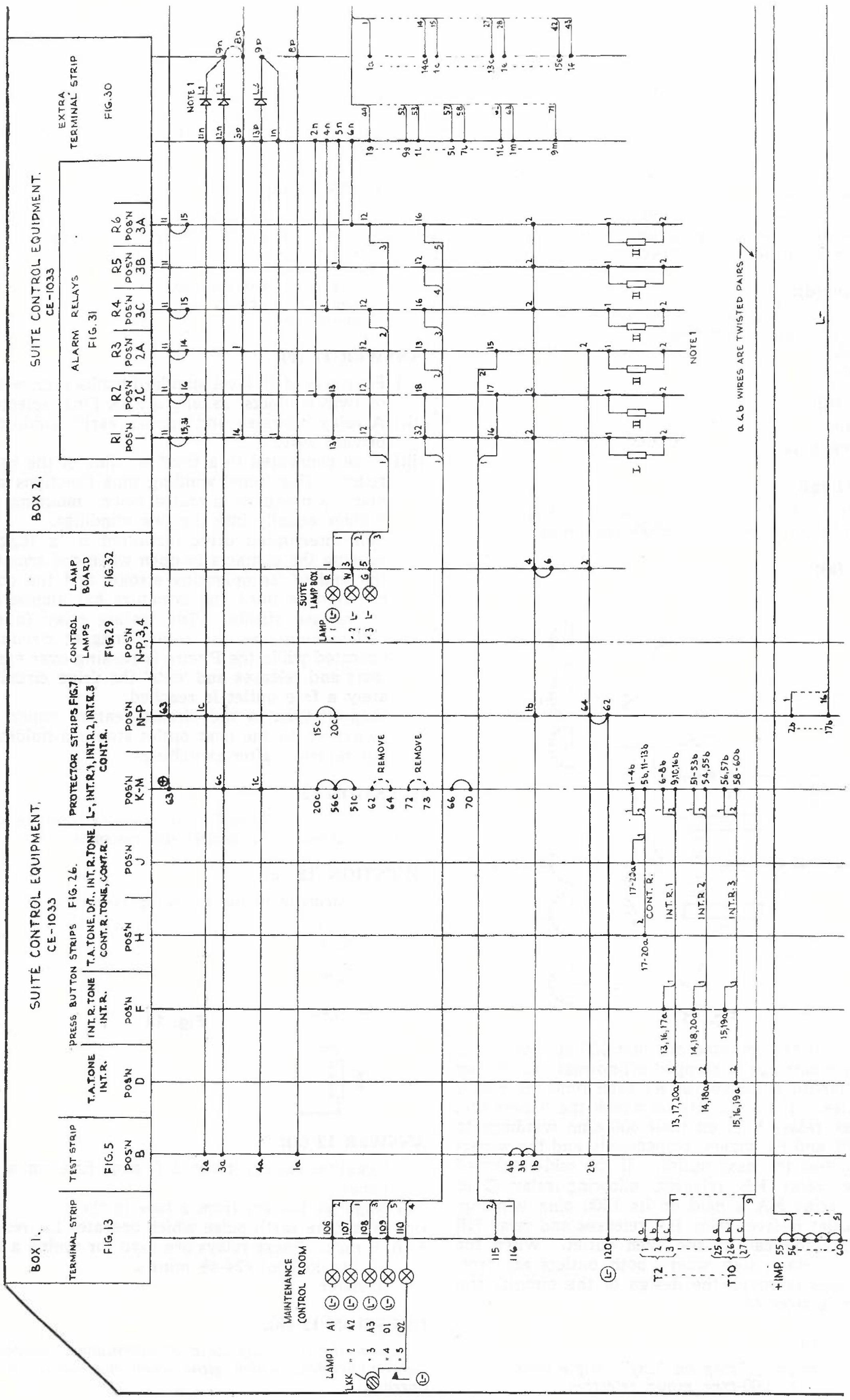


Fig. 12

ANSWER 12 (b):

See Table 3. The required answers are shown in bold type.

TABLE 3.

Alarm Relay	Suite Lamp Box	Maintenance Control Room	Alarm Lead
R1	Lamp 1	Lamp 2	A2
R3	**Lamp 1**	**Lamp 1**	**A1**
R4	**Lamp 2**	**Lamp 3**	**A3**
R6	**Lamp 3**	**Lamp 4**	**O1**

QUESTION 12 (c):

Name the alarm leads which are cabled from an SR rack in ARF 102 exchanges, and to which of the above "R" relays are they strapped?

ANSWER 12 (c):

Lead	Relay	
BL	R6	(indication of blocked circuit)
SSLS	R3	(rack fuse alarm)
SLS	R1	(minor fuse in jackbox)
SLS-V	R1	(important fuse in jackbox)

QUESTION 12 (d):

Explain briefly the method used to prevent interference between wires in a tone distribution cable.

ANSWER 12 (d):

(i) The tone lead is to be a twisted pair.
(ii) First wire to be tone lead, and the second wire to be earthed at one end and left open at the other end, usually the ringing machine end.

QUESTION 13 (a):

Draw the principles used to connect together, and switch, two batteries and associated charging plant to form the power source of a modern telephone exchange. Include in your drawing the power source for metering.

ANSWER 12 (a):

See Fig. 14.

QUESTION 13 (b):

What is the usual floating voltage per cell and state the output voltage control range required of the power arrangement for a telephone exchange power source?

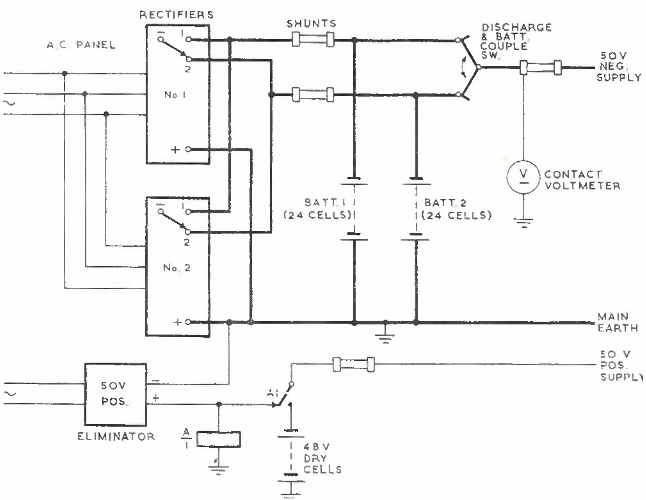


Fig. 14

ANSWER 13 (b):

(i) 2.17 volts per cell, ± 0.03 volts.
(ii) 51.3 volts to 52.8 volts.

QUESTION 13 (c):

List the precautions necessary to be observed during the initial installation and charge of a battery.

ANSWER 13 (c):

(i) Smear petroleum jelly over lugs before assembly.
(ii) Before 'burning' place a shield of heat resistant insulating material (miscolite or similar) over the cell, or at least a damp cloth.
(iii) Provide suitable dark glasses if 'burning' is by electric arc method.
(iv) No burning after cells on charge.
(v) No smoking in battery rooms.
(vi) Spanners and other tools to be suitably insulated.
(vii) A clear plastic face mask must be worn.
(viii) Safety vents must not be removed or loosened after cells are filled with acid. Check that they are dry, clean, and firmly screwed down.
(ix) Ventilating fans must be of the brushless type.

QUESTION 14 (a):

What is meant by the term "GRADING" when used in conjunction with automatic exchange trunking connections?

ANSWER 14 (a):

Method of interconnecting trunks when a cyclic order of search of a switch over outlets is used.

QUESTION 14 (b):

Draw the grading pattern for 2 racks of 2000-type group selectors with rack grading facilities using 2 feeds per rack and 4 individuals, 4 pairs and the remainder of the outlets commoned. Your drawing should use standard symbols and typical designations.

ANSWER 14 (b):

See Fig. 15.

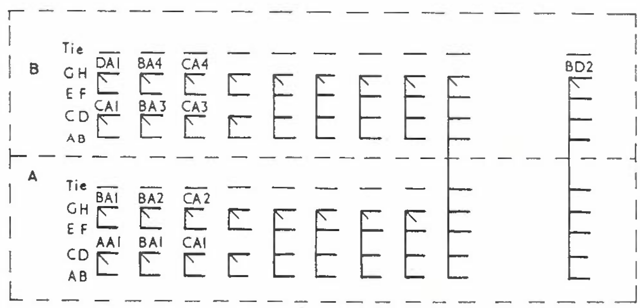


Fig. 15

QUESTION 14 (c):

List three (3) reasons for limiting the size of gradings in a telephone exchange.

ANSWER 14 (c):

(i) To facilitate tracing of calls.
(ii) To lessen congestion of tie cable circuits.
(iii) To minimise crosstalk caused by exchange equipment.

QUESTION 14 (d):

Explain briefly the difference between a trunk connecting frame (TCF) and trunk distributing frame (TDF).

ANSWER 14 (d):

TDF cables are connected to grading strips and these are jumpered to the next rank of selectors or to a TCF. TCF is to interconnect incoming to outgoing trunks.

Examination No. 5941-5945 19th July 1969 and subsequent dates to gain part of the qualifications for promotion or transfer as Technician (Telecommunications), Postmaster-General's Department.

Telecomm. Principles — Section B (ctd.)

QUESTION 9 (a):

What is the bias on the single stage pentode amplifier shown in Fig. 16 if the anode voltage is 150 volts and the screen-grid voltage is 125 volts, both with respect to earth?

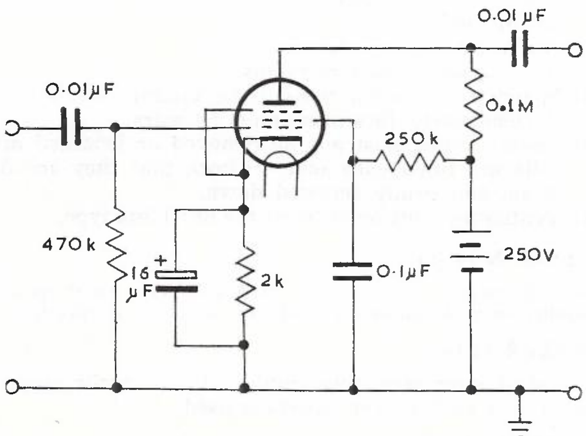


Fig. 16

ANSWER 9 (a):

$$\text{p.d. across } 0.1\text{M} = 250 - 150 = 100\text{V}$$

$$Ia = \frac{E}{R} = \frac{100 \times 10^3}{100 \times 10^3} = 1\text{mA}$$

$$\text{p.d. across } 250\text{k} = 250 - 125 = 125\text{V}$$

$$Isg = \frac{E}{R} = \frac{125 \times 10^3}{250 \times 10^3} = 0.5\text{mA}$$

$$I_k = 1.5\text{mA}$$

$$E = 1.5 \times 10^{-3} \times 2000 = 3 \text{ volts.}$$

QUESTION 9 (b):

The 16μF capacitor in Fig. 16 becomes short circuited. Explain the effect that this would have on:

(i) The d.c. operation of the stage.

(ii) A signal through the stage.

ANSWER 9 (b):

(i) Bias would fall to zero, so the anode and screen currents would increase. The anode voltage and screen grid voltages would both fall, due to the increased p.d. across the 0.1M and 250k resistors.

(ii) The signal through the stage would be distorted because the loss of bias would cause one half cycle to drive into the positive section of the characteristic.

SECTION C

ANSWER THREE QUESTIONS FROM THIS SECTION

QUESTION 10 (a):

Draw the simplified block diagram of a basic cathode ray oscilloscope.

ANSWER 10 (a):

See Fig. 17.

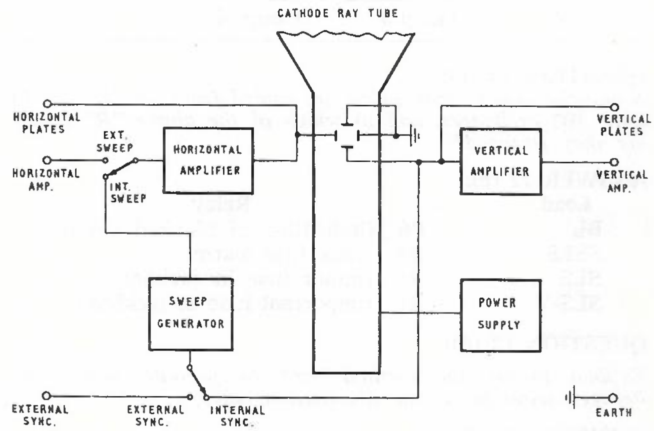


Fig. 17

QUESTION 10 (b):

Draw the waveshape of the voltage applied to the horizontal deflecting plates when viewing the waveshape of a signal. Briefly explain the reason for the shape of the wave.

ANSWER 10 (b):

See Fig. 18.

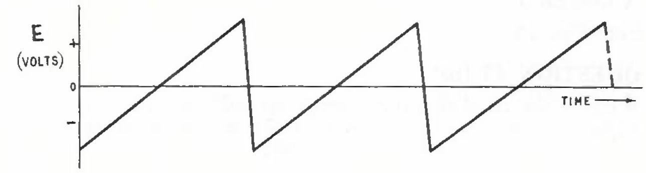


Fig. 18

The waveform is of a 'sawtooth' shape so that the beam will be moved across the screen at a uniform rate. The voltage rises at a linear rate and the beam is deflected proportionally to the instantaneous value. The sharp reduction of the voltage causes the beam to return rapidly to the left side of the screen.

QUESTION 10 (c):

Briefly explain the function of the following controls:

(i) 'X' Shift.

(ii) 'Y' Amplitude.

ANSWER 10 (c):

(i) Controls the horizontal position of the trace and so moves the pattern left or right for the best viewing position.

(ii) Controls the gain of the vertical amplifier and thus the height of the pattern.

QUESTION 11:

A type of rectifier circuit is shown in Fig. 19.

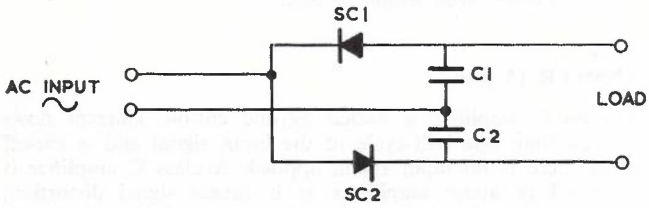


Fig. 19

QUESTION 11 (a):

Name the type of circuit shown.

ANSWER 11 (a):

Single phase voltage-doubler.

QUESTION 11 (b):

Briefly explain the operation of the circuit.

ANSWER 11 (b):

Assume no load is connected; on one half-cycle SC1 conducts and SC2 blocks. C1 charges via SC1 to the peak value of the input voltage. (Top plate is negative.)

On the next half cycle, SC1 blocks and SC2 conducts. C2 now charges via SC2 to the peak value of the input voltage and again the top plate is negative. The combined voltages of C1 and C2 are twice the peak voltage of the input and are connected across the load.

When the load is connected, the capacitors discharge slightly, but each is recharged on alternate half cycles. As the load current increases, the average voltage across the capacitors decreases and the output voltage decreases.

QUESTION 11 (c):

A 100 volt 50Hz alternating supply is connected to the input of Fig. 19. What will be the value of the output voltage under no-load conditions.

ANSWER 11 (c):

Output voltage = twice input peak voltage

$= 2 \times 100 \times 1.414$

$= 282.8V$

QUESTION 12 (a):

Negative feedback applied to electron tube amplifiers can be either Negative Voltage Feedback or Negative Current Feedback. Briefly explain the difference between the two terms.

ANSWER 12 (a):

In either type of feedback, a voltage is fed back to the input 180 degrees out of phase with the input signal. In negative voltage feedback, this voltage is proportional to the output *voltage.*

In negative current feedback, the voltage fed back is proportional to the output *current.*

QUESTION 12 (b):

State three advantages of applying negative feedback to an amplifier stage.

ANSWER 12 (b):

Reduction of noise, etc. generated in the stage.

Reduction of distortion generated in the stage.

Gain of the stage is more independent of changes in supply voltages, component characteristics, etc.

QUESTION 12 (c):

Part of the circuit of a two stage amplifier is shown in Fig. 20. Add to the circuit negative voltage feedback over the both stages including the output transformer, and briefly explain the operation of the feedback circuit.

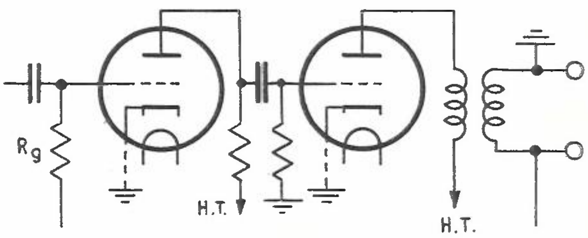


Fig. 20

ANSWER 12 (c):

See Fig. 21.

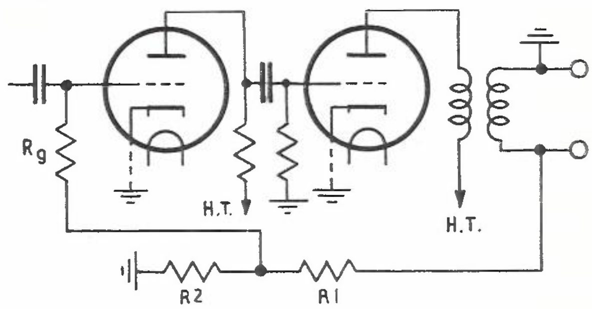


Fig. 21

When a positive half cycle of signal is applied to the grid of the first tube, the 180° phase change through each tube produces a positive at the primary of the output transformer. The transformer is connected so that the top of the secondary is positive. The secondary voltage is applied across R2, causing the top of R2 to be negative. The p.d. across R2 is 180° out of phase with the original signal, so that negative voltage feedback has been achieved. Resistors R1 and R2 form a voltage divider, which determines the amount of feedback voltage.

QUESTION 13 (a):

Transistor amplifiers can be operated in three main classes. Label the diagrams in Fig. 22 to indicate the class that each diagram represents and draw the output signal for the input cycle shown in each diagram.

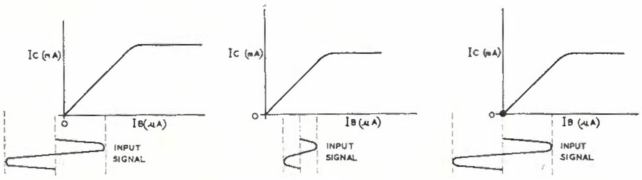


Fig. 22

ANSWER 13 (a):

See Fig. 23.

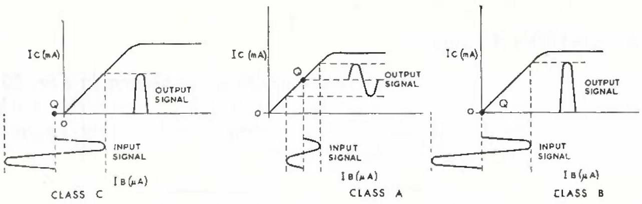


Fig. 23

QUESTION 13 (b):

Briefly explain the operation of each class of amplifier, giving examples where each would be used.

ANSWER 13 (b):

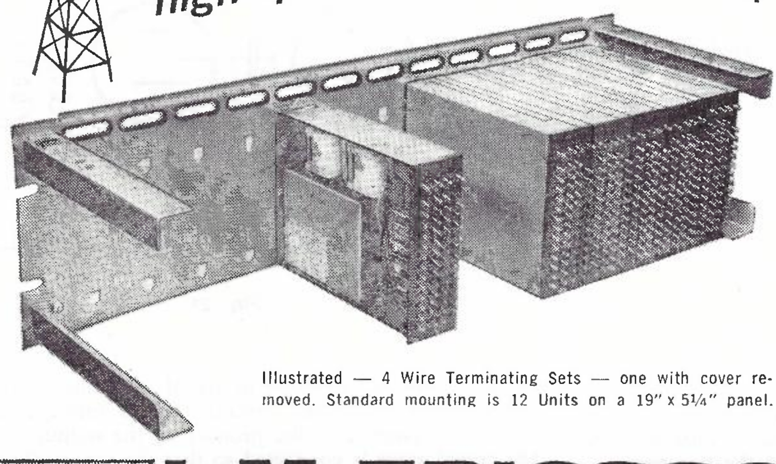
A class C amplifier is biased beyond cut-off. Current flows for less than one half-cycle of the input signal and is cut-off when there is no input signal applied. A class C amplifier is not used in audio amplifiers as it causes signal distortion, but is commonly used in high frequency (R.F.) amplifiers. The clipped signal is restored by the use of tuned circuits.

A Class A amplifier is operated on the linear portion of the characteristic. It is biased so that collector current flows continuously during the complete cycle of the signal, even when no signal is present. Since the input signal causes equal changes of the collector current in each half cycle, the output waveform is a complete replica of the input waveform. It is used in the voltage stages of audio amplifiers, and in stages of amplifiers where low distortion or low intermodulation is required.

A class B amplifier is biased to approximate collector current cut-off, so that the collector current is approximately zero when no signal is applied. Current flows only during that half cycle of input signal voltage that aids the forward bias. This method of bias is often used because it results in the good d.c. power efficiency. Power amplifiers often use class B operation and have two transistors, one for each half cycle of operation. (Push-pull operation.)

designed for efficient, high quality communication networks . . .

4 WIRE TERMINATING SETS AND HYBRID COILS



Illustrated — 4 Wire Terminating Sets — one with cover removed. Standard mounting is 12 Units on a 19" x 5¼" panel.

For use on high quality amplified voice frequency circuits at points where a 2 wire to 4 wire conversion is required. All units incorporate blocking capacitors in the line and network windings and basic components to provide for the average line balance network. Terminating sets contain variable attenuator pads in both the Hybrid-In and Hybrid-Out sides.

For further information please write giving application details.

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FACTORY: CNR. WILLIAMS RD. & CHARLES ST., NORTH COBURG, VICTORIA. 'PHONE: 35-1203 . . . TELEGRAPHIC ADDRESS: "TRIMAX" MELB.

LM53

TECHNICAL NEWS ITEM

I.T.U. SEMINAR

In harmony with the I.T.U. programme of providing technical assistance in kind to developing countries, a short seminar under the general heading "The Development and Operation of Sound and Vision Broadcasting Services" was held at the Shore Motel in Sydney on 17 and 18 October 1969, immediately following meetings of the Engineering Committee of the Asian Broadcasting Union.

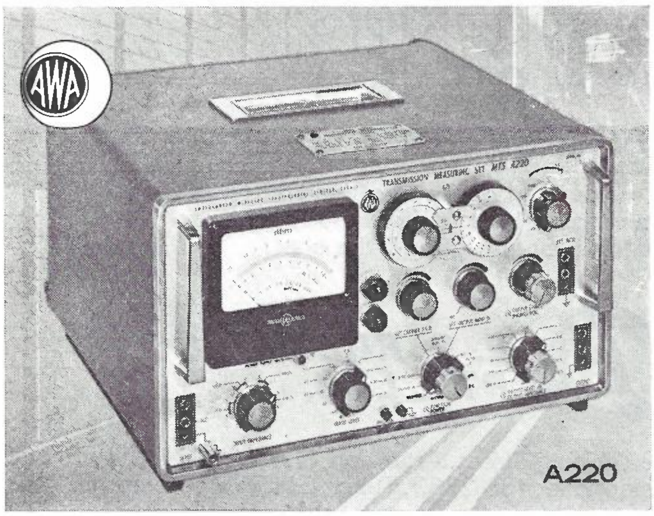
Friday 17 October was devoted to three separate technical sessions in the form of group discussions led by the A.B.C., A.B.C.B., and the A.P.O. respectively, on matters coming under the jurisdiction of each.

On Saturday 18 October, Asian delegates were shown over the Redfern radio terminal and later taken on a conducted visit to places of tourist interest in the vicinity of Sydney. Delegates were also guests of the Department at a social function on Saturday evening.

Mr. C. J. Griffiths, O.B.E., First Assistant Director-General, Engineering Works chaired the seminar and Mr. J. L. Knott, C.B.E., Director-General, delivered an address of welcome.

A total of 70 delegates and observers attended the engineering seminar including 14 overseas delegates from Japan, Nationalist China, U.K., Malaysia, Singapore, India New Zealand, Thailand, Turkey, Brunei and Iran.

The Choice of Transmission Engineers



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REGULATED POWER SUPPLY

HEAVY DUTY — MAINS OPERATED

A Regulated Power Supply designed basically for the replacement of storage batteries used in the design and testing of mobile radio equipment, and other laboratory, production testing, manufacturing and service installations.

TYPE PS 90

The regulator is of conventional design using a differential comparator to provide an error signal to control the operation of the four parallel connected power transistors via a voltage amplifier and two Darlington connected low-power transistors. Base current for the Darlington connection is supplied from a constant current source which may be adjusted to minimize the output impedance. The output voltage may be adjusted by a front panel control within the limits stated for each range.

An overload circuit, which operates if the output current exceeds 120% of full load current, is provided to turn off the regulator thereby protecting both the regulator and the external circuit. A current sensing circuit is used to fire an SCR which completely removes base drive from the series transistors. Normal operation is restored by removing the overload and pressing the reset button on the front panel. Thermal cutouts are used on each power heat sink for overload protection under excessive ambient temperature conditions.

SPECIFICATIONS

Input:	240V ± 10% 50 Hz.
Output:	Range 1, 5-8V DC 20A max. Range 2, 10-16V DC 17A max. Range 3, 22-32V DC 10A max.
Regulation:	Load and Line 0.2% on all ranges.
Ripple and Noise:	Less than 20 mV p-to-p on all ranges.
Output Impedance:	Less than 5 milliohms.
Overload Protection:	Fixed electronic tripout at 20% overcurrent on all ranges. Pushbutton reset on front panel.
Circuitry:	All silicon solid state.
Metering:	Separate 4" voltmeter and ammeter.
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- ★ Long-term stability
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- ★ Generous power safety factor
- ★ Fully insulated moulded body

IRC, the developer of Metal Glaze, now offers a new, low-cost, .moulded Metal Glaze resistor, value engineered for optimum precision and reliability.

The thick-film Metal Glaze resistance element, 100 times thicker than conventional films, defies catastrophic failure, withstands high temperatures and high overloads, and is impervious to environmental extremes. Its fully insulated moulded body resists solvents, corrosion and mechanical stresses and has a dielectric strength of 500 VRMS.

Load life stability is excellent. Resistance change is typically less than .5% after 1000 hours, ¼ watt at 70° C.—four times better than Mil-R-22684 specification allowance.

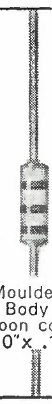
For operation at lower ambients, take advantage with confidence of this mighty midget's inherent stability characteristics. For instance, at 40° C. you can give it a full ½ watt.

Manufactured in Australia by IRC AUSTRALIA

CAPSULE SPECIFICATIONS

IRC Type RGQ

Commercial rating:	½ W @ 40° C.
Resistance:	6.2Ω to 150KΩ
Tolerances:	Std. ± 5%
	Special ± 2%
Temp. Coefficient:	± 200 ppm/° C. max.
Voltage:	350 V. max.



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A person's medical record is compiled from birth and stored in a computer bank. The benefits are obvious. A Melbourne man holidaying in Brisbane falls ill. The doctor only has to dial the computer bank for the man's complete medical history. But the whole Datel scheme would have been impossible without cable to carry the voices and the data. Over 20 million miles of wire cable have been laid in Australia. As development continues, the demand for cable will be even greater. Austral Standard Cables are ready to meet it.

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Automatic Electric Company,
Northlake, Illinois, U.S.A.
Automatic Electric (Canada) Ltd.,
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QUICK DELIVERY The Hitachi C23H crossbar exchange can be delivered to any site in a short time.

FAST SETUP Simply transport the unit to the installation site, anchor it to the concrete foundation and connect AC power cables and external telephone lines. No other work is required; it's ready for service within a month.

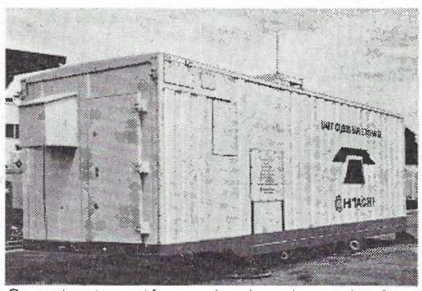
NO DAILY MAINTENANCE Operational data are automatically indicated by the Maintenance Data Recorder, eliminating the need for routine testing. Maintenance personnel at a remote office can supervise and test the exchange. Personnel also can identify malfunctions through the unit's remote alarm system.

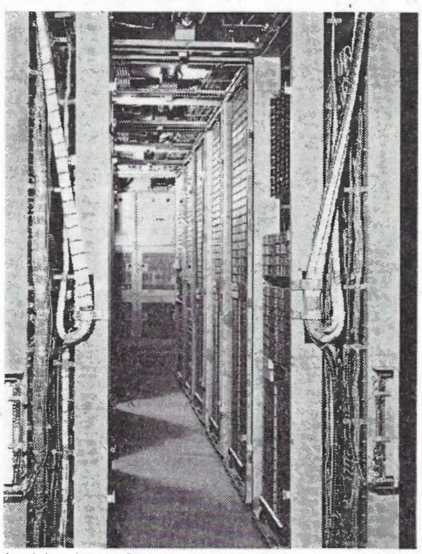
HIGH-SPEED DIALING Works with 20 pps dial telephones.

FLEXIBLE ROUTING Alternative routing facilities available among trunk lines.

WEATHERPROOF UNIT The entire unit is safeguarded against rain and dust and is fully air-conditioned.

CAPACITY Any number of units may be used in parallel (1000 lines per unit).


Completely self-contained unit ready for cable connections.


Inside view of unit. Back-to-back installation saves space.

INTERCONNECTION The Hitachi exchange can directly interconnect with all present exchanges of any type and is compatible with MFC signaling systems.

POWER SUPPLY Two silicon rectifiers and battery supply adequate power to run the unit; if AC power fails, the battery will supply power for one normal day.

	C23HA	C23HD
No. of Subscribers	1,000	1,000
Traffic Capacity (Erlangs / Line)	0.083	0.166

Hitachi is the exclusive supplier to the Nippon Telegraph & Telephone Public Corporation, and to date has sold 500 exchanges which are being used in Latin America, Southeast Asia, the Middle East, and Africa, as well as in Japan.

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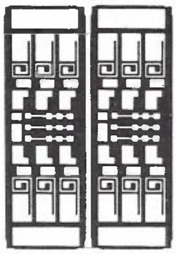
Hitachi can also supply upon request local crossbar exchanges, toll crossbar exchanges and PABX small to large capacity exchanges.

IN MICROCIRCUITRY

how close can you photograph 2 objects and still have clear separation between their images?



WRAY GIVES YOU THE ANSWER:

This table shows the extremely high resolution of the Wray range of copying lenses. It assumes monochromatic light of 0.5461 μ and that the lenses are used at the conjugates for which they are designed. These resolution figures represent line pairs and do not count a black line and a white space as two.

**Also available is a 45mm. f/4 lens covering ½" square at a reduction ratio of 50:1 with a resolution of 280 lines/mm.*

Wray Precision Lens*	Reduction ratios available	9.5° semi-field (under-covering)	12° semi-field (normal)	14.5° semi-field (stretched)
3" f/4	25:1 10:1 5:1 2:1	¾" square 280 lines/mm.	1" square 240 lines/mm.	1¼" square 200 lines/mm.
5" f/4	40:1 20:1 10:1 5:1	1¼" square 240 lines/mm.	1⅔" square 200 lines/mm.	2" square 160 lines/mm.
10" f/4	20:1 5:1	2½" square 200 lines/mm.	3¼" square 150 lines/mm.	4" square 100 lines/mm.

Wray Microcircuit lenses are specially designed for a maximum area of coverage with the highest possible resolution. A wide range of Wray copying lenses is available through the Australian Distributors.

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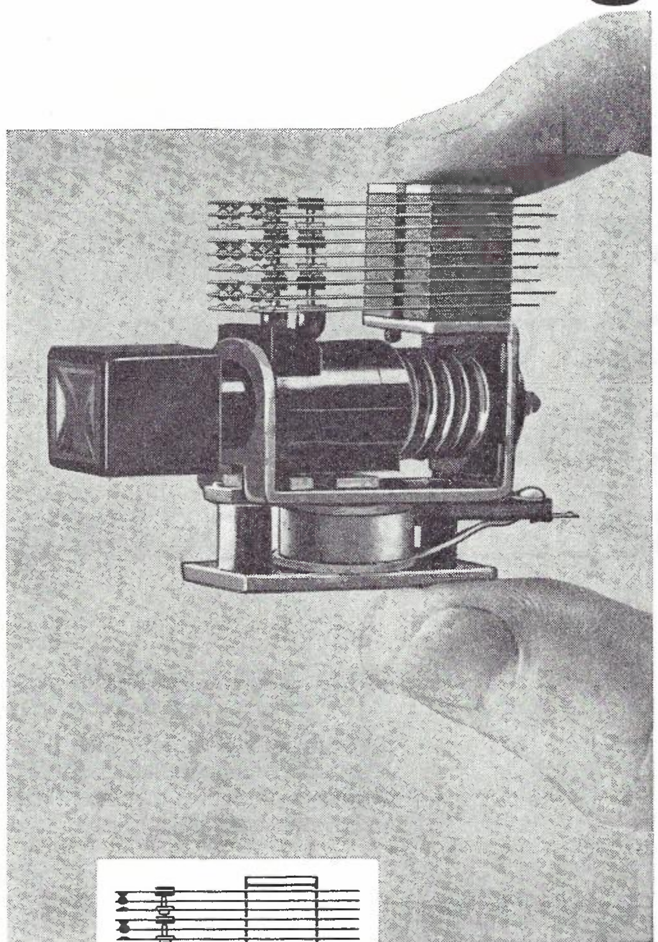

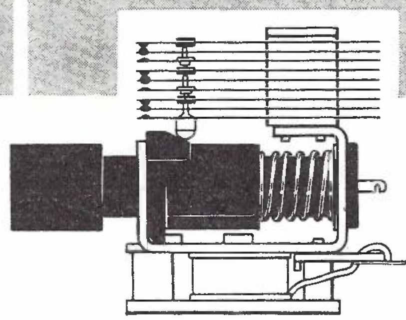

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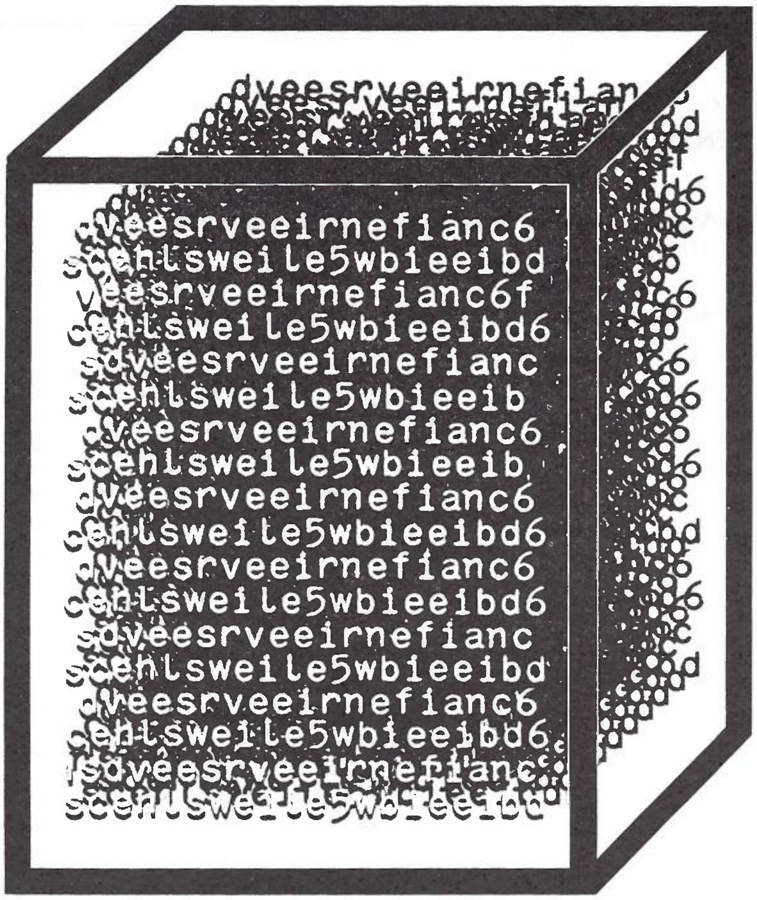

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THE TELECOMMUNICATION JOURNAL OF AUSTRALIA

VOL. 20 No. 1
FEBRUARY 1970

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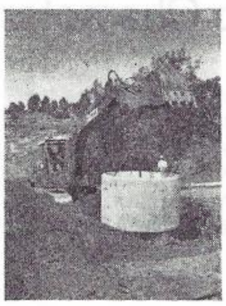


COVER
Installing the Perth-Carnarvon Cable

The TELECOMMUNICATION JOURNAL of Australia

ABSTRACTS: Vol. 20, No. 1

BERGMAN, D. F.: 'The ARF Minor Switching Centre'; Telecom Journal of Aust., Feb. 1970, page 50.

Basic network and equipment design considerations leading to modification of the ARF exchange to allow it to switch S.T.D. traffic in country areas are described. A switching facilities specification is developed and reference is made to the new Reg-H4 and Reg-ELP.

HANNAH, A. and HARDING F. J.: 'Design Aspects of the Perth-Carnarvon Coaxial Cable System'; Telecom Journal of Aust., Feb. 1970, page 3.

This paper discusses design aspects of the Broadband equipment, balanced pair carrier systems and cable plant associated with the Perth-Carnarvon coaxial cable system. The broadband equipment is transistorised and temperature-controlled with underground repeaters. Remote power fed 12 channel transistorised repeaters operating on the interstitial quads, provide minor trunks. Single quad feeder cables employing 40 lb per mile copper conductors link rural exchanges to the main cable route. Underground repeater housings, the gas pressure alarm system, manhole arrangements and thermal insulation problems are discussed.

HIGGINS, P. and KEIGHLEY, R.: 'Management Control Systems'; Telecom Journal of Aust., Feb. 1970 page 74.

In this paper the programming, scheduling and control phases of management are discussed and a set of principles for integrated management control systems is developed. A systematic approach to management system design is described.

HUSTON, J. A.: 'Installing the Perth-Carnarvon Coaxial Cable'; Telecom. Journal of Aust., Feb. 1970, page 29.

This paper deals with the methods used to lay and joint a polythene jacketed lead sheathed four tube coaxial cable over more than 600 miles under a variety of terrain conditions. On this project, for the first time in Australia, the totally buried concept for a coaxial cable installation was adopted (excluding terminal buildings). The tight timetable demanded a new set of installation plant and principles; cost considerations and successful trials on other projects led to the adoption of mole plow techniques other than trenching; the cable was placed 4 ft. below the ground surface by the plow even through rock. The relative fragility of the cable was a major factor throughout.

JONES, L. A.: 'The Perth-Carnarvon Cable Project; Planning Aspects'; Telecom Journal of Aust., Feb. 1970 page 19.

A short survey is given of the development of industry and telecommunications in the region of Western Australia served by the coaxial cable system. Possible solutions to the problem of meeting the rapidly-expanding demand for circuits are discussed, leading to the decision taken in 1966 to proceed with a 12MHz cable system. Details of the planning aspects of the main and peripheral systems are provided, followed by some information on proposed extensions.

KELLOCK, A.: 'Communication Satellites'; Telecom Journal of Aust., Feb. 1970, page 43.

The method of locating satellites in geostationary orbit and the general characteristics of commercial communication satellites and earth stations are briefly described in this paper. Outlines are given of proposals for domestic satellite systems in various countries and of progress in Australian studies.

LARSSON, I. W., and REID, D. M.: 'Transmission Testing of New Telephone Circuits'; Telecom Journal of Aust., Feb. 1970, page 60.

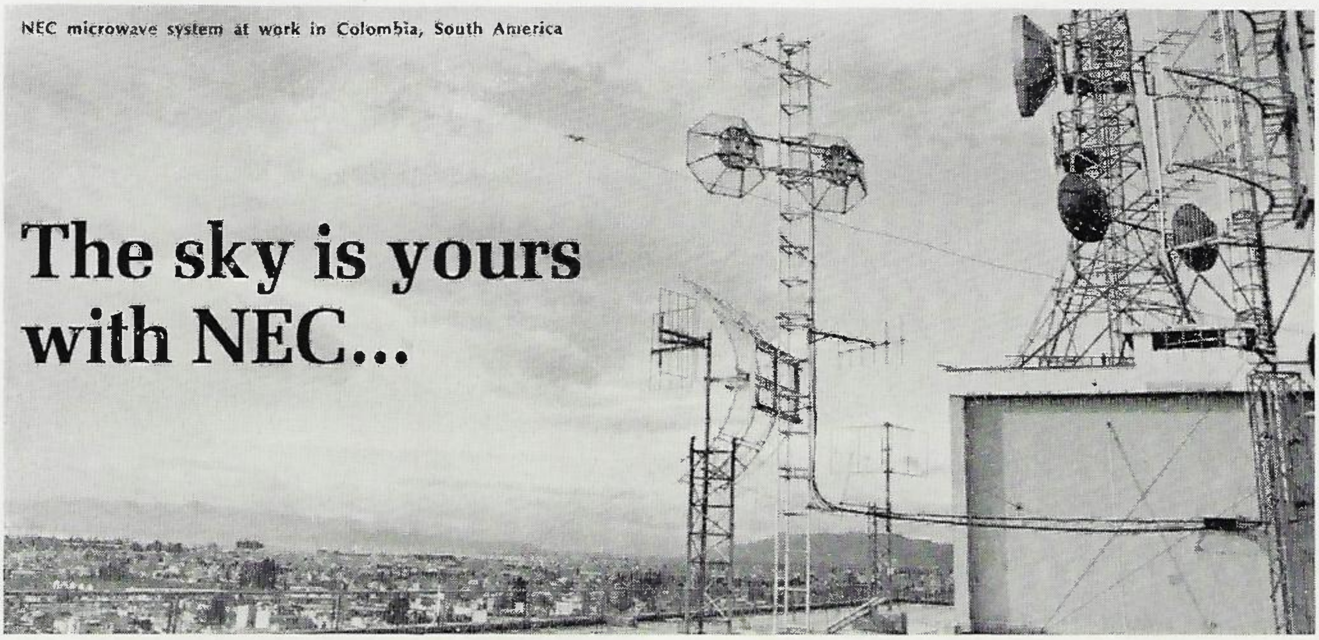
Transmission testing procedures being used in Victoria to commission new telephone circuits are described in this paper. The telephone circuit is defined and the activities relating to the successful commissioning of new telephone circuits are detailed. The types of testing instruments and equipment used are also discussed briefly.

PROVAN, G. A.: 'Development in Main Distributing Frames'; Telecom Journal of Aust., Feb. 1970 page 68.

This article describes some of the problems presented by the new Lonsdale m.d.f. and some changes that have been adopted which are especially advantageous on large m.d.f.s. A large part is devoted to the problem of jumper density and the ways in which it can be minimised. Jumpering practice which avoids damage to the insulation of existing jumpers is described. The increased terminating capacity of the new 100 pair link mounting has enabled a single m.d.f. to suffice for Lonsdale Exchange.

SCOTT, F. M.: 'Dual Telephone Jacks for Manual Switchboards'; Telecom. Journal of Aust., Feb. 1970, page 79.

Facilities are required to allow the connection of two telephonists' headsets to an operating position for training, monitoring and staff changeover purposes. This article reviews some of the methods used in the past to provide this facility and gives details of an improved circuit provided in A.P.O. System AFM402.



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Microwave radio relay systems laid by NEC in Japan, Australia, Brazil, Iran, India and many other countries have reached 107,340,000 channel kilometers or well over the equivalent of a 120 channel duplex telephone link to the moon.

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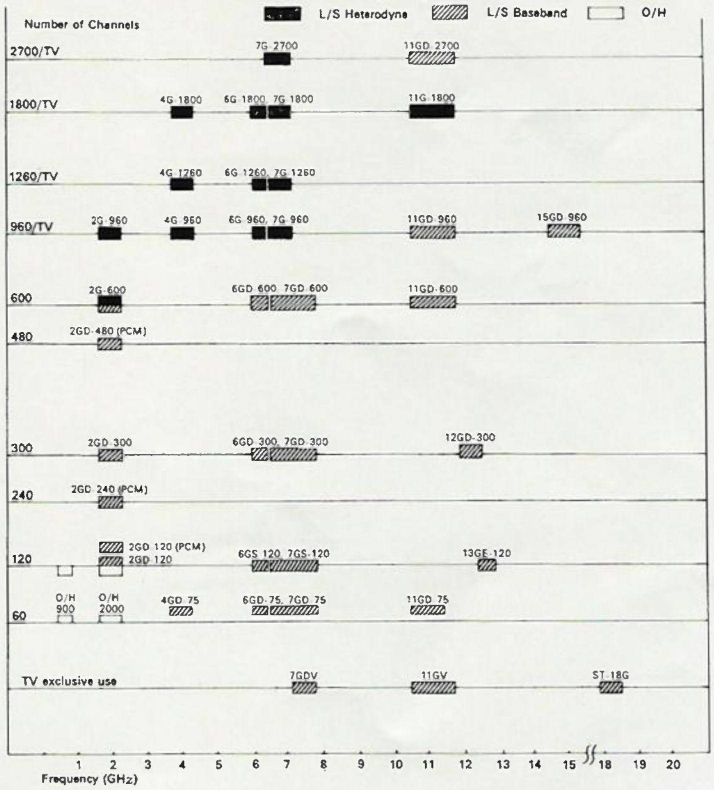

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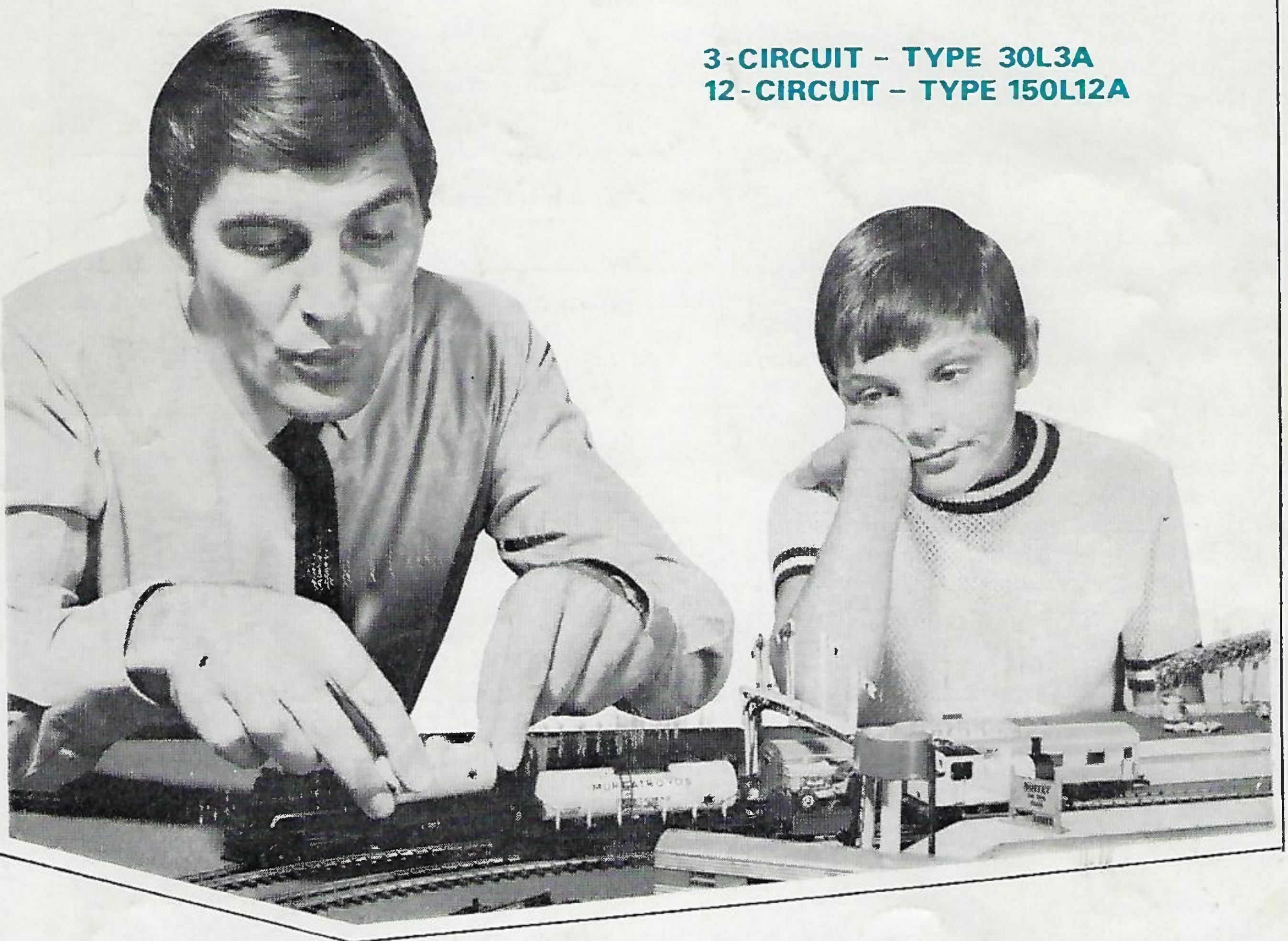
The systems comply with CCITT recommendations so that several 3-circuit systems can operate over the same pole route, and several 12-circuit systems can be operated over parallel pairs on the same pole route, in each case with minimum crosstalk.

3-CIRCUIT - TYPE 30L3A
12-CIRCUIT - TYPE 150L12A



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