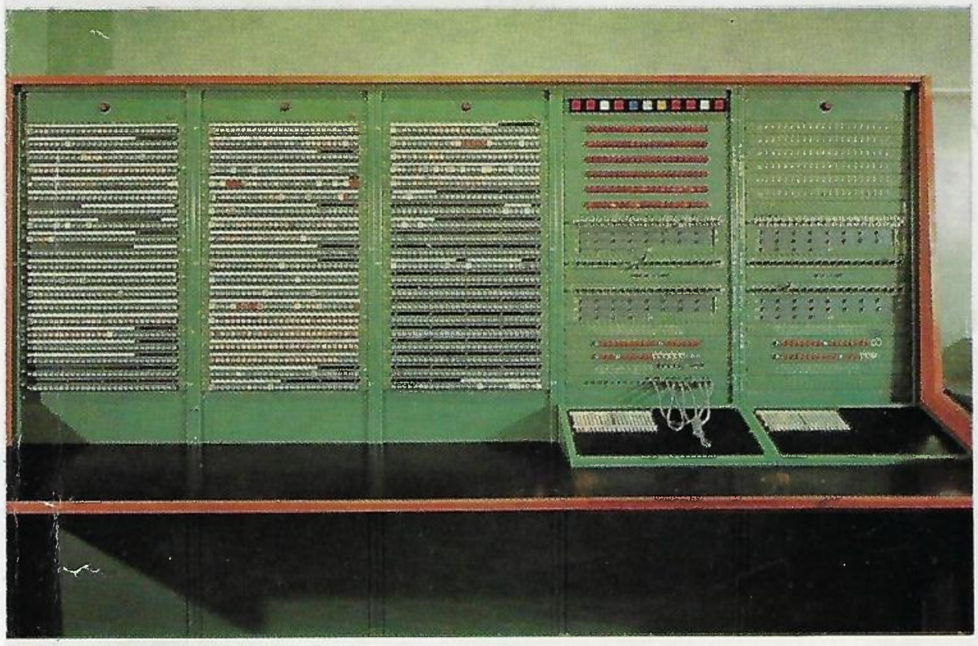
THE

Telecommunication Journal OF AUSTRALIA



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VOL. 19 No. 1 Registered at the General Post Office, Melbourne, for transmission by post as a periodical. FEBRUARY, 1969

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THE TELECOMMUNICATION JOURNAL OF AUSTRALIA

VOL. 19 No. 1
FEBRUARY 1969

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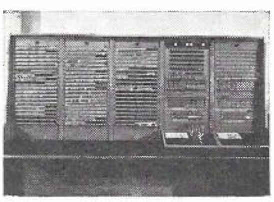

COVER
Remote Blocking and Occupation Display
Haymarket Exchange

The TELECOMMUNICATION JOURNAL of Australia

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

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

Residents of Australia may order the Journal from the State Secretary of their State of residence; others should apply to the General Secretary. The subscription fee for Australian subscribers is 1 dollar per year, or 40 cents each for single numbers. For overseas subscribers the fee is 1 dollar and 50 cents per year, or 50 cents for single numbers. All rates are post free. Remittances should be made payable to The Telecommunication Society of Australia.

Information on how to prepare manuscripts for the Journal is available from members of the Board of Editors.

Contributions, letters to the editors, and subscription orders may be addressed to:

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Box 1069J, G.P.O. Adelaide, S.A. 5001.
Box T1804, G.P.O. Perth, W.A. 6001.
Box 1522, G.P.O. Hobart, Tas. 7001.

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OBITUARY

MR. T. A. HOUSLEY, C.B.E., B.Sc., F.I.E.Aust.

The sudden death of the Director-General, Mr. T. A. Housley, C.B.E., B.Sc., F.I.E.Aust., on 10th October, 1968, at the age of fifty-seven years, came as a deep shock to Post Office people throughout Australia. As the news spread among the staff there was a feeling of personal loss and sadness. Loss, because Mr. Housley was a man of great human understanding whose warm and friendly personality had won affection and respect from all quarters. Sadness, because many felt that his career as Director-General held so much promise and potential for the future.

Mr. Housley made a wide contribution to the advancement of telecommunications. His early career was in the Queensland Administration where, after joining the Department in 1926, he was appointed as an engineer in the Radio Section. His sphere of influence extended to New Guinea and the Pacific Islands and during the 1939-45 War he played a vital role in defence communications. In 1946 he was promoted to the Department of Civil Aviation where as Chief Airways Engineer he made a significant contribution to the establishment and development of radio, radar and communication facilities for civil aviation.

In 1951 he was appointed Assistant General Manager, Overseas Telecommunications Commission (Australia) where his influence was extended to international communications. As convenor of the Pacific Cable Management Committee he played a prominent role in the provision of the COMPAC and SEACOM cables. He represented Australia on many delegations affecting Australian communications interests and was its representative on the Interim Communication Satellite Committee.

Mr. Housley became General Manager of the Overseas Telecommunications Commission (Australia), in 1956. His contribution as a senior administrator in this position brought him wide praise and showed that his administrative capacity was of the highest order. He was awarded the C.B.E. in 1961.

In 1965 he was appointed to lead the Post Office—the Department in which he began his public service career thirty-nine years before.

Mr. Housley's three years as Directo-General were marked by progress on many fronts, but perhaps the most significant development was the decision to proceed with fundamental changes in the methods of financing Post Office activities. The new financial arrangements introduced in July 1968 are a landmark in the history of the Australian Post Office, a landmark with which Mr. Housley's name will be irrevocably linked.

Always ready to mix with his staff, Mr. Housley took every opportunity to talk with them about their work and to participate in their various activities. In July 1968 he delivered an address on the new financial arrangements to the Victorian Engineers Group of the Professional Officers Association (see the previous issue of this Journal). His handling of the subsequent question and answer session won wide acclaim from the large number of engineers present.

Many tributes have been paid to Mr. Housley, but perhaps the one he would have valued the most came from the Postal Telecommunication Technicians Association when it marked his passing with these words: "This Association has lost a very good friend, a man of integrity and ability but above all a man with a full measure of humanity,"

The Telecommuncation Society has also lost a friend and on behalf of all members extends deep sympathy to Mrs. Housley and her family.

MR. R. V. McKAY, M.I.E.Aust.

Mr. R. V. McKay, a former Engineer-in-Chief of the Australian Post Office passed away in London on 4th December, 1968. Mr. McKay was one of the first three trainee Engineers in the Post Office, joining as a cadet in 1908, and qualifying as Engineer in 1913. He acted immediately in the grade equivalent to Divisional Engineer and was appointed in 1914 at the age of twenty-one years.

A man of great vision and foresight, he exerted a dominating influence in the field of telephone equipment, first in New South Wales during the period 1924 to 1934 and subsequently at Central Office. He was Engineer-in-Chief in the critical period 1940 to 1950. His energy and drive in this position were largely responsible for the successful role played by the Department in providing national communications during the critical war years and subsequently in the immediate post-war years when material shortages and heavy demand for services brought many technical and administrative problems.

In 1950 Mr. McKay went to London to represent the Post Office in England and on the Commonwealth Telecommunication Board. He retired from Post Office duty in 1956 after 48 years of outstanding service. He continued his work on the Commonwealth Telecommunications Board for a further three years, before retiring from that position in March 1959.

During his long association with the Post Office Mr. McKay made a significant contribution to its development on both the technical and administrative fronts. He had marked influence on the development of the automatic telephone exchange networks in the period when automatic equipment was first being installed. His inspiration and leadership as Engineer-in-Chief for ten years undoubtedly set the foundation for the introduction of many new developments which today have brought to Australia a telecommunication service which ranks among the best in the world.

COMMISSIONING TESTS FOR THE ARM GRID.

*I. W. LARSSON, A.R.M.I.T., Grad. I.E.Aust.**

The recent establishment by the Australian Post Office of the ARM Grid has been described in a previous issue of this Journal (Ref. 1), and development and design aspects leading to the introduction of ARM.20 crossbar trunk exchanges have also been mentioned in earlier issues of the Journal.

An important aspect of the establishment of the ARM grid was the commissioning tests, and this paper outlines some of the features of these tests. The basic types of commissioning tests and procedures adopted were the subject of joint discussions between Headquarters and State engineers. As a result of these discussions, Headquarters issued the ARM Commissioning Test Instruction, which was used by the States to ensure systematic testing of all important facilities of the ARM grid. This instruction also assisted with the co-ordination of testing activities between the States involved in the installation of the ARM grid.

This paper describes the main features of the testing plan and gives details of the methods used in performing some of these tests, but with particular reference to the Geelong ARM Exchange Network. A further aim of this paper is to give an appreciation of the nature of ARM network commissioning and the service aspects to be checked, matters which will be of increasing concern to service engineers as the ARM grid network continues to expand.

THE GEELONG ARM NETWORK.

The Geelong ARM exchange was installed with an initial capacity of 400 incoming, 400 outgoing, and 200 both-way circuits. At the time of the establishment of the National ARM grid (28th November, 1967), 278 incoming and 334 outgoing circuits were connected to the Geelong ARM exchange. Geelong is the centre of a secondary switching area and is situated some 45 miles south-west of Melbourne. The ARM exchange serves originating exchanges within the Geelong secondary area and switches to intrastate routes up to 120 miles west of Geelong.

Interstate exchanges connected to the Geelong ARM exchange include Haymarket ARM in Sydney, Launceston ARM in Tasmania, North Adelaide and Edwardstown ARF tandems, and Franklin SxS exchange in South

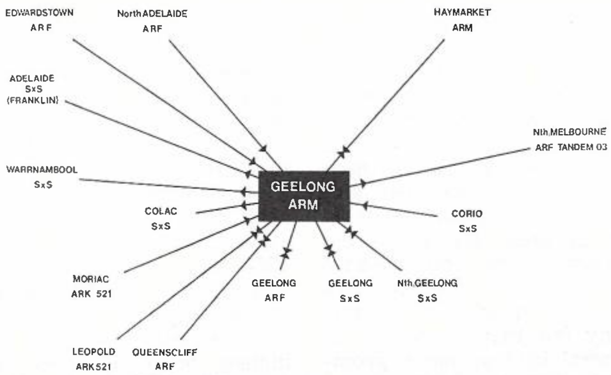

Fig. 1 — Routes Connected to the Geelong ARM Exchange, November 1967.

Australia. Fig. 1 shows the routes which were connected to the Geelong ARM exchange at the time of commissioning in November, 1967.

The Geelong ARM exchange was installed by L. M. Ericsson under contract and was departmentally supervised by the Contract Exchange Installation Division. Following successful acceptance testing the ARM exchange was handed over on the 8th August, 1967, to Country Exchange Installation, No. 2 Division, who commissioned the exchange and network, subsequently cutting over Stage 1 on 29th October, 1967, and Stage 2 on 28th November, 1967.

ORGANISATION.

In the case of the Geelong installation it was realised even before the installation of the ARM exchange commenced that network testing in the final stages of the installation would need to be co-ordinated and that both installation and service engineers, not only at the ARM, but also at the distant-ends, would need to become familiar with the new methods of line signalling and the new types of line signalling relay sets which were being installed. In November, 1965, the Geelong ARM Network Implementation Committee (GANIC) was established to co-ordinate not only material supply and installation programming, but also the scheduling of final network testing. The composition of GANIC is shown in Fig. 2.

Reference to Fig. 2 gives a clear indication of the total involvement of engineering staff in the implementation of one ARM.20 exchange and network. Fig. 2 also makes reference to the Central Office ARM Grid Co-ordination Conference, which was established in November, 1966, to review the progress of the 5 ARM installations in hand at that time, namely, Haymarket, Newcastle, Canberra, Launceston and Geelong. In July, 1967, a Central Office co-ordination meeting was called with representatives from all States involved with the establishment of the National ARM Grid, to review the proposed network testing and commissioning schedules. The result of this meeting was the setting up of co-ordinating testing officers in each State, who would be responsible for organising test schedules and perform the necessary liaison duties to ensure a smooth running testing programme. Also, as

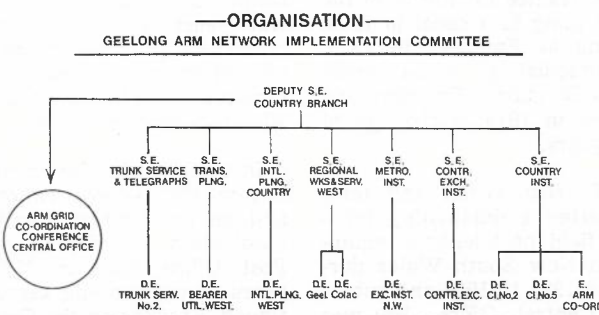

Fig. 2 — Composition of the Geelong ARM Network Implementation Committee — GANIC.

* Mr. Larsson is Engineer Class 2, ARM Design and Coordination, Victoria.

a result of this meeting, a comprehensive list of test telephone numbers was prepared for use by testing officers during the network testing stage.

ROLE OF THE SERVICE ENGINEER.

Just prior to the commencement of installation of the Geelong ARM network it was evident that many engineers from different areas would be involved over the period of installation and pre-cutover testing of the network. Amongst the engineers included in GANIC were service engineers from Geelong, Colac and Trunk Service. These engineers were included in the committee so that they would be aware of the progress of installation work and informed of both the ARM and distant-ends service requirements. One of the first items involving service engineers on the Geelong project was the layout of the Service Control room and this matter was resolved at GANIC meetings.

In the commissioning instructions issued by Headquarters, active participation by service engineers in the planning of the testing programme was called for. In this field the service engineer can offer valuable assistance because of his knowledge of the local originating and terminating networks especially when tests have to be made from various types of PABX's, PT's, intercommunication systems, and other types of subscribers' apparatus existing in the particular network. It is considered that the service engineer can give valuable assistance in the preparation of network test schedules where such a schedule involves local exchanges in his area of control.

The commissioning instruction also stipulated that a drawing should be prepared for each distant-end exchange having access to the ARM grid, showing the trunking and signalling arrangements for each particular type of route. Fig. 3 represents a typical drawing and shows a telephone circuit from a step-by-step exchange, using FUR-L1S-K relay sets, parts 1 and 2 connected to the ARM exchange, using FIR-Z type relay sets.

Signalling conditions are shown for three types of call, namely, multi-metering, unit fee and non-metering, and the pulse conditions which occur at points G, J and K on the trunking diagram and shown under similar references on the pulse diagram. For example, it can be seen that a multi-metering call originated from a public telephone, K, would be barred access immediately the fleeting reversal was returned from the FUR-L1S-K relay set. The line signalling conditions G, for a multi-metering call show that following the receipt of an answer signal, the subscriber is metered. The next meter pulse is suppressed by the FIR-Z relay set in the ARM exchange in accordance with the modified Karlsson system of metering. Subsequent pulses at the appropriate charge rate are applied to the calling subscriber's meter. Further, should the B party clear, but the A party remain on the line, metering of the A subscriber continues till such time as either the A subscriber clears or a forced released condition is returned from the ARM after a time supervision period of 72 to 144 seconds. This type of diagram readily displays the above information and serves both as a service and training aid. Similar drawings should be prepared in all cases where originating exchanges have S.T.D. access.

There are many other aspects in an ARM exchange and network which are of concern to service engineers and some of these aspects have been covered in a previous issue of the Journal. (Ref. 2.) Transmission testing facilities, including the use of 117x test numbers, automatic transmission test units and special ARM four-wire buttinskis are service aids being developed at the present time and are of interest to service engineers and it is hoped to cover these facilities in future issues of the Journal.

OUTLINE OF NETWORK TESTING PLAN.

The purpose of the Network Testing Phase was to ensure that all switching and signalling facilities offered by the local ARM exchange and the ARM grid were functioning correctly and it was for this purpose that the Headquarters Commissioning Testing Instruction was prepared. Because of the complicated inter-signalling and inter-working problems inherent in such a large network as the ARM Grid, the need for careful testing of individual telephone circuits followed by comprehensive end to end checks was essential.

Before the network testing commenced at Geelong, an examination of the Stage 1 and Stage 2 cutovers was made to determine the order in which the terminal exchanges should be scheduled for testing. Stage 1 was scheduled for cutover on the 29th October, 1967, and Stage 2 on the 28th November, 1967. Fig. 4 shows the

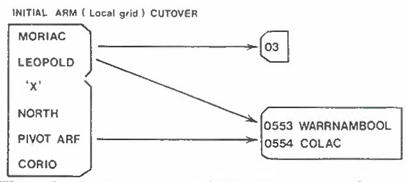

Fig. 4 — Geelong ARM Network Stage 1 Requirements.

exchanges associated with Stage 1 of the cutover, and these took first priority in the network testing plan. Fig. 5 shows the Stage 2 cutover requirements, which included the addition to the ARM exchange of routes to Queenscliff, Sydney, Adelaide and Launceston.

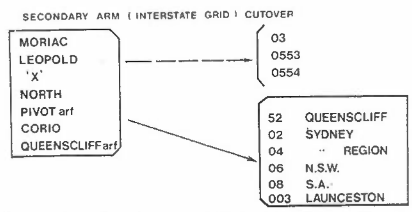

Fig. 5 — Geelong ARM Network Stage 2 Requirements.

Prior to the commencement of the commissioning tests, the ARM exchange itself had been tested by the contractor in accordance with the functional testing instructions prepared by Headquarters. These included func-

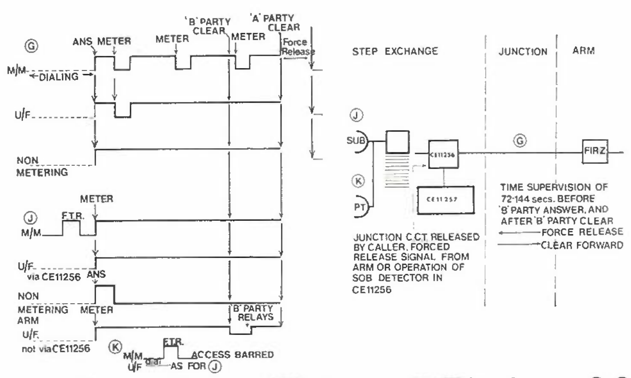

Fig. 3 — Typical Diagram Showing STD Access Facilities from a SxS Exchange.

TABLE 1 — TELEPHONE CIRCUIT TESTS

Test	ARM to Step		Step to ARM		ARM to ARF		ARF to ARM		ARM to ARM		ARM to ARK		ARK to ARM	
	Phys.	Carrier	Phys.	Carrier	Phys.	Carrier	Phys.	Carrier	Phys.	Carrier	Phys.	Carrier	Phys.	Carrier
Seize forward	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Proceed to send (seizure acknowledge)		X		X										
Pulsing (dialling)			X	X	X	X					X	X	X	X
Call KM											X	X		
Ring Tone					X	X					X	X		
Busy Tone	X	X	X	X	X	X					X	X		
Answer	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Metering			X	X			X	X					X	X
Clear Back (B party clear)	X	X	X	X	X	X	X	X	X	X	X	X	X	X
B party re answer	X	X			X	X			X	X	X	X		
Clear forward	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Release guard	X	X					X	X						
Forced Release - Time Supervision	X	X	X	X	X	X	X	X			X	X	X	X
Blocking (back-busying)	X	X			X	X	X	X	X	X				
Channel Failure		X		X		X		X		X		X		X
Non-Metering			X	X			X	X					X	X
Discriminating Functions of M/M Rep'tr			X	X										
SOB Access Barring, FIR, PT tone etc.			X	X										
Marginal Tests LME pulse ccts.														
Physical ccts. decadic pulsing														
Transmission Tests														
Noise & loss (including Pad Switching)	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Frequency Response and Shift														
Stability and echo balance														

tional tests of all line signalling relay sets, as well as tests on markers, registers, tariff equipment and internal trunking of the exchange. Tests on the internal trunking at the exchange included checks on poling, pad switching and transmission through the switching equipment.

A 100 per cent. check was made by the Contract Exchange Installation Division of all strappings carried out during installation, including markers, test blocks, registers and line relay sets. Following these checks, test calls from each ARM inlet to each ARM outlet were made and each register was tested for access to all codes, including service codes and spare codes. All FIR-Z type relay sets were tested for correct tariff settings on all tariff rates.

Tests on all outgoing and incoming trunk and junction circuits were made by Country Installation No. 2 Division to check the correct functioning and interworking of equipment at each end of the trunk or junction circuit. Table 1 summarises these tests. At the originating local ARF exchanges, registers and SR relay sets were checked to see that they functioned correctly on S.T.D. calls. These tests were made over single telephone circuits, that is from the ARM exchange to the distant exchange and vice-versa.

The next stage of testing involved the setting up of test calls over two telephone circuits, which were switched as follows:—

(a) Junctions from originating exchanges to the ARM and switched to trunks and junctions outgoing from the ARM.
(b) Trunks outgoing from one ARM to a distant ARM or crossbar tandem switched to telephone circuits outgoing from the distant exchange.

Test calls were made over the ARM grid involving three or more telephone circuits, to check MFC and decadic signalling under the most severe conditions that would be encountered by telephone subscribers who would be using the grid. In the case of Geelong multi-link calls were made via Geelong, Haymarket and Newcastle ARM's.

The final stage of testing consisted of sample test calls made from various types of subscribers' apparatus to ensure that unforeseen service difficulties were reduced to a minimum. The Telecommunications Division performed the greater part of these tests and reported any service difficulties back to the Engineering Division for technical analysis.

The foregoing summarises the types of tests which were carried out during the commissioning period and some of the tests referred to above will be explained in further sections of this paper.

MARGINAL TESTS ON PULSE SIGNALLING.

The L.M.E. pulse signalling system is used in the ARM exchange network and employs long and short signalling elements. A detailed description of this system was given in an early issue of the Journal (Ref. 3). The marginal tests which were specified in the Commissioning Instruction were carried out on line signalling relay sets at both the ARM and distant end exchanges independently, followed by overall tests from the ARM to distant end exchanges as specified in the functional tests referred to in the following section of this paper.

Marginal tests were performed on response times and pulse lengths, the test limits being:

	Response times.	Pulse lengths.
Short pulse	80 ± 20 mS	150 ± 30 mS
Long pulse	275 ± 75 mS	600 ± 150 mS

To check the response times of both long and short pulses, Test Set No. 31 was used to send pulses of known length into the RL lead of the relay set under test, and relays F2 and F7 observed. Relay F2 operated when a short pulse condition was recognised and relay F7 operated for a long pulse condition. In the case of the short pulse, the response time was tested by sending a 60 mS pulse, and checking that relay F2 did not operate. A 100

TABLE 2: PULSE LENGTHS OBSERVED AT COLAC ON FIR-T3S-GT RELAY SETS.

Circuit Number	Answer	B Party Clear	Forced Release	Thermal Time Out	A Party Release
1	171	721	1125*	68	565
2	162	738	1151*	72	681
3	164	736	1307*	70	689
4	180	771*	1165*	61	676
5	169	727	1034*	74	642
6	170	689	1112*	73	649
7	175	738	1011*	73	661
8	169	726	1082*	65	600
9	179	731	940*	63	672
10	179	726	1103*	63	713
11	176	723	1019*	63	678
12	189*	733	1094*	74	668
13	166	596	994*	76	608
14	170	879*	1189*	74	656
15	172	708	1068*	68	662
16	164	655	964*	72	636
17	187*	740	1118*	R.Set Faulty	
18	167	722	1056*	72	682
19	161	820*	1048*	66	619
20	173	710	1073*	65	604
Test Limits	120-180 mS	450-750 mS			450-750 mS

mS pulse was then sent on the RL lead and relay F2 was checked to see that it had operated. The same method was used to check the response time of the long pulse except that the minimum limit pulse was 300 mS, at which F7 should not operate and the maximum limit pulse 450 mS at which F7 should operate. If the recognition relays F2 and F7 performed satisfactorily under these tests, no results were recorded. However if, for example, relay F2 did operate at the 60 mS limit, a shorter pulse was sent to determine the actual response time of the relay. Results of this type were recorded and following discussions with Headquarters the appropriate code element relays were retimed to bring the response time within limits.

To check the pulse lengths generated by the line signalling relay for backward signals, such as proceed to send, answer and B party clear, it was necessary to manually operate the appropriate relays in the line signalling relay set and observe the resultant pulse length produced on the SL lead. The resultant pulses were measured on a Test Set No. 31. Results obtained from one such series of tests conducted on FIR-T3S-GT relay sets at Colac, are shown in Table 2.

Where the measured pulse lengths were outside the specified limits they were marked with an asterisk and the faulty conditions subsequently examined.

The most significant feature of the results obtained at Colac was the forced release condition being outside limits in every case. This condition was brought about by incompatibility in timing between the FIR-T3S-GT relay set and the associated S x S switching equipment. A Works Specification to correct this condition was issued by Headquarters, as mentioned in the following section on Functional Tests.

The Commissioning Instruction calls for sample testing on pulse signalling to check the safety margins in production line relay sets. From the experience gained to date with the pulse signalling system, the author considers that the sample tested should be substantial, and that after a period of say, twelve months, a re-check of the pulse signalling system should be made, as outlined above, to determine any drift tendencies in the safety margin.

FUNCTIONAL TESTS ON TELEPHONE CIRCUITS.

Section 4 of the Headquarters Commissioning Test Instruction outlined the types of functional tests to be made over individual trunk and junction circuits. A summary of functions tested and the types of telephone circuits used is shown in Table 1. One of the duties of the Supervising Technician ARM Networks was to prepare and personally supervise detailed prototype tests for all new distant-end equipment and report any circuit weaknesses to Headquarters for examination to determine the type of corrective action to be taken. During the functional testing phase at Geelong, testing staff were asked to report any further malfunction immediately to the ARM Co-ordination Engineer, or the Supervising Technician ARM Networks. No local modifications to circuitry or adjustments to relays, except of course for obvious component failures, were permitted. An example of the procedure followed at Colac, where a malfunction was detected, will be covered later in this section. Records of test results were kept for fault conditions only.

Following the distribution of the Headquarters Commissioning Tests, the Country and Metropolitan Installation Sections of the N.S.W. Administration prepared detailed functional test instructions based on the principles set down in the Headquarters Instruction for use by testing staff in the field. The New South Wales instructions were produced in booklet form, which came to be known as the Yellow Book, and was used at most, if not all, of the initial ARM installations when functional tests were performed. The preparation of detailed test procedures for each type of distant-end equipment, brought about a uniform approach to testing, and hence uniformity of network performance. This booklet also included sections on transmission measuring which will be referred to later in this paper. An example of the functional test sequence for an ARM outgoing relay set FUR-TM-C is shown in Table 3.

TABLE 3: FUNCTIONAL TESTS FOR ARM OUTGOING CIRCUITS USING RELAY SET FUR-TM-C

No.	Test	Method	Observation.
1	Idle condition	——	Check all FUR relays are in the released condition.
2	Seize Forward (SxS routes)	Use Test Box	Check F20 operates. Check F17 operates and then releases.
3	Pulsing (SxS routes)	Use Test Box	Check F20 releases and operates in step with the pulses.
4	Seize Forward and Information Signalling (mfc routes)	Use A.E.T.	Check F20 operates and remains operated during and after signalling. Check F17 operates and then releases.
5	Ring Tone (mfc routes)	——	Check for ring tone after test 4 before distant end answers.
6	Answer	Distant end answers	Check F25 operates and releases. Check F23 releases before F24 releases.
7	Clear Back	Distant end clears, ARM holds circuit	Check F25 operates and releases. Check F24 releases before F23 releases. Check F19 operates.
8	"B" party reanswers	Distant end reanswers 10 seconds after hanging up in test 7.	Check F25 operates and releases. Check F23 releases before F24 releases. Check F19 releases.
9	Clear Back	Distant end clears, ARM holds circuit	Check F25 operates and releases. Check F24 releases before F23 releases. Check F19 operates.
10	Time Supervision	After test 9, ARM holds circuit with D/E cleared	Check distant end equipment is cleared forward after D/E time supervision period. Check ARM FUR BL lamp for full glow.
11	Clear Forward and Release Guard	ARM clears after test 10	Check all FUR relays have released. Check BL lamp on FUR rack for full glow flash.
12	Channel Failure	ARM sets up call and D/E answers. The channel is failed (E and M leads O/C) and both ends clear Allow FUR to repeat sequence again, then restore channel	Check F19 operates and after time supervision pulse, check F17 operates and releases, followed by the release of F16 and F13. Check FUR and distant end equipment clear after time supervision period. Check BL lamp on FUR rack for full glow flash.
13	Busy Tone, (SxS routes)	ARM makes call and D/E Tech. to force selector to 11th step	Check for busy tone.
14	Blocking	D/E to take normal blocking action. ARM to attempt call during blocking	Check BL lamp on FUR rack for full glow. Check that call does not proceed.

It can be seen that the tests listed in the Test Column of Table 3 compare with those in Table 1. The next column indicates the method of performing each test and the last column details the operate and release conditions of particular relays, and the condition of the BL lamp, which should be observed. If the circuit is functioning correctly, the observed conditions in the relay set will agree with those set down in column 3. This form of testing was found to be a very satisfactory method of checking the functions of individual telephone circuits and did in fact reveal some functional irregularities.

One example of a failure discovered during functional tests occurred while testing on the Colac circuits outgoing from Geelong. When checking the B party release condition, it was found that forced release of the A party did not occur, and preliminary investigation showed that there was an excessive pulse length on the backward forced release signal from the FIR-T3S-GT relay set at Colac, and that the B party release facility was also faulty.

Subsequent investigation, part of which is mentioned in the previous section on Marginal Tests on Pulse Signalling, revealed that both the above conditions were caused by the misoperation of a relay in the FIR-T3S-GT relay set during forced release conditions. The exact details of the operating sequence of the B party release condition observed at Colac were forwarded to the Switching Systems Design Section at Headquarters for investigation and the specification of necessary corrective action. Within two weeks of this information being received at headquarters, the Exchange

Equipment Design Section had issued a Works Specification detailing modifications to be made to overcome this circuit weakness, the Works Specification being sent to field staff by teletype in the first instance. The advantage gained by adopting the above procedure of detailed fault investigation by the testing staff on site, and immediately forwarding this information regarding the fault condition back to the Design Engineer at Headquarters, is that when corrective action has been determined all States are informed simultaneously of the fault condition and corrective action to be taken. In this case, it meant that all exchanges which were using the FIR-T3S-GT relay set received notification information at the same time as the Colac exchange, from which the report originated. Probably one of the most important aspects of large switching networks is the need for uniformity of switching equipment, and in particular, line signalling relay sets. The process of reporting even the most minor problems in network switching back to the Design Engineer is essential.

TRANSMISSION TESTS.

The transmission tests as outlined in Section 10 of the Commissioning Test Instruction were based on an Engineering Instruction prepared by the Long Line Equipment Section, Headquarters. The purpose of the Long Line Equipment Engineering Instruction was to introduce standard line-up procedures for telephone circuits to give effective control over the transmission losses of all equipment, comprising the complete telephone circuit between two exchanges. The procedures introduced new reference points in lieu of the hybrid line point for line-up purposes. In each exchange a certain point was defined as the transmission reference point and a connection between two reference points is termed a link. A link comprises the line signalling relay sets at both ends of the connection, together with the associated line or bearer equipment. The measurements made over the links included the line signalling relay sets and switching equipment. It was at the commissioning period of the first ARM exchanges that this method of transmission measuring was being introduced.

In practice, it was found that the ARM transmission reference point, as defined by the Engineering Instruction, was inaccessible from a practical point of view, and the nearest access points were found to be the test jacks in the FUR and FIR line signalling relay sets, In general, all outgoing tests were made at the FUR relay sets and all incoming tests at the FIR relay set. In some cases, incoming circuits were extended through the exchange to a convenient test FUR relay set, at which the incoming circuit transmission tests were performed. The extension of incoming circuits to a test FUR relay set had the advantage of bringing the transmission testing point nearer to the transmission reference point and avoided the necessity of having to manually operate relays in the FIR relay set, a process which is prone to error. Wherever possible, electrical operation of the relevant relays was used.

When performing transmission tests at the FIR and FUR relay sets it was necessary to use an ARM automatic exchange tester to set up the correct switching conditions for transmission testing. An A.W.A. A215 type transmission measuring set, shown in Fig. 6, was connected to the automatic exchange tester and was d.c. isolated from the line signalling relay sets by means of a transformer. However, the two A215 sets used at Geelong were not available until relatively late in the commissioning test programme and other methods which were not entirely satisfactory had to be employed. The use of centre point d.c. signalling in the ARM line signalling relay sets made the matter of d.c. isolation a little involved and more care was required to set up the testing equipment before transmission tests could be made.

All transmission tests performed over trunk and junction circuits were made in the A party seized and B party answered condition. These conditions sometimes had to be obtained artificially, that is, by manually pressing up relays to achieve the correct circuit condition for transmission testing. It was also important to ensure that all VF terminations were cleared from across the circuit during these tests. It was under these conditions that transmission testing was carried out at Geelong over the commissioning period.

The transmission tests to be made were specified by Section 10 of the Commissioning Test Instruction and are as follows:—

(a) Link loss measurements on all circuits terminating at the ARM exchange.

(b) Frequency response measurements on 10 per cent of the circuits in each route at the following spot frequencies: 200 Hz, 300 Hz 400 Hz, 820 Hz, 1.6 kHz, 2.4 kHz, 2.7 kHz, 3.0 kHz, 3.4 kHz and 3.6 kHz.

(c) Stability balance return loss on all 2-wire/4-wire and 4-wire/2-wire circuits with the distant-end of the 2-wire line terminated in its nominal impedance for this test.

(d) Echo balance return loss measurements on all 2-wire/4-wire and 4-wire/2-wire circuits with the distant end of the 2-wire line terminated in its nominal impedance. Measurements to be made psophometrically.

(e) Noise measurements on all circuits measured psophometri cally. The measurement to be made over the link with the far end terminated in its nominal impedance.

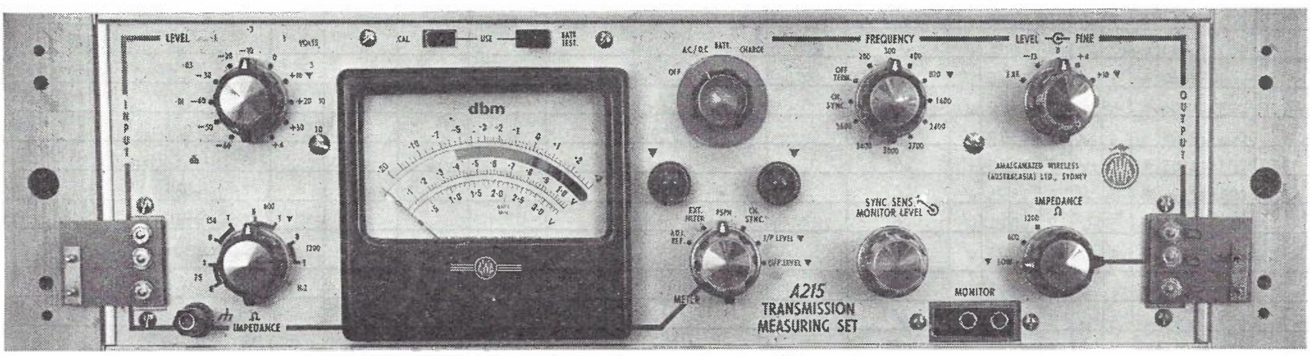

Fig. 6 — A.W.A. A215 Transmission Measuring Set.

TABLE 4: SAMPLE OF STABILITY BALANCE RETURN LOSS MEASUREMENTS—GEELONG ARM.

Distant Exchange	Frequency		
	300 Hz	820 Hz	3kHz
Geelong SxS	23 dB	28 dB	21 dB
North Geelong SxS	16 dB	19 dB	22 dB
Leopold ARK 521	23 dB	25 dB	27 dB
Colac SxS	10 dB	16 dB	27 dB
Warrnambool SxS	10 dB	15 dB	28 dB

All Geelong measurements were made in accordance with (a), (b) and (c) only, due to a delay in the supply of adequate instrumentation. Tests (d) and (e) were carried out after cut-over as time permitted. All link losses specified for the Geelong network were achieved, and Table 4 shows a sample of the stability balance return loss measurements obtained.

The results of transmission testing at the Geelong ARM installation were quite favourable considering the lack of adequate testing equipment and the uncertainty of testing points at the distant end exchanges. However, since that time considerable effort has been expended in trying to improve transmission testing techniques by two working parties, and in the near future better techniques, together with better instrumentation, should bring about an improvement in transmission testing standards.

TESTS FROM SUBSCRIBERS' APPARATUS.

These tests were designed to check the compatibility of the line and information signalling system with the various types of subscribers' apparatus which would have access to the ARM grid, and to ensure that unforeseen service difficulties in the ARM grid were reduced to a minimum. The telephones used to originate calls for this series of tests were each fitted with subscribers' meter so that the different multi-metering charge rates could be observed, and where possible, telephone to telephone calls were made. Where test telephone numbers were not available, calls were made to self-answering relay sets or test call and answer relay sets. The initial telephone to telephone network tests were performed by Country Installation staff, followed by service checks originated by the Telecommunications Division staff, thus increasing the size of the sample tests made. These tests resulted in the detection and rectification of several minor network problems.

Lists of telephone test numbers which were used for network testing were prepared in each State, with the assistance of the local Telecommunications Divisions, who issued orders for connection of special test number telephones to be used purely for ARM network testing. Individual State test number lists were subsequently circulated to all States through the co-ordinating officer at Headquarters.

In order to obtain comparable results for the network tests, it was necessary that the Testing Officer be made fully aware of the tests that were to be made and the observations he should make. At the Geelong Installation it was decided to present the necessary details on an ARM Network Test Schedule proforma which was prepared and distributed to engineering testing staff. An example of the pro forma is shown in Fig. 7 and the

ARM NETWORK TEST SCHEDULE - GEELONG AREA — Stage 1 Tests

Origin Exchange : Pivot - Launceston (ARF) — Date : 4th October, 1967

Junction No.	Check Dial Tone	Dial B subscriber's number and start stop watch after last digit dialled	Charge Rate	Post Dialling Delay	Answer Meter Pulse	1st M/metering pulse	" " 2nd	" " 3rd	Correct Destination	Check that metering reversals if audible are of a sufficiently low level not to be ANNOYING	These tests only 1 call in 10: Re-start stop watch on B party release	Check that metering continues during B party release time out	B party release time	Check that metering does not occur on B party forced release	Check that metering is discontinued on B party forced release	Check that metering does not occur on A party release	Satisfactory transmission of speech and tones	Check reception of tone on barred codes	Remarks
		003 21534	W	6	✓	7	13	19	✓	✓	✓	✓	85	✓	✓		✓		St. John
		003 22833	W	6	✓	10	16	22	✓	✓	✓	✓	80	✓	✓		✓		" "
		003 23276	W	5	✓	10	16	22	✓	✓						✓	✓		" "
		003 24733	W	7	✓	11	17	23	✓	✓						✓	✓		" "
		003 25560	W	6	✓	9	15	21	✓	✓						✓	✓		" "
		003262843	W	9	✓	6	12	18	✓	✓						✓	✓		" "
		003311300	W	5	✓	9	15	12	✓	✓						✓	✓		" "
		003312099	W	4	✓	9	15	12	✓	✓			159				✓		" "
		003444505	W	4	✓	7	13	19	✓	✓						✓	✓		St. John (Sub.)
		003622190	W	5	✓	9	15	21	✓	✓			75				✓		Deloraine
		003972373	W	5	✓	9	15	21	✓	✓						✓	✓		Longford
		003973150	W	4	✓	11	17	23	✓	✓						✓	✓		Bishopbourne ARK Unattended
		003936277	W	4	✓	7	13	19	✓	✓						✓	✓		Carrick 936276 Sub.
		003944017	W	5	✓	7	13	19	✓	✓						✓	✓		Tatana
		00226658	X	9	✓	6	11	16	✓	✓			127				✓		Hobart (Telecom.)

Fig. 7 — Geelong ARM Network Test Schedule.

details included show the results of test calls made from a telephone connected to the Geelong ARF exchange to terminal exchanges accessible via the Launceston ARM exchange.

One of the important functions to be observed during the test call procedure was the correctness of the charge rate applied to the calling telephones meter for each test call that was made. Reference to Fig. 7 shows that periods between the first three multi-metering pulses were recorded and any discrepancy in pulse rates was checked immediately. In general there were three groups of codes that were checked from the Geelong subscribers' telephones and these groups were categorised as follows:—

(a) Local area test numbers;
(b) Local area service codes.
(c) Distant area or Grid test numbers.

Calls were originated from each of the Geelong area originating exchanges with ARM access, to selected test numbers. These test numbers are shown in Figs. 8, 9, 10, which represent the categories listed above. With reference to Fig. 8, test calls made between any two subscribers connected to terminal exchanges in the Geelong charging area would be metered at the rate shown on the tabulation. For example, a call from Geelong to Lethbridge ARK would be metered at the "A" rate, but a call originated at Queenscliff to Lethbridge ARK would be metered at the "F" rate.

Similarly Fig. 9 shows the appropriate charge rates applied when exchanges in the Geelong local area

GEELONG ARM - LOCAL AREA TEST NUMBERS

Service Codes	Test Call Destinations	Charge Rate for all Geelong Originating Zones
0 1 1	Manual Assistance	N
0 1 2	Trunk Enquiries	N
0 1 3	Directory Information	N
0 1 5	Phonograms	N
0 1 7 3	Early Morning Calls	L
0 1 7 4	Phonogram Enquiries	N
0 1 7 6	Manual Assistance for M.C.P.T.'s	N
0 1 7 7	Phonograms for M.C.P.T.'s	L
0 1 8	Melbourne Calls from Selected P.T.'s	N
0 0 0	Emergency	N
1 1 0 4	Time	L
1 1 0 7	Sports Results	L
1 1 0 0	Service Difficulties	N
		L Unit Fee N Non-metering

Fig. 9 — Geelong ARM — Local Area Service Codes and Charge Rates.

Exchange prefixes are listed. Reference to the local test number directory will be necessary to give B party numbers.

Geelong District Codes	Test Call Destinations	Charging Zones Charge Rate Codes									
		Anglesea	Bannockburn	Geelong	Inverleigh	Lara	Meredith	Queenscliff	Torquay	Winchelsea Sth.	Wingeel
2 1 1-5 4 3 1-6	Geelong ARF Belmong ARF	L	L	L	L	L	A	L	L	A	A
5 1 1 1 2 1 5 2 1 5 3 1 1 2 1 5 4 1 1 2 1 5 5 1 1 2 1 5 6 5 7 1	Drysdale Manual Queenscliff ARF Queenscliff Manual Barwon Heads Manual Ocean Grove Manual Wallington RAX St. Leonards RAX	A	A	L	A	A	F	L	L	F	F
5 8	Moorabool SxS	L	L	L	L	L	A	L	L	A	A
5 9 1 1 2 1 5 0	Portarlington Manual Leopold ARK	A	A	L	A	A	F	L	L	F	F
6 1	Torquay SxS	L	A	L	L	A	A	L	L	A	A
6 3 1	Anglesea ARK	L	A	L	L	A	A	A	L	L	L
6 4 1 6 4 5 1	Mt. Duneed RAX Freshwater Creek RAX	L	A	L	L	A	A	L	L	A	A
6 5 6 1 6 6 1	Gnarwarre RAX Moriac ARK	L	L	L	L	A	L	A	L	L	L
6 7 1 1 2 1	Winchelsea Manual	L	A	L	L	A	A	A	L	L	L
7	Nth. Geelong&Corio SxS	L	L	L	L	L	A	L	L	A	A
8 1 1	Bannockburn ARK	A	L	L	L	L	L	A	A	A	L
8 1 7 8 1 9	Lethbridge ARK Maude ARK	L	L	A	L	A	L	F	A	L	L
8 2 1 8 3 1 8 4	NU tone (Lara ARK after BT c/o) NU tone (Little River ARK ultimate) NU tone (Anakie RAX after BT c/o)	A	L	L	A	L	L	A	A	F	A
5 8 to 8 8 9 1 9 to 9	Belmont SxS Belmont SxS Portable Geelong "X" SxS	L	L	L	L	L	A	L	L	A	A
9 0 1 5 9 0 1 6	Lara ARK (821 after BT c/o) Anakie RAX (841 after BT c/o)	A	L	L	A	L	L	A	A	F	A
9 0 2 9 0 3 9 0 5 9 0 6	Geelong "X" Large Group Final Ceres RAX Comm. Offices Indialling PABX Stonehaven RAX	L	L	L	L	L	A	L	L	A	A
9 0 8	Geelong "X" S.A.R.S.	L	L	L	L	L	L	L	L	L	L

Fig. 8 — Geelong ARM — Local Area Test Numbers and Charge Rates.

GEELONG ARM - GRID TEST NUMBERS

STD Codes 0 A B C D E F G H	Test Call Destinations	Charging Zones Charge Rate Codes									
		Anglesea	Bannockburn	Geelong	Inverleigh	Lara	Meredith	Queenscliff	Torquay	Winchelsea Sth.	Wingeel
0 2 4 5 1 1 1 1 1 *	Sydney French's Forest Exch.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
0 2 8 3 9 1 1 1 *	Sydney Five Dock Exch.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
0 3 6 0 1 8 4 9	City West Exch.	M	F	F	M	F	F	F	F	M	M
0 3 4 8 9 1 0 7 9	Northcote Telecom.	M	F	F	M	F	F	F	F	M	M
0 4 2 2 8 8 3 6 0 *	Wollongong DTM's Office	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
0 4 9 6 1 6 2 1 7 *	Newcastle DTM's Office	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
0 5 2 2 1 2 1 2 6	Geelong "Pivot" L.L.Room	L	L	L	L	L	L	L	L	L	L
0 5 5 3 2 1 8 5 *	Warrnambool Trunk Exch.	M	M	M	M	M	M	M	M	M	M
0 5 5 3 8 7 1 *	Warrnambool-Purnim Manual	M	M	M	M	M	M	M	M	M	M
0 5 5 4 9 5 9 9 *	Colac Trunk Exch.	A	F	F	A	F	F	M	F	L	A
0 5 5 4 4 6 1 *	Colac-Beeac Manual	A	A	F	A	F	A	M	F	L	L
0 6 3 5 4 1 0 4 *	Lithgow Trunk Exch.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
0 6 2 7 2 8 6 0 *	Canberra Trunk Exch.	X	X	X	X	X	X	X	X	X	X
0 7 2 9 6 5 0 0 1 *	Brisbane-Wynnum Exch.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
0 7 2 8 6 1 6 1 4 *	Brisbane-Cleveland Exch.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
0 8 2 5 1 3 2 9 9 *	Adelaide-STD Test Phone	X	X	X	X	X	X	X	X	X	X
0 8 2 5 1 1 7 7 7 *	Adelaide-Liaison S/T	X	X	X	X	X	X	X	X	X	X
0 9 ——	Spare Level ——										
0 0 1 ——	Spare Level ——										
0 0 2 2 6 6 5 8 *	Hobart Telecom. Office	X	X	X	X	X	X	X	X	X	X
0 0 2 *		X	X	X	X	X	X	X	X	X	X
0 0 3 6 2 2 1 9 0 *	Deloraine Exch.	W	W	W	W	W	W	W	W	W	W
0 0 3 3 1 1 3 0 0 *	St.John Exch. (Laun.)	W	W	W	W	W	W	W	W	W	W
0 0 4 2 1 3 2 9 *	Devonport Exch.	W	W	W	W	W	W	W	W	W	W
0 0 4 4 1 8 0 4 *	Wynyard Exch.	W	W	W	W	W	W	W	W	W	W
0 0 5 ——	Spare Level- ——										

* Note - Only one call is required on these codes. Two numbers have been supplied in case of B sub. busy condition received.

9 AM to 6 PM

Code	Day Rate	Night Rate
A	45 sec.	60 sec.
F	30	45
M	15	20
Q	10	15
W	6	9
X	5	6
Y	4	5
L	Unit Fee	
N	Non-metering	

Fig. 10 — Geelong ARM — Grid Test Numbers and Charge Rates.

called any of the local service codes. Details relating to charging rates for destinations outside the Geelong charging area are shown in Fig. 10. It can be seen, with reference to Fig. 10, that a call made from the Anglesea charging zone to French's Forest exchange, Sydney, would be charged at the "Y" rate. The details of both day and night rates were included with this testing information to ensure that charge rates were checked correctly.

Extensive tests were carried out from all public telephones in the Geelong area to check the barred access facility. All public telephones were barred access to STD codes, but allowed access to certain nominated routes. When a barred code was dialled, forced release conditions were applied to the call from the multi-metering repeater and busy tone returned to the calling party. This facility was checked at all public telephones. Also it was necessary to physically check all barred coin services to see that the instrument strap was changed to the STD position, and that the fleeting reversal from the multi-metering repeater did, in fact, bar access.

Tests from subscribers' apparatus carried out in accordance with the details shown above, took approximately three weeks to complete and the fault incidence during this phase of testing at Geelong was remarkably low considering the prototype nature of some of these tests. The low fault incidence is attributed to the thoroughness of the pre-commissioning tests carried out both at the ARM and Distant End exchanges.

The Telecommunications Division pre-Cutover service checks were carried out during the fortnight preceding Stage 1 cutover, and further checks were made shortly before the introduction of Stage 2. A summary of the results of the Telecommunications checks for Stage 1 cutover are shown below:

(a) No. of check calls 1213
(b) No. of effective calls 763
(c) No. of ineffective calls due to subscriber 316
(d) No. of ineffective calls due to the Department 63
(e) Post dialling delays:
Maximum .... (secs.) 17
Minimum .... (secs.) 1
Average .... (secs.) 6.3
(f) Percentage of calls with post-dialling delay of 10 seconds or less 97.4%

The ineffective calls due to the Department, shown in (d) above, included several calls which matured but failed to meter. In most instances this condition was traced to manual operators at distant exchanges failing to operate the meter key at the appropriate instant. However, since the operators were being familiarised with the facilities of the ARM network at that time, failures of this type were expected. By the time of Stage 1 cutover, all manual exchange operators had been instructed in the correct operational procedures and the above condition did not recur.

Also, several ineffective calls reported in (d) above were held and traced by engineering staff to determine in which part of the network the call had failed. This method of operation is most successfully done when the ARM exchange is not carrying live traffic, that is, before cutover, and when selected relay set time out facilities can be cancelled at will.

The techniques outlined above assisted engineering staff in the detection and correction of network problems before cutover. In fact, the whole exercise only emphasises the need for adequate pre-cutover engineering testing, followed by a combined network check call programme carried out by both Telecommunications and Engineering Division staff in a co-ordinated manner.

CONCLUSION.

The successful commissioning of the ARM grid, on the 28th November, 1967, consisting of the 5 ARM exchanges: Haymarket, Newcastle, Canberra, Launceston and Geelong, was the culmination of some two years of installation effort. It was over this period of time that liaison channels between the individual engineers and technical staff at the ARM exchanges were established, thus ensuing a sound basis for the co-ordination of the Grid commissioning tests. From the author's retrospective observations over the commissioning stage of the initial ARM exchanges, certain activities stand out significantly and these were the setting down of the principles of commissioning tests by Headquarters Engineers, the additional work done by the N.S.W. Engineering Administration in preparation of more detailed commissioning instructions in the Yellow Book for use by field staff on the job, the alertness of field staff in reporting circuit weaknesses, and the co-operation afforded by Headquarters Engineers in solving the many problems raised.

One of the most important factors to emerge during the establishment of the ARM Grid was the necessity for co-ordination of all future ARM installations to be connected to the ARM grid. It is considered that co-ordination must be maintained on a continuing basis, especially in the case of introduction of new, or alteration to existing Interstate routes. It is essential also that Service Staff at all ARM exchanges in the Commonwealth be made aware of the introduction or cancellation of routes and changes in numbering and zoning.

From the experience gained on the Geelong ARM project, through the working of the GANIC committee and the practical difficulties encountered, it is essential that all parties to be involved in the installation and service of new ARM exchanges should be fully informed of the project in its very early stages and that the matter of programming commissioning tests should be undertaken at an early stage in the project.

ACKNOWLEDGMENTS.

The author wishes to record his appreciation of the assistance given by Mr. T. Allan, Supervising Technician, ARM Networks, and the engineers and staff of Country Installation No. 2 Sub-section, over the commissioning period of the Geelong ARM network, and in the preparation of this paper.

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A TRANSMISSION LEVEL CHECKER

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INTRODUCTION.

With the establishment of the subscriber trunk dialling (S.T.D.) network the operator who made the connection, using cords, between the local subscriber and the trunk line circuit, is no longer available. Since the telephonist was required to supervise the call, she could perform rudimentary checks to determine the suitability of the connection. By listening to the calling subscriber and the called subscriber the operator could note excessive loss or noise, if present, and if necessary establish an alternative connection. On an S.T.D. call this minimal transmission check has been lost.

Details for the operation of the S.T.D. network in the Australian Post Office have already been outlined (Refs. 1 and 2), and generally automatic means will be used for the first time in the supervision of the transmission performance of this network. Extensive use will be made of traffic route testers (T.R.T.'s) fitted with the Automatic Transmission Test Unit (A.T.T.U.) for operation with the distant test call answer relay set (T.C.A.R.S.) (Ref. 3). A different type of answer relay set, which terminates the circuit and provides 1.5 second bursts of 820 Hz tone separated by 1.5 seconds will be used for the T.R.T. grade of service checks when a transmission test is not required.

The provision of automatic testing equipment and service aid devices does not preclude the provision of portable measuring sets. The automatic testing plant will determine if a fault exists, but testing instruments must be available for point to point testing to localise the fault. Transmission testing is no longer the exclusive function of the carrier terminal technician; transmission measurements of the S.T.D. network will have to be made from the terminal telephone exchange and will require the provision of instruments such as the transmission level checker (T.L.C.).

This paper describes a T.L.C. (see Fig. 1) which will give the automatic telephone exchange technician a convenient means for performing accurate functional transmission checks.

DEVELOPMENT OF THE T.L.C. TYPE A205.

As the telephone network grows in complexity it requires different testing techniques to be evolved, and more sophisticated and more expensive instruments are required for installation and maintenance work. Instruments are developed because a need has arisen for their existence, and because existing apparatus is not suitable. The T.L.C. is no exception; it was first built as a manual tester by the Victorian Trunk Service Section. This group established the first T.C.A.R.S. network and developed automatic transmission circuit testing, using the A.T.T.U. fitted to the Junction Routiners and operating into T.C.A.R.S. The technique was used for checking automatically the transmission performance of the extended local service area (E.L.S.A.) network. Faults found by the automatic tests had to be cleared and a portable transmission measuring set (T.M.S.) was required for manual measurement with the distant T.C.A.R.S.

The requirement of this T.M.S. was different from any others used by the A.P.O. in that it was to be used for transmission measurement from the outgoing relay set, where loop hold currents must flow in the instrument's input transformer. With existing instruments (Slems, A215, A220 etc.)

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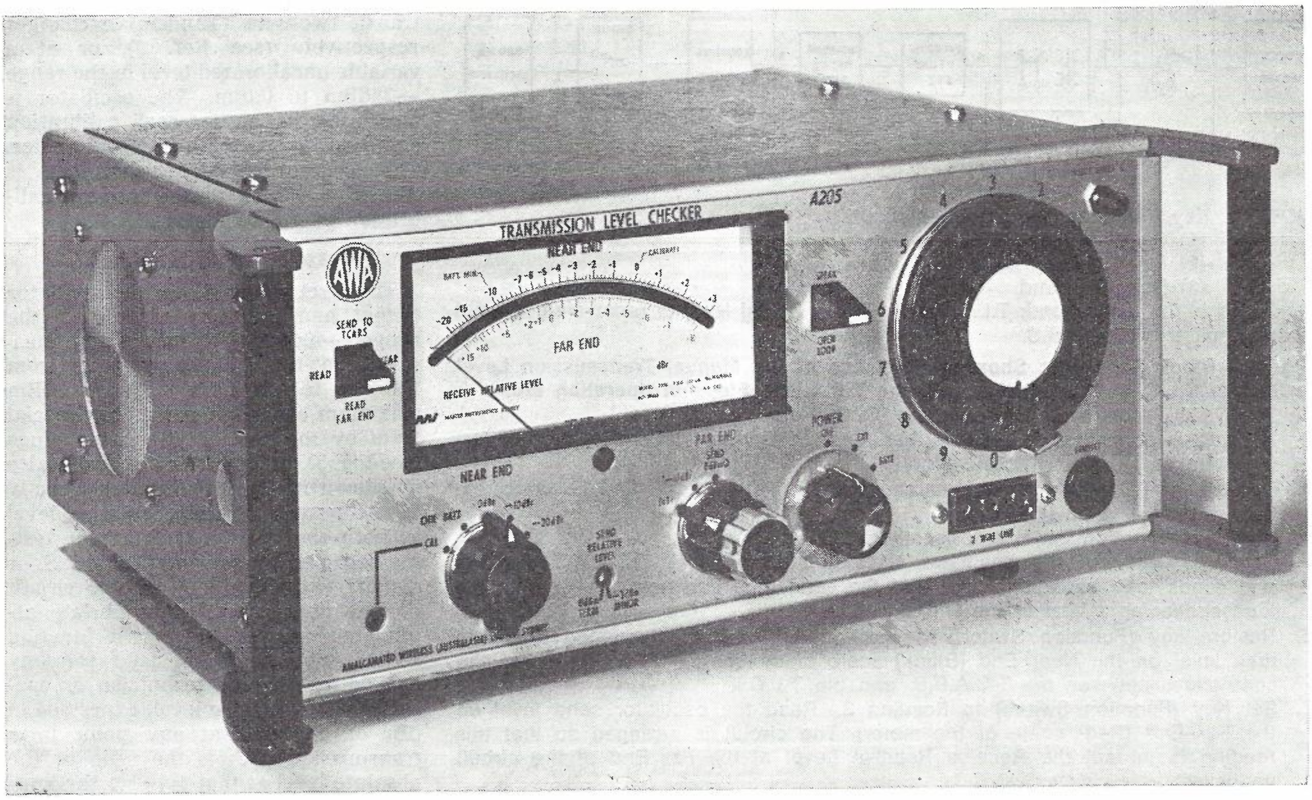


Fig. 1 — The Transmission Level Checker Type A205. The speaker grill and slot for screwdriver speaker volume adjustment can be seen on left hand side panel.

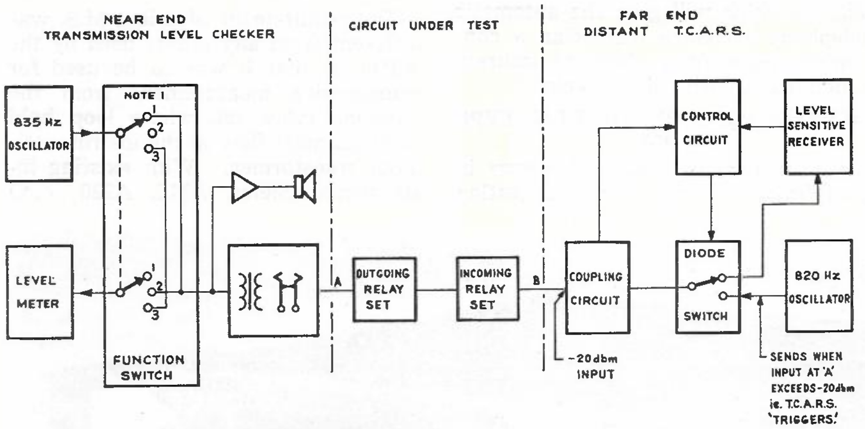
unbalance d.c. must not be allowed to pass through the T.M.S. input transformer. Other facilities, such as loop disconnect dialling for calling the T.C.A.R.S. telephone speech circuit, arrangements for operation with the distant T.C.A.R.S., together with a monitoring loudspeaker, were added (see Fig. 2). The circuitry and meter scale of the manual tester were arranged so that the transmission loss in both directions of transmission could be determined by using the distant T.C.A.R.S., and without the need to contact the distant technician. Semi-automatic transmission testing was thus introduced. (Details will be given later.)

The principle of the manual tester was accepted by the Central Administration (Ref. 4), and after considering the transmission requirements of the telephone network (Ref. 5), extra facilities were added, and a specification of the T.L.C. was prepared. The subsequent design, development and manufacture of the instrument was undertaken by Amalgamated Wireless (Australasia) Ltd.

DESCRIPTION OF T.L.C. TYPE A205.

The T.L.C. is a small manually operated device intended for connection to step-by-step, two-wire exchange outgoing relay set, providing facilities for the dialling of the distant T.C.A.R.S, and enabling circuit functional checks to be carried out.

The device may also be used as an interface unit for test instruments, providing d.c. isolation, dialling and loop - hold facilities; an additional circuit is included for checking the battery feed transmission bridge of the final selector and relay sets for insertion loss. For the latter function, loop-hold facilities are provided at both send and receive terminations, and dialling and loudspeaker monitoring can be carried out on the two-wire receive line.



NOTE 1: Key (Function Switch) Positions
(1) Send to T.C.A.R.S.
(2) Read Near End
(3) Read Far End.

Near End is the testing end; T.L.C. reads (Black Scale) level of receive signal sent over circuit from T.C.A.R.S.

Fig. 2 — Block Schematic Showing Operation of the Manual Transmission Level Checker T.L.C. in Conjunction with the T.C.A.R.S. Steps in operation are:—

1. The T.L.C. is connected to outgoing (O/G) Relay Set, or
2. If T.L.C. is connected to a subscriber's inlet, dial tone is heard in the monitoring speaker.
3. The distant T.C.A.R.S. access number is dialled, after the T.C.A.R.S. identification sequence is finished then;
4. Set Key (Function Switch) to position 1.
5. Gradually increase the oscillator level output until the T.C.A.R.S. triggers and sends tone back; this tone and the send tone can now be heard in the loudspeaker as a beat of the two signal tones.
6. Restore key (Function Switch) to Position 2. Read the incoming (Receive) tone level on the Near End (Black) scale of the meter. (This measures the circuit loss between the T.C.A.R.S. and the T.L.C.).
7. Set Key (Function Switch) to Position 3. Read the oscillator send level on the Far End (Red) scale of the meter. The circuit is arranged so that this reading is in fact the Receive Relative Level at the Far End of the circuit under test.

NOTE: The Far End is defined as the end of the circuit (where the T.C.A.R.S. is) remote from the testing end.

The instrument consists essentially of an 835 Hz oscillator having a very stable output level which may be adjusted over a wide range.

The standard frequency used for carrier circuit and network transmission testing is 820 Hz, which is the frequency sent from the T.C.A.R.S.; however, 835 Hz is sent from the T.L.C. so that an easily noticeable beat between the 835 Hz and 820 Hz will be recognised when the T.C.A.R.S. triggers.

In some instances a beat will not be heard and triggering of the T.C.A.R.S. will be noted by a change in level of the tone from the loudspeaker of the T.L.C. This will occur when the receive tone from the T.C.A.R.S. is high compared with the tone sent from the T.L.C. The incoming tone, if high, can pull the oscillator in the T.L.C. to change frequency and synchronise to the frequency of the higher level tone. The stability of the level of the T.L.C. instrument oscillator is closely controlled by a temperature compensated d.c. reference voltage and is completely free from the effects of supply voltage variations.

Oscillator Section.

The oscillator output may be transmitted to the line under test at two fixed levels, 0dBm and —3dBm, the reference levels for terminal and transit two-wire (Tandem) exchanges respectively (see Ref. 5), or at a variable uncalibrated level in the range —28dBm to 0dBm. The oscillator is also used as an internal calibration standard for a built-in level meter. The accuracy of all measurements is therefore related to the internal calibration of the oscillator.

Level Meter Section.

The level meter allows the oscillator output and incoming signals in the range —40dBm to +3dBm to be measured, in the frequency range from 150 Hz to 4000 Hz. The +3dBm maximum can be increased for special tests by the use of attenuator plugs (see Fig. 3). The meter has two scales as shown in Fig. 4 calibrated directly in the terms of receive relative level at both the near end (T.L.C. or testing end) and the far end (T.C.A.R.S. or distant exchange end) of the circuit or line under test. Appropriate attenuators are selected by the function switch, obviating the need for any calculations by the technician or operator. The relative level, expressed in dBr of a signal at any point in a transmission path is the ratio of the absolute level at that point to the level of the same signal at a predetermined reference point in the system. This

Fig. 3 — The 4dB Attenuator Pad. It is used to extend the range of the T.L.C. and is plugged into the T.L.C. and the measuring cord plugged into the back of the pad. Note 4MM connector.

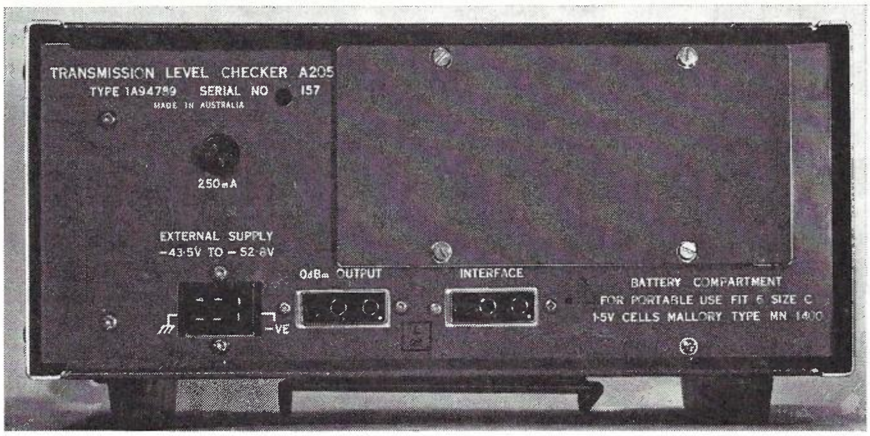


Fig. 6 — Rear View of T.L.C. Note interface, oscillator output, and external battery connector. Only two screws are removed to replace internal cells.

reference point is the exchange reference point in the terminal telephone exchange, which is 0dBm. The design of the T.L.S. was based on this concept, but also took into account the —3dBr reference at the minor switching exchange (Ref. 5).

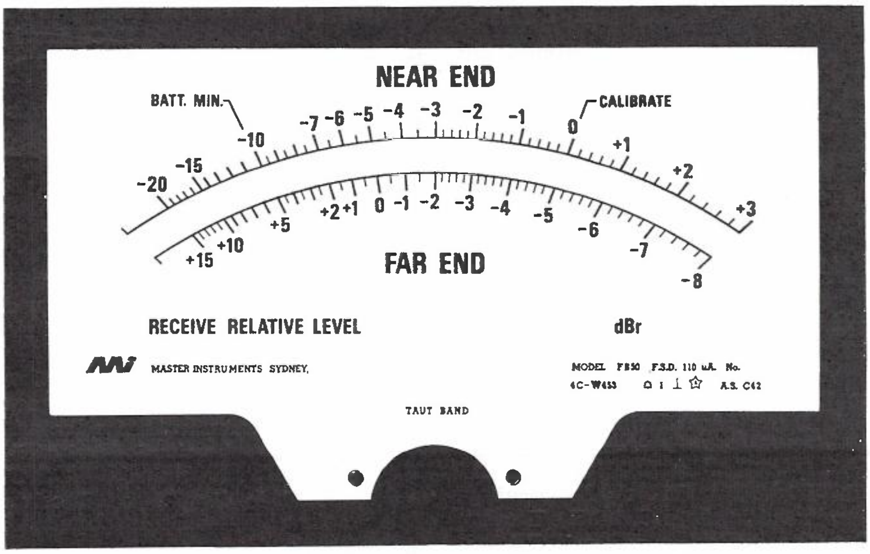


Fig. 4 — The Meter Scale of the T.L.C. Type A205.

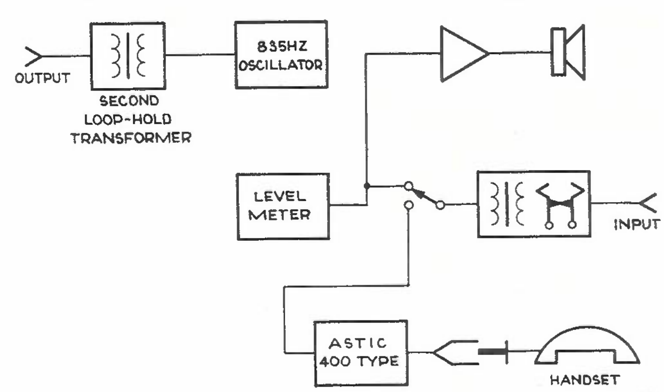


Fig. 5 — Four-wire Operation and Speech (2-wire), Monitoring Facility. In this mode the T.L.C. can be used to measure the insertion loss of a final selector or relay set battery feed bridge (See Text).

FACILITIES.

The oscillator and level meter are coupled to a two-wire circuit (outgoing relay set in step-by-step exchanges or a subscriber's inlet in a crossbar ARF, ARK etc., exchange) through a loop-holding transformer having a low insertion loss and capable of carrying up to 125 mA d.c. without variation of performance. A B.P.O. type telephone dial is connected in the two-wire line circuit and an ASTIC type 400 telephone handset facility is also provided. Except when the telephone facility is being used, any signal present at the two-wire line sockets may be heard on the loudspeaker, which is fitted in the instrument. The two-wire line socket is the Siemens and Halske type 9-Rel. kli 6aa, which is the standard A.P.O. instrument socket. A special mounting plate is supplied with the T.L.C. to replace this socket if required with either the twin-type carrier jack or a tip ring sleeve C.B. jack.

4-Wire Operation.

A second loop-hold transformer is included on the rear panel, as illustrated in Fig. 5 and shown in Fig. 6 to permit the oscillator output to be fed to a separate line at a precise level of 0dBm, whilst using the level meter section and other facilities at the normal two-wire line socket. 13dB attenuator plugs (see Fig. 3) are available so that—13dBm is available from this source, the loop-hold condition is then no longer available. This output at 0dBm with loop-hold conditions allows the transmission loss in a final selector or relay set battery feed bridge to be readily measured.

Measuring Loss in Relay Sets.

The 0dBm output is connected to a number chosen on the final selector multiple, and the two-wire line socket of the T.L.C. is connected to the final selector input. The final selector multiple number which was chosen is now dialled, the ring (ringing current) is tripped by the loop hold transformer, and the 835 Hz tone is sent through the final selector, the reading on the black scale of the meter will give the insertion loss of the final selector. After the test it will be necessary to operate the non-locking pushbutton fitted to the top right hand corner of the front panel near the dial. The operation of this button inserts a series condenser to open circuit the loop provided to the final selector multiple.

T.L.C. Input Impedance.

For normal measurements the input impedance is 600 ohms; however, for measurements involving hybrid transformers it may be desirable to match the return loss of the input to that of equipment with a capacitatively coupled input. In this case the return loss of the two-wire input to the T.L.C. may be deliberately degraded at low frequencies without interrupting the d.c. loop. A spring return pushbutton (mentioned above) enables a one microfarad capacitor to be inserted in the unbalanced side of the loop-hold input transformer, in series with the 600 ohm input impedance. It will be necessary to operate this pushbutton if a small beat variation is noticed when reading the instrument meter.

Interface Facility.

It is sometimes necessary to carry out more complete circuit measurements than those which can be performed with the T.L.C. In such cases the additional instruments required may be of the type which do not permit loop-hold conditions, and when this happens the loop hold, speech, calling circuits, etc., are usually set up in an interface unit which is connected between the instrument and the exchange equipment (i.e., between two equipment faces), interface. An external oscillator or level meter may be connected as illustrated in Fig. 7 to a two-wire line using the loop-hold, dialling and handset facilities of the T.L.C. The external oscillator or level meter should be connected to the interface socket on the rear panel (see Fig. 6), whereupon the internal oscillator and level meter of the T.L.C. are automatically disconnected, although audio monitoring is retained. The insertion loss of the interface circuit is 0.4 dB. The maximum level is 0dBm.

The Meter Scale.

The T.L.C. meter scale is shown in Fig. 4. The top scale, which is black, is the normal dB meter scale. The lower scale is coloured red and has its zero mark at the -5dB point of the black scale; all values to the left of this zero mark are marked positive, while those to the right are marked negative and shown as dBr. The black and red scales are designated Near End and Far End respectively. The two scales are further designated Receive Relative Level.

T.L.C. Panel Colour.

When the keys and switches are operated to the red designations, this indicates the red meter scale should be noted. If a meter reading is obtained with the keys and switches operated to the black designation then the black meter scale should be read.

OPERATION WITH T.C.A.R.S.

The usual method of operation of the T.L.C. with the T.C.A.R.S. is shown diagrammatically in Fig. 2 and is briefly outlined below. To simplify the explanation assume the circuit under test has no loss. After the distant Far End T.C.A.R.S. has been called by using the T.L.C., and T.C.A.R.S. identification procedure completed, the test circuit is set up with the T.L.C. at the Near End and the distant Far End of the circuit is terminated in the T.C.A.R.S. The key (function switch) send to T.C.A.R.S. on the T.L.C. is now operated and the

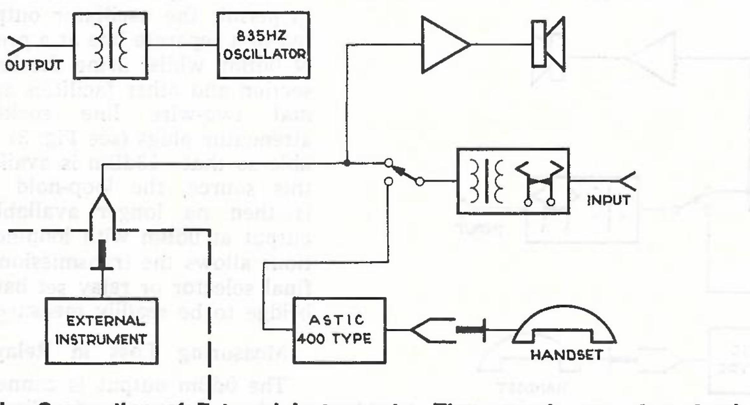


Fig. 7 — The Connection of External Instruments. The normal measuring circuit is replaced by the external instrument. However, the 835 Hz from the back panel is available.

835Hz send tone from the T.L.C. is heard in the instrument speaker. The oscillator output from the T.L.C. is now slowly increased until the send level at point A Fig. 2, is —20dBm; this is also the level at point B, Fig. 2, since the circuit under test has no loss.

The input level to the T.C.A.R.S. is now also —20dBm, the T.C.A.R.S. triggers and sends back a 820 Hz tone (for terminal exchanges the level of the tone sent from the T.C.A.R.S. is 0dBm from the exchange reference point).

This 820 Hz tone is heard in the loudspeaker of the T.L.C. as a beat with the 835 Hz being sent from the T.L.C. The key (function switch) on the T.L.C. is restored to Read Near End and the Receive Relative Level Near End is read on the black scale of the meter. The tone from the T.C.A.R.S. is sent for five seconds. When the tone from the T.C.A.R.S. ceases, the key is operated to Read Far End and the receive relative level, at the T.C.A.R.S. end of the circuit is read from the red scale of the meter. Since the loss in the circuit is zero, a reading of zero will be obtained on the red scale, or as the T.L.C. circuit is arranged so that a reading of zero on the bottom red scale represents an output of —20dBm, the circuit loss is zero.

If the circuit under test had a loss of 3dB, then the level sent at A in Fig. 2 would have to be 3dB greater than before, so that —20dBm is received at the T.C.A.R.S. As the output from the T.L.C. oscillator is increased from minimum output the pointer moves across the meter scale from left to right until the meter pointer is 3dB higher than before, that is over the —3dBr mark. The T.C.A.R.S. triggers and circuit measurements are made. This means that the circuit level at B is 3 dB low from nominal; in other words at B in Fig. 2, the Receive Relative Level is —3dBr, as shown on the red scale.

Providing the Send Relative Level (screwdriver adjustment on front panel, see Fig. 1) is set at 0dBm, the Far end switch set to 0dBr, and the oscillator output control of the T.L.C. is adjusted so that the meter pointer is over the zero mark on the red scale, then —20dBm is being sent from the T.L.C. into the line connected at point A in Fig. 2. If the Send Relative Level switch as shown in Fig. 8 is operated to the —3dBm position and all other settings remain as before, the output from the T.L.C. is —23dBm. This allows the T.L.C. to be pre-set for terminal or minor switching exchange operation (Ref. 5).

When the T.C.A.R.S. has been adjusted for terminal exchange conditions of sending 0dBm at 820 Hz and trig-

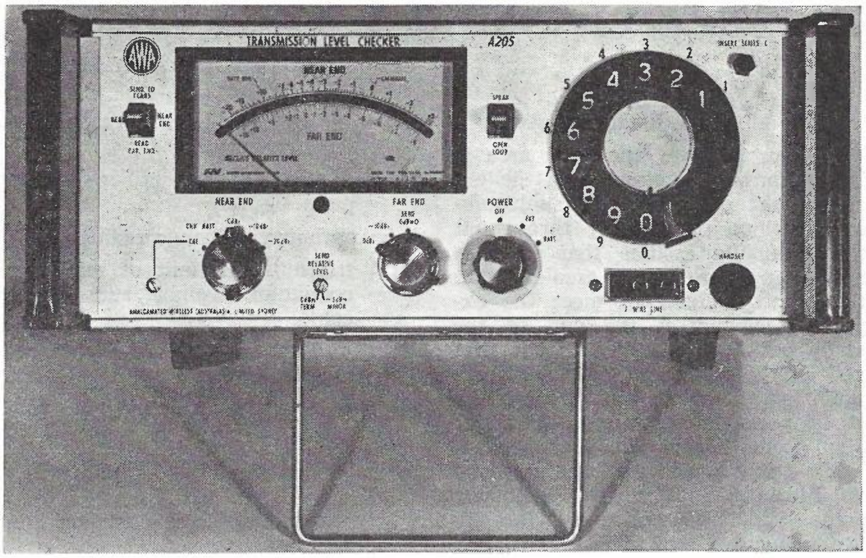


Fig. 8 — Front Panel View of T.L.C. The face is tilted at 15° by the stand attached to the bottom of the instrument.

gering when the T.C.A.R.S. input is —20dBm, then:

(a) The black scale reading, together with that of the Near End attenuator switch, will give the circuit loss in dB from the T.C.A.R.S. (Far-End) to the T.L.C. (Near End).

(b) The red scale reading together with that of the Far End attenuator switch, will give the circuit loss in dB from the T.L.C. (Near End), to the T.C.A.R.S. (Far End).

The T.L.C. terminates the circuit in 600 ohms and measures the voltage across this termination. The result is displayed on the meter and expressed in dB.

Maximum Network Loss.

The maximum insertion loss at 820 Hz between terminal exchange reference points, measured between 600 ohm terminations, is 15dB (Ref. 6).

CONCLUSION.

The T.L.C. has been developed so that transmission measurements can be performed from the d.c. switching point of the telephone exchange. The T.L.C. provides for the first time a T.M.S. which will give the automatic telephone exchange technician a convenient means for performing accurate functional transmission checks on circuits at a frequency of 820 Hz in conjunction with the distant T.C.A.R. Set. The testing is semi-automatic, since the distant exchange technician is not required to participate in the tests.

Generally, measuring equipment available for telephone network transmission testing must not carry d.c. in the instrument input circuitry. The T.L.C., via its interface facility, allows the use of this type of T.M.S. for carrying out additional transmission tests. Arrangements have been incorporated in the instrument so that the transmission loss of an exchange relay set can be measured.

The T.L.C. can be used as a normal T.M.S. such as for the measurements of the output of the multi-frequency code tone generator in crossbar exchanges. High impedance audio monitoring can be carried out on d.c. circuits by the operation of the keys to Read Far End and Open Loop.

It is considered that the T.L.C. will fill a long-existing need for a suitable instrument for performing transmission measurements on d.c. circuits in the telephone exchange. One hundred of these T.L.C.'s were delivered in June, 1968.

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APPENDIX.

T.L.C. PERFORMANCE SPECIFICATION.

General.

Operating Temperature Range—0°C to 50°C.

Calibration Temperature — 25°C.

Sending Signal.

Frequency — 835Hz ± 5 Hz.

Reference Output Level — 0dBm ± 0.1 dB in 600 ohms.

Output Impedance — 600 ohms Nominal.

Send Relative Level 0dBm0:—
 0 dBm ± 0.1 dB.
 —3 dBm ± 0.15 dB.

Send Level 0dBr Far End Range:—
 —10 to —25 dBm0.

—10 dBr Far End Range:—
 0 to —15 dBm0.

Level Meter.

Frequency Range—150Hz to 4000 Hz.

Near End Ranges—
 0dBr (0dBm) ± 0.10 dB.
 —10 dBr (—10 dBm) ± 0.15 dB.
 —20 dBr (—20 dBm) ± 0.20 dB.

Note when used as a level meter the Near End meter scale is used and dBr read as dBm.

Far End Ranges—Accuracy at —5dBr scale point.
 0dBr ± 0.15 dB.
 —10 dBr ± 0.15 dB.

Input Impedance—600 ohms Nominal.

Meter Protection.

The meter circuitry is protected against high power pulses caused by dialling and switching of the telephone circuits.

Power Supplies.

Internal 9V Battery.

6 cells, size C. 1.5V Alkaline Mallory type MN1400 or Ever Ready type HP11. Approximate life 100 hours, with typical usage. Equivalent carbon zinc cells may also be used, but are not recommended as their life would be short.

Note. — Cells are enclosed in a leak resistant moulded plastic carrier.

External 48V Supply.

48-volt supply specified in para. 3.1 A.P.O. Specification 1002. Full performance of the instrument is maintained in the normal 15-second break and emergency conditions. (Specified voltage range —52.8V to —43.5V). A 250 mA fuse is fitted in the negative line.

Rack Mounting Arrangements.

Rack mounting adaptor plates are available to rack mount the instrument on the standard 19 in. carrier rack side; however, the instrument is intended for portable use.

Dimensions and Weight.

Height (including feet) — 5⅞ in.

Width (including handles) — 13⅞ in.

Depth (including handles) — 10⅝ in.

Weight (including battery) — 12 lb.

TELEPHONE EXCHANGE AREA PLANNING

*K. W. SMITH, A.R.M.T., M.I.E.Aust.**

PART 1 — ECONOMIC RADIUS

Introduction

It is the purpose of this part of the paper to establish a simple yet satisfactory method of determining the relationship between the radius of an exchange area and the total capital costs of the subscribers lines, trunk or junction lines, exchange equipment and buildings for areas of constant telephone density. It will be shown that for a given density there is a radius at which the total costs are a minimum. This is termed the optimum economic radius.

Understandably, annual charges are of predominant importance in the detailed calculation of economics where plant is installed at different times and for different provisioning periods in a particular exchange area or network. An economic assessment based on annual charges is necessarily a prime requirement for the planning of an individual exchange area.

This study, however, is confined to the general case of determining the economic radius of an exchange area in relation to the expected density of subscribers and for this reason, and because it is assumed that all plant is provided in the first year of the study, capital costs have been used throughout. The use of capital costs also enables ready assessment of the effect of cost variations.

Examine any telephone exchange and its associated external plant network and you will find that it is unique in that it differs in some respect from every other exchange area. Furthermore, each individual area is provided with telephone plant in the most economic manner to suit its own situation. How then can we determine the optimum economic area (or radius) if every area has its own particular optimum?

The answer is that we must take factors common to all exchanges, stabilise these factors in the form of an ideal exchange area and then vary the dimensions of the area and the associated factors and determine the least cost for any given set of conditions.

This idealised situation then becomes the starting point for practical planning which of necessity must take account of the innumerable differences which make each exchange area unique.

* Mr. Smith is Engineer Class 2, External Plant Planning, Victoria.

The Idealised Exchange Area

For our purpose, the ideal area is in the form of a circle with the exchange at the centre and the subscribers distributed uniformly throughout the area. We assume that there is no existing plant in this area and that the plant required to meet the expected demand at the end of the study period is installed in the first year of the study. The effect of using provisioning periods shorter than the study period for some or all major plant items has not been considered.

If we now consider a large area and its break-up into smaller exchange areas (Fig. 1) we notice that for any arrangement there are some items which are common to all proposals. These are the number of lines of switching equipment and that part of the junction or trunk plant which is proportional to the number of subscribers. It can also be shown that the route length of subscribers cable plant is theoretically constant although in a particular situation study the length may vary and part of the subscribers plant may share a common route with trunk or junction plant.

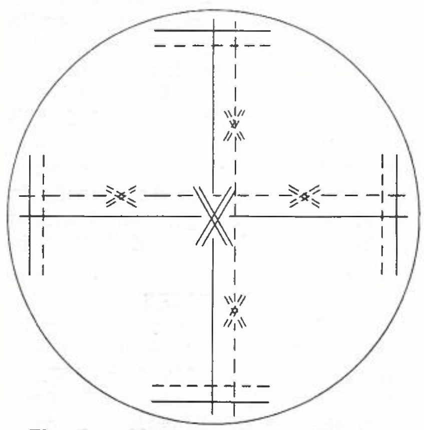

Fig. 1 — Alternative Arrangements.

The concept of the ideal exchange area applies to both rural and urban areas but the calculation of the economic radius of these areas will be treated separately because of major differences which occur in practice.

List of Symbols

a = subscriber's external plant cost related to excavating, cable sheathing and other common costs.

B = gradient of subscriber's external plant reticulation cost.

b = factor relating B and w.

w = subscriber's cable average conductor weight.

P = number of subscriber's cable pairs.

R = optimum exchange radius.

d = transmission limit of minimum conductor weight subscriber's cable.

f = gradient of subscriber's transmission limits.

Ce = external plant cost per subscriber.

Ci = internal plant cost per subscriber.

Cj = junction or trunk cost per subscriber.

Ct = total cost per suscriber.

S = subscriber density per unit area.

Ka = ratio of route to radial distance for average subscriber.

Ko = cable occupancy percentage.

L = ratio of route to radial distance for furthest subscriber.

g = subscriber's internal plant cost related to site, building and common equipment costs.

h = junction or trunk costs related to excavating and other common costs.

a, b, d, f, g, h will vary according to local circumstances of cost structures, working methods, transmission limits, etc. For example, the same symbols have been used in the determination of both the rural and urban economic radius because they have the same meanings but of course, they have different actual values in the two sets of calculations.

Rural Economic Radius

Subscribers External Plant. Subscribers cable provided in rural areas is generally of 10lb to 20lb conductor weight with some pairs loaded with 88mH coils at a nominal 6000 foot spacing. The cable is plastic jacketed and plastic insulated and mole-ploughed directly into the ground to an average depth of eighteen inches.

Average capital costs per route mile of this type of construction are shown in Fig. 2.

The equation $Ce = a + BP$
$= a + b.w.P$ ....(1)
accurately represents the costs. Cable pair mileage and conductor weight differ for each layout of exchanges but the excavating costs (a) are constant and are therefore deleted from subsequent operation on the equation.

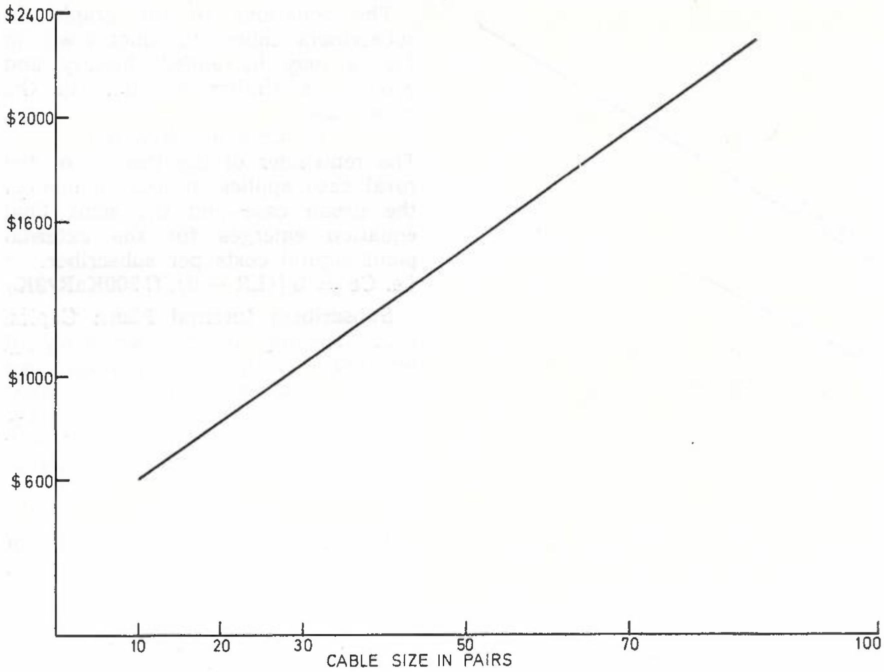

Fig. 2 — Average Capital Cost per Route Mile of Loaded, Mole-ploughed, Plastic Sheathed, Plastic Insulated Rural Subscribers' Cable.

TABLE 1: SUBSCRIBERS TRANSMISSION LIMIT (MILES)

Conductor Weight	2½lb	4lb	6½lb	10lb	20lb
Unloaded cable	1.77	2.62	3.41	4.37	7.0
Loaded cable	—	3.3	4.7	6.5	12.5

The gauge of cable used (w) will be determined by the route distance to the furthest subscriber and the transmission limits applicable. The route distance to the furthest subscriber may be assumed to be L times the radial distance. Then the extreme route distance becomes LR. Cable provision is normally one gauge for part of the route and the next higher gauge for the remainder, but in this study it is assumed that costs are adequately represented by using an average conductor weight derived from an equation relating the subscribers transmission limits to the average conductor gauge. Plotting the transmission limits for discrete conductor weights (Table 1) shows that between any two adjacent weights the limit $= d + fw$.

Equating extreme route distance and transmission limit

$$LR = d + fw$$

Rearranging and substituting for w in (1)

$$Ce = b\,[(LR - d)/f]\,P \quad \ldots . (2)$$

For a circular exchange area of radius R the total cable pair mileage required to serve the subscribers can be shown to be

$$= 2\pi\, SKaR^3/3$$

The subscribers contained in the circular exchange total $\pi R^2 S$. Therefore the average working pair mileage per subscriber

$= 2\pi\ SKaR^3/3\pi R^2S = 2KaR/3$. For a percentage cable occupancy of K_0 the average cable pair mileage per subscriber becomes

$$P = (2KaR/3)\ 100/K_0 = 200\ KaR/3K_0$$

Substituting in (2), the average capital cost per subscriber for external plant in a rural exchange area becomes

$$Ce = b\,[(LR - d)/f]\ 200KaR/3K_0 \quad \ldots\ldots\ldots\ldots\ldots\ldots . (3)$$

Note: For some types of exchange equipment the signalling limit may be less than the transmission limit. In such cases average conductor weight is determined from a plot of signalling limit versus discrete conductor weight and the same form of equation applied. With the availability of individual line signalling extenders the need for consideration of restrictions imposed by signalling limits will be reduced.

Subscribers Internal Plant: Switching equipment to serve a given number of subscribers in a locality may be provided at one exchange or dispersed over a number of exchanges. (Fig. 1). Substantially the same amount of individual subscribers equipment will be required in each case but site, building and common equipment costs will be dependent upon the number and size of exchanges. Therefore only the latter

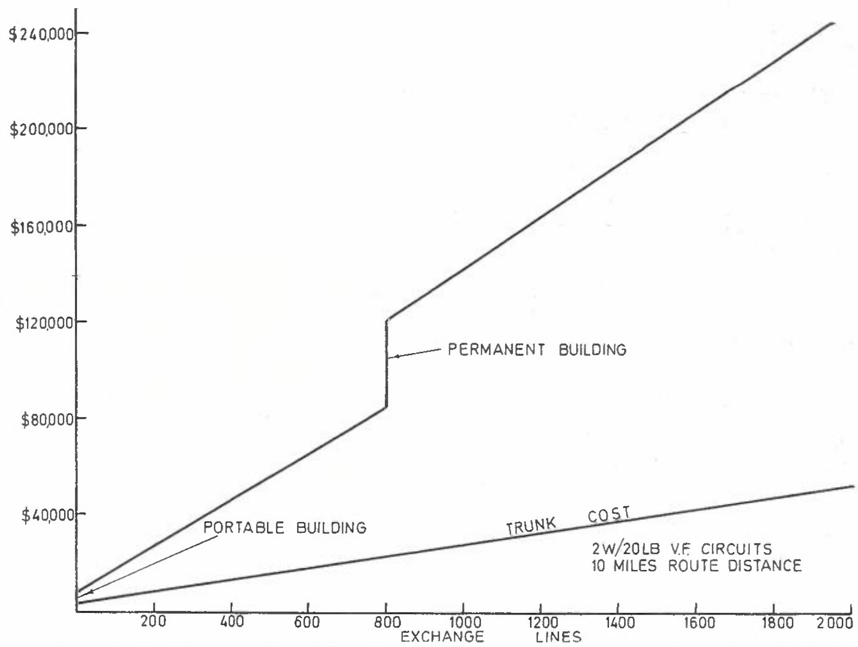

Fig. 3 — Capital Cost of Rural Trunks and Crossbar Exchanges including Building and Site.

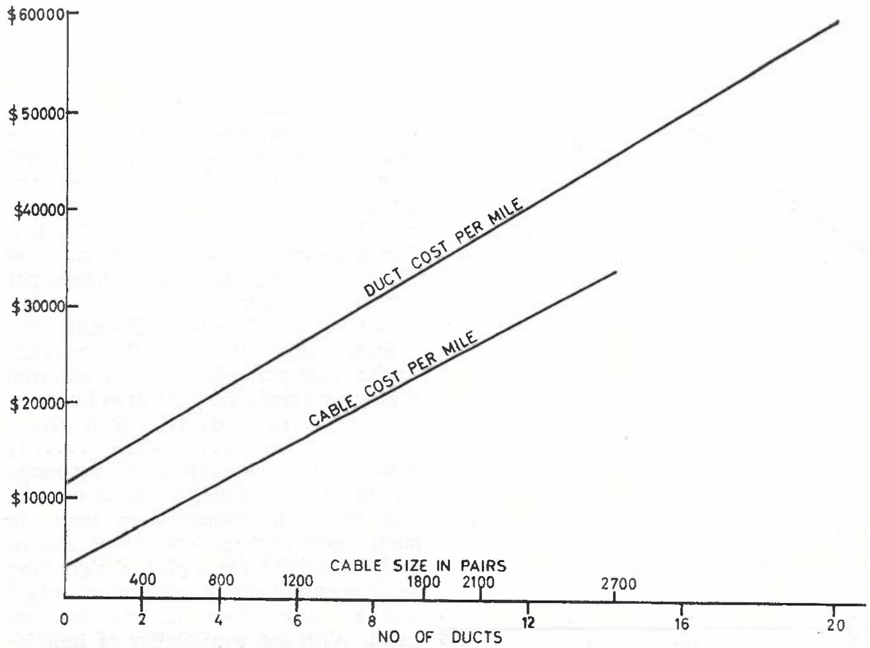

Fig. 4 — Capital Cost of Urban Subscriber Reticulation.

costs are relevant to the study and from Fig. 3 the capital cost per subscriber for internal plant in rural exchange areas is

$$Ci = g/\pi R^2 S$$

Trunks and Junctions: This study does not include the factors involved in the provision of main trunk switching exchanges as the location and size of these is irrelevant to the study of exchange boundaries related to subscriber densities. In practice, however, the existence or necessity for a large building to accommodate trunk switching equipment may have a bearing on the location of the subscribers exchange.

The cost function for trunk or junction lines comprises a fixed charge corresponding to the establishment of the route and a charge proportional to the number of subscribers in the area. That part of the cost which is proportional to the number of subscribers will be independent of the number of junction routes (number of exchanges) and may therefore be omitted.

The average distance of Victorian rural terminal exchanges from their switching centres is ten miles and the normal method of trunk provision is assumed to be 20lb cable using 2-wire passive V.F. circuits. The cost of providing these circuits for various exchange sizes is shown in Fig. 3 and the equation to this, based on the capital costs for trunks and junctions and omitting costs which are independent of the number of exchanges, is

$$Cj = h/\pi R^2 S$$

Urban Economic Radius

Subscribers External Plant: The distinguishing features of urban reticulation in Victoria in comparison to rural reticulation are the predominance of unloaded 4lb conductor cable and the provision of ducts. For our purposes it will be assumed that each duct will contain an average of 1000 cable pairs and the duct cost per pair mile is therefore one thousandth of the duct cost per linear mile.

The equations to the graphs of subscribers cable and duct costs in Fig. 4 may be added directly and produce a similar equation to the rural case,

i.e. $Ce = a + b.w.p.$

The remainder of the theory for the rural case applies in like manner to the urban case and the same final equation emerges for the external plant capital costs per subscriber.

i.e. $Ce = b\,[(LR - d)/f]\,200KaR/3K_0$

Subscribers Internal Plant: Capital costs relating to the provision of telephone exchange bulidings and A.R.F. equipment for urban areas are shown in Fig. 5 and similar to the rural case, the capital cost per subscriber for internal plant may be represented as:

$$Ci = g/\pi R^2 S$$

Junction Plant: An assessment of the Melbourne Metropolitan Network showed seven miles to be the average junction route length from tandem to terminal exchanges and the assumption was made that the average junction/subscriber ratio was 1 : 10. Naturally in practice this ratio varies with the traffic requirements of the individual exchanges but the result of this exercise was not affected significantly by fairly substantial variations.

Fig. 5 shows the capital cost for junctions and again the cost per subscriber may be represented as:

$$Cj = h/\pi R^2 S$$

Calculation of Economic Radii: The relevant cost of providing telephone plant per subscriber in an exchange

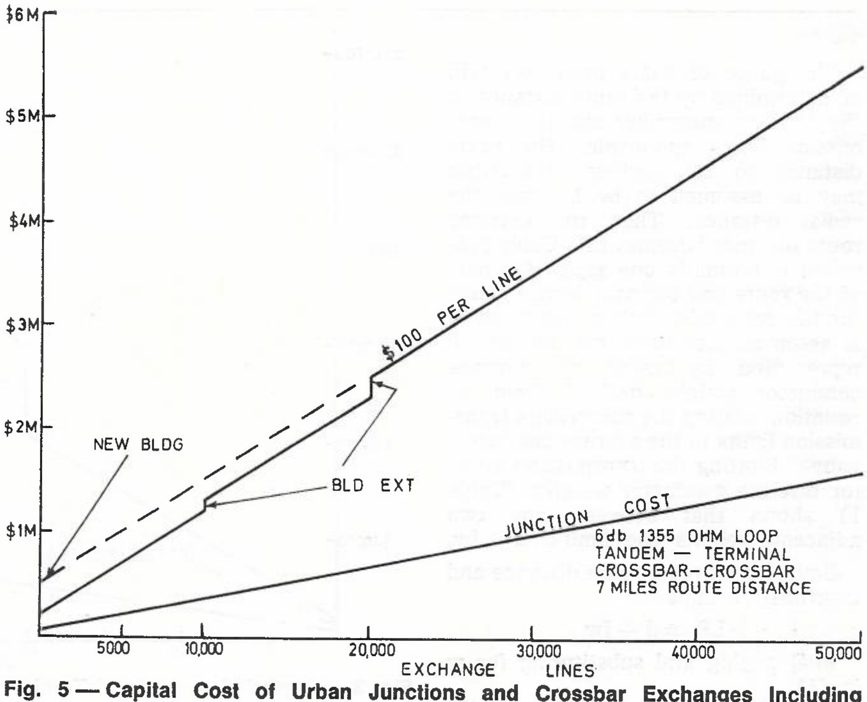

Fig. 5 — Capital Cost of Urban Junctions and Crossbar Exchanges Including Building and Site.

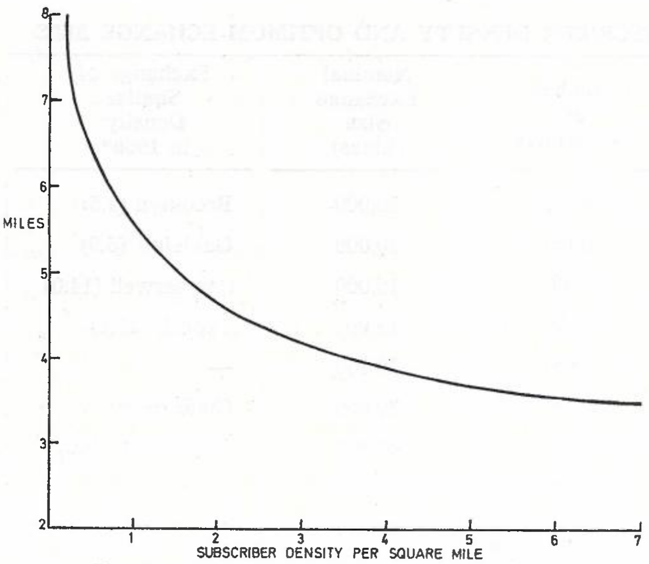

Fig. 6 — Optimum Rural Exchange Radius.

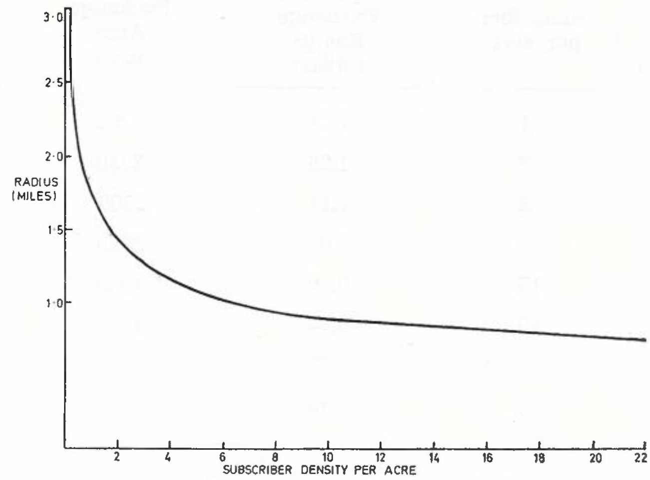

Fig. 7 — Optimum Radius of Urban Exchanges.

area of radius R may now be represented by

$$C_t = Ce + Ci + Cj$$
$$= b\,[(LR - d)/f]\,200KaR/3K_0 + g/\pi R^2S + h/\pi R^2S$$

and this cost will be a minimum when the differential $dC_t/dR = 0$.

$$dC_t/dR = 100\,Kab\,(2LR - d)/3K_0f - (g + h)/\pi R^3S = 0.$$
$$S = 3K_0f\,(g + h)/100\pi KabR^3\,(2LR - d).$$

The results for various densities and radial distances with the cost structures shown for rural and urban exchanges are illustrated in Figs. 6 and 7.

Effect of Variations in Cost Structures and Transmission Limits: The economic radius of an exchange area is most affected by variations in external plant costs and this is shown clearly in Fig. 8 for rural exchange areas. Operating on the assumption that in the foreseeable future we may expect a progressive decrease in costs due to improved techniques and efficiency, then we may also expect an increase in economic radius. However, the overall increase in radius will not be very great so that areas optimised on present costs will coincide with the economic optimum for many years.

Extending transmission and signalling limits affects economic radius through the effect on external plant costs.

Fig. 9 shows the change in relative total cost with exchange radius for various subscriber densities and indicates that exchange areas larger than the optimum may be tolerated with less penalty than areas smaller than optimum.

It is essential to clearly understand that variations in costs of items shown to be common to all exchange area

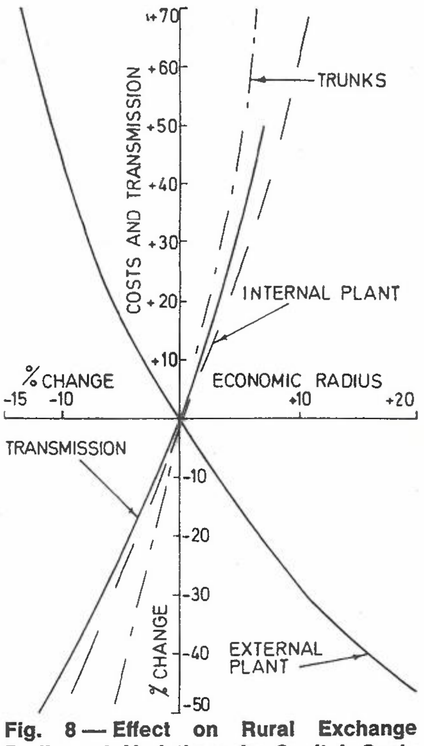

Fig. 8 — Effect on Rural Exchange Radius of Variations in Capital Costs and Subscribers' Transmission Limits for Densities of up to seven Subscribers per Square Mile.

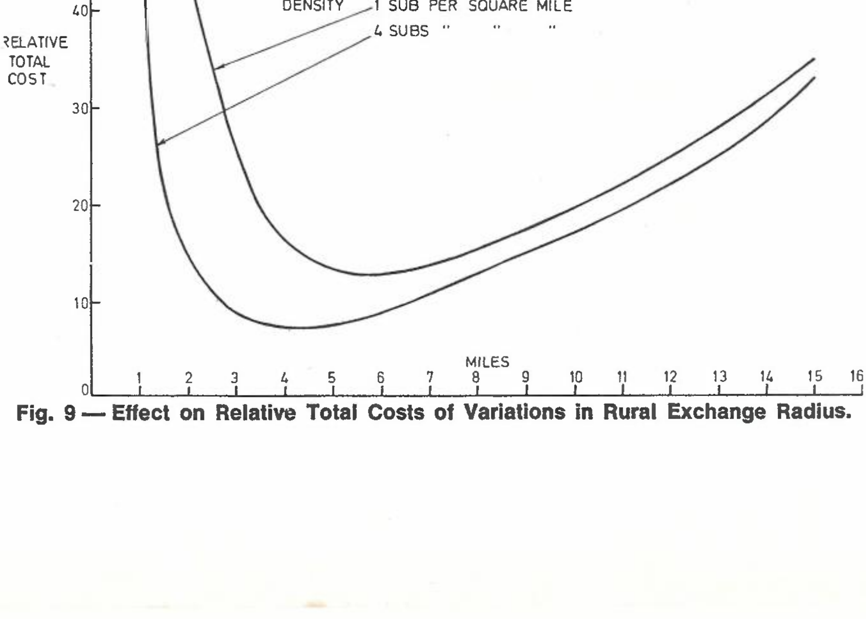

Fig. 9 — Effect on Relative Total Costs of Variations in Rural Exchange Radius.

TABLE 2: THE RELATIONSHP BETWEEN URBAN SUBSCRIBER DENSI TY AND OPTIMUM ECHANGE SIZE

Subscriber per acre	Optimum Exchange Radius (Miles)	Exchange Area (acres)	Number of Subscribers	Nominal Exchange Size (Lines)	Exchange of Similar Density in 1968*
1	1.77	6400	6400	10,000	Brooklyn (2.5)
3	1.28	3330	9990	10,000	Oakleigh (5.5)
5	1.11	2500	12500	15,000	Camberwell (14.0)
7	1.0	2000	14000	15,000	Toorak (20.4)
15	0.80	1300	19500	20,000	—
25	0.74	1100	28000	30,000	Civic (66.0)
50	0.58	680	34000	40,000	City West (100)
100	0.49	490	49000	50,000	—

*Expected density in year 2015 is shown in brackets.

layouts do not affect economic radii at all. For example a new cable laying method that reduced laying costs by 30% of present figures would not alter the economic radii except for any effect the method may have on trunk or junction provision. Similarly a fall or rise in the subscribers line exchange equipment costs as distinct from common equipment would have no effect on the economic radii.

Conclusion

The rigid application of an optimum economic radius to each exchange area is of course impossible but factors emerge from this study which enable economic control of plant provision without loss of flexibility.

For instance, no exchange area with a subscriber density of more than 1.0 sub. per acre should have its boundaries so far from the exchange that the furthest subscriber is beyond the transmission and signalling limits of 4lb conductor cable. Stated another way, if urban exchanges are properly located and their boundaries appropriately placed then all subscribers reticulation may be provided with 4lb conductor cable.

Similarly for rural areas with a density greater than 2 subscribers per square mile, 10lb loaded cable should be adequate.

A demographic survey of the Melbourne Metropolitan network has provided information on present and expected future subscriber densities in each exchange area. Table 2 indicates a few typical cases and from this a further important conclusion may be drawn. The majority of the exchanges in residential or light commercial and industrial areas do not require buildings or sites with a capacity in excess of 20,000 lines in 50 years' time. Exchanges with a capacity beyond 20,000 lines are justified only in the very high density commercial centres of large cities.

Some complicated economic radius studies have been undertaken in other countries, and, although cost structures and geographical features are different in each case, there is a similarity between the results of the overseas studies and this study which indicates that, irrespective of varying conditions, the optimum economic radius of a telephone exchange area lies within fairly well defined limits. The method outlined in this paper is simple to use and produces results which are adequate as a guide to practical planning.

PART 2: VICTORIAN RURAL EXCHANGE AREA PLANNING

The purpose of Rural Exchange Area Planning is to establish, within the framework of economics and transmission and signalling limits, a network of automatic exchange sites and boundaries covering the whole of the State of Victoria outside the Melbourne Metropolitan Area, but including the Melbourne Extended Local Service Area. These exchange area plans become the bases for Regional Network Plans incorporating details of switching, numbering and trunking in accordance with the Community Telephone Plan for Australia. After approval, the Regional Network Plans are implemented as financial allocations permit.

It is anticipated that eventually about 1055 automatic exchanges will serve the Victorian rural areas and the telephone plant provided (external, internal and trunks) will have a capital value approaching 200 million dollars. Obviously the economics of the exchange area design are of primary importance.

Plan Preparation

Each Rural Exchange Area Plan covers a number of exchange areas usually comprising a Secondary Switching Area or a Telephone District whichever is required for the relevant Regional Network Plan.

Maps are obtained or prepared for this area (scale 1 inch = 1 mile) showing road configurations, railways, township locations and important physical features such as rivers, lakes, State forests, Crown lands, etc.

A section of one of these maps is shown in Fig. 10.

The Engineering Division (Country District Works) responsible for this area (or Planning Branch staff as appropriate) then adds the following information.

(a) The location of existing exchanges.
(b) The location of existing rural subscribers.
(c) The location of residences of non-subscribers.
(d) Future known changes to physical features.
 e.g.
 (1) Area to be inundated by proposed dam.
 (2) Area to be absorbed by extension of mining operations.
(e) Minimum subsistence land holdings if known.
(f) Plant in situ both trunk and subscriber.
(g) Location of high-voltage power lines (66kV and above) for power co-ordination purposes.

Proper preparation of these maps (and later assessment of telephone demand) requires that various authorities should be contacted for information on existing and proposed land usage. These authorities are the local P.M.G. officers and State Government Authorities such as:

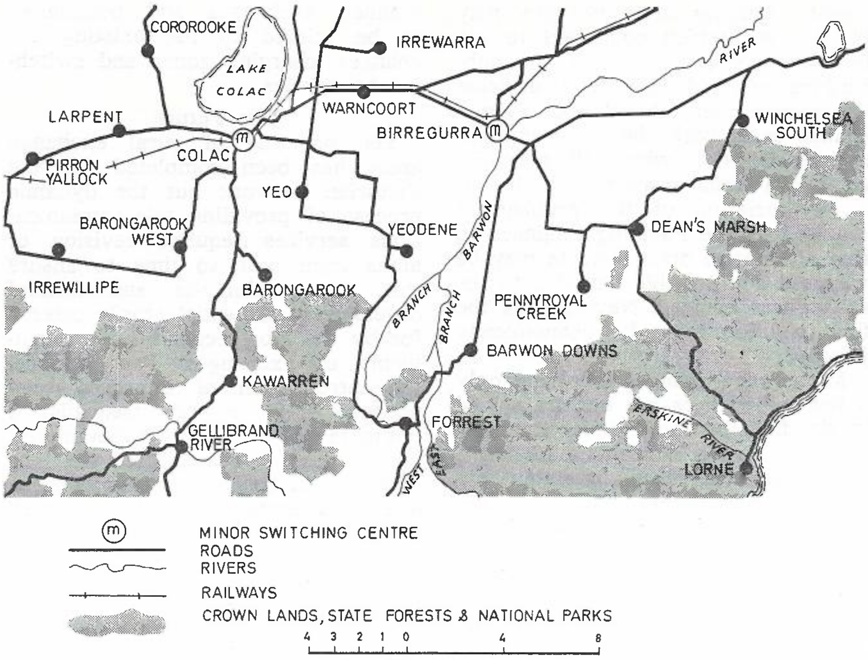

Fig. 10.

(a) Agricultural Department
(b) Country Roads Board
(c) State Development Division of the Premier's Department
(d) State Electricity Commission (Power Co-ordination)
(e) Forests Commission
(f) Latrobe Valley Development Advisory Committee, of the Premier's Department (if appropriate).
(g) National Parks Authority (Premier's Department)
(h) Rural Finance and Settlement Commission
(i) Soil Conservation Authority
(j) State Rivers and Water Supply Commission
(k) Other authorities if deemed necessary e.g., Local Government Authority (Shire Council), Town and Country Planning Board, Private Development Bodies, Commonwealth Census Bureau.

Planning Exchange Areas

Twenty years has been selected as the optimum study period because, in rural areas, demand over this period can be predicted with acceptable accuracy. The provisioning period varies for the different plant items and ranges from over 20 years for buildings down to 4 years for some equipment items.

To facilitate a broader appreciation of the area to be planned a number of 1 inch = 1 mile plans (prepared as described previously) are joined together to form an overall plan of the region.

Initially 'Fixed Points' are determined. These are locations where ultimate exchanges must be provided such as cities, towns or community centres containing a large number of subscribers (perhaps 100 or more subscribers depending on the area).

A determination is then made of the approximate boundaries of the fixed point exchanges based on the theoretical optimum exchange radius for the rural subscriber density. (To determine this density the 'town' subscribers are ignored and the approximate area divided by the anticipated 20-year rural subscribers only, i.e., uniform growth over the area considered. If this were not done application of the theoretical optimum exchange radius data would produce an incorrectly smaller area).

Where the planned boundaries for the fixed point exchanges overlap, the common boundary is determined by the location of the existing subscribers and their present reticulation unless these may be economically rearranged.

The areas not included inside the boundaries of the fixed point exchanges must then be examined and exchange locations and boundaries determined, using the principles of signalling and transmission limits and optimum exchange radius data.

Practical aspects now intervene in what, so far, has been a basically theoretical optimum design. The selection of exchange sites is affected by—

1. Location of existing exchange (if any).
2. Whether the existing exchange requires replacement. (It may be an automatic exchange capable of extension and therefore better left on its present site.)
3. Route of trunks to existing exchange. For economy, a new exchange should be located on a trunk route but a new method of trunking or trunk provision may be under consideration and this should be investigated.
4. Location and type of existing external subscribers' plant and its expected life.
5. The copper centre of the area under consideration.
6. The presence of intersecting roads near the theoretically desirable site allowing access to all parts of the exchange area.
7. Whether conditions exist that allow the actual route length of subscribers cables to be less for one set of exchange layouts than for others. Similarly one layout may avoid the need for cabling over a particularly difficult section of route. These aspects can be of prime importance.
8. The presence or expected installation of high voltage power lines. (In Victoria low voltage power is available at almost all locations for operation of the exchange equipment).
9. Topography. The desired site may be subject to inundation by flooding or be in a high bush fire danger zone. (The latter may be alleviated by clearing around the site).
10. Departmentally owned property (e.g., a line depot) may be available for an exchange location.

The final selection of a site is left to the plant engineer in charge of the area who complements these factors with extensive local knowledge. If the selection of actual sites shows that it is not possible to conform generally to the economic radius it is preferable to extend the radius rather than reduce, as this involves less economic penalty.

Exchange boundaries are not delineated exactly by Planning Branch but straight lines are drawn on the map to show the approximate boundary. The absolute boundary is finally determined by—

1. Transmission and signalling limits for the type of exchange which is expected to be installed. This is taken to be a Crossbar exchange except where definite information is available that another type of exchange will be provided.
2. Topography forming an accepted natural boundary such as Crown Lands, State Forest or other areas likely to remain devoid of subscribers; rivers which may or may not be readily crossable by cable;

mountainous areas; lakes, dams, etc.

3. Existing underground cable reticulation.
4. Location of subscribers and probable development.
5. Relationship to surrounding exchanges, i.e., boundaries should be approximately midway between exchanges. One exception could be where a large urban exchange is adjacent to a rural exchange. In this case it may be better to have the common boundary nearer to the urban exchange and avoid 20lb cables or loaded cables interspersed with normal suburban reticulation.

The local Divisional Engineer decides the final detailed exchange boundary which should follow, within practical limits, the boundary laid down by Planning Branch.

The boundaries now planned may include subscribers from nearby small exchanges (whole or part) and a decision must be made as to whether these exchanges should close and their subscribers form part of the newly planned exchange or whether the small exchange should remain and the planned exchange be readjusted accordingly. Normally the small exchange is eliminated but if it happens to be an automatic exchange with capacity for many years then it may be economical to retain the existing exchange and re-adjust the planned boundaries. Each case requires an individual assessment.

Where amalgamations of existing exchanges (whole or part) are proposed, charging zone changes may be involved which could act to the detriment or advantage of the subscribers affected. The final decision and approval or otherwise of a zone change rests with the Telecommunications Division who will normally conduct a traffic dispersion study but an appreciation of the problem is required by the Planning Engineer so that alternative arrangements may be analysed and possible hardship to the subscribers avoided. Nevertheless the final solution must be economically justified.

Minor zone changes involving only a few subscribers are usually solved in the field by the District Engineer and the District Telephone Manager. In an amalgamation involving exchanges in different zones, an exchange name is often retained but the new exchange is physically located within another zone. Authorisation for the resultant alteration to telephone charges is provided by an amendment to Telephone Regulations.

When tentative exchange site locations and approximate boundaries are delineated on the 1 inch = 1 mile plans for the area under consideration, it is necessary for the Planning Engineer to confer with the District Engineer and consolidate the plan. The exchange site locations and boundaries on the consolidated plan are then scaled on to a smaller plan (Scale 1 inch = 4 miles) to permit distribution as required. For convenience, Group Charging and Trunk Switching Plans (CP53) are used for this purpose and this also enables the planned exchanges and boundaries to be related to the existing exchanges, charging zones and switching boundaries.

The Future

The planning of rural exchange areas has been completed for the Victorian network but the dynamic process of providing telecommunications services requires revision of areas from time to time to ensure that new techniques and natural development are satisfactorily catered for by the most economical arrangements of exchanges. For instance, the introduction of improved telephones may extend transmission limits far beyond today's boundaries but it must be remembered that the extension of transmission limits alone does not economically justify very much larger exchange areas.

Eventually, replanning of exchange areas must occur and the starting point of any replanning procedure should be to establish economic parameters such as an optimum economic radius as a basis for sound planning and the planning engineer will then have a useful tool to support his judgment during the preparation of a new plan.

FURTHER READING

N. M. Macdonald, 'Engineering Economics and its application to Telephone Plant Design'; The Telecom. Journal of Aust., June 1954, Vol. 10, No. 1, p.13.

Y. Rapp, 'The General Plan for a Multi-exchange Area'; Ericsson Technics, November 2, 1964.

TECHNICAL NEWS ITEM

GLASS FIBRE OPTIC WAVEGUIDES FOR LASER TRANSMISSION

A two-year feasibility study into the use of glass fibre optic waveguides for modulated Laser light transmission is currently underway at the British Post Office Research Laboratory at Dollis Hill. Investigations are being conducted into methods of modulating Laser beams, the means of coupling the Laser into the very fine optical fibres, and the production of optical fibres with sufficiently low attenuation characteristics.

The optical fibre consists of an inner glass core, clad by glass with a lower refractive index. By suitable choice of materials there is no loss of light from the fibre, even when curved. The endoscope is an example of the use of this effect for viewing the inside of body cavities.

For the B.P.O. application, very long fibres with a diameter of about 0.1mm and maintained to an accuracy of 1% over a length of 3km have to be obtained. However, the main difficulty is in the production of sufficiently high purity glass. At the present time, impurities in the glass cause light scattering resulting in energy losses from the fibre and giving an attenuation characteristic of the order of 1000dB/km. To make a practical system, with cable lengths of 3km to 6km, a loss of less than 20dB/km must be achieved.

Significant advances in these technologies will be required before it can be expected that this means of realizing a potentially high capacity transmission medium might be suitable for extending facilities of high channel capacities to subscribers' premises. The theoretical channel capacity obtainable in this way, although much greater than is required at the moment, would be a means of providing the required bandwidth necessary for anticipated future requirements for more sophisticated subscriber's terminals such as 'viewphones' and computer access points.

CENTRALISED MAINTENANCE PRACTICES OVERSEAS

*B. J. CARROLL, A.R.M.I.T.**

INTRODUCTION

Recently the author visited a number of overseas telephone administrations to investigate the various techniques used for the maintenance of telephone exchanges. This article describes the completely centralised system of maintenance organisation adopted by the Royal Board of Telecommunications, Sweden and a private telephone operating company, the Helsinki Telephone Company, in Finland.

The techniques described have been developed from the result of detailed investigations and studies extending over many years. In each case the improvements obtained in productivity and service performance have been achieved, not by the use of new, novel or complex methods of supervising plant performance but mainly by the introduction of improved techniques in engineering management. The improvements include the use of modern data techniques for the continuous supervision of performance productivity and costs, and the introduction of more efficient methods of planning, scheduling and controlling of all maintenance activities.

In concluding the article the author describes the progress being made towards the introduction of centralised maintenance in Australia and draws attention to some of the distinctive features of the organisation of the Australian Post Office which must be taken into consideration when making comparisons with results achieved overseas.

TELECOMMUNICATIONS ORGANISATION IN SWEDEN

The Swedish Telecommunication Authority is a State owned organisation controlled by the Board of Telecommunication, which is responsible to the Government Ministry of Communication. The Board comprises the Director-General and five other members. The Central Administration is divided into six departments, Administration, Financial, Operations, Industrial, Projecting and Development each under the control of a Director. The distinctive features of this administration compared with the A.P.O. are that it is completely divorced from any postal business, it is practically self-financing and it manufactures about 25% of its equipment requirements in its own factories in direct competition with industry.

During the past 15 years the administration has, in common with the A.P.O., been faced with the problems of satisfying a high growth rate and, at the same time, coping with the conversion of the local and trunk networks to automatic working. This, together with growing competition from industry, has placed high demands on the available finances, material resources and skilled personnel and, in order to meet this development, improve productivity and provide an acceptable grade of service to the subscriber at a reasonable cost, a completely new form of field organisation was introduced.

Sweden, which has a population of 8 million people, 3.7 million telephone services and 7,165 telephone exchanges, is at present divided into four regions which cover a total of 20 telecommunication areas. For control of the long distance network the country is divided into six areas, with the overall control for network management being exercised from Stockholm. Thus each Regional Director is responsible for five telecommunication areas and one or two long distance areas.

The Director of a Telecommunication Area has four divisions reporting to him namely Personnel and Secretarial, Sales, Plant Construction and Operations. The Operations Division is a completely self-contained, highly specialised section which is responsible for the maintenance of exchange, subscriber and external plant, whilst the Construction Division is responsible for all activities associated with the provision of services, that is the planning, coordination and execution of all exchange, subscriber and external plant installation projects (refer Fig. 1). Large cable construction and other miscellaneous projects are handled by a specialised section under the Director of Operations (H.Q.). The Sales Section is the equivalent of our Telecommunications Branch. Under this new organisation there is a clear line of demarcation between maintenance and providing work and, for the first time, all activities, including Planning, Traffic, Engineering and Sales have been rationalised under the control of the Director of the Telecommunication Area. The physical area covered by a Telecommunication Area will very largely depend upon the telephone density. A typical area will include between 100,000 and 200,000 lines and up to 200 exchanges.

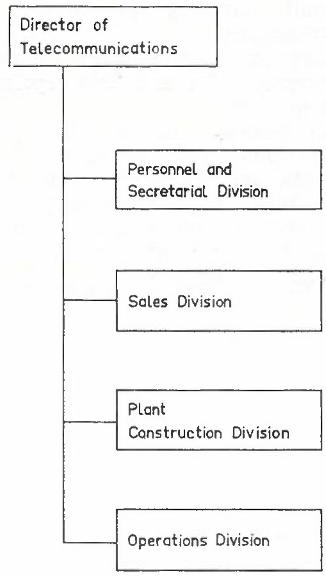

Fig. 1 — Oerebro Telecommunication Area Organisation Chart.

Main Features of the New Operations Division Organisation

The main features of the new Operations Division are listed below:—

1. All staff employed on exchange, subscriber and external plant maintenance are members of the same division and are controlled from the one fault and job distribution centre.
2. Data techniques are employed to provide continuous measurement of plant performance, productivity and cost with an absolute minimum of clerical effort.
3. Experienced field supervisors operate the control centre, thus relieving engineers of non engineering work.
4. A staff section provides specialised engineering attention to methods, practices, supervision, planning, traffic engineering, switching, transmission, lines and mechanical aids.
5. The scope and efficiency in the planning and performance of maintenance work is greatly improved.
6. Field supervisors are relieved of all clerical work and technical field supervision is improved.
7. Staff requirements are matched to the work load.
8. Better utilisation is made of skilled staff.
9. All requests for information, meter readings, connections, disconnections, diversions and fault reports are received and programmed by the maintenance centre.

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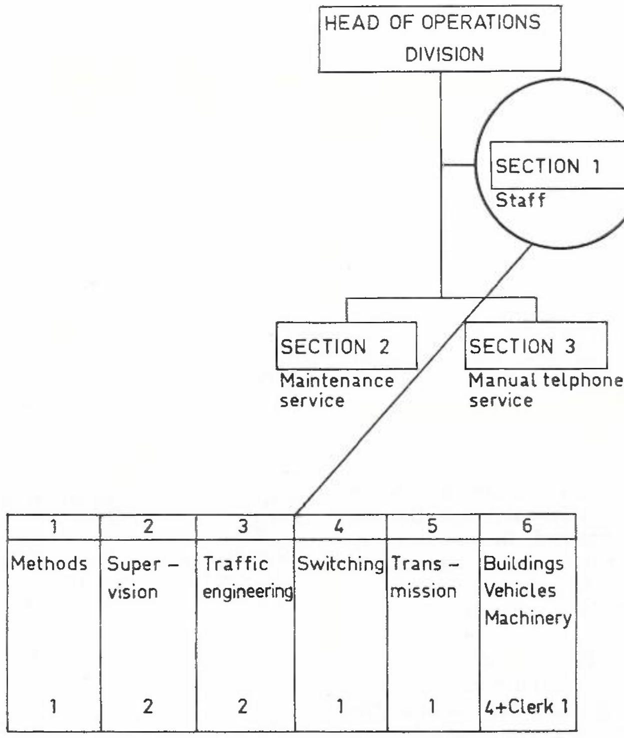
10. Improved methods of supervising service and plant performance from a central point are introduced.
11. Fault handling procedures are streamlined.
12. Communication between the maintenance office and field repairmen is improved.
13. All records such as cable plant, junctions and subscribers line cards, are centralised. Only basic essential information is provided in the exchanges and this is updated as necessary from the centre.

Oerebro Operations Division

After considerable and detailed study a trial of the new Telecommunication Area organisation was set up in 1965 at Oerebro. The area, which measures approximately 70 miles by 45 miles has approximately 120,000 subscribers connected to 192 terminal exchanges and is completely automatic. The switching equipment consists of the AGF500 line mechanical switching system and crossbar equipment installed as early as 1952.

The Operations Division employs the line and staff form of organisation similar to that of the Bell System (Fig. 2). The Staff Section (Fig. 3) provides the engineering services and administrative support to the Line Section (Fig. 4), which is responsible for carrying out all the corrective and preventive maintenance work in the area. The Engineering Management of the Line Section is under the control of an Operations Engineer, who is assisted by experienced supervisors. The manual telephone service referred to in Section 3 (Fig. 3), is the equivalent of our information and assistance service provided by the Telecommunications Division.



Note. Figures refer to number of personnel.

Fig. 3 — Operations Division Section 1 Staff Section.

Corrective Maintenance: The Oerebro area is divided into four sections for corrective maintenance. Each section contains 30,000 to 50,000 lines and is under the control of a field supervisor, who is directly responsible for the maintenance of exchange subscriber and external plant in his area. A field supervisor controls 8-12 repairmen who usually work in the one area (Fig. 4 and 5). Repairmen are at present in two categories, cable repairmen and exchange and subscriber equipment repairmen who can also repair lead-ins and small cables. For more difficult exchange faults a field supervisor can be called in or a specialist can be directed to the exchange by the control centre. Cable repairmen do their own fault location and all repairmen do their own testing. In future it is proposed to train specialists in the exchange maintenance, as exchange faults represent only 6% to 10% of the fault work. For rural areas cable repairmen will be trained to repair subscribers equipment also. Cable repair work has been reduced from a two man to a one man operation, thus reducing the cost of repairs. When two men are required, assistance can be arranged through the centre by contacting by radio another repairman in the area.

Preventive Maintenance: It will be noted in Fig. 5 that a special section handles all the preventive maintenance work for exchange equipment and all cable repairs for the entire communication area. Cable repairs are carried out by a mobile staff of 26 and a staff of 10 repairmen are responsible for the preventive or project maintenance work on exchanges

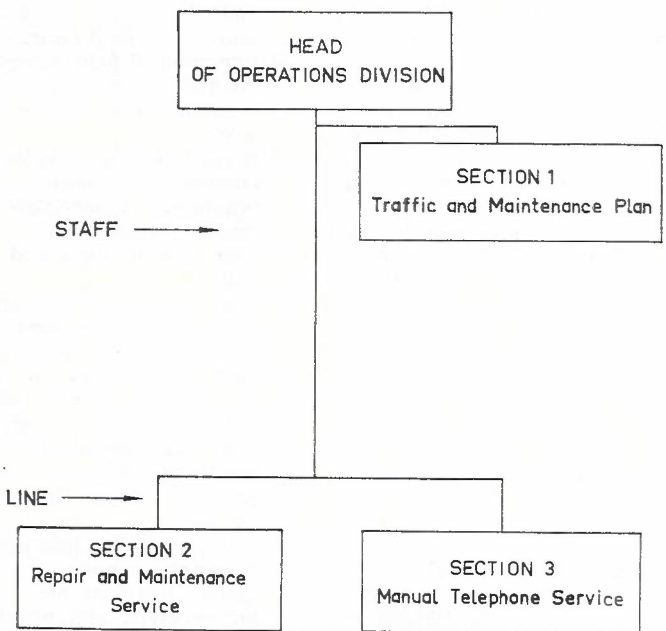


Fig. 2 — Operations Division Organisation Chart.

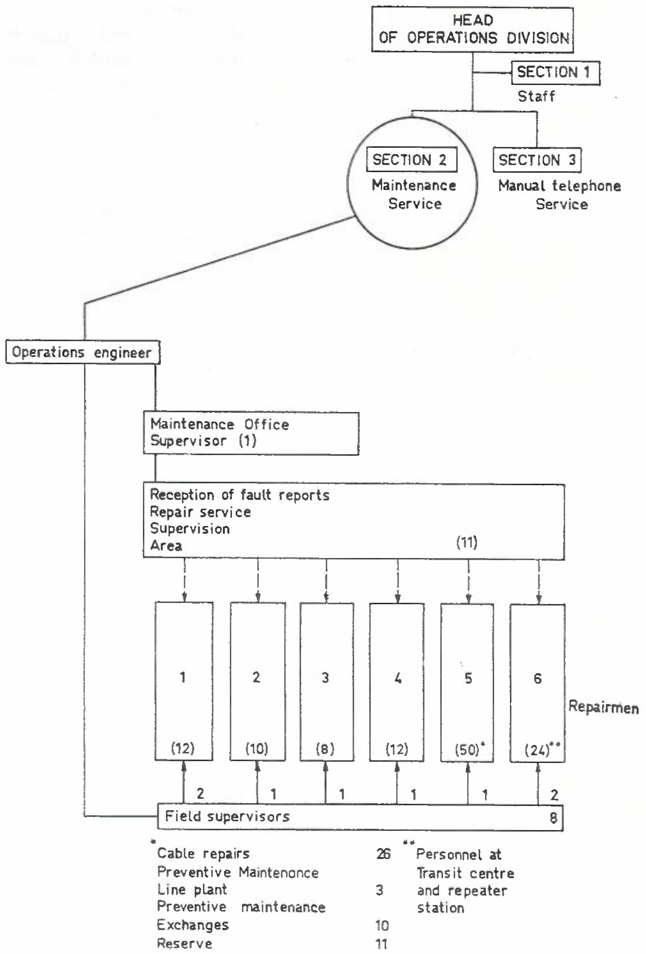


Fig. 4 — Operations Division Section 2 Maintenance Service

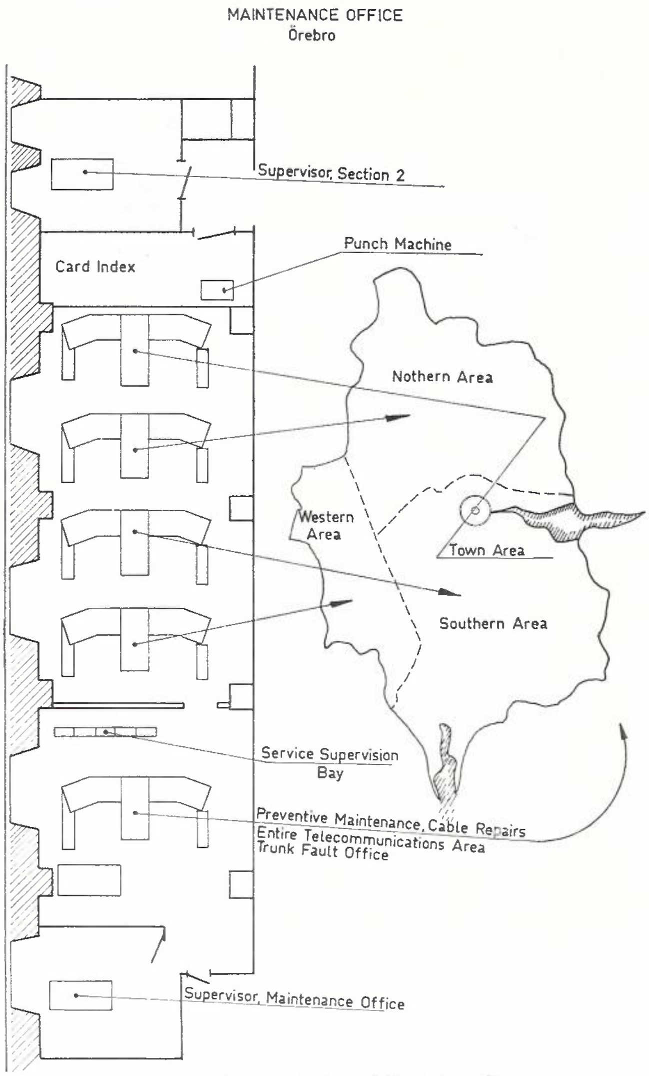


Fig. 5 — Maintenance Office Oerebro.

for the whole area. This type of work is planned by the maintenance office engineer from the analysis of plant performance results and in consultation with field supervisors who are responsible for the condition of the equipment and standards of workmanship in their particular sections.

Centralised Supervision: A service supervision panel is located in the maintenance office and all exchange alarms and service alarms for attended and unattended exchanges are displayed on this panel. On receipt of an alarm, a special punch card is made out and the card is handed to the area despatcher for the attention of the appropriate mobile repairman.

In the Oerebro area the traffic route testers (TRT's) are centralised in the main exchange building and, at present a battery of eight TRT's is being installed. These TRT's are controlled from the centre and the results recorded on centrallographs mounted on the service supervision panel. In order to avoid unproductive recording of results the TRT's are fitted with a percentage failure type of service alarm to indicate when the call failure on a particular route exceeds the predetermined action limit, say 1.5% on observe service. The TRT's call into answering relay sets at distant exchanges and perform a rough transmission test. The TRT's can originate calls from test lines at larger exchanges by the remote control of the A party calling number in the distant exchange. A new answering relay set has also been developed for use at outlying exchanges. This base, when called by a centralised TRT, can then originate a number of calls from that exchange and transfer the results of these calls to the maintenance centre over the test line calling into the answering relay set.

In order to provide the Maintenance Office Supervisor with an immediate indication of the fault workload in the various sections a number of resettable meters are provided. These meters are controlled by the operator who has three different keys by which she can release a call from her position. By operating the appropriate key she can immediately indicate on the meter whether a fault report has been received or a fault cleared. A lamp display indicates the number of repairmen working in each area.

Operation of the Maintenance Centre: All subscribers' faults and reports from other areas are received by specially trained female operators who also test the subscribers' lines, diagnose the possible location of the trouble and assign the work to field repairmen according to the urgency of the report and the route of the repairman. Two operators with access to subscribers' master cards are assigned to an area with 30,000 to 50,000 lines. A female operator receives the same salary as a repairman and it has been proved that female operators are far more efficient than

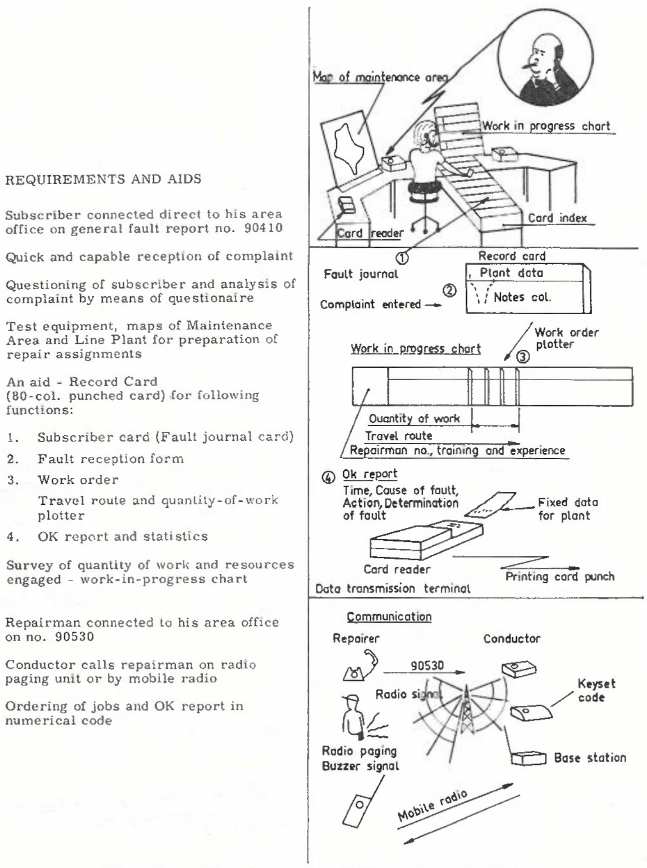


Fig. 6 — Maintenance Office Repair Area.

men at this type of occupation. The target for speed of answer is 5 seconds.

When a fault report is received the operator removes the subscriber's card from the card cabinet (Fig. 6) and enters the type of fault report on it in code form. In this way she has the previous fault history in front of her when testing the line and issuing the fault to a repairman. The card used is a special 80 column IBM card which has written on the top the usual information concerning the subscriber's name, number, address, external plant connections and equipment. This information is also punched on the card. A standard form of interrogation procedure has been prepared in order to assist the operator to diagnose the possible location of the fault. Facilities for testing subscribers' lines are provided by a small console mounted on the operator's position. Test facilities were not available for small remote exchanges.

Having determined the nature and possible location of the fault the operator can assign the job to a repairman by placing the card in the 'work in progress' chart which is provided for each repairman. (The operator controls up to 8 repairmen.) This chart enables the operator to balance the workload between repairmen working in that particular area. Details of the repairman's training and experience are entered on the left hand side of the chart (Fig. 6). When the fault is cleared details of the fault code, repairman's identity code, travelling time and total time are entered on the card, which is then placed in the card reader. The fixed information is automatically recorded on a statistical card and the details of the fault are then punched onto the statistical card by the card punch machine. The subscriber's card is then returned to the master card cabinet (Fig. 7). Cards with distinctive colouring are used for subscribers' equipment, switching plant, junction circuits, transmission equipment, cable plant, special plant, work order (i.e. MDF work, meter readings, disconnections, diversions, etc.) and personnel records. Operators and repairmen are provided with a book which details the codes to be used for all activities and fault clearing.

The streamlining of the fault handling procedure is evident from the above practices. The one operator handles the receipt of the fault, testing and despatching, and for recording purposes the subscriber's master card is the only document used. Clerical work is at a minimum and the data for statistical records is obtained by use of punched cards.

Each repairman has a personnel card which is used to record his attendance, overtime allowances and travelling time. This card is used for salary calculations and costing. Repairs, fuel consumption and mileage of the motor vehicles are also recorded by punch cards.

Statistical Information: The statistical cards are sent to Stockholm monthly for computer analysis and statistics are obtained on productivity, performance and cost, the goal being to achieve a working statistic, the results of which are expressed in values which can be used as a basis for administrative or technical action in the Operations Section of the Tele-

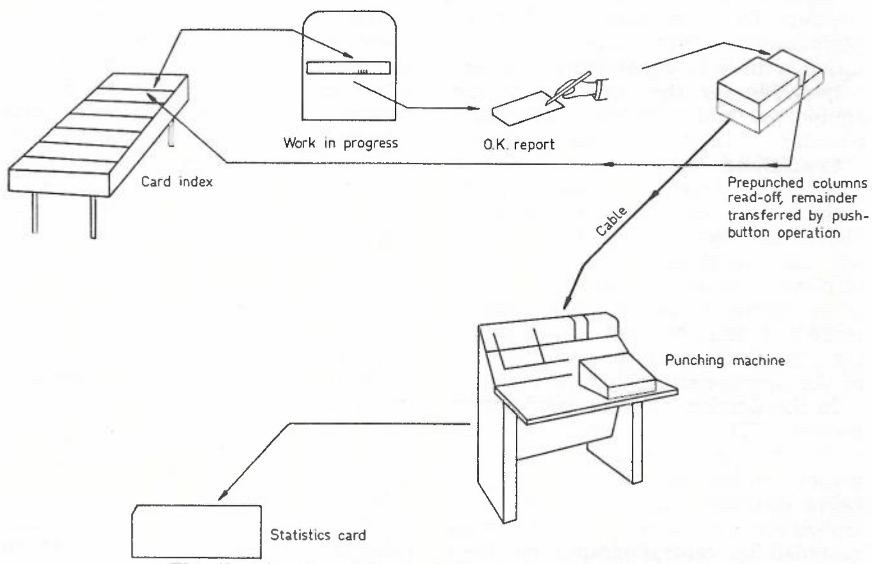


Fig. 7 — Route of Record Card after Fault Report.

communication Area. Typical statistics recorded at present are:—

1. Groups of subscribers' lines for equipment at exchanges where the pre-determined normal fault incidence is exceeded.
2. Cables and distribution areas with high fault incidence.
3. Subscribers' lines with repeated faults.
4. Methods of detecting faults.
5. The distribution of costs and time spent on preventive and corrective maintenance, no fault found, travelling, etc.
6. The ratio between effective time and total time for each repairman or group.
7. The average time for each activity or fault.
8. Repairmen with repeated faults.
9. Repairmen who exceed the average fault clearing time by more than 50% on a pre-determined number of faults.

It should be mentioned that the computerized information system employed by the operations division is designed as an integral part of a completely computerized management and operation information system which is under development.

Staffing: As a general rule, exchanges with less than 10,000 lines are not staffed. However, in the Oerebro area some crossbar exchanges with 5,000 and 6,000 lines had a resident staff of one repairman who could be called upon to assist with the maintenance of adjacent smaller exchanges in the area. The only three exchanges with a resident staff were the 9,000 line ARM Secondary switching centre, the Oerebro exchange, 45,000 lines AGF500 Point (one supervisor and six repairmen), and a 15,000 line AGF exchange (one supervisor and three repairmen).

In Oerebro the total corrective and preventive maintenance on the switching equipment for the 120,000 lines was carried out by a field staff of 26. This represents approximately 0.43 manhours per line including travelling time. As a general guide for the operations area, staff is provided on the basis of one man per 1000 lines for the maintenance of exchange, cable, and subscribers' plant.

Results Oerebro Operations Division

Service Samplings: The figures quoted below are the service observation results for the last six months of 1967. These results are claimed to be better than average with respect to congestion and switching loss. Register access is provided for service sampling. Portable observation equipment is used at smaller exchanges.

	Local	Trunk
Effective calls	64%	73%
Total Customer Loss	35%	26%
Congestion Loss	—	0.7%
Switching Loss	0.6%	0.6%

The expected values for congestion plus switching loss are as follows—

Local Exchange Area	1%
Local Network	2%
Distant Network (S.T.D.)	5%

The above figures represent the median value obtained from many hundreds of thousands of calls observed at the registers, and are comparable with results obtained in the Melbourne metropolitan area and on S.T.D. traffic in Australia.

Fault Reports (Yearly Basis):

Telephone Exchange Equipment—
50 faults/1000 lines
Substation and Lead in—
300 faults/1000 lines
Cable Plant—
150 faults/1000 lines

The figures include an average of 20%NFF (No Fault Found).

Whilst this data is not strictly comparable because of the difference in the two networks, the technical assistance reports on telephone exchanges for the Melbourne area average 156 per 1000 lines and subscriber and external plant repair requests 1056 per 1000 lines. This is more than twice the fault rate of Oerebro.

It must be realised that it is difficult to make direct comparisons with this type of statistic, particularly with respect to telephone exchange equipment faults as the initial fault classification is made in the A.P.O. by operators not trained to the same standard as those in Oerebro. The fault report rate would also be influenced by the type of switching equipment and the fault reporting habits of the subscribers. These habits are also influenced by the fact that the area is completely serviced by common control switching equipment and subscribers do not gain service assistance from the fault repair centre. (The Melbourne figures refer to the last quarter 1967.)

Productivity on a Yearly Basis: Telephone Exchange Switching Plant Maintenance— 0.43 manhours/line
Subscriber and External plant—
1.2 manhours/line
Total manhours per line. Exchange Subscriber and External Plant Maintenance (includes Engineers and Control Centre staff)—
2.0 manhours/line.

The above figures refer to maintenance activities only and do not include any work associated with installation or rearrangement.

The 1967/68 Commonwealth average for exchange maintenance is 3.84 manhours/line and for subscribers' equipment maintenance is 1.68 manhours/line. This makes a total of 5.52 manhours/line/year excluding external plant maintenance.

Fault Clearing in Subscriber and External Plant: The percentage faults cleared within 8 hours is shown below:—

(i) Built up areas 65%
The target is 90% by 1972.
(ii) Country Areas 54%
The target is 90% by 1972.
(iii) Percentage of faults with a duration of 5 days.
Built up areas 11%
The target is 0% by 1972
Country areas 16%
The target is 0% by 1972

Stores Handling: It was noted in Sweden that all clerical work associated with the ordering of stores for maintenance purposes is removed from field staff. A number of unattended secondary stores are set up and these stores are restocked once a week from the main store by a visiting stores vehicle. No bin tally cards are kept but a red flag is placed on a peg board to indicate items which are out of stock. Recording of expenditure on maintenance material is carried out at the main store only.

Application of the Oerebro Trial to Capital City Networks

At present the principles of the Oerebro trial are being applied to the Stockholm Telecommunication Area which has 700,000 lines (900,000 telephones) within a radius of 10 miles. It is claimed that Sweden has the highest telephone density and the third highest calling rate in the world.

Owing to the large number of lines in this area it is being divided into 4 sections of about 200,000 lines each and the section which covers Stockholm itself has already been set up. The section covers 270,000 lines (390,000 telephones). A further three control centres will be set up adjacent to this one on the same floor. The one staff section will still provide the engineering support to the three line sections as the problems in all sections will be similar; however, the number of staff in each section will be in proportion to the work load. The engineers in the staff section are usually specially trained by the Administration and do a course of three years duration after reaching matriculation standard.

Owing to the higher fault rate an operator with two assistants is assigned to each position and five positions cater for the 270,000 lines. On the average eight repairmen are controlled by each operator who also receives the fault reports and tests the lines. The set up differs from the

Orebro trial in that specialist teams are employed on the maintenance of exchange equipment, private automatic branch exchanges (PABX's), private manual branch exchanges (PMBX's), public telephones and cable repairs.

The 270,000 exchange lines are maintained by a staff of 112, which represents 0.9 manhours per line for exchange maintenance in large city areas. The 390,000 telephones, PT's and PBX's are serviced by a staff of 65 repairmen which represents 0.3 manhours per telephone.

TELECOMMUNICATIONS ORGANISATION IN HELSINKI

Telecommunication services in Finland are shared between the Post Office and a number of independent co-operative companies. The Post Office handles all trunk and international traffic, and local traffic in the more sparsely populated areas. On the other hand, 80% of all telephone sets belong to independent companies. The total number of telephones in Finland is over 890,000, making a density of 19 per 100 inhabitants.

Helsinki Telephone Company

The biggest independent company in Finland is the Helsinki Telephone Company, which services approximately 800,000 inhabitants in an area of 1,400 sq. miles. The company is owned by its shareholding member-subscribers. Of the 250,000 subscriber lines, 90% are member-subscribers. The activities of this company are completely divorced from any postal business.

On joining the company, a member-subscriber buys one share per subscriber line. A share costs $350 Australian, which represents the average expense of installing a subscriber line and all related equipment at the exchange and the subscriber's end. The revenue from this source forms the company's basic capital.

Customers who need a telephone but do not wish to join the company pay a deposit of either $75 or $22 and an annual rent of $35 or $50, including maintenance and servicing. Member-subscribers pay an annual maintenance fee of $14. If a non-member subscriber later buys a share, his deposit is credited to him.

Call charges are the same for members and non-members. The number of calls is recorded by automatic call counters fitted to each subscriber's line. Local calls cost 1.5c per call. The charge for a conversation between different call areas is the basic 1.5c plus 1c a minute. Some 86% of the subscribers are in the city local-call area and the rest are distributed between 14 rural areas.

These basic rates do not differ for private and business subscribers. PBX's with up to 100 extensions are rented and subscribers pay rent and special servicing fees. PBX's with over 100 extensions are owned by the subscribers, who pay servicing fees.

There are approximately 340,000 telephone sets. The density in the whole concession area is 40.5 and in the town of Helsinki 49.8 per 100 inhabitants. PBX's number 2,600. All these figures are rising at 6-10% annually.

The highest administrative body is the company's Board of Delegates which is directly elected by the member-subscribers. This board appoints a Board of Directors, which appoints the Managing Director and the Directors of Operations, Research, Finance, and Purchasing and Real Estate.

The company was founded in 1882 six years after Bell introduced the telephone. The first automatic exchange was built in the early 1920s and since 1960 the area has been completely automatic. The switching equipment consists of 87,000 lines step, 152,000 lines crossbar and 30,000 lines EMD. The step equipment is mainly German built pre 2000 type but includes some pre 2000 type equipment manufactured in 1922. Automatic routiners are not provided in the step exchanges.

The concept of centralised control of all maintenance activities was considered as early as 1938. However, owing to the war it was not put into practice until the late 1940s. The aims of the maintenance organisation are the same in principle as those of the Orebro trial and no doubt this system was considered in detail by the investigating committee who were responsible for the reorganisation in Sweden.

The Operations Department

The Director of Operations is in control of four departments, Planning, Installation, Operation and Workshops. The Operations department is a specialised section which deals with the maintenance of exchanges, subscriber and external plant (Fig. 8). The term 'network' refers to subscribers equipment and external plant. Fault reception testing and the control of maintenance activities associated with subscriber and external plant are handled by the network department along lines similar to the subscriber fault despatch centres operating in Australia. Fault reports are received by the fault office (similar to our Service Centre) and the reports conveyed to a section which attaches the report to the subscriber's master card and forwards it to the testing section where faults are diagnosed as exchange subscriber or external plant faults. The exchange faults are transferred to the telephone exchange department.

Fault distribution is as follows:

1. Exchange and Cross Connections	6%
2. Trunk network	2%
3. Cable network	8%
4. Open wire lines	2%
5. Indoor Cabling	7%
6. Substation equipment	58%
7. PABX equipment	17%

Maintenance of Exchanges

For exchange maintenance, the concession area is divided into five districts each in charge of a master (senior technical officer). These are further divided into sections each of which has its own mechanics (technicians), under a technician (technical officer). The masters are in charge of the work and give their directives to field staff via the control centre. A master is responsible for the maintenance of 50,000 to 80,000 lines of

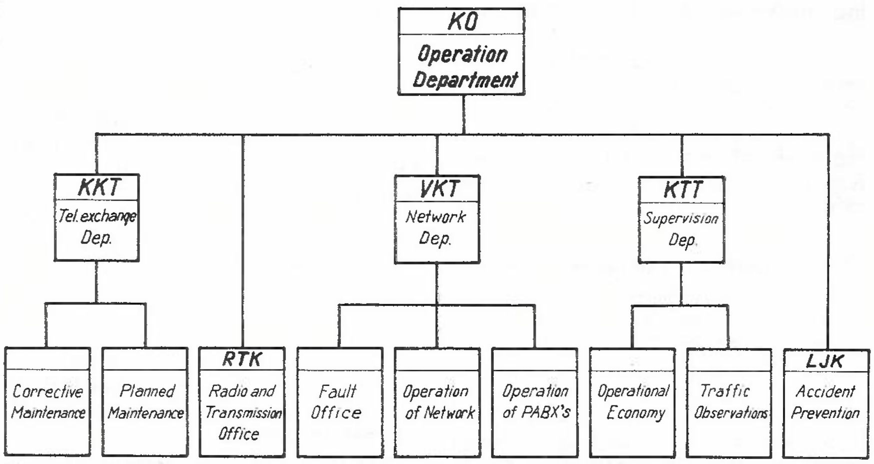


Fig. 8 — Organisation of the Operations Department, Helsinki Telephone Company, Finland.

exchange equipment and the technicians under his control are responsible for the quality of the work. (The titles in brackets refer to the equivalent A.P.O. staffing designations.) Masters and technicians enter the service with a higher education standard than mechanics and are trained for approximately 3 years on a special course.

Corrective Maintenance: The staff employed on corrective maintenance (fault rectification) receive their directions via the control centres. The faults are allocated in priority order and with due consideration to economy in travelling.

Preventive Maintenance: The preventive testing and project maintenance work is planned for the whole area by the planned maintenance section. This work is ordered by the analysis of performance indicators, such as service observation, traffic route testing, subscribers fault reports, the analysis of found faults and by reports from the masters who are the technical field supervisors responsible for the condition of the plant in their areas.

Staffing: Fig. 9 indicates the number of staff employed on exchange maintenance for the 270,000 lines installed. It will be noted that the cleaning for the 174 exchanges is carried out by a staff of 21 female cleaners. The corrective maintenance is performed by a field staff of 70, whereas the project maintenance is carried out by a staff of 40 which includes 18 females who are employed on the more routine type of work such as cleaning, oiling, wiper replacement and routine testing and adjustment. The only installation activity associated with the telephone exchange operation department is the planning, installation and maintenance of the power plant, including the prime mover associated with standby power units.

The general operation of the control centre is supervised by a master who is directed by the operations engineer. This leaves the engineering staff free to concentrate on methods, practices, performance analysis, and traffic problems.

Data techniques are employed for all recording and analysis work. All work associated with the testing of subscribers' lines, connection of services, divisions, meter readings, etc. is controlled and programmed from the subscribers' maintenance section.

In the Helsinki network crossbar and step exchanges under 8,000 lines do not have a permanent resident staff.

Centralised Supervision

Alarms: The performance of attended and unattended exchanges is controlled from the maintenance centre. Disturbances in the form of exchange alarms are automatically recorded in the control centre. Special alarm transfer equipment is used and the date, time, exchange, and identity of the alarm is recorded on a paper tape. An alarm is also given whenever the exchange is entered. The main door of the exchange can also be opened by remote control after the caller has identified himself and stated the reason for his visit. The alarm system makes use of the switching plant to call the control centre and this system is checked daily from the maintenance centre by setting up a call to a special number in the exchange.

Service Sampling: Centralised service observation is employed with samples spread over the whole month from all exchanges. S.R. observation is used at crossbar exchanges and 1st selector observation at step exchanges. Computers are employed for analysis.

Manual Test Calls: Two operators are continually employed on making manual test calls.

Traffic Route Testing: Centrally located traffic route testers are used to sample switching performance on various routes; 600-800 calls are made each day. A tape recorder is used to indicate conditions encountered on lost calls. A special congestion signal is used.

Fault Analysis: All alarms and found faults are recorded on punched cards and the results analysed by a computer monthly. The Helsinki Administration uses this detailed analysis to detect faulty components, design defects, and to determine the nature and extent of the preventive or corrective maintenance necessary.

Traffic Supervision: A centralised traffic recording system designed in the immediate post war period is employed to provide an early indication of route congestion.

Telephone Exchange Department 1. 1. 68.											
		Corrective Maintenance					Planned Maintenance				
			Exchange Districts	Technical Control	Operation Planning	Job Distribution		Work Groups (Projects)	Work Planning	Power Group	
Engineers	1	3					1				5
Masters			5	1	1	1		1	1	1	11
Technicians			8	1				1	1		11
Technical office staff					2	13			2		17
Mechanics			54	3				16		4	77
Men			3					4		10	17
Women			21					18		3	42
Total of Staff 180											

Fig. 9 — Personnel Telephone Exchange Department, Helsinki Telephone Company.

Results Achieved

(i) Service Sampling Local (1967)
- Effective Calls 76% (70)
- Customer Loss 21.9% (28)
- Congestion Loss 1.8%
- Switching Loss 0.46% (1.1)
- (The figures in brackets refer to similar statistics for the Melbourne Network.)

(ii) Exchange Fault Reports
- Fault reports per 1000 lines/year Crossbar Exchange 75
- Fault reports per 1000 lines/year all Exchanges 140

(iii) Productivity
- Crossbar Exchange Maintenance 0.3 manhour/line
- Total for all Switching Equipment 0.54 manhour/ line
- Total for Exchange Equipment Maintenance 1 manhour per line (Approx.) (This includes Engineers, Control Centre staff, Clerical and Cleaners.)

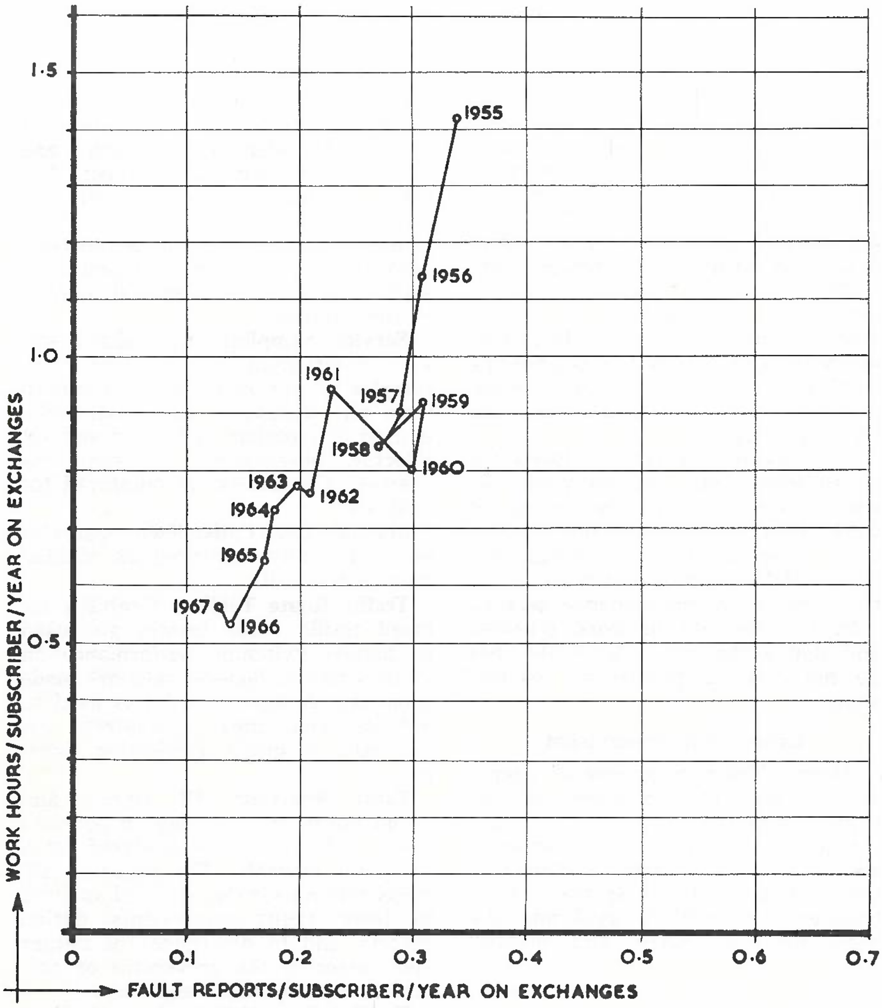


Fig. 10 — Results achieved in Maintenance Work in H.T.C. 1955-1967.

Fig. 10 clearly indicates the improvements that have been achieved since 1955. The maintenance manhours per line for field staff employed on exchange maintenance has been reduced from 1.4 to 0.54 overall and the fault report rate has dropped from 300 to 140 per 1000 lines over the same period. It is also of interest to note that the external plant and subscribers equipment maintenance (excluding PT's), averages out at 1.0 manhour per line per year for field staff which is a similar figure to that obtained in Oerebro, Sweden.

MAINTENANCE PRACTICES IN AUSTRALIA

Distinguishing Features of A.P.O. Networks

In comparing the maintenance organisations and results achieved by overseas administrations with those of the Australian Post Office it is necessary to give due consideration to the type, age and reliability of the switching equipment as well as the trunking configurations, telephone density, area and service standards of our network.

From the results achieved it is evident that the common control switching equipment installed by these administrations is more reliable than the step equipment which constitutes at least 75% of our switching plant. A further influencing factor is that overseas plant design has been stabilised over many years whereas the A.P.O. has only recently introduced crossbar equipment into its metropolitan, rural and trunk switching exchanges. Although approximately 25% of the switching equipment is crossbar it is spread throughout the network and in many cases during this initial period forms relatively small extensions to step exchanges. Under these circumstances it is not possible to achieve the maximum benefits. It was noted in Sweden that disturbances to switching equipment for installation extensions are, in the main, reduced to at least 2 year periods.

In general the trunking configurations overseas are simpler and owing to the higher population density larger parcels of traffic are carried by the trunk and junction routes. In cases where small direct routes are used there is a tendency in the initial stages to over provide the circuits on these routes.

Whilst it is considered that centralised maintenance techniques could be readily applied to our metropolitan networks there would be a number of problems to solve in country areas due to the relatively low telephone density and large geographical area involved. It has been the experience in Sweden that in telecommunication areas with as little as 35,000 lines spread over large areas, the operating costs have been up to three times as high as for metropolitan areas.

The above remarks are not intended in any way to detract from the overall advantages claimed for the introduction of centralised maintenance techniques and in fact it could be argued that although these particular features of our network will influence the results obtainable they also strengthen the case for the introduction of these principles. During the financial year 1967/68 some 7.5 million manhours were expended on the maintenance of automatic exchanges and as this represents 90% of the field costs it is therefore this area where improvements in management and staff utilisation will have a marked effect on the overall operating costs. For the last financial year these costs including administration and material were $22.4 million. The expenditure in other maintenance fields (i.e. external plant, subscribers' equipment, and trunk switching equipment) totalled approximately $36m. for the same period.

Progress towards Centralisation in Australia

During the past decade the approach to the maintenance of exchange and subscribers equipment has been under constant review and worthwhile improvements have been made in respect to service standards and labour productivity. In the exchange maintenance field there has been a constant improvement in labour productivity of about 4% per annum. Action is in hand to centralise the control of subscriber and external plant maintenance in metropolitan areas, and in some cases all test desk activities associated with the testing of subscribers' lines also have been centralised. The testing load has been reduced by the rationalisation of the need for testing, the introduction of automatic test desks at exchanges

(APR) and by providing field staff with the suitable test equipment to locate faults. Special testing facilities have been developed in the remote testing of subscriber lines at distant exchanges over derived circuits.

The next step towards centralisation could be to arrange for all M.D.F. work associated with the connection of new lines, disconnections, diversions, and meter readings etc. to be controlled from the Centre responsible for directing subscribers repair work.

Development of a Computerised Management Information System: The Telephone Exchange Equipment Section in conjunction with the Industrial Engineering Section at Headquarters, with assistance from State administrations has developed a management information and control system for exchange maintenance activities.

The information section is now being converted for computer analysis. The object of introducing the information system at this stage on a trial basis is to obtain factual data which will assist in the review and design of the ultimate management control system and in determining the form of organisation best suited for exchange maintenance work. The system will be engineered so that it will be compatible with similar systems in use in other fields and will ultimately form a segment of the overall operations and management information system.

Amalgamation of Maintenance Districts: The amalgamation of a number of small technician's districts into a single large district has resulted in improved plant performance and productivity. For example in the metropolitan regions in Perth the manhour figure for exchange maintenance has been reduced from 3.4 to 2.65 over the past year.

Overseas administrations have found that when exchanges are not staffed on a permanent basis, the performance improves because maintenance activity is reduced to essential work and this in turn reduces faults arising from staff activity. This also applies to the preventive maintenance project work, as teams employed on this work become very skilled in the repair and adjustment of the switching plant.

Replacement of Obsolete Equipment: Action is in hand for the planned replacement of all obsolete pre-2000 type equipment by 1983 and this will result in the upgrading of facilities and service performance, especially in New South Wales where some of the larger key switching centres are equipped with equipment up to 40 years old.

Developments in Maintenance Aids: As the major portion of the telephone traffic is still switched via step equipment there is a need in the A.P.O. to consider more sophisticated methods of supervising plant performance than those adopted by overseas administrations and development work over recent years has been oriented towards this end. This includes the development of functional testers with print-out facilities for all step exchanges, the automatic release of lines held in step exchanges, cable fault alarms, modifications to control registers at ARF exchanges to detect no progress calls to step and crossbar numbers. The installation of automatic disturbance recording equipment at crossbar exchanges, improvements in congestion supervision, and the development of special answering bases for use with traffic route testers. These relay sets will have facilities to generate outgoing calls from remote exchanges and to transfer the results of the test calls to the parent TRT. Alarm extension equipment is being purchased to enable a number of different alarms to be transferred over physical or derived circuits.

Network Performance Analysis Centres: N.P.A.C.'s similar to those at present in operation for metropolitan networks are being set up to cover the Trunk and Country Network. In N.S.W. centres are also being set up at 3 of the larger Secondary Switching Areas.

CONCLUSION

Considerable progress is being made with the introduction of centralised maintenance in the subscriber and external plant fields. The application of the larger district concept to exchange maintenance work will provide engineers and field staff with practical experience in maintaining satisfactory service standards whilst lifting the control of staff resources from the individual exchange level to the overall network level.

Whilst the merits of the various forms of field organisations using centralised maintenance can be debated, the ultimate choice must be based on operating cost and service performance. In Sweden a staff of 4,500 (including engineers and control centre personnel) are employed by the operations department for the maintenance of exchange, subscriber, and external plant, for 3.8 million lines. This represents 2.2 manhours per line per year. The target is 1 man per 1000 lines. In Helsinki where centralised maintenance is organised slightly differently, the figure at present is 1.5 men per 1000 lines or approximately 3 manhours per line. In Australia for the financial year 1967/68 some 22 million manhours were charged to the maintenance of exchange, subscriber and external plant for approximately 2.5 million lines. This represents 8.8 manhours per line, however the figure includes work which is not charged against maintenance activities overseas, i.e. work in exchanges associated with new services or the rearrangement of line plant or subscriber equipment.

The performance of the switching plant in Australia as viewed from service assessment result is no better than results achieved overseas although our subscribers receive better service with respect to fault clearance.

Whilst it is realised that many factors must be considered in making direct comparisons, the results achieved by overseas administrations when centralised maintenance techniques have been introduced (irrespective of the organisational structure adopted) confirm our own studies on the application of these techniques to the A.P.O. This means that centralised maintenance should be further developed and introduced within a framework suitable to our operational environment. It will be essential that the form of field organisation to be used for centralised maintenance be dimensioned in conjunction with the setting of acceptable service and performance standards which then become the objectives to be maintained.

ACKNOWLEDGMENTS

The author gratefully acknowledges the valuable assistance and friendly co-operation received from the Royal Board of Telecommunications (Televerket) Sweden and Management and Staff of the Helsinki Telephone Company, Finland during his overseas investigation into exchange maintenance practices.

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THE DESIGN OF RELAY CONTACT NETWORKS

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INTRODUCTION

Most design problems faced by the relay set designer involve sequential circuits. The relay set may be regarded as a network with inputs and outputs, and the output states are governed not only by the input states but the order in which inputs occur. Thus normal line potential received by a crossbar cord circuit (SR) relay set for an S.T.D. call results in quite different outputs on the meter wire (r-wire) before and after a reversal of line polarity is detected. The SR relay set requires a memory function to 'remember' previous inputs which may influence the output resulting from subsequent inputs.

Although considerable effort has been spent on deriving methods for the systematic design of sequential circuits, no really satisfactory method has been devised to date that can be readily used by the occasional circuit designer—particularly the designer of relay circuits. Most relay circuit designers rely on intuitive design methods. However, although the intuitive method is usually best for sequential circuits, a number of readily mastered and very usable techniques are available for the methodical synthesis of combinational circuits. In combinational circuits the output is determined by the input independent of the sequence of input variations. A sequential network with the memory elements included contains combinational contact networks and the use of a simple design technique to produce these networks can save time and guarantee a 'good' circuit.

At this stage the term 'good' circuit should be defined. We may call any circuit that produces the desired result 'good'. The degree of 'goodness' of a circuit depends on parameters determined by the designer in each particular case. The 'best' circuit may variously be defined as the one with the least number of contact springs overall, or the one with the least number of springs on a specific relay, or the one with the springs evenly distributed over all relays, or in any other way demanded by the occasion. There is no way of proving that a particular circuit is 'best' other than by trying all possible 'good' circuits produced by the various synthesising methods and comparing the results — a very time-consuming operation unless the design method can be programmed for processing by a computer. This latter course is used where a large number of devices or relay sets are to be manufactured and optimization of the circuit is important. For many applications a simple manual method that will always produce a 'good' circuit is usually sufficient to meet a designer's needs.

There are three main techniques currently available for network synthesis—methods deriving from Boolean algebra, numerical methods and a method based on a program of operations. This paper discusses the first and last of these methods.

BOOLEAN ALGEBRA

Boolean algebra is the classical tool for the synthesis of logic problems, of which contact networks are a special case. It suffers from the main defect that manipulation of functions containing large numbers of variables is difficult. Apart from the basic theorems defining the algebra, no rules can be laid down for the systematic simplification of functions and it is virtually impossible to be sure that anything near to 'best' solution has been derived after much time-consuming manipulation. However, a graphical method is available to readily simplify Boolean expressions, but this also is very difficult to apply for more than 4 to 5 variables.

Boolean algebra has been well described in many publications (Refs. 1 and 2). For completeness a brief summary of the rules of this algebra is included here.

Boolean algebra is a logical algebra which deals only with the truth or falsity of propositions, whereas common algebra deals with quantities. Variables in Boolean algebra can only assume one of two values, 0 and 1. In a contact network, 1 represents a short circuit and 0 an open circuit. A number of operations can be performed on Boolean variables, but only three are commonly used in switching network synthesis:—

(i) INVERSION—logical negation
  $\bar{a}$ is the inversion of variable a

(ii) AND—logical multiplication
  a.b is the logical product of a AND b (Note: the stop between a and b is often omitted.)

(iii) OR—logical addition
  a + b is the logical addition of a OR b

The relationship of these functions to relay contacts is shown in Fig. 1. It can be seen that if a is regarded as a make contact of relay A, a short circuit is provided if A is operated (A = 1). Similarly $\bar{a}$ is a break contact and the circuit is broken if A is operated. Series make contacts of relays A and B provide a circuit only if A AND B are both operated (ab). Parallel make contacts of A and B provide a circuit if either A OR B are operated (a + b).

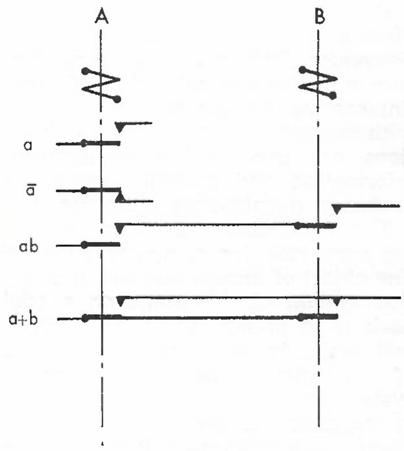

Fig. 1

Before considering further how Boolean algebra can aid in network synthesis, we will summarise the Laws, Axioms and Theorems that define this algebra, and which must be known to manipulate switching functions.

1. 0.x = 0
   0 represents an open circuit, and a network having a contact in series with an open circuit always presents an open circuit.
2. 1.x = x
   1 represents a short circuit. In this case the state of contact x above defines the network.
3. 0 + x = x
4. 1 + x = 1
5. $x\bar{x} = 0$
   A series network containing a make and break contact of the same relay always presents an open circuit regardless of the state of the relay. This axiom ignores the possibility of transient states as contacts of a relay operate in sequence (the make making before the break breaking) and this fact must be remembered by the circuit designer when using this design technique.
6. $x + \bar{x} = 1$
7. xy = yx
   The order in which series contacts occur does not influence the circuit function.
8. x + y = y + x

* Mr. Crew is Engineer Class 3, Electronic Switching, P.M.G. Laboratories. See Vol. 17, No. 1, Page 77.

9. $(x\ y)\ z = x\ (y\ z)$
10. $(x + y) + z = x + (y + z)$
11. $xxx\ .\ .\ .\ .\ x = x$
A number of make contacts of the one relay placed in series or parallel have the same effect as a single contact.
12. $x + x + x + \ldots + x = x$
13. $\overline{(x\ y)} = \bar{x} + \bar{y}$
Two break contacts in parallel produce the opposite (inverted) circuit condition to two make contacts in series.
14. $\overline{(x + y)} = \bar{x}\,\bar{y}$
Two break contacts in series produce the inversion of two make contacts in parallel.
15. $y + yx = y$
This can best be seen by examination of Fig. 2.

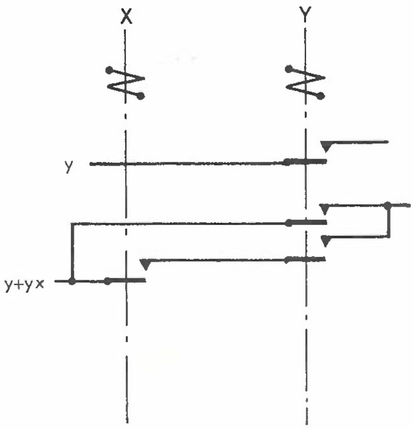

Fig. 2

16. $a(a + x) = a$
This can be seen from Fig. 3, or by the algebraic manipulation:—
$a(a + x) = aa + ax$
$= a + ax$ from 11.
$= a$ from 16.

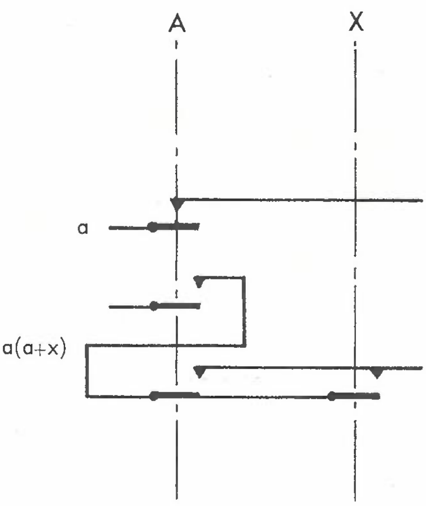

Fig. 3

17. $(x + y)z = xz + yz$
18. $xy + z = (x + z)(y + z)$
This can be seen from a circuit sketch or by the algebraic manipulation:—
$(x + z)(y + z)$
$= xy + xz + zy + zz$
$= xy + xz + yz + z$ from 11.
$= xy + xz + z$ from 15.
$= xy + z$ from 15.
19. $a + \bar{a}\,x = a + x$
which can be obtained from
$a + \bar{a}\,x = (a + ax) + \bar{a}x$ from 15.
$= aa + ax + \bar{a}x$ from 11.
$= aa + ax + \bar{a}x + 0.$ from 3.
$= aa + ax + \bar{a}\,x + a\,\bar{a}$ from 5.
$= (a + \bar{a})(a + x)$
$= 1\,(a + x)$ from 6.
$= a + x$
By similar manipulation it can be shown:—
20. $\bar{a} + ax = \bar{a} + x$
21. $a\,(\bar{a} + x) = ax$
22. $ax + \bar{a}\,y + xy = ax + \bar{a}\,y$
23. $(a + x)(\bar{a} + y)(x + y) = (a + x)(\bar{a} + y)$

Care must be taken when manipulating Boolean algebra that invalid simplifications are not used. An example, commonly employed in normal algebra but not correct for Boolean algebra, is to divide both sides of an expression by a common factor or to subtract a common term from both sides of an expression.

An example of Boolean algebra manipulated to simplify a circuit is shown in Fig. 4. This represents—

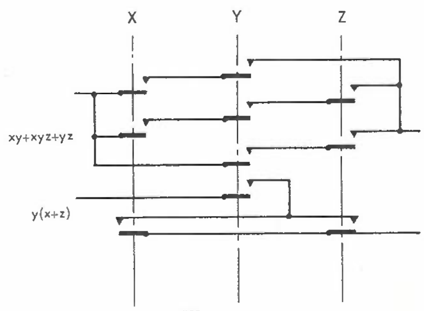

Fig. 4

$f(x) = xy + xyz + yz$
$= xy + x(yz) + (yz)$
$= xy + yz$ from 15.
$= y(x + z)$

It will be noted that this method of circuit representation depicts make and break units only. Changeover units can be introduced by combining makes and breaks at convenient circuit nodes, but this operation must be performed by inspection. A further inspection may show that some changeover units should be specified as make-before-break units to prevent momentary circuit discontinuities. It must be emphasised that no systematic methods of network synthesis account for the transit time of relay contacts which can be considerable on slow operating or releasing relays. The designer must watch for situations where such transit times can be troublesome.

THE KARNAUGH MAP

Boolean algebra provides an algebraic technique for synthesising contact networks by a process of simplifying a function obtained from a truth table, but all but the simplest functions demand a skill at Boolean manipulation not achieved without constant practice. The map method (Refs. 3 and 4) which will now be described provides a presentation of the switching function in a form which allows the necessary steps to simplification to be more readily seen.

The 2^n fundamental products (states) of n variables may be represented by an n-dimensional cube. Fig. 5 shows 2- and 3-variable figures. The 2-dimensional figure is a square and the corners represent all possible logic products of the two variables while the sides represent each variable and its inversion or prime. For example, side B is defined by corners AB and $\bar{A}$B for which B is the constant term. Note that in moving along any side from one corner to another only one variable changes state, from unprimed to primed. Similarly for the cube, the corners represent 3-variable products, the edges represent 2-variable products and the surfaces represent each variable or its prime.

To see how these figures can assist in the simplification of Boolean ex-

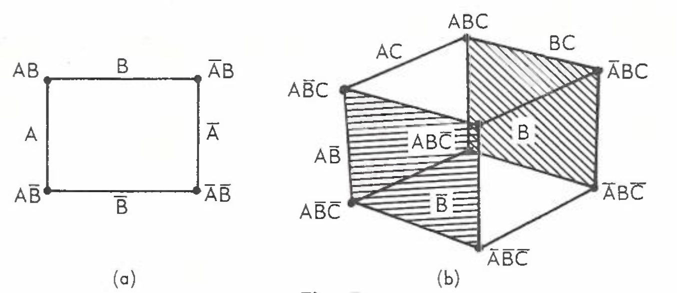

Fig. 5

pressions, consider the switching function

$$f(x) = \bar{A}\bar{B}\bar{C} + A\bar{B}C + \bar{A}\bar{B}C + \bar{A}BC + A\bar{B}\bar{C}$$

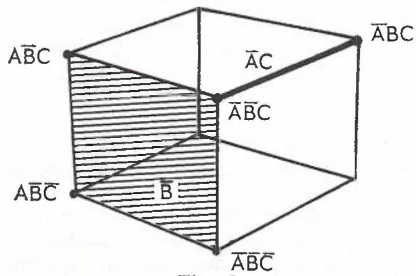

Fig. 6

This can be represented on the cube of Fig. 6 by the five designated corners. But the four corners $A\bar{B}C$, $\bar{A}\bar{B}C$, $\bar{A}\bar{B}\bar{C}$, $A\bar{B}\bar{C}$ define the surface $\bar{B}$ and vice versa. And the two corners $\bar{A}\bar{B}C$, $\bar{A}BC$ define the edge $\bar{A}C$ and vice versa. So we can define the five edges by a surface and an edge, and write $f(x) = \bar{A}C + \bar{B}$
This can be verified by normal Boolean manipulation.

Thus the cube provides a convenient method of simplifying a switching function. However, 3-dimensional figures are tedious to draw, and 4 and higher dimensional figures impossible. To retain the advantages of this graphical method of Boolean manipulation and make the figure easier to deal with, a 'map' of squares is drawn, each square representing a product of all the variables. Fig. 7 shows maps for 2, 3 and 4 variables. Note that adjacent squares only exhibit a change in one variable, and that the squares at either end of row or column are considered adjacent. Note also that each variable and its prime can be represented by a block (or row, or column) of 2^{n-1} squares, called sub-cubes, where n is the number of variables represented by the map. Fig. 8 shows how other groups of sub-cubes can represent logic products of 2 variables on a 3-variable map.

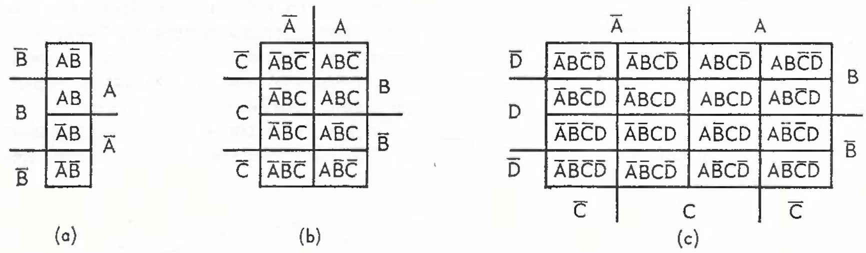

Fig. 7

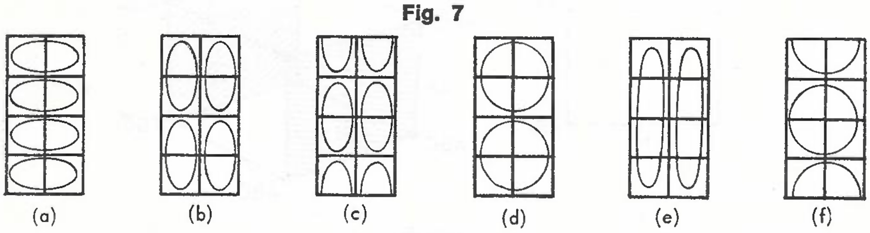

Fig. 8

If a function contains more than four variables a multiplicity of 4-variable maps are used. For example a 5-variable map consists of two 4-variable maps as shown in Fig. 9. This is about the limit of numbers of variables that can conveniently be handled by the map method.

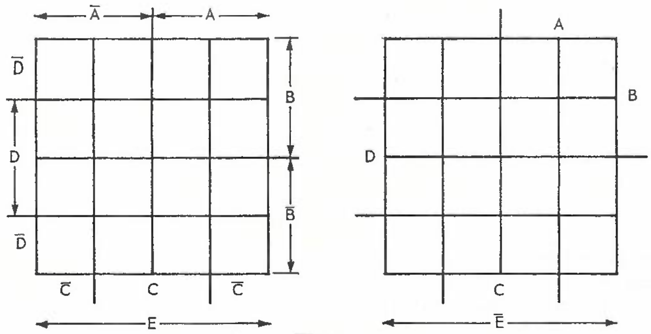

Fig. 9

The usefulness of the map method derives from its property that sub-cubes (square or rectangular groupings) represent product terms that are simpler than the fundamental products. The switching function is marked on the map as a series of 1's which represent products for which the function is true, i.e., for which the contact network is a short circuit.

Examination of the map allows grouping of the 1's into as few and as large sub-cubes as possible and gives the function in its simplest form. For example, Fig. 10 shows the simplification of two functions:—

(a) $AB + \bar{A}B = B(A + \bar{A})$
$= B$

(b) $\bar{A}\bar{B}\bar{C} + \bar{A}\bar{B}C + A\bar{B}C$
$= \bar{A}\bar{B}\bar{C} + \bar{B}C(\bar{A} + A)$
$= \bar{A}\bar{B}\bar{C} + \bar{B}C$
$= \bar{B}(\bar{A}\bar{C} + C)$
$= \bar{B}(\bar{A} + C)$
$= \bar{A}\bar{B} + \bar{B}C$

Note that a 1 may be used more than once in the formation of sub-cubes, but the sub-cubes between them must encompass all of the 1's at least once.

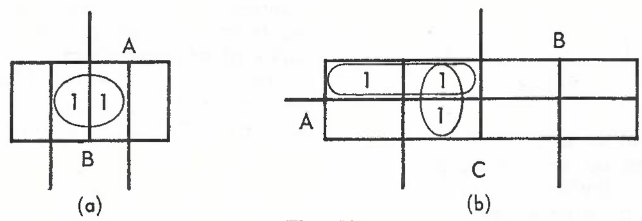

Fig. 10

If the original function includes products not containing all variables, i.e., not fundamental products, the appropriate sub-cubes have to be filled with 1's. An example is shown in Fig. 11.

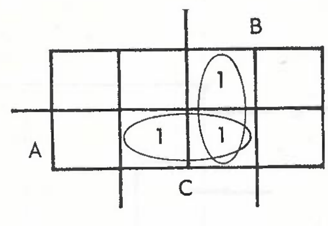

Fig. 11

If the function to be simplified by the map method is expressed as a product of sums rather than as a sum of products, individual sums can be shown on their own maps and a combined map formed by performing

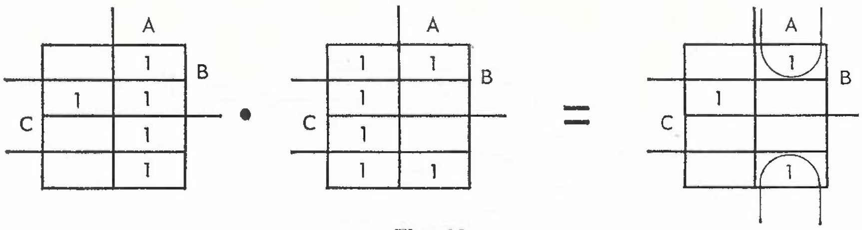

Fig. 12

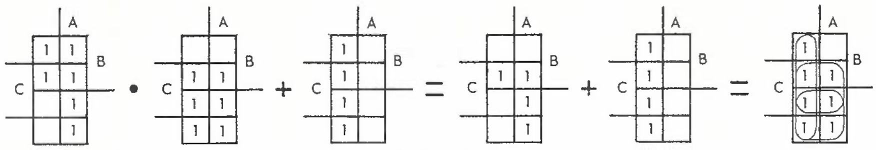

Fig. 13

the logic AND operation of each set of corresponding squares. An example is shown in Fig 12. Similarly a function in a mixed form can be simplified graphically by applying the logic operations to corresponding squares as shown in Fig. 13.

Quite often the circuit condition under some configurations of the variables is unimportant or the configuration does not occur in practice. The circuit designer may make use of these 'don't care' conditions by assigning to them values **(0 or 1)** for the purpose of simplifying the final circuit. Consider the case shown in Fig. 14 where the basic function is $f(x) = \bar{A}\,C + ABCD$.

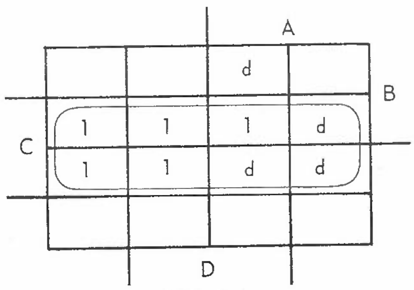

Fig. 14

The fundamental products $AB\bar{C}D$, $ABC\bar{D}$, $A\bar{B}CD$ and $A\bar{B}C\bar{D}$ are 'don't care' conditions, and these are marked on the map with a 'd'. In defining sub-cubes the d's may be classed as 1's or 0's as desired. In the example the fundamental product $AB\bar{C}D$ has been assigned an 0 value and the remainder have been assigned 1 values.

The Karnaugh map provides a convenient method of manipulating switching functions to produce a simplified circuit, but the number of variables that can be handled is limited and although multiple output circuits can be produced by this method the technique for so doing requires considerable experience with maps on the part of the designer.

Example of Application

To demonstrate the use of Boolean algebra and the map method, an example of a contact network is presented. This is the transmission bridge logic of relay set FUR-T5F-H which controls signalling over pulse code modulated carrier systems. Four relays are involved—F2, F3, E1 and E2. F2 is the relay set holding relay. F3 operates at answer and holds to F2. It releases slowly after F2. E1 and E2 are PCM carrier E-lead relays which represent the state of the two signalling wires (Ref. 7) (See Table 1).

TABLE 1

E1	E2	Condition
0	0	blocking or force release
0	1	answer
1	0	idle
1	1	seize acknowledge, meter.

The first task is to construct a truth table (Ref. 2) for the network. In this case six networks are required, two to apply negative potential to the windings of the battery feed relay (F1), two to apply positive potential to the windings of relay F1, and two to apply negative potential to the a and b wires. These last networks are required to charge the line to normal polarity on release of the relay set, to prevent flicking of relay F1.

The circuit is shown in Fig. 15. Networks 1 and 2, 3 and 4, and 5 and 6 are symmetrical so we need only design the three networks 1, 2 and 3. The truth table is given in Table 2. (The last two columns of Table 2 will be explained later.)

The relays are redesignated A, B, C and D for ease of writing Boolean expressions.

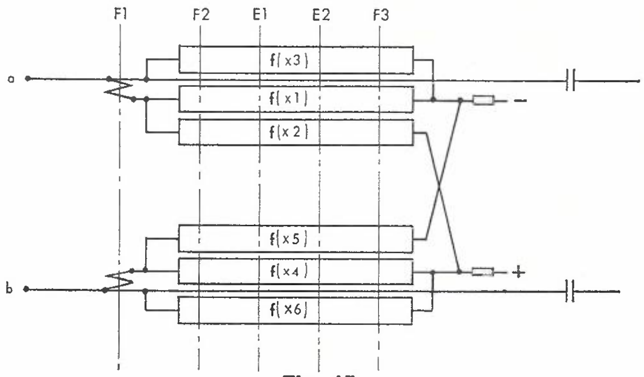

Fig. 15

TABLE 2

State No.	A (F3)	B (E1)	C(E2)	D(F2)	$f(x_1)$	$f(x_2)$	$f(x_3)$	I_1	I_2
0	0	0	0	0	1	0	0	K	Ø
1	0	0	0	1	1	0	0	K	Ø
2	0	0	1	0	1	0	0	K	Ø
3	0	0	1	1	1	0	0	K	Ø
4	0	1	0	0	1	0	0	K	Ø
5	0	1	0	1	1	0	0	K	Ø
6	0	1	1	0	1	0	0	K	Ø
7	0	1	1	1	1	0	0	K	Ø
8	1	0	0	0	0	0	1	Ø	K
9	1	0	0	1	0	0	0	Ø	Ø
10	1	0	1	0	0	0	1	Ø	K
11	1	0	1	1	0	0	0	Ø	Ø
12	1	1	0	0	0	0	1	Ø	K
13	1	1	0	1	0	1	0	L	Ø
14	1	1	1	0	1	0	1	K	K
15	1	1	1	1	1	0	0	K	Ø

The allocation of relay weights, or their position on the truth table, is optional and can influence the ease of function manipulation and the final circuit. The configuration shown was selected after a number of trials of alternative configurations.

Considerable care must be taken in the allocation of network states to the truth table, particularly when the network configuration is thought to be non-occurring, as spurious configurations may occur. In this author's experience it is rarely that a 'don't care' condition can be placed on a truth table.

A few comments on the state allocations in Table 2 are appropriate. Prior to answer — relay A(F3) not operated — normal polarity is applied to the battery feed relay F1. After answer some conditions represent the answer signal — reversed polarity — and others represent meter pulses — normal polarity. Still other conditions represent force release, or open circuit. The line charging potential is only applied after answer and on release of the connection — A(F3) operated and D(F2) released.

The three switching functions may be written down from the truth table as follows:

$$\begin{aligned} f(x_1) &= \bar{a}\bar{b}\bar{c}\bar{d} + \bar{a}\bar{b}\bar{c}d + \bar{a}\bar{b}c\bar{d} \\ &\quad + \bar{a}\bar{b}cd + \bar{a}b\bar{c}\bar{d} + \bar{a}b\bar{c}d \\ &\quad + \bar{a}bc\bar{d} + \bar{a}bcd + abc\bar{d} \\ &\quad + abcd \\ &= \bar{a}\,[\bar{b}\bar{c}(\bar{d} + d) + \bar{b}c(\bar{d} + d) \\ &\quad + b\bar{c}(\bar{d} + d) \\ &\quad + bc(\bar{d} + d)] \\ &\quad + abc(\bar{d} + d) \\ &= \bar{a}\,[\,\bar{b}(\bar{c} + c) + b(\bar{c} + c)] \\ &\quad + abc \\ &= \bar{a} + abc \ldots \qquad (1) \\ &= \bar{a} + bc \ldots \qquad (2) \end{aligned}$$

The equation (1) could have been obtained directly by examination of the truth table. The long-hand method has been shown to demonstate the possible complexity of switching functions and their subsequent simplification.

$$\begin{aligned} f(x_2) &= ab\bar{c}d \\ f(x_3) &= a\bar{b}\bar{c}\bar{d} + a\bar{b}c\bar{d} + ab\bar{c}\bar{d} \\ &\quad + abc\bar{d} \\ &= a\bar{d} \end{aligned}$$

The circuit derived from these functions is shown in Fig 16. Fig. 17 shows the same circuit derived using equation (1) for $f(x_1)$, which by inspection shows a possible combination of $f(x_1)$ and $f(x_2)$ contacts, and uses of changeover contacts, as given in Fig. 18. This demonstrates that the simplest expression of a switching function may not always be the best one to employ.

The circuit shown is for one side of the transmission bridge only. The other side is symmetrical, although connecting to the reversed polarities, and a combination of the two sides can be made by inspection using changeover contacts.

The role of the Karnaugh map in this problem is to simplify the original switching function derived from the truth table. In this example a simplified switching function can be derived immediately by inspection of the truth table but this is not generally the case. The map for simplifying $f(x_1)$ is shown in Fig. 19.

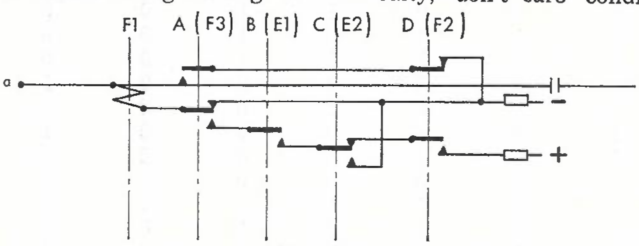

Fig. 16

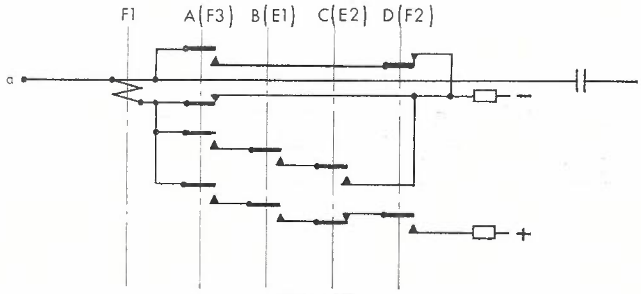

Fig. 17

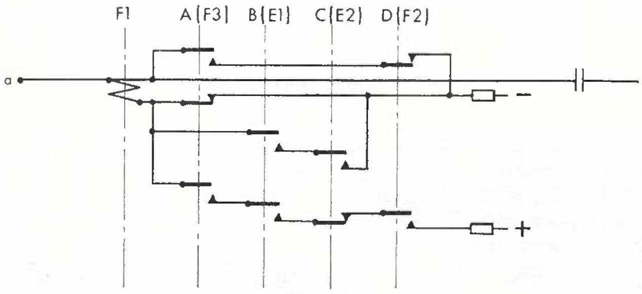

Fig. 18

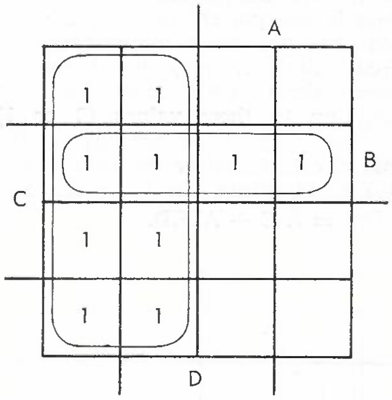

Fig. 19

THE BINARY DECISION PROGRAM

An excellent technique for the methodical synthesis of contact networks exists in the binary decision program (Refs. 5 and 6). Large numbers of variables can be handled without difficulty, 'don't care' conditions may be utilised to optimise the resultant circuit, and multiple input and output networks can readily be produced.

The binary decision program is composed of a series of two-address conditional transfer instructions of the form

Tx; A, B

This represents the instruction: 'examine variable x; if x is 0, go to address A, if x is 1 go to address B'. If this instruction itself is situated in address location C the representative circuit may be drawn as in Fig. 20. The binary decision instruction represents a changeover contact unit.

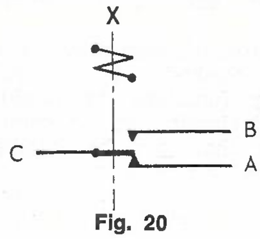

Fig. 20

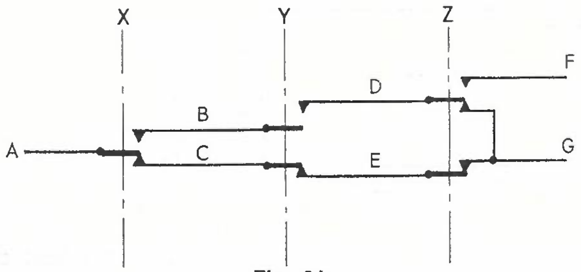

Fig. 21

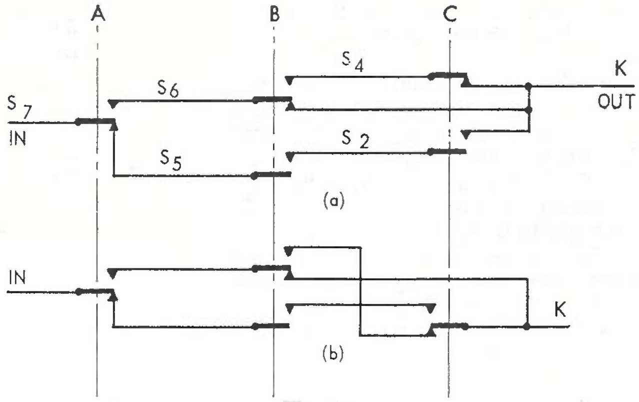

Fig. 22

A contact network may be represented by a program of binary decision instructions. This is illustrated in Fig. 21. The circuit connections are allocated addresses A, B, C, etc. A is the address of the input to the network and F and G are the two output addresses. Where the output is zero (open circuit network) this is represented in the program by address Ø and an instruction containing Ø as one of the addresses represents a make or a break contact unit, thus:—

Ty; Ø, D is a make
Ty; E, Ø is a break

The complete program representing the network of Fig. 21 is:—

A. Tx; C, B
B. Ty; Ø, D
C. Ty; E, Ø
D. Tz; G, F
E. Tz; Ø, G

Obviously if a program of binary decision instructions could be derived from a truth table representing a circuit specification, the circuit could itself readily be obtained from the program. A method of doing this will now be demonstrated, and it will be seen that a quite efficient circuit can be produced. Consider the truth table of Table 3.

TABLE 3

State No.	A	B	C	f(A,B,C)	Output
0	0	0	0	0	Ø
1	0	0	1	0	Ø
2	0	1	0	0	Ø
3	0	1	1	1	K
4	1	0	0	1	K
5	1	0	1	1	K
6	1	1	0	1	K
7	1	1	1	0	Ø

The switching function f(A,B,C) is given two forms, the normal form of 1's and 0's, and with the zero output replaced by Ø and the 1 output replaced by K, which will be the output address.

The output for states 0 and 1 depends only on the state of variable C as A and B are constant (both 0) for these two states. We may therefore specify the corresponding outputs by an instruction located in address S_1

S_1 Tc; Ø, Ø

However this is not a binary 'decision' because no matter what condition C adopts the resulting output is Ø. We may thus write that address S_1 is in fact address Ø:

S_1 Ø

Now consider states 2 and 3. Again the output is determined by C only and we may write in address S_2 the instruction

S_2 Tc; Ø, K

For states 4 and 5 we have

S_3 Tc; K, K

which can be replaced by address K. For states 6 and 7 we have

S_4 Tc; K, Ø

It is now necessary to consider the effect of variable B on the output. For states 0 and 1 B is 0, and for states 2 and 3 B is 1. For all these states A is constant so the output can be represented by the instruction in address S_5

S_5 Tb; S_1, S_2

that is, when B = 0 the output is determined by the condition of C in states 0 and 1, and when B = 1 the output depends on the condition of C in states 2 and 3. These latter conditions are represented by the instructions in locations S_1 and S_2 already obtained. It is also noted that S_1 is in fact location Ø so we can write

S_5 Tb; Ø, S_2

Similarly for states 4 to 7 we can write

S_6 Tb; S_3, S_4
or S_6 Tb; K, S_4

Finally we must consider the effect of A varying from 0 to 1 and following similar reasoning to that above we may write

S_7 Ta; S_5, S_6

S_7 is in fact the input to the circuit. We now have a program of instructions as follows:—

S_7 Ta; S_5, S_6
S_6 Tb; K, S_4
S_5 Tb; Ø, S_2
S_4 Tc; K, Ø
S_2 Tc; Ø, K

The corresponding circuit is given in Fig. 22(a). By inspection it can be seen that the make and break unit on C can be replaced by a transfer unit as in Fig. 22(b). This fact can also be seen directly from examination of instructions S_4 and S_2 of the program.

The example given in an earlier section to illustrate the use of Boolean algebra in designing a circuit for relay set FUR-T5F-H is here repeated using the binary decision program technique. In this case it is not necessary to design three individual networks. The last two columns of the truth table in Table 2 represent two inputs I_1 and I_2 corresponding to the two terminals of the battery feed relay winding, Fig 15, and with three outlets, Ø, K (negative battery or normal polarity) and L (positive battery, or reversal). The following program is obtained:

S_{111} K
S_{112} K
S_{113} K
S_{114} K
S_{115} Ø
S_{116} Ø
S_{117} Td; Ø, L
S_{118} K
S_{121} K
S_{122} K
S_{123} Ø
S_{124} Tc; S_{117}, K
S_{131} K
S_{132} Tb; Ø, S_{124}
I_1 Ta; K, S_{132}
S_{211} Ø
S_{212} Ø
S_{213} Ø
S_{214} Ø
S_{215} Td; K, Ø
S_{216} S_{215}
S_{217} S_{215}
S_{218} S_{215}
S_{221} Ø
S_{222} Ø
S_{223} S_{215}
S_{224} S_{215}
S_{231} Ø
S_{232} S_{215}
I_2 Ta; S_{215}

This gives the circuit of Fig. 18, which is the same as that obtained previously. The binary decision program has eliminated the visual inspection required to combine the three networks and to combine make and break contacts as changeover units.

As with Boolean algebra, the way the truth table is presented affects the final circuit. By changing the weighting of the variables (that is, their position in the truth table) the number of contacts on a particular relay may change and the overall number of contacts may also vary. Generally the most significant variable (left hand side of the truth table) has one changeover for each input, and the number of contact units increases as we move to the right, towards the outputs. Quite often the number of contacts decreases for the least significant variable (right hand side of the truth table) due to mergers in the network, but this depends on the circuit specification.

It is not necessary to draw the circuit from a program to check its suitability for a specific application. The number of contact units on each relay can be obtained directly from the program, following the rules:—

(a) Tx; A, B represents a transfer unit on relay X
(b) Tx; Ø, B represents a make unit on relay X
(c) Tx; A, Ø represents a break unit on relay X
(d) Tx; A, Ø and Tx, Ø, A represent a break and a make on X which may be combined in a transfer unit.

It must be remembered that, as for any circuit synthesised by methodical processes, no account is taken of the operate and release time of relays, nor of the transit time of contacts. It is always necessary to check a circuit to see if transfer units should be changeover or make-before-break units.

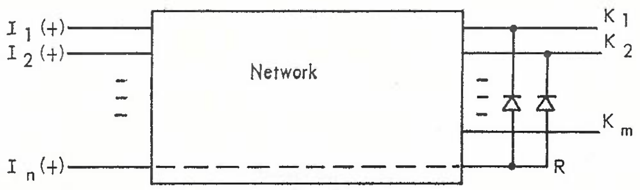

Fig. 23

A further point remains to be made concerning the binary decision program. By its very nature it is not possible to specify a connection between an input and more than one output for a specific network state, although an output may be connected to a number of inputs in a particular state. This is the essential condition for networks having disjunctive outputs and conjunctive inputs. If it is necessary to connect an input to a number of outputs in one network configuration this may be achieved by specifying a 'false' output R for that configuration. It is then necessary to connect R to the required outputs by some suitable means which retains disjunctivity between the outputs concerned. Fig. 23 shows one example of how this may be achieved. Input I_n is connected to both outputs K_1 and K_2 via 'output' R for a certain network configuration.

CONCLUSION

Two basic methods of combinational network synthesis have been described. The choice of method to be used depends on the application. The Karnaugh map is usually best for single input and output networks having four or less variables. For more complex networks the binary decision program is suitable. Although it does not always produce the 'best' circuit, as it does not allow the formation of direct leads, networks synthesised by this method will only be marginally 'worse' than the best circuit.

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SYSTEM AFM 402: THE A.P.O. FOUR WIRE CORD TYPE MANUAL ASSISTANCE CENTRE: PART 1

*F. M. SCOTT**

INTRODUCTION

Trunk traffic has increased rapidly since the introduction of subscriber trunk dialling (S.T.D.) and continues to grow as more use is made of the service and as more subscribers are given access to the S.T.D. equipment. Nevertheless, there is still a demand for manual assistance from subscribers located in non-S.T.D. exchanges, from subscribers unfamiliar with or unwilling to use the S.T.D. facilities, by coin telephone users, and by hotel and business managements who require their trunk calls individually priced for accounting purposes. Despite the relief given by the introduction of extended local service areas (E.L.S.A.) and S.T.D. the number of manually assisted trunk calls continues to rise.

At the time when the introduction of a new automatic trunk switching system—A.R.M. type crossbar—was being planned, the opportunity was taken to redesign, improve and modernise the associated manual assistance services. Two types of manual assistance switchboards were envisaged—a cordless position for use at the larger centres, and a cord type position for the smaller country exchanges. Specification No. 994 (Ref. 1) was produced by the A.P.O. listing the facilities required on the two types of switchboards. Earlier articles in this Journal by Wright, Elliott and Chamberlain (Refs. 2, 3 and 4), dealing with trunk switching developments and facility requirements for the cord and cordless switchboards, provide a suitable introduction to this article.

The purpose of this paper is to give a general description of the Cord Type Switchboard electrical design explaining how the facility requirements are translated into circuit elements and highlighting improvements to previous trunk switchboards.

This article is divided into two parts. Part one in this issue deals with the new system generally and with the manual assistance position in detail. Part two will appear in a later issue and will cover the line relay sets and miscellaneous service positions.

EXISTING MANUAL SWITCHBOARDS

Manual assistance on trunk calls is currently provided by three types of operating positions:

(i) Siemens cordless trunk positions associated with motor uniselector type semi-automatic trunk exchanges. These are installed at Canberra, Sydney (Dalley), Melbourne, Adelaide, Lismore, Mt. Gambier and Bunbury.

(ii) Sleeve control cord type trunk positions associated with automatic or C.B. multiple local exchanges and 2VF signalling and transit selector switching equipment. These are installed at Perth and many of the larger country exchanges.

(iii) Magneto, or modified magneto with lamp signalling, positions. These are installed at Brisbane, Hobart, and many of the provincial centres.

In Types (i) and (ii) provision is made for calls to be switched on a four wire tail-eating connection. On the cord type switchboard (ii) a four wire connection is established on through cord circuits but requires an extra pair of cords (net cords) to be plugged up to complete the hybrid network circuit. As the use of the net cords is not essential to establish a connection they are frequently not used. This results in an additional transmission loss of approximately 6dB on a through switched call. Even on automatically switched calls via the trunk motor uniselectors four wire switching is not always employed because of the difficulty in maintaining correct poling of the hybrid line and hybrid network pairs. In these cases the 2VF line relay sets are strapped for two wire switching.

Interconnection on magneto type switchboards is always two wire switching.

THE NEW CORD TYPE MANUAL ASSISTANCE EXCHANGE

The equipment designed for this exchange comprises the following:

(i) A cord type operating position for trunk assistance traffic.
(ii) A cordless type operating position for special services traffic.
(iii) A monitor's turret.
(iv) A supervisor's turret.
(v) Relay set equipment directly associated with the operating positions, e.g. connect, position and telephone circuits, registers, etc.
(vi) Line relay sets providing terminations for incoming and outgoing lines connected to the exchange.
(vii) A marker controlled crossbar switching stage associated with the special services positions.

All of this apparatus is covered by the A.P.O. System designation AFM 402. This code has the following meaning:

A — Exchange
F — Manual Cord type
M — Handling mainly trunk network traffic
4 — Using four wire switching
02 — Second design in this series.

(Note: System designation AFM 401 applies to an earlier cord type four wire switchboard design based on an adaptation of the sleeve control type switchboard. The initial installation of this system was at Parkes, N.S.W.)

System AFM 402 is an entirely new approach to the manual switchboard problem and is not based on earlier A.P.O. trunk switchboard designs.

The initial design of the trunk assistance switchboard position for System AFM 402 used S.T.C. type push button keys for control functions on the keyshelf and is coded Type S. A later version uses ERGA type keys and is coded Type E. The other operating positions are designed for the use of ERGA keys only.

DESIGN ORGANISATION

The design and development of System AFM 402 was carried out by the A.P.O. using its own staff and resources. A project design group comprising an Engineer, Senior Technical Officer, Technical Officers and Technical Assistants was formed to undertake all aspects of the electrical design. This included circuit design, relay dimensioning, prototype building, laboratory testing and final documentation. Although attached to headquarters, the project group was based in Queensland and made use of drafting and laboratory services of that State.

The mechanical design of the operating position carcases and turrets was handled separately by the Headquarters Mechanical and Electrical Services Subsection. (Ref. 5.)

GENERAL DESCRIPTION OF SYSTEM

Trunk Assistance Operating Position

The specification for the trunk assistance (T.A.) operating position contains the following essential features:

(a) The four wire speech connection must be completed using only one plug.
(b) Push button type keys are preferred.

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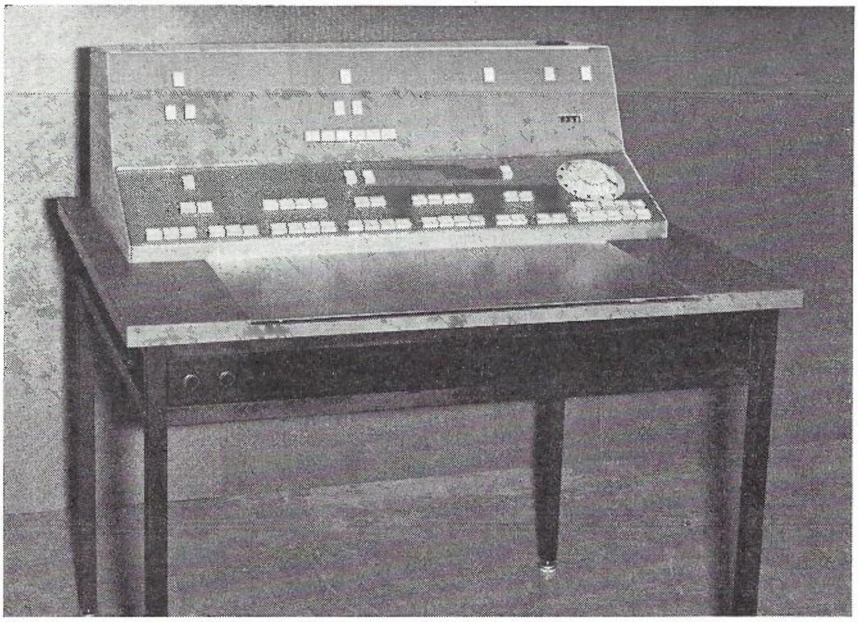

Fig. 1 — Special Services Position.

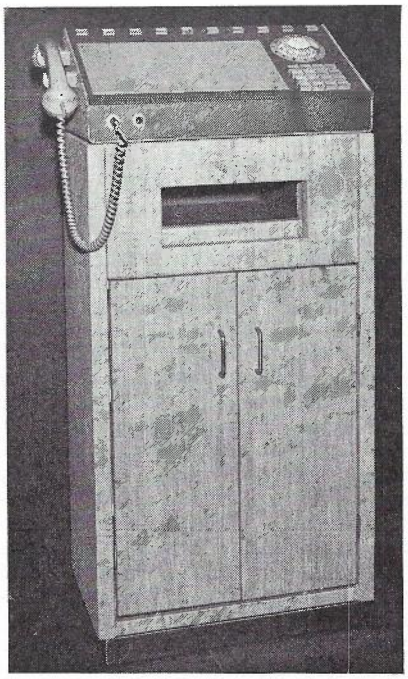

Fig. 2 — Monitors Turret and Pedestal.

(c) Key sender dialling to be used.
(d) The height of the line multiple not to exceed 15in above the keyshelf to allow the telephonist a clear view across the top of the operating position.
(e) No relay equipment to be mounted in the position.
(f) Clear leg room to extend under the keyshelf to the rear of the position.
(g) The overall appearance of the position to be modernised and made aesthetically pleasing.

Fig. 1 on page 55 shows a T.A. position equipped with a Type S keyshelf. Each Type S position is 31in wide, 45in high and 37in deep. Unit type construction is used so that each position is entirely self-contained. The frame of the position is made from mild steel panels covered with a vinyl fabric. The working surface of the keyshelf is covered with ABS material (Acrylonitrile Butadiene Styrene, Resin).

A suite of Type S positions is built-up by placing the required number of unit positions side-by-side. Each position contains three panels of line multiple with provision for 100 lines in each panel. The line multiple may be made-up to repeat the appearance of each line every 3, 4 or 5 panels according to the size of the installation. Two end sections, one 2 panels wide and the other 3 panels wide, are available for use as cable entry, storage and control sections. Two relays are fitted in the keyshelf of each operating position to provide coupling between adjacent positions, but all other relays are mounted externally to the position. Cable entry may be provided through the legs of each position. At the time of writing, the design of the Type E position was not finalised.

Special Services Operating Position

Cordless operation of the special services (S.S.) position is required. This position handles trunk enquiry, directory information, complaints and interception traffic. It consists of a mild steel turret covered with ABS and vinyl fabric, mounted on a desk of special construction. ERGA type push button keys are used and a standard telephone dial is fitted. (See Fig. 1.)

Monitor's Turret

This is small mild steel turret and mounts on a mild steel pedestal which incorporates storage facilities for stationery. (Fig. 2 refers.)

Supervisor's Turret

The supervisor's turret is of similar dimensions and contruction to the S.S. position turret and is intended for table mounting. It provides a large array of keys, lamps and meters to control and supervise the functioning of the exchange. (See Fig. 3.)

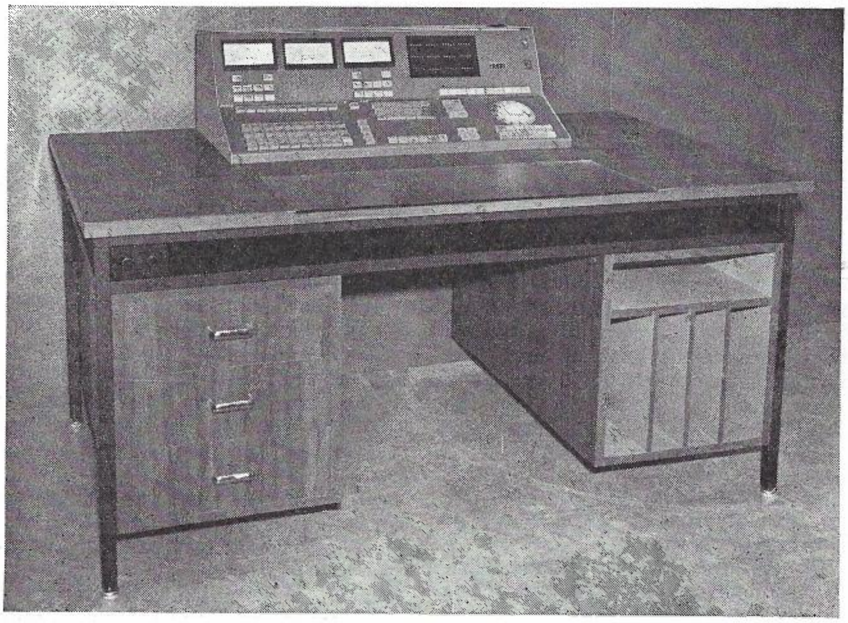

Fig. 3 — Supervisor's Turret and Table.

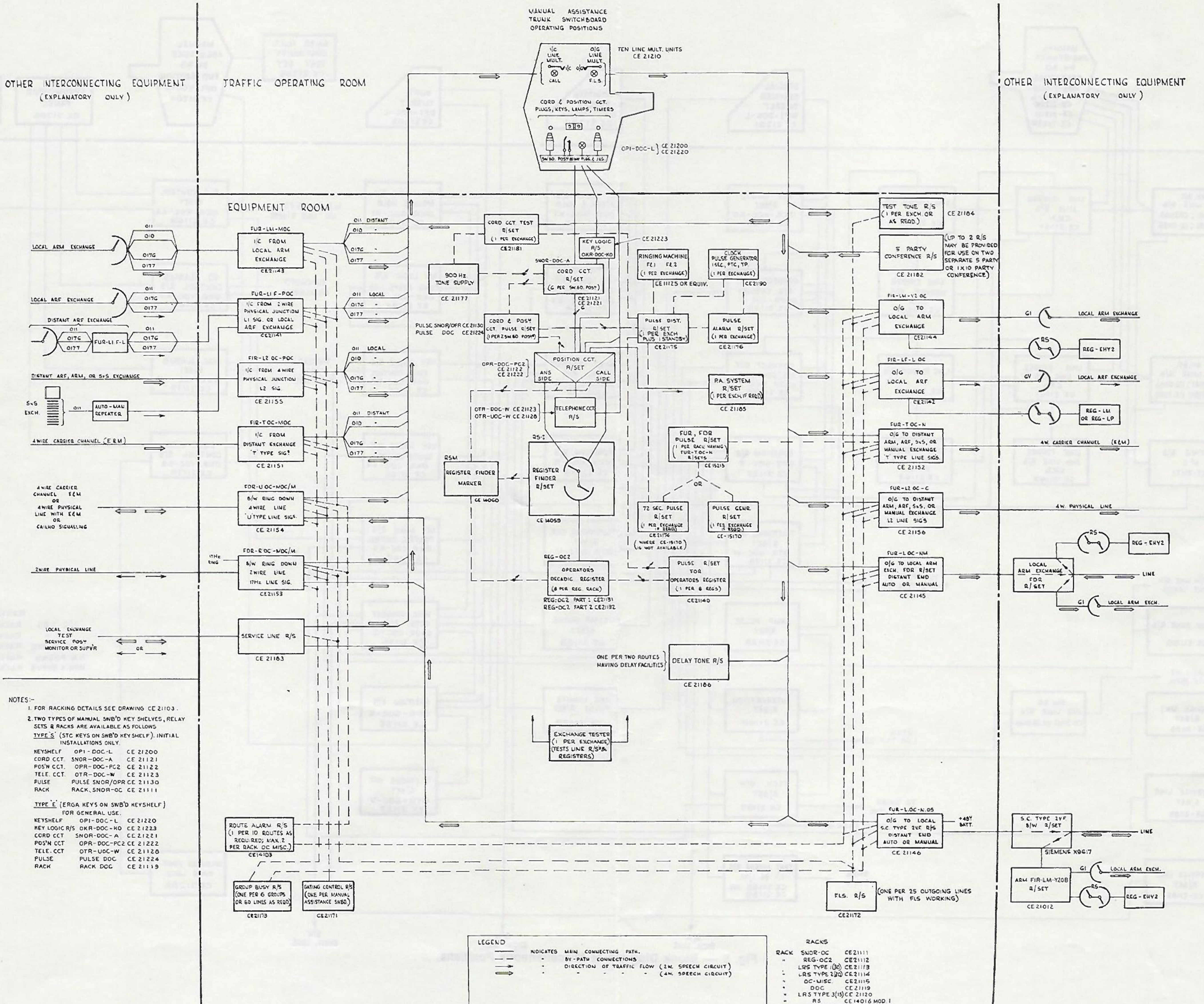

Fig. 4 — Block Diagram of Trunk Assistance Positions.

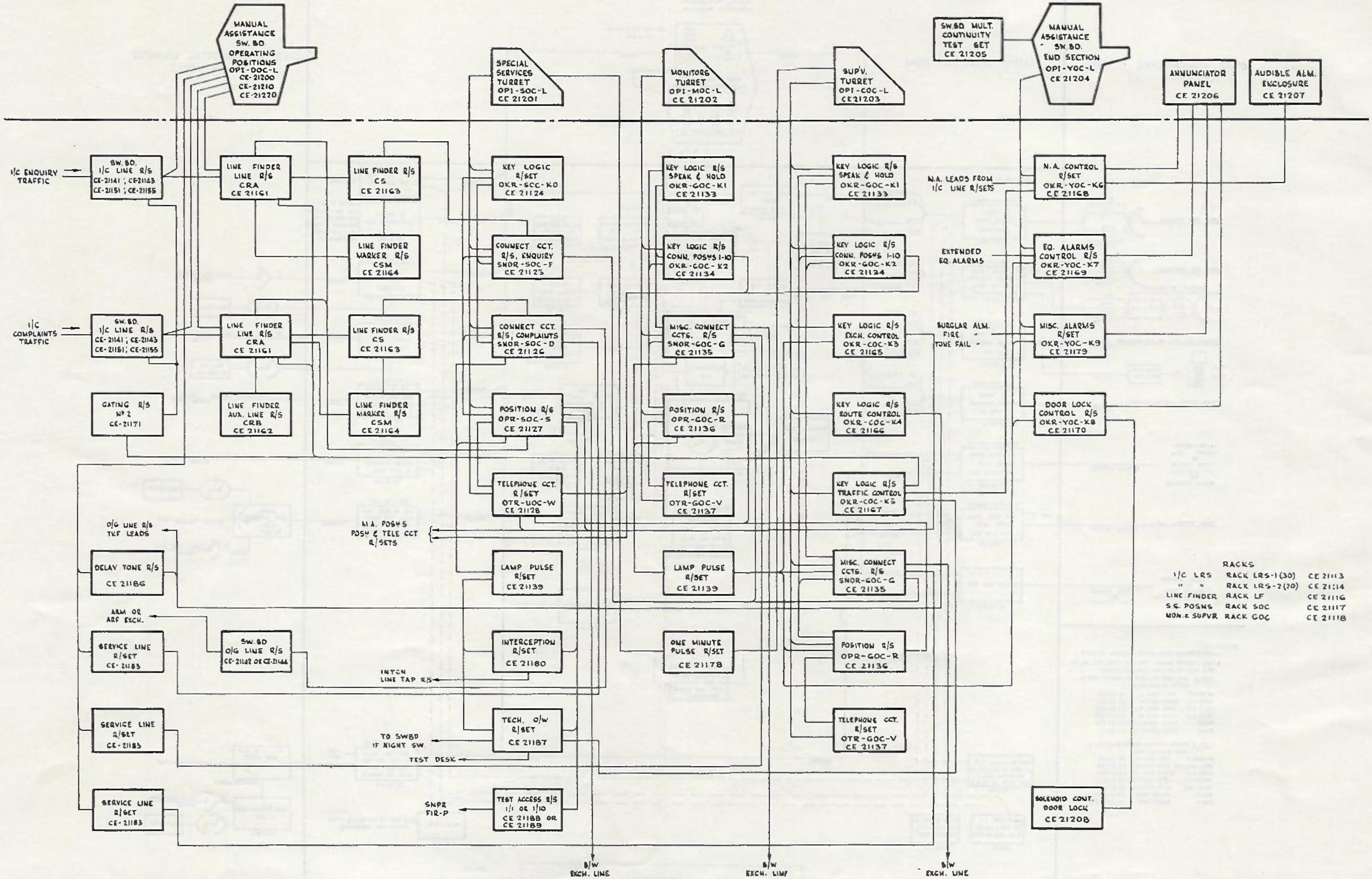

Fig. 5 — Block Diagram of Miscellaneous Positions.

Equipment

A.P.O. R series relays (L.M.E. RAF, RAB and RAH type) are used throughout. These are mounted in BCH type relay sets mounted on BDH type exchange racks. The AFM 402 system includes the following array of equipment:

Relay set types	69
Rack types	11
Key panel types	7
Printed Circuit Board types	9

Each item is separately coded and has an individual drawing number. In addition, drawings are available for mechanical details, components, layouts, cabling, terminations and miscellaneous aspects.

Design Limits

As the relay equipment is mounted remotely from the operating positions, the resistance of the interconnecting cabling must be included in calculations of operating limits. The system is designed to operate at a nominal 50 volts with limits of 42 and 56 volts. The full factor of safety on relays is provided at 45 volts. The maximum allowable resistance in the cabling between relay sets and operating positions is 50 ohms per single wire.

Block Diagrams

The fundamental difference between the trunking of cord and cordless type positions lies in the different switching media used. The cord type position uses plugs and jacks on the switchboard as the switching mechanism while the cordless position controls the operation of a distant selector to perform the interconnections. In the new cordless manual assistance switchboard System AFG 201 these selectors are crossbar switches which are part of the ARM exchange. The cord type switchboard, in contrast, is independent of the local switching systems and therefore can be installed at centres either not requiring an ARM exchange, or in advance of a proposed ARM installation. The external trunking of a cord type exchange is very flexible as suitable interface relay sets can be designed to match any foreign signalling system. The provision of direct routes is thus simple and economical.

Fig. 4 shows a block diagram of the apparatus associated with trunk assistance positions. The group of relay sets immediately below the operating position in the centre of the drawing are those directly associated with the individual positions. Each position has six cord circuits, a position circuit and a telephone circuit. These are designated SNOR, OPR and OTR respectively. The 'E' type position has a key logic relay set (OKR) in addition. Relay sets for two operating positions, including a common pulse relay set, mount on one rack (SNOR-OC for Type S, and DOC for Type E). Each position has access to two registers (REG-OC2) one through the answer side of the cord circuits and one through the call side. Coupling between OPR and REG is via a register finder RS. Pulse and tone generating and distributing equipment, and test apparatus make up the remainder of this group. Relatively heavy cabling is involved between the keyshelf (OKI) and the equipment racks (approximately 240 wires per position) so it is desirable to minimise the distance between switchboard and equipment.

The switchboard line multiple is cross-connected by jumpers on an I.D.F. to appropriate incoming or outgoing line relay sets shown in the block diagram as two columns one on either side of the positional equipment. The line relay sets shown are those designed to date, but further types may be added as different signalling schemes and interworking conditions are evolved.

All speech paths to and from the operator and via the switchboard cord circuits are directional four wire. If two wire lines are connected, the line relay sets must make provision for a 2 wire/4 wire conversion. A four stage gating system is provided on incoming traffic to equalise waiting times and to prevent the unfortunate call condition where a particular caller in a busy period may be repeatedly by-passed by an operator and thus wait an excessively long time to be answered. Free line signalling (F.L.S.) is provided on outgoing lines.

Fig. 5 shows a block diagram of the miscellaneous positions provided at an exchange using system AFM 402.

The special services position has two connect circuits for terminating traffic, i.e. enquiries, information and time, and three connect circuits giving through switching facilities for complaints traffic. The incoming line circuits are of the same type as those employed for the T.A. positions. These are trunked to the line finder switch CS via an auxiliary line circuit CRA. An appearance of these lines is provided on the T.A. switchboard but the call lamps are controlled so that they do not glow when the S.S. positions are staffed. In slack traffic periods, e.g. at night, the S.S. positions will be unstaffed and all enquiry and complaints calls will be answered at the T.A. positions. An additional auxiliary line circuit CRB is associated with relay set CRA on incoming complaints lines. The line finder CS is controlled by the marker CSM. Up to three CS relay sets may be associated with each CSM. CS contains a crossbar switch having ten verticals and 12 horizontals. Two horizontals are used to provide HA/HB switching to increase the number of inlets to 20. Each vertical is associated with a particular connect circuit on the S.S. positions. Thus each CS can serve two S.S. positions. The line finder rack, rack-LF accommodates the relay sets associated with two marker groups.

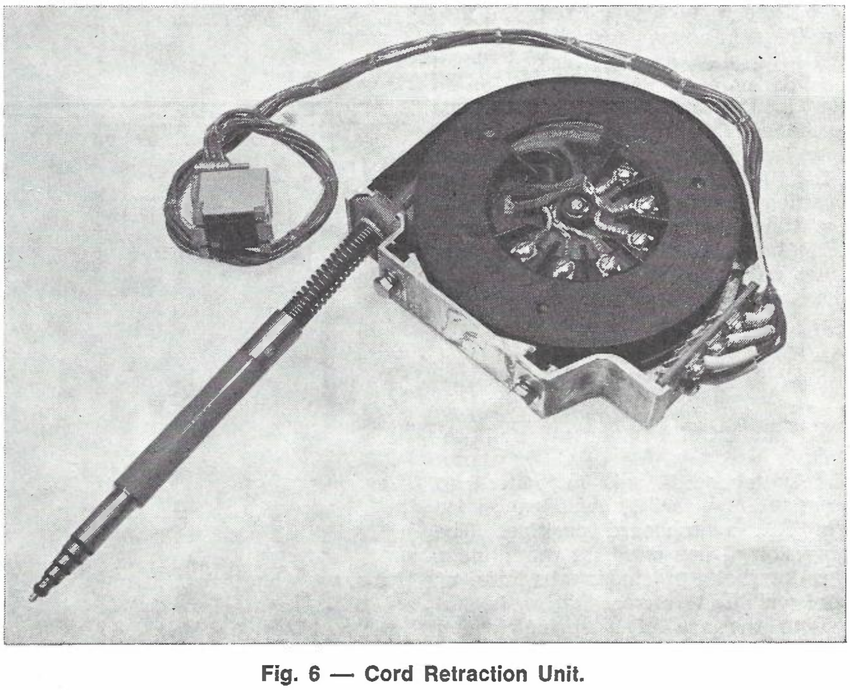

Fig. 6 — Cord Retraction Unit.

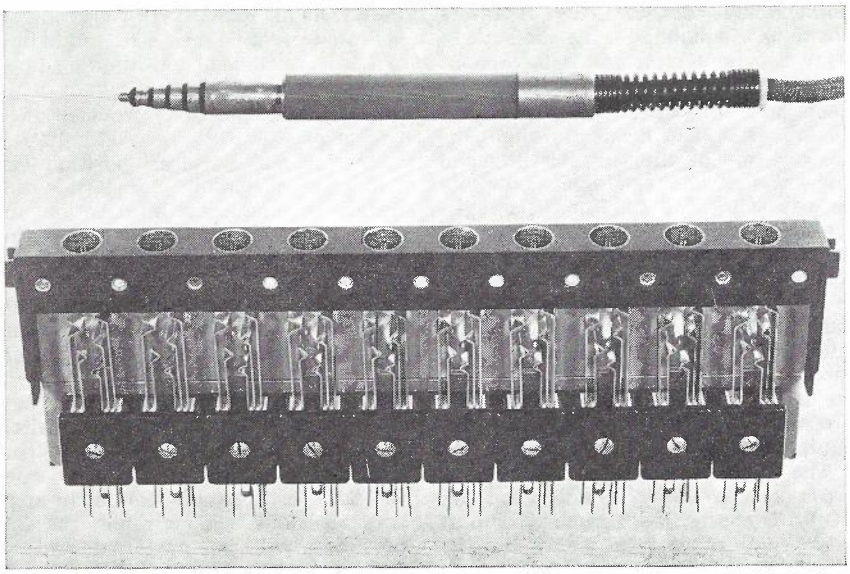

Fig. 7 — Six-pole Plug and Jack Strip.

The positional relay sets associated with the S.S. position are the OKR, SNOR-F, SNOR-D, OPR and OTR. These mount on Rack SOC which accommodates relay sets for two S.S. positions.

The lamp pulse, interception, technician's order wire, and test access relay sets shown in line below the S.S. position turret on the block diagram also mount on Rack SOC as they are associated with the S.S. positions.

A monitor's turret requires the following positional relay sets: OKR-K1, OKR-K2, SNOR-G, OPR and OTR. The same relay sets are required also for the supervisor's turret except that OKR-K2 may not be needed when one or more monitors in addition to the supervisor is stationed at the exchange. The functions of these relay sets will be dealt with later. Rack GOC provides mounting for the positional relay sets associated with the supervisor and up to four monitors. In addition the rack accommodates control relay sets actuated from the supervisor's turret and switchboard end panel.

COMPONENTS

A number of components not previously used by the A.P.O. on standard switchboards was introduced to meet the new facility specification for the T.A. switchboard position. The provision of increased leg room under the keyshelf precludes the use of cord weights to retract idle cords, and led to the use of a spring loaded drum which could be contained within the keyshelf.

Fig. 6 shows the cord retraction unit comprising the retraction wheel, the switching cord and plug, and a second cord and plug used to connect the unit within the keyshelf. To replace a cord, the whole unit is removed from the keyshelf. The keyshelf plug is first disengaged from the jack, then a screw loosened to release the unit. The plug is a six pole device consisting of tip, sleeve and 4 intermediate rings. A six way cord connects the plug to screw terminals on the cord reel.

The associated line multiple jack has six connecting springs. Fig. 7 shows a 6 pole plug and jackstrip. Ten jacks are combined in each jackstrip which is 189mm long. A ten way lamp strip is associated with each jack strip. One 10-way jackstrip and one 10-way lamp strip are combined and wired to an 80 point plug to form a ten line multiple unit. These units are fitted to the line multiple panels and the 80 point plug is engaged in an 80 point jack placed over the cable trough in the rear of the position. The actual multiple wiring is therefore the inter-cabling of the 80 point jacks placed across the top of the cable trough. This wiring can be prepared in the factory, workshop or depot for positioning along the trough by the installer. The ten line multiple units are then plugged in to the appropriate 80 point jacks.

Fig. 8 shows the two models of S.T.C. keys used on the Type S keyshelf. The key on the left has an electromagnet which will retain the key in the operated position after it is pressed manually. The right hand side key is non-locking and has a coil restore spring. Fig. 9 shows two views of the ERGA key used on the Type E keyshelf and on each of the miscellaneous position turrets. It is non-locking, and has two changeover contact units on one side and two lamp sockets on the other. This is the

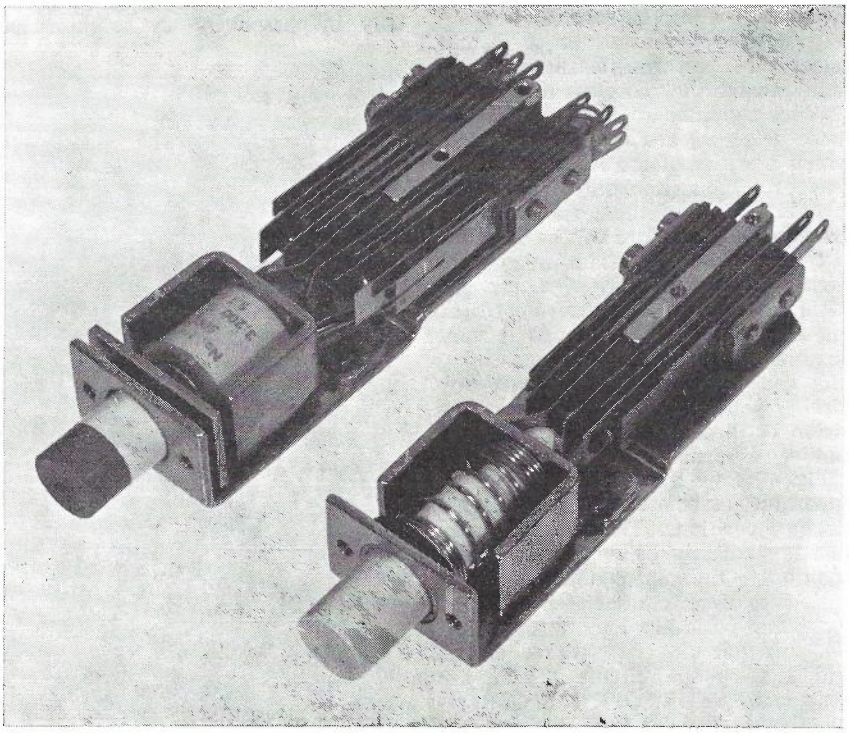

Fig. 8 — S.T.C. Keys.

only assembly used. Fig. 10 shows the LICON microswitch key used for digit keys on the Type E keyshelf.

Call timers are B.P.O. No. 44BH Type 9C. Two start positions are provided—one for ordinary subscribers and one for coin telephones. The timer is also plug ended and may be removed easily for maintenance.

A lever key is readily distinguishable in the operated condition due to the displacement of the lever, but with a push button key an associated lamp is required to show that the key is operated or has been pressed. Thus push button keys which have a locking function have an associated 'key operated' lamp.

CABLING

There are two main cable runs between the T.A. positions and the associated racks:

(i) From each position to the associated positional relay sets.
(ii) From the first appearance of the line multiple to the I.D.F.

There are three methods available for cabling to the switchboard:

(i) Through the legs of individual positions.
(ii) Through the legs of the end position.
(iii) Through an end section.

The actual method used at a particular installation will depend upon the availability of cabling ducts or holes in the floor immediately below the operating positions.

Both cable runs terminate on 80 point jacks at the switchboard end. Thirty-six jacks are allocated for line multiple wiring and four jacks for positional wiring. The installer places the multipled 80 point jacks in position and connects the I.D.F. cables to the first appearance jacks. If an extension to the initial suite of positions is anticipated, at least one additional appearance of 80 point jacks—and preferably the ultimate requirement—should be provided initially, insulated and stored in an end section. The advantages of the use of multipled 80 point jacks and ten line multiple units are as follows:

(i) Ten line multiple units can be ordered from a factory or postal workshop where production techniques result in reduced costs.
(ii) The multiple wiring between 80 point jacks can also be bulk ordered.
(iii) Wire terminations by the installation staff on the job are considerably reduced, thus cutting installation time.
(iv) The number of wires terminating in the confined space behind the line jack and lamp strips is halved.
(v) Wiring faults in the multiple are either on the 80 point jack or at either end of the form on the ten line multiple unit. The 80 point jacks are easily accessible through the rear of each position whereas the ten line multiple units may be unplugged and removed from the switchboard for attention.

Notwithstanding the fact that additional apparatus in the form of the 80 point plugs and jacks, and additional wire terminations has been introduced, it is expected that the aforementioned advantages should more than outweigh these disadvantages. It should be noted that a range of cable lengths is necessary to interconnect the 80 point jacks depending on whether a 3, 4 or 5 panel multiple is used and in the case of the 4 and 5 panel multiples on whether appearances are on adjacent positions or separated by an intermediate position. This is because the panels are not equidistant along the switchboard — those on the same position are closer than adjacent panels of adjacent positions.

Cabling to the special services turret and supervisor's turret runs on

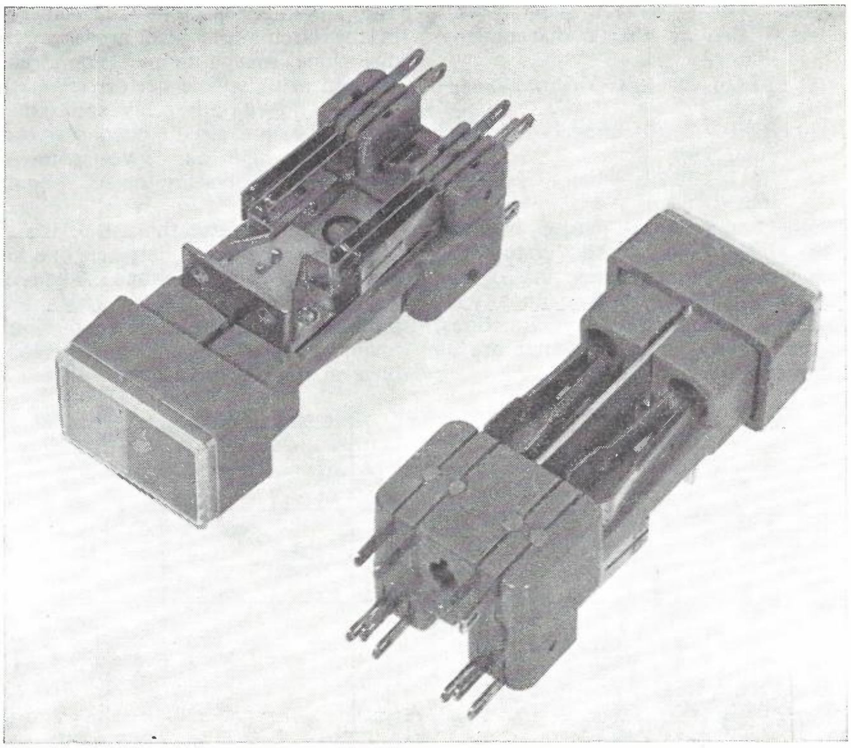

Fig. 9 — ERGA Keys.

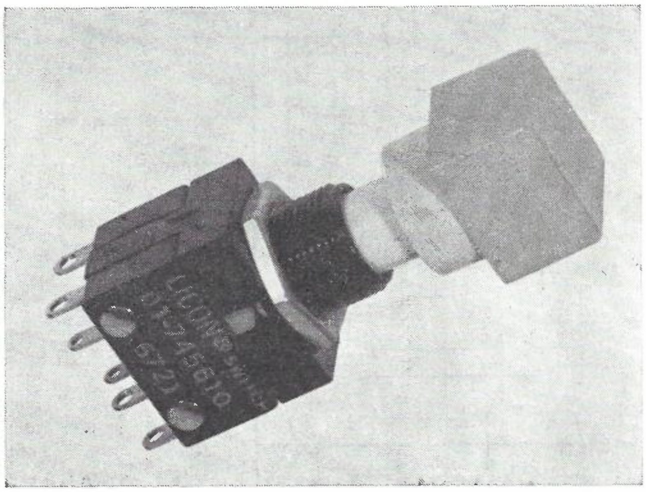

Fig. 10 — LICON Key.

the outside of the table legs under a suitable cover strip and enters the base of the turret where it terminates on a group of 80 point plugs. Provision is made in the design of the monitor's pedestal for internal cable access. The cables also terminate on 80 point plugs.

TRANSMISSION AND SIGNALLING

Transmission and signalling between the line relay sets and the cord circuit is over a six wire circuit — the six wires switched by the 6 pole plugs and jacks. Four of the wires are used to provide 'go' and 'return' speech pairs and over each is superimposed a longitudinal (cailho) d.c. signalling path for call supervisory signals. The direction of d.c. signalling is opposite to that of the speech on each pair. Thus the 'go' speech pair carries backward supervisory signals, while the 'return' speech pair carries forward supervisory signals. The forward signals are—ring, recall, decadic impulsing, and clear forward. The backward signals are: answer, clear back and ring. The wires of the pair carrying speech towards the switchboard are designated a1, b1—those carrying speech away from the switchboard are designated a2, b2. The fifth wire or 'C' wire is used for seizing, holding and busying the line relay sets from the cord circuit (equivalent to the sleeve wire of previous switchboard circuits). The sixth wire or 'd' wire which is connected to the sleeves of the plugs and jacks is used for information signalling between line circuit and cord circuit relay sets. Most of the signals consist of 150 mS pulses of negative or positive polarity. The following signals are provided at appropriate times during incoming or outgoing calls:

(a) Incoming relay set identification.
(b) Tone cut off.
(c) Speak key operated.
(d) REG-L or REG-Y available.
(e) REG-L or REG-Y disconnect—idle.
(f) REG-L or REG-Y disconnect—busy.
(g) REG-OC2 disconnect— sending complete.
(h) REG-OC2 disconnect— sending incomplete.

Other signals are passed between line circuit and cord circuit by sequencing the initial closure of the forward and backward cailhos with respect to certain relay functions. Signals passed in this manner are as follows:

(a) REG-OC2 not required.
(b) Ring down type line. (Causes OPR to send manually timed ring in lieu of 150 mS pulse).
(c) Proceed-to-send.

Amplifiers are fitted in the line relay sets where necessary to provide the correct speech levels to operator and line. In cases where the line relay set is connected to a local carrier channel no amplification may be necessary, in fact a reduction in level may be required; in which case an attenuator replaces the amplifier. Line relay sets containing 2 wire/4 wire conversions require two amplifiers in addition to the hybrid transformer. The amplifiers provide suitable gain in the circuit and also preserve unidirectional speech on each side circuit. No pad switching is performed in the cord or line circuit relay sets except where the line circuit connects to an ARM exchange and level adjusting pads are controlled by the ARM equipment.

Fig. 11 illustrates the use of the six wire interconnection between line and cord circuits, in a simplified schematic form. The transposition of the speech pairs in the cord circuit enables uniform wiring of incoming and outgoing lines in the line multiple.

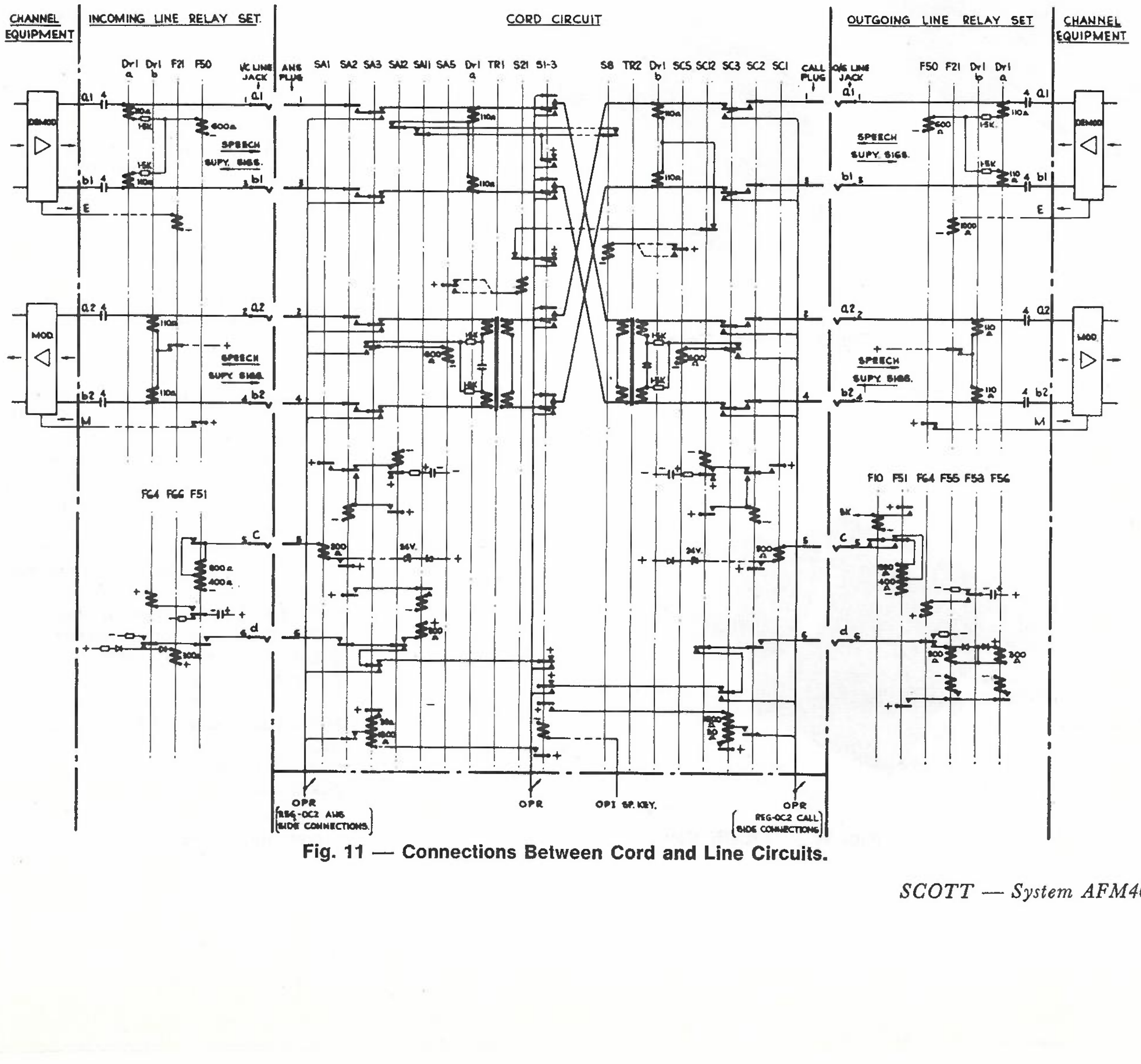

Fig. 11 — Connections Between Cord and Line Circuits.

THE TRUNK ASSISTANCE POSITION CIRCUITS

Cord Circuit (SNOR)

Each T.A. position is equipped with six cord circuits. All cord circuits are of the same design and provide demand switching facilities. All calls are switched directional four wire. The following categories of traffic may be switched:

(i) Subscriber to trunk.
(ii) Trunk to trunk.
(iii) Trunk to subscriber.
(iv) If necessary, subscriber to subscriber (e.g. party lines).

Calls may be completed on demand or reverted by the operator. The answer side of a cord circuit may be used for incoming or outgoing traffic, but the call side is restricted to handling outgoing calls only. This does not impose a penalty on operating as the standard procedure specifies the use of the answer plug for answering incoming calls. Circuitry on the answer side of the cord circuit is more complex as it contains elements necessary for both directions of traffic. The answer side is normally set for outgoing traffic. When the answer plug is inserted into an incoming line jack an identification signal is passed via the 'd' wire to cause the circuit to switch to its incoming mode.

Each cord circuit on the keyshelf comprises an answer plug and cord, a call plug and cord, two cord retraction mechanisms, a speak key, a monitor key, a call timer, lamps for answer side supervision, call side supervision, timer supervision, speak key operated and monitor key operated. An additional key per cord circuit for conducting a routine test on the timer is mounted on a 10-way key strip in the miscellaneous field of the line multiple space.

The functioning of the push button keys is different on the Type S and Type E positions. On the Type S keyshelf the speak and monitor keys hold electromagnetically when pressed. A speak key is released by:

(i) Pressing another speak key.
(ii) Pressing the monitor key in the same cord circuit.
(iii) Pressing the speak release key in the position circuit.

A similar release pattern applies for the monitor keys.

As the keys on the Type E keyshelf are non-locking in construction a memory relay circuit is associated with each key. These are contained in the OKR relay set. Release of a speak key connection may be performed in three ways:

(i) By pressing the same key a second time.
(ii) By pressing another speak key.
(iii) By pressing the monitor key in the same cord circuit.

A release key in the position circuit is not provided as the press-to-operate-press-to-release function is adequate. The monitor key release arrangements are similar to those of a speak key.

In busy traffic periods the principle of mutual key release expedites the operation of the position as only one key operation is necessary to switch the speech or listening commons from one cord circuit to another or to change from speaking to monitoring (or vice versa) within the same cord circuit. This is in contrast to the release of one key and the operation of another, as with lever keys. Push keys are also quicker and less fatiguing to manipulate. In periods of slack traffic it would be necessary to make use of the release keys on the Type S position, and to re-press the same key on the Type E position to effect release.

Check circuits are provided on both 'S' and 'E' systems to ensure that only one speak key function and one

TABLE 1: CORD CIRCUIT SUPERVISORY LAMP INDICATIONS. Demand Call from Another Operator with Through Supervision.

Condition.	Answer Side Supervisory Lamp.	Call Side Supervisory Lamp.
1. Cord Circuit idle	OFF	OFF
2. Answer plug inserted in I/C line jack to answer I/C call (speak key normal)	Slow Flash	OFF
3. Answer plug inserted in I/C line jack to answer I/C call (speak key operated)	OFF	OFF
4. Recall before answer	Slow Flash	OFF
5. Speak key operated to acknowledge recall before answer	OFF	OFF
6. Call plug inserted in O/G jack to obtain B subscriber	OFF	ON
7. Register connected to call side	OFF	ON
8. Register disconnected — B subscriber idle or sending completed	OFF	ON
9. Register disconnected — B subscriber busy, congestion, or sending incomplete (e.g., Time out).	OFF	Fast Flash
10. B subscriber answers	OFF	OFF
11. Recall following answer signal	Slow Flash	OFF
12. Speak key operated to acknowledge recall following answer signal	OFF	OFF
13. B subscriber clears	OFF	ON
14. Recall following clear back signal	Slow Flash	ON
15. Speak key operated to acknowledge recall following clear back signal.	OFF	ON
16. Clear forward received from answer side	ON	ON
17. Plugs removed from line jacks	OFF	OFF

monitor key function can be operative simultaneously, provided they are not within the same cord circuit. The position Routing Information and P.A. System keys are included in the speak key mutual release chain. The key operated lamp associated with each speak and monitor key glows when its particular key function is effective.

Provision is made in the cord circuit of Type E positions for the handling of data transmission traffic. When the position data key is pressed in association with the cord circuit monitor key, the speak key function in that cord circuit is nullified. This prevents intrusion of the operator inadvertently. Listening is still permitted. This facility may be cancelled by pressing the speak key and data key.

Supervisory lamp indications for various types of calls are listed in Tables 1, 2 and 3.

TABLE 2: CORD CIRCUIT SUPERVISORY LAMP INDICATIONS.
Incoming Call from Ring Down Line.

Condition	Answer Side Supervisory Lamp
1. Cord circuit idle	OFF
2. Answer plug inserted in I/C line jack to answer I/C call (speak key normal)	Slow Flash
3. Answer plug inserted in I/C line jack to answer I/C call (speak key operated)	OFF
4. Recall signal	Slow Flash
5. Speak key operated to acknowledge recall	OFF
6. Clear forward signal	Slow Flash (As there is no difference in lamp indication between recall and clear forward on an R/D line, the telephonist must determine which condition exists by operating the speak key and challenging across the connection.)
7. Plug removed from I/C line jack	OFF

TABLE 3: CORD CIRCUIT SUPERVISORY LAMP INDICATIONS.
Outgoing Call to Ring Down Line.

Condition.	Answer or Call Side Supervisory Lamp
1. Cord circuit idle	OFF
2. Plug inserted in O/G line jack	ON
3. Operator rings forward on O/G line	OFF
4. Ring back from O/G line	ON
5. Speak key operated to investigate reason for lamp glow	OFF

Note: With ring down operation there is no positive indication of answer, clear back and ring off conditions. The circuit design is such that the supervisory lamp glows on an out-going call until the initial operation of the ring key to ring forward, then a simulated answer signal is sent from the line circuit to the cord circuit.

Special precautions are taken in the timer control circuit to prevent misoperation and overcharging. A timer may be started when the cord circuit is idle so that a call on another cord circuit on which supervision is defective can be timed; but once the cord circuit is taken into use three conditions must prevail before the timer will step:

(i) both plugs must be inserted in line jacks,
(ii) answer supervision must be received on both sides of the cord circuit,
(iii) the timer start key must be operated.

When the timer is off-normal the cord circuit is blocked to further use. If the plugs are withdrawn leaving the timer off-normal the timer lamp will light as a warning. Resetting the timer clears the cord circuit for further use.

The timer Routine Test key is effective only when the cord circuit is idle. It provides a fast means of positioning the timer on 2.8, 5.8 and 8.8 minutes so that lamp indications and coin telephone tone may be checked. When the routine test key is operated, the timer magnet is stepped at 2½ times per second in lieu of every 6 seconds. The momentary operation of the Routine Test Step On key allows the timer to recommence stepping to the next three minute check point.

From Fig. 11 it will be seen that the 'c' conductor of the plug is the only active lead in the idle condition. The pick-up relay (SA1 or SC1) is backed by a diode to prevent misoperation to positive polarity on the 'd' wire of a busy jack should the 'c' wire of the plug touch the jack sleeve during plug insertion. A 24 volt series zener diode prevents operation to negative potentials of less than 24 volts. Thus the idle condition on a line jack 'c' wire is above 24 volts negative (normally 48 volts negative) and the busy condition less than 24 volts negative (normally about 7 volts). Negative potentials on the 'd' wire are kept below 24 volts. When a plug is inserted into a line jack marked idle, the SA1 (or SC1) relay operates followed by SA2 (or SC2) after a delay period provided by SA12 (or SC12). Relay SA2 (or SC2) connects full earth potential behind the SA1 (or SC1) relay for holding purposes and switches through the remaining conductors to the plug. The slow release of SA12 (or SC12) times an interval used for extending certain category marking signals from the line circuit to the cord circuit.

Incoming line relay sets must identify their class to the cord circuit, and outgoing line relay sets must indicate whether or not an operator's register is required to complete the call. Two types of ringing are provided—a normal single pulse (150 mS) ring for general use, and a manually controlled ring for use on party lines and multi-office trunk lines. The type of ringing required in the line relay set is signalled to the cord circuit during pick-up. The ringing signal is an open circuit of the forward cailho path over the a1, b1 wires. The following logic is observed:

(i) All line circuits are assumed to be outgoing unless identified by a category signal as incoming.

(ii) An outgoing line circuit is assumed to require the use of an operator's register unless a category signal indicates otherwise.

(iii) Line circuits are assumed to require single pulse ringing unless a category signal ordering manually controlled ringing is received.

The various signals used between cord and line circuits, their means of application and duration are shown in Table 4. Four signal paths are used, viz. a1, b1 cailho; a2, b2 cailho; c and d wires. Attention is drawn to the distinct difference between the pick-up and seize forward signals applied to an outgoing line relay set. Pick up of the relay set occurs when a plug is inserted into the line jack. This busies the relay set to other operators, extinguishes the F.L.S. lamp and prepares the relay set for subsequent operation. A 'seize forward' signal results in the line or register associated with the line relay set being engaged for the call. Similarly, on release, a clear forward signal will release the outgoing line, intermediate selectors and the B subscriber, but the line relay set will remain blocked to follow-on use until the plug is removed from the line jack.

On demand calls, answer and clear back signals from the B subscriber are received in the cord circuit from the outgoing line relay set and repeated to the incoming line relay set. It is the function of the incoming line circuit to repeat or block the backward signals as required by the service level to which it is connected. In some incoming line relay sets optional strappings are provided for this purpose. Forward supervisory signals, i.e.: recall and clear forward, are received by the answer side of the cord circuit but only the clear forward is repeated to the call side. A recall signal can be originated only by another operator. The clear forward gives lamp supervision on the answer side of the cord circuit, releases the outgoing line and B subscriber and the resulting clear back signal gives lamp supervision on the call side. The incoming and outgoing line relay sets remain blocked until the plugs are removed from the line jacks.

On revertive calls through clearing is initiated when clear back signal is received simultaneously from both answer and call sides of the cord circuit.

THE POSITION CIRCUIT

The position circuit control keys are arranged in two groups—one on each side of the keyshelf. The keys on the left hand side are associated with speak, ring and miscellaneous functions while those on the right provide register connection and control, and digit keying. Fig. 12 shows a layout of the keyshelf for the Type S position.

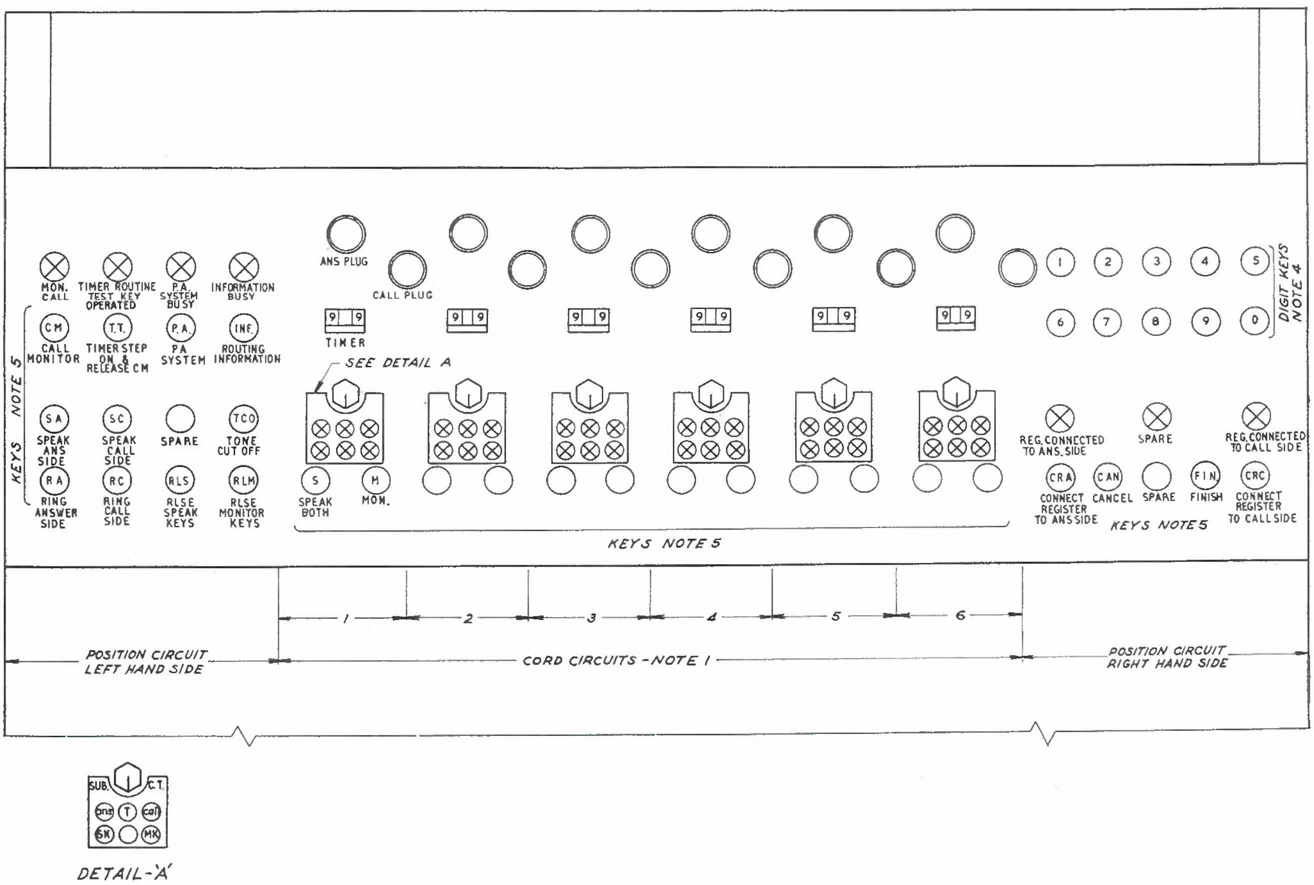

Fig. 12 — Layout of Type "S" Keyshelf.

TABLE 4: SIGNALLING BETWE EN CORD AND LINE CIRCUITS.

Signal	Duration (mS)	Polarity, Closed Cct. (C.C.) or Open Cct. (O.C.)	Conductor(s)	Direction C = Cord Circuit L = Line Circuit	When Signal Applied
1. Pick-up	Continuous	CC	c	C to L	Plug inserted in jack
2. Category—I/C line circuit	150	—ve	d	L to C	Immediately following plug insertion
3. Category — NoREG-OC2 required	Continuous	CC	a2, b2/cailho	L to C	After release of SA12 or SC12
4. Category—Manually controlled ringing	Continuous	CC	a2, b2/cailho	L to C	During release of SA12 or SC12
5. Speak key operated	Continuous	—ve	d	C to L	Duration of speak key operation
6. Seize forward	Continuous	CC	a1, b1/cailho	C to L	I/C call—after release of SA12 O/G call—when REG-OC2 is ready to send or when SA12 or SC12 release if no REG-OC2 category is given
7. Pick-up acknowledgment	Continuous	CC	a2, b2/cailho	L to C	On I/C call following receipt of seize forward signal
8. Proceed to send	Continuous	CC	a2, b2/cailho	L to C	When O/G line circuit is ready to receive impulses
9. Category—REG-L/Y2 available	150	—ve	d	L to C	Following receipt of seize forward signal in O/G L.R.S.
10. D.P. from REG-OC2 to REG-L/Y2	33 (each)	OC	a1, b1/cailho	C to L	Sending from REG-OC2 following receipt of proceed-to-send signal
11. D.P. from REG-OC2 to line	67 (each)	OC	a1, b1/cailho	C to L	(as item 10)
12. REG-L/Y2 disc. — idle	150	+ve	d	L to C	When REG-L/Y2 completes sending
13. REG-L/Y2 disc. — busy	150	—ve	d	L to C	When REG-L/Y2 completes sending
14. REG-OC2 disc.—sending complete	150	+ve	d	C to L	When REG-OC2 completes sending
15. REG-OC2 disc.—sending incomplete	150	—ve	d	C to L	When REG-OC2 detects error or times out
16. Tone cut off	150	+ve	d	C to L	When T.C.O. key pressed.
17. Ring forward or recall sent as single pulse	150	OC	a1, b1/cailho	C to L	When ring key operated
18. Ring forward or recall sent under key control	Continuous	OC	a1, b1/cailho	C to L	For duration of ring key operation
19. Recall received	150	OC	a2, b2/cailho	L to C	When received via I/C line circuit
20. Answer signal received	150	OC	a2, b2/cailho	L to C	When B subscriber answers
21. Answer signal sent	150	OC	a1, b1/cailho (on answer side only)	C to L	Following receipt of B party answer in cord circuit on demand call
22. Clear back signal received	600	OC	a2, b2/cailho	L to C	When B subscriber clears, or following sending of clear forward signal
23. Clear back signal sent	600	OC	a1, b1/cailho (on answer side only)	C to L	Following receipt in cord circuit of B party clear or received recall signal on demand call
24. Clear forward received	600 or Continuous	OC	a2, b2/cailho	L to C	When A subscriber clears
25. Clear forward sent	Continuous	OC	a1, b1/cailho	C to L	(a) Demand call—when A sub. clears (b) Reverted call—when clear back received from both sides of cord circuit
26. Release	Continuous	OC	c	C to L	Plug removed from jack

Keys on the left hand side comprise:— speak answer, speak call, ring answer, ring call, tone cut off, speak key release, monitor key release, connect to routing information position, connect to public address system amplifier, timer routine test step on, and call monitor. Lamps are associated with the last four keys.

All keys except the call monitor are non-locking. The call monitor key holds electromagnetically until released by the timer routine test key. The speak answer and speak call keys in association with a cord circuit speak key, split the through connection allowing the telephonist to speak to either the A or B subscriber. The ring keys are used for sending ring forward and recall signals which are passed over the a1, b1 cailho as a 150 mS or key controlled open circuit depending upon the line relay set category mark. Operation of the tone cut off key applies a 150 mS pulse of positive potential to the line circuit 'd' wire where coin telephone (C.T.) tone disconnection is initiated.

Order wire working to other operating positions is not provided but key switched access to the routing information operator and public address system is included. The call monitor key is used by the telephonist to request the monitor's presence at the operating position for assistance with traffic matters. Lamps light on the monitor's post, the annunciator panel, the operating position and adjacent to the call monitor key. The key is reset by the monitor on arrival at the operating position. Alternatively the monitor may decide to remain at the monitor's post and speak to the calling telephonist via the call monitor circuit. On the Type E keyshelf this causes automatic release of the call monitor key and when all speak keys are normal the telephonist's speech commons are switched to the monitor.

A data transmission key is provided on the Type E keyshelf to set any of the cord circuits so that the speak key function may be immobilised. The call monitor key on the Type E position is reset by re-pressing the same key or remotely by the monitor if she answers the call at the monitor's turret.

Right hand side keys are:— connect register to answer side, connect register to call side, finish, cancel, and the ten digit keys 1 to 0. Lamps associated with the register connect keys light when the position circuit is coupled to a register. Provision is made for dual register working in the position circuit, provided that one register works on the answer side and the other on the call side. The two registers may operate within the same cord circuit or in different cord circuits.

A register is called by first operating a cord circuit speak key then pressing either the connect register answer or connect register call key, in the position circuit. When a register is coupled the connect register lamp lights. Digits are then keyed to the register. The cord circuit may be released if desired when the connect register lamp lights as the circuit is no longer dependent upon its operation.

Thus a telephonist may key-up a number on one cord circuit, speak on a second, and monitor on a third—all simultaneously, if desired. At the end of the digit setting, the finish key is pressed to start digit transmission from the register and to free the digit keys for use with a second register, if required. If a mistake in keying is made, the cancel key is pressed to release the stored digits and disconnect the register. Re-operation of the register connect key will result in another register being connected.

The position circuit relays and associated components are contained in two relay sets. The OPR handles the control, signalling, through transmission and coupling functions, while the OTR contains the operators telephone circuit consisting of two amplifiers, a current feed relay and combining network. Fig. 13 shows a simplified diagram of the telephone circuit (OTR). The transmit amplifier delivers its output into the two speech circuits SA and SB. The voltages are equal but opposite in polarity. The SA and SB pairs also convey speech signals from the A and B subscribers to Pad 1 and thence to the receive amplifier and operators receiver. Speech from the A subscriber will be received on SA and speech from the B subscriber on SB. The telephonist's voice produces two inputs to Pad 1. If the voltages on SA and SB were exactly equal and out of phase they would cancel out. It is arranged that the resistance of the two paths from TA to Pad 1 are slightly unequal so that a small residual voltage exists at the input to RA to provide side tone in the operator's receiver. The receive amplifier also has inputs from the monitoring leads MA and MB via Pad 2. Pads 1 and 2 provide decoupling between the speech and monitoring leads. Pad 2 has an additional 6 dB attenuation to reduce the received level of monitored speech. Each of the resistors shown in the combining network has a nominal resistance of 5,600 ohms so that the connection of the operator to a working line in either the speaking or monitoring condition causes negligible loss to the through circuit. Crosstalk between side circuits, when the operator is connected, i.e. from SA-SB, MA-MB, is better than 55dB, while crosstalk from one group to another, i.e. SA-MA, MB-SB etc., is better than 75dB.

Automatic coupling of positions is provided. A telephonist may use cord circuits of the next adjacent position when it is unstaffed as they will be coupled to her own position circuit. The coupling is automatically performed when the headset plug is removed from the telephone jack. An unstaffed position will automatically couple to the previous adjacent position, if that position is staffed. No more than two keyshelves can be coupled to a position circuit.

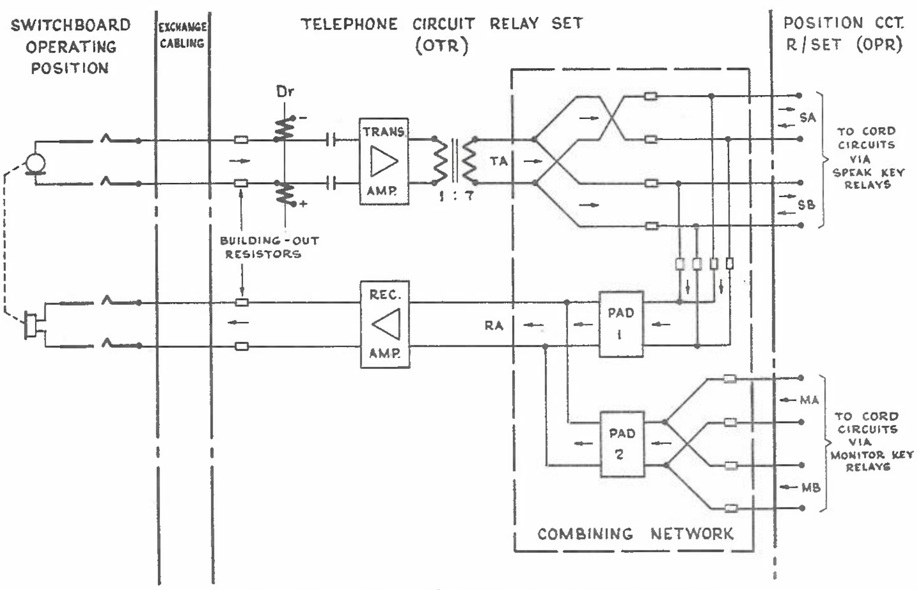

Fig. 13 — Simplified Circuit of OTR-UOC-W.

Two telephone jacks are provided on the front edge of each keyshelf. They are each 4-pole and are comprised of a tip, a sleeve, and 2 intermediate rings. Auxiliary springs on the jacks control the switching of resistors which ensure that the transmitter current, transmitted speech level, received speech level and terminating impedances offered to the transmit and receive amplifiers remain constant with either one or two headsets plugged in.

THE OPERATOR'S REGISTER

Two types of operator's registers were originally envisaged for use with the cord type switchboard. Initially, a comparatively simple decadic sending type devoid of analysing and translation functions but available for early installations; and an ultimate type capable of full m.f.c. sending and possessing the analysing capacity of a leading crossbar register. The design of the second type will depend upon the future demand for the AFM 402 system and experience in traffic handling obtained from the use of the decadic register. It would probably be similar in general concept to the new ARF REG-LP and may share some of its peripheral relay sets (e.g. analysers, code senders, decadic senders, etc.).

The decadic register (REG-OC2) is essentially an extension of the key sender arrangement used on some sleeve control type trunk switchboards but, through the use of improved cord and position circuits, it does not restrict the operation of a position while digits are being transmitted. Digits are keyed to the register over 5 wires using an error sensing 2-out-of-5 code. The received digits are checked for validity then placed into a relay store having a capacity for up to 15 digits. Sending from the register does not commence until all digits have been keyed, and the finish key is pressed. A category signal sent from the outgoing line circuit to the register, via the cord and position circuits, determines whether decadic sending occurs at 10 or 20 i.p.s. If REG-OC2 sends direct to line then 10 i.p.s. sending is used, but if the digits are received by a local ARM or ARF register the sending speed is increased to 20 i.p.s.

When sending direct to line, REG-OC2 cannot determine the test condition of the B subscriber's number, so after the last digit is sent the register marks the cord circuit for 'register disconnect idle', then releases. On calls via a local ARM or ARF register, REG-OC2 waits after the last decadic digit is sent, and receives from REG-L or REG-Y, 'd' wire signals indicating the true condition of the B party telephone. These are passed to the cord circuit. Release of REG-OC2 occurs in one of five ways:

- (i) If the cord circuit plug is removed from the line jack.
- (ii) If the 'cancel' key is operated.
- (iii) After completion of sending at 10 i.p.s.
- (iv) Following completion of sending to an ARM or ARF register and after receipt of backward signals indicating the condition of the B subscriber.
- (v) By time out.

Three periods of time supervision are provided in the register:

- (i) 6-12 seconds from seizure of REG-OC2 to receipt of the first keyed digit and also between successive digits.
- (ii) 18-36 seconds from despatch of the last digit to REG-L or REG-Y, and return of the B party signals.
- (iii) 1-2 seconds is allowed for the removal of holding conditions in the position circuit after release of the register is signalled. If the release cycle fails, the register forcibly detaches itself from the position circuit.

The register is split into two relay sets for convenience. Part one controls digit receipt, checking and sending, external signal receiving and sending and time supervision. Part two contains the digit selection and storage relays. As sending and receiving do not occur simultaneously the one selection chain is used for steering the keyed digits into one of the fifteen store positions, then after resetting, steps over the stores in the same order to read out the digits for transmitting as decadic pulses. The registers are coupled to the position circuits via ARF type register finders controlled by a register finder marker. As four RS-I and one RSM relay sets provide a coupling group serving up to 32 positions (each position requires two connections) and 20 registers, one RSM would be sufficient for most small to medium sized installations. To provide an insurance against an RSM fault rendering the whole exchange inoperative, two RSM relay sets are normally provided and partial use made of each of the two RS groups on the rack. This will provide a maximum access of 64 positions to 40 registers. The ratio of positions to registers may of course be varied within these limits as determined by traffic tables, and field measurements.

Eight registers mount on a Rack REG-OC2.

(Part 2 of this article will appear in a later issue of the Journal)

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DESIGN OF A CORD TYPE TRUNK SWITCHBOARD CONSOLE

*H. J. LEWIS**

INTRODUCTION.

With the development of Manual Assistance Centres for ARM Trunk Exchanges, a new switchboard console was required, which would be modern in appearance, easy to operate and economically manufactured. (See Fig. 1.) The operation of this switchboard and associated equipment in A.P.O. networks is described in Ref. 1. This article is concerned with the new construction features introduced into the switchboard, the reasons for their selection, and the advantages that will apply in service.

The design was based on achieving optimum results in:

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(a) Low production costs, while maintaining a high quality product.
(b) Easy installation, both in the original establishment and in future extensions.
(c) Convenient and pleasant operating conditions.
(d) Minimum 'down-time' for maintenance work by providing easy access and plug-in type subassemblies.
(e) Easy reconditioning of switchboards without removal from service.

Photographs of the earliest telephone exchanges show that the switchboards were a tall continuous rack structure with a small shelf for docket writing. The operators evidently walked up and down the row of racks plugging up connections with long draped cords. Over the years the general shape has not changed, but a more compact structure has evolved, with the operator seated and able to reach all lines.

Some recent American cordless trunk switchboards have been built with consoles in pairs, with the appearance of two P.B.X. type boards. Also, cordless trunk switchboard suites, such as installed at the Dalley Street Exchange in Sydney, are of the desk type, with free leg room beneath the console. However no cord type boards of this console type construction had been developed in Australia until recently.

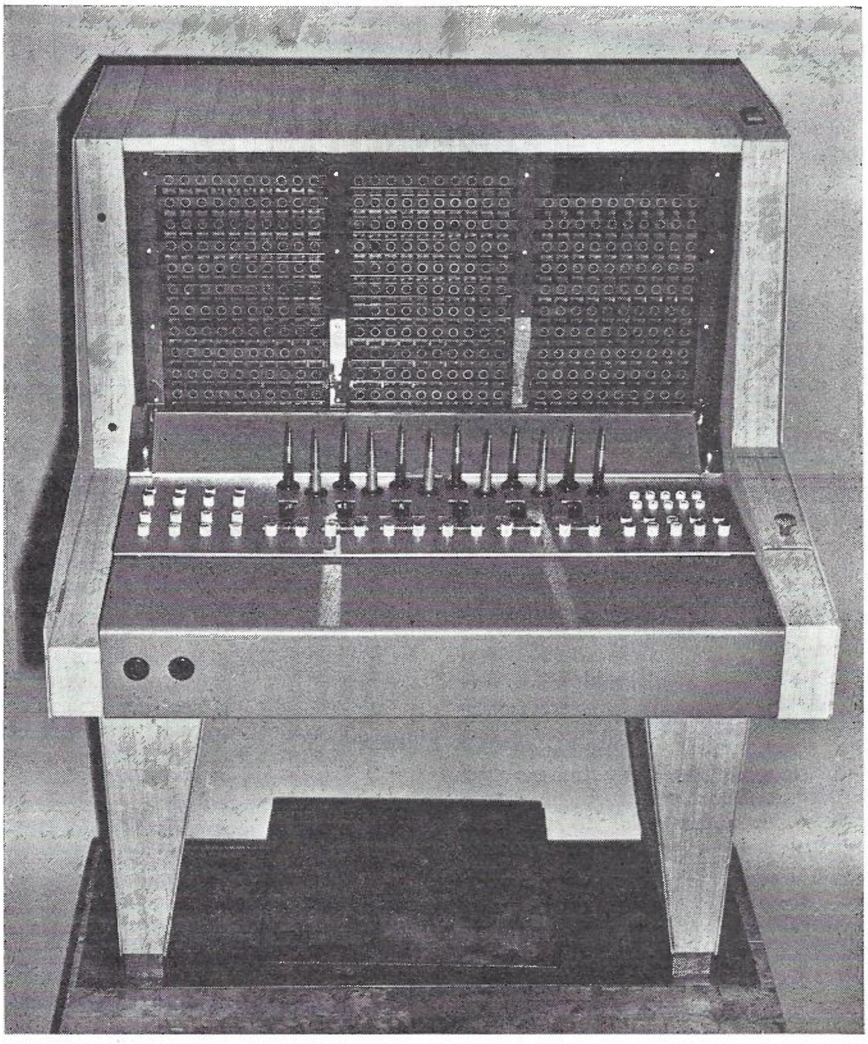

Fig. 1 — New Cord Type Trunk Switchboard.

BASIC DESIGN.

Determination of Basic Shape of Console.

The first steps in designing the console, after the circuit design of the equipment had been completed (Ref. 2), were:

(a) Establish the area and volume of equipment to be installed on the Keyshelf.
(b) Determine the number of lines required in the multiple, the arrangement of panels which formed the multiple and appearance on each operating position.
(c) Determine the number of operating positions likely in each suite, and the need to extend the suite at a later date.
(d) Establish the desirable overall height of the suite, whether it would be free standing, back-to-back, or used as a single position on any occasion.
(e) Determine the volume of cable to be wired to the multiple and keyshelves.
(f) Assess the size and locations of the auxiliary equipment such as notice frames, index units, and key compartment for telephonist.
(g) Determine the method of access for maintenance of the equipment.
(h) Determine the methods of installation which will require a minimum of work, and provide maximum flexibility in assembly and additions.

From this information, outline sketches were prepared of the minimum dimensions of the working portion of the switchboard. These sketches allowed general profiles of the essential dimensions of the switchboard, as well as frontal appearance to be provided.

Before further progress was possible it was necessary to examine the various types of material from which the switchboard could be made. Previous switchboards usually had been made with a heavy steel section frame, with wood-panelled facings. These materials did not assist shaping, and as a result switchboards were rectangular, heavy and bulky. Also, they led to wiring and maintenance procedures which were a conglomeration of trouble.

Although the multiple and keyshelf of the new switchboard is somewhat akin to switchboards which have been in use for many years, a basic difference exists. All the control relays except two position couple relays, are mounted on a rack away from the console.

Investigations of various types of cord storage devices produced a reeling type of 'cord retraction unit' used by the German Post Office, which was ideal for a desk-type console with free leg space.

The circuit demanded a four-wire cord, and the most suitable jack and lamp strip for use with this was also a German design, which was smaller than previous units. This allowed a maximum of 360 lines to be provided in the multiple in a smaller area than had been possible on previous cord type switchboards.

From all these changes it was possible to design a sheet steel console of much simplified construction, which allowed all of the requirements listed above to be met, and at the same time allowed flexibility in selecting a pleasing shape.

At this stage, many freehold sketches were made of possible shapes to accommodate the equipment. Each of these sketches was examined against the following criteria:

(a) Could it be readily manufactured without expensive tooling?
(b) Could it be installed with minimum work?
(c) Did it provide ready access for maintenance of the equipment?
(d) Was it a pleasant shape which provided operator comfort?

In regard to this latter quality, reference was made to British Standard Specifications 3044, 3079 and 3404, which cover the Anatomical, Physiological and Anthropometric Principles in the Design of office Chairs and Tables, and office Machine operators' Chairs and Desks, and to design information provided by the Bell Telephone Company. (Ref. 3.) (See Fig. 2.)

A design was selected from all this information and a full-size rough prototype shell of the proposed shape made for showing to the user divisions of the Department.

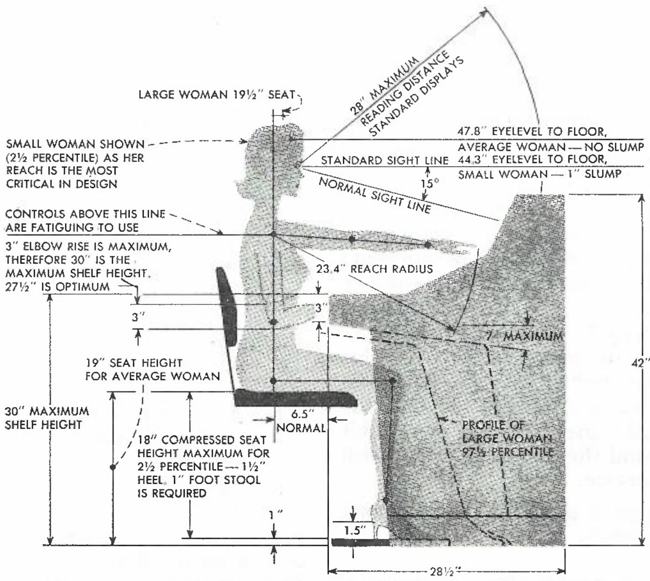

Fig. 2 — Bell Laboratories Switchboard Operator Dimensions.

Facing Materials.

At this stage, available facing materials were examined. The requirements were for materials which had the following qualities:—

(a) A non-reflective, durable warm-to-touch material for the keyshelf, which would not mark with ball point pen ink, and provide a pleasant colour scheme.
(b) A durable coating for the sheet metal carcase, which was available in a suitable range of colours and could be cleaned with normal cleaning materials and easily replaced if damaged.

Keyshelf.

The material selected to satisfy the requirement for the keyshelf was an ⅛in. A.B.S. plastic sheeting with a micro-cell finish. The A.B.S. is a tough material which can be formed to shape with heat. The colour selected was a grey-green to match the present telephone instrument.

As there are limitations in the types of adhesive for use with A.B.S. plastic, fixing of this material to the steel sheeting was done by counterboring the rear face of the panel, and attaching metal-thread screws as studs by means of an A.B.S. adhesive between an A.B.S. washer and the panel. (See Fig. 3.) This allows removal or refitting of the A.B.S. during manufacture or if necessary, during reconditioning, and avoids the use of screw heads on the outer surface.

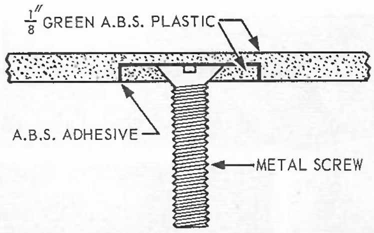

Fig. 3 — Method of Fixing Studs to Rear of ABS Keyshelf Panel.

The micro-cell finish on the face of the A.B.S. sheeting greatly reduces glare, whilst providing a reasonably smooth writing surface for dockets.

Carcase.

P.V.C. wall fabric was selected for coating the steel carcase, in preference to the use of pre-coated steel sheet, for several reasons:

(a) It is not possible to easily repair damage to the pre-coated steel arising from cuts and burns.
(b) The range of colours and finishes of pre-coated steel is limited, whereas an extensive range of colours and surface textures is available in wall fabrics.
(c) Manufacture with pre-coated steel is complicated by difficulties in covering cut edges of the metal, particularly at corners, in spot welding from one side, in handling throughout the cutting and folding work, and in using heavier gauges of metal where extra strength is required.
(d) Recoating the switchboard carcases in situ in the field when

damage or wear occurs, is not possible with pre-coated steel.

The material selected for the prototype and later used in production, is a 'tawny biege' wall fabric with a coarse textured finish. This material can be cleaned with a soapy damp cloth, and is readily fixed with contact adhesives provided a suitable priming coat is applied to the steel.

The design of the metal work and assembly of the carcase is such that the frame can be recoated in the field if damage or wear occurs.

Preparation of Full-size Model.

Before proceeding to construct and equip a prototype switchboard a full-size model of the carcase was made to demonstrate to the user group the shape of the proposed switchboard, its general appearance, and its functions from the operator's viewpoint. This was considered an essential operation if the switchboard is to fulfil the needs of the user.

Several small amendments were proposed to the model by the operating staff, which improved access to the multiple, and layout of the key-shelf controls.

The 'index' for use with these switchboards was discussed also with the user group at this stage. As a result it was possible to design a built-in Index unit of neat appearance. The cards are enclosed in clear plastic envelopes, which act as leaves of the index. The insert of the index unit is removable from the main body and any plastic leaf can then be changed. In service, spare index inserts will be provided, which will allow an instant change-over when an amendment to the index is necessary. The index unit also includes a small compartment for housing personal belongings of the operator.

DESIGN AND CONSTRUCTION OF PROTOTYPE.

Having set the basic shape of the switchboard, materials of construction and operating layout, the next step was to design the technical construction to provide:

(a) Requirements for easy installation;
(b) Requirements for maintenance of equipment;
(c) Method of manufacture to minimise cost, ensure durability, provide good appearance, and to make the switchboard convenient to operate.

INSTALLATION FEATURES.

The carcase is a modular unit which may be bolted together to form a suite of any length. Bolts are passed through matching holes in the flanges of each end of the frame.

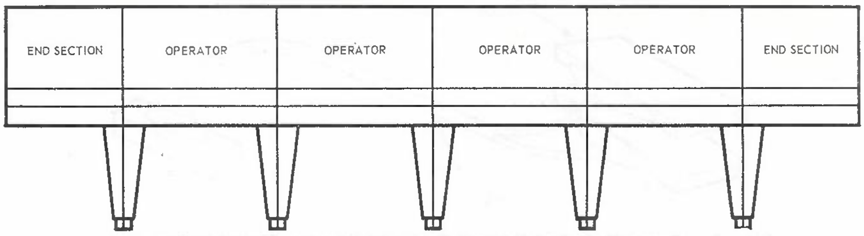

Fig. 4 — Profile of Typical Suite of Switchboards.

Each carcase is screwed to the floor by two bolts through each leg portion. Adjustment for irregularities in the floor level are accommodated by 1/16 in. packing plates. Modified carcases without equipment are used as end sections to complete the leg structure of the outer operating positions, provide a location for miscellaneous testing and switching devices, and a termination for the free end of the cabling, which may be used for future extensions (Fig. 4).

Previous cord type trunk switchboards have approached nightmare proportions in installation as well as maintenance, due to their cabling methods. Without change from the former methods of suspending cables across the rear of the multiple and terminating directly on the jacks and lamps, this switchboard would have been very difficult to wire. This increase in difficulty was due to the use of six - conductor jacks and the smaller size of both the jack and lamp strips. These are of German origin. The jack is mounted on its strip by a single screw and is very quickly removed for replacement and is very accessible for cleaning and adjustment.

A special clamp screw was designed to hold the strip in position. This screw is fitted into a tubular guide which extends beyond the rear of the jack or strip, making it very easy to remove the jack or lamp strip, to which it is common. (See Fig. 5.)

The answer to the cabling problem was to install two cabling ducts in the switchboard which transversed each position and carried the cable from the entry end to the far position of the suite. Across the top of these ducts were fitted 40 Ericsson 80-point knife jacks and the multipling is done on the rear of these jacks inside the cable duct (Fig. 6).

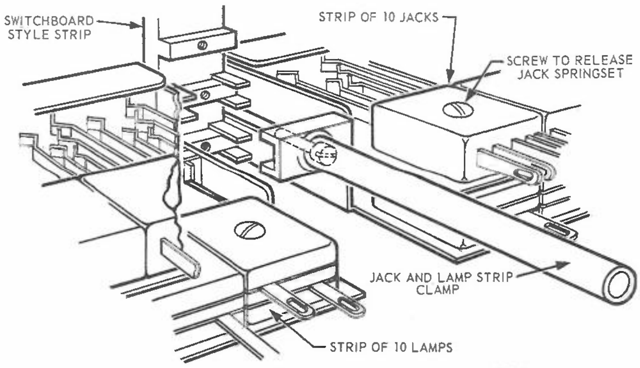

Fig. 5 — Method of Securing Jack Lamp Strips.

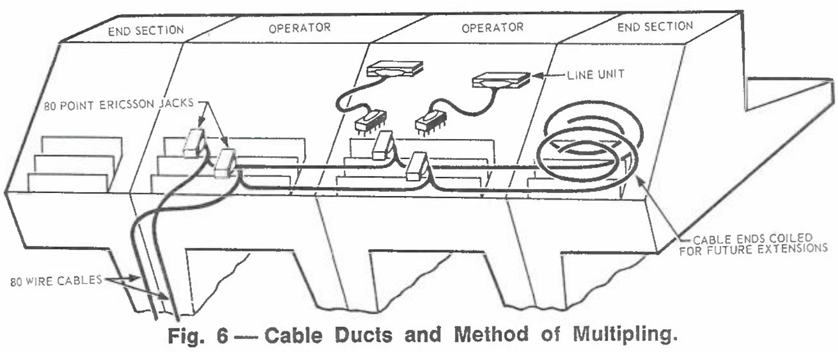

Fig. 6 — Cable Ducts and Method of Multipling.

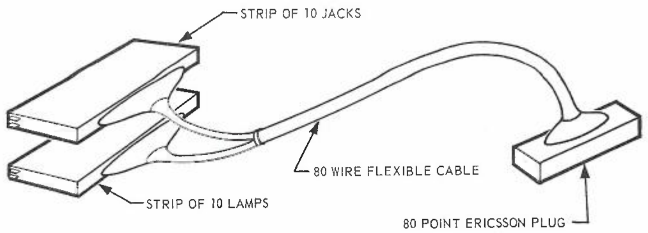

Fig. 7 — Line Unit for Connecting Cabling to Switchboard Face.

Eighty-wire cables are used so that each cable is terminated on a separate Ericsson jack. The wiring to the multiple on the face of the switchboard is completed by a removable line unit consisting of one lamp strip and one jack strip to provide ten lines (Fig. 7).

The advantages of using such a line unit are:

(a) They can be fitted as extensions are required. Actually, new circuits can be added in a few minutes by removing the two clamp screws to release the 1 in. dummy strip, substituting the line unit, replacing the clamp screws and plugging the 80-point Ericsson plug into the jack on the cable duct.

(b) They provide ready access to the rear of the jacks and lamp sockets as the flexes are well spaced and can be moved aside.

(c) They can be quickly replaced if faulty, without any unsoldering.

(d) Alternatively, they allow quick removal of the jack or lamp strip for cleaning or minor maintenance.

The cable entry illustrated in Fig. 8 (a) is the tidiest method of introducing the cabling into the suite. Approximately 10,000 wires in 80-wire cables may be brought up through any leg assembly (two half legs). The inner side of the leg may be removed to assist feeding cable through the leg.

When entry through an adjacent wall is required, the method in Fig. 8 (b) is to be used, while the method in Fig. 8 (c) provides for overhead entry.

The whole keyshelf unit may be fitted after the carcase has been installed and wired. Likewise it can be removed quickly from the switchboard if it is necessary to do major maintenance work (see Fig. 9). This is achieved by using three 80-point Ericsson jacks and plugs on the cable trough to connect the keyshelf wiring, and three Painton jacks and plugs on the rear of the keyshelf to connect to miscellaneous wiring on the carcase to the keyshelf. The keyshelf is attached to the carcase by 13 hinge screws and the two staybracket bolts.

Minor maintenance is done by lifting the keyshelf and swinging it forward on its hinged front edge.

Cord retraction units and timers are connected to the rear of the keyshelf by jacks and plugs, and may be removed by either unlatching in the case of the cord units, or unscrewing three screws to release the timers.

All keys and lamps are mounted on sub-assembly plates fitted with pillar screws to provide easy and quick removal, if necessary. All components are spaced so that ready access is provided to the springsets for cleaning or adjustment.

Some compromise was necessary in the type of pushbutton key used as unfortunately the range of available commercial keys of a durable but economical nature was limited. It is hoped that a more suitable key is available for future production and that it is a combined key and lamp with adequate facilities and a good light output.

An interesting docket clip was developed for the writing area of the keyshelf. Previous switchboards have been fitted with metal clips which require two hands to fit the docket and which are rather unsightly. On the new switchboard the writing area is slightly lower than the equipment area, and at a point of meeting, a strip of artificial sealskin is fitted under the overlap (Fig. 10). Dockets are easily pushed forward with one hand into the slot formed by the overhang, and are held by the bias of the sealskin.

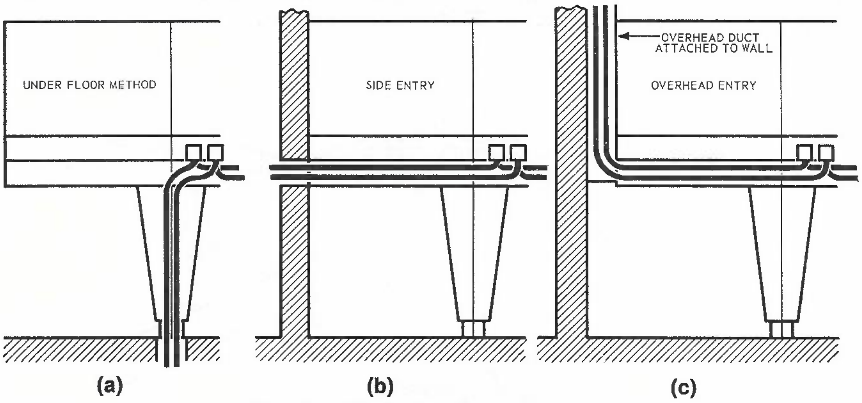

Fig. 8 — Methods of Cable Entry.

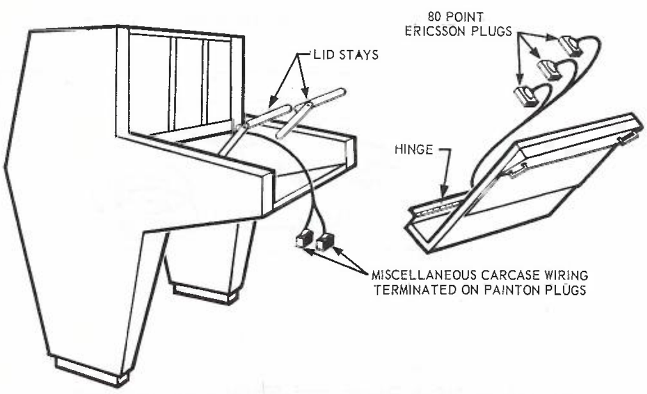

Fig. 9 — Keyshelf Removed from Switchboard.

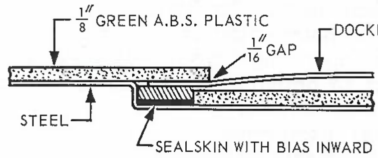

Fig. 10 — Method of Holding Dockets in Keyshelf.

The telephonist's phone jacks are recessed into the front of the keyshelf to reduce the possibility of damage to the plug if it protruded fully, and was bumped by brushing against it. Guide bushes are provided to assist entry of the plug, and a sufficient length of the plug protrudes to allow removal without pulling on the cord.

MAINTENANCE FEATURES.

All of the equipment has been selected with a view to minimum maintenance, and the methods of mounting the equipment have been designed to give good access for cleaning and adjustment of the components, and quick removal when replacement is required.

The items on which maintenance will be necessary due to normal wear are:

(a) Jacks and lamp sockets in the multiple;
(b) The lamps;
(c) The keys on the keyshelf;
(d) The cords;
(e) The timeclocks.

The jack and lamp sockets on the multiple may be removed as a unit by unplugging the Ericsson jack from the cable trough, and releasing the four special clamp screws which secure them to the panel. Therefore the jacks and lamps for a whole row of ten lines can be replaced in a few minutes. Alternatively, after removing two clamp screws, either the jack or lamp strip can be released and withdrawn sufficiently to clean springs, or if necessary to completely remove any individual jack or lamp socket by release of a single mounting screw.

All lamps are replaced from the front of the switchboard after removal of the lamp caps in the case of the keyshelf, or by sliding the designation strips aside on the multiple lamp strip.

Access to all of the equipment on the keyshelf is obtained by swinging the keyshelf to the vertical position, where it is held by lid stays.

Sufficient spacing has been provided between keys to allow cleaning or adjustment of springs. The keys are mounted in small groups on sub-assembly plates which may be removed quickly after undoing either two or four pillar screws.

The cord and its retraction unit are mounted on a bracket with a quick release clip (Fig. 11). After unplugging the Painton plug on the output side from the keyshelf, the complete assembly may be removed. Replacement of a cord unit is completed in less than two minutes.

No major maintenance is expected on the mechanism of the cord retraction unit. A very cunning method of avoiding a commutator is used on the cable drum. A flat plastic strip with six conductors embedded in it is coiled contrawise to the cord in an adjacent compartment. The outer end is connected to the cord and the other to fixed terminals on the shaft. As the drum rotates the plastic strip uncoils.

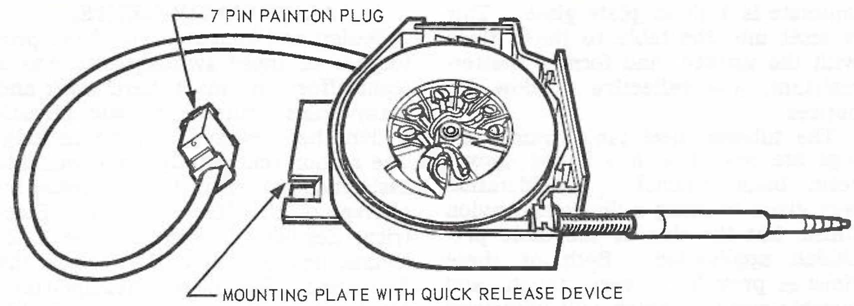

Fig. 11 — Cord Retraction Unit Assembly.

A similar arrangement applies to the time clocks, except that a Jones plug is used to terminate the cord and it is necessary to remove three mounting screws to release the clock.

The complete keyshelf may be replaced in a few minutes, as described earlier in this article, if major maintenance is necessary.

COST, DURABILITY, APPEARANCE AND OPERATING ASPECTS.

The major portion of costs of this switchboard is related to the equipment.

The metal chassisless type of construction used for the carcase is one of the most economical forms of manufacture, which at the same time allows flexibility in shaping and finishing. The sheet metal can be formed on conventional machines and spot or arc welded.

The A.B.S. sheet plastic used on the keyshelf is easily machined or formed to shape by heat, and its toughness prevents chipping or cracking. In regard to life cost, it is probably as economical a finish as could be provided for a durable, colour-fast and easily-cleaned result.

A stainless steel foot is fitted at the bottom of each leg. This provides an attractive finish, as well as a durable area to withstand floor cleaning fluids or knocks from floor-cleaning tools.

The appearance is pleasant and the open construction of the leg area and the low overall height, provide a spacious and comfortable result.

The colour scheme used on the initial installations has been a tawny biege for the covering fabric and a grey-green for the keyshelf. These colours could be varied as required within the available commercial range, which in the case of fabrics is very extensive. The A.B.S. is available in several other colours.

There is scope for further improvements in future cord type switchboards. The switching keys used on the keyshelf are robust and will give good service; however, they do not include a lamp in the knob and the separate lamp fitting designed to match does not provide the illumination sought. This is probably the point at which a major improvement can be made, as at present no robust illuminated switching key is available at reasonable cost, which has both the required brightness and switching facilities.

AUXILIARY EQUIPMENT.

Associated with the operator's suite, monitor's, supervisor's and special services (concentration) tables were required. These were designed to match, as far as possible, the general appearance and finish of the operator's position (see Figs. 1, 2 and 3 of Ref. 2).

Features in the design of these units which are of interest are:

(a) Erga type switching keys;
(b) Non-reflective glass notice plate;
(c) Coating of the metal legs of the tables.

The Erga keys provide a good illumination and overcome the difficulty mentioned previously; however, they are not available in a latching type and could not be used in the operator's consoles without major change in the circuitry.

The caps of these keys provide for the insertion of loose colour and designation screens in either of two compartments, which are illuminated by separate lamps. Designations can be made by cutting photographic negatives of pre-printed designations into the required sizes. Colour screens are cut from thin flat plastic sheets.

Access to the keys for maintenance is by inverting the switchboard unit, or in the monitor's switchboard, by removing the top cover. The keys are removed in banks by unscrewing mounting screws.

Non-reflective glass notice plates are used for the writing area on the supervisor's and special service tables. Thin non-reflective glass used for picture framing forms the upper surface and fixed to it with a plastic laminate is a 32 oz. plate glass. This is inset into the table to finish flush with the surface and form a shatter-resistant, low reflective window for notices.

The tubular steel table frame and legs are coated with a baked epoxy-resin black enamel. Consideration was given to using a dip-coated nylon finish, but the size of the table precluded application. Both of these finishes provide a very tough and durable surface, which will withstand abrasion, chipping and cleaning processes very satisfactorily.

ACKNOWLEDGMENTS.

Design and construction of the prototypes of these switchboards was a team effort and much hard work and many trials, frustrations and investigations have passed in their making. The author acknowledges the valuable assistance and contributions made by officers of the Mechanical and Electrical Services Laboratory, the Telecommunications Division, and the Equipment Section at Headquarters. Many other officers provided valuable advice and commercial processors and suppliers were most helpful.

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TECHNICAL NEWS ITEM

INTERNATIONAL WORKING PARTY TO STUDY USE OF GEO-STATIONARY SATELLITE ORBIT

At its recent Interim Meeting in Geneva, Study Group IV of C.C.I.R. (International Radio Consultative Committee) passed a resolution to set up an International Working Party to study the use of the geo-stationary satellite orbit. The Working Party is to be comprised of one member from each of the Administrations of Australia, Canada, France, Federal Republic of Germany, Japan, Poland, United Kingdom, U.S.A., and U.S.S.R., together with the Chairman of Study Group IV. The U.K. is to provide the Chairmanship of the International Working Party.

The C.C.I.R. is an organ of the International Telecommunications Union and deals with its work in fourteen Study Groups. Study Group IV studies technical questions and makes recommendations and reports on Space Systems and Radio-Astronomy; the Australian representatives at the recent meeting were Messrs. E. R. Craig (Australian Post Office) and N. S. Feltscheer (Overseas Telecommunication Commission). An important part of the work of the Study Group concerns communication satellite systems.

With only a few exceptions, communication satellites now use the geo-stationary (or synchronous) satellite orbit. This particular orbit is at an altitude of 22,300 miles, and because it can accommodate only a finite number of satellites sharing the same frequency bands, it has been likened to a natural resource such as iron ore, oil or the radio frequency spectrum. Thus a study programme to consider the technical factors influencing the efficiency of use of this orbit has been prepared. Some of these factors are:

- The tolerable levels of interference noise in different communication-satellite systems;
- The apportionment of thermal, interference and intermodulation noise;
- The radiation patterns of the earth station and satellite antennae;
- The difference in the values of radiated power used on the one hand by different earth stations and on the other by different communication-satellites;
- The required protection ratios resulting from the various baseband processing and modulation techniques;
- Factors affecting the multiple use of the same frequencies within a single communication-satellite;
- Errors in communication-satellite position and attitude;
- Polarisation discrimination.

The object of the Study Programme is to establish criteria to provide for the orderly development and most effective use of the orbit. At the meeting, it was recognised that this study is of some urgency because of the World Administrative Radio Conference (Space) now planned for late 1970 or early 1971.

THE VICTORIAN STATE DISASTER PLAN

*C. H. HOSKING, B.Sc., M.I.E. Aust.**

INTRODUCTION.

The Dandenong Ranges bushfire of January, 1962, which caused serious loss of property and endangered the lives of many persons, showed very clearly a lack of co-ordination of effort between the various bodies responsible for fighting the fires and those who gave and offered assistance and support. Volunteer fire fighters were not organised or employed efficiently, there was no traffic control plan to prevent sighteers causing traffic congestion, and there was a serious communication problem due to congestion of both radio frequencies and the public telephone network.

As a direct result of these experiences, a meeting of representatives of all organisations involved directly or indirectly in combating disasters in Victoria was called. Naturally, most of these organisations were State Government Departments or Instrumentalities, including:

Victoria Police,
Country Fire Authority,
Forests Commission,
Victorian Hospitals and Charities Commission,
Australian Red Cross,
Melbourne Harbour Trust.

Also invited to participate were representatives of the Armed Services, Department of Civil Aviation and the Post Office.

Each organisation was requested to formulate a plan to become its part of an overall co-ordinated plan to combat natural disasters. From these the Victorian State Plan was developed.

OUTLINE OF ORGANISATION.

The Chief Commissioner of Police was appointed as Co-ordinator of the State Disaster Plan. To assist the Co-ordinator, a number of Chiefs of Divisions has been appointed. The various divisions include:

Operations,
Police,
Medical,
Equipment,
Transport,
Communications,
Welfare.

The Operations Division in a particular disaster is the authority primarily responsible for combating the disaster. In the case of fire it is the Country Fire Authority, the Forests Commission, or the Metropolitan Fire Brigade; in the case of flood or serious accident, it is the Police Department.

The function of the other divisions is to provide *support* to the Operations Division in combating a disaster. It is specifically intended that the supporting organisations should *not* interfere in any way with the normal responsibilities of the operating authority.

The Communications Division is the responsibility of the Post Office and its main tasks are:

(i) Co-ordinating the communications of all authorities involved in the operations;
(ii) Providing the additional communications required for the efficient co-ordination of the operation.

The initial concept of the Plan was based largely around a disaster within the metropolitan area of Melbourne or the outer metropolitan area, such that the support assistance would come from the considerable resources of the metropolitan area.

The Plan visualises the need to deal with disasters of varying degrees of seriousness. These are classified as follows:

Stage 1.—Minor disasters which do not require special co-ordination of assistance and are dealt with by the appropriate authorities, e.g., motor car accidents (Police) and building fires (Fire Brigade).

Stage 2.—More serious disasters which can be dealt with by co-ordinated action at a local level, without the need for assistance from beyond the local area.

Stage 3.—Serious disasters which cannot be handled at the local level and for which major assistance is required.

Under Stage 2 disaster conditions a headquarters designated the Disaster Area headquarters is established. At this headquarters there is a senior Police officer acting as Co-ordinator, a senior officer of the operating authority in charge of combating the disaster, and representatives of the participating supporting divisions, including always a representative of the Post Office.

In this case requests for support assistance are arranged through the Police Co-ordinator by the local representatives.

When the disaster extends to the point where it is beyond the resources of the local area, the Police Commissioner declares it a Stage 3 disaster. A Co-ordination H.Q. is then established at Police H.Q. in Melbourne. This headquarters is staffed by Liaison Officers appointed by each of the Divisions involved in the co-ordinated operation. Requests for assistance are transmitted to Co-ordination H.Q. from the Disaster Area H.Q., and the appropriate Liaison Officer arranges the required assistance.

If necessary, an Assembly Area is established in one of the outer suburbs of Melbourne, where support such as volunteer fire fighters and additional equipment is assembled and directed into the disaster area. This is to avoid large numbers of uncontrolled groups travelling into the disaster area having difficulty in reaching the correct location and producing traffic congestion.

COMMUNICATIONS.

Adequate communications are essential for a combined operation of this type. The Communications Division (Post Office) provides a network of direct land lines between the various headquarters for the co-ordination of the combined operation. The exact arrangement depends on the particular circumstances applying in the disaster, but Fig. 1 represents the communication diagram intended for use in a Stage 3 disaster on the outskirts of Melbourne. The Police Department also establishes radio telephone links between Co-ordination H.Q., Assembly Area and Disaster H.Q.

Because of the importance of adequate land line communication the State Disaster Plan requires that headquarters locations are selected always in consultation with the local Divisional Engineer.

Forward of Disaster Area H.Q. generally mobile radio communication is used by the Police, the operating authorities such as the Country Fire Authority (C.F.A.) and Forests Commission.

Often there is a deficiency in the communications of one of the participating organisations which can best be satisfied by radio. To help overcome these deficiencies, the Post Office has been offered assistance by the W.I.A. and the R.A.C.V.

W.I.A. has formed its own emergency organisation entitled Wireless Institute Civil Emergency Network (W.I.C.E.N.). W.I.C.E.N. operates specifically under the control of the Post Office. It comprises a group of well-disciplined radio amateurs who provide and maintain their own equipment. They are able to provide a very wide range of communication facilities, from a local network of mobile services to long distance point to point links.

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* Mr. Hosking is Supervising Engineer, Country Branch, Victoria.

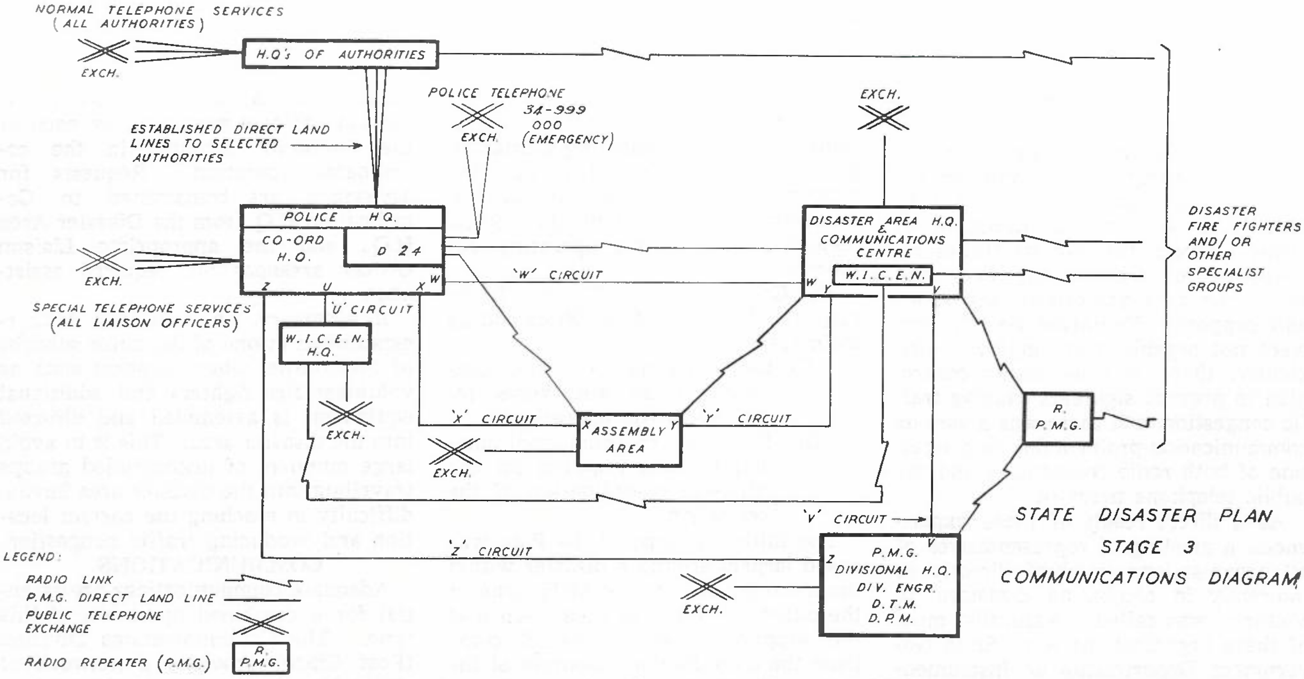

Fig. 1 — Communication Diagram for Stage 3 Disaster on Outskirts of Melbourne.

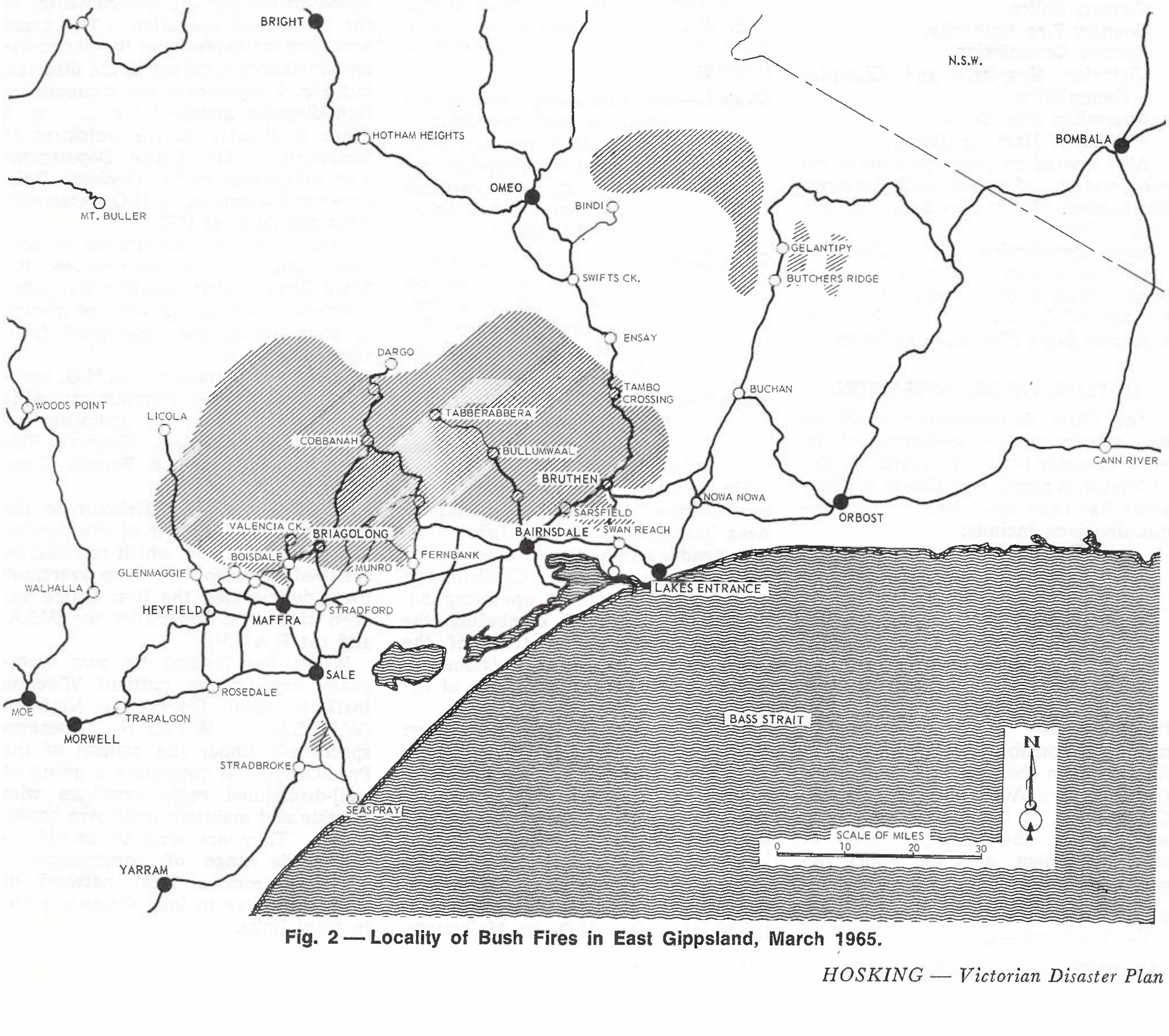

Fig. 2 — Locality of Bush Fires in East Gippsland, March 1965.

The R.A.C.V. has a number of patrol vehicles equipped with two-way radio which they will make available during emergencies at a request from the Post Office. They have their own mobile base stations and portable aerial mast, so they can establish a network in any area. Being skilled mechanics the R.A.C.V. patrol men are able to fill a dual role in emergencies.

The Department has strongly advocated direct land line telephone communication for co-ordination and control purposes in emergencies, whilst recognising the place for mobile radio telephone communication. Radio communication is most suitable and in fact the only practicable means of communication in forward areas in fire fighting where units in communication are on the move. However, from main headquarters, which are reasonably fixed, rearwards, direct land line telephone links offer the most reliable and convenient communication, without the problem of interference or congestion which can be experienced with radio and without the problem of congestion which could be encountered on the public telephone network.

THE PLAN IN ACTION.

The first test of the State Disaster plan came in Feb. - March 1965, when serious bushfires developed in the forests of East Gippsland and threatened the townships to the south of the forest areas. These fires remained a serious threat for a period of nearly three weeks until rain finally put them out. The locality of these fires is shown in Fig. 2 with the areas affected by fires shaded. During this time the fires were fought by fire fighting crews brought from all areas of the State by the C.F.A. and the Forests Commission, and by Army units and State Electricity Commission fire protection units from the nearby Latrobe Valley.

The fire fighting operations were co-ordinated and supported from headquarters firstly at Lucknow, near Bairnsdale, and then later at Bruthen, further to the east. The Police and Post Office were actively engaged in the support operations. A comprehensive network of direct telephone lines was provided between the main headquarters and the many sector headquarters nearer the fire fronts. Direct lines were also provided from the field headquarters back to police headquarters in Melbourne, and to C.F.A headquarters in Melbourne. (See Fig. 3.)

The fires, which spread over a large area, on a number of occasions and in many places threatened, and in some instances interrupted, the Post Office aerial trunk routes. The district lines staff were, however, mobilised for instant action and as a result no major route was completely interrupted for more than three hours, although two minor routes were out of order for longer periods because fires made it unsafe to enter the area early.

Nevertheless, to guard against the possibility of major and long-term interruption to some of the more remote localities, the W.I.C.E.N. was asked to provide radio links to these localities. W.I.C.E.N. mobile units were also used to assist in fire spotting for the fire fighting authorities.

The R.A.C.V. also provided a number of patrol vehicles with mobile radio and with their own base station. These vehicles patrolled the roads carrying out emergency mechanical repairs to fire fighting vehicles and at the same time radioing back advice to headquarters of locations where residual fires were menacing poles on the trunk routes, thus enabling prompt action to protect these routes. They were also used to pass messages between the fire headquarters and important outposts where normal land line communication was not readily provided.

REGIONAL FIRE CO-ORDINATING COMMITTEES.

There is no doubt that the application of the principles of the State Disaster Plan played a major part in preventing a tragedy in East Gippsland in 1965. However, although no lives were lost, considerable property damage was done and the State Government called a conference of all organisations to consider what action

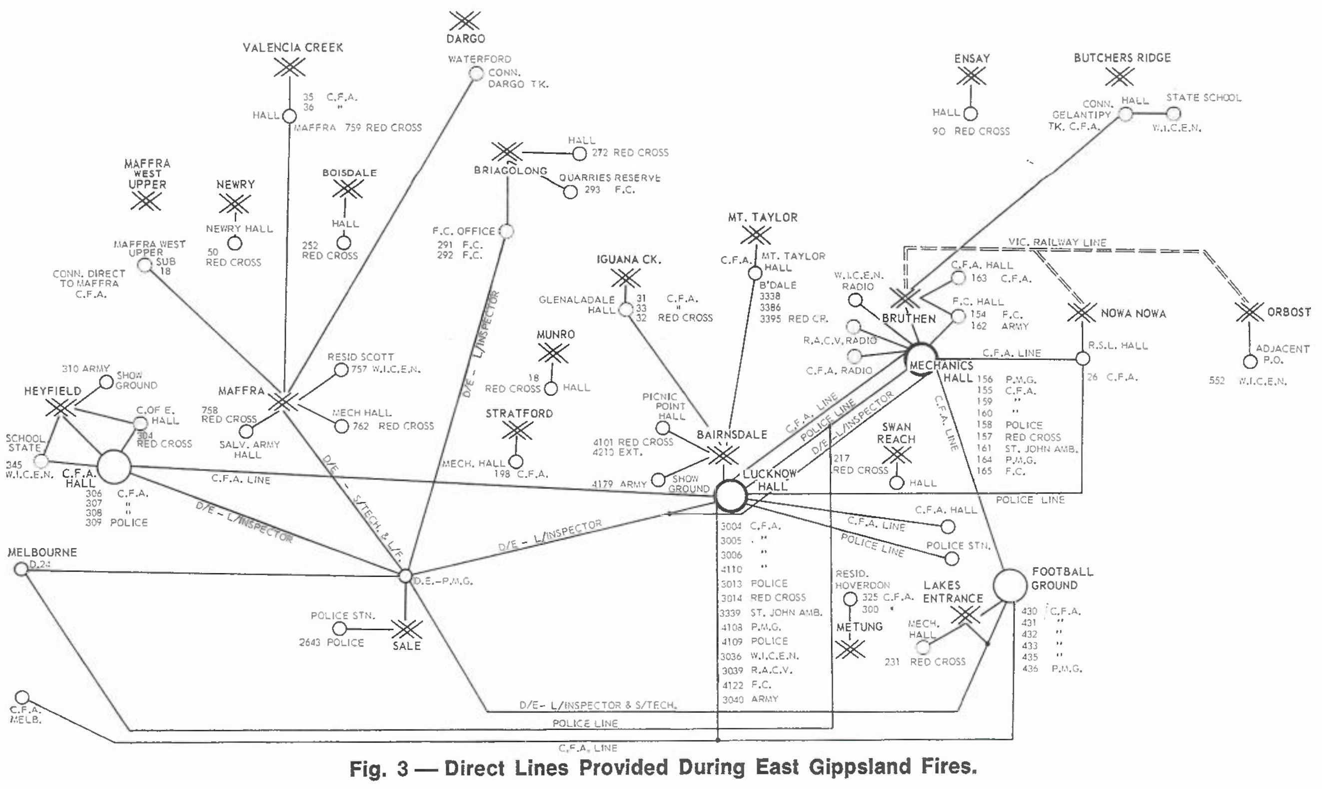

Fig. 3 — Direct Lines Provided During East Gippsland Fires.

was required to further improve the organisation for preventing the development of major bushfires and for suppressing the fires that do occur.

One important result of this conference was that the Post Office undertook to investigate the radio communication requirements of the Rural Fire Brigades and to advise on the best means of satisfying these requirements. This investigation and the recommendations are not appropriate to this article.

The other important decision of this conference was that the State Disaster Plan should be supplemented by the establishment of Regional Fire Co-ordinating Committees. These committees have been set up in each Country Fire Authority Region (which was mutually agreed upon as the most convenient unit) and comprise representatives of the following organisations:

- Police,
- Country Fire Authority,
- Forests Commission,
- Post Office,
- Rural Fire Brigades' Association*,
- Urban Fire Brigades' Assocation*.

*These Associations represent the volunteer fire fighters.

The representatives are senior officers of these organisations, with executive authority in their areas so that the committees can be really effective.

The functions of the committees are to pre-plan and provide support in fire prevention and suppression operations and to act as a regional co-ordinating committee within the State Disaster Plan in respect of fire emergencies. The Police representative on the Committee is the Regional Co-ordinator.

The Post Office representative is the Divisional Engineer for the area concerned. These committees have been most valuable from the point of view of the Post Office's involvement in the State Disaster Plan, as Divisional Engineers have been able to have probable disaster areas or operational headquarters pre-selected and have over a period been able to take advantage of any opportunity to pre-wire these headquarters, or at least plan the provision of telephone facilities so that in an emergency there will be no delay in their provision.

Apart from the actual pre-planning performed by these Committees, they have been extremely valuable in that they have brought together in relatively close relationship the people in the area mainly concerned with combating bushfires. The personal relationships thus established are of inestimable value in dealing with emergency situations.

The Post Office has established the means of rapidly providing the land line communications required under disaster situations. At the Melbourne Trunk Terminal a patch panel has been set up with access to trunk lines to all parts of the State, to the junction network of the metropolitan area and to a number of lines terminating on magneto telephones at Police headquarters, Country Fire Authority headquarters, and at Forests Commission headquarters. In most country areas and particularly in the areas most subject to bushfires, public halls and other suitable buildings determined by the local Regional Fire Co-ordinating Committee, as likely to be used as field headquarters, have been pre-wired and action taken to ensure the availability of adequate cable pairs.

Thus when a landline is required between a field headquarters established in a pre-selected building and one of the Melbourne headquarters, the land line can be installed within a minimum space of time.

Since the Gippsland fires in 1965 all bushfires in Victoria beyond the capacity of local brigades have been brought under control from field headquarters, which co-ordinate the brigades brought in from other parts of the State. A field headquarters is controlled by a Senior C.F.A. officer working with the local Police Co-ordinator, who arranges and co-ordinates the locally provided support to the fire fighting forces. Normally land lines are provided between the field headquarters and C.F.A. headquarters in Melbourne, and sometimes Forests Commission or Police H.Q. in Melbourne, in addition to lines between key local offices.

The establishment of the Co-ordination Headquarters at Police H.Q. in Melbourne to arrange and co-ordinate support from the metropolitan area has not been necessary during this period even during the potentially dangerous fires which occurred in the near metropolitan Dandenong Ranges early in 1968.

CONCLUSION.

The Victorian State Disaster Plan has successfully achieved close co-operation along mutually acceptable lines between organisations whose interests are normally quite varied, so that the means of controlling disasters can be pre-planned and executed in the most effective manner. The bushfires which have occurred in Victoria since 1962 have, it is believed, been prevented from assuming disaster proportions only because of effectiveness of this Plan.

The Post Office in Victoria has played an active role in the development of the Plan and willingly participates in its operation because of its appreciation of its responsibility to assist in the protection of the community in general, and also because of concern for the security of its own staff, property and plant.

MELBOURNE-KYNETON COAXIAL CABLE TRANSISTORISED LINE EQUIPMENT

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

INTRODUCTION

The completion of the Melbourne-Kyneton coaxial cable system marks the first stage in the provision of an important broadband route in the Australian trunk network. Existing and proposed coaxial cable routes in Victoria as at 1968 are shown in Fig. 1. A 4 tube coaxial cable of 0.375 ins. internal diameter has been laid between Melbourne and Kyneton and extension of this cable to Castlemaine and Bendigo will take place during 1969 with further extension to Echuca in 1970/71. The completion of the first stage of this broadband route to Kyneton was necessary to provide sufficient trunk channels for S.T.D. and operator use required at the cut-over of Kyneton Automatic telephone network in September, 1968. Extension to Bendigo will provide the required Castlemaine-Melbourne trunk relief and a completely independent alternate broadband route to Bendigo and Ballarat from Melbourne. Future alternate routing from Melbourne to Adelaide via Mildura and to Sydney via Echuca will be provided on this coaxial cable broadband route.

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This article describes the line equipment installed on the Melbourne-Kyneton coaxial cable broadband route. This equipment is the first fully transistorised system of German manufacture to be installed in Australia using temperature controlled level regulation of underground repeaters. The advent of this transistorised equipment has introduced new techniques for accommodating the dependent power fed repeaters in sealed metal containers located underground in manholes. Economical advantages gained from installing transistorised line equipment result from reduced initial capital costs, less space for equipment accommodation and considerably lower annual maintenance charges. The development of transistorised amplifiers has also led to the adoption of new techniques in power feeding, level control and supervision.

The carrier transmission equipment was supplied by Siemens Industries Ltd., and installation and lineup has been completed by the Australian Post Office. Expert assistance in lineup of the equipment has been provided to the A.P.O. staff by a Company Engineer.

By using transistors in lieu of valves, only one supply voltage is required and a simple method of series feeding direct current power to the amplifiers of the coaxial repeater equipment is possible. This has reduced the number and size of components in the intermediate repeaters to such an extent that the repeaters, including power supply, supervisory and pilot equipment, for both directions of transmission, can be accommodated in a small container of about half a cubic foot in volume.

Siemens have developed underground repeaters of uniform construction for the full range of coaxial high frequency bearers for 300 channels (60-1300kHz), 960 channels (60-4028kHz) and 2700 channels (300-12,000kHz). As all repeaters are of the same physical size, it is a simple matter to increase the channel capacity on a route by adding an extra repeater with a wider bandwidth in the middle of each repeater section and changing the existing repeater for one with the wider bandwidth. Thus, by halving the repeater section length, the system bandwidth and hence channel capacity is tripled approximately in three possible stages.

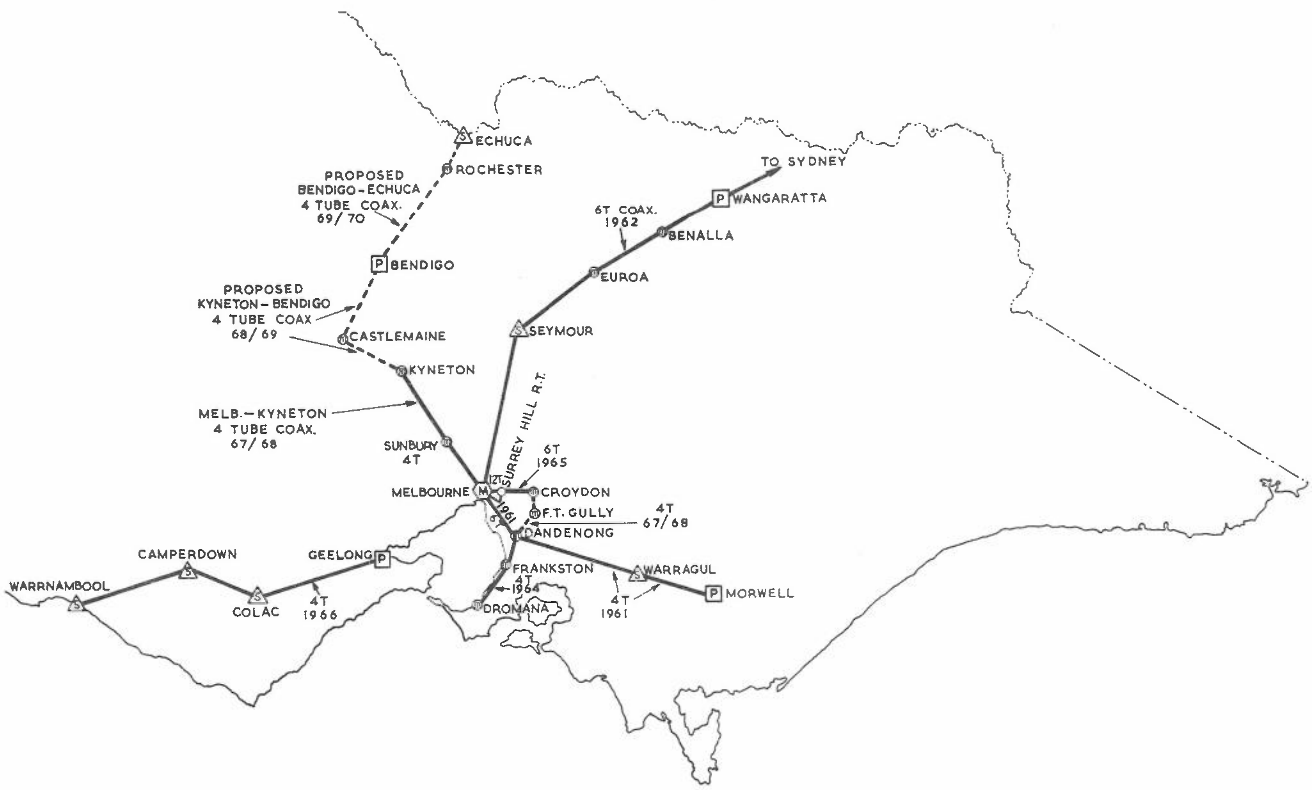


Fig. 1 — Existing and Proposed Coaxial Cable Routes in Victoria, 1968.

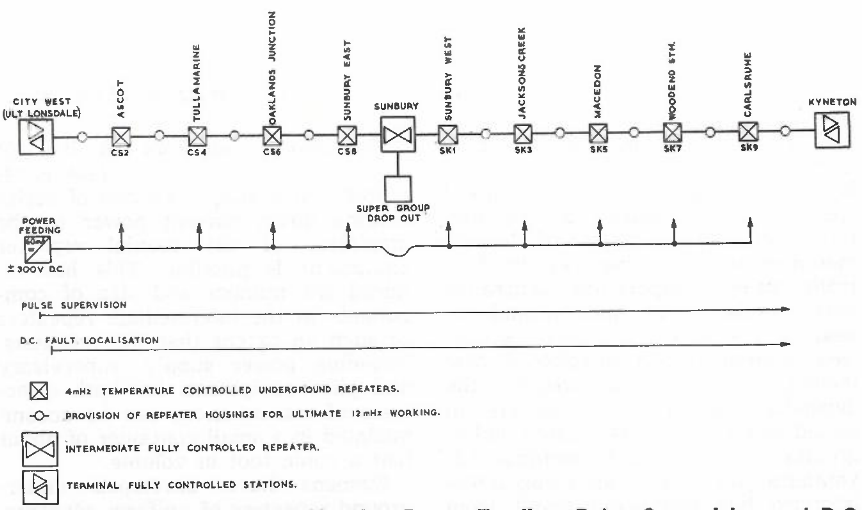


Fig. 2 — Repeater Location Showing Power Feeding, Pulse Supervision and D.C. Fault Localisation.

ROUTE LAYOUT

Fig. 2 shows the layout of the repeater equipment and associated power feeding and supervision of the Melbourne-Kyneton coaxial cable route. This route has been laid out and external plant provided for future 12MHz systems of 2,700 channel capacity by providing repeater housings at nominal spacings of 5,000 yards with a tolerance of ±75 yards. Initially, repeaters of 4MHz bandwidth for a 960 channel system have been installed in each alternate repeater housing, providing a repeater section of nominal length 10,000 yards. Four underground repeaters have been provided between the terminal at City West and the main dropout repeater station at Sunbury, with a further five repeaters between Sunbury and Kyneton. The repeater points adjacent to Sunbury on either side are both 4 and 12MHz amplifying points. For the 4MHz line equipment the short cable section length is compensated by adjustable building-out units located on the line amplifier rack at Sunbury.

The development of a 4 tube coaxial route such as this Melbourne to Kyneton and Bendigo route, is envisaged to be:

(a) Equip tubes 1 and 2 with repeaters for a 4MHz system (960 channels) at the outset;
(b) two years before this initial capacity is absorbed equip tubes 3 and 4 for a 12MHz system (2,700 channels) and recover the 4MHz system from tubes 1 and 2;
(c) two years before the 2,700 channel capacity is absorbed equip tubes 1 and 2 with a 12MHz system.

By this means the line system starts off with 960 channels capacity and is capable of 6-fold increase to 5400 channels before major works for augmentation of the route are necessary. Of course, it is possible that by the time this expected development of the line system is completed, advances in technique will have introduced new concepts in line transmission.

As shown in Fig. 2 the remote power feeding unit is located at City West, and power is fed to all underground repeaters as far as the repeater nearest to Kyneton. The power feeding by-passes Sunbury, and the line amplifier and channelling equipment at Sunbury repeater station is powered locally from the station 50 volt battery installation. The remote power feeding is by direct current of 60 milliamps constant current regulated, and is fed over a loop consisting of the inner conductors of the coaxial tubes which are used for the carrier transmission path.

The pulse supervision and d.c. fault location provided with this Melbourne-Kyneton system are new techniques to our coaxial cable routes, and must be carried out from the remote power feeding station. The testing distance coincides with the power feeding section.

Further details of these techniques will be described later in this article.

GENERAL DESCRIPTION

A coaxial cable system may be considered in two main categories; namely the 'Line Equipment' which is associated with the coaxial tubes over the whole route to form a bearer circuit of large bandwidth, and 'Multiplex' equipment at the terminal and intermediate dropout stations which assembles the VF speech channels into appropriate form for transmission over the broadband circuit.

The 'Multiplex' (F.D.M.) equipment comprises a series of modulation stages to form a line frequency band to a scheme recommended by the C.C.I.T.T. The modulation stages are:

(a) Channel Modulation, which produces 12-channel basic groups in the frequency band 60-108kHz,
(b) Group Modulation, where a basic supergroup of 60 channels is formed in the frequency band of 312-552kHz from five basic groups and
(c) Supergroup Modulation, where 16 basic supergroups are translated into a V960 line frequency band of 60-4028kHz. The frequency plan of the Siemens V960 transistorised line system is shown in Fig. 3. Also shown in Fig. 3 are the line pilots of 4287 and 60kHz; the main regulating pilot 4287kHz is always provided while the 60kHz regulating pilot is required only for routes having more than 20 unattended repeaters. The 60kHz pilot may be used also for frequency comparison along the route. The fault locating signal of 4660kHz lies above the line frequency band to allow

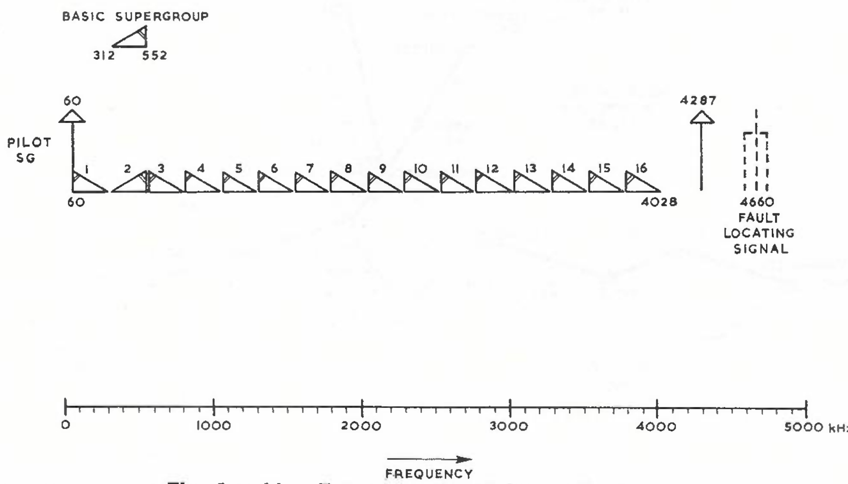


Fig. 3 — Line Frequency Allocation V960 System.

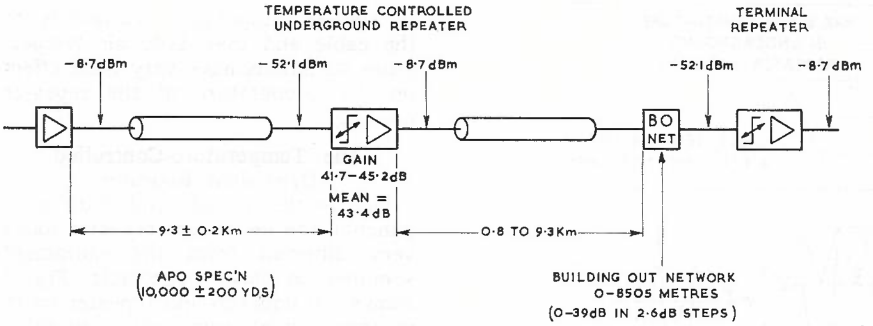


Fig. 4 — Repeater Section Design for German Type Temperature Controlled Underground Repeaters.

measurements on a working system without interference to the transmission path.

LINE EQUIPMENT

The basic function of the line equipment is to provide amplification and equalisation to compensate for the attenuation of the cable as closely as possible. Repeaters are inserted at regular distances along the route to recoup the cable attenuation losses, and enable satisfactory channel noise standards to be achieved.

Basic thermal noise and intermodulation noise together with the power handling capacity of the repeaters are the determining factors in the design of repeater section lengths and associated line amplifiers. For a desired signal-to-noise ratio the signal input to the amplifier cannot be allowed to fall below a minimum level. Therefore the transmitting level of the system is one important consideration in obtaining the signal-to-noise ratio required for a coaxial cable system. The transmitting level must be adjusted taking the repeater section loss into account to ensure that the desired signal input voltage is produced at the input of the succeeding line amplifier. There is an irreducible noise power associated with a particular transmission bandwidth, and the signal arriving at a repeater must not be allowed to approach this level within the desired signal-to-noise ratio. Certain values of transmitted level and signal-to-noise ratios are required for different repeater spacings, and a curve can be prepared which shows an area where results near the optimum can be obtained. Operation outside this area requires uneconomic power handling ability, or impossible noise and intermodulation performance.

As shown in Fig. 4 the nominal repeater section required for the German designed amplifiers installed on the Melbourne-Kyneton route is 9.3 ±0.2 kilometers based on a mean cable temperature of 10 degrees C (which gives an attenuation of 43.4 dB for the highest transmission frequency of 4028kHz). This is slightly more than the A.P.O. nominal length of 10,000 yards (9.144km), but this is compensated in the adjustment tolerance in the underground repeaters. Also, as the A.P.O. nominal length is based on a mean cable temperature of 15 degrees C, the nominal repeater section length at this temperature would be reduced by 1%, which gives a length of approximately 9.2km. The nominal input and output levels of the amplifier are — 52.1dBm and — 8.7dBm at the highest transmitted traffic frequency.

The attenuation of a coaxial cable rises with the square root of the frequency. It depends not only on the length of the line and frequency but also on the cable temperature. The variations in attenuation induced by temperature changes amount to 0.2% per degree C, and act upon the attenuation in the same manner as variations in cable length. Coaxial cable systems with many repeaters in tandem require automatic regulation of gain to compensate for the variation of attenuation due to temperature change. Each amplifier is designed to have an equalising characteristic to compensate as closely as possible for a standard repeater length section, the repeater having a small range of adjustment to make the actual section length equal to the standard length at some standard temperature.

Regulation of the signal levels at all frequencies is also necessary to maintain the repeater output within a small range, since excessive thermal noise results if the level drops too low, and non-linear distortion products cause noise if the level rises too high and overloads the amplifiers.

Temperature Control of Underground Repeaters

In these transistorised dependent repeaters, a simple method of level stabilisation has been adopted. The ambient temperature of the repeater directly controls the gain via a temperature dependent resistance connected in the equaliser circuit of the feedback path in the repeater, providing effective automatic level control.

The accuracy of the temperature control action depends upon how closely the repeater temperature follows the cable temperature of the preceding cable section. Underground cables are subject to the same temperature variations as the surrounding soil and, as the temperature rises, the line attenuation increases. Similarly the line attenuation decreases as the temperature falls. Therefore, if repeaters can be accommodated underground at the same depth as the cables and isolated from the influence of external temperature, the repeater will follow the temperature variations of the cable.

Fig. 5 shows the yearly variations of soil temperature at a depth of 4 feet—these readings are the averages of readings taken in Melbourne by the Bureau of Meteorology, over a period of 80 years. During the course of a year the soil temperature varies in a

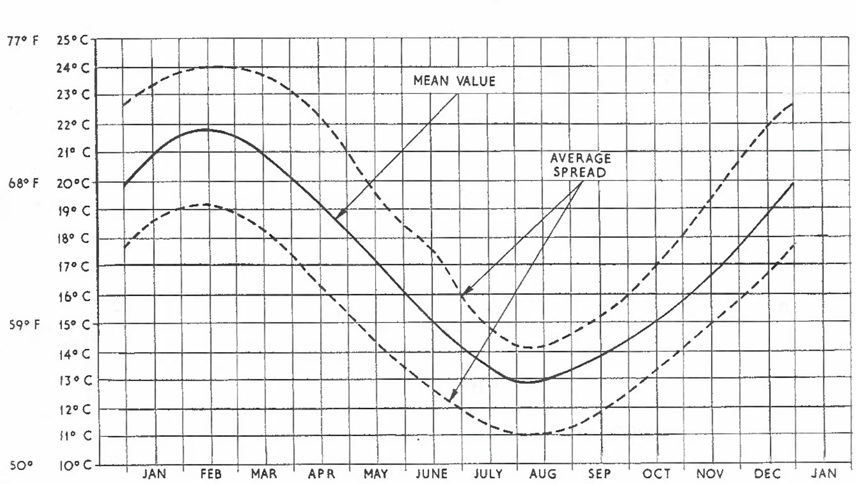


Fig. 5 — Yearly Variation of Soil Temperature at a Depth of Four Feet in Melbourne Area.

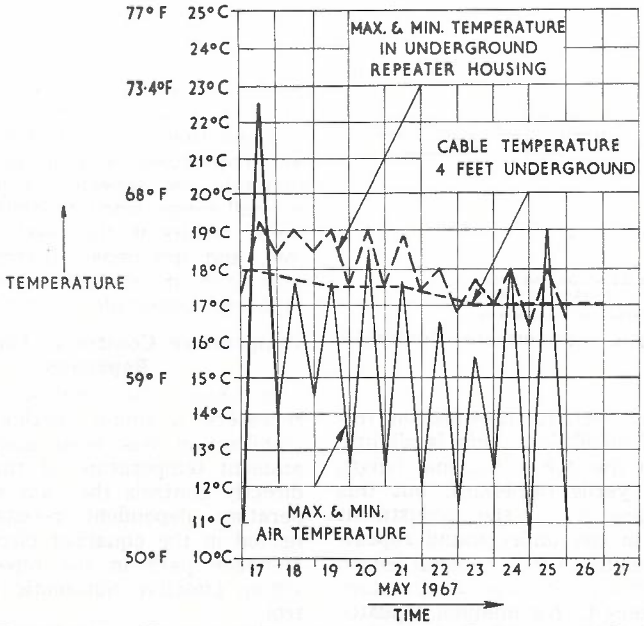


Fig. 6 — Temperature Measurements at a Typical Underground Repeater Site near Melbourne.

cycle about a mean value of approximately 17 degrees C. Below about 3 feet, the temperature is substantially independent of daily air temperature variations, and the temperature is primarily determined by the yearly climatic cycle. The maximum mean temperature is approximately 22 degrees C (72 degrees F) and occurs about mid-February, while the minimum temperature is approximately 13 degrees C (55 degrees F) and occurs early in August.

The temperature underground at a depth of approximately 3 feet lags behind the average surface temperature by about 2 weeks. Also, at a depth greater than 3 feet the temperature at a given point differs by not more than one or two degrees from the temperature occurring at a considerable distance away at the same depth in about the same type of soil; this means that the temperature variations at the repeater site are representative of the temperature variations over the preceding repeater section of approx. 5.6 miles.

This curve also represents the attenuation change of the coaxial cable route over a period of a year. The cable temperature coefficient as previously stated is 0.2% per degree C. For the Melbourne-Kyneton route which is approx. 55 miles in length the annual attenuation variation at 4028kHz for temperature variation shown by the curve would be approx. 8.3dB.

Fig. 6 shows the temperature measurements taken at an experimental underground repeater station set up at Fishermen's Bend Line Depot in May, 1967. It will be noted that the daily temperature variation of the cable buried 4 feet underground is very small. In this test the temperature in the underground repeater housing which included a dissipation of two watts of power to simulate a repeater power drain followed the cable temperature within approx. 1 degree C. This shows that repeaters accommodated underground at the same depth as the cable are exposed to similar temperature variations to the cable and that daily air temperature variations have very little effect on the temperature of the repeater housings.

The Temperature-Controlled Dependent Repeater

Due to the use of solid state components, the dependent repeater looks very different from the equipment supplied on earlier contracts. Fig. 7 shows the underground repeater (with external cover removed) containing the amplifiers for both directions of transmission along with facilities for the temperature or pilot control of gain and for overall route supervision.

A schematic diagram of the repeater equipment is shown in Fig. 8. The main elements are the power filters, the transistorised amplifiers, power supply unit, d.c. fault location switching unit and by-path band-pass filter for the high frequency fault location pulses. The power filters are located at the input and output of each direction of transmission to separate the d.c. power feeding from the transmission path. The line amplifier is connected between the high-pass ends of the power separating filters, while the d.c. power feeding path is connected via a resistor, and reversed biased zener diode combination between the low pass sections of the power separating filters. The zener diode has a breakdown voltage exceeding the line amplifier working voltage; normally all the regulated direct current flows through resistors

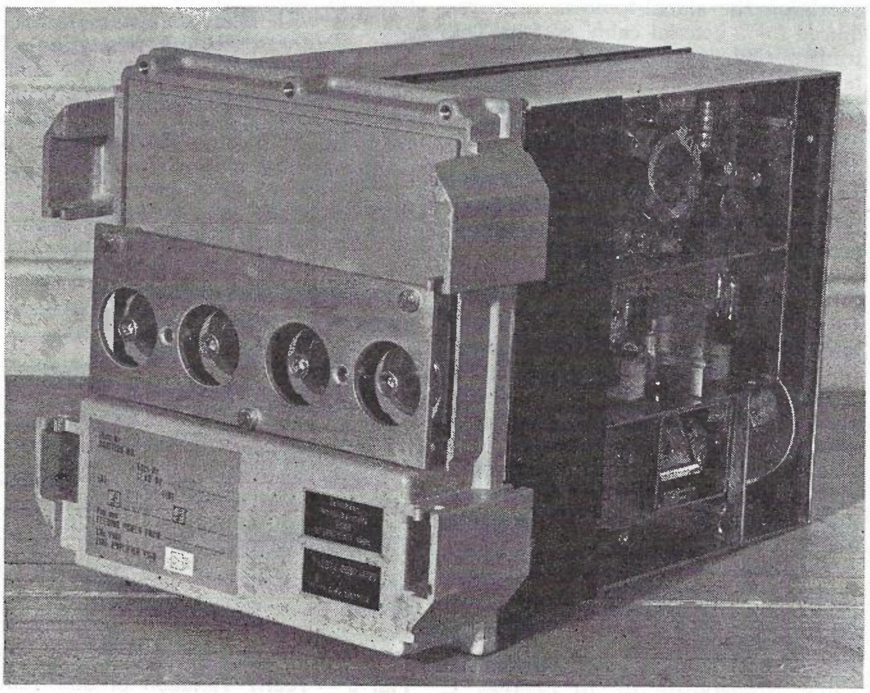


Fig. 7 — Underground Repeater with External Cover Removed.

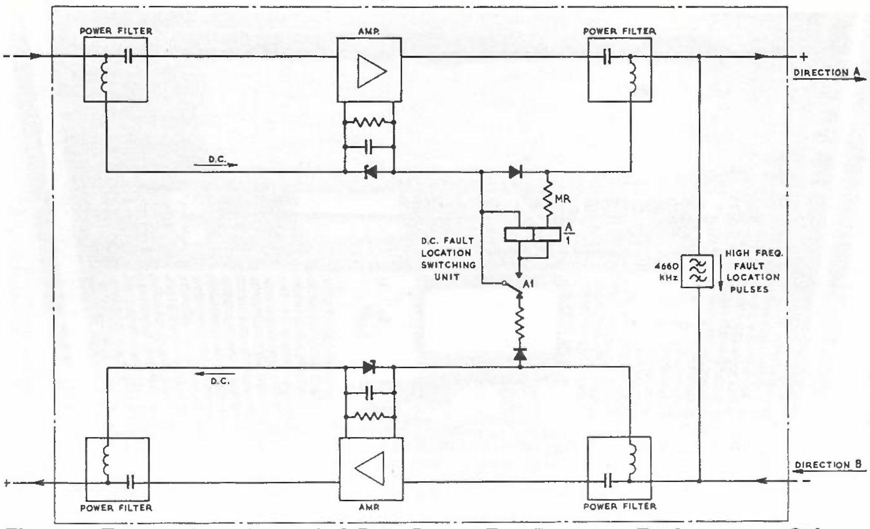


Fig. 8 — Temperature Controlled D.C. Power Fed Repeater Equipment — Schematic.

in the line amplifier to develop the voltages required. The main function of the zener diode is to provide, due to its limiting action, protection to the amplifier should large interference voltages occur on the route. The capacitor in parallel with the zener diode acts as a bypass to a.c. currents that may be superimposed on the feeding current and so prevents hum modulation from occurring.

The amplifier comprises three transistor stages with common emitter connection and overall feedback which ensures the desired stability and linearity of the gain required for low intermodulation noise. At the input and output of the repeater the principle of mixed current/voltage feedback is employed with the aid of transformers. The input and output impedances are thus matched to the characteristic impedance of the coaxial cable. Long term variations of transistor characteristics have negligible influence on gain or impedance matching due to the large amount of negative feedback applied.

The feedback path includes an equalising network which ensures that the frequency response of the gain of the amplifier is exactly equal to the frequency response of the cable attenuation. This equalising network includes a contactless variable resistance to provide for manual adjustment for the tolerances in repeater section cable lengths up to ± 200 meters and automatic correction for attenuation variations in the repeater section due to cable temperature changes. The automatic correction of gain is necessary as previously explained because the cable attenuation at a depth greater than 3 feet varies gradually over the period of a year in the order of up to ± 10 degrees C from the mean temperature and causes a change in cable attenuation of approx. ± 0.9dB at 4028kHz per repeater section.

The contactless variable resistance is a novel component in the form of a magnetic-flux-dependent resistor which consists of a semi-conducting material indium antimonide with additions of nickel antimonide; it has an extremely high charge mobility so that its resistance can be varied considerably by the influence of a magnetic field. The resistance is independent of the polarity of the magnetic field applied, which may be a permanent magnet or an electro-magnet. Fig. 9 shows the setting mechanism embodying the flux-dependent resistor.

The flux-dependent-resistance is located in a fixed position between the poles of a permanent magnet. By means of screwdriver control the permanent magnet is moved over the flux-dependent resistor, thus varying the magnetic flux density which penetrates the resistor, and thereby varying its resistance. By this means the gain of the amplifier is adjusted to match the attenuation of the repeater section.

A second and important characteristic of the flux-dependent-resistor is that its resistance also varies with temperature, and by predetermined doping of the material, the resistance can be given a temperature dependence providing exact temperature control of gain for each position in the setting range of the permanent magnet, and thereby controlling the gain as a function of the temperature of the surrounding soil.

The placement of the setting mechanism in the repeater assembly is shown in Fig. 9. In pilot controlled repeaters, this unit is not provided, and the space is used to accommodate the pilot pick off filter and pilot receiver. The rectified output from the pilot receiver is used to control a thermistor placed in the equaliser network of the amplifier feedback path in lieu of the magnetic-flux-dependent resistor.

Access to the screwdriver adjustment control for setting the gain of the temperature controlled dependent repeater to match the repeater section length is obtained by removing the outer cover of the repeater. All that is required is to set the control to the known measured length of the re-

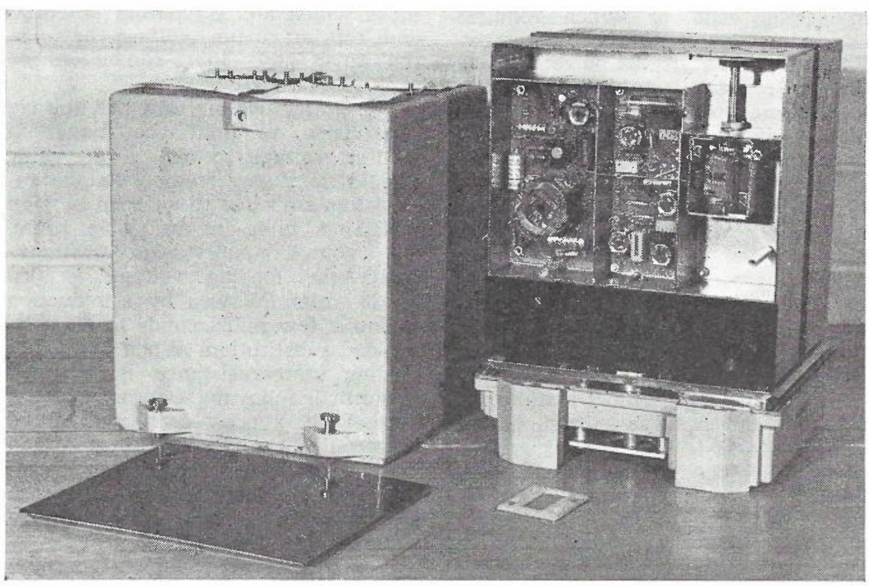


Fig. 9 — Underground Repeater Containing Setting Mechanism with Flux-dependent-Resistor Shown at Right Hand Side.

peater section, shown in kilometers on the adjustment control scale.

POWER FEEDING

With valve operated coaxial line equipment the most reliable way of feeding dependent repeaters is to transmit high voltage a.c. from a terminal or intermediate main repeater station over the inner conductors of the coaxial cable thus forming a single phase a.c. transmission line to feed several dependent repeaters in series over the same conductors used for the two directions of the carrier transmission. At the power feeding station, to ensure continuity of power for the station equipment and remote power feeding, it is necessary to install a 'No-break' a.c. power supply plant which is costly to provide and maintain. At the fed repeater stations the power is drawn from the high voltage a.c. power feeding circuit via a stepdown transformer and fed to a power supply unit which produces the various voltages required for the amplifiers and accessory circuits.

Since the power requirements for transistor amplifiers are much simpler and only a single voltage is required, it is possible to use series fed d.c. power. Remote power feeding by d.c. greatly simplifies the dependent repeaters as special supply circuitry is not required other than the usual power separation filters.

The d.c. remote power feeding consists of 60 milliamp constant current and is arranged over a loop consisting of the inner conductors of the two coaxial tubes which are used for the carrier transmission path. Up to a maximum of 12 repeaters may be fed in series, each of which requires approximately 2 watts of power. Referring to Fig. 8, the power feeding d.c. is separated from the carrier transmission path by high pass filters at the input and output of each underground repeater and taken via a resistor and zener diode combination to develop the voltage required for the repeater transistors. The last fed repeater is a special repeater which has a d.c. connection between the inner conductors of the coaxial tubes used for the two directions of transmission to complete the d.c. power feeding loop.

At the power feeding station the negative and positive output of the remote power feeding unit is applied to the inner conductors of the coaxial tubes via power separating filters installed at the top of the line amplifier rack.

Fig. 10 shows the remote power feeding slide-in chassis which is located on the line amplifier rack. The input power supply to this unit is taken from the 48 volt exchange battery and the output produced is 60mA regulated to ± 2%. This output is maintained irrespective of the load connected within a range of resistance of 500 to 10,000 ohms, and varies between 30 and 600 volts depending on the number of repeaters to be fed. This voltage is balanced with respect to the outer conductors of the coaxial tubes which are at floating potential and the maximum voltage between the inner and outer conductors of each tube is 300 volts.

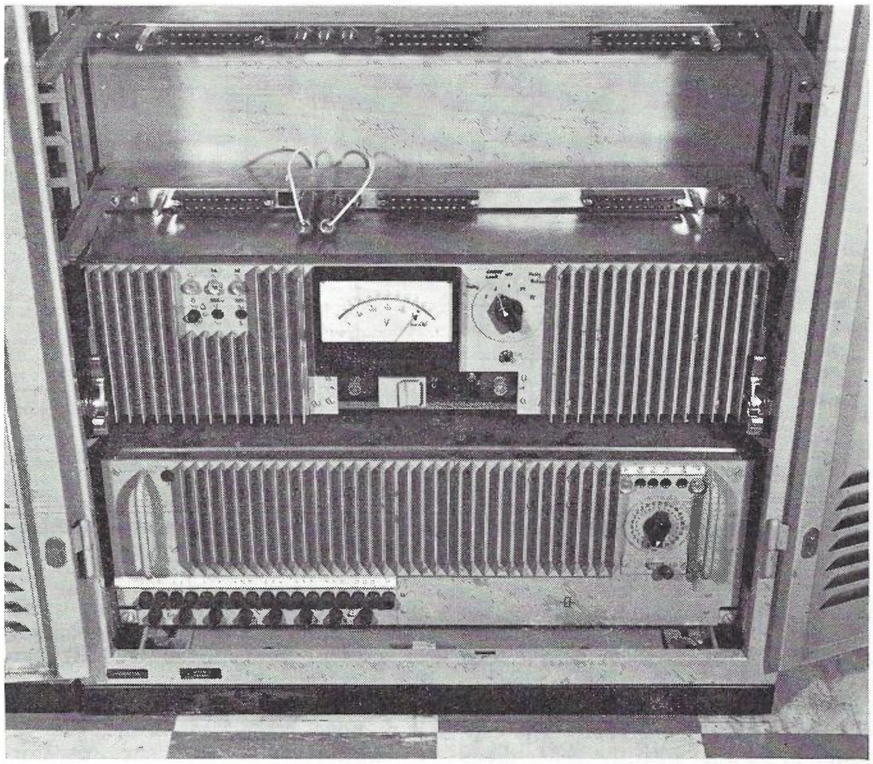


Fig. 10 — Lower Portion of Line Amplifier Rack Showing Remote Power Feeding Slide-in Chassis and Rack Power Supply (At bottom).

The power feeding unit has voltage supervision to limit the maximum feeding voltage to 650 ± 30 volts. Should the power feeding voltage exceed this limit due to an open or high resistance fault in the cable route, the voltage supervision instantly limits the feeding voltage to 650 ± 30 volts followed by a reduction within a few milliseconds to 60 volts by load substitution. When the power feeding loop resistance is returned to normal, following clearance of the cable fault, a relay connected in the power feeding circuit operates and disconnects the substitution load, allowing the feed voltage to return automatically to the normal service value.

A current supervision unit consisting of a magnetic amplifier reactor in the output of the power feeding unit automatically disconnects the power feeding should the output current exceed 20 milliamps above nominal (i.e. 80mA) due to over-voltage input or an internal fault in the power feeding unit. A delay of 500 milliseconds is included in the over-current disconnection to cover the regulation time of the power feeding unit.

The power feeding unit has special features incorporated in the design of the equipment which guards against the possibility of electric shock to staff working on the coaxial cable route, and the precautions necessary at the power feeding station are limited to arranging for the power feed to be disconnected before work is commenced on a coaxial tube associated with the remote power feeding loop.

A selector switch allows the feeding current, output voltage and balance voltages to be read on the meter included on the power feeding slide-in chassis shown in Fig. 10.

FAULT LOCATION

General

The method of housing the dependent repeaters in underground containers raises a number of new maintenance problems and requirements. The repeaters must be practically free from the need for maintenance, but when the need arises speedy location of faults both in the amplifiers and repeater section cable must be

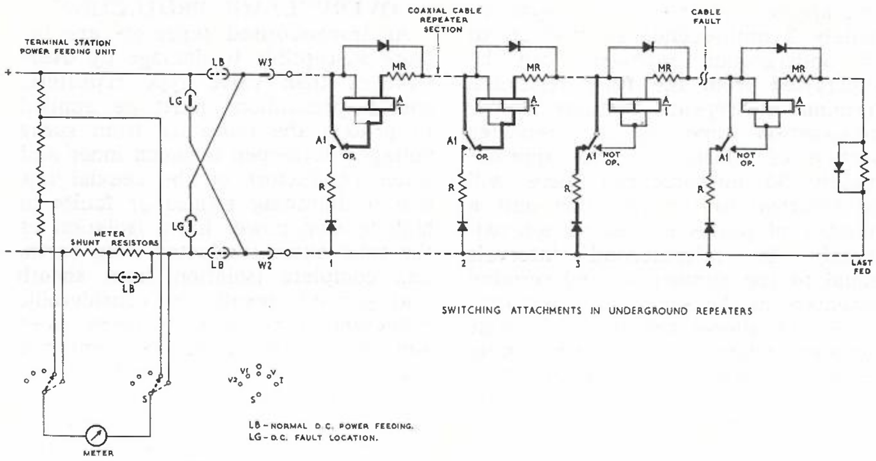


Fig. 11 — D.C. Fault Location Schematic Circuit.

possible. With Siemens type transistorised coaxial line equipment, no alarms are fed from the dependent repeaters to the attended control-station, as with valve operated equipment located in repeater station buildings, and new techniques of fault location have been developed. Fault location is carried out from the power feeding stations and the supervised sections of the coaxial cable route coincide with the power feeding sections.

The occurrence of a fault on the link is indicated by an alarm given by the pilot receivers at the terminal or main repeater stations which allow the Line Control Station to determine the main repeater section in which the fault exists. It is then necessary to locate the fault within this section. Generally the fault will fall into two categories; one where the power feeding is interrupted (e.g., due to a cable fault) and the other where the power feeding current is still flowing (repeater failure). For both categories a special location method is used, the first being by d.c. and the other by a pulse method. The method of fault location can be determined by referring to the meter on the front of the power feeding unit located on the line amplifier rack which feeds the main repeater section containing the fault.

D.C. Fault Location

D.C. fault location is used in the event of a discontinuity in the feeding loop due to a cable break. To locate by d.c. a line interruption, the polarity of the power feeding voltage is reversed by a switching connector provided on the power feeding unit (refer to Fig. 10) and the fault location potential is applied. The details of the d.c. fault location method are shown in Fig. 11.

In each underground repeater up to the repeater immediately preceding the break, the reversed current flows through a relay winding in the switching attachment and a precision resistor MR is placed in the power feeding circuit. In the normal direction of power feeding the relay winding and precision resistor are shunted by a diode.

The zener diodes (refer to Fig. 8) in each repeater due to the reversed polarity now have only a low potential drop which shunts the power supply unit resistors in the repeaters. In the last repeater preceding the break, the diode and resistor complete the power feeding loop via contacts of the unoperated relay. At the other repeaters the contacts of the operated relays open the shunt path. As a constant current is applied for the d.c. fault location test, the resulting output voltage indicated by the meter on the power feeding slide-in chassis is directly proportional to the number of measuring precision resistors put

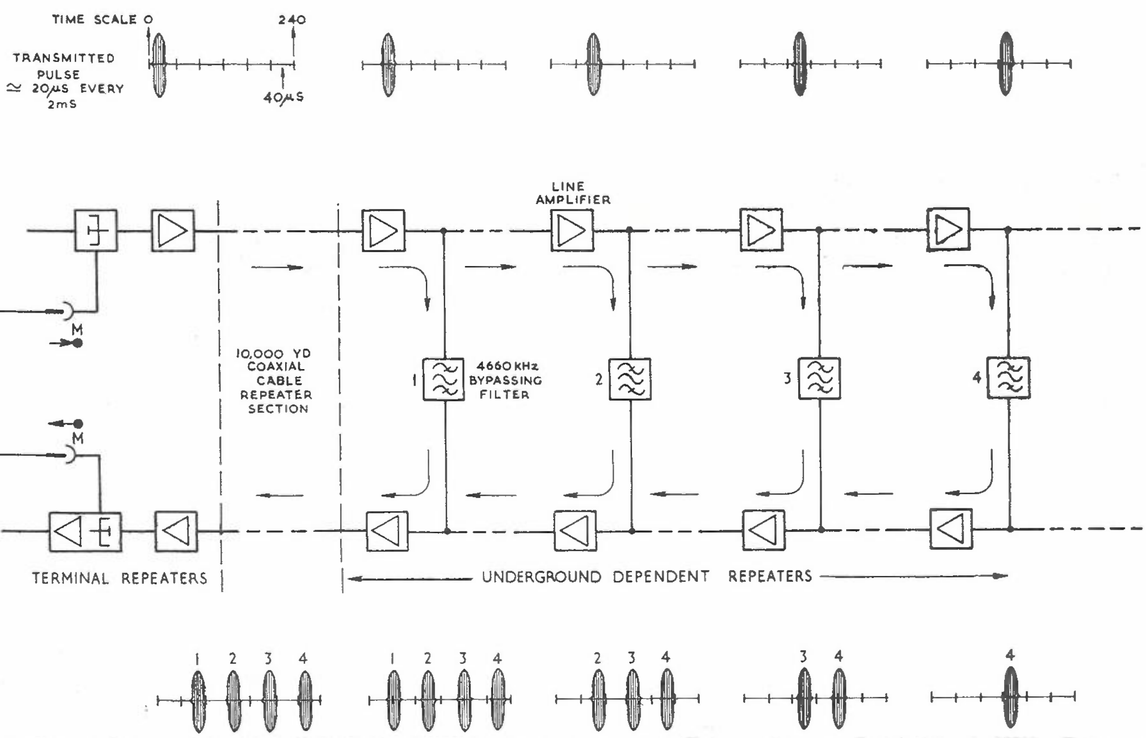


Fig. 12 — Operating Principle of Pulse Teletester Supervisory Pulses over Four Repeater Sections of 4MHz Repeaters.

into circuit. Hence, the number of repeaters ahead of the break can be read directly on the instrument scale shown in Fig. 10. This method of fault location also has the advantage that the correct repeater section will be indicated if the insulation resistance is reduced at the point of discontinuity due to entrance of moisture into the cable.

Pulse Location

If the power feeding current is still in operation, a pulse supervision method can be used to locate a defective repeater. The principle of operation of this method is shown in Fig. 12. Each underground repeater is equipped with a simple by-passing filter. The output of a teletester (pulse fault locator) is connected to the measuring injection jack in the transmit path of the terminal repeater and the input to the teletester is connected to the measuring injection jack in the receive path of the terminal repeater. The teletester sends pulses of carrier frequency of 4660kHz which lies above the line frequency band so that supervisory measurements may be carried out without interrupting the transmission path.

At each underground repeater the pulses are transmitted to line and also injected into the return direction of transmission via the by-passing filter. Due to the different propagation times of the pulses returning via each supervisory by-pass filter of the individual underground repeaters, the pulses appear at the receiver staggered in time so that they can be individually measured. The amplitude of each pulse is representative of the operating condition of the path it has passed and in particular the repeater through which bandpass filter the pulse returns. The pulses are approximately 20 microseconds long and are sent at intervals of approximately 2 milliseconds so that up to 25 underground repeaters can be supervised from the fully regulated terminal and repeater stations. As the propagation time over a repeater section of 10,000 yards is approximately 30 microseconds there will be returned to the receiving unit a number of pulses spaced at approximately 60 microsecond intervals equal to the number of underground repeaters in the supervision section.

Fig. 13 shows the portable pulse teletester which allows each returning pulse to be selected and the amplitude of the pulse displayed as a dB reading on the meter. Three control knobs allow adjustment of a delay network within the unit to select the correct incoming pulse. When commissioning the system the individual settings of these controls are determined and recorded for the pulse representing each repeater.

For recording of repeater section gain over long periods of time a recorder can be connected to the pulse tester unit. This is particularly useful in locating intermittent faults along the cable route. Also the entire pulse sequence can be viewed on an oscilloscope.

A facility on the remote power feeding unit allows the feeding current to be reduced by approximately 20%. By reducing the power feeding current during the pulse supervision measurements, any amplifier which is commencing to deteriorate may be detected, for example, with reduced current gain due to transistor ageing the feedback and stability are reduced and such a repeater would be more susceptible to changes in gain due to power supply changes. Reducing the power feeding current will affect the performance of such a repeater and reveal its deterioration.

OVERVOLTAGE PROTECTION

As transistorised repeaters are far more susceptible to damage by overvoltages than valve type repeaters, special precautions must be applied to protect the repeaters from surge voltages developed between inner and outer conductors of the coaxial line due to lightning strikes or faults in high tension power lines. Isolation of the tube outer conductor from earth, i.e., complete isolation from sheath and ground, results in considerable reduction of potential between inner and outer conductors as compared with the same line under the same surge conditions but with the outer conductor earthed. This is because voltages induced in the cable sheath can only cause interfering currents via the capacitive reactance of the distributed capacitance between the cable sheath and inner conductor through the outer conductor of the coaxial tube. At low frequencies this reactance is high and the voltages and currents appearing at the inner conductor are very low.

Under lightning discharge conditions the reduction of surge voltages with the outer conductor isolated from ground may not be of itself sufficient protection for the transistorised repeaters and under extreme cases breakdown between cable sheath and outer conductor may take place. Therefore it is necessary to design the repeaters to include protection from such overvoltages.

Power separating filters play an important part in the overvoltage protection of a repeater. The attenuation of the separating filters for the transmission path is very high in the frequency range below the line frequency band, i.e., below 60kHz, so that the powerful low frequency portions of a lightning pulse or power induced surge are prevented from

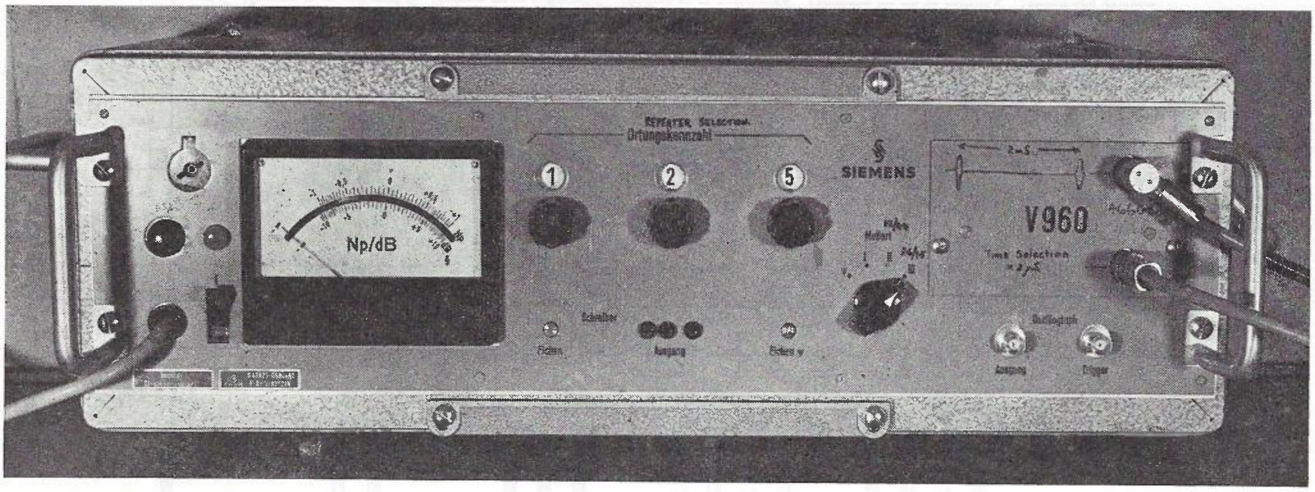


Fig. 13 — Portable Pulse Teletester.

entering the input and output repeaters.

Lightning discharges can also result in very high voltage peaks being induced in the coaxial line with frequency components that fall in the transmission path range, which could pass via the high-pass sections of the power feed filters to the input of the amplifiers, and destroy the transistors if effective overvoltage protection were not provided.

As shown in Fig. 14, to prevent such damage, the power filters contain a coarse protective unit at the coaxial tube input which consists of two overvoltage arrestors connected in parallel, having a static firing voltage of 850 volts. This operate voltage is sufficiently high so that the normal power feeding voltage does not operate the arrestors. These arrestors absorb most of the energy of the incoming surge wave. Two further arrestors in parallel with an operate voltage of 90 volts are provided at a point where the d.c. power feed voltage is blocked off by a capacitor. These arrestors thus provide protection to limit the voltage surges to a sufficiently low value so that any residual interfering power can be absorbed by diodes. Similar protective measures are provided at both the input and output of the repeaters. Two voltage surge arrestors are connected in parallel in the interests of greater reliability, particularly as underground repeaters are required to operate without maintenance for many years.

ACCOMMODATION OF UNDERGROUND TRANSISTORISED REPEATERS

With valve type coaxial cable line equipment having rack mounted dependent repeaters it was necessary to provide a building to accommodate the rack mounted transmission equipment and the coaxial cable terminations and associated gas pressure plant. In the new practice of underground installation, the manhole replaces the building and a metal housing maintained under gas pressure accommodates both the coaxial cable tube terminations and the transmission equipment.

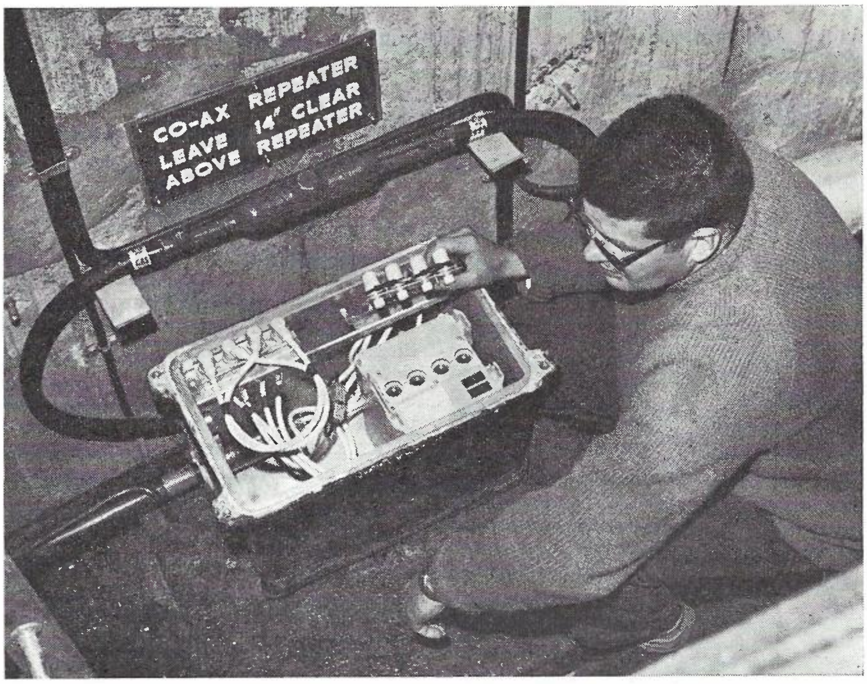


Fig. 16 — Coaxial Cable Pothead Terminations About to be Connected to Repeater Input Sockets.

Fig. 15 — Typical A.P.O. Underground Housing with 4MHz Repeater installed and Spare Coaxial Tubes Patched Through.

Fig. 15 shows an equipped typical housing. The manholes also accommodate cable joints and a gas pressure control equipment panel on which a termination is provided for orderwire access under a waterproof cover. The repeater housing which has approximate dimensions of length 22 inches, width 13 inches and height 16 inches has been designed as a gas tight cast iron box to hold sufficient coaxial line equipment for a 4 tube coaxial cable equipped to its capacity. It will accommodate repeaters of either U.K. design or German design. Thus, two 4MHz or a 4MHz plus 12MHz, or two 12MHz repeaters of either design may be accommodated in the one housing. The housings are connected to the main cable ends by means of a pair of coaxial cable tail units comprising standard 4 tube non layer cables, with factory made epoxy resin gas seals and mounting flanges for watertight connection to the repeater housing. The four tubes emerge from the prefabricated pothead inside the housing as individual semi-flexible cables terminated in male angle connectors. These connectors are fitted to a mounting plate and mated directly to the Siemens repeater input sockets as shown in Fig. 16. Any spare tubes are patched through at the repeater housing as shown in Figs. 15 and 16 by means of short patching links. The coaxial sockets are attached to a mounting plate by circlips to facilitate mating with the

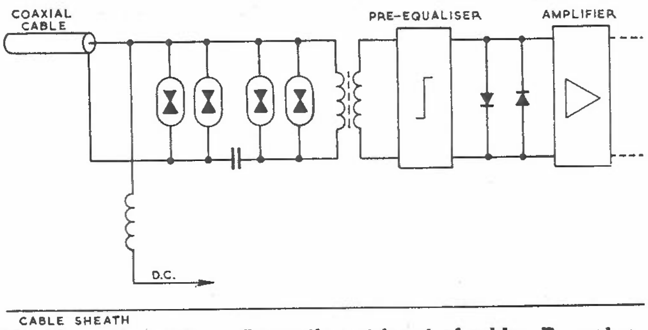


Fig 14. — Overvoltage Protection at input of a Line Repeater.

coaxial pothead termination plugs which are left attached to the housing main plate.

LINE AMPLIFIER RACKS IN TERMINAL AND REPEATER STATIONS

General

The equipment in terminal and fully-regulated repeater stations is accommodated in cabinet type racks. A typical rack is shown in Fig. 17. A

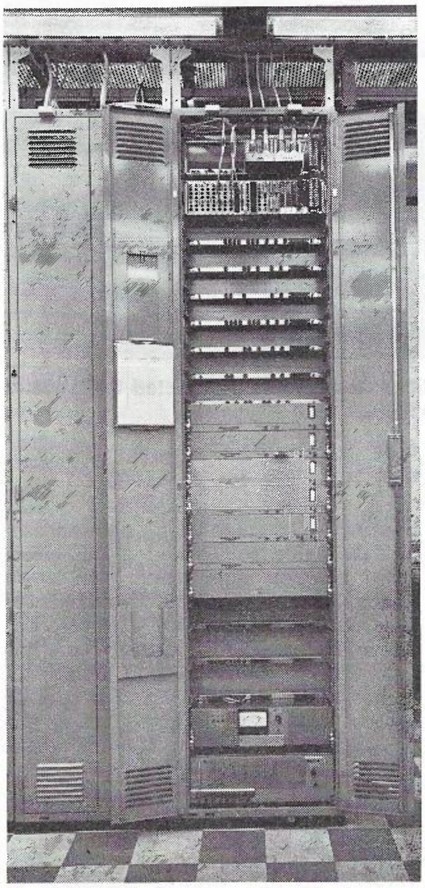


Fig. 17 — Line Amplifier Rack for Terminal and Main Repeater Stations.

universal rack is used which is 2.6 meters high and accommodates the line equipment for four V960 systems in a terminal station and two systems including supergroup dropping facilities in a fully regulated repeater station. Power separating filters for terminating 8 coaxial tubes are mounted at the top of the rack and a total of four remote power feeding units can also be accommodated in the lower portion of the rack.

It is worthy of note that this transistorised line equipment rack provides a space saving in the order of up to 8 to 1 when compared with the earlier type Siemens valve operated coaxial line equipment installed at a terminal station. At a main intermediate repeater station such as Sunbury the one solid state line amplifier rack takes the place of six racks which would be required for the repeater line equipment for two coaxial cable systems of valve type.

Terminal Stations

Fig. 18 shows the block diagram of a terminal equipment. The F.D.M. input and output levels in both transmit and receive directions is –33dBm. Where older type supergroup modulator racks are provided, the receive direction level can be strapped to provide a level of –23dBm. The station cable equaliser (S.C.E.) is a plug-in unit in the terminal panel which can be adjusted to compensate for up to 100 meters of station cable between the superground modulator racks and line amplifier rack in 20m. steps.

The transmitting chassis contains all the equipment used in the transmit direction. The pilot stop filters are necessary to remove signals from frequency band which could cause interference to the pilots. The 4287 kHz regulating pilot, and when required also the 60kHz pilot, are added to the line frequency band in the pilot injection unit.

The 4287kHz pilot is always generated by an oscillator contained in the transmitting slide-in-chassis while the 60kHz pilot generator is only provided when necessary. External connection to a master carrier supply may be provided as an alternative when frequency comparison is required on the route. Connection in this case is made via a bandpass filter and stabiliser unit.

Two flat line amplifiers, type G, follow the pilot injection unit. These raise the signal band to the required transmit level. A pre-emphasis network inserted between the two flat amplifiers improves the signal-to-noise ratio by increasing the transmitting level of the high frequencies where the cable attenuation is greater. At the output of the second flat amplifier the levels of the pilots are supervised by the pilot monitors. If the pilot levels drop by more than 3dB from the nominal level, an alarm is given.

The building out network is an adjustable unit to compensate for a repeater section between the terminal repeater station and first underground dependent repeater which is shorter than can be covered by the adjustment provided on the dependent repeater line amplifier. Thus the repeater section loss is 'built out' to be within the setting range of the repeater. Finally, the signal band is passed to line via the high pass section of the power separating filter.

The power feeding current is applied to the underground repeaters via the low-pass leg of the power filter.

The measuring input jack allows measuring voltages at any frequency between 60kHz and 4.7MHz, or the 4.660MHz pulses for fault location to be added to the line frequency band via a hybrid unit. The de-emphasis network connected to the measuring output of the second line amplifier offsets the pre-emphasis for measuring purposes by equalising the total line frequency band to a flat level of –34.4dBm.

In the receiving direction, a second power filter accommodated together with the first one in a common casing, separates the incoming carrier line frequency band from the power feeding current. The line equipment used in the receive direction of transmission is located in the receiving chassis and the equaliser chassis. The incoming signal is fed from the power separating filter via a building out network to the line amplifier, E, which is identical in electrical design with the pilot regulated line amplifier in the dependent repeaters and operates at the same output levels. This amplifier compensates for most of the frequency-dependent line attenuation. The attenuation/frequency response of the equaliser in the feedback path of the amplifier is matched to the attenuation of the cable by means of the 4287kHz pilot receiver and associated regulator assembly. The gain versus frequency curve of the amplifier E thus corresponds to the attenuation slope in a repeater section of nominal length.

The output of the amplifier E is fed to a separate equaliser chassis which contains various adjustable equalisers and, when required, an equaliser controlled by the 60kHz pilot signal. This corrects equalisation errors in the lower part of the transmission band which are caused mainly by the temperature coefficient of the cable being slightly higher at these lower frequencies. These errors are only significant on cable routes with 20 or more intermediate repeaters, and the 60kHz pilot regulating equipment is installed only at fully regulated repeater stations along the route following a total of 20 intermediate repeaters. When the 60kHz pilot equaliser is not provided, a 15dB attenuator is included in the transmission path in lieu.

The equaliser panel contains adjustable equalisers for pilot level equalisation and an echo equaliser for 'mop-up' equalisation. A flat gain amplifier, G, in the equaliser panel offsets the basic loss of the equalisers.

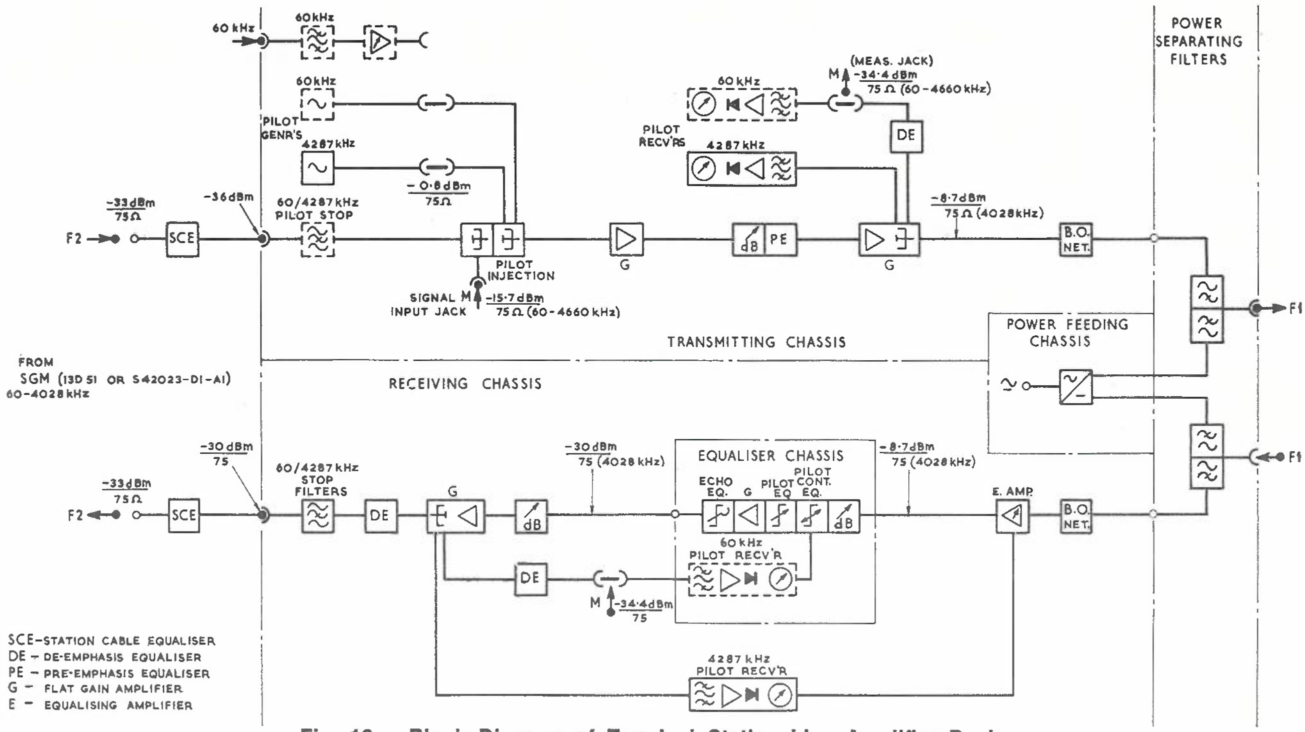


Fig. 18 — Block Diagram of Terminal Station Line Amplifier Rack.

The pilot equaliser allows the levels of the 60kHz and 4287kHz pilots to be varied independently of each other with respect to the line frequency band thus allowing readjustment of the pilot levels to concise values.

The echo equaliser, also termed the 'mop-up' equaliser, allows correction of residual attenuation errors, which have accumulated in the line transmission path between two fully regulated terminal or repeater stations. Cable impedance irregularities cause some of these residual errors. The echo equaliser, which is continuously variable over the whole line frequency range, has been designed according to the Fourier principle. Cosine-shaped spectrum signals are tapped from a multi-section delay network and combined with the line frequency band to offset errors. When adjusting the echo equaliser it is necessary to view the high frequency line attenuation characteristic on a level tracer. The degree of accuracy which was obtained with the echo equaliser adjustment resulted in the overall frequency response in both directions on the Melbourne-Kyneton route after adjustment being within ±0.2dB over the frequency range 60kHz to 4.7MHz.

The output of the equaliser unit is taken via an attenuator pad to a flat gain amplifier, G, followed by a de-emphasis network which is complementary to the transmitting terminal pre-emphasis network. Pilot stop filters are provided to eliminate the line pilot frequencies from the transmission band before being extended to the terminal F.D.M. equipment.

Inputs to pilot receivers are taken from the output of the last amplifier, so that all important units are monitored. The receive signal measuring jack M allows the monitoring of fault locating pulses and measurement of signal voltage levels in the range 60kHz to 4.7MHz. The de-emphasis network makes this a flat level point.

FULLY REGULATED REPEATERS WITH DROPPING OF SUPERGROUPS

As mentioned earlier, these main repeaters are accommodated in the same universal rack as used at terminals. Each contains the essential transmit and receive units as well as the equipment required for extra equalisation and remote power feeding. Fig. 19 shows the block diagram of the main repeater with dropping facilities—only one transmission path is shown as the other direction is identical.

Each transmission path is equipped with a receive panel, an equaliser panel and dropping panel. The equaliser panel of the main repeater is the same as used in the receiving direction of the terminal equipment. The receive panel is also similar, except the pilot stop filters and the de-emphasis networks are omitted in the transmission path, and a measuring injection unit is installed in place of the attenuator unit in front of the flat gain amplifier, G. The dropping panel contains the line transmitting equipment comprising flat gain amplifiers, 4287kHz pilot receiver equipment, line building out network and measuring signal injection units with associated emphasis networks. The dropping panel also contains the dropping path emphasis networks, pilot-band stop filters and level adjusting pads to provide correct levels to the dropping station F.D.M. equipment.

The stop filter panel, which provides the equipment for both transmission paths, comprises dropping hybrids, band stop filters and 60kHz band-pass filters. The 60kHz pilot by-passing circuit is required because the band stop filter is designed as a high-pass filter which would also block any 60kHz signals required for regulation and frequency comparison. By use of the band stop filter, SG1 and 2 are stopped in the through transmission path. This allows SG1 and 2 to be dropped and replenished at the intermediate repeater station. Any other supergroup from 3-16 may be dropped also, but the respective line frequency band continues on along the main transmission path and of course cannot be re-used at any subsequent station.

Pilot stop filters prevent the 4287 kHz and 60kHz line pilots from entering the dropped path. The 60 kHz stop filter in the path outgoing from the dropping station prevents

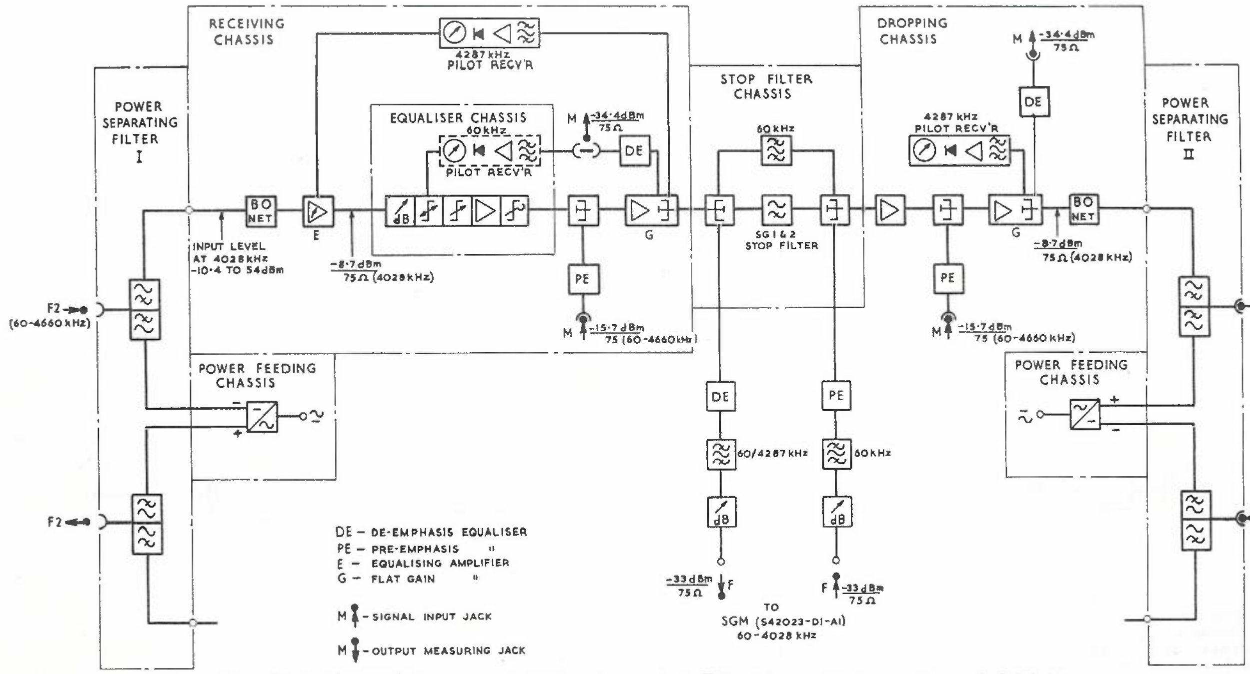


Fig. 19 — Block Diagram of Fully Regulated Repeater with Dropping of SG1+2.

falsification of the route pilot due to residual 60kHz carriers.

Dropping and replenishing of supergroups 1 to 5 or 7 to 16 can be arranged by installing appropriate dropping filter units in place of dropping hybrids.

CONCLUSION

The availability of solid state coaxial cable line equipment provides a considerable advance in broadband coaxial cable techniques, and provides economic improvement over the equivalent valve operated systems. The main advantages are considerably reduced capital costs, less accommodation space requirements and small operating costs due to very low power requirements and increased reliability. The remote power feeding by d.c. eliminates the need for the complex No-break a.c. power plant, and the underground accommodation of dependent repeaters in manholes results in a considerable capital cost saving due to the elimination of unattended buildings.

TECHNICAL NEWS ITEM

P.M.G. CALLS TENDERS FOR LARGE CAPACITY TRUNK EXCHANGE

The P.M.G. Department recently called tenders for the supply of a large automatic telephone trunk exchange to be installed in the new Pitt Exchange Building at present being constructed in Sydney. The tender invitation calls for an exchange with an initial capacity of 9,800 trunk and junction lines and 200 manual assistance positions for national and international calls, and specifies an 'in service' date of 1973.

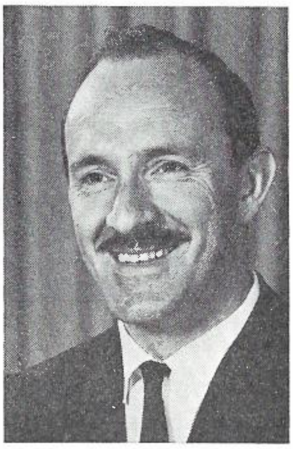
It is expected that exchanges offered will be capable of expansion to 50,000 line capacity and will utilize electronic stored programme processor control and electromechanical speech path switching. Subscribers' exchanges of this type have been placed in service in several countries including the U.S.A., Canada, Belgium and Sweden and trunk exchanges are currently in production for installation in the Netherlands, Sweden and Denmark. Having a maximum capacity 8-10 times that of the crossbar automatic trunk exchange equipment used in Australia, electronic exchange equipment would be used initially to switch the high volumes of trunk traffic in the capital cities. Electronic switching would thus complement rather than replace electromechanical crossbar equipment in the Australian trunk network.

To meet the forecast 20 year trunk traffic requirements for Sydney, at least 50,000 trunk inlets will be needed in addition to the existing Haymarket crossbar automatic trunk exchange and the Dalley motor-uniselector semi-automatic trunk exchange, which are expected to reach a maximum combined capacity of approximately 12,000 lines and 160 manual assistance positions by 1973.

The use of stored programme control provides a flexible switching machine whose facilities may be readily modified to meet changing requirements and which is capable of taking automatic action to re-route calls to maintain service in the trunk network under conditions of local overload or route failure. The equipment is expected to occupy substantially less floor space than crossbar equipment, carry high traffic per line, require a reduced number of simpler types of line signalling relay sets and, it is hoped, allow the use of more efficient manual trunk operators' positions. With processor control, the exchange would also be capable of switching other types of traffic, such as data, to help meet the growing demand for specialised services in Australia.

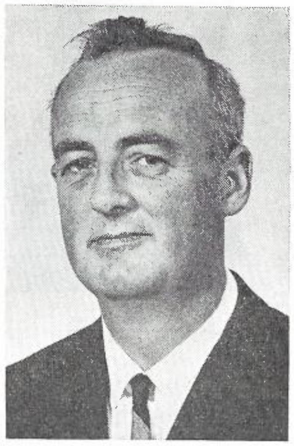
The Pitt exchange is expected to be one of the most advanced civil systems in the world and will help to maintain Australia's position among the technically advanced telecommunication nations.

OUR CONTRIBUTORS



I. W. LARSSON

F. M. SCOTT



K. W. SMITH

I. W. LARSSON, author of the article, 'Commissioning Tests for ARM Grid', joined the Postmaster-General's Department in Hobart, as a Technician-in-Training in 1947, qualifying as a Technician in 1951 and later as a Senior Technician. Following completion of his training, he was employed in the Country Installation, Burnie and Launceston Divisions, rising to Shift Supervising Technician. In 1953 he travelled to Kandersteg, Switzerland, to attend the Fifth World International Rover Moot, after which he travelled to London to take up employment with the British Post Office for a period of six months as a Technician 2A, in the London Centre Area.

In 1958, Mr. Larsson was transferred to Headquarters as A/g. Group Engineer in the Telephone Equipment Section where he was engaged on the preparation of Engineering Instructions and Works Specification for telephone equipment and 3000 type relay design. In 1960 he was appointed Trainee Engineer in Victoria and completed the Diploma in Communication Engineering at the Royal Melbourne Institute of Technology. In 1963 he was appointed Engineer Class 1 in the Long Line and Country Installation No. 2 Sub-Section in Victoria where he was employed on Country Installation work in the Geelong, Colac and Warrnambool areas.

In September 1965, he was seconded from the Country Installation No. 2 Sub-Section to prepare the special conditions of contract for the installation of the Geelong ARM exchange following which he was responsible for checking the network associated with the Geelong ARM exchange. He was appointed Engineer Class 2 in 1966, and at present occupies the position of Engineer Class 2, ARM Design and Co-ordination.

Mr. Larsson is presently a member of the Headquarters ARM Transmission Measurements Working Party and Chairman of the Long Line Equipment Installation and Transmission Testing Study Group in Victoria. He is a Graduate Member of the Institution of Engineers, Australia.

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F. M. SCOTT, author of the article 'The A.P.O. Four Wire Cord Type Manual Assistance Centre' was attached to the A.P.O. Headquarters Exchange Equipment Section in a position of Engineer Class 3 as Project Engineer for the design and development of System AFM 402. He is appointed to the position of Engineer Class 2, Contractual Installations in the Country Equipment Section, Queensland, but for the past $4\frac{1}{2}$ years has worked in the Switching and Facilities Section of Headquarters Planning Branch and the Exchange Equipment Section of the Engineering Works Division.

He joined the Postmaster-General's Department in 1944 as a Junior Mechanic and commenced acting as Engineer in 1949 after qualifying in telephone equipment and other subjects. Appointment as Engineer followed in 1953. Mr. Scott had 15 years experience as an Engineer in Queensland before his temporary transfer to Headquarters, having worked in Metropolitan Service, Trunk Service, Country Installations, and the Telephone Equipment Design Subsections. In addition to State work he represented Queensland on a number of Headquarters Circuit Committees from 1953 to 1964 being associated with the design of the SE.50 selector circuits, E.L.S.A. network circuit design, System ARF 102 initial circuit assessment and the Central Office Circuit Committee.

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K. W. SMITH, author of the article, 'Telephone Exchange Area Planning', joined the Victorian Administration of the P.M.G's Department as a Trainee Engineer in 1956. After graduating in Radio Engineering at the Royal Melbourne Technical College at the end of 1956 he took up duty as an Engineer Grade 1 in Metropolitan District Works. The following year he commenced a period of three years as Group Engineer with Metropolitan District Works followed by one year as Group Engineer with Metropolitan External Plant Planning. Since 1962 Mr. Smith has been a Group Engineer with Country External Plant Planning where he has had experience with external plant planning for all parts of Victoria and particular responsibility for rural and provincial exchange area planning. He is a Member of the Institution of Engineers, Australia.

J. P. SALTER

C. H. HOSKING

B. J. CARROLL

J. P. SALTER, Author of the Article 'A Transmission Level Checker', was educated at the Dubbo High School, and after completing a course for Broadcast Operator began his career as a trainee technician announcer in Commercial Radio. He joined the Postmaster-General's Department in 1948 as an Exempt Technician's Assistant, and subsequently passed an examination for appointment as Technician (Radio). He was appointed Cadet Draftsman in 1951. He completed the Diploma of Electrical Engineering at the Sydney Technical College in 1959 and transferred as Engineer, Trunk Service. His early Trunk Service experience was in the maintenance of open wire and telegraph systems, in N.S.W. He was associated with the Sydney-Melbourne Coaxial cable system and the introduction of TV on cable while being the Engineer in charge of the City South Carrier Terminal. A few years ago he became involved with transmission testing problems, and the development and provisioning of testing equipment for transmission systems. Recently he has been concerned with the establishment, and development of a T.C.A.R.S. network and network performance testing in N.S.W. Mr. Salter was appointed, in 1968, as Engineer Class 3, in the recently created Trunk Service No. 4 Division (Network Performance). He is a Graduate Member of the Institution of Engineers.

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C. H. HOSKING, author of the article, 'The Victorian State Disaster Plan', joined the Department in Melbourne in 1936 as a clerk and was appointed Cadet Engineer in 1937, qualifying as an engineer in 1941. After a period in Victoria as an engineer, in Metropolitan Lines and Telephone Equipment Sections, and acting Divisional Engineer, Training (Technical) he was appointed in 1949 Divisional Engineer, Lines Section, Headquarters, where he worked in the Work Methods and Practices Subsection. He transferred back to the Victorian Administration in 1956 as Divisional Engineer, Metro. District Works and in 1959 commenced acting as Supervising Engineer, Coaxial Cables. In this position he was responsible for the installation of the Melbourne-Morwell and Sydney-Melbourne coaxial cables. On completion of the latter project he was appointed Supervising Engineer, Regional Works and Services (North) in the Country Branch. Mr. Hosking graduated Bachelor of Science from the University of Melbourne in 1940, and is a Member of the Institution of Engineers (Australia).

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B. J. CARROLL, author of the article, 'Centralised Maintenance Practices Overseas', joined the Postmaster-General's Department as a Lineman-in-Training in 1941. After 4 years in the A.I.F. he returned to the Department and qualified as a technician in 1947 and as a senior technician in 1948. With 10 years field experience in the maintenance of exchange and subscribers equipment he was promoted as a trainee engineer in 1958 and obtained an Associateship Diploma in Communication Engineering from the Royal Melbourne Institute of Technology in 1960. He was appointed to the position of Engineer Class 1 in a Metropolitan Service Division in Melbourne and was subsequently promoted to Engineer Class 2 in 1963. During this period he gained considerable practical experience with the maintenance of Pentaconta and L. M. Ericsson crossbar equipment. In 1965 he was appointed as Engineer Class 3, Telephone Exchange Equipment Section, Headquarters, and in this position is responsible for the development of maintenance techniques for metropolitan, country and trunk switching equipment. In March, 1968 he visited a number of overseas telephone administrations to study the latest developments in centralised maintenance techniques.

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L. A. WHITE, author of the article, 'Melbourne-Kyneton Coaxial Cable Transistorized Line Equipment', joined the Department as a Technician-in-Training in 1948 and qualified as Engineer in 1951. Since 1957 he has occupied the position of Engineer Class 3, Long Line and Country Installation, in Victoria, responsible for the installation of all types of exchange switching and carrier transmission. Mr. White has been associated with the provision of equipment for all of the broadband systems in Victoria and was a co-author of the paper on the first of these systems, the Melbourne-Morwell coaxial cable system which was published in Vol. 13, Nos. 4 and 5 of the Journal. Mr. White is a Member of the Institution of Engineers, Australia.

L. A. WHITE

ANSWERS TO EXAMINATION QUESTIONS

Examination No. 5785, 29th June, 1968, and subsequent dates to gain part of the qualification for promotion or transfer as Senior Technician (Telecommunications), Postmaster-General's Department.

TELEPHONE SUBSCRIBER'S EQUIPMENT.

Question 1:

Fig. 1 is the circuit of an 801 telephone.

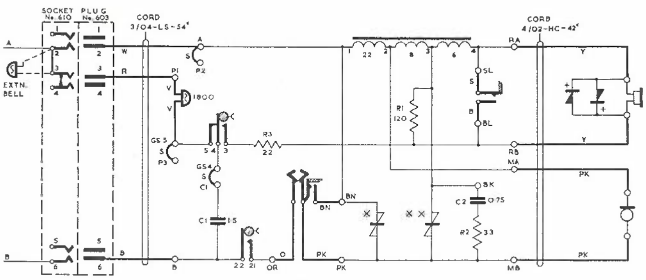


Fig. 1

QUESTION 1 (a):

Explain why the permanent magnet in the receiver is not affected by the transmitter battery while a call is in progress.

ANSWER 1 (a):

The 1.5 microfarad capacitor prevents direct current from passing through the receiver.

QUESTION 1 (b):

Draw the relevant parts of the 801 telephone circuit which show the anti-sidetone circuit of the telephone.

ANSWER 1 (b):

See Fig. 2.

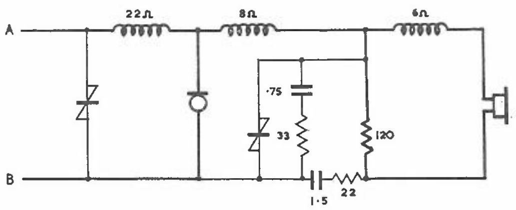


Fig. 2

QUESTION 1 (c):

What is the effect of including the two voltage dependent resistors (VDR), one across the line and the other across the balance network.

ANSWER 1 (c):

The main effect of the line VDR is to produce the desired regulation of 'send' and 'receive' efficiency by shunting audio frequencies under the control of the d.c. voltage across the line terminals.
The main effect of the network VDR is to produce an improved sidetone suppression by shunting the network so that a balance with the combined impedance of the line and line VDR is achieved.
This gives the desired improvement in sidetone attenuation on short loops. At zero loop the sidetone is 7dB better than that of the unregulated circuit.

QUESTION 2 (a):

List the equipment you would order for the installation of an intercommunication system to provide for seven (7) internal extensions and one external extension.

ANSWER 2 (a):

Item	Quantity	Remarks
A10 telephone	7	
Transfer unit 3A	1	
Telephone	1	Normal Instrument
Battery eliminator	1	Rating 0.75A. Also backboard if required
Cable, 20 pair	As required	Multiple cable, internal extensions
Cable, 10 pair	As required	Main to transfer unit
Cable, 3 pair	As required	Outdoor extension cable
Cable, 2 pair	As required	d.c. power from eliminator.

QUESTION 2 (b):

Outline two ways in which you can provide for service on the above installation during AC power failure.

ANSWER 2 (b):

Any two of the following:

(i) Provision of standby battery of dry cells connected when d.c. power from the eliminator fails.

(ii) Temporary provision of a power lead if a pair is available.

(iii) Operation of keys on the transfer unit to extend one exchange line to the external extension.

(iv) For each exchange line, provide an extension bell at a selected indoor extension. Also at the same extension provide a relay which will release on power fail and short circuit contacts AA1, AA3 or AB1, AB3.

QUESTION 2 (c)

What secrecy facilities are available on an A10 intercommunication system?

ANSWER 2 (c):

Normally calls from extensions to exchange lines are secret. However, an exchange line supervision facility may be granted from one of the extensions. Strapping on this instrument permits monitoring of an exchange line, which is already in use.

Calls by the external extension on an exchange line are secret.

Under night switched conditions the external extension may make secret exchange calls, but any calls made by an internal extension on the night switched exchange line can be overheard by the external extension.

QUESTION 3 (a):

Fig. 3 shows a configuration for standard facility Plan 4 (parallel/portable telephones).

What is the maximum number of telephones that can be provided for this service?

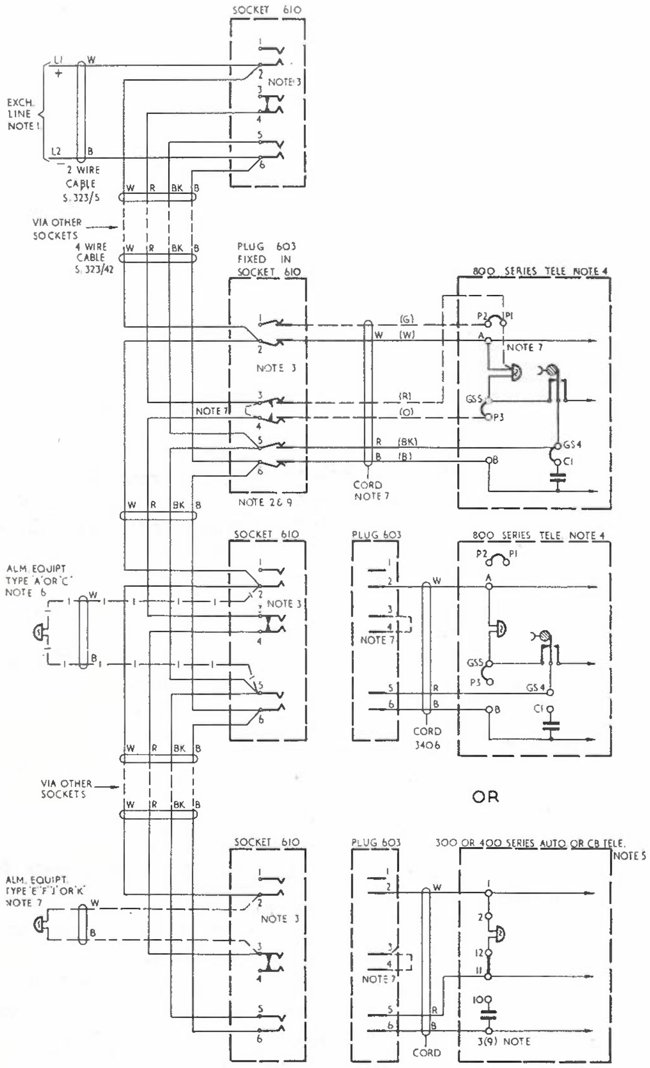


Fig. 3

ANSWER 3 (a)
Three (3).

QUESTION 3 (b):
What is the maximum number of portable points (sockets) that can be provided on this service?

ANSWER 3 (b):
Six (6).

QUESTION 3 (c):
What alterations must be made to a standard 800 series telephone if it is to be used as a portable instrument on this service?

ANSWER 3 (c):
(i) Remove link between terminals A and P2.
(ii) Shift the bell conductor from terminal P1 to A.
(iii) Shift red cord conductor from terminal P1 to GS4.
(iv) Park the link removed in (i) between terminals P1 and P2.
(v) Remove the link between terminals GS4 and C1 on portable telephones only.
(vi) In the plug, shift the red cord conductor from tag 3 to tag 5.
(vii) When a silent telephone bell is required, omit (i), (ii) and (iv).

QUESTION 4 (a):
Assume you are in charge of a Fault Despatch Centre. What statistics (records) do you consider would give you an indication of the subscribers' satisfaction with the repair service?

ANSWER 4 (a):
Delay in clearing faults, i.e., lapsed time between reporting and clearing.
Number of previously reported faults.
Number of special inspections.
Number of written complaints.

QUESTION 4 (b):
What instructions would you give to:
(i) the testing officer;
(ii) the technicians who repair subscribers' telephones; that would ensure that the subscriber gains a good impression of the Department?

ANSWER 4 (b):
(i) Be courteous when discussing the fault with the subscriber, i.e., good tone; show that you want to help correct the fault condition with a minimum of inconvenience to the subscriber.
Avoid delay between receiving the report and testing the service.
Carry out the test with the minimum inconvenience to the subscriber and, where possible, tell the subscriber what further action will be taken and when.
After fault clearance or investigation not involving a visit to the subscriber, advise the subscriber of the result.
(ii) Important points are:
Courtesy;
Appearance;
Punctuality;
Efficient workmanship;
Inform the subscriber of the result.

QUESTION 5:
You are required to inspect an installation in a subscriber's premises. Detail briefly the important points you would look for while inspecting:
(a) Cabling
(b) Location of apparatus
(c) Records.

ANSWER 5:
(a) **Cabling.**
All wiring should be run as inconspicuously as possible. Staples, clips, etc., should be at regular and approximately equal intervals. Wiring on exposed surfaces should run vertically or horizontally.
Except at crossings, fixed telephone wiring should not be closer than 2 in. from electric lighting or power cables, conduits, sprinklers or gas pipes.
The sheath of 1 pair or 2 pair cable should enter an instrument, battery box or terminal block for approximately 1 in. only. Sufficient unsheathed conductor should be provided to enable terminals of the apparatus to be freely reached with slack and spare. In a battery box sufficient unsheathed conductor should be left to allow the dry cells to be removed from the box for inspection without disconnecting the wires.
(b) **Location of Apparatus.** The telephone should be installed where good natural or artificial light permits satisfactory operation by the subscriber and inspection and adjustment of service by the technician.

The following should be considered in choosing a location that would be free from accident hazard:
Proximity of stairs.
Proximity of electric wires, switches, outlets or earthed objects.
Proximity of doors.
Projection of apparatus into shafts or passageways used for handling heavy merchandise likely to damage the telephone apparatus.
Extension cords for telephones across a passageway.
Proximity of objects making it difficult to remove or work on telephone.
Proximity of fragile objects that would be damaged if the handset were dropped.

(c) **Records.**
The exchange or extension number should be neatly entered on the label of the dial or dial dummy.
Where the service is provided by using pairs in indoor distribution boxes, details of cross connection and telephone number should be neatly entered in the cable book or card.

QUESTION 6:

Show by simple schematic diagrams the following circuit conditions for a standard lamp signalling C.B. cord type P.M.B.X. (Details of relay and key contacts are not required.)
(i) Extension calling switchboard
(ii) The speech path for an extension to extension call
(iii) The speech path for an exchange to extension call.
(iv) The operator dialling an exchange call.

ANSWER 6:

(i) See Fig. 4.

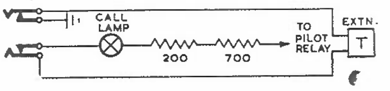


Fig. 4

(ii) See Fig. 5.

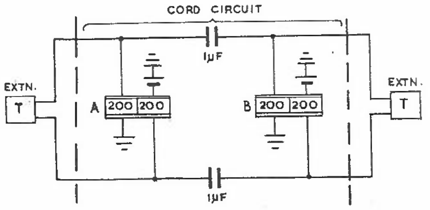


Fig. 5

(iii) See Fig. 6.

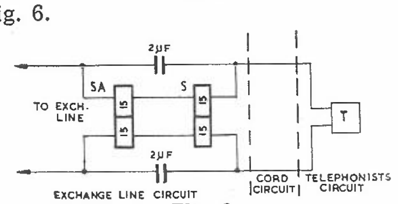


Fig. 6

(iv) See Fig. 7.

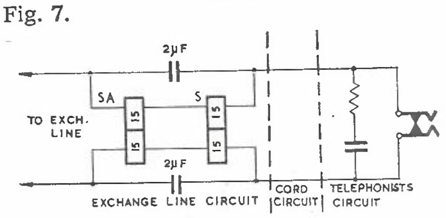


Fig. 7

QUESTION 7:

After installing a C.B. floor type P.M.B.X., what tests in each of the following categories should be made before placing the switchboard into service:

QUESTION 7 (a):

Test with test desk?

ANSWER 7 (a):

For each exchange line, speak to the test desk from the switchboard and obtain a test of insulation and loop resistance and receive a ring.
On exchange line No. 1 (with power off), use a switchboard cord circuit to connect each extension in turn to the night switching jack of this line. Speak to the test desk from each extension telephone and obtain a test of insulation and loop resistance and receive a ring.
During the above tests, if the normal means of testing dials is by means of the test desk, obtain a test on the switchboard and extension dials.

QUESTION 7 (b):

Local tests?

ANSWER 7 (b):

Call the switchboard from each extension telephone and receive a ring from the switchboard.
Test the operation of all switchboard cord circuits on the test jacks provided on the switchboard.
Test the operation of the night alarm circuit and buzzer by lifting the handset of an extension telephone.
Test the 'on-off' operation of the power switch.
Test the exchange line for correct polarity to ensure that negative potential is on the B side of the line.
Observe the transmission and reception of the operator's telephone circuit during the above tests.
Test front and rear ringing of each exchange cord to a selected extension.
Test operation of the hand generator.
Night switch an extension to each exchange line in turn (by inserting the front plug into the appropriate night switching jack), and check for dial tone and breaking dial tone.

QUESTION 8 (a):

The nation-wide subscriber's dialling plan has a trunk access code and a maximum of eight numerical digits for subscribers' numbers.
(i) Which digit is allocated as trunk access code?
(ii) Give an example of a national number for a subscriber in a 7 digit local numbering scheme.
(iii) Which is the 'A' digit in your answer to (ii)?

ANSWER (8 (a)

(i) 0.
(ii) 03 842-1157.
(iii) The 'A' digit is the digit following the trunk access code. In the example above it is the digit 3.

QUESTION 8 (b):

In the numbering plan context, what is the difference between a local number and a national number? When is each used.

ANSWER 8 (b):

A national number consists of an area code followed by the local directory number.
For calling within the same numbering plan area, only the local directory number is used (dialled).
For calls beyond the same numbering plan area, the complete national number must be dialled.

QUESTION 9 (a):

With the aid of a sketch, describe the Varley loop test for localising an earth fault on a line and explain how this principle is based on that of the Wheatstone Bridge.

ANSWER 9 (a):

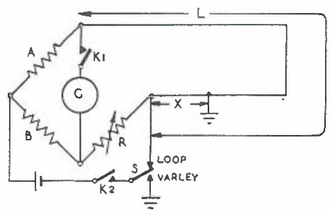


Fig. 8

L = loop resistance in ohms.
X = single wire resistance from testing point to fault.
R = resistance of variable arm of the bridge.
A and B are resistances of fixed arms of the bridge.

Select one wire which has high value of IR and loop this wire with the faulty wire at the distant end. The loop resistance L is measured with K1 and K2 operated and switch S in the 'Loop' position. At balance, A/B = L/R and if the ratio arms are aqual (A/B = 1), then L = R ohms.

With the switch S moved to the 'Varley' position, again balance the bridge. If the ratio of arms A/B is still 1, then

$$\frac{A}{B} = \frac{L - X}{R + X} = 1$$

$$L - X = R + X$$

$$\text{or } 2X = L - R$$

$$X = \frac{L - R}{2} \text{ ohms}$$

The first test, to find the loop resistance, is a straight Wheatstone Bridge test, i.e., when there is zero current in the meter, A/B = L/R. The Varley test uses the same principle except that now the balancing arm R also includes X ohms single wire resistance to the fault.

$$\frac{A}{B} = \frac{L - X}{R + X}$$

$$\therefore A(R+X) = B(L-X)$$

$$AR+AX = BL-BX$$

$$X(A+B) = BL-AR$$

$$\therefore X = \frac{BL-AR}{A + B}$$

If ratio arms are equal (A = B)

$$\text{then } X = \frac{L-R}{2} \text{ ohms}$$

QUESTION 9 (b):

When localising an earth fault by the Varley loop test, a balance was obtained when all of the resistance arms on the bridge were each 100 ohms.
If the loop resistance of the line under test was 540 ohms, calculate the distance to the fault from the testing point. (Assume that the line resistance is 88 ohms per mile loop.)

ANSWER 9 (b):

Loop resistance L = 540 ohms
Varley reading R = 100 ohms

$$\text{Single wire resistance to fault } X = \frac{L-R}{2} = \frac{440}{2} = 220 \text{ ohms}$$

Line resistance = 88 ohms per loop mile
= 44 ohms per single wire mile

$$\text{Distance to fault} = \frac{220}{44} = 5 \text{ miles}$$

QUESTION 10 (a):

Show with trunking diagrams the call routing for each of the following calls in a C type P.A.B.X.:
(Designate the relay sets and switches involved in each type of call.)
(i) An extension to extension call
(ii) An extension to switchboard call
(iii) A switchboard to exchange call.

ANSWER 10 (a):

(i) See Fig. 9.
(Link circuit acts as final selector.)

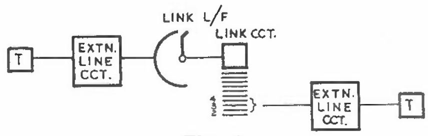


Fig. 9

(ii) See Fig. 10.

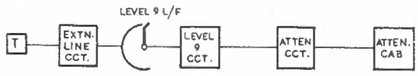


Fig. 10

(iii) See Fig. 11.

Fig. 11

QUESTION 10 (b):

Briefly explain the following P.A.B.X. facilities:
(i) Camp on busy
(ii) Trunk offering.

ANSWER 10 (b):

(i) Calls incoming to a busy extension from the public exchange or operator 'camp on' until the extension clears. The extension is then automatically re-rung and switched to the caller.
(ii) Trunk offering enables the operator to advise a busy extension that an incoming call is waiting. A warning tone is provided.

QUESTION 11 (a):

What circuit is usually provided at each of the following types of P.A.B.X. to enable an extension to be tested from an exchange test desk:
(i) At a linefinder type P.A.B.X.?
(ii) At a C and CA type P.A.B.X.?

ANSWER 11 (a):

(i) A test cord circuit is provided at the manual board. The testing officer gains access to an extension in one of the following ways (depending upon local practice in each State):
   (a) After calling on one of the normal incoming lines (usually the least busy), the P.A.B.X. telephonist is asked to connect the pair of test cords between this line jack and the jack of the extension to be tested.
   (b) A 4-wire test junction is accessible to the test selector and is wired via a relay set at the P.A.B.X. to a single test cord on the manual board with associated call and clear lamps and Speak key.

(ii) (a) The Test Extension key, when provided, is wired into either the last or the first exchange line. It is operated when an extension is to be tested.

(b) In some areas it is the practice to have all P.A.B.Xs. provided with a special test circuit, accessible from the test selector as described in (i) (b) above, and this includes C and CA types. In this case there are no test cords, the least busy or last exchange line is used, but the actual relay set is bypassed by the test circuit after the exchange line finder is positioned by keying in the normal way. When neither of these arrangements is provided, the technician must make suitable temporary cross-connections at the P.A.B.X.

QUESTION 11 (b):

What test set is used for testing the selectors of:
(i) A line finder type P.A.B.X.?
(ii) A uniselector type P.A.B.X.?

ANSWER 11 (b):

(i) Testing of linefinder of P.A.B.Xs. is done using a Test Set No. 1 (or 1A). This is a portable test set which enables the testing of all the important functions of group selector repeaters, final selector repeaters and final selectors. Line finders and allotters may be checked by means of a buttinski and using a spare line circuit in each group. The technician's telephone is sometimes wired via a key to serve this purpose.

(ii) Test Set No. 1 (or 1A) is also used for testing group selectors (or group selector repeaters) and final selectors in uniselector type P.A.B.Xs.

QUESTION 12 (a):

The Special Service on Faulty Lines (also known as a 'hospital' circuit) is a circuit that provides a temporary service for subscribers whose telephone would otherwise be out of order owing to fault conditions.
What fault conditions can be catered for by the circuit?

ANSWER 12 (a):

(i) Line earthed on one side.
(ii) Line open on one side.
(iii) Line looped or short-circuited.
Note.—'Hospital' circuits may also be used on lines with foreign battery—Reference E.I. TEL. Exchanges C4340.

QUESTION 12 (b):

Show with simple schematic sketches the circuit conditions that exist between the subscriber's instrument and the equipment side of the exchange M.D.F. when the special service facility is used to provide service for each fault condition listed above.

ANSWER 12 (b):

(i) See Fig. 12.

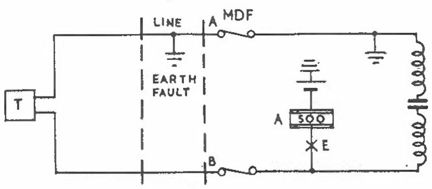


Fig. 12

(ii) See Fig. 13.

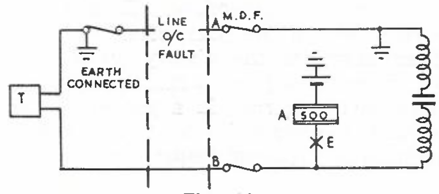


Fig. 13

(iii) See Fig. 14.

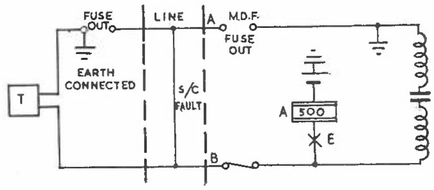


Fig. 14

QUESTION 13 (a):

State the correct sequence of operating and releasing the appropriate test desk keys when applying the Selector Release facility to a looped line.

ANSWER 13 (a):

The testing officer dials the number and the busy lamp glows. The Private Control key (KPC) is now operated, followed by the Selector Release key (KSR) and the busy lamp is extinguished. The testing officer restores the Private Control key and then restores the Selector Release key.

QUESTION 13 (b):

With the aid of schematic diagrams, describe the method of testing a subscriber's line for:
(i) Loop resistance
(ii) Insulation resistance.

ANSWER 13 (b):

(i) See Fig. 15.
Keys operated are:
Resistance Test Key (KRT).
Low Scale key (KLS).

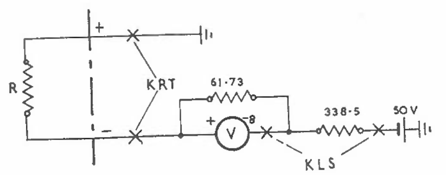


Fig. 15

(ii) See Fig. 16.
Keys operated are:
Resistance Test Key (KRT).
Insulation Res. Key (KIR).

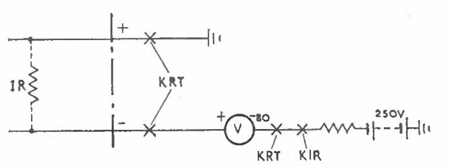


Fig. 16

QUESTION 13 (c):

What procedure is designed to highlight those subscribers which have a history of excessive faults?

ANSWER 13 (c):

The Special Inspection procedure. Details of repair requests are recorded on the back of master cards. The testing officer examines the history on the back of the master card when testing for a fault. If more than two coded entries have occurred in a period of two months, the master card is referred to the Supervising Technician for consideration of a special inspection.

QUESTION 14 (a):

What is the acceptable range of impulse make ratio from a subscriber's line when measured from a test desk?

ANSWER 14 (a):

35 per cent. to 39 per cent. (See E.I. TEL. Subs. Q 0001, para. 4.1 (vi)).
Note.—34 per cent. to 39 per cent. as quoted in Telephony 3 was also accepted.

QUESTION 14 (b):

In what way does the spark quench on a telephone affect the make ratio measured from the test desk?

ANSWER 14 (b):

It increases the make ratio by approximately 3 per cent. for a 2 microfarad capacitor.

QUESTION 14 (c):

What are the common sources of impulse distortion in a telephone network?

ANSWER 14 (c):

Spark quench in telephone.
Line resistance high or low.
Low insulation resistance of line.
Cable capacity.
Impulsing relays out of adjustment.
Low exchange battery voltage.
Transmission bridge.

QUESTION 14 (d):

What design features are incorporated in the dial to ensure that a selector is seized and ready to receive pulses before the pulse train arrives?

ANSWER 14 (d):

There is an interdigital pause of 400 - 500mS. This is made up of:
(i) the time to wind up the dial (about 200mS) and
(ii) the lost motion period—a mechanical delay between the time of release of the dial and the production of the first pulse. In the No. 10 dial lost motion (200mS) is produced by the slipping cam. In a trigger dial it is the time taken to pick up the trigger and transfer it to the pulsing position (230mS).

QUESTION 14 (e):

Under what conditions is a local selector most likely to receive a pulse train before the selector is seized and ready?

ANSWER 14 (e):

The most likely cause is dialling before receipt of dial tone. It can also be caused by a faulty slipping cam in a No. 10 dial.
If on wind-up the cam slips before reaching the forked stop, the lost motion period, after release, will be reduced (extra digits will also be produced).
Other factors are:
(i) Digit 1 has the shortest wind-up time and thus the shortest interdigital pause.
(ii) Fast dials will have a shorter lost motion period.

Examination No. 5786, 29th June, 1968, and subsequent dates to gain part of the qualification for promotion or transfer as Senior Technician (Telecommunications) Post-Master-General's Department.

TELEPHONE EXCHANGE EQUIPMENT.

QUESTION 1 (a):

Describe briefly what is meant by the following terms when used in conjunction with switching systems:—
(i) *STEP BY STEP switching system.*
(ii) *COMMON CONTROL switching system.*
(iii) *Hunting circuits.*
(iv) *Finding circuits.*
(v) *Selecting circuits.*
(vi) *Conditional selection.*

ANSWER 1 (a):

(i) A system which has switching stepped under the control of the subscriber's dialling information.
(ii) Switching is performed independently of the subscriber's dialling information. Common apparatus controls the setting of stages, releasing itself after switching.
(iii) The first available path is selected from several identical ones, e.g., hunting for a free trunk to a 1st group selector.
(iv) A particular path requiring service is identified from a number of paths, e.g., a line finder.
(v) A particular path is selected from several available paths on a predetermined basis, e.g., selecting a direct or alternate route.
(vi) The switching operation (or selecting) is dependent upon fulfilling a number of conditions.
For example, in a link system:
—there must be a free route available in the desired route,
—there must be a free link circuit available between the partial stages and this link must have access to the free outlet.
—the free link must be accessible from the inlet to the first partial stage.

QUESTION 1 (b):

What salient operating feature is required of a relay used to respond to dialled pulses in step-by-step automatic systems? Name the type of armature fitted to such relays.

ANSWER (1 (b):

The relay must have the same operate and release characteristic. An Isthmus armature is fitted.

QUESTION 1 (c):

Complete the following statements relating to 3000 type relay features:—
(i) *A maximum of......coil tags can be fitted for terminating coil windings.*
(ii) *A red enamel marking on a coil tag denotes the........ end of a winding.*
(iii) *The springs on a standard relay are usually.......... mils thick.*
(iv) *The silver type of contact material is usually used to carry and break currents of up to........mA.*

ANSWER 1 (c):

(i) 5; (ii) inner, earth or positive; (iii) 14 mils; (iv) 300mA.

QUESTION 1 (d):

Explain briefly the effect of adding three nickel iron sleeves over the normal soft iron core of a relay.

ANSWER 1 (d):
It increases the V.F. impedance of the relay. (A.C. fluxes are confined to the surface layer of the core due to the "skin effect." The nickel iron alloy has high permeability, a low eddy current loss and a low hysterisis loss, which all combined increases the impedance. However, it becomes saturated at the magnetic force used for relays and so its permeability drops. By fitting three 12 mil. sleeves of nickel iron, the effect of saturation is eliminated, as the iron core carries the D.C. flux, the D.C. characteristics of the relay are practically unaltered and its impedance to V.F. currents is greatly increased.)

QUESTION 2 (a):
List six (6) methods provided in an exchange to supervise the operating performance of an automatic exchange.

ANSWER 2 (a):
Reference E.I. TEL. Exchanges M 0112, Para. 2, 3. Any six of the following:
Telephone service observations.
Traffic route testing.
Analysis of subscriber trouble reports.
Alarms and automatic surveillance devices, such as service alarms, RKR and route alarms.
Analysis of fault records.
Staff reports and testing of equipment.
Visual inspection of plant.
Analysis of dead level traffic.
Meters.

QUESTION 2 (b):
Describe briefly four (4) of the methods listed in your answer to 2 (a) and explain how they are used.

ANSWER 2 (b):
See E.I. TEL. Exchanges M 0112.

QUESTION 3 (a):
Explain briefly the main function of the service alarm system used in ARF 102 crossbar exchanges and the conditions which cause the alarm to operate.

ANSWER 3 (a):
The service alarm is used for supervision of common control equipment, such as markers, code receivers and registers. Each time such a device cannot complete its function because of a fault a time out will result and one impulse will be sent to an impulse counting circuit, which is reset at predetermined time intervals. When the number of throw-outs is excessive a service alarm is given.

QUESTION 3 (b):
Describe the procedure you would adopt to determine the particular device causing a service alarm.

ANSWER 3 (b):
Operation of the connecting key associated with the Service Alarm lamp connects a group of resettable meters to the throw-out leads from a group of devices. The meter connected to the faulty device will advance rapidly and from the service alarm appropriation chart the associated faulty device is indicated.

QUESTION 3 (c):
What fault is indicated when the SSLS lamp is glowing on an SLA/B rack?

ANSWER 3 (c):
The rack fuse has operated.

QUESTION 4 (a):
Complete the following table of information concerning service tones used in Australian automatic exchanges.

ANSWER 4 (a):

Tone	Frequency	Interruptions
Dial Tone	33Hz.	Continuous Tone
Ring Tone	400 Hz modulated by Interrupted Ring	0.4 sec. tone, 0.2 sec. off 0.4 sec. tone, 2.0 sec. off
Busy Tone	400 Hz	0.375 sec. on, 0.375 sec. off or .75 sec. on, .75 sec. off

QUESTION 4 (b):
Service tones for many automatic exchanges are produced by a combined alternator and inductor tone generator. Describe briefly, with the aid of a sketch, the principle used to generate dial tone with this type of equipment.

ANSWER 4 (b):
Fig. 1 shows the principle of the inductor tone alternator. The magnetic circuit reluctance varies with the relative positions of the soft iron rotor and the stator teeth. As the position of the rotor changes it varies the magnetic flux and a.c. is induced in the generating or pick-up windings. The original magnetic excitation may be from either a separate exciting winding or from a permanent magnet. (One rotor disc and stator assembly is provided for each tone.)

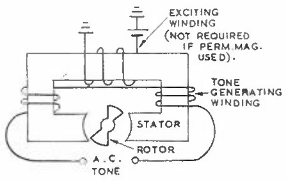


Fig. 1

The frequency of the output is one Hz per rotor tooth per revolution. For dial tone (33 Hz), the rotor has two small slots —arranged so that the two teeth occupy the greater part of the periphery—and the stator has two small teeth or poles. Usually the two stator teeth and slots occupy the same space as one tooth and the adjacent slot in the rotor. Fig. 2 shows how the adjacent stator pole windings are in opposite directions, so that the induced voltages are series aiding.

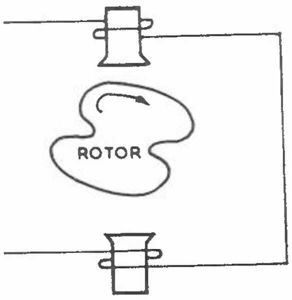


Fig. 2

QUESTION 5 (a):
Explain briefly the purpose of the following circuits provided in conjunction with test desk facilities at an automatic exchange:
(i) Trunks to the M.D.F. exchange side.
(ii) Test and Plugging Up Lines.

ANSWER 5 (a):
(i) To give access to both the inside portion and the outside portion of a line without changing the connection at the M.D.F.
(ii) To release exchange equipment held by a faulty line.
To give N.U. tone (or equivalent) to callers.
To enable testing of the line.
To provide an indication on the test desk when the fault clears.
To give immediate service to the subscriber when the fault clears.

QUESTION 5 (b):
List the various subscribers' line faults that can be catered for by using the test and plugging up lines circuit.

ANSWER 5 (b):
Earth on B line or battery on A line.
Earth on A line, battery on B line or short circuited line.
Open circuit line.

QUESTION 5 (c):
Explain briefly the functions of the test and plugging up lines circuit when a call is received for a faulty P.B.X. line connected to the circuit.

ANSWER 5 (c):
If the private is extended via the test shoe of the circuit:
The private is earthed and the P.B.X. final selector will step over the line;
If the line is the last in the group then the caller receives busy tone.
If the private is not extended via the test shoe, then the incoming ring is tripped and N.U. tone is given to the caller.

QUESTION 6 (a):
Explain briefly, with the aid of sketches, the basic testing circuit used in many motor uniselector applications in switching circuits. Include in your answer an explanation of the features which prevent double seizure of an outlet.

ANSWER 6 (a):
Fig. 3 shows a basic testing circuit.

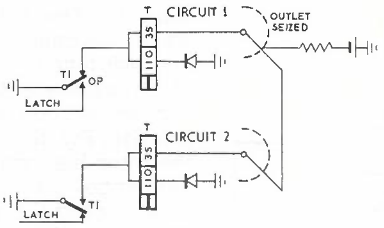


Fig. 3

Relay T has two windings in series during testing. When a marked outlet is reached, the relay operates to the battery on the P wire. The T1 contact in changing over opens the latch circuit and short circuits the 110 ohm winding of T. This guards the outlet by reducing the P wire potential to about 3V.
A rectifier in series with the 110 ohm winding of each relay ensures that at low potentials the test circuit resistance is too high and the current is too low for operation of the test relay. When testing a free outlet the potential across the rectiifier is high enough to keep its resistance relatively low. Thus the voltage resistance characteristic of metal rectifiers in the conducting direction provides an additional safeguard.
Should two motor uniselectors arrive at the same free outlet simultaneously, double selection still cannot occur. Both test relays could operate in parallel, but neither would hold since each 35 ohm winding shunting the other would prevent a large enough current in each relay. The two armatures would vibrate on their make contacts until out of step. One would then operate and hold, and the other release, allowing its switch to drive on in search of another contact.

QUESTION 6 (b):
State the maximum number of contacts over which a motor uniselector can search during the minimum interdigital pause period of a dial.

ANSWER 6 (b):
The number tested in one complete revolution.

QUESTION 7 (a):
Draw the basic trunking diagram of a 90 line ARK 511 exchange.

ANSWER 7 (a):
See Fig. 4.

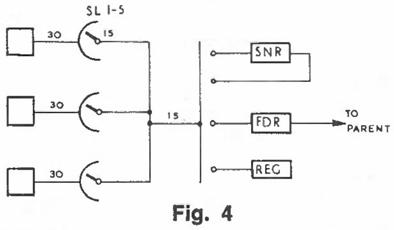


Fig. 4

QUESTION 7 (b):
List the four main functions of the local link relay sets (SNR).

ANSWER 7 (b):
Ring to the B subscriber, ring tone to the A subscriber.
Supply of battery feed to A and B parties.
Meter the A party when the called subscriber answers.
Supervises the call by:
Timing out if the B party does not answer. (A party is then connected to line lockout.)
Clearing the calls if the B party clears, but the A party does not.

QUESTION 7 (c):
Explain briefly the purpose of the fleeting test reversal when applied to an ARK calling subscriber's line. At what stage of the call from an ARK is this test applied to the calling subscriber's line.

ANSWER 7 (c):
To identify lines restricted to local calls only.
After the caller's line has been identified and the number has been transferred to the AX relay set.

QUESTION 8 (a):
Sketch a typical trunking diagram of an ARF102 crossbar terminal exchange. Show clearly on your diagram the position of the I.D.F.'s which are used to cross-connect the different devices and selecting switches. Your sketch should omit marker, alarm and tone generator I.D.F. connections.

ANSWER 8 (a):
See Fig. 5.

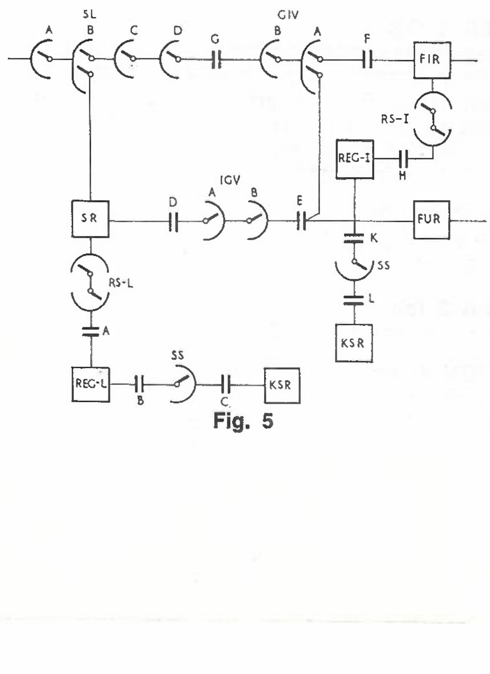


Fig. 5

QUESTION 8 (b):
Designate each I.D.F. shown in your answer to question 2 (a) with a letter and explain briefly the purpose of each I.D.F.

ANSWER 8 (b):
The I.D.F.'s are used to interconnect the links and control devices to the next stage in the manner most suited to the trunking design and grade of service, and distribute the outlets after interconnection. The purpose of each I.D.F. designated in Fig. 5 is as follows:—
A—To facilitate interconnection of RS-L outlets to a limited number of registers.
B—Distribution of Registers L over SS switches.
C—Interconnection of SS outlets to a limited number of KSR's.
D—Cross connection of SR's to any 1GV inlet.
E—Interconnection of 1GV outlets.
F—Distribution of FIR's over GIV inlets.
G—Interconnection of GIV outlets.
H—Interconnection of RS-I outlets to a limited number of Reg. I.
K—Distribution of Registers I over SS switches.
L—Interconnection of SS outlets to a limited number of KSR's.

QUESTION 8 (c):
Explain briefly the purpose of a BT relay set in an ARF102 switching system, and name the rack(s) which are fitted with a BT relay set.

ANSWER 8 (c):
In each SR, FIR and FDR there is a time release circuit. Under certain circumstances, e.g., fault tracing and testing, it is necessary to lock a connection and it must be possible to cancel the time release.
Racks fitted with a BT relay set are SR rack, SR-B rack, FIR-B rack and FDR rack.

QUESTION 9 (a)
Name the relays in the SR relay set which are operated during conversation on a call from an ARF subscriber to a step-by-step subscriber in the same exchange. Assume that the register is disconnected after setting the SR in the unit fee junction condition.

ANSWER 9 (a):
S1, S4, S6, S9, S10, S11, S12.

QUESTION 9 (b):
At what stage of a unit fee call from an ARF subscriber to a step-by-step subscriber will the caller's meter operate?

ANSWER 9 (b):
(i) When the calling party clears; or
(ii) When the calling party is placed on line lockout because the SR has timed out after the B party clears.

QUESTION 9 (c):
List, in their correct operating sequence, the relays which operate in the SR relay set after the called party answers on a call between ARF subscribers connected to the same exchange.

ANSWER 9 (c):
S8, S5, S9.

QUESTION 9 (d):
Explain briefly why it is necessary to provide an MR relay set on public telephone lines connected to an ARF exchange.

ANSWER 9 (d):
A P.T. requires a line polarity reversal when the called party answers as a signal to disable the transmitter until coins have been collected.
The SR does not give a reversal to the calling subscriber's line when answer is recorded, and an MR relay set must threfore be provided on each P.T. line to perform this function.

QUESTION 9 (e):
State which wire is used to transfer an answer signal to the MR from the SR relay set and give the signal condition on this wire.

ANSWER 9 (e):
The R wire; 1000 ohm +.

QUESTION 10 (a):
State briefly what is meant by the following terms when used in a telephone traffic context:—
(i) grade of service
(ii) overall grade of service
(iii) pure chance traffic
(iv) smooth traffic.

ANSWER 10 (a):
(i) The proportion of calls lost at the first attempt in the busy hour due solely to lack of switching equipment.
(ii) The aggregate probability of a lost call, over all switching points in setting up a call.
(iii) Traffic such that a call is as likely to originate at any one moment as at any other. (Pure chance traffic is generated by a large number of individual subscribers who make their calls independently of the calls of the other subscribers. In practice, groups of subscribers larger than 100 tend to originate this type of traffic, as in a uniselector group.)
(iv) Smooth traffic has fluctuations about the average, which are smaller in general than those of pure chance traffic. The traffic at any instant will not vary greatly from the average traffic measured over a period of time. (Smooth traffic may be observed on direct or first choice routes where alternate routing is used, and also on the early choice circuits of a step-by-step grading.)

QUESTION 10 (b):
Explain briefly when 'smooth traffic' conditions occur in telephone switching.

ANSWER 10 (b):
When the number of sources from which the calls can originate is small and the traffic is large.
At a certain stage in the switching process when traffic peaks in any previous group have been spread over a number of groups due to interconnecting arrangements.

QUESTION 10 (c):
State the type of connecting scheme which would be employed between:
(i) the outlets of 4th selectors to final selectors (2000 type equipment),
(ii) the outlets of a 1GV switching stage to FUR relay sets (crossbar type exchanges).

ANSWER 10 (c):
(i) Grading scheme of outlet multiples.
(ii) Interconnection scheme.

QUESTION 11 (a):
Explain briefly what is meant by the following terms when used in conjunction with ARF102 crossbar signalling:
(i) compelled sequence.
(ii) 'A' series signals of the signalling scheme.
(iii) 'B' series signals of the signalling scheme.

ANSWER 11 (a):

(i) Compelled sequence signalling means that a forward signal will remain on line until such time as a revertive signal is received and vice versa.

(ii) "A" signals provide routing information to the register so that it knows which digit to transmit and the type of terminating equipment.

(iii) "B" signals provide information regarding the condition and class of the required subscriber's line.

QUESTION 11 (b):

Explain briefly the sequence of MFC signalling operations when a subscriber with number 7598000 calls the number 7592460 in the same ARF102 exchange with a GIV stage. (The frequencies of the various signals are not required.)

ANSWER 11 (b):

Fig. 6 shows in diagram form the MFC signalling for this call.

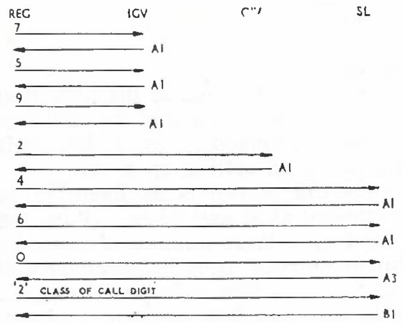


Fig. 6

When all digits have been stored in Reg-L the 1GV marker is called and digit 7 is sent.

The marker returns an A1 signal, which results in digit 5 being sent forward.

The marker returns another A1 signal and digit 9 is sent to 1GV. This povides enough information for the 1GV to switch to GIV and return an A1 signal after test. Digit 2 is received in GIV, which switches the call to SLM and returns an A1 signal after test.

Digit 4 is received in CD-SM and an A1 signal returned to Reg-L. Reg-L sends digit 6, which is stored in CD-SM and an A1 signal is returned to Reg-L, which sends digit 0 to CD-SM. When CD-SM receives the last digit SLM is called and an A3 signal is returned to Reg-L to prepare it to receive B signals.

The A3 signal is acknowledged by the register sending an extra digit '2,' indicating the class of caller. After test, SLM sends a B1 (free line) signal to Reg-L, the call is 'through connected' and Reg-L and SLM are released.

QUESTION 12 (a):

Explain briefly what is meant by the term 'cut-drive' principle when referring to 2000 type automatic equipment operation.

ANSWER 12 (a):

The 'cut-drive' principle is used in hunting for free outlets. A self interrupted drive actuated by a toggle action causes the switch to hunt. In conjunction with this, a testing relay, contacts of which maintain the self-drive circuit, remains operated to the earth condition encountered on all busy contacts. When a free outlet is reached, the test relay releases and its contacts 'cut' the self-drive circuit.

QUESTION 12 (b):

Explain briefly the principles of trunking and operation from penultimate selector banks to 200-line final selectors in 2000 type equipment.

ANSWER 12 (b):

To accommodate the 200 lines, the final selectors are fitted with a 600-point bank (3 x 200 point units). The bottom unit contains the + and — of the first hundred lines, the middle unit contains the + and — of the second hundred lines, while the top unit contains the 200 private wires for both 100 groups.

When the switch is stepped to any position, the wipers have access to two lines, and it is necessary to choose between the two. To effect the selection, a WS or wiper switching relay is included in the final selector circuit, and calls from odd levels of the penultimate selector are trunked through the WS relay, causing the call to be switched to the upper 100 unit. Calls from even levels do not operate the WS relay and the call proceeds to the lower 100 unit.

QUESTION 12 (c)

Describe, with the aid of a sketch, the principles used to avoid impulse distortion and interference with transmission on calls to the second 100 line group of a 200-line final selector.

ANSWER 12 (c):

Fig. 7 shows the incoming connections to a 200-line final selector.

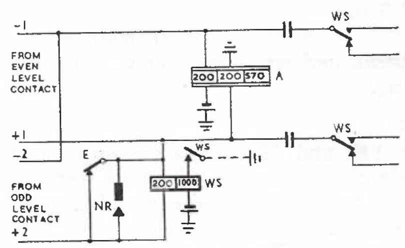


Fig. 7

During the vertical impulsing the 200 ohm winding of the WS relay is short-circuited by contacts of the E relay. At the end of the first impulse train relay E operates, WS operates in series with one winding of A and holds on its 1000 ohm winding. At the first rotary step, NR springs operate and the 200 ohm winding of WS is once more short-circuited to avoid impulse distortion and transmission interference.

QUESTION 13 (a):

Draw a block diagram showing the relationship between the relay sets which form the 2/160 GV marker in ARF102 equipment. Identify each type of relay set.

ANSWER 13 (a):

See Fig. 8.

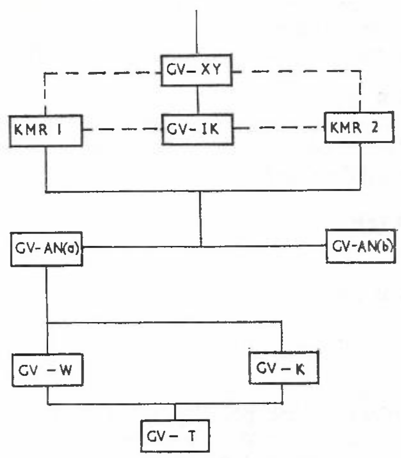


Fig. 8

QUESTION 13 (b):
Give the main basic function of each of the relay sets shown in your answer to 13 (a).
ANSWER 13 (b):
GV-XY—identifies the calling inlet.
GV-IK—connects the identified inlet to the selected code receiver.
GV-ANa—analyses the route.
GV-ANb—analyses the number length.
GV-T—indicates the idle outlets of a selected route.
GV-W—identifies the wanted route.
GV-K—selects and tests an outlet.
KMR—code receiver.
QUESTION 13 (c):
If the number length analyser of a GV marker consists of one GV-AN part 1b and two GV-AN 2b relay sets, state:
(i) the maximum number of two digit codes that can be expanded for three digit analysis.
(ii) the maximum number of three digit codes that can be expanded for four digit analysis.
ANSWER 13 (c):
(i) 100; (ii) 38.
QUESTION 14 (a):
Explain briefly the bypath test principles used when selecting a switching path through the SL stage on an incoming call in ARF102 equipment.
ANSWER 14 (a):
When the SLM is first seized a number of relays operate, indicating which free links between the SLC and SLD stage are available, and have access to the calling SLD inlet.
When the subscriber's number has been registered, relays operate indicating the free SLA verticals with access to the called number.
From the free verticals indicated, a selection is made of an SLA vertical with access to both the called number and the incoming SLD circuit.
A 'vertical' row in the SLA and SLB stages is selected. This decides the SLB switch to be used for this call.
Five verticals on the selected SLB switch are available for incoming calls. Of these, tests select a vertical with access to the calling SLD inlet. This automatically selects a 'horizontal' row in the SLB and SLC stages.
Every horizontal row in the SLC stage has two verticals which can be reached from a certain SLD inlet. The final test selects one of these two SLC verticals.
QUESTION 14 (b):
Draw a block diagram to show the functional groups of equipment with the relay sets which form a typical SL stage code receiver. Your block diagram should include sufficient information to show the outline of the operation of the code receiver.
ANSWER 14 (b):
See Fig. 9.

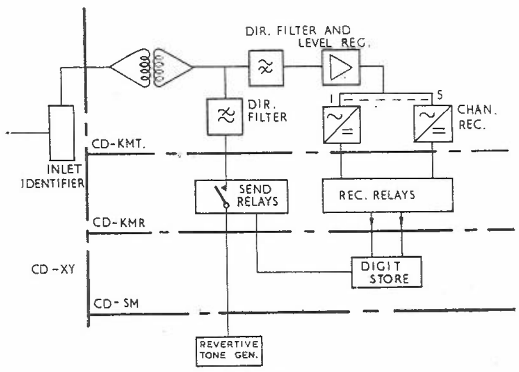


Fig. 9

ANSWERS TO EXAMINATION QUESTIONS

— AMENDMENT

Examination No. 5634 — 1st July 1967 and subsequent dates. To gain part of the qualification for promotion or transfer as Senior Technician (Telecommunications), Radio and Broadcasting Equipment, Postmaster-General's Department.

PART A — BROADCASTING EQUIPMENT

Editorial Note: The answers given on page 87, Vol. 18, No. 1, for question 1. (b), parts (i), (ii), (iv), and (vi) of the above examination, are inaccurate or incomplete and may be misleading. The following answers should be substituted.

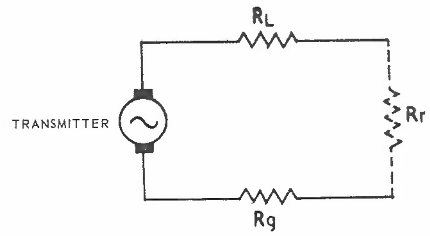
ANSWER 1. (b)

(i) Effective height of aerial between $\frac{1}{2}$ and $\frac{5}{8}$ wavelength to give the maximum primary service area and minimise fading. (The actual height is determined by ground conductivity. For average ground conductivities, heights of 0.55 to 0.57 wavelength are appropriate.)

(ii) Capacity top to increase the electrical height more economically than by providing the full physical height required.

(iv) Sectionalizing point (series inductor connecting insulated section of mast) to increase the electrical height as in (ii) but, in addition, to provide a convenient means of adjusting height by insertion of positive or negative reactance, or a combination network to enable optimum operation on two frequencies simultaneously.

(vi) Earth mat to increase radiation efficiency. (The transmitter delivers its power into a load which may be considered as a series combination of the following resistances:
RL representing the losses in the radiator,
Rr the radiation resistance, i.e. the resistance of the propagating medium, and
Rg the resistance of the ground.



As the power dissipated in RL and Rg is wasted, these resistances must be kept as low as possible so that the maximum voltage may be developed across Rr).

Exam. No. 5801-5805 (Technician) Section A (continued from Vol. 18, No. 3, p. 297).

QUESTION 5. (a).

A variable frequency source is connected to an unknown circuit and a number of impedance measurements taken, the results of which are shown in Fig. 12. Complete the circuit to show the arrangement between A and B which will produce the characteristic shown in Fig. 12 and briefly explain the reason for the shape of the graph.

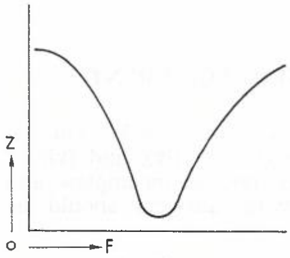


Fig. 12.

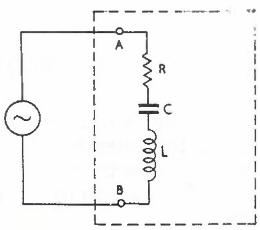


Fig. 13.

ANSWER 5. (a).

See Fig. 13. The series circuit will produce the characteristic shown as it is taken through resonance. Below the resonant frequency, the effect of X_C predominates. Z is initially high, but decreases with frequency. At resonance, the effects of X_L and X_C (on Z) cancel out, and the total Z is equal to R. Above resonance, X_L becomes increasingly larger than X_C and Z rises with frequency.

QUESTION 5. (b).

When a 200 ohm resistor, a 100mH inductor and a capacitor with a 650 ohm reactance are connected in series to a 800Hz (c/s) supply, the circuit current is 0·4 amps. Calculate the supply voltage and circuit impedance ($2\pi = 6{\cdot}25$).

ANSWER 5. (b).

$$\begin{aligned} X_L &= 2\pi fL \\ &= 6{\cdot}25 \times 800 \times 0{\cdot}1 \\ &= 500\Omega \\ (X_C - X_L) &= 650 - 500 \\ &= 150\Omega \\ Z &= \sqrt{R^2 + (X_L - X_C)^2} \\ &= \sqrt{200^2 + 150^2} \\ &= 250\Omega \\ E &= I \times Z \\ &= 0{\cdot}4 \times 250 \\ &= 100 \text{ Volts.} \end{aligned}$$

SECTION C

QUESTION 1. (a).

Fig. 14 shows a single stage transistor amplifier. State the type of bias arrangement used and briefly explain the factors that determine the value of the bias.

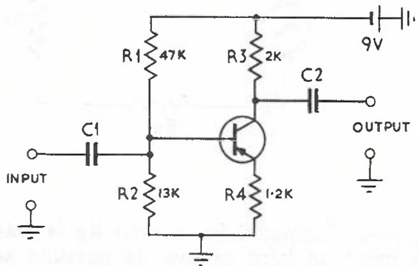


Fig. 14.

ANSWER 1. (a).

Combination Bias. Bias is determined by the difference in potential between the base and emitter. Base potential is determined by the potential across R2, which with R1 forms a voltage divider across the 9 volt supply. The emitter potential is determined by the p.d. across R4. This p.d. is developed by the emitter current through the 1·2k resistor R4.

QUESTION 1. (b).

The emitter current for the circuit in Fig. 4 is 1·5mA. Neglecting the effect of base current, determine:
(i) the bias on the transistor.
(ii) the collector-emitter voltage.

ANSWER 1. (b).

$$\begin{aligned} E \text{ base} &= \frac{13k}{13k + 47k} \times 9 \\ &= 1{\cdot}95\text{V negative} \\ E \text{ emitter} &= 1200 \times 1{\cdot}5 \times 10^{-3} \\ &= 1{\cdot}8\text{V negative} \\ E \text{ bias} &= 1{\cdot}95 - 1{\cdot}8 \\ &= 0{\cdot}15 \text{ Volts negative} \\ E \text{ across R3} &= \frac{2000 \times 1{\cdot}5}{1000} \\ &= 3\text{V} \\ Ece &= 9 - (3 + 1{\cdot}8) \\ &= 4{\cdot}2\text{V.} \end{aligned}$$

QUESTION 2. (a).

Draw the circuit of a push-pull output stage of a transsitor amplifier using input and output transformers. Include bias arrangements.

ANSWER 2. (a).

See Fig. 15.

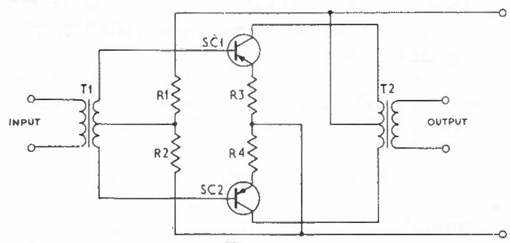


Fig. 15.

QUESTION 2. (b).

Briefly explain what is meant by Cross-over Distortion in class B push-pull transistor amplifiers and state how its effect is reduced.

ANSWER 2. (b).

It is the distortion produced when class B amplifiers are biassed to cut-off. As shown in Fig. 16(*a*), the characteristic has a bend at low values of base current. This causes distortion of the output, particularly at low values of signal.

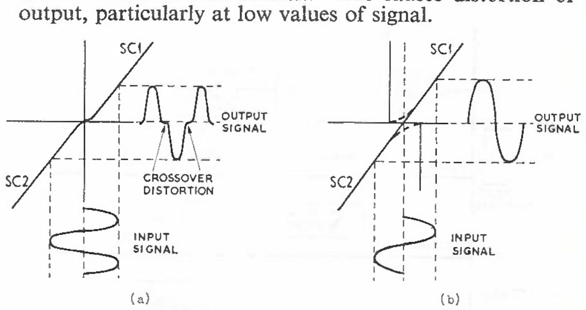


Fig. 16.

When a small value of forward bias is applied, (Fig. 16*b*) the combined characteristic of the transistors is almost a straight line and the distortion is greatly reduced.

QUESTION 3. (a).

With the aid of a block diagram, explain the three basic requirements that are necessary for the operation of any oscillator.

ANSWER 3. (a)

Fig. 17 shows that the basic requirements are an amplifying device to supply the necessary output power and make up for losses; a frequency determining circuit to select the oscillator frequency and a positive feedback circuit to supply the selected frequency to the input of the amplifier in the correct phase.

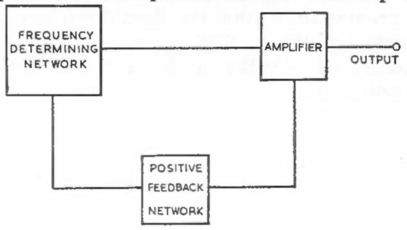


Fig. 17.

QUESTION 3. (b).

The term Astable applied to multivibrators means a circuit which produces a continuing output with or without external triggering signals. What is meant by the terms Monostable and Bistable?

ANSWER 3. (b).

Monostable oscillators remain in the one stable state until an external trigger is applied, and return to that state a fixed time interval after the signal is removed.
Bistable oscillators have two stable states and remain in either one until changed by an external trigger signal.

QUESTION 3. (c).

With the aid of a diagram, explain the principle of a Beat Frequency Oscillator.

ANSWER 3. (c).

Fig. 18 shows the basic diagram of a B.F.O. The frequency is changed by the variable frequency oscillator. The output of both oscillators is fed into the modulator, the desired sideband selected by the filter from the sum and difference products and amplified to the desired level. A gain control is usually included in the amplifier.

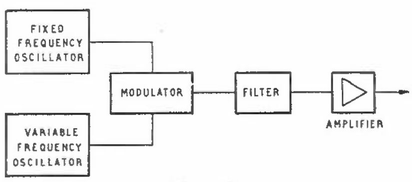


Fig. 18.

QUESTION 4. (a).

Draw the circuit of a single phase full wave power rectifier using two silicon diodes and a transformer with a centre-tapped secondary. Include a capacitor input ripple filter and briefly explain the operation of your circuit, including reference to the polarity of the output voltage.

ANSWER 4. (a).

See Fig. 19.

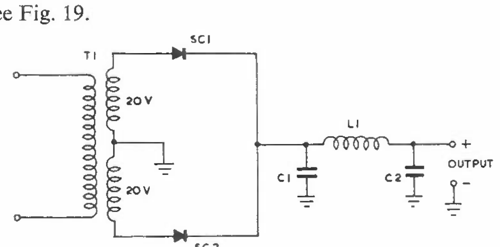


Fig. 19.

When the top of the secondary is positive, current is via SC1 and the choke L1 to the load and back to the centre-tap of the transformer via the earth connection. The second half cycle is through SC2, L1 and through the load in the same direction. L1 reduces the ripple voltage by opposing any change in current. C1 and C2 also reduce the ripple voltage, and by supplying current when the transformer voltage falls, maintain a relatively constant load voltage. The output polarity is shown on Fig. 19.

QUESTION 4. (b).

Each half of the secondary winding of the transformer in (a) supplies 20 volts at 400Hz (c/s). Determine the approximate no load output voltage and ripple frequency.

ANSWER 4. (b).

The output voltage is equal to the peak voltage of one winding of the secondary.

$E = 1{\cdot}4 \times 20$
$= 28$ Volts approx.

Ripple frequency is twice the supply frequency

$F = 2 \times 400$
$= 800$Hz.

QUESTION 5. (a).

Draw the basic circuits and attenuation versus frequency characteristics of:
(i) a low-pass filter;
(ii) a high-pass filter;
(iii) a band-pass filter.

ANSWERS 5. (a).

See Fig. 20.

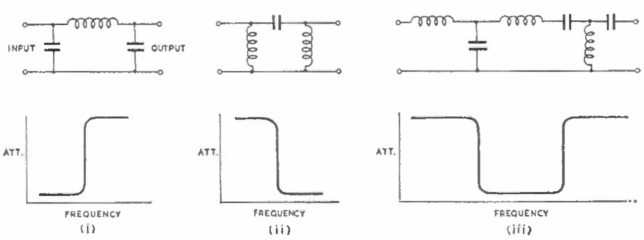


Fig. 20.

QUESTION 5. (b).

A low-pass filter has an attenuation of 50dB at 8kHz (kc/s). What will be the output power in mW and dBm when the input is +6dBm at this frequency?

ANSWER 5. (b).

$$\text{Output in dBm} = 6 - 50$$
$$= -44\text{dBm}$$
$$-\text{dBm} = 10 \log \frac{1}{P1}$$
$$44 = 10 \log \frac{1}{P1}$$
$$\text{A-log } 4{\cdot}4 = \frac{1}{P1}$$
$$25{,}000 = \frac{1}{P1}$$
$$P1 = \frac{1}{25{,}000}\text{ mW.}$$

Examination No. 5787; 29th June, 1968, and subsequent dates, to gain part of the qualification for promotion or transfer as Senior Technician (Telecommunications), Transmission Equipment, Postmaster-General's Department. (Some of the answers give more detail than would be required to obtain full marks for the questions. The additional information, studied in conjunction with the references listed, should be helpful to students.)

PART A — LINE TRANSMISSION EQUIPMENT.

QUESTION 1 (a):

List the test signals which are applied to broadcast programme transmission lines during tests to measure transmission performance. Your answer should include power levels and frequencies. State any precautions which must be taken in applying the test signals.

ANSWER 1 (a):

Test signals are applied to a broadcast programme channel for line-up of level and to measure frequency response and harmonic distortion. Frequency ranges for typical programme channels are 50 Hz — 5000 Hz for physical lines and 50 Hz — 7000 Hz, or 50 Hz — 10,000 Hz for carrier programme channels.

The frequency used for line-up of a programme channel is 1000 Hz. Frequencies used in the frequency response test should cover the programme channel range and typical frequencies are 50 Hz, 100 Hz, 3000 Hz and 5000 Hz for physical lines. For carrier programme channels additional frequencies of 7000 Hz and 10,000 Hz, as appropriate, are used. The level used for this test is —4dBm; that is, 12dB below the line-up level.

The frequency used for the harmonic distortion test should not exceed 800 Hz. A typical frequency used is 400 Hz.

Programme channel line-up is performed at a level of +8dBm (1000 Hz).

Distortion is measured using a level not greater than +16dBm, that is, 8dB above the line-up level.

Certain precautions, regarding power levels, must be taken when applying test signals. A large number of programme channels are provided on broadband systems using coaxial cable and radio bearers and some of these programme channels use pre-emphasis to improve the programme signal-to-noise ratio. Care must be exercised in performing certain tests, particularly frequency response tests, to avoid overload of the radio or coaxial cable systems.

The precautions regarding test levels can be summarised as follows: No test signal should exceed +16dBm, and test signals greater than 1000 Hz should not exceed —4dBm at the reference point (+8dBm line-up level). Any test signal in excess of +8dBm in level should be applied to only one channel at a time and for a maximum duration of 10 seconds.

QUESTION 1 (b):

(*i*) *What value of noise would you expect to measure on a high quality programme line between two major centres, for example Capital cities 600 miles apart? Give the standard programme level at the point of measurement.*

(*ii*) *What is the ratio in dB of this noise level to the maximum test signal applied?*

ANSWER 1 (b):

For programme channels up to 500 miles in length the weighted noise should not be worse than 49dB below +8dBm; a ratio of at least 57dB would therefore exist between the noise level and the maximum test signal level. For a channel 600 miles in length the ratio can be about 1dB worse; that is 56dB between maximum test signal level and the noise level.

References: Engineering Instructions; PLANNING, Trans and Line Systems 0 2010; Long Line Equipment, General and Line Systems 0 2010; LONG LINE EQUIPMENT, General, P 0280. Technical Training Publication MLR 049.

QUESTION 2:

Fig. 1 represents part of the receive equipment of an F.M. V.F. Telegraph system employing group modulation.

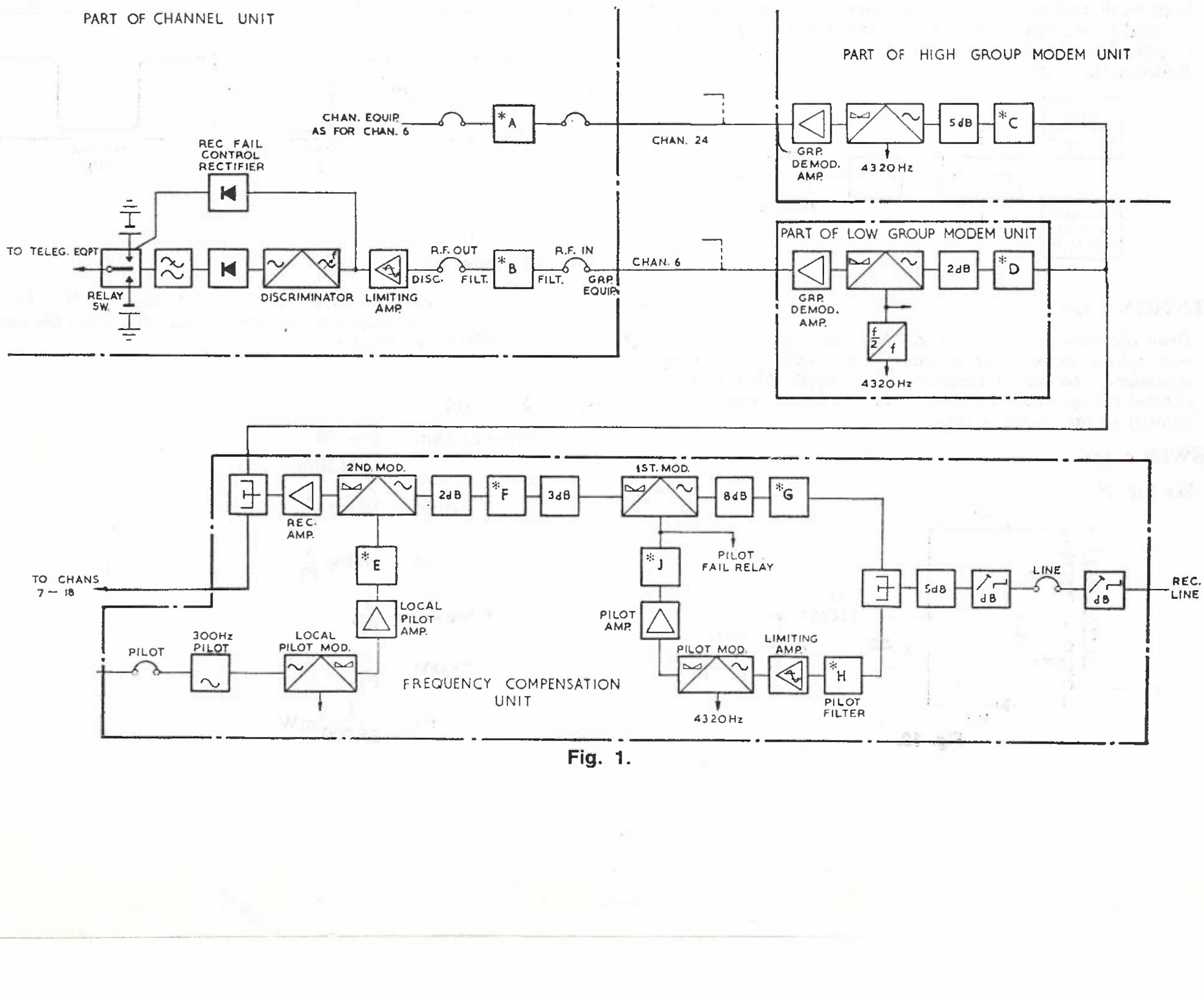


Fig. 1.

A number of blocks are left blank and marked with letters A-H and J. Indicate for each, the type of filter, and the frequencies or frequency bands which must be passed or stopped.

ANSWER 2:

The diagram is part of a T.M.C. (Aust.) system and the frequencies given in this answer are for this type of system. Full marks were allotted to candidates who gave channel frequencies for the T.M.C. (U.K.) system.

A 1140 ± 60 Hz (Bandpass) F 4280 to 7370 Hz (Bandpass)
B 1140 ± 60 Hz (Bandpass) G 3250 Hz (Lowpass)
C 2520 to 3240 Hz (Bandpass) H 280 to 320 Hz (Bandpass)
D 360 to 1080 Hz (Bandpass) J 4000 to 4040 Hz (Bandpass)
E 4020 Hz (Bandpass)

Reference: Technical Training Publication MLR 033.

QUESTION 3 (a):

What do you understand by the terms Return loss, Stability balance return loss and Echo balance return loss?

ANSWER 3 (a):

Return loss is a measure of the degree of impedance match between two impedances. It is the ratio of the power reflected from a termination to the power incident to the termination, expressed in dB. It is defined by the formula:—

$$\text{Return loss in dB} = 20 \log_{10} \frac{Z1 + Z2}{Z1 - Z2}$$

Under matched conditions return loss theoretically is infinite, but practical figures for matched conditions are from 45—50dB.

Under the extreme conditions of mismatch, with either a short circuit or open circuit load, the return loss figure is 0dB.

Stability balance return loss and echo balance return loss are applied to 2-wire/4-wire terminations of 4-wire circuits. The loss across a hybrid can be divided into normal hybrid loss (6.5 —7dB) and 'return loss.' The return loss is determined by the impedance ratio of the balance network and the line.

Stability balance return loss gives an indication of the amount of speech energy returned to a talker from the distant hybrid. It is measured (using frequencies covering the speech range) between the send and receive paths of the hybrid four-wire circuit, with the two-wire circuit terminated in its nominal impedance.

Echo balance return loss is the 'weighted' return loss of the balance network impedance against the impedance of the two-wire line terminated in its nominal impedance. It gives an indication of the effect of the returned energy on the talker. It is measured between the send and receive paths of the hybrid. A speech weighting noise generator is used as a signal generator. This consists of a random noise generator and a speech weighting network and produces an output to simulate normal speech energy distribution in the frequency range from 300 - 3400 Hz. The measuring device is a psophometer, which records the received signals as they would affect the average human ear.

Delay distortion, if excessive, has a degrading effect on the transmission performance as regards echo, but this feature is not considered in the echo balance return loss measurement.

QUESTION 3 (b):

Describe how you would measure the stability balance return loss of the circuit shown in Fig. 2, at the 4-wire exchange.

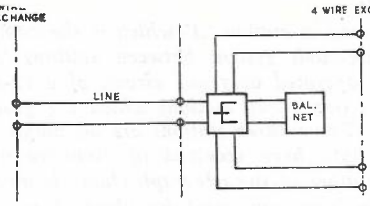


Fig. 2.

ANSWER 3 (b):

Fig. 3 shows the test arrangement to measure the stability return loss of the circuit. It is necessary to terminate the two-wire line in its characteristic impedance at the two-wire exchange. A test signal is then applied at the four-wire input to the hybrid and the signal level is measured at the four-wire output of the hybrid. The test signal is applied at a level similar to the normal circuit level at the hybrid-in point. The measurement is first made at 1kHz, and then can be measured for a number of frequencies in the range 0.3 - 3.4 kHz. The measured loss includes the hybrid loss, which is generally regarded as 6.5 - 7dB. The hybrid loss is deducted from the total loss to obtain stability balance return loss.

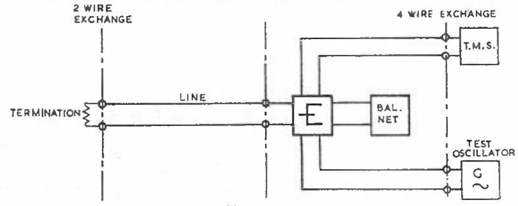


Fig. 3.

References: Technical Training Publications CP 236 and MLR 025.

QUESTION 4:

Draw a simple block diagram of the receiving terminal line equipment for a 6MHz coaxial cable system. Describe each item briefly and indicate its purpose. Facilities for change over to spare units need not be shown. Multiplexing equipment is not required.

ANSWER 4:

A suitable answer to this question is contained in the Technical Training Publication CP 226, 'Coaxial Line and Supervisory Equipment.' The main items of receiving terminal line equipment are included in Fig. 8, although standby and changeover equipment are not required in the answer. The pilot receiving equipment could also be simplified to one unit with three pilot control outputs.

The purposes of the equipment items are contained in Section 6. More information is given in the section than is required for the answer.

Reference: Technical Training Publication CP 226.

QUESTION 5 (a):

List briefly the responsibilities applying to a group control station as set out in Departmental Engineering Instructions.

ANSWER 5 (a):

The answer to this question is given in Engineering Instruction LONG LINE EQUIPMENT, General P 0100, paras. 3.1 and 3.2 (ii).

QUESTION 5 (b):

Show by means of a diagram the extent of the equipment included in a group and a group link.

ANSWER 5 (b):

The answer to this question is given in Engineering Instruction LONG LINE EQUIPMENT, General P 0100, Fig. 1 (a).

Reference: Engineering Instruction Long Line Equipment General P 0100.

QUESTION 6:

You are located at station 'A' which is the control terminal of a V.F. Telegraph system between stations 'A' and 'C'. The system is operated over one circuit of a 12-circuit group which includes two group sections which are group-connected at station 'B'. These three stations are all major cities.

Complaints have been received of excessive mutilation of signals on a number of the telegraph channels incoming to 'A' and these have been confirmed by observation.

What action is necessary to:

(i) Determine the cause of the trouble?

(ii) Make the V.F. telegraph channels good?

The necessary action must be set down in the sequence you would follow. You may assume the system is either A.M. or F.M.

ANSWER 6:

In order to determine the cause of the trouble it is necessary to obtain as much information as possible from the telegraph section regarding all the faulty telegraph channels. From this information it should be possible to ascertain if all the channels of the system are involved, if one or both directions are affected, if all the faulty channels are in the one V.F.T. system or whether other systems on the same route are involved. If other systems are involved it could be that the telegraph systems share one of the two group sections. An analysis of the telegraph channels involved could pinpoint the trouble to a possible common source.

The prime consideration is to restore service, and the action taken would be dictated by the initial analysis of the fault reports. Assuming that only one system is involved, and no indication of a group section fault is received, it is necessary to patch the V.F.T. system. If traffic conditions are normal, the system is patched to its nominated first choice patch. If the nominated patch is from A - C the patch is performed simultaneously at terminals A and C under the direction of the control station. It could be that two channels, one from A - B and one from A - C constitute the patch. In this case a patch is also required at station B. The telegraph channels are checked on their temporary bearer and, if satisfactory, are handed back to traffic.

Tests are then made to locate the faulty line or equipment. Both A.M. and F.M. telegraph systems are affected by interruptions exceeding about 5 ms, and also noise, particularly impulsive noise, on their bearer. In addition, A.M. systems are affected by variations in level and F.M. systems are affected by frequency shift (out of synchronism). The tests made, including listening tests, should be designed to determine these conditions.

To locate the fault, the overall system can be divided into telegraph terminal equipment and bearer. Each of these can be further subdivided. If the telegraph channels are satisfactory when patched to the first choice bearer, the fault would be in the bearer. This can be tested A - B and B - C to locate the faulty section. When line or group regulation is used the faulty section may be located by reference to the regulators.

If the fault is located to a section, additional tests should be made to give a more precise location. The telegraph bearer can be further subdivided into line equipment, group equipment, sub-group equipment and channel equipment. If part of a broadband system, then super-group and master-group equipment could be involved. Tests, or examinations of other fault reports, should be made to find whether the fault affects both directions of transmission, is confined to one terminal, is causing variations in level, affects all channels, affects one sub-group, etc. From the information obtained a more precise location should be made.

If the telegraph channels remain faulty when patched to the first choice bearer, the bearer should be retested, and if satisfactory, the telegraph terminal equipment is suspect. An analysis of the telegraph channel fault reports may give an indication of the faulty equipment. Most A.M. V.F. telegraph systems are assembled as 18 or 24 individual channels, but most F.M. V.F. telegraph systems are assembled in sub-groups of six channels. Test should also be made to determine whether the fault is in the transmit or receive equipment of the telegraph terminals.

When the cause of the trouble has been located and fixed, arrangements can be made to return the telegraph system to its normal bearer. It is advisable to restore the patch at a time of light traffic because an interruption will occur in the restoring process. The traffic authorities should be informed of the changes.

QUESTION 7 (a):

Draw a block schematic diagram illustrating the arrangements necessary to temporarily patch a broadcast programme channel to a channel of a 12-circuit carrier telephone system.

ANSWER 7 (a):

Either Fig. 39 or Fig. 40 of Engineering Instruction, LONG LINE EQUIPMENT, General P 0010, are suitable diagrams for this answer. Generally the programme is applied to 'Mod. In' of the carrier telephone channel (Fig. 40). Part (b) of each figure, showing alternative patching when the receive station is a splitting centre, is not required.

QUESTION 7 (b):

What is the bandwidth you would expect to transmit under these conditions?

ANSWER 7 (b):

300 Hz - 3400 Hz.

QUESTION 7 (c):

What limitations would apply to the use of such a channel for programme transmission?

ANSWER 7 (c):

Because of the limited bandwidth available on a telephone channel, it is unsuitable for music and should be used for voice transmission only.

Reference: Engineering Instruction, LONG LINE EQUIPMENT, General P 0100.

QUESTION 8:

With the aid of a sketch, describe the equipment provided and its method of operation for automatic gain regulation at a minor coaxial cable repeater.

ANSWER 8:

A suitable answer to this question is contained in the Technical Publication CP 226, 'Coaxial Line and Supervisory Equipment.' The main elements of typical pilot regulation equipment are given in Fig. 25 and a description of its method of operation is given in paras. 9.6 and 9.7.

Reference: Technical Training Publication, CP 226.

PART B — RADIO COMMUNICATION EQUIPMENT.

QUESTION 9:

Describe the test set-up and the method you would use to reduce a high 70kHz noise level in a 960 channel radio bearer which is operating with a normal level of basic noise.

ANSWER 9:

Since the basic noise level is normal, a high noise level in the 70 kHz test slot implies that either the modulator or demodulator (or both) is non-linear and requires adjustment. Special equipment is available, which will measure the degree of non-linearity, such as the G.E.C. derivative test equipment which is described.

Fig. 4 shows the test set-up for measuring the derivative response of a modulator. The derivative test unit delivers a 70 MHz signal, which is frequency modulated at 70 kHz and swept from 61 to 79 MHz at a 70 Hz rate. This frequency modulated signal is applied to the demodulator, where it is detected and then the baseband output is fed into the BB IN socket on the display unit. The 70 Hz component is filtered out and the 79 kHz signal is amplitude detected. The resulting d.c. voltage is used to provide a vertical deflection on the C.R.O., which will be proportional to the non-linearity of the demodulator.

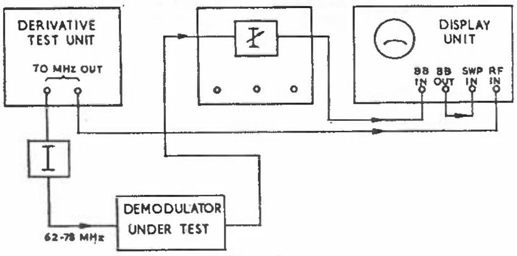


Fig. 4.

The horizontal deflection voltage is derived by detecting the swept 70 MHz signal in the discriminator of the display unit.

The vertical sensitivity of the display unit is calibrated by changing the level of the 70 kHz modulating signal by a known amount (usually 1dB) and noting the change in vertical deflection on the C.R.O.

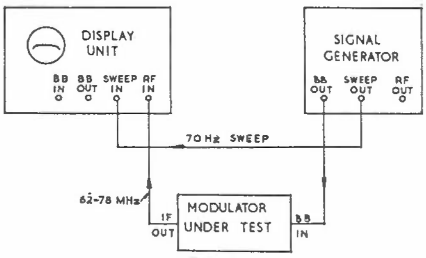


Fig. 5.

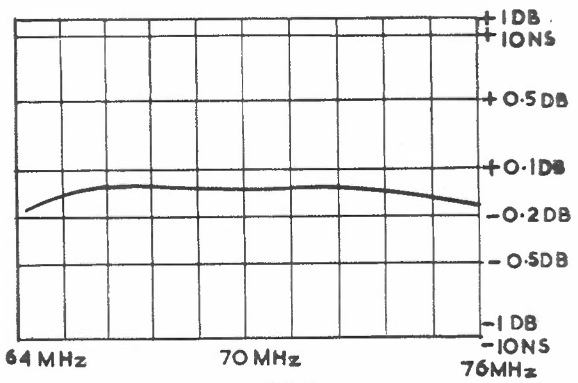


Fig. 6.

Fig. 5 shows the test set-up for measuring the derivative response of a modulator. The signal generator provides a 70 Hz saw-tooth voltage with a 308 kHz signal superimposed on it. This is fed into the modulator, which produces a swept 70 MHz signal in the output with a 308 kHz F.M. component. The R.F. signal is applied to the display unit, where it is demodulated, the 308 kHz signal is amplitude detected and the resulting d.c. voltage is used for vertical deflection as before. Fig. 6 shows a typical result.

Before carrying out a modulator derivative test (which makes use of the discriminator in the display unit), it is necessary to ensure that the back-to-back derivative response of the equipment is within the specified limits. In this check, the swept 70 MHz signal from the generator is fed to the display unit through a suitable attenuator. The discriminator in the display unit is then adjusted for maximum linearity. Allowance is made for remaining non-linearity by drawing a suitable graticule on the C.R.O. face with a grease type pencil. (The generator is designed to have a negligible linearity error.)

QUESTION 10:

A broadband radio system operates as follows:

Bearers	*Traffic being Carried*
101	*Protection*
102	*Protection*
103	*Telephony (960 channels Interstate)*
104	*Telephony (960 channels Interstate)*
109	*Regional Television*

Bearer 109 has failed and remains failed throughout the following events:—

(*i*) *Describe the series of automatic switching operations (including a description of transfer and operate times) which will occur if bearer 103 now fails due to a deep fade.*

(*ii*) *What automatic switching operations would have occurred had bearer 103 muted due to a failure of a receiver I.F. amplifier?*

(*iii*) *What automatic switching operation would have occurred in case (i) had bearer 102 failed?*

ANSWER 10:

The switching system discussed below assumes that all pilot failures take precedence over all noise failures. On some of the very latest switching systems where the noise switching level approaches the pilot switching level, both have equal priority.

In the event of a deep fade on bearer 103, the noise detected by the 103 noise receiver will increase to the noise switching level. As the protection bearer is carrying T.V., however, no switching takes place, because the 103 pilot is still being received, whilst the pilot on 109 is lost. As the fade deepens, 103 pilot is eventually lost, and because Interstate telephony has priority over regional T.V., switching occurs with a transfer time of approximately 50mS, of which only about 1mS is due to the operate time of the relay.

Note.—The transfer time due to pilot failure where the protection bearer is available, will typically consist of the following:—

1. Propagation time (1mS for 186 miles) approx. 2mS
2. Operate time of reed relay .... approx. 1mS
   or Operate time of diode switch .... approx. 5uS
3. Sensing time of V.F. signalling tone detector and switching logic circuitry. ... approx. 17 mS

Total .... approx. 20mS

Had the protection bearer 101 been available, switching would have occurred due to noise, and the resulting traffic time lost would have been 1mS (or less in the case of I.F. switching), due to the operate time of the switch.

It should be noted that any bearer can carry traffic throughout a deep fade until the muting level is reached and the pilot lost. Fig. 7 shows a typical sequence of events during a progressive fade, and typical ranges of signal level over which the various alarm and switching circuits operate. In the latest systems, the noise fail switching can be set nearer the mute point than the —98 dBW shown.

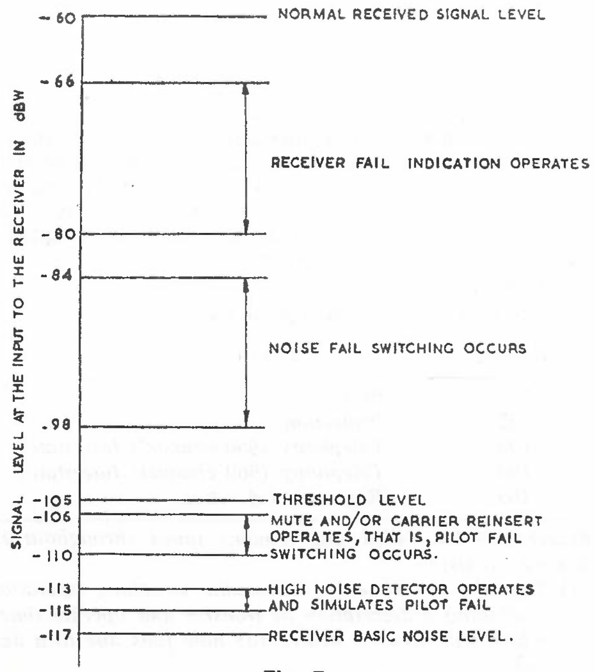


Fig. 7.

Had bearer 103 muted abruptly instead of fading slowly to the mute point, the T.V. traffic on bearer 101 would have been replaced by the higher priority traffic on bearer 103 with a traffic time lost of approx. 50mS. Any mute failure gives, of course, a pilot failure.

Had bearer 102 failed, no switching would have resulted because bearer 102 is an even number and therefore carries traffic in the opposite direction. However, telesignalling would have given alarms at both terminals to show that bearer 102 had failed. In addition, the switching logic would have been inhibited in such a way as to prevent switching in case bearer 104 failed.

QUESTION 11:

Describe the method of white noise testing microwave radio bearers. How are the results interpreted?

ANSWER 11:

A white noise test set is used to measure the intermodulation distortion produced in a radio telephone bearer. The test set consists of the following units:—

(i) A white noise generator which produces a signal with a uniform spectrum and which has statistical properties similar to that of the multiplex signal. The bandwidth and level are adjustable.

(ii) A set of three bandstop and three bandpass filters with centre frequencies chosen to fall near the lower, middle and upper limits respectively of the band of frequencies occupied by the multiplex signal.

(iii) A selective receiver with an effective bandwidth of 3.1 kHZ.

Before proceeding with the white noise test, the bearer equivalent must be checked and reset if necessary within ± 0.25 dB of the nominal value. If an adjustment is necessary, the modulator deviation should be checked before making any other adjustments.

There are two general types of white noise sets: one designed to give the result of the noise test directly in terms of the Noise Power Ratio (NPR) and the other designed to give the result directly in terms of the Signal to Noise Ratio (S/N). The only significant difference between the two types of sets is in the receiver. In the set designed for N.P.R. readings the receiver consists essentially of a calibrated attenuator and uncalibrated level meter. In the set designed for S/N readings the level meter is generally a calibrated power meter.

The method of using the white noise sets designed for direct N.P.R. measurement is described below. The bearer to be tested is taken out of traffic and the white noise set is connected to the bearer as shown in Fig. 8.

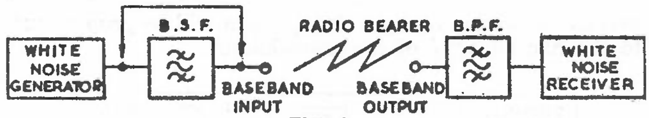


Fig. 8.

The calibrated attenuator of the white noise receiver it set to some arbitrary low value and the meter set to the zero reference calibration by means of the receiver's variable gain controls. Let the attenuator reading be ydB (as the actual signal in the slot is removed by the bandstop filter; this reading is proportional to the total noise level in the 3.1 kHz bandwidth). The bandstop filter is now shorted out and the calibrated attenuator is adjusted until the meter returns to the original setting. Let this reading be xdB. (This reading is proportional to the signal plus noise level).

Then N.P.R. = x-y dB, i.e., this reading is effectively the ratio of the total signal power to the noise power in the telephone channel bandwidth (assuming that noise is very much smaller than the signal).

If we wish to derive the signal to noise ratio (S/N), or more correctly, the standard test-tone to noise ratio, this may be obtained by adding to the N.P.R. the number of dB given by the ratio of the standard test tone level (0dBm0) to the actual noise signal power in the 3.1 kHz measuring channel. For a 960 channel system this additional factor is equal to 16.3dB. An additional 2.5dB must be added to obtain the signal to weighted ratio noise, therefore S/N (dB weighted) = N.P.R. + 18.8 dB for a 960 channel system.

Noise measurements are made at the three slot frequencies. For a 960 channel system, these frequencies are 70 kHz, 2438 kHz and 3886 kHz. The noise as measured above consists of two components:

Basic noise, which comprises the thermal noise due to the baseband equipment and that originating in the equivalent resistance at the front end of the receiver.

Intermodulation noise, due to the non-linearity of the amplitude and phase characteristics of the equipment.

To obtain a measure of the basic noise on a bearer, an N.P.R. measurement is made with the generator output level reduced sufficiently to ensure that no intermodulation distortion is produced. The particular level chosen for this test is normally 0dBm0. The factor used to convert the N.P.R. taken at 0dBm0 to S/N is 33.6dB, i.e., 18.8 + 14.8 for a 960 channel system.

High basic noise could result from low signal strength on one or more paths or defective baseband amplifiers.

The intermodulation noise consists of two main components caused by:

Non-linearity of the modulator and demodulator.

Delay variations in the I.F., R.F. and radio propagation path.

At the lower baseband frequencies, the intermodulation noise is almost entirely due to the non-linearity of the modulator and demodulator. At the upper baseband frequencies it is due to the sum of the non-linearity and group delay variations, with the group delay being the controlling factor. Thus, a high intermodulation noise reading obtained in the bottom slot, indicates the modulator and demodulator linearity needs checking, while a high noise in the top slot indicates excessive group delay variations which could originate in the I.F. and R.F. amplifiers and antenna feeders. Multipath propagation effects can cause the top slot readings to vary with time.

More information on the performance of the bearer may be obtained by measuring the N.P.R. with various white noise input levels from 0dBm0 up to 10dB above the fully loaded condition. A graph of typical results is given in Fig. 9.

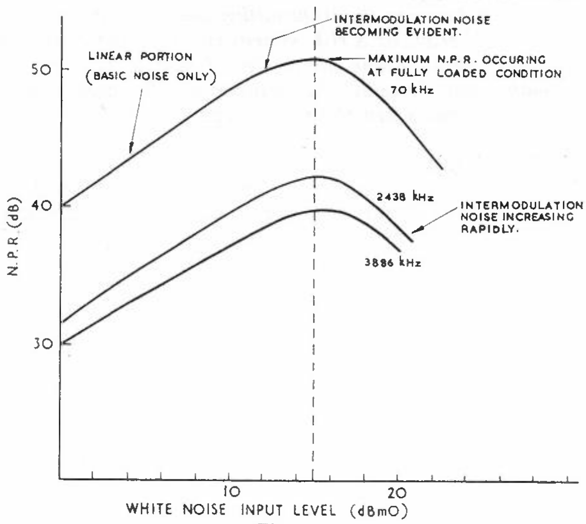


Fig. 9.

QUESTION 12:

You have just completed a visit to a radio bearer repeater site where you have restored a bearer to traffic. Describe in detail the radio bearer service report you would prepare and give the reason or reasons why you would enter each item. In answering this question you should use two columns, the left one being used for the description of each item, and the right one being used for the reasons.

ANSWER 12:

QUESTION 13 (a):

Describe one antenna in each band which is used in radio-communication service in:

(i) the H.F. band;

(ii) the V.H.F. band;

(iii) the S.H.F. band.

Give details of the construction, dimensions both physical and electrical, feed arrangements and input impedance. Sketch the E and H plane radiation patterns of each antenna.

ANSWER 13 (a):

(i) H.F. band—Rhombic. Construction details and patterns are given in the Technical Training Publication, Radio 2, paper 4, pages 31 and 32. The E plane of a rhombic antenna is HORIZONTAL and the H plane is VERTICAL.

(ii) V.H.F. band—Yagi. A typical two-element yagi antenna comprises a nominal half wave-length dipole spaced approximately 0.2 wave-length in front of a passive reflector element. The reflector element may be a self-supported continuous tube attached to the main support. The electrical length of the reflector is approximately half wave-length plus 5 per cent., that is, it is inductive in reactance. Alternatively, a passive director element which is electrically shorter than half wave-length may be mounted in front of the dipole and used instead of the reflector. The dipole may be either a simple dipole split at the centre to provide a current feed point, or a folded dipole formed from tubing insulated from the support. The impedance of the antenna is approximately 50 ohms using a simple dipole or 200 ohms using a folded dipole, as the reflector reduces a dipole's normal impedance. The forward gain is approximately 2.5 dB reference a dipole in free space when mounted several wave-lengths above the ground. The front to back ratio is approximately 6dB.

Radio Bearer Service Report.

Site No.	Identifies the geographic location of the equipment and so allows analysis into State and Division.
Bearer No.	Identifies the direction and section in which traffic is being carried.
Complaint or Observation	Provides information as to why the service action (routine or fault clearance) was carried out.
Planned Activity	Records the type of routine (if relevant).
Common Equipment	Allows analysis of the reliability of equipment which is associated with all the bearers at a site; e.g., N.S. set.
Unit, Component and Fault Cause	Provides basic data used to discover weaknesses in equipment and allows planning of future preventive maintenance.
Time Commenced) Time Cleared)	Determines duration of a fault condition.
Traffic Trunk Lost	Determines effect of fault on telecom. traffic.
Man Hours and Material Cost	Allows comparison of costs of different manufacturers, systems, bearers, sites and methods and so helps management plan future provisioning policy and service activity. (Material cost is sometimes derived at State H.Q. rather than being directly entered in the field.)
Signature	To allow reference in unusual cases.

The E plane of a yagi antenna is in the plane of all the elements, the H plane is at right angles to the E plane and is along the direction of fire. (Fig. 10).

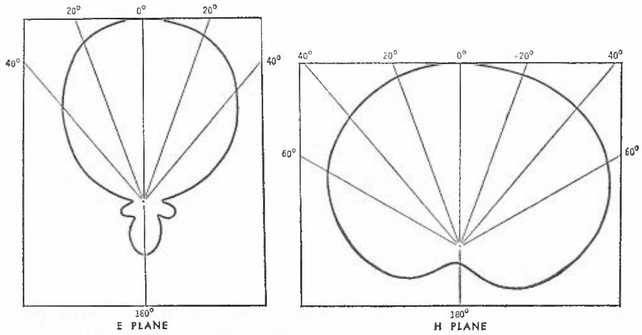
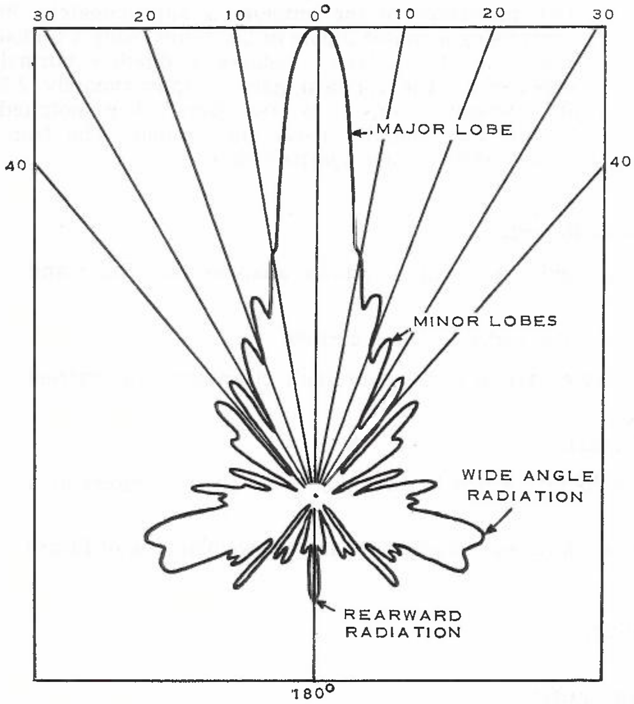


Fig. 10.

(iii) A high gain reflector antenna for the S.H.F. band uses a parabolic reflector sometimes called a "dish." The reflector is made from spun aluminium and is manufactured to close tolerances. Diameters are usually about 8 ft. up to 15 ft. The primary feed reflector is in some cases a dipole, but at frequencies above 2GHz is more usually an electromagnetic horn which is a flared or fan-shaped section of the waveguide. The polarisation of the antennas depends upon the plane of the radiator waveguide feed and often can be changed by adaptable mounting arrangements. Dual inputs may be obtained by separate horizontally and vertically polarised radiator waveguide feeds. An E and H plane radiation pattern is shown in Fig. 11.



E AND H PLANE

Fig. 11.

QUESTION 13 (b):

Calculate the velocity of propagation of a coaxial cable which has a dielectric constant of 2.0.

ANSWER 13 (b):

Velocity of propagation in air is 186,000 miles/sec.

Velocity of propagation in coaxial cable:

$$= \frac{186,000}{\sqrt{2}}$$

$$= 131,200 \text{ miles/sec.}$$

Reference: Technical Training Publication, Radio 2.

QUESTION 14 (a):

Propagation between the transmitting and receiving antennas of a V.H.F., U.H.F., or S.H.F system can take place by other than a direct path Name the modes of transmission of these other paths and describe the process of the modes giving details of how and when the mode occurs

ANSWER 14 (a):

The modes are reflection, refraction and diffraction.

(i) Reflection. Referring to Fig. 12, a wave striking a reflecting surface is shown in this diagram. The wave strikes the ground but cannot penetrate it. If the surface was absent the wave would advance unchanged, but the presence of the surface changes the direction of the wave part, as shown by A.O.B. The angle of incidence equals the angle of reflection and they are in the same plane. For horizontally polarised waves, a phase change of about 180° occurs at the points of reflection, but for vertically polarised wave the phase change is between 0° and 180°. Certain loss occurs on reflection and a coefficient of reflection can be determined by the ratio of the

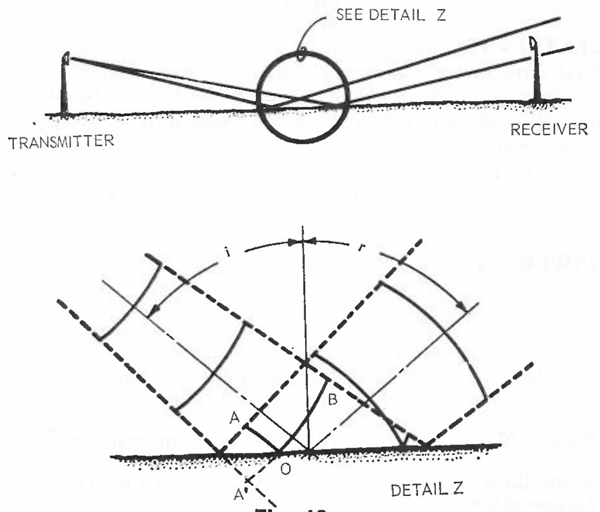


Fig. 12.

energy per second leaving the surface to the energy per second incident to the surface. Reflection often occurs from the ground between a transmitting and receiving antenna, or from mountains, buildings or even steel structures close to the direct path.

(ii) Refraction. In Fig. 13, a wave is shown being refracted through a mass of air which is denser than the air surrounding it. Because the mass of air is denser than the surrounding air, the wave is slowed down as it crosses the interface. As the wavefront is oblique to the interface, the slowing down occurs at different instantaneous times, resulting in a change of direction. As shown, this wave velocity is less in the air mass than in the surrounding air and line A.O.B. represents the new direction of the wavefront. The angle 'r' to the 'normal' is the angle of refraction. A beam travelling from a lighter to a denser medium

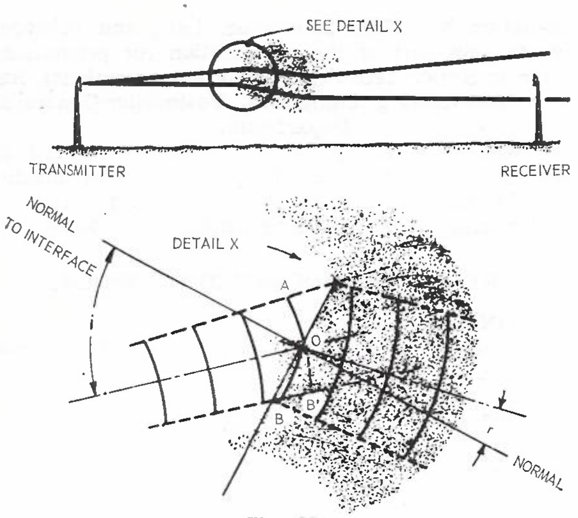


Fig. 13.

is 'refracted' towards the normal and for vice versa the beam is refracted away from the normal. Refraction often occurs when a wave encounters layers of hot air trapped above the direct path or by columns of rising or falling air in the direct path.

(iii) Diffraction. A wavefront passing over an obstacle causes re-radiation in all directions, as shown in Fig. 14. The re-radiation is not from one point but from

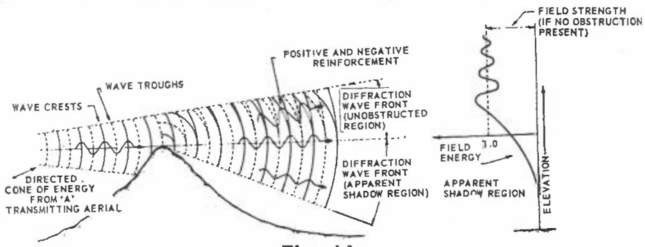


Fig. 14.

a large part of the surface of the obstacle. Therefore the re-radiation and subsequent bending of the waves as they graze the earth's surface can cause radiation in the geometric shadow of an obstacle. Diffraction of a wave can be utilised to reach an area in 'shadow,' particularly if this obstacle has a knife edge. Diffraction can occur also around buildings or cliffs close to the direct path.

QUESTION 14 (b):

Give the names and approximate heights of the ionospheric layers encountered by the transmission of High Frequencies during the day, and state their normal role in radiocommunication.

ANSWER 14(b):

Ionospheric Layer.	Height.
D	50 - 90kM
E	90 - 140kM
F1	200 - 250kM
F2	300 - 350kM

During the day the D layer absorbs the energy of wavefronts up to approximately 2MHz, so that no reflection occurs. At frequencies higher than this, the D layer is penetrated and reflection may occur from the E layer above it, depending upon the angle of incidence of the wave and the frequency. When the angle of incidence is small, a critical frequency will be reached when the E layer is penetrated and a wavefront may travel on through the F_1 and subsequently may reach the F_2 layer. Reflection may occur again, depending upon the frequency and the angle of incidence at these layers, but complete penetration can occur. Reflection from the ionospheric layers will allow greater distances to be spanned by high frequency transmissions than would be possible from the ground-wave mode.

References: Technical Training Publications MLR-O51 and Radio 2.

QUESTION 15 (a):

Draw the circuit of a three phase, half wave rectifier using delta/star transformer and mercury vapour rectifiers. Show the approximate voltages at various points and the output waveform, assuming a D.C. output on load of 500 volts suitable for application to radio equipment.

ANSWER 15 (a):

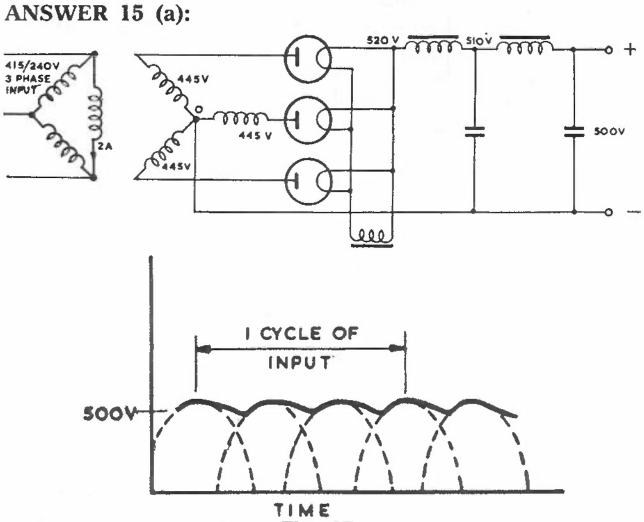


Fig. 15.

QUESTION 15 (b):

If the R.M.S. current in each delta winding of the transformer was 2 amps, what would be the power consumption of the rectifier? Assume the voltages approximated in (a) and a power factor of 0.8.

ANSWER 15 (b):

The voltage per phase assumed in (a) is 415V, if 2A flows in each delta winding then the power in each winding is 415 x 2 x 0.8 watts.

Total power = 415 x 2 x 0.8 x 3
= 1990 watts.

Reference: Technical Training Publication, Radio 2, Radio, Tucker and Wilkinson, Volume 3.

QUESTION 16 (a):

Show how energy can be transferred along a rectangular waveguide and illustrate the electric field pattern at one instant.

ANSWER 16 (a):

A suitable answer is given in the Technical Training Publication MLR 052, para. 7.2, and Fig. 20 and Fig. 22. In addition, when two wavefronts are simultaneously present so that they cross each other at an angle as shown in Fig. 20, the fields inside the guide satisfy the boundary conditions imposed by the walls and energy is transmitted. Fig. 22 shows the resultant field configuration.

QUESTION 16 (b):

Compare the advantages and disadvantages of a waveguide with other R.F. transmission lines.

ANSWER 16 (b):

Low conductor loss. The surface area of a waveguide is large enough to reduce the conductor loss considerably compared with a two-wire line, which only has relatively small conductors. Compared with a coaxial cable, the inner conductor losses are not present in a waveguide.

Low dielectric loss. A waveguide has no dielectric other than air, therefore dielectric losses are lower than for transmission lines with separators and other forms of insulation.

Negligible radiation loss. The electromagnetic field of a waveguide is confined inside the guide, but with other transmission lines, particularly unshielded lines, losses are considerable.

High power handling capacity. Voltage breakdown of insulation is possible with other transmission lines, but is not easily possible with waveguides, therefore the power handling capacity is high.

Restriction of frequency range. A waveguide operates with low losses between two frequency limits; outside these limits the losses are high. Other transmission lines have a larger frequency range of operation. At frequencies below about 1 GHZ the dimension of a waveguide becomes impractically large.

QUESTION 16 (c):

State the modes of transmission of a rectangular waveguide and illustrate at least two of them.

ANSWER 16 (c):

Modes of transmission. Two modes of transmission are possible in general terms, the transverse electric (TE) mode and the transverse magnetic (TM) mode. Examples of typical modes of operation are:

TE_{10}, TE_{01}, TE_{20}, TE_{11}, TM_{11} — Where the number of half-cycle variations of the transverse fields that exist along the wide dimension of the waveguide are indicated by the first digit, and along the narrow dimensions by the second digit. Subscript 0 indicates no variation.

Two typical modes of transmission are illustrated in Fig. 16 and Fig. 17.

Reference: Technical Training Publication MLR 052.

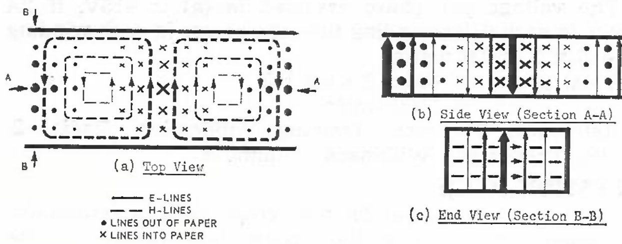


Fig. 16.

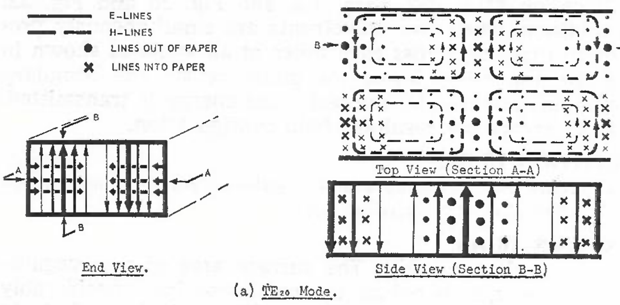


Fig. 17.

Examination No. 5788; 29th June, 1968, and subsequent dates, to gain part of the qualification for promotion or transfer as Senior Technician (Telecommunications), Radio and Broadcasting Equipment, Postmaster-General's Department.

(Some of the following answers give more detail than would be required to obtain full marks for the questions. The additional information, studied in conjunction with the references listed, should be helpful to students.)

PART A — BROADCASTING EQUIPMENT.

QUESTION 1:

Answer briefly the following questions about an anode-modulated Class C amplifier.

QUESTION 1(a)

Why is it desirable to use grid-leak bias, and how should the resistance of the grid-leak compare with the value of capacitance used?

ANSWER 1(a)

To obtain high efficiency from the modulating stage, the grid must be driven hard enough so that on the positive peaks of grid voltage, the anode current is controlled only by the anode voltage (line OA on the anode characteristic —Fig. 1) The valve is then 'anode limited.'

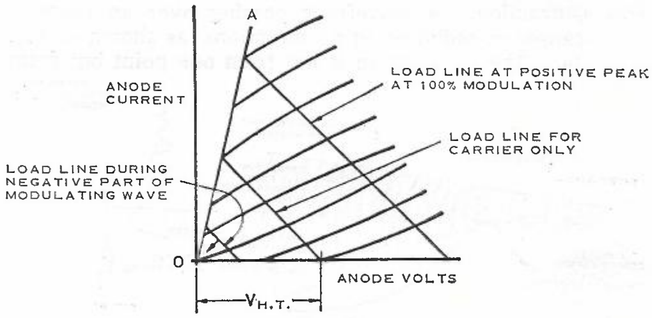


Fig. 1

As the modulating voltage varies the anode supply potential, the grid voltage necessary to provide anode limitation also varies. Provided the grid drive remains constant, the changing grid current will vary the bias developed across the grid-leak so that the peak positive grid potential is automatically adjusted.

The time constant (CR) of the grid capacitor and resistor must be less than one half-cycle of the highest modulating frequency.

QUESTION 1 (b):

What is the relation between the grid bias and the radio frequency voltage applied to the grid? How would this vary with changes in anode supply potential?

ANSWER 1 (b):

To permit anode limitation under all conditions of modulating voltage, the grid bias is normally adjusted to 2½ to 3 times the cut-off grid voltage in the unmodulated condition. The peak grid drive will then be approximately 3½ to 5 times the cut-off voltage.

The grid drive is maintained constant, so that as the anode supply potential decreases, the grid bias will increase, and as the anode supply potential increases, the grid bias will decrease.

QUESTION 1 (c):

How does the anode efficiency of the system (modulator + modulated amplifier) vary as the modulation level is increased from zero to 100 per cent.?

ANSWER 1 (c):

Provided that the anode-modulated amplifier always operates in the anode limited condition, its anode efficiency will be maintained constant at approximately 70 per cent. for all levels of modulation.

At zero modulation the Class B modulator delivers no power, but, because it is biassed very close to cut-off, it dissipates very little input power so that its contribution to the overall efficiency is small. As the modulation percentage increases, the modulator input and output power both increase, until at 100 per cent. modulation the modulator is providing sideband power equal to half the carrier power, at about 65 per cent. efficiency.

Consequently, the anode efficiency of the system will remain practically constant at about 60 per cent. for all levels of modulation.

Reference: Radio, Tucker and Wilkinson, Vol. 3, pages 72-78

QUESTION 2 (a):

With the aid of a simplified circuit diagram, describe the principle of operation of a radio frequency combining unit suitable for combining the power outputs of two identical medium frequency broadcast transmitters.

ANSWER 2 (a):

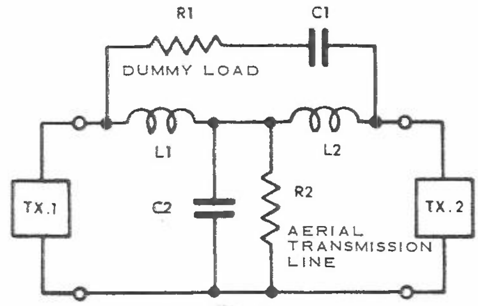


Fig. 2.

Fig. 2 shows the circuit of a typical R.F. combining unit. The combining unit is in the form of a bridged-T network, with the aerial and dummy load as shown. Normally the two transmitters are delivering equal in-phase voltages, so no current will flow in the dummy load R1, and R1 and C1 can be ignored.

If each transmitter is considered separately, the combining unit may be divided into two L sections, as shown in Fig. 3.

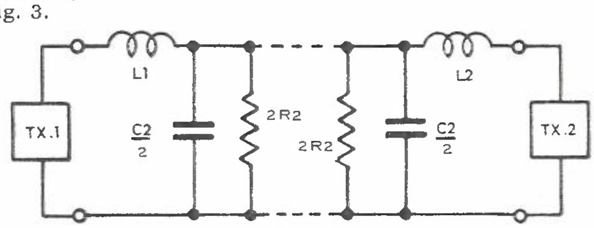


Fig. 3.

Each L section is designed to match the output impedance of its transmitter to a resistive load which is twice the impedance of the aerial transmission line.

Thus, when the two transmitters are operating identically, each operates into a matched load and their combined power outputs are delivered to the aerial. If the two transmitters are not operating identically, each still operates into a matched load, but current will flow in the bridge arm, R1 and C1, and the unbalanced portion of the power will be dissipated in the dummy load R1.

QUESTION 2 (b):

What will be the effect on the combined power output and on the operation of the combining unit of:

(*i*) *a minor decrease in the power output of one transmitter?*
(*ii*) *a complete failure of one transmitter?*
(*iii*) *reversing the phase of the radio frequency input to one transmitter?*
(*iv*) *reversing the phase of the modulating signal input to one transmitter?*
(*v*) *a harmonic component in the radio frequency output of one transmitter?*

ANSWER 2 (b):

(i) The combined power output to the aerial will be twice the power of the lower-powered transmitter, and the unbalanced power, that is, the difference in the power outputs of the two transmitters, will be dissipated in the dummy load.
(ii) The power output to the aerial will be half the power of the remaining transmitter. The other half of the power will be dissipated in the dummy load.
(iii) The total combined power output will be dissipated in the dummy load and no power will be delivered to the aerial.
(iv) The combined power of the modulation components will be dissipated in the dummy load, while the combined unmodulated power of the two transmitters will be delivered to the aerial.
(v) The harmonic component and any consequent unbalanced power output will be dissipated in the dummy load, and the matched portion of the combined power output will be delivered to the aerial.

Reference: Technical Training Publication, MLR 170, pages 10 - 11.

QUESTION 3 (a):

Show with a block diagram the necessary components of a standard signal generator suitable for broadcast receiver measurements. List the essential features and performance requirements of the instrument.

ANSWER 3 (a):

See Fig. 4.

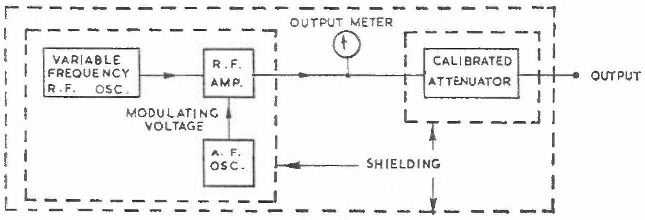


Fig. 4.

The signal generator frequency range must be sufficient to cover the tuning range of the receiver and its intermediate frequency and to check for spurious responses outside this range. It must be stable in frequency and output level and be completely free, if possible, from harmonic or spurious frequency generation. All components must be stable with temperature and time, power supplies must be adequately regulated and decoupled to prevent interaction, and all sections of the generator must be adequately shielded to prevent stray radiation.

The modulating output from the 400 Hz or 1000 Hz audio frequency oscillator must be adjustable to provide a known percentage modulation of the R.F. signal. The R.F. output must be adjustable to a known level indicated on the output meter. The maximum output should be sufficient to check the overload characteristics and spurious responses of the receiver. The output level is controlled by a calibrated attenuator, variable in small known steps, and matched to the impedance of the generator and load. The minimum output should be well below the receiver noise level.

QUESTION 3 (b):

Describe briefly how you would use the signal generator to measure:
(i) the sensitivity of the receiver;
(ii) the adjacent channel selectivity of the receiver;
(iii) the image rejection of the receiver.

ANSWER 3 (b):

For each of these tests, the receiver A.G.C. is disconnected:

(i) The sensitivity of a receiver must be measured with respect to a specified signal-to-noise ratio. It will be assumed that the receiver S/N ratio is 15dB. The signal generator is connected to the receiver aerial terminals and an output meter to the receiver output. With no output from the generator, the receiver gain control is adjusted to give an output meter reading 15dB below 50 mW. With the signal generator modulated 30% at 400 Hz, its output attenuator is adjusted to give a receiver output of 50 mW. The signal generator output in microvolts is then the receiver sensitivity at the operating frequency. This measurement is repeated over the frequency range of the receiver.

(ii) With the receiver and signal generator adjusted for 50mW output. the signal generator is reset to the adjacent channel frequency (usually taken either as ±9kHz or ±10kHz from the test frequency), and its output is increased until the receiver output is again 50mW. The ratio of the off-tune output to the on-tune output of the signal generator is the adjacent channel selectivity of the receiver.

(iii) With the receiver and signal generator adjusted for 50mW output, the generator is reset to a frequency on the opposite side of the receiver local oscillator frequency and separated by twice the intermediate frequency from the test frequency. The generator output is increased until the receiver output is again 50mW and the ratio of the off-tune output to the on-tune output of the generator is the image rejection of the receiver.

References: Radio, Tucker and Wilkinson, Vol. 3, pages 172-176; Technical Training Publication, Radio 2, Paper 8, pages 3 - 8, 16.

QUESTION 4 (a):

The output of an audio frequency amplifier is transformer coupled and uses a single beam-tetrode valve. Show with the aid of a circuit diagram how negative voltage feedback could be applied to this stage.

ANSWER 4 (a):

A variety of circuits are available and all are equally acceptable provided they are adequately specified. The most useful is, basically, that shown in Fig. 5.

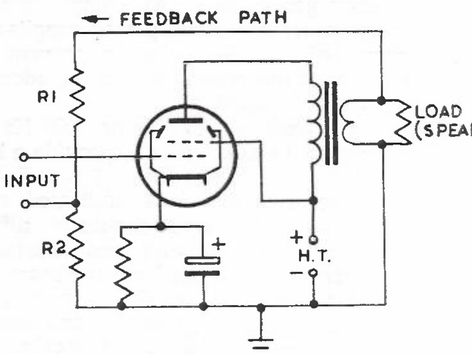


Fig. 5.

The feedback voltage is proportional to the voltage across the secondary of the output transformer, and is opposite in phase to the input signal. The degree of feedback can be adjusted by varying the ratio of R_1 and R_2.

$$\text{Feedback ratio } B = \frac{R_2}{R_1 + R_2}$$

Negative feedback reduces the gain of the amplifier. If A is the amplifier gain without feedback, the gain of the amplifier with feedback (A^1) is given by:

$$A^1 = \frac{A}{1 - AB}$$

where B is negative for negative feedback.

QUESTION 4 (b):

Explain the effect of this type of feedback on:
(i) the internal impedance of the amplifier;
(ii) the amplitude-frequency response of the amplifier;
(iii) the amplitude distortion produced by magnetic saturation in the output transformer.

ANSWER 4 (b):

(i) The internal impedance of the amplifier is reduced. The output impedance with feedback:

$$Zo^1 = \frac{Zo}{1 - AB}$$

where B is negative for negative feedback.

(ii) The response of the amplifier is improved at both high and low frequencies, as the amplifier gain is held constant by feed-back at all frequencies, for which A is greater than A^1.

(iii) Any distortion produced in the amplifier or output transformer will tend to be cancelled by the negative feedback of an equivalent voltage to the amplifier input. The distortion with feedback:

$$d^1 = \frac{d}{1 - AB}$$

However, if the output is sufficient to saturate the output transformer after feedback is applied, no reduction in this distortion is possible.

References: Radio, Tucker and Wilkinson, Vol. 3, pages 11 - 12, 15 - 17, Technical Training Publication Radio 1, Paper 4, pages 24 - 28.

QUESTION 5 (a):

Sketch the waveform of the pulse and bar video test signal showing the duration and time position of the pulse and the bar relative to the synchronising pulse.

ANSWER 5 (a):

See Fig. 6.

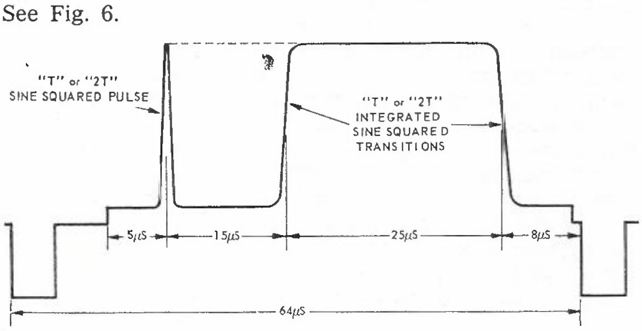


Fig. 6.

QUESTION 5 (b):

Draw the output pulse waveform from an "ideal" 5MHz low pass filter when the input signal is:
(*i*) *a 2T pulse;*
(*ii*) *a T pulse.*

ANSWER 5 (b):

(i) See Fig. 7 (Top).
(ii) See Fig. 7 (Bottom).

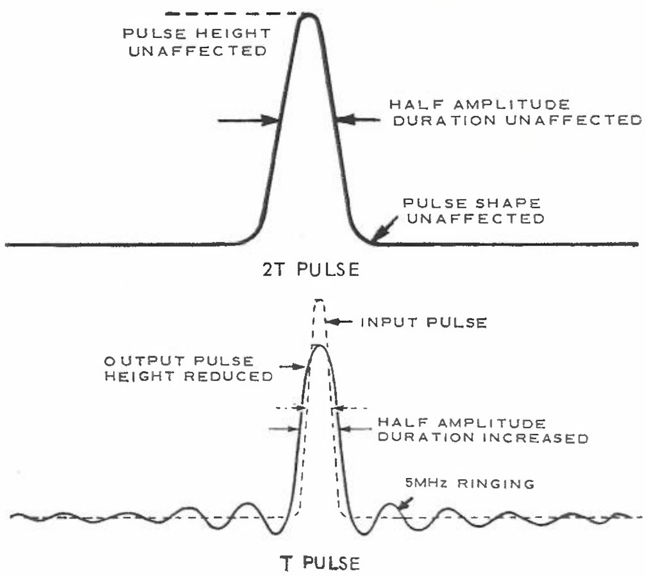


Fig. 7.

QUESTION 5 (c):

A test of a television system gave the following results:

Pulse shape	2%*K*
Pulse to bar ratio	1%*K*
Bar tilt	1%*K*
50Hz square wave tilt	3%*K*

What is the K rating of the system?

ANSWER 5 (c):

The 'K' rating of the system is equal to the largest of the four results listed above, that is Ks = 3 per cent.

OR

The 'K' rating of the system is equal to the largest of the first three results listed above, that is Ks = 2 per cent. and the 50 Hz square wave K factor is 3 per cent.

Reference: Technical Training Publication, CP 307, pages 24 - 30.

QUESTION 6 (a):

Draw the output voltage waveform for each of the following conditions of Fig. 8:
(*i*) *Network "A" fed with a square voltage wave at:*
(*a*) *50Hz;* (*b*) *10kHz.*
(*ii*) *Network "B" fed with a square voltage wave at:*
(*a*) *50Hz;* (*b*) *10kHz.*

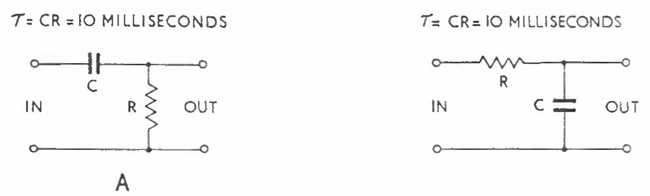


Fig. 8.

ANSWER 6 (a):

See Fig. 9:

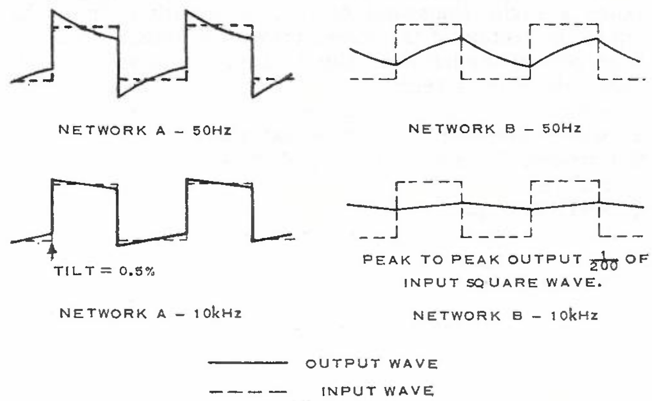


Fig. 9.

QUESTION 6 (b):

What is the ratio between the 50Hz square wave peak-to-peak voltage at the input to network 'A" and the peak-to-peak value of the output waveform?

ANSWER 6 (b):

$$\frac{\text{Peak-to-peak input}}{\text{Peak-to-peak output}} = \frac{1 + \frac{1}{e}}{2} = \frac{2}{3} \text{ (approximately).}$$

Reference: Technical Training Publication CP 309.

QUESTION 7 (a):

Name three items of television equipment which have "keyed" clamps.

ANSWER 7 (a):

Typical items are:
T.V. transmitter modulators, level stabilising circuits, etc.
Line clamping amplifiers (stabilising amplifiers).
Picture generating equipment cameras, flying spot scanners, etc.
Picture monitors.
Oscilloscopes (special types).

QUESTION 7 (b):

What are the main advantages of a "keyed" clamp over a peak rectifier clamp (D.C. restorer)?

ANSWER 7 (b):

Fast acting for input signal changes in both directions; they are two-way clamps.
Able to clamp accurately to a specific level.
Satisfactory for clamping signals of relatively small amplitudes.
Capable of clamping on any section of a repetitive waveform; that is, back porch, sync tip, etc.
Able to clamp video signals of both polarities.
More immune to noise than the peak rectifier clamp.

QUESTION 7 (c):

Can a "keyed" clamp completely remove a low frequency interfering signal from a video signal? Give reasons for your answer.

ANSWER 7 (c):

No, not completely. The keyed clamp restores one point in the mixed video plus interfering signal waveform to a fixed reference potential once per line. The interfering low frequency can cause a finite error in the video signal over the line period. For example, with a 1-volt peak-to-peak 50 Hz interfering sine wave signal, the error per line period varies sinusoidally between ±10 mV over the 20 mS period of the 50 Hz interfering signal. Thus, even with perfect clamping action, approximately ± 1.5 per cent of line tilt can occur. On a picture monitor, this would cause a slight sinusoidal brightness variation from the top to the bottom of the screen varying in extent (contrast) from zero at the left-hand side to a maximum at the right-hand side of the screen.

(Examiner's Comment: 'Yes' was accepted as a correct answer if qualified by a similar explanation.)

References: Technical Training Publication CP 310, pages 16 and 18.

QUESTION 8 (a):

Explain the meaning of the term "gamma" as applied to a television system.

ANSWER 8 (a):

The slope or gradient of the transfer characteristic, plotted on log-log graph paper, relating the input and output of a system, is called the gamma of the system. (See Fig. 10.)

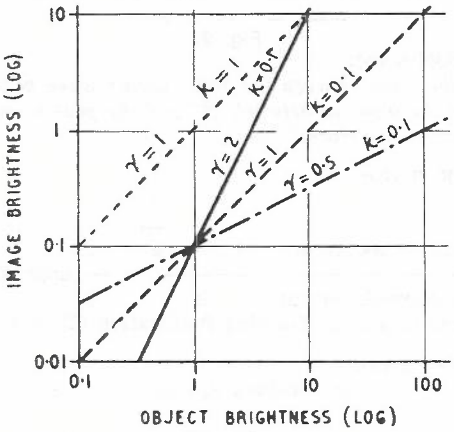


Fig. 10.

The term 'gamma' is used in referring to the relationship between the input and output brightness of a complete television system and also to the characteristics of components within the system; for example, the relationship between the screen brightness and the grid-cathode voltage of a picture tube.

The sloping lines in Fig. 10 represent different object-image brightness relationships, each of which can be defined by a formula in which the gamma is numerically equal to the exponent connecting the image and object brightness. For example, if the image brightness (Bi) is proportional to the square of the object brightness (Bo) we can write:

$$Bi = kBo^2.$$

In this case the exponent is equal to 2 and the gamma is, therefore, 2.

For a gamma of 1.0, Bi = kBo, and

for a gamma of 0.5, $Bi = kBo^{0.5}$

The factor k in these relationships does not affect the gamma, but adds a constant to the log of the object brightness and causes the sloping lines to be moved vertically on the figure.

QUESTION 8 (b):

What is the approximate average gamma of a picture tube and how is this compensated for in the television system?

ANSWER 8 (b):

The average gamma for a normal picture tube is approximately 2.5.

To compensate for the greater than unity gamma of the picture tube, all picture signal generating equipment is adjusted to have a gamma of less than unity, that is, 0.4 to 0.5 approximately. The overall system gamma is equal to the product of the gammas of the separate parts of the system.

Reference: Technical Training Publication CP 306, pages 14-21.

PART B — RADIO COMMUNICATION EQUIPMENT.

QUESTION 9 (a):

Describe the principles of a reflectometer and show how it is used in impedance matching an antenna.

ANSWER 9 (a):

Fig. 11 shows the basic construction of a typical reflectometer.

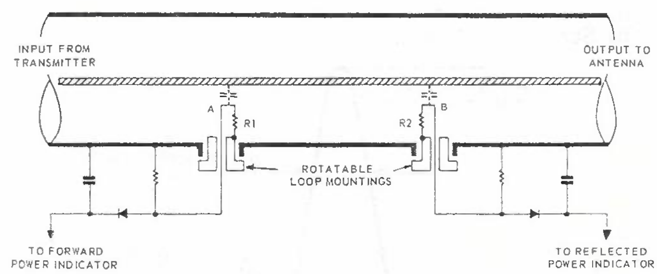


Fig. 11.

In this type, two short directional coupling loops (A and B) on rotatable mountings are fitted inside a short length of rigid coaxial line. The length of each loop is a small fraction of λ at the frequency of measurement. One end of each loop is terminated in a resistance (R_1 or R_2) and the other ends are connected to rectifier type voltmeters. Alternatively, a single voltmeter may be switched to either loop.

Loops A and B are coupled to both the electric and magnetic fields of waves travelling along the transmission line in either direction. Rotation of a loop so that it is no longer parallel to the inner conductor of the coaxial line, does not affect the capacitive coupling but reduces coupling to the magnetic field.

Consider an incident wave travelling along the line from left to right. The combined capacitive and inductive pick-up between loop A and the line is such that the effects of the two fields are balanced out in the termination R1, but are additive in the voltmeter circuit. With respect to loop B, however, the fields are additive in the termination R2, but balance out in the voltmeter circuit. Incident waves, therefore, give a reading on a voltmeter connected to loop A, but not on one connected to loop B.

Conversely, the relative value of a reflected wave travelling in the reverse direction from right to left, is indicated on a voltmeter connected to loop B, but not on one connected to loop A.

The relative amplitudes of the incident and reflected waves may, therefore, be read separately. Careful attention to the physical symmetry of the assembly and adjustment in the degree of rotation of each loop, ensures accuracy and complete separation of the two wave components.

During the process of matching a coaxial transmission line to an antenna, the reflectometer may be used to measure the ratio of the incident and reflected waves. Matching is satisfactory when the ratio is large, that is, in the order of 100 : 1.

QUESTION 9 (b):

An H.F. antenna is required to be matched by the use of a stub. A pick-up loop and R.F. ammeter only are available to assist with the work of matching. Describe the method you would use.

ANSWER 9 (b):

The two end connections of the pick-up loop are connected to the R.F. ammeter. As the antenna operates in the H.F. range, an open wire transmission line is assumed. R.F. power is applied to the antenna and the pick-up loop is moved along the transmission line, taking care that the loop is always parallel to and at a constant distance from

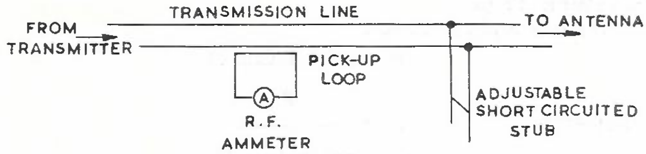


Fig. 12.

the transmission line. If an excessive current is indicated by the ammeter, repeat the measurement with a larger separation distance. The locations on the transmission line of maximum and minimum standing wave currents and the values of the currents are noted. A short circuited stub (see Fig. 12) is cut to a length, and connected across the transmission line at a point, as indicated by standard graphs. Where graphs are not available, a stub with an adjustable short circuit is connected at some intermediate point between maximum and minimum currents. The position of the stub and its length is adjusted in a step by step procedure until measurement of current as previously outlined shows that the ratio between maximum and minimum, that is, the standing wave ratio, has been reduced to a small value such as 1.01 : 1.

QUESTION 10 (a):

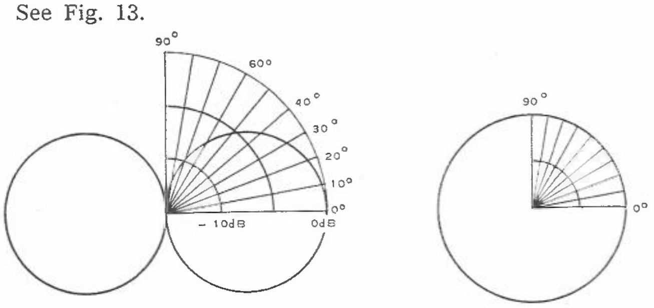
Sketch the E and H plane patterns of the following antennas, with suitable amplitude scales, so as to indicate the gain, in relation to a reference antenna, of all lobes:

(i) a dipole in free space;
(ii) a "Pine-tree" array of end fed dipoles, stacked vertically;
(iii) an S.H.F. antenna with a paraboloid reflector.

State the reference antenna that applies.

ANSWER 10 (a):

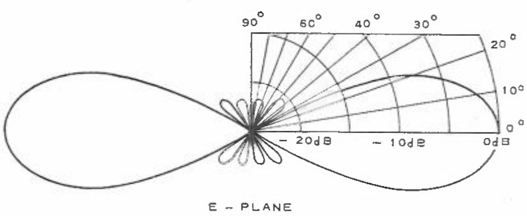
See Fig. 13.



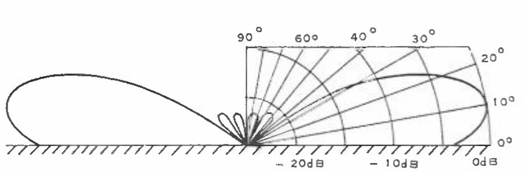
E - PLANE H - PLANE

GAIN = APPROX. 2dB REFERENCE AN ISOTROPIC ANTENNA.

½λ DIPOLE IN FREE SPACE



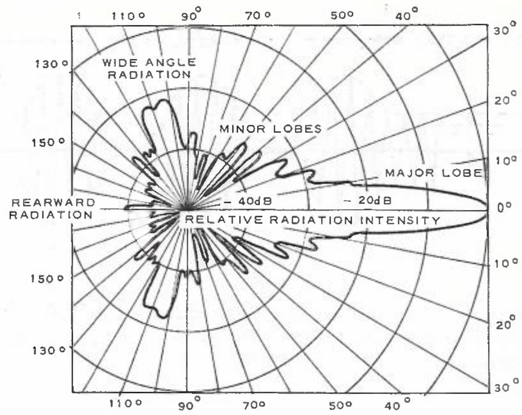
E - PLANE



H - PLANE

GAIN = APPROX. 12dB REFERENCE AN ISOTROPIC ANTENNA

"PINE-TREE" ARRAY



E - PLANE AND H - PLANE

GAIN = APPROX. 40dB REFERENCE AN ISOTROPIC ANTENNA.

ANTENNA WITH PARABOLOID REFLECTOR

Fig. 13.

The reference antenna is either a half-wave dipole in free space or an isotropic antenna (an imaginary antenna that radiates waves of equal strength in all directions), as applicable.

QUESTION 10 (b):

Describe the tests that you would carry out to show that a recently erected 450MHz yagi array was correctly installed and ready for use.

ANSWER 10 (b):

Make a thorough physical examination of the system to see that it is mounted securely, the connections are tight, the system appears watertight, and the elements appear correctly assembled.

Check the plane of polarisation is the same as that of the other end terminal.

Check the direction of fire is in the direction of the other end terminal.

Measure the approximate overall length of the driven element and calculate the frequency of resonance. Check that this is in the frequency band of transmission.

Check with a simple ohmmeter that the elements are continuous, particularly across construction joints.

Check that the coaxial feeder is continuous by temporarily looping the inner to the outer conductor at one end and measuring at the other.

If a diagram of the balun is available, determine if a d.c. condition across the antenna input is possible and, if so, check the loop resistance.

With the feeder connected to the antenna, measure the standing wave ratio (S.W.R.) at the receiver input or the impedance at that point, measuring at the specific frequency of transmission. If necessary, adjust the antenna driven element length to obtain a satisfactorily low S.W.R.

QUESTION 11 (a):

If the voltage at any instant on a 50 ohm coaxial cable is not to exceed 1,000 volts, what would be the maximum carrier power of an amplitude modulated transmitter, modulated to 100%, that may be connected to the cable:

(i) when the antenna system is exactly matched?
(ii) when an S.W.R. of 2:1 is present on the cable (assume negligible cable loss)?

ANSWER 11 (a):

(i) The modulated voltage wave on the cable may be represented by Fig. 14.

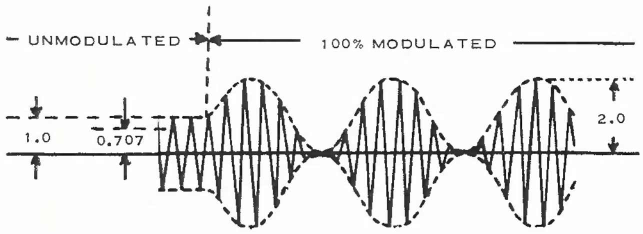


Fig. 14.

The maximum voltage at the peak during the 100 per cent. modulated condition is twice the peak during the unmodulated condition and therefore the R.M.S. value of the carrier voltage:

$$= \frac{1000}{2\sqrt{2}} = 353 \text{ volts.}$$

Therefore, carrier power:

$$= \frac{E^2}{R} = \frac{(353)^2}{50} = 2.5 \text{ kW}$$

(ii) When there is an S.W.R. of 2.0 on a transmission line, the voltage variation along the line may be represented as shown in Fig. 15.

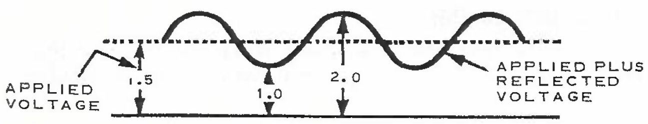


Fig. 15.

Therefore the ratio of applied to maximum (standing wave) voltage:

$$= \frac{1.5}{2.0} = 0.75$$

and carrier power:

$$= \frac{(353 \times 0.75)^2}{50} = 1.4 \text{ kW.}$$

QUESTION 11 (b):

Give a brief statement on each of the factors that determine the choice of a transmission line for a particular service.

ANSWER 11 (b):

Some factors that determine the choice of a transmission line are:
The frequency band to be transmitted.
The characteristic impedance.
The power-handling ability.
Attenuation.
Interference and radiation.
Ease of handling.
Environmental conditions.
Installation and maintenance.
Brief statements on each of these factors are given in the Technical Training Publication CP 321, Page 2.

QUESTION 12 (a):

Calculate the current rating of fuses to be used in the 440 volt power lines of a 3 phase transmitter power supply, such that the transmitter will be protected against the power load exceeding 4 kilowatts. Assume a power factor of 0.9.

ANSWER 12 (a):
Power is a 3-phase circuit:

$$P = \sqrt{3}\, E\, I \cos \phi$$

Therefore,

$$I = \frac{P}{\sqrt{3}\, E \cos \phi}$$

$$= \frac{4000}{\sqrt{3} \times 440 \times 0.9} = 5.83 \text{ amperes.}$$

The fuses must blow when a current greater than 5.83A flows.

QUESTION 12 (b):
Draw the circuit of a full-wave rectifier suitable for supplying power to a low power transmitter, showing the approximate component values, voltages at various points and output voltage waveform. If the rectifiers used in the circuit were a thermionic type. indicate the peak inverse voltage that would apply.

ANSWER 12 (b):
See Fig. 16.

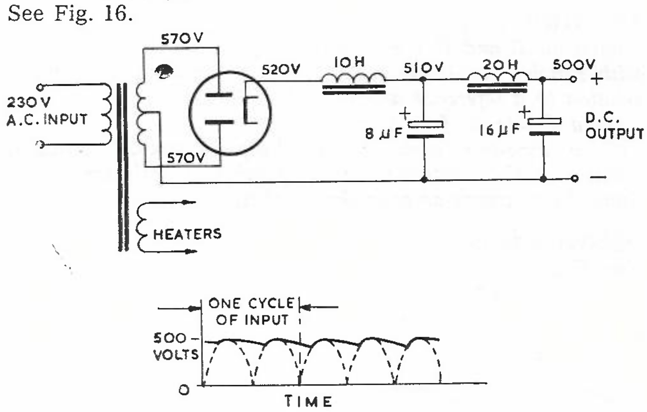


Fig. 16.

Peak inverse voltage = 570 x 2 x $\sqrt{2}$ = 1610V, less the voltage drop across the rectifier of, for example, 10V, = 1600V.

QUESTION 13:
A radio system operates as follows:

Bearers	*Traffic being carried*
101	*Protection*
102	*Protection*
103	*Telephony (960 channels Interstate)*
104	*Telephony (960 channels Interstate)*
109	*Regional Television*

The following events occur:

Time	*Event*
0900	*Bearer 109 fails*
0901	*Bearer 103 fails due to a deep fade*
0903	*Bearer 103 recovers*
1200	*Bearer 103 mutes due to the failure of a receiver local oscillator*

Describe the series of automatic switching operations which will occur due to the above events. Your answer should include a description of transfer and operate times. Had bearer 102 failed at 0902, how would these automatic switching operations have been affected?

ANSWER 13:

The switching system discussed below assumes that all pilot failures take precedence over all noise failures. On some of the very latest switching systems, both have equal priority.

At 0900 hours bearer 109 fails and is automatically switched to the protection bearer 101.

At time 0901, a deep fade on bearer 103 occurs and the noise detected by the 103 noise receiver will increase to the noise switching level in a few hundred milliseconds. As the protection bearer is carrying TV, however no switching takes place, because the 103 pilot is still being received whilst the pilot on 109 is lost. As the fade deepens, 103 pilot is eventually lost, and because Interstate telephony has priority over regional T.V., switching occurs with a transfer time of approximately 50 mS, of which only about 1 mS is due to operate time of the relay.

Note: When the protection bearer is not already in use, the switching transfer time will typically consist of the following:

1. Propagation time (1mS for 186 miles) ...... approx. 2mS
2. Operate time of reed relay .... approx. 1mS
3. Sensing time of VF signalling tone detector and switching logic circuitry ...... approx. 17mS

Total approx. 20mS

Had the protection bearer 101 been available, switching would have occurred due to noise, and the resulting traffic-time-lost would have been 1mS (or less in the case of I.F. switching) due to the operate time of the switch.

It should be noted that any bearer can carry traffic throughout a deep fade until the muting level is reached and the pilot lost.

Fig. 17 shows a typical sequence of events during a progressive fade, and the approximate ranges of signal levels over which the various alarm and switching circuits operate.

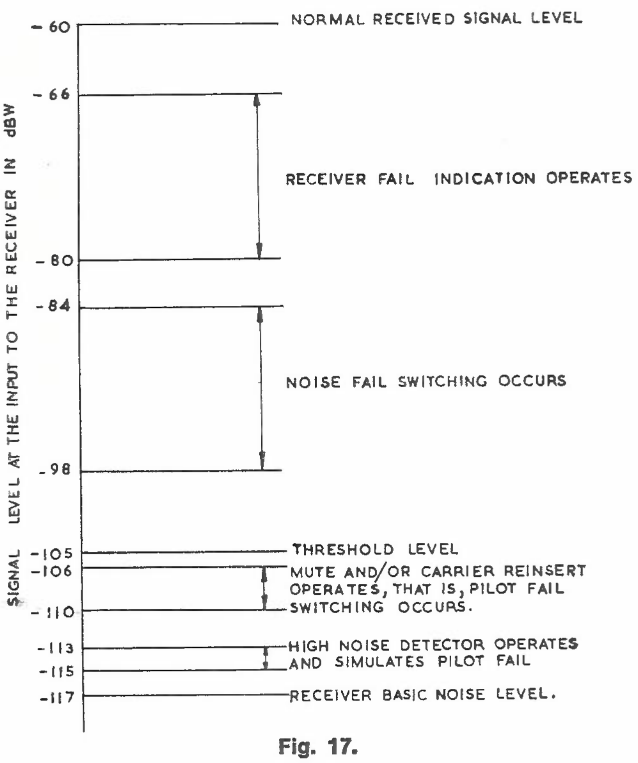


Fig. 17.

At time 1200, since bearer 103 mutes, the bearer 103 pilot is immediately lost and the TV traffic on bearer 101 would be replaced by the traffic from bearer 103 with a traffic-time-lost of 50mS.

Had bearer 102 failed at 0902, no switching would have resulted because bearer 102 is an even numbered bearer and therefore carries traffic in the opposite direction. However, telesignalling would have been sent to both terminals, giving alarms to show that bearer 102 had failed. In addition, the switching logic would have been inhibited in such a way as to prevent switching in case bearer 104 failed later.

QUESTION 14:

Describe the test set-up and the method you would use to reduce a high 3886kHz noise level in a 960 channel radio bearer which is operating with a normal level of basic noise.

ANSWER 14:

A system which operates with a normal level of basic noise and has a high noise level in the 3886kHz test slot suggests that the system has excessive group delay. To compensate for this effect, adjustable group delay equalisers are incorporated in the I.F. sections of the equipment. These may be located in the transmitter section and/or in the receiver section and may also be in the modems. To measure and adjust the group delay characteristic of, say, an I.F. amplifier, the G.E.C. group delay measuring equipment may be used as shown in Fig. 18. The test set-up shows how the equipment is connected for measurement and adjustment of group delay in a 960 channel receive I.F. amplifier.

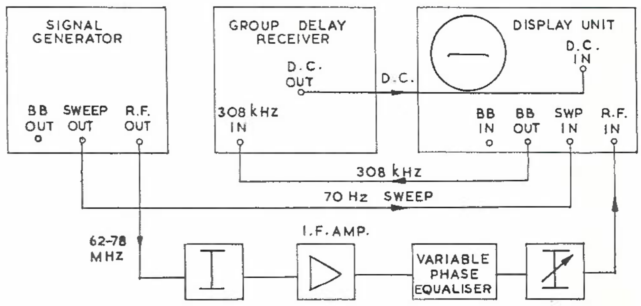


Fig. 18.

The signal generator provides a 70MHz signal which is frequency modulated by a 308kHz signal and swept over a frequency range of approximately 61MHz to 79MHz. This signal is passed through the I.F. amplifier and the associated phase equaliser, after which it is fed into the display unit, where the R.F. signal is demodulated. The detected 308kHz signal is then taken from the baseband output socket of the display unit and fed into the group delay receiver to be phase demodulated. The attenuators show in Fig. 18 are used for impedance matching and to ensure that the correct level is being applied to the display unit.

In the group delay receiver, the 308kHz signal is split into two paths. In one path, the signal is amplified and passed through a very sharp filter which almost completely removes any phase variations. The other path consists of an amplifier only. The outputs of the two paths are combined and detected, giving a d.c. voltage which is proportional to the phase difference of the two outputs and, therefore, also proportional to the group delay of the equipment under test. This voltage is then used to provide the vertical deflection of the C.R.O. in the display unit.

To calibrate the C.R.O. graticule, a 10nS delay line is switched in or out in one of the two signal paths of the group delay receiver and the gain of the display unit adjusted until the deflection corresponds to the 10nS mark on the graticule.
Before carrying out this test, it is necessary to check the back-to-back group delay of the test equipment. For this test the equipment set-up is the same as in Fig. 18, except the I.F. amplifier and equaliser are bypassed. If the residual group delay is outside the specified limits, the phase equaliser in the display unit will require adjustment. When adjusting a group delay characteristic, it is also necessary to check the frequency-amplitude response, since a flat group delay characteristic will only give a flat frequency-amplitude response with one particular setting of the group delay equaliser.

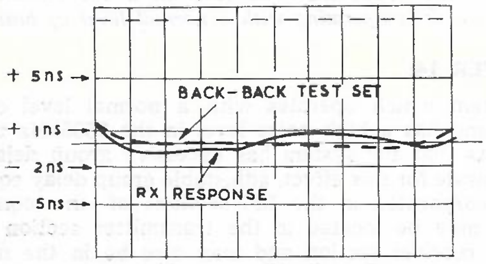


Fig. 19.

Fig. 19 shows a typical group delay response (960 channel) of a receiver I.F. amplifier and equaliser, after adjustment.

QUESTION 15:

Describe in detail either the receiver or the transmitter of a telesignalling system which time division multiplexes the telesignalled conditions.

ANSWER 15:

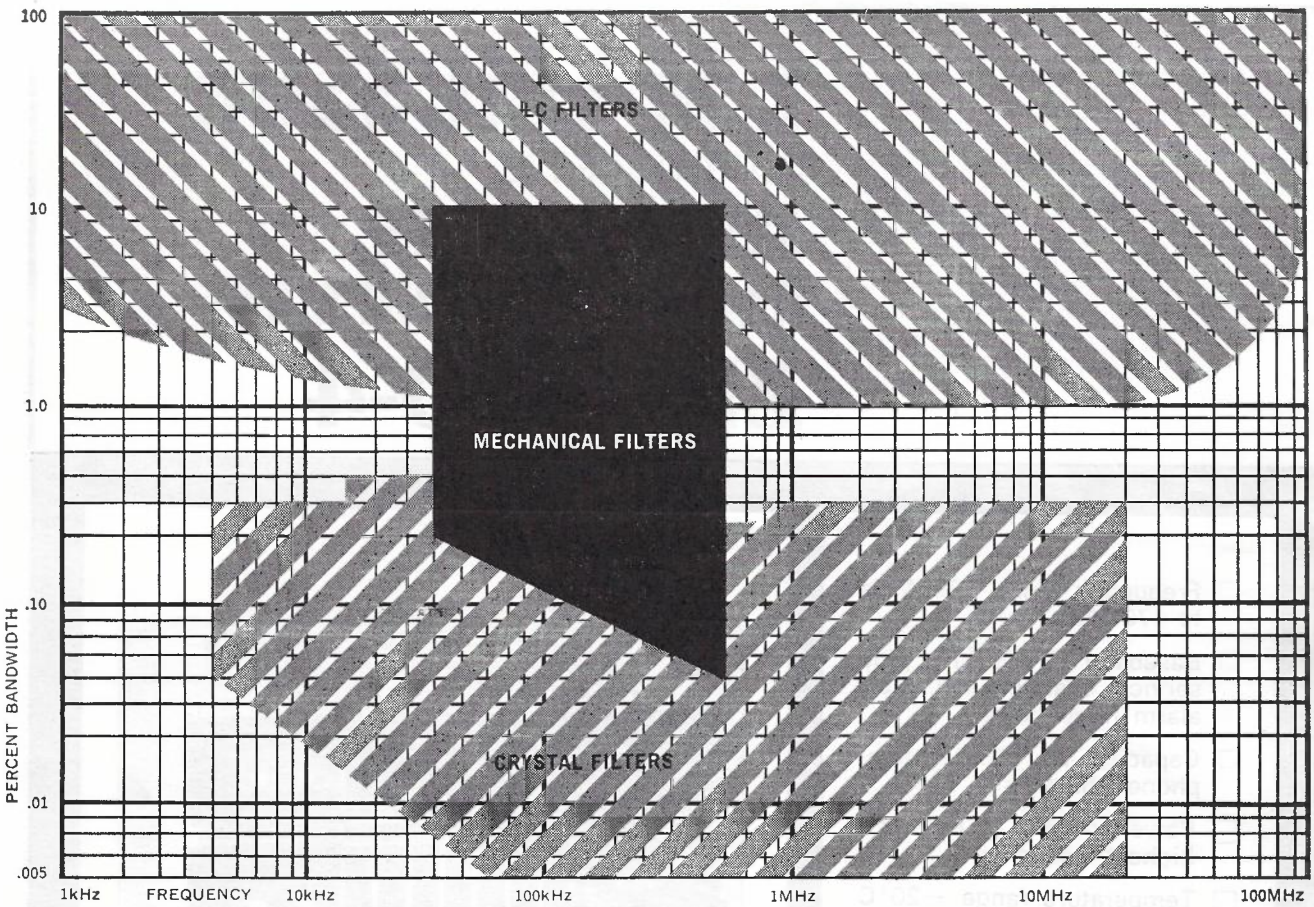
For details of the receiver and transmitter of a typical telesignalling system, refer to "Answers to Examination Questions," Telecommunication Jounal (Australia), Vol. 18, No. 2, page 199.

QUESTION 16:

In relation to the operation of wave guides, what do you understand by the following terms:
(i) Group velocity?
(ii) Phase velocity?
(iii) Cut-off frequency?
(iv) The guide wavelength?

ANSWER 16:

The answers to this question are contained in Technical Training Publication, MLR 052, pages 5 and 20 - 22.



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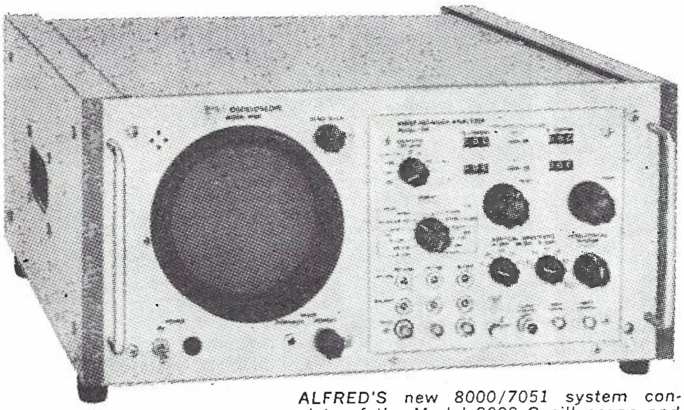
• 8000/7051 SYSTEM



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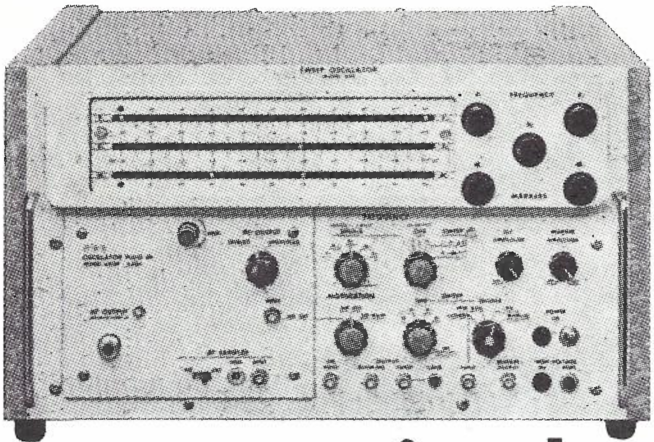

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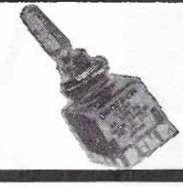

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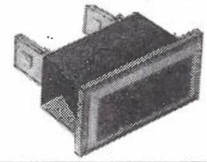

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VOL. 19 No. 1
FEBRUARY 1969

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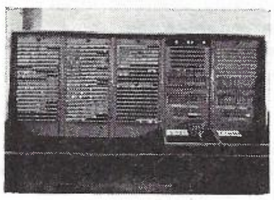

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The TELECOMMUNICATION JOURNAL of Australia

ABSTRACTS: Vol. 19, No. 1

CARROLL, B. J.: 'Centralised Maintenance Practices Overseas'; Telecom. Journal of Aust., Feb. 1969, page 25.

This article describes the completely centralised system of maintenance organisation adapted by the Televerket Sweden, and the Helsinki Telephone Company, Finland, for the maintenance of Exchange Subscriber and External Plant. It includes details of the advantages of their particular organisation, the methods of supervising plant performance productivity and costs, and results obtained. It concludes with a brief review of the progress being made in Australia with similar techniques and points out some of the distinctive features of the operating environment which must be considered in applying overseas techniques and in comparing results.

CREW, G. L.: 'The Design of Relay Contact Networks'; Telecom. Journal of Aust., Feb. 1969, page 34.

This paper is largely based on a number of discussions conducted by a group of circuit design engineers in the Australian Post Office during 1967. It describes three non-numerical techniques which may be used for circuit design — Boolean algebra, Karnaugh maps, and binary decision programmes. The three techniques are compared by applying them to the same problem.

HOSKING, C.: 'The Victorian State Disaster Plan'; Telecom Journal of Aust., Feb. 1969, page 61.

This paper describes the arrangements set up in the State of Victoria to meet large-scale emergencies. It describes the role of the P.M.G.'s Department with particular reference to the communications which are provided for the emergency organisation.

LARSSON, I. W.: 'Commissioning Tests for ARM Grid'; Telecom. Journal of Aust., Feb. 1969, page 4.

A general description of the commissioning tests carried out for the establishment of the ARM grid, with particular reference to the Geelong ARM network. Preliminary organisation of testing schedules and the various types of tests performed are briefly discussed.

LEWIS, H. J.: 'Design of a Cord Type Switchboard Console'; Telecom. Journal of Aust., Feb. 1969, Page 55.

This article outlines the steps taken in the physical design of a new Cord-type trunk switchboard. It introduces novel cabling and multipling methods, use of drum-type cord-retraction units, and jack-in type 'Line Units' on the multiple, which allow easy maintenance and quick addition to extensions. A fabric-covered steel carcase of modular construction is fitted with a durable non-glare keyshelf and novel docket holding device. The leg room is unobstructed and open due to the use of the cord retraction units.

SALTER, J. P.: 'A Transmission Level Checker'; Telecom. Journal of Aust., Feb. 1969, page 13.

A general description of the facilities and uses of the transmission level checker (T.L.C.) is given, together with details of its operation with the test call answer relay set (T.C.A.R.S.). Reasons why the T.L.C. can be used for semi-automatic measurement of the transmission loss of a telephone circuit at 820 Hz, in both directions of transmission, without the need for distant end staff, are outlined. The article, which is accompanied by photographs and functional schematic circuits, is not a comprehensive description of the T.L.C., nor of its design or manufacture.

SCOTT, F. M.: 'System AFM 402: The A.P.O. Four-wire Cord Type Manual Assistance Centre'; Telecom. Journal of Aust., Feb. 1969, page 41.

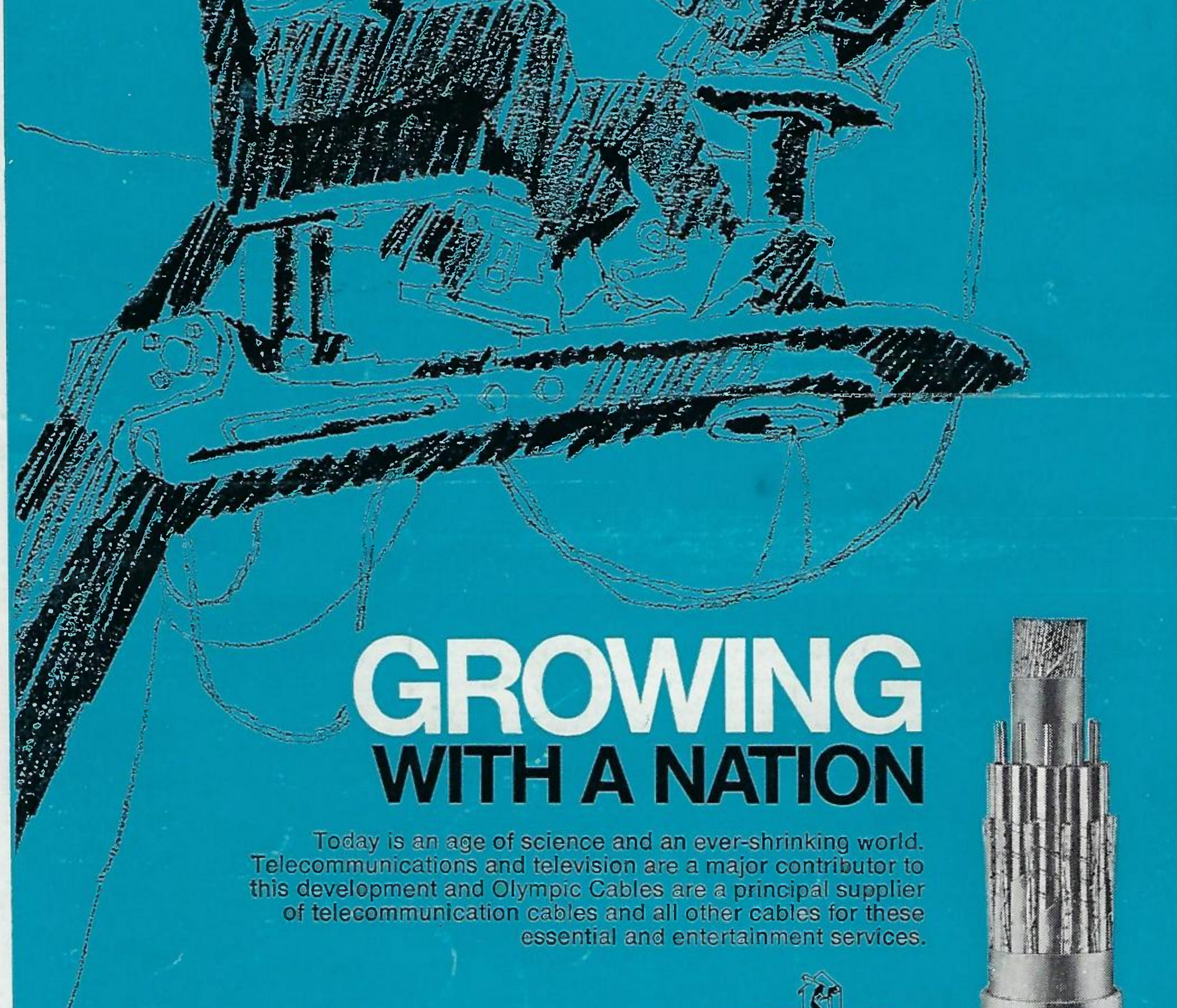
This paper describes the general electrical design features of A.P.O. System ARM 402, which comprises a cord-type operating position for manual assistance traffic, a cordless type operating position for special services traffic, monitors and supervisors' turrets, positions and line relay sets, and a marker-controlled crossbar switching stage. The manual assistance position is described in detail.

SMITH, K. W.: 'Telephone Exchange Area Planning'; Telecom Journal of Aust., Feb. 1969, page 18.

This paper is in two parts. Part 1 is a description of a method of determining the optimum economic radius of a telephone exchange area with relation to the subscriber density. Part 2 gives an outline of the procedure followed in the planning of rural exchange areas in Victoria.

WHITE, L. A.: 'Melbourne - Kyneton Coaxial Cable Transistorised Line Equipment'; Telecom. Journal of Aust., Feb. 1969, page 65.

This paper describes fully transistorised coaxial cable line equipment of German manufacture. The equipment uses temperature controlled level regulation of underground repeaters and incorporates new techniques for power feeding, level control and supervision.



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