THE

Telecommunication Journal OF AUSTRALIA

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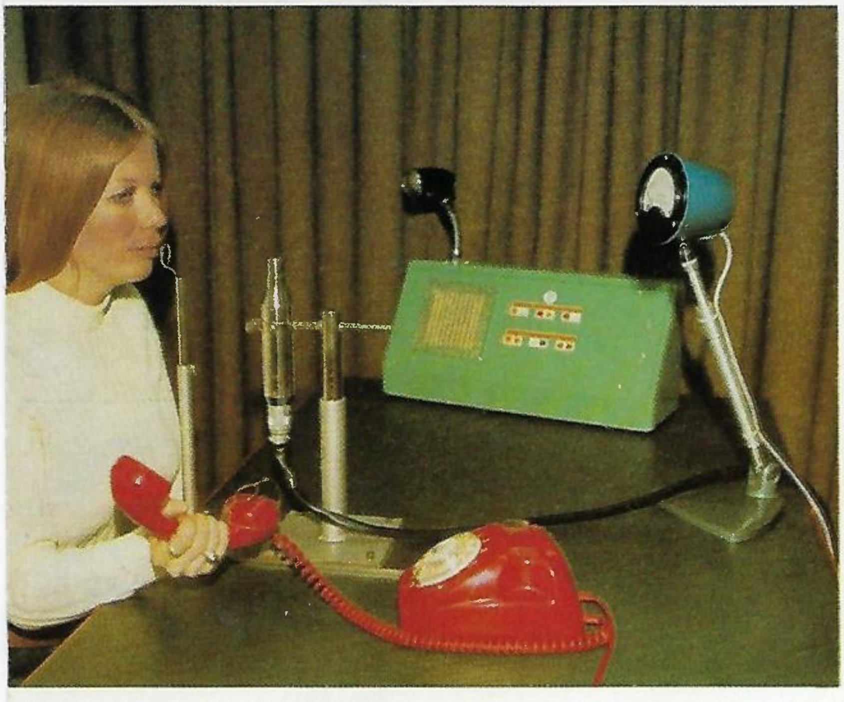
MULTIPARTY RURAL SYSTEMS

CANTOT

COUNTRY FAULT RECORDING

POWER DISTRIBUTION



Vol. 21 No. 3

OCTOBER, 1971

NEW SUBSCRIPTION RATES

NOTICE TO MEMBERS AND SUBSCRIBERS

In view of increasing production and operation costs associated with the Society's journals and activities, the Council of Control has reluctantly decided to increase annual membership and subscription fees with effect from the 1972 calendar year.

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(R. G. Kitchenn)
General Secretary.

October 1971

THE TELECOMMUNICATION JOURNAL OF AUSTRALIA

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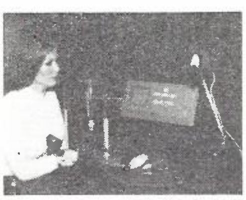

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ADVERTISING

ALUMINIUM CONDUCTORS IN PAPER INSULATED TELEPHONE CABLES

*R. A. CLARK, B.E., M.I.E. Aust., M. A. RHEINBERGER, B.E. B. A., Grad. I.E. Aust., and A. W. SISSON, Grad. I.E. Aust.**

INTRODUCTION

Copper Prices and Shortages

The price of copper has fluctuated over the last twenty years. It has twice shown marked increases for lengthy periods, firstly from 1950 to 1959, and secondly from 1964 till the present time. The more stable price level from 1958 to 1964 was substantially higher than that prior to 1950 and the prices in 1970, whilst dropping from the record highs, are substantially above those in 1964, and may be expected to remain so. The Australian consumer prices for both copper and aluminium (Ref. 1) are shown in Fig. 1. The trends are similar in other countries and reflect a world market situation.

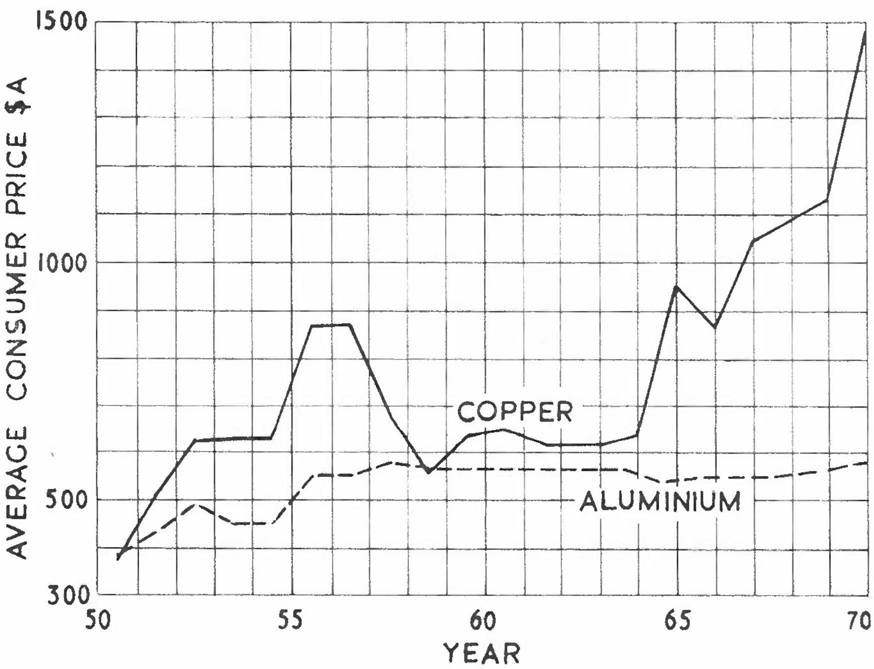


Fig. 1. — Annual Average of Australian Consumer Prices for Copper and Aluminium.

On both occasions that copper prices have shown marked upward trends, the A.P.O. (Australian Post Office) has directed development effort toward substitute materials, principally aluminium. Fig. 1 shows that aluminium has also increased in price, but the change has been small compared to copper and the future price is predicted to remain more stable. The development effort during the 1950-1958 period was minimal and proceeded no further than the manufacture of trial lengths of plastic insulated and sheathed cables which were never installed. Some knowledge of manufacturing was gained but jointing and servicing problems were not really confronted. However, in 1964, industrial problems at Mt. Isa Mines temporarily forced Australia to import rather than export copper. This, and the coincident price increases, meant the A.P.O. had to restrict its installation of new cables. The result was an enforced programme to develop aluminium as a substitute for copper conductors to the point, at least, where substitution could be made in the event of future shortages of copper.

Initial A.P.O. Decisions

Simultaneous studies of the economics of aluminium conductor cable, including duct penalty costs and service problems, led the A.P.O. to concentrate initial development effort in the field of large size paper insulated underground cables. The maintenance practices in Australia, where the paper insulated subscribers main cables and junction cables are protected from moisture entry by gas pressure, seemed adequate to avoid the disasters of the 1950's experienced by the American Bell System in their extensive installations of paper insulated aluminium conductor cables (Refs. 2, 3, 4). Reports on the British Post Office experience with the Dover-Deal experimental cable installed in 1955, tended to support this (Ref. 5).

NETWORK ECONOMICS

Cable Costs

The manufacturing conditions and processes in Australia for aluminium and copper conductor cables with moisture-barrier sheaths have been studied. Approximate costs for cables containing 200 pairs or more are compared in Figs. 2 and 3. Fig. 2 generalises the cost comparison for copper prices ranging from \$A600 to \$A1400 per ton (2240 lbs.) and aluminium prices from \$A400 to \$A700 per ton. Fig. 3 gives the comparison for the same range of copper prices and the specific aluminium price current in Australia (\$A586 per ton for Properzi quality EC. grade ingots). These comparisons reveal, for example, that with copper at \$A1400 per ton, (a price that has been exceeded in Australia for most of 1970), cables with aluminium conductors electrically equivalent to 0.9 mm (approx. 19 AWG) copper are 46% cheaper than copper conductor cables. Or, in another measure, the savings exceed \$A10 per thousand pair yards (\$A1.67 million per bcf.).

Similar graphs could be prepared for other sheath types, but moisture-barrier sheaths constitute about 80% of current Australian usage of large sized paper insulated cables. In most cases other sheaths are more expensive than moisture-barrier and both the percentage difference in cost and the gross difference in cost are reduced.

Duct Costs

Large sized paper insulated cables in Australia are usually installed in 4″ diameter ducts. These ducts are considered suitable for cables up to 3½″ external diameter. The pair capacity of ducts when used with aluminium conductor cables is only 2/3rds of that achievable with copper conductor cables of the same resistance and mutual capacitance. Depending on the achieved pair occupancy of ducts,

*Mr. Clark (see Vol. 14, No. 5/6, page 423) & Mr. Sisson (see Vol. 20, No. 2, page 181) are Engineers Class 4, and Mr. Rheinberger is Engineer Class 3, Lines Section, Headquarters.

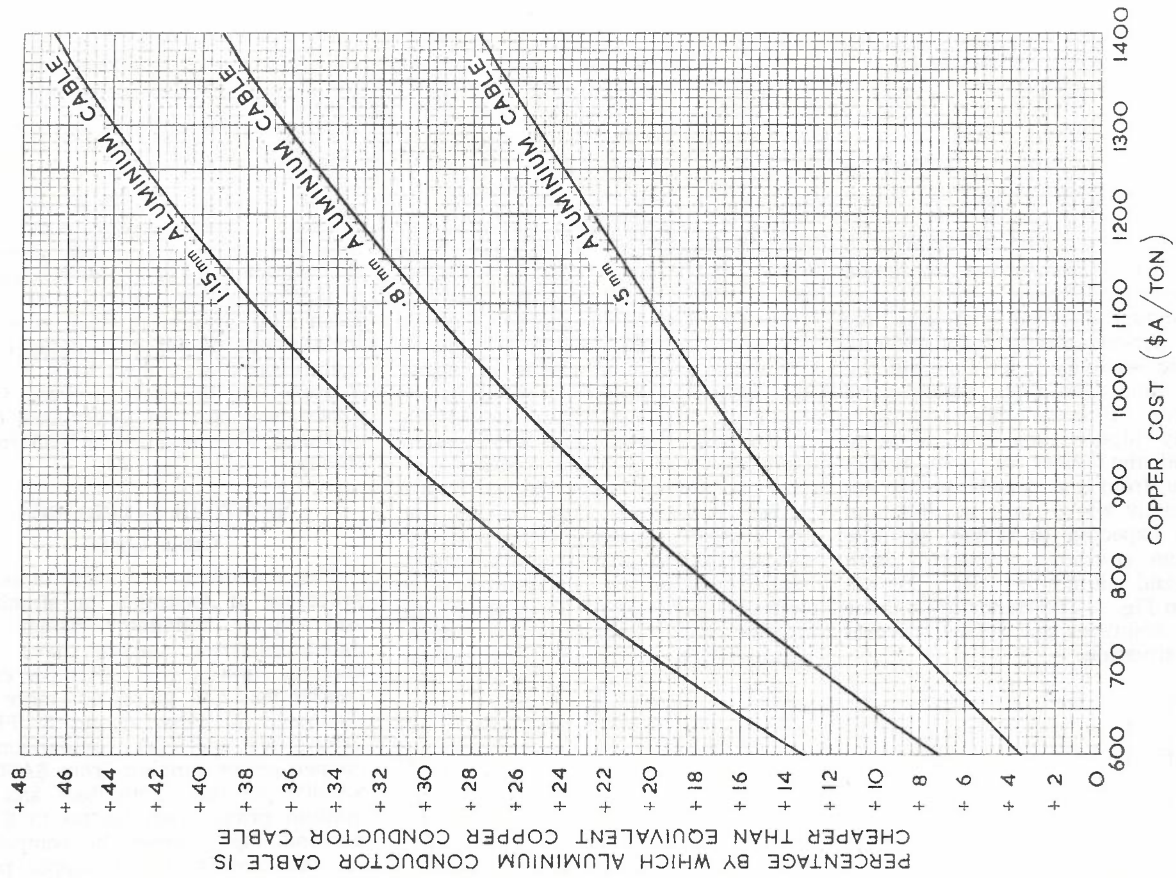
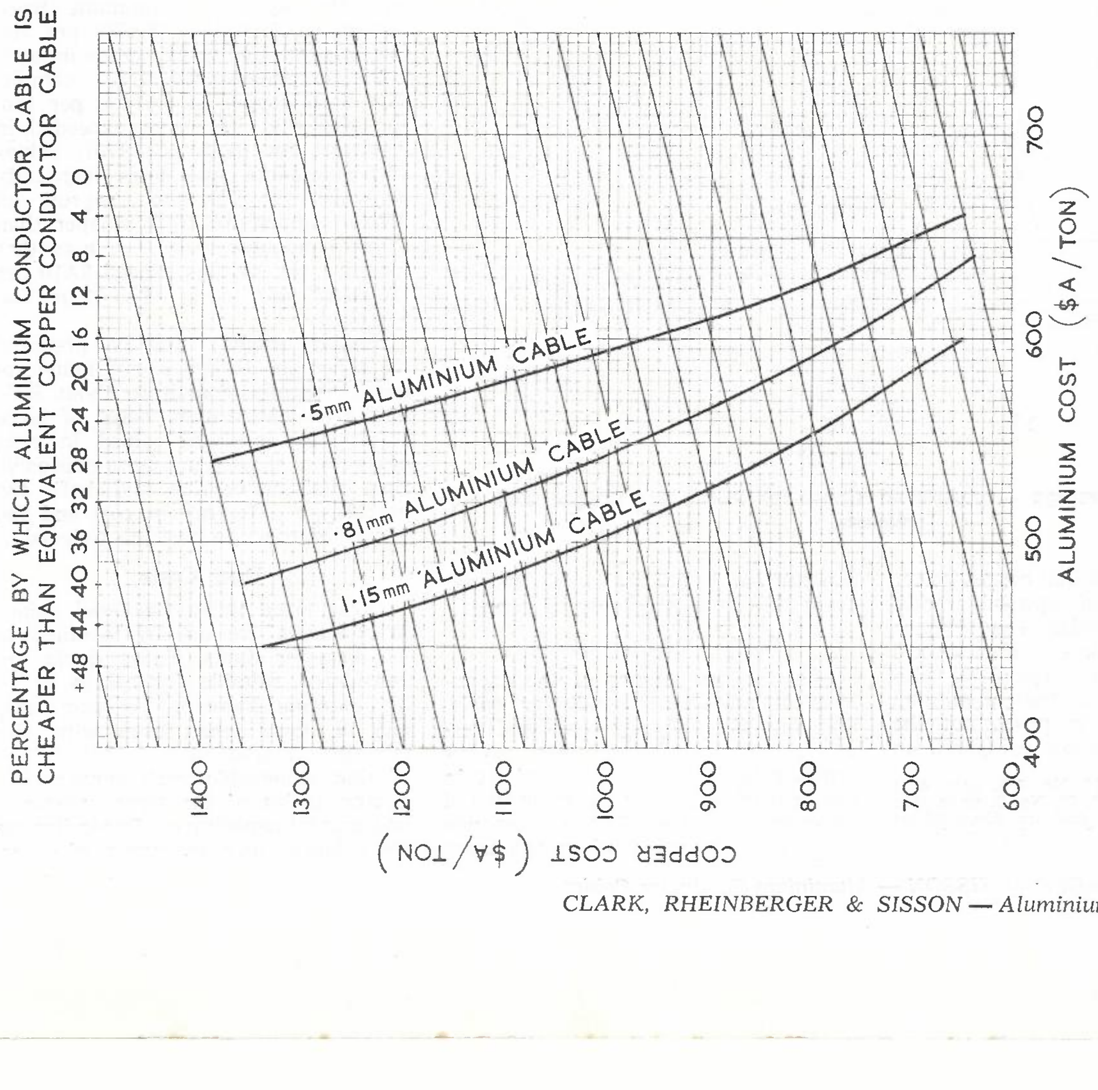


Fig. 3. — Effect of Copper Cost on Copper/Aluminium Cable Price Relativities (Aluminium $A586 per Ton).



KEY: PLOT THE POINT OF RELEVANT COPPER & ALUMINIUM COST; PROJECT THE POINT ALONG THE DIAGONAL TILL IT INTERSECTS THE RELEVANT CONDUCTOR LINE THEN PROJECT IT VERTICALLY TO THE TOP SCALE TO FIND THE PERCENTAGE BY WHICH ALUMINIUM CONDUCTOR CABLE IS CHEAPER THAN THE EQUIVALENT COPPER CONDUCTOR CABLE

Fig. 2. — General Price Comparison of Copper and Aluminium Conductor Cables (Moisture-Barrier Sheaths).

savings in cable costs could be more than offset by the costs of the additional duct space required.

In Australia, duct costs vary widely depending on the installation situation. Typical costs are:—

Cost per 1000 yards in "easy" conditions = \$A(5600 + 2650 D)
Cost per 1000 yards in "average" conditions = \$A(7100 + 3250 D)
Cost per 1000 yards in "difficult" conditions = \$A(10100 + 4500 D)
where D is the number of ducts provided.

Cable Installation and Maintenance Costs

In assessing the economics of aluminium it has been assumed that the installation and maintenance costs of aluminium conductor cables are not substantially different from those of copper conductor cables. However, these costs are a function of both sheath length and conductor yardage and the sheath length factor predominates. In a typical network the greater diameter of aluminium conductors causes a greater sheath length of aluminium to be required. Hence the total installation and maintenance costs debited against aluminium in the economic comparisons are greater than debited against copper.

City Junction Plant

Provisioning Periods: City junction cables in Australia are usually provided by v.f. loaded 0.9 mm or 0.63 mm (approx. 19 A.W.G. or 22 A.W.G.) copper conductor cables. Most of these are maximum-sized, 600/0.9 or 1200/0.63. With present circuit growth rates such cable sizes normally cater for 4 to 10 years development. These provisioning periods are close to the optimum indicated by economic analyses. Smaller cable sizes are used only where maximum-sized cables lead to substantial diseconomy.

To adopt the maximum-sized aluminium conductor alternatives, 400/1.15 mm (approx. 17 A.W.G.) and 800/0.81 mm (approx. 20 A.W.G.) would reduce the average provisioning period by one-third and increase the duct requirements by half. Studies of the economics of such substitutions have been conducted using the Present Value of Annual Charges (P.V. of A.C.) method of economic comparisons for two typical circuit growth rates and a series of installation situations.

The results, based on an interest rate of 7½% and a duct provisioning period of 20 years, inclusive of a standard allowance of 25% for unforeseen requirements, are summarised in Table 1.

TABLE 1: BREAK-EVEN COPPER COSTS FOR VARIOUS DUCT SITUATIONS

Duct Laying Conditions	Ducts Available on Route	Break-even Copper Cost (\$A/ton) High Growth Rate*	Break-even Copper Cost (\$A/ton) Medium Growth Rate**
Average	0	1060	840
	1	1150	990
	2	1150	840
	many	below 600	below 600
Difficult	0	1280	970
	1	1400	1190
	2	1400	980
	many	below 600	below 600

*High Growth rate is 240 pairs per year for 0.63 mm copper or 120 pairs per year for 0.9 mm copper.
**Medium Growth rate is 120 pairs per year for 0.63 mm copper and 60 pairs per year for 0.9 mm copper.

Theoretically, the duct provisioning period should differ for the two conductor types, for the two growth rates and for the two laying conditions. For minimum P.V. of A.C., it should be less than 20 years, being 10 years for the aluminium conductor high growth rate/average duct cost situation. The use of duct provisioning periods based on minimum P.V. of A.C. reduces the "break-even" copper cost considerably.

Duct costs can usually be expressed in the form Cost = \$ (A + B.D), where A and B are constants, and D is the number of ducts. In the determination of optimum provisioning periods the costs of both the first and the subsequent installations should be taken into account as the period depends on the ratio of the "B" of the first installation to the "A" of the subsequent installation. Field engineers often foresee grave difficulties and high costs in future duct works and favour long provisioning periods. However, a 2 : 1 change in the B to A ratio alters an optimum of 10 years by only about 3 years. In Australia the use of provisioning periods below 20 years is not accepted practice.

Negative Impedance Repeaters (NIRs): The effect of aluminium conductors on the economics of using NIRs has also been studied. Here the circuit bearer cost difference between conductor gauges, duct costs included, is important. The P.V. of A.C. difference between 0.9 mm and 0.63 mm copper bearers is \$A23 per mile for copper at \$A950 per ton. It increases to \$A26 per mile for copper at \$A1350 per ton. For aluminium at \$A586 per ton the difference between the equivalent gauges, 1.15 mm and 0.81 mm is \$A26. For higher duct costs these differences rise but the rise is greater for aluminium as the duct component of the difference is 70% whereas for copper it is about 40%. Hence NIRs continue to be applicable with aluminium conductor cables.

Pulse Code Modulation (P.C.M.) Systems: The interaction of 24 channel P.C.M. systems on the relative economics of aluminium and copper conductor cables has been broadly assessed. P.C.M. can expand the circuit capacity of unit twin cables by about 6 times, and as a result for a given circuit growth rate, the cable pair provision rate can be reduced. As indicated by Table 1, the "break-even" copper price is lower with reducing pair provision rates. Thus P.C.M. improves the case for aluminium. However, the converse does not always apply because the lower cost of aluminium increases the circuit length at which P.C.M. proves in on new cables, i.e. there are circuit lengths and copper prices for which P.C.M. is economic on copper conductor cables but is not economic on aluminium conductor cables.

City Subscribers Plant

Most of the large sized cables used in Australia for city subscribers have 0.4 mm (approx. 26 A.W.G.) copper conductors; some 0.63 mm copper is used but 0.5 mm (approx. 24 A.W.G.) is no longer installed.

In 0.4 mm, sizes up to 2,700 pair are used and the distribution of usage over the size range is:—

Size	Percentage of Sheath Length
2700	1
2400	4
1800	13
1200	17
800	12
600	14
400	22
300	17

The aluminium equivalent to 0.4 mm copper, 0.5 mm, can be installed in sizes up to 1800 pair, i.e. direct size-for-size substitution is possible for 95% of the length purchased. Pair sizes 1800, 1200 and 800 in copper virtually fill a 4″ duct and use of aluminium in these sizes does not incur duct penalty costs. Occasionally a second cable is installed, or planned for installation, in ducts carrying 600, 400 and 300 pair copper cables and second cables could be placed with 400, 300 and 200 pair aluminium cables. Hence it is only for a proportion, perhaps 50%, of the 600 pair requirement and all of the 2700 and 2400 requirement that the duct penalty is significant. The "break-even" copper cost for these sizes has not been assessed in detail but would be dependent on duct costs and growth rates and would be typically in the range $A1000-$A1200. Where there are no duct penalties, i.e. for over 80% of our usage, the "break-even" copper cost is below $A600.

For 0.63 mm copper subscribers cables, most of the usage is in sizes 800 pair and smaller and direct size-for-size substitution is practicable with the "break-even" copper cost again below $A600.

INSTALLATION AND MAINTENANCE ASPECTS

The A.P.O. Cable Network

In the early 1950's the A.P.O. commenced a programme of gas pressurisation of underground cables. The underground cable network at that time was entirely lead sheathed and a static pressurisation system was adopted and applied to the more important trunk cables. The system has been extended to include all trunk and junction cables and almost all subscriber main cable. The static concept, which relied on a completely defect-free sheath, has been substantially retained, but compressor-drier installations are now common and small flow rates are tolerated without corrective action. At an exchange, a flow of up to 2 cu. ft. per hour is classified as acceptable for any one cable.

The subscriber main cables are those from the exchange to the pillar (a cross-connecting flexibility point) and are essentially paper insulated. Prior to 1968 these cables were lead sheathed but the majority of new cables are now moisture-barrier sheathed. The tails to the pillars incorporate a gas seal and the distribution cables beyond the pillar to the subscribers are generally polythene insulated and sheathed and not placed under gas pressure.

The pressure system is connected to an alarm which operates if the pressure at any of the remote contactors falls below a given value (about 8 lbf/sq. in.) or the flow rate at the exchange to any one cable exceeds 2 cu. ft. per hour. An alarm is treated as urgent and will involve staff recall if it occurs outside normal working hours. The gas used is dry air and the driers applied at compressor installations ensure that the air enters the cable at less than 5% R.H. at the ambient temperatures experienced in Australia.

Corrosion

Laboratory Studies: During 1966 the Research Laboratories of the A.P.O. investigated the corrosion of paper insulated aluminium conductors under different humidity conditions with and without d.c. voltage on the wires (Ref. 6). This work showed that below 40% R.H. at 30°C the corrosion rate becomes small, and a figure for the corrosion threshold in a paper insulated cable has been taken as that amount of distribution moisture represented by 30% R.H. at 30°C. This temperature is seldom exceeded as far as buried cables in Australia are concerned. Moreover, the insulation resistance of paper with this quantity of distributed moisture is below that normally classified as acceptable. Also the conditions are much worse than those which could occur while the cable remains under dry air pressure protection. Whilst the threshold figure was not completely established by laboratory testing the margin of safety was such that complete confidence could be held in paper insulated aluminium conductor cables provided that the cables were maintained under dry air pressure and the aluminium-copper joint to the terminating tails kept within the pressure system.

The investigations in 1966 covered the rate of corrosion, the characteristics of the by-products of corrosion which would occur if moisture actually entered the cable, as well as the drying-out of wet cables. Above the corrosion threshold aluminium conductors corroded faster than copper conductors and corrosion continued after the removal of applied potential. The cathodic wire in the case of aluminium was also seriously corroded due to the amphoteric character of the metal. An aluminium to copper joint produced one of the worst situations for corrosion under high relative humidity conditions. The insulation resistance of paper insulated aluminium conductors could not be restored to an original value after corrosion occurred and the drying time was longer than the drying time for paper insulated copper conductor cable, since the hydrated aluminium oxide does not lose all combined water at temperatures normally used for drying cables.

Fault Statistics: The conclusion that aluminium conductor cables would almost always necessitate replacement rather than repair in the event of actual water entry did not seriously affect their suitability for application to the A.P.O. network when considered in relation to the effectiveness of the gas pressure protection system. The service-affecting fault probability of cables under gas pressure is determined by the incidence of mechanical damage and experience has shown that only a small percentage of cases of mechanical damage lead to water entry. A study of fault statistics from 1958-1964 showed that about 10 faults per year per 100 sheath miles of installed cable occurred in cables over 54 pair, both gassed and non-gassed. Unfortunately the statistics do not distinguish between main subscriber and junction cables under gas pressure (generally above 100 pair) and distribution cables, but since most main subscriber and junction cables are located in multi-way duct runs, one can be fairly sure that the mechanical damage faults in gas-pressured cables would be below that quoted above for general cables over 54 pair. With only a small percentage of these cases presenting a worse hazard because of water entry when compared to copper conductor cables, the metallurgical penalty of aluminium from a corrosion viewpoint was considered insignificant.

CONDUCTOR JOINTING

Inherent Difficulties

Both aluminium and copper form oxide films on clean surfaces but the speed of formation and the nature of the film is significantly different in each case. The aluminium oxide film (Al_2O_3) reforms almost instantaneously after cleaning and rapidly thickens until it reaches a depth of about 100A° (0.0000004 inches). The film is hard and adherent, amorphous and non-conducting. It is for this reason that the simple twist joints used with copper conductors are unsatisfactory with aluminium and any jointing method used must include a method for oxide removal whilst jointing is proceeding.

The aluminium oxide film is insoluble in liquid or solid aluminium metal and can be removed by purely mechanical means. It will, however, reform immediately with perfect continuity, unless the underlying pure metal is protected by moisture-free petroleum jelly or some other agent which excludes air. Chemically, the film is remarkably inert but is attacked by chlorides and fluorides, which are therefore used in special soldering and welding fluxes. Once the oxide film has been successfully removed, the contact resistance between aluminium surfaces is no larger than in the case of copper.

Many Administrations have already replaced twist joints in copper conductor cables with more reliable techniques such as connector jointing or soldering. When aluminium conductors were first examined in this country the only well-developed connector system appeared to be the B-wire which was classified as being generally unsuited to the helically-lapped paper insulation used in Australia. In addition, there were complications regarding availability and special tool requirements when considered in relation to small-scale trials. For these reasons, initial investigations were confined to soldering, welding and pressure joints which could be made with available tools.

Table 2 gives some of the more important physical properties of aluminium and copper. The specific heat of aluminium is high compared to copper but due to its much lower density, roughly equivalent amounts of energy are required to heat equal volumes of both metals to a given temperature such as is required in soldering or welding. Aluminium is softer than copper and this characteristic affects the design of connector joints, especially when aluminium to copper connections are required. The difference in melting temperature gives rise to difficulties in welding aluminium to copper conductors.

TABLE 2: SOME PHYSICAL AND ELECTRICAL PROPERTIES OF ALUMINIUM AND COPPER

Property	Annealed Aluminium	Annealed Copper	Al/Cu Ratio
Resistivity (micro ohm-cm)	2.803	1.724	1.625
Tensile Strength (lbf/in^2)	10000—14500	33500—36000	0.35
Minimum Elongation (%)	35	50	0.7
Brinell Hardness	23	45	0.5
Melting Point (°C)	660	1083	0.61
Density (gm/cm^3)	2.7	8.9	0.304
Specific Heat (cal/gm) at 20°C	0.214	0.092	2.32
Thermal Conductivity (cal/sec/cm^{2}cm/°C)	0.54	0.92	0.59
Temperature Coefficient of Resistance at 20°C/°C	0.0040	0.0039	1.03
Standard Electrode Potential			
to Copper	—2.17V		
to Iron	—1.26V	+0.91V	
to Lead	—1.58V	+0.60V	

Initial Trials

Several methods of conductor jointing were examined and of these, crimped sleeves and tip welding were chosen for initial field trials. Available tools for cold pressure welding, though giving satisfactory joints in a laboratory environment, were found to be completely impracticable for field use. Soldering techniques were also investigated in initial developmental work. The fluxes used are highly corrosive and the joint requires very thorough post-cleaning. Ultrasonic soldering methods were considered but were rejected, as the requirement for a 230 V a.c. source could not always be met in the field. It was concluded that, in general, soldering was not a preferred method, particularly when its low productivity was considered.

Tip Welding: This method had already been used by the British Post Office (B.P.O.) in the experimental Dover-Deal cable installation in 1955 (Ref. 5). A pair of conventional pliers connected to the negative terminal of a 24 V battery is used to grip the twisted wires near the tip. The positive terminal is connected to a carbon rod which is briefly touched to the tip of the wires, the rod being enclosed in an insulating holder. The passage of the high current melts the ends of the aluminium wires, producing a blob of metal at the tip which can make a satisfactory joint. Special preparation of the wires is not necessary as the temperature generated is high enough to produce fusion of the aluminium and at the same time destroy the oxide film. The B.P.O. experience indicated that this method was quite satisfactory for aluminium-aluminium joints. However, the method is unsatisfactory for aluminium-copper jointing owing to the formation of a brittle zone at the metal junction due to the differing melting points of the two metals. The results of comparative laboratory testing of this method are given subsequently in this paper.

Crimped Sleeve Jointing: This method consists essentially in fitting a sleeve over the conductors which have been previously stripped of their insulant, and crimping this sleeve onto the conductors with a specially designed tool. The joints produced using a sleeve designed to be crimped by a standard nicopress tool are simple pressure joints and differ from cold pressure welding in that no fusion of metal occurs. Initial A.P.O. tests on 1.15 mm conductors showed that two methods were feasible — a joint with untwisted wires and a joint made by twisting the wires together and then crimping a sleeve over the twisted tail.

Comparative Results: In both crimped sleeve and tip welding techniques, a considerable amount of laboratory work was carried out to evaluate the anticipated lifetime performance of joints made between aluminium-aluminium in 0.63 mm and between aluminium-copper in various copper conductor gauges. All joints were submitted to accelerated heat-ageing tests at 105° for a total of 12 weeks with intermediate measurements at 1, 3 and 6 weeks. It was considered that this test would simulate the relaxation in a joint which is in service for a period of 20-30 years. For a jointing method to be considered satisfactory, the contact resistance of all samples had to vary by less than 10 milliohms over the full test period.

Metallurgical tests showed that the jointing of aluminium-aluminium wire using a crimped aluminium sleeve produced a good metal flow, breaking the oxide film, provided the inside and outside diameters of the sleeve were carefully chosen. The results were equally satisfactory with ¾ H or fully

TABLE 3: RESULTS OF LABORATORY TESTS (ALUMINIUM-ALUMINIUM CONDUCTORS) CRIMPED SLEEVE AND TIP WELDED JOINTS (AFTER AGEING FOR 2000 HOURS AT 105°C).

Wire Combination		Crimped Sleeve Details				No. of Samples	Occurrences of Resistance Increase (milliohms)			
Al mm	Al mm	Mat.	Ext. Diam mm	Int. Diam mm	Crimp		> 10	> 100	> 1000	Max.
0.63	0.63	Al	3.18	1.32	X	40*	25	1	1	> 2500
,,	,,	,,	,,	,,	X	20	0	0	0	< 1
,,	,,	,,	,,	,,	XP	45	0	0	0	9.5
,,	,,	Cu	,,	1.27	X	10†	5	4	1	> 2500
,,	,,	,,	,,	,,	X	10φ	5	2	2	,,
,,	,,	,,	,,	,,	XX	10†	9	5	5	,,
,,	,,	,,	,,	,,	XX	10φ	8	4	2	,,
,,	,,	,,	4.78	1.70	XX	10†	6	5	5	,,
,,	,,	,,	,,	,,	XX	10φ	8	8	5	,,
,,	,,	Al	3.66	1.59	X	10†	5	2	1	,,
,,	,,	,,	,,	,,	XX	10†	2	1	0	266
,,	,,	,,	,,	,,	X	10φ	5	0	0	64
,,	,,	,,	,,	,,	XX	10φ	0	0	0	3
,,	,,	,,	3.25	,,	X	10†	3	1	0	151
,,	,,	,,	,,	,,	XX	10†	3	0	0	17
,,	,,	,,	,,	,,	X	10†	3	0	0	37
,,	,,	,,	,,	,,	XX	10φ	1	0	0	36
,,	,,	,,	3.66	,,	XE	10φ	0	0	0	3
,,	,,	,,	,,	,,	XXE	10φ	0	0	0	7.5
0.63	0.63	Tip Welded				40	0	0	0	4
,,	,,	,, ,,				100	0	0	0	1
,,	,,	,, ,,				66–	0	0	0	8

Code: * field joints, all others being laboratory joints; † fully annealed wire;
φ ¾ H wire; X standard Nicopress tool; XX undersize tool;
P Alconac paste; E epoxy dipped; – 2 open circuits not included.

TABLE 4: RESULTS OF LABORATORY TESTS (ALUMINIUM-COPPER CONDUCTORS) CRIMPED SLEEVE AND TIP WELDED JOINTS (AFTER AGEING FOR 2000 HOURS AT 105°C).

Wire Combination		Crimped Sleeve Details				No. of Samples	Occurrences of Resistance Increase (milliohms)			
Al mm	Cu mm	Mat.	Ext. Diam mm	Int. Diam mm	Crimp		> 10	> 100	> 1000	Max.
0.63	0.51	Al	3.18	1.32	X	40*	37	16	5	> 2500
,,	,,	,,	,,	,,	,,	50*	47	34	15	,,
,,	,,	,,	,,	,,	,,	30	13	1	0	124
,,	,,	,,	,,	1.25	,,	40	14	1	0	203
,,	,,	Cu	,,	1.27	,,	30	0	0	0	9.7
,,	,,	,,	,,	,,	,,	40	17	7	1	1100
,,	,,	,,	,,	,,	,,	22	7	1	0	117
,,	0.4	Al	,,	1.32	,,	12	12	8	8	> 2500
,,	,,##	,,	,,	,,	,,	12	5	2	0	179
,,	0.5	,,	3.18	1.32	,,	57	56	31	6	> 2500
,,	0.4##	,,	,,	,,	,,	62	54	22	3	,,
,,	0.5	Cu	,,	1.27	,,	33	24	7	0	172
,,	0.4	,,	,,	,,	,,	20	15	7	0	68
,,	,,##	,,	,,	,,	,,	20	16	3	1	> 2500
,,	0.5	,,	2.67	1.19	,,	40	2	0	0	16
,,	0.63	,,	3.18	1.42	,,	35	2	0	0	10.5
,,	0.4	,,	2.67	1.19	,,	40	28	11	0	492
,,#	0.5	,,	3.18	1.42	,,	40	6	0	0	17
0.63	0.5	Tip Welded				20	1	0	0	24
,,	0.4	,, ,,				40–	1	0	0	73

Code: * field joints, all others being laboratory joints; # two wires used;
wire doubled; – 3 open circuits not included.

annealed wire, but in both cases, with 0.63 mm conductors, twisting was necessary before crimping. The early results with aluminium-copper joints were not as satisfactory, however, and it was shown that improvements were possible using copper instead of aluminium sleeves. Furthermore, in the case of aluminium-copper jointing, a number of different copper conductor sizes were involved compared to a single aluminium size. This necessitated the use of several different sized copper sleeves. After considerable experimentation, three sizes were chosen. Although initial results displayed variability among different joints made by the same operator, results improved with operator practice. Tables 3 and 4 give results of resistance measurements on trial joints using these techniques.

Tip Welding appeared a preferable method of making aluminium-aluminium joints. Laboratory results, as given in Tables 3 and 4, showed the majority of these joints to be of excellent quality. Poor joints were readily recogniseable as they were invariably open circuit. This differed from the behaviour of a potentially poor crimped joint which could have an initial low resistance, but over a period deteriorate slowly to a high resistance condition. As previously indicated, it was found that tip welding of aluminium-copper wires was most unsatisfactory and could not be recommended for field use.

During 1965-66, the initial trial installations of aluminium conductor cables were undertaken. These trials are discussed in detail later. The jointing methods used were tip welding for aluminium-aluminium and crimped copper sleeves for aluminium-copper. The field results for crimped sleeve joints were generally very good although jointing productivity was very low compared to A.P.O. standard copper jointing. The major proportion of all tip-welded joints appeared to be sound, but it was evident that further work was required to evaluate the tip-welding process in terms of voltage and current requirements and weld-times, in order to remove the subjective aspects present in the rudimentary method employed.

The general conclusion reached from the trials was that, whereas the jointing methods produced adequate joints, they were by no means optimum nor entirely practicable for use on a large scale. Further developmental work was continued on the jointing problem, for although the methods adopted had fulfilled the aim of providing an alternative in the case of shortage, it was clear that improvements were necessary before aluminium could be considered an economic substitute.

Later Experiments

Overseas experience indicated that connector-type joints made with a special tool offered an economic solution for a simple, high quality joint necessary in a modern network. By the time initial cable trials were completed, investigations in this country had confirmed that similar practices should be adopted by the A.P.O. and offers were being sought to establish the most suitable type of connector.

Several types of connector joints were available for initial experimentation. Of these the B-Wire connector (originally developed in the U.S.A.) was not really satisfactory with the ribbon paper insulant used in Australia. It was considered that the most suitable connector would be one applied from a magazine-fed, power-driven tool and which preferably pierced, as well as clamped, ribbon insulation. Initial tests up to mid 1967 indicated that the A-MP connector appeared promising although at least two sizes were necessary to satisfy all common conductor gauges that could be encountered in a field situation. The standard copper conductor connectors were evaluated by the A.P.O. (Ref. 7) for jointing aluminium conductors. Though not recommended by the suppliers for field use with aluminium, they were chosen for use in the subsequent field trials of 0.5 mm aluminium conductor cables. Results of laboratory tests on these connectors are given in Table 5.

CABLE MANUFACTURE

Metallurgical Considerations and Choice of Hardness

There are some metallurgical characteristics of aluminium which require a modification to established techniques used in cable manufacture. For electrical conductivity, fully-annealed wire is the best choice. High conductivity enables a smaller wire to be used thereby reducing cable insulation and sheathing costs, but the lower tensile strength of fully-annealed wire is a disadvantage when cable hauling is considered. Furthermore, manufacturing processes impose minimum tensile strength properties. However, wires of intermediate temper with high values of tensile strength have caused wire handling problems in Australia. Hence, an important initial problem is to determine the best economic compromises between conductivity and tensile strength for available wire-drawing processes.

An early problem in A.P.O. investigations lay in the fact that cable manufacturers in Australia receive aluminium wire supplies from different sources. It was observed when selecting the wire for use in initial trial cable installations, that the harder tempers exhibited a "kinking" phenomenon. This "kinking" was characterised by an initial bend of sharp angle, which, when bending was repeated, always occurred at the same point with the result that failure took place after very few cycles. H16 wire ($\frac{3}{4}$ hard) from one manufacturer manifested this phenomenon but wire of similarly designated temper from the other supplier was satisfactory. These findings indicated that specifications mainly intended for power applications were unsuitable for communication cable requirements. In these specifications the requirements for tensile strength and elongation are too broad and result in wires which, whilst meeting these requirements, may nevertheless still exhibit "kinking".

The conductor of a telephone cable must possess sufficient strength for hauling purposes and this necessity was pronounced in early developmental work undertaken in Australia where a heavy lead sheath was used. More relaxed requirements were foreseen for cables provided with a moisture-barrier sheath. Cable hauling practices for copper conductor cables were based on a maximum hauling tension given by the formula:—

$$\begin{array}{c}\text{Maximum}\\\text{Hauling}\\\text{Tension}\\\text{(lbf)}\end{array} = \begin{array}{c}\text{Conductor}\\\text{Weight}\\\text{per mile}\\\text{(lbs)}\end{array} \times \begin{array}{c}\text{Number}\\\text{of}\\\text{Pairs}\end{array}$$

or 6000 lbf, whichever was the smaller and it was considered possible that, if fully annealed wire were used, the tensile strength at yield of the cable could be exceeded, particularly in long lengths of small size cables.

Data was not available on general hauling tensions experienced with local-type cables and to obtain comparative information on this aspect, as well as manufacturing and jointing, as a basis for later decisions, it was resolved that initial trials should be carried out with cables of both $\frac{3}{4}$H wire (without "kinking") of tensile strength approximately 21000lbf/sq. in. and elongation 1.5% and fully-annealed wire of tensile strength approximately 12000lbf/sq. in. and elongation 16%. By this approach it was hoped to determine whether the fully annealed wire could be satisfactory for processing and subsequent cable hauling and if not, whether the $\frac{3}{4}$H wire, which appeared the maximum hardness permissible for wire jointing in pure aluminium, would prove adequate. In terms of wire costs, fully hard wire was the cheapest, followed

TABLE 5: RESULTS OF LABORATORY TESTS (HEAT AGEING AND TEMPERATURE CYCLING) ON WIRE JOINTS WITH A-MP CONNECTORS.

Conductors		R_1							R_2							$\triangle R$						
Mat.	Diam	N_1 for R(mΩ)					Value (mΩ)		N_2 for R(mΩ)					Value (mΩ)		N_3 for R(mΩ)					Value (mΩ)	
	mm	2	5	10	20	50	Max.	Mean	2	5	10	20	50	Max.	Mean	2	5	10	20	50	Max.	Mean
Cu	0.91	2	—	—	—	—	2.31	1.51	17	9	4	2	—	28.6	6.81	9	8	2	2	—	26.9	5.3
Cu	0.63	16	—	—	—	—	4.00	2.37	20	10	9	6	3	1000	75.9	11	9	8	4	3	996	73.5
Cu	0.63	16	—	—	—	—	4.40	2.27	20	8	6	2	1	51.0	9.32	13	7	5	2	—	46.6	7.00
Cu	0.41	20	—	—	—	—	4.80	4.27	20	1	—	—	—	5.30	4.47	—	—	—	—	—	0.80	0.16
Al+	0.63	20	—	—	—	—	3.60	2.99	20	—	—	—	—	4.50	3.38	—	—	—	—	—	1.80	0.44
AlØ	0.63	20	—	—	—	—	3.40	2.97	20	2	—	—	—	6.30	3.71	2	—	—	—	—	3.10	0.69
Al+	0.51	20	6	—	—	—	8.20	4.89	20	18	1	1	1	9000	479	2	1	1	1	1	8990	474
Conductors		R_3							R_4							$\triangle R$						
Cu	0.91	—	—	—	—	—	1.41	1.17	2	—	—	—	—	2.15	1.47	—	—	—	—	—	0.81	0.32
Cu	0.63	4	—	—	—	—	2.23	1.87	20	3	—	—	—	7.60	2.98	3	1	—	—	—	5.53	1.38
Cu	0.63	3	—	—	—	—	2.07	1.88	18	—	—	—	—	2.75	2.38	—	—	—	—	—	0.88	0.37
Cu	0.41	19	—	—	—	—	4.10	3.72	19	—	—	—	—	4.70	4.28	—	—	—	—	—	1.20	0.61
Al+	0.63	20	—	—	—	—	2.90	2.61	19	—	—	—	—	3.90	3.03	—	—	—	—	—	0.60	0.07
AlØ	0.63	20	—	—	—	—	2.73	2.46	20	—	—	—	—	4.20	3.26	—	—	—	—	—	1.70	0.80
Al+	0.51	18	—	—	—	—	4.70	4.31	18	15	—	—	—	8.90	6.01	5	—	—	—	—	4.20	1.71

Code: +fully annealed wired

Ø $\frac{3}{4}$H wire

R_1 Resistance before Heat Ageing

R_2 Resistance after 20 hours at 105° C

R_3 Resistance before Temperature Cycling

R_4 Resistance after 25 Temperature Cycles

$\triangle R$ Change in Resistance

N_1, N_2 No. of connector with joint resistance $>$ R

N_3 No. of connectors with change in joint resistance $>$ R

Note: 20 samples for each conductor type.

by fully-annealed wire with intermediate tempers of higher cost. Consequently, if it could be shown that annealed wire was satisfactory, then an economically attractive solution would be available since recourse would not be needed to the ¾H wire.

As is discussed, in the next section, the initial trials with 0.63 mm conductor indicated the suitability of fully-annealed wire from a field viewpoint. The hauling tension encountered did not result in excessive wire breaks and the handling characteristics of the fully annealed wire were satisfactory. It was concluded that the same would apply for 0.5 mm conductors with a moisture-barrier sheath and factory trials were arranged to ensure the suitability of these finer conductors from a manufacturing viewpoint. It was found in these trials, that with slight modifications of the tension of pay-off and take-up stands at the paper-lapping and twinning stages, no undue difficulties would be experienced. Some details are given later in this section. It should be borne in mind that in Australia helical paper insulation is used wherein low tensions (1-2 lbf) are encountered.

Wire Drawing and Annealing

In Australia, the aluminium rod is produced from 99.7% purity ingots using the Properzi process. The 9.5 mm rod is reduced to 2.1 mm wire at which point it is annealed and then finally drawn to the required diameter, the final speeds being approximately 1500 metres/minute with a controlled tension of 0.75 lbf. The final wire is delivered to spools holding some 70 lb.

Continuous annealing is not available in this country for aluminium conductors as the problems of arcing at the conducting pulleys and adequate conduction through the aluminium oxide film have not been satisfactorily solved. This limitation has not been serious up to the present time since only limited quantities of aluminium have been processed for telephone cable manufacture. Furthermore, the choice of a fully-annealed wire, rather than some intermediate temper, means that the real economic demand for continuous annealing has been avoided. However, it is realised that a continuously annealed wire has better metallurgical characteristics than batch annealed and furthermore, the loss of production in the event of power failure to the annealing ovens, dictates continuing attempts to develop continuous annealing in readiness for increased aluminium usage. Batch annealing is carried out at 270°C for 15 minutes in 800 lb. lots. This produces a wire of maximum tensile strength 14000lbf/sq. in. and a minimum elongation of 15%. Strict attention to adequate tension control at the final wire drawing stage has been found necessary to ensure free-flaking to the paper-lapping machines.

Paper Lapping

The machines formerly used for copper conductors have been found suitable with some modifications to the tension control of the pay-off spools and the die components. Most of these machines operate at about 3000 rpm. Factory joints in the wire are made by cold pressure welding with a "Koldweld" machine.

Twinning and Stranding

A variety of machines is used for twinning; most of these are double twist and produce up to 1000 metres per minute of twinned conductors. Some modification was required to the supply and take-up tensions to compensate for the lower tensile strength of the aluminium conductors.

Unit twin cable has recently been adopted as standard for all cable in the exchange area network. The machines used for unit construction are of the drum-twister design with stationary pay-off stands and rotating capstans. For unit cabling the pay-off stands have 100% back-twist. The largest machine in use can handle finished core on drums of flange diameter 96 inches, and operate at about 59 rpm.

In early developmental work, the effect of the paper lapping, twinning and stranding operations on the metallurgy of the cable conductors was assessed by measurement of tensile strength and elongation characteristics at various stages throughout the manufacturing process. The results indicated a very slight increase in tensile strength (for 14400 to 14800 lbf/sq. in.) due to work hardening but no significant reduction in elongation. This work led to the modification of the British Standard, B.S. 2627, for the specification of the annealed aluminium wire to be used. A maximum tensile strength of 15000 lbf/sq. in. with a minimum elongation of 10% is now specified for samples taken from the completed cable.

Sheathing, Drying and Electrical Testing

Moisture-barrier sheath has now been satisfactorily developed in Australia and is rapidly replacing lead as the standard sheathing material for large size exchange area telephone cable. For this operation, the paper-wrapped cable core is electrically dried to meet an insulation resistance requirement of 25000 megohms mile.

In cooling the cable sheath, extra horizontal rollers must be fitted along the cooling trough to force the light-weight cable below the surface of the water since this cable has an average specific gravity of less than unity.

Another problem peculiar to aluminium conductors was associated with the operation of electrical cable core drying. Here is was found that special high pressure clamps were necessary to break the oxide film and guarantee a satisfactory electrical connection for the high amperage drying current.

Aluminium conductor cables did not present any special difficulties in electrical testing. It was originally thought that conductor ends might require soldering for electrical tests but twist joints and standard clips were found to be adequate.

Typical Factory Test Results

The results of factory tests on typical manufactured lengths of cable are given in Tables 6 and 7. These are provided for cables supplied for both series of trials (see next section), and in addition some results are provided for more recent cables of 0.81 mm and 1.15 mm gauges.

Table 6 gives results for the cables of 0.63 mm gauge manufactured for trial installation in 1965. These cables were electrically equivalent to 0.5 mm copper conductor cables. Table 7 shows results for cables manufactured for the trial series commencing in 1969 where the conductor gauge was 0.5 mm, electrically equivalent to 0.4 mm copper. In both cases the cables satisfied the specification. The cables of 0.5 mm gauge were manufactured with insulant paper of 0.06 mm thickness and this resulted in a mutual capacitance lower than specified. Investigations are proceeding aimed at determining the best method of increasing the mutual capacitance by decreasing the paper thickness or by the use of smaller closing dies at the paper lapping and unit wrapping stages.

Table 7 also provides factory results of cables with conductors of 0.81 mm and 1.15 mm. Again, the only difficulties appear to lie in the achievement of a mutual capacitance closer to the nominal 0.072 microfarads per mile. To meet this figure with 1.15 mm conductors, and also the specified external diameter, it will probably be necessary to use strings under the insulating paper. To maintain the high speed operation of the lapping machines, a polythene string is favoured.

FIELD EXPERIENCE (1965-70)

Initial Trials (0.63 mm)

The first trials were commenced in 1965 with the installation of some 8000 KPY (Kilo pair yard) of cable in sizes ranging from 400 to 1200 pairs. These lead-sheathed cables were

TABLE 6: FACTORY RESULTS (0.63 mm UNIT QUAD).

Pair Size	Average Mutual Capacitance (μF/mile)	Capacitance Unbalance for 500 yard lengths (pF)				Mean Conductor Resistance (ohms/mile) (60°F)	External Diameter (inch)
		Side - Side		Side - Earth			
		Av.	Max.	Av.	Max.		
600	0.0715	191	720	237	1096	131.4	2.17
800	0.0714	182	716	229	1775	132.0	2.50
1200	0.0717	150	554	229	1174	134.8	2.96
Recommended Limits	0.075	350	1400	500	2400	138.2	

TABLE 7: FACTORY RESULTS (0.5, 0.81, 1.15 mm UNIT TWIN).

Conductor Gauge (mm)	Pair Size	Average Mutual Capitance (μF/mile)	Capacitance Unbalance for 500 yard lengths (pF)		Mean Conductor Resistance (ohms/mile) (60°F)	External Diameter (inch)
			Adj. Pr.-Pr.	Adj. Pr.-Pr.		
			Av.	Max.		
0.5	200	0.0660	22	72	213.2	1.24
,,	300	0.0629	18	60	208.8	1.47
,,	600	0.0653	22	92	208.0	2.00
,,	1200	0.0658	22	71	213.7	2.76
,,	1800	0.0657	19	71	213.5	3.39
Recommended Limits		0.0750		220	220.4	
			Adj. Pr.-Pr.	Pr.-E.		
			Max.	Max.		
1.15	100	0.0718	71	453	42.90	1.80
	400	0.0644	80	648	43.65	3.43
Recommended Limits		0.0750	140	1500	44.20	
0.81	100	0.0671	69	648	84.34	1.34
	800	0.0673	71	876	88.46	3.36
Recommended Limits		0.0750	180	1500	89.00	

installed between exchange main distribution frames and cabinet or cable distribution points. At the time of these installations concentric quad cable was generally in use for the larger (0.63 mm and 0.9 mm) gauge copper conductor subscriber cables. However, a unit quad design was chosen for the trial aluminium cables to facilitate the use of slack-splice jointing if this became desirable.

Conductors of 0.63 mm diameter were chosen since they presented the least developmental problems for cable manufacturers while at the same time proving their processes. Because the 0.63 mm gauge was also a standard copper conductor diameter, use could be made of the same insulation paper, strings, lay lengths of quadding and stranding, and other manufacturing processes.

Control of Trials

The main purpose of these trials was to determine at installation and throughout its service life, the performance of paper insulated, aluminium conductor cable under normal operating conditions. Data was gathered on hauling, jointing and electrical characteristics at installation together with a continuing appraisal of the in-service performance of the cable through regular tests and fault reports. The electrical tests made were of insulation resistance, loop resistance and resistance un-balance on all pairs. Other field reports provided opportunity for the separate recording of service aspects, e.g. quarterly tests of loop resistance and resistance unbalance readings of selected test pairs and a service history of any faulty pairs, sheath failures or other cable faults.

The aluminium-aluminium joints were generally made by tip welding with a small percentage being performed by placing 3.66 mm external diameter aluminium sleeves of bore 1.70 mm over a twisted aluminium joint and applying two crimps. Aluminium-copper joints were made with copper sleeves of 3.18 mm external diameter and 1.42 mm bore or 2.67 mm external diameter sleeves with 1.19 mm bore depending on the combination of conductors to be jointed, and in both cases applying three crimps.

Results of Trials

This cable was placed in five locations over the period May, 1955-January, 1968. Standard hauling techniques were used except that two types of attachment were employed — a cast epoxy resin eye and an end spike with standard hauling grip (as used by the British Post Office).

Cable Hauling: The trials indicated that there were no undue difficulties in the handling and hauling of the cable when compared with an equivalent diameter copper conductor cable. The hauling eye, which is the A.P.O. preferred method, was found to be satisfactory with aluminium conductor provided that a change was made to the method of removing the paper. With copper an oxyacetylene burning method is used but this proved unsuitable for aluminium and manual stripping was necessary.

Hauling tensions experienced during the trials were comparable with those for copper conductor cables. Details of hauling tensions encountered with these lead sheathed cables are given in Table 8 together with the cable lengths and weights/foot.

Jointing: Apart from the actual wire jointing methods used, which were tedious and time consuming, no other difficulties were encountered during cable jointing.

The tip welding method provided a mechanically and electrically acceptable joint but had several disadvantages:—

(i) it was difficult to control the weld;
(ii) the carbon electrode required continual cleaning;
(iii) the welding flash was severe on the eyes;
(iv) batteries required frequent charging;
(v) productivity was low, typically 50% of that for joints in copper conductor cables.

The crimped sleeve method of jointing was electrically and mechanically satisfactory but difficult to perform in the field. Several disadvantages were noted:—

(i) it was sometimes difficult to insert the twisted conductors into the sleeve;
(ii) there were difficulties in sliding a paper insulating sleeve over the crimped metallic sleeve because of the lugs formed on the latter during the pressing operation;
(iii) the crimping tool was awkward to use in confined spaces;
(iv) in aluminium-copper joints when using fully annealed aluminium wire, there was a tendency for the aluminium wire to "wrap around" the copper wire rather than the two forming a uniform twist;
(v) once again the productivity was about 50% of that for joints in copper conductor cables.

Electrical Measurements: At the completion of each installation, measurements were made of Loop Resistance, Resistance Unbalance and Insulation Resistance. Periodic measurements were continued on selected test pairs for the following five years. Test pairs were selected to include working and non-working circuits, and both tip welded and crimped sleeve conductor joints. The results of resistance unbalance measurements from the date of installation to the end of 1967 are included in Table 9 and show that little difference can be observed with either time or between the two methods of jointing used.

Water Damage to Installed Cables: In one location a partially completed cable joint was found to be damp. Attempt were made to dry the cable by applying heat at the duct mouths, and working it towards the joint area, as dry air was blown into the cable from adjacent joint positions. After attempts to improve the insulation resistance by this method were made

TABLE 8: FIELD INSTALLATIONS — LENGTHS, CABLE WEIGHTS, AND HAULING TENSIONS.

Pair Size	Weight (lb/yd)	Length (yds)	Tension (lbf)	Remarks
1200	23	148	3500	
		258	2000	
		265	5000	
		288	3250	
		305	2500	
		104	1000	
		172	3500	3½″ duct
		212	5500	,,
		97	1000	
		107	1500	
		152	800	
		233	1800	Exch. entry
		238	1500	,, ,,
		163	5000	
		163	4000	
		170	5100	
		276	2800	
1000	19	122	650	
		200	1000	
		293	1500	
		304	1300	
		330	1400	
		398	1700	
800	18	150	3725	
		235	2500	
		380	2500	
		401	1500	
		453	5500	
600	14	221	500	
		253	500	
		416	1300	
		472	1400	
		480	1400	
400	10	300	4800	See Note 1
		300	3000	,, ,, ,,
1800	8	90	1200	Exchange entry
,,		206	5000	Offset manhole
,,		300	6000	,,
,,		300	6000	S bend
,,		196	3000	Exchange entry
,,		98	1000	
,,		208	4500	Severe bends
,,		213	1000	
,,		108	800	
,,		270	4000	
1200	6	63	1800	3½″ duct
,,		330	800	
,,		287	600	
,,		266	800	Vertical bend
,,		254	600	
,,		219	750	
,,		281	800	Vertical bend
,,		183	250	
600	3	63	600	3½″ duct
,,		134	1500	right angle bend
,,		110	1000	
,,		296	250	
,,		217	50	
,,		250	NR	
,,		139	,,	
300	2	301	NR	
,,		165	,,	
,,		139	1000	See Note 1
200	1	310	1000	,, ,, ,,

Note 1: Cables hauled over another cable in the same duct.

TABLE 9: FIELD INSTALLATIONS — RESISTANCE UNBALANCE

Cable Experiment	Date	Resistance Unbalance (mean)					
		Welded Joints			Sleeved Joints		
		No. of Pairs	Ohms Unbal.	% Unbal.	No. of Pairs	Ohms Unbal.	% Unbal.
No. 17 A (0.63 mm Conductors)	16.8.65	14	1.30	.25	10	1.05	.20
	21.9.65	14	0.99	.19	10	0.92	.17
	24.11.65	14	1.05	.20	10	0.54	.18
	25.1.66	14	1.05	.20	10	0.56	.18
	18.7.66	14	1.11	.21	10	1.00	.19
	18.7.67	14	1.00	.19	10	1.15	.22
No. 17 B (0.63 mm Conductors)	17.11.66	32	0.20	.10	32	0.64	.13
	4.4.67	32	0.13	.07	32	0.17	.09
No. 16 A (0.63 mm Conductors)	4.7.66	40	0.46	.18	9	0.56	.22
	18.10.66	40	0.31	.12	9	0.33	.13
	16.2.67	40	0.42	.16	9	—	—
	17.5.67	40	0.32	.12	9	0.22	.08
	20.10.67	40	0.92	.35	9	0.89	.34
No. 16 B (0.63 mm Conductors)	18.5.66	5	0.51	.20	5	0.57	.22
	25.8.66	5	0.66	.26	5	0.50	.19
	21.11.66	5	0.45	.18	5	0.52	.20
	21.2.67	5	0.44	.17	5	0.58	.23
	24.5.67	5	0.43	.16	5	0.54	.21
	25.8.67	5	0.42	.16	5	0.54	.21
No. 30 A		Connector Joints					
(0.5 mm Conductors)	21.12.69	40	0.72	.16			
	3.2.70	40	0.75	.16			
	15.5.70	40	0.68	.13			

for some days, a bag sleeve fitted with an air valve was used to close the joint. Air was then introduced at adjacent joint positions until a pressure of 10 lbf/sq. in. was measured at the damaged joint. This air was then released and the procedure repeated with dry air and the insulation resistance was thereby sufficiently improved to allow jointing to be resumed at the damaged joint. At the completion of all jointing, dry air was fed into the cable at the exchange pot head until the insulation resistance reached a satisfactory value.

At another location a partially completed joint was immersed as a result of water entering a manhole following a flash flood. The water flowed in both directions from the open joint. Attempts were made to dry the cables by passing dry air through them from the other ends of the cable lengths. After the consumption of twenty cylinders of dry air, insulation resistance had not risen above 200 ohms between wires of a pair. Both lengths had to be replaced.

Conclusions from Early Trials

Notwithstanding the difficulties experienced in the conductor jointing process and the confirmation of expected difficulties in drying out water-damaged aluminium conductor cable, the first trial installation was considered a success. Since 1965, these cables have continued to operate without faults that can be adduced directly to the use of aluminium conductors.

It was decided to proceed with a second series of trials in 0.5 mm gauge. This gauge, the most frequently used in subscriber main cable networks, accounts for some 50% of the total paper insulated cable requirements. Fully annealed wire was found satisfactory from a field viewpoint in the early trials and it was confidently expected that light-weight moisture-barrier sheath (by this time adopted as standard for duct cable) would remove any cable hauling difficulties due to the smaller gauge. Factory experiments undertaken in late 1966 revealed very few problems in manufacture. There was no significant change in the tensile strength or elongation characteristics of the aluminium, and the wire breaks which did occur were associated with mechanical damage to the conductor prior to the paper-lapping stage. Two grades of wire were used, one of tensile strength 14000 lbf/sq. in., the other of 12000 lbf/sq. in.

Consequently it was decided to proceed with installations of 0.5 mm conductor cables with two main objectives:—

(i) to establish a technique which would enable 0.5 mm conductor to be quickly introduced should the copper supply position deteriorate;

(ii) to gain additional field information so as to permit finer economic comparisons of aluminium and copper cables to be made.

It was also decided to commence developmental work on the larger gauges, i.e. 0.81 and 1.15 mm.

The poor productivity of the jointing methods used in the first installations made the decision to use connector jointing, as already mentioned, more readily acceptable although the A-MP connectors chosen had not been designed for use with aluminium, nor have they been adopted in Australia for copper conductors.

FIELD EXPERIENCE (1969-70)

Subsequent Trials (0.50 mm)

These were begun in 1969 and comprised 6000 KPY of cable in sizes ranging from 200-1800 pair in the subscribers' main cable network. These polythene/aluminium moisture-barrier sheathed cables were of unit-twin construction.

From these trials only limited information is available. However, the hauling tensions, lengths, and unit weights are shown in Table 8 and the available measurements of loop resistance and resistance unbalance are given in Table 9. Subjective reports from the field have commented favourably on the combination of a lightweight moisture-barrier sheath with aluminium conductors, particularly with regard to the ease of handling.

The fact that the cable floats necessitated the fitting of cable clamps at each manhole. Factory-fitted hauling eyes cast in epoxy resin were used in this trial and were satisfactory in most cases. The only difficulties were experienced in the largest cable sizes where the increase in cable diameter due to the casting made hauling more difficult. Subsequent developmental work has enabled a hauling eye to be produced which is almost flush with the cable sheath surface.

The trial cables were installed at four locations. The final electrical tests at installation at the first location indicated a completely acceptable jointing technique, but the tests at the next installation revealed 43 faults in 1800 pairs and of these all but 8 were open circuit faults. After testing with a pulse-echo set, the faults were found to be spread over most of the joints in the cable and subsequent examination showed them to be at the entrance to the connector. These faults were repaired by fitting new connectors and during this process a further 17 broken wires were detected and repaired. The joints were closed and the cable re-tested. It was then found that 25 new faults still existed of which 23 were open circuits. It seemed evident that further attempts to clear the cable would only produce more faults, so it was decided to leave these faults uncleared. Complete test results are not yet available for the third and fourth locations.

An examination of faulty conductor joints removed from the second location indicated that the primary cause of the open circuit faults was due to heavy notching of the 0.5 mm aluminium conductor during pressing. This occurred due to misalignment of the conductor with respect to the insulation securing tang. Subsequent lateral movement of the conductor with respect to the connector body caused its failure in shear. In one case the misalignment was such as to cause direct shearing of the conductor by the tang. It is now necessary to determine whether the misalignment of the conductors during pressing is the result of

(i) incorrect adjustment of the jointing machine
(ii) operator error in positioning the wires
(iii) the inability of the jointing machine to handle wires of 0.5 mm diameter of fully-annealed aluminium without damage.

Future Installations

At the present time, 10000 and 2000 KPY in 0.5 mm and 1.15 mm gauges respectively are being manufactured for further field installations. The jointing of 0.5 mm conductors will be effected with A-MP connectors. However, no suitable connectors are available for the larger gauge and these conductors will be jointed by an improved method of welding. The welding tool operates on the principle of two closely controlled currents, switched by transistors; a pre-heat current followed by a welding or fusing current. The electrodes are continually cleaned. These installations are scheduled to take place during 1970-71.

CONCLUSION

Optimum Mutual Capacitance

The Australian Post Office decision to substitute aluminium for copper in paper insulated cables, whilst retaining a pure electrical equivalence, has been made with the knowledge that paper insulated cables will comprise the bulk of larger size balanced pair subscribers main and junction cables installed in this country over the next decade.

The question of an optimum mutual capacitance design to accompany such a significant change in the proportionate costs of cable, duct and labour, as clearly demonstrated in the work of H.J.C. Spencer (Ref. 8) of the British Post Office, has not been overlooked. However, the practical implications of a complete change in mutual capacitances for different cable types and usage situations, and the implications of increasing high frequency operation in such cables, makes a study of optimum mutual capacitance for the future go far beyond the scope of this paper. It would include comparative studies of different insulation types, including plastics, which will play an increasingly important role in the future.

Future Plans

The A.P.O. will be extending its installations of paper insulated aluminium conductor cables over the full range of conductor gauges, particularly the 0.5 mm subscribers main cable field, where extensive installations are already planned. It is hoped, that from January 1972 onwards, the choice between aluminium and copper conductor cables will be based mainly on network economic desiderata.

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TRANSMISSION OF DATA OVER LEASED LINKS

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INTRODUCTION

The rapid growth of data services within Australia in recent years has necessitated close attention to many transmission factors which were hitherto relatively unimportant. Telephony and low speed machine telegraphy services have only required such basic factors as frequency response, cross talk and noise to be controlled. However, higher speed data modems, which have developed from telegraph techniques, use modulation methods to increase the information content of signal without substantially increasing the modulation (or baud) rate, and are less tolerant to other factors such as short interruptions and phase instability. An understanding of the critical characteristics of various communications facilities used by the Australian Post Office (A.P.O.) is essential in order that satisfactory data transmission services can be provided. This is particularly important when high speed data transmission on data links is proposed.

This paper describes the many transmission factors relevant to data transmission, and relates these to characteristics of Post Office plant likely to be used for leased links. Practical aspects of equalisation, maintenance and performance of leased links used for data transmission are also discussed.

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TERMINOLOGY

Data Link: The connection between data modems, providing the required bandwidth for data transmission.

Data Service: The connection between the interfaces with data processing equipment. It includes the data modems and data link.

Carrier Section: The carrier derived connection between points of access.

Physical Section: The physical (cable or open wire pair) connection between points of access.

SPECIFICATIONS FOR LEASED DATA LINKS

General

The current Australian Post Office tariff schedule for leased services (1st May, 1969), provides for a wide range of links for data transmission. The expansion of data services in Australia has primarily been met with the use of voice (or 3kHz) bandwidth links, however some demand for group (or 48kHz) bandwidth links is being experienced. Data transmission over supergroup (or 240 kHz) bandwidth links is largely in the experimental stage overseas, and is unlikely to be required in Australia for some years, however, some experience of the characteristics essential to data operation has been gained with the recent introduction of newspaper facsimile transmission between several Australian capital cities.

Voice Bandwidth Links

Two basic types of leased voice bandwidth (3 kHz) data links can be provided as follows:—

Standard Data Link: For data transmission at rates of 1200 bits per second and below. This type of link has similar performance to that of a direct telephone circuit between two terminal exchanges, but has the advantages of four wire operation. No special equalisation is provided for purposes of data transmission.

At these relatively low rates of data transmission, a high level of interference is required before difficulties are experienced, and suitability of a standard quality link for data transmission may often be gauged by the ability to conduct an acceptable telephone conversation.

TABLE 1: COMPARISON OF TRANSMISSION PERFORMANCE CHARACTERISTICS REQUIRED FOR SPECIAL QUALITY VOICE BANDWIDTH DATA LINKS

Performance Characteristics		M102 (Formerly M89)	C2	C4	S1	S3
Reference Frequency		800 Hz	1000 Hz	1000 Hz	1000 Hz	1000 Hz
Overall Loss		Not specified	16 dB±1	16 dB±1	Not specified	Not specified
Variation of Overall Loss With Time	Short term	±3 dB	±3 dB	±3 dB	—	—
	Long term	±4 dB	±4 dB	±4 dB	±4 dB	±2 dB
Attenuation Distortion	300-3000 Hz	$^{+6}_{-2}$ dB	$^{+6}_{-2}$ dB		$^{+6}_{-2}$ dB	$^{+3}_{-1}$ dB
	300-3200 Hz			$^{+6}_{-2}$ dB		
	500-2800 Hz	$^{+3}_{-1}$ dB	$^{+3}_{-1}$ dB		$^{+3}_{-1}$ dB	$^{+1.5}_{-0.5}$ dB
	500-3000 Hz			$^{+3}_{-1}$ dB		
Group Delay Distortion	1000-2600 Hz	< 500 μS	< 500 μS	< 300 μS	< 500 μS	< 100 μS
	600-2600 Hz	< 1500 μS	< 1500 μS		< 1500 μS	< 300 μS
	500-2800 Hz	< 3000 μS	< 3000 μS		< 3000 μS	< 600 μS
	800-2800 Hz			< 500 μS		
	600-3000 Hz			< 1500 μS		
	500-3000 Hz			< 3000 μS		

Special Quality Data Link: For data transmission at rates of 2400 bits per second and above. Equalisation of attenuation and group delay distortion is provided as necessary to meet the limits recommended by C.C.I.T.T. Recommendation M102.

Under special circumstances and by negotiation, for example in provision of sections of international data links, or for high speed data services, links may be provided to meet special specifications.

Several recommendations and specifications have been formulated to cover the essential transmission performance characteristics of special quality leased voice bandwidth data links, for data transmission at speeds of 2400 bits per second and above. The more relevant documents are:—

C.C.I.T.T. (International Consultative Committee on Telephone and Telegraphs) — Recommendation M102 (Formerly M89), White Book, Mar Del Plata, 1968
F.C.C. (Federal Communications Commission — U.S.A.) Tariff Schedule 260
(i) C2 Conditioning
(ii) C4 Conditioning
D.C.A. (Defence Communications Agency — U.S.A.) Technical Schedules
(i) S1 Conditioning
(ii) S3 Conditioning

A comparison of the performance specifications described in the above documents is shown in Table 1. Analysis of these details will indicate that in respect to attenuation and group delay distortion, and variation of overall loss with time, M102 is identical to C2 and S1. However, the latter schedules also specify the significant factors of basic and impulsive noise, single tone interference, harmonic distortion, phase jitter and frequency error. C4 places more stringent limits on attenuation and group delay distortion, but in other respects is identical to C2, while S3 is more stringent in most parameters.

Group Bandwidth Links

Specifications for group bandwidth (48 kHz) data links have not yet been firmly established and are under detailed study by C.C.I.T.T. Pending international agreement, the following interim objectives for significant parameters have been adopted by the A.P.O. for group bandwidth links occupying the nominal spectrum 6-54 kHz:—

Data Signal Level	: −5dBmO
Attenuation Distortion	: ±3dB over range 12–49 kHz
Group Delay Distortion	: < 25 μs over range 12–49 kHz
Basic Noise	: < −31 dBmO
Impulsive Noise	: < 60 counts in 30 minutes at a threshold of −2·5 dBmO.
Single Tone Interference	: < −34 dBmO
Long Term Loss Variation	: ± 2·5 dB
Short Term Loss Variation	: ≯ 10 events in 24 hours, or ≯ 1 event in 30 minutes outside limits of ± 3 dB from nominal.
Harmonic Distortion	: No harmonic greater than −35 dBmO for a fundamental level of −5 dBmO.
Phase Stability	: Phase Jitter < 8° peak-to-peak Phase Hits ⩽10 events in 30 minutes exceeding ±15° peak-to-peak.

Depending on the type of group bandwidth modem and techniques of group extension to subscribers premises finally adopted by the A.P.O., these interim objectives may require modification in the future.

Supergroup Bandwidth Links

Although supergroup bandwidth (240 kHz) links are unlikely to be required for data transmission for some years, it is of interest to note the requirements for the somewhat analogous newspaper facsimile transmission, which has now been in operation for some time between several Australian capital cities. The problems associated with newspaper facsimile transmission are common to data transmission, since both services are sensitive to disturbances that cause distortion of wave shapes.

Since no international specification has been formulated for the essential transmission parameters of supergroup bandwidth links, conditioning is presently carried out so that the specific requirements of customer equipment are satisfied, however, the objective is to establish a universal compromise. In respect to supergroup bandwidth links for newspaper facsimile transmission, the following interim objectives have been adopted:—

Attenuation Distortion	: ±2 dB over range 328–532 kHz
Group Delay Distortion	: < 5 μs over range 328–532 kHz

These objectives depend significantly on the modulation pattern, frequency spectrum and sensitivity to specific impairments for types of equipment and applications.

FACTORS AFFECTING TRANSMISSION OF DATA

An understanding of the many operational factors which can influence data transmission, including those which are presently unspecified or under study, is necessary in order to assess the suitability of communication facilities for data transmission. The occurrence of these factors in certain types of transmission links, and under certain conditions of operation, will be examined later in this paper. The factors of most concern are:—

Loss (See Table 1): Both short and long-term variations with time in overall loss on a data link can be expected. Short-term loss variations are caused by dynamic regulation of carrier repeaters and systems, switching to standby facilities, radio propagation path difficulties, operational errors, or normal maintenance activities. Such variations are relatively infrequent and do not occur periodically. The intervals are often referred to as "dropouts". Long-term loss variations are caused by temperature changes, equipment ageing, etc.

Attenuation Distortion (See Table 1): Variations in transmission loss over the signal band cause distortion in the received spectrum and, in turn, the data signal waveform. If uncorrected, useful bandwidth, and consequently the rate of data transmission is limited.

Noise: Data signals can withstand relatively high basic noise levels, but impulsive noise having a duration similar to data symbol intervals, and levels comparable to that of the data signals can cause significant impairment. Types of noise interference likely to be encountered are as follows:—

Basic Noise (See Table 2): This is dependent on the constitution of the data link, and particularly on the operational length of frequency division multiplex carrier systems included.

Quantizing Noise: Quantizing noise is produced as a result of link routing via a pulse code modulation system.

Impulsive Noise (See Table 2): This type of interference arises from electrical storms, exposure to other electrical systems, and non-linear operation of plant, e.g., overloading. In this respect, leased data links have considerable advantages over switched connections via the public telephone network, since the latter suffer from inherent transient interference due to operation of electromagnetic devices in the switching equipment.

In the case of *voice bandwidth* data links, F.C.C. Tariff Schedule 260 technical conditions recommend that the normal aggregate r.m.s. data signal should be 5 dB higher than the threshold level where one impulsive count per minute is observed. This is based on a test set with a maximum counting rate of 7 per second.

The distribution of impulsive noise levels above the threshold level is of interest in assessing the relationship between basic noise and impulsive noise levels. Typically, one-tenth of the number of impulses can be expected for every 7 dB increase in measuring level. Relative to an objective of 15 counts in 15 minutes at a threshold of —21 dBm0, it might therefore be expected that 1.5 counts would be noted in 15 minutes at a threshold of —14 dBm0.

Group Delay Distortion: This is the differential of the phase/frequency response over a group of frequencies and must be normalised at a selected reference frequency for end-to-end measurements. The effect is to cause side frequency components to undergo differing phase shifts, resulting in distortion of the composite waveform received (see Table 1).

Return Loss: Wherever impedance mismatch occurs, delayed multiple echoes of the data signal can appear at the receiving end. Such echoes may have amplitudes as great as 10 dB below the main signal, and may be delayed in time from 0-150 milliseconds in typical cases. The effect is to generate an independent interfering signal which can result in severe intersymbol interference and maloperation of the data receiver.

Ripple encountered during measurement of both attenuation and group delay may indicate impedance mismatch. However the lack of ripple must not be construed as indicating satisfactory return loss, as the results depend on many factors including the location and bandwidth of the test equipment.

In respect to voice bandwidth links, a balance return loss at hybrid junctions of at least 12 dB over the frequency range 500 to 2800 Hz is desirable in order to achieve adequate echo attenuation.

Frequency Error: This results from operation of most frequency division multiplex equipment in a single side-

TABLE 2: COMPARISON OF TRANSMISSION PERFORMANCE CHARACTERISTICS REQUIRED FOR SPECIAL QUALITY VOICE BANDWIDTH DATA LINKS

Performance Characteristics	M102 (Formerly M89)	C2	C4	S1	S3
Basic Noise	Under study. Three noise limit classes have been proposed as follows: (i) —51dBm0 (ii) —45dBm0 (iii) —38dBm0	Link Length (Miles): 0-50, 51-100, 101-400, 401-1000, 1001-1500, 1501-2500, 2501-4000, 4001-8000, 8001-16000	Noise Limit (dBm0): —59, —56, —53, —49, —47, —45, —43, —40, —37	Link Length (Miles): As for C2 and C4	Noise Limit (dBm0): As for C2 and C4
Single Tone Interference	Under study. 3dB below basic noise objective has been proposed.	3 dB below basic noise objective.	As for C2	As for C2 and C4	As for C2 and C4
Impulsive Noise	Under study. Not greater than 18 counts in 15 minutes exceeding levels between —18 and —21dBm0 has been proposed.	Not greater than 15 counts in 15 minutes exceeding a level of —21 dBm0.	As for C2	Not greater than 15 counts in 15 minutes exceeding a level of —18dBm0.	As for S1
Harmonic Distortion (Test level —13dBm0)	Under study. Not greater than —43dBm0 for any harmonic has been proposed.	Not greater than —43dBm0.	As for C2	As for C2 and C4	As for C2 and C4
Return Loss	Not defined	Not defined	Not defined	Not defined	Not defined
Longitudinal Balance (to Earth)	Under study	Not defined	Not defined	40 dB minimum	As for S1
Frequency Error	Under study. ±5 Hz has been proposed.	±5 Hz	±5 Hz	±5 Hz	±5 Hz
Phase Jitter (peak to peak)	Under study. 15 degrees in the range 20-300 Hz has been proposed.	8 degrees	8 degrees	15 degrees	15 degrees

band suppressed carrier mode. Because the carrier is not transmitted, and must be reinserted locally, there will be differences in frequency between the modulating and demodulating carriers. Each component of a data signal may therefore suffer a frequency error, and this upsets any harmonic relationship which may have existed between components. The effect is of most significance in narrow band frequency shift operation, such as backward error detection channels in data modems (see Table 1).

Phase Jitter: The instantaneous phase of the received data signal is likely to jitter by up to 15° peak to peak, typically at rates of 150 Hz and below, causing interfering sidebands with magnitudes of the order of 18 dB below the level of the data signal. This is primarily due to the fundamental and harmonics of ripple in power supplies appearing in the master oscillator of broadband carrier equipment, and being multiplied through many stages (Often referred to as "hum modulation"). Phase jitter also arises due to generation of 16⅔ Hz ring tone, and may in some instances be caused by impure carrier supplies. The effects of phase jitter are most evident on data modems using narrow band frequency shift or multi-level phase modulation (see Table 2).

Phase "Hits": These are sudden changes in phase of the order of ±30-40°, but sometimes up to 360°, which can occur by switching of carrier supplies not in phase, or substitution of a broadband facility having a different propagation time. Such phase changes are accompanied by amplitude "dropouts" during recovery to steadystate conditions. The occurrence of these events is infrequent, typically in the order of 30 per day per link, however, errors in data are introduced on each occasion.

Non-Linearities: Impairment to data signals can be caused by non-linearities in communications facilities, such as compression and overload conditions. The resulting second-order modulation products may fall within the baseband spectrum of the data signal, and cause distortion if coincident with the line signal (see Table 2).

ALLOCATION AND PREPARATION OF LINKS

Voice Bandwidth Links

Allocation of physical and carrier transmission sections for a proposed voice bandwidth data link is made on the basis of either a standard or special quality data link requirement. A decision on the number of voice frequency connected sections to be introduced, for reasons of patching flexibility, must be made at this time. To minimise group delay distortion, and the need for group delay equalisation, the number of sections is usually kept to a minimum. End-to-end patching of the overall carrier section is therefore adopted provided that suitable patch facilities can be made available. With the rapid growth of the Australian trunk network, the situation in this respect is becoming more favourable. Four-wire links are provided between data modems to avoid problems of echo.

When a special quality data link is required, attenuation equalisation of physical sections from the carrier terminals to the data modems is first carried out. The degree of equalisation, and location of equalisers, is dependent on the attenuation distortion of the individual physical sections, and also on subsequent mop-up equalisation which may be carried out when variable group delay equalisers are likely to be provided. Under the latter circumstances, coarse equalisation of physical sections to ±2 dB limits over the V.F. range is carried out. Before more complex equalisation of the data link is carried out, impedance irregularities are corrected, and V.F. amplifiers are included if necessary.

Group Bandwidth Links

Stringent requirements are imposed on the allocation of group bandwidth (48 kHz) data links. From an initial choice of 5 groups of a supergroup, the following restrictions can apply:—

Where a through supergroup filter is used, groups 1 and 5 exhibit unsymmetrical group delay distortion, rendering equalisation difficult by normal methods.

Group 3 includes the supergroup regulation pilot frequency and must be avoided.

Group 4 has in some cases been found to suffer interference from adjacent supergroups.

Based on the above considerations, group 2 is generally found to be the best choice for data operation. Whichever group is selected, the use of through group filters must be restricted in order to avoid excessive group delay non-linearity at band edges.

Initial preparation of group bandwidth data links first involves attenuation equalisation for pair cable sections. It has been found desirable to employ variable attenuation equalisers in initial installations, as these simplify lineup, and reduce the delay distortion arising from pair cable sections sufficiently for it to be neglected.

GROUP DELAY EQUALISATION

General

The basic principle of group delay equalisation is to introduce finite group delay at selected frequencies throughout the range, such that with the exception of ripple variations between the selected frequencies, group delay remains substantially constant. The inclusion of limits for such ripple has merit, and has been advanced in some instances, e.g. N.A.S.A. wideband data links.

Voice Bandwidth Links

Prior to 1969, whenever group delay equalisation of Post Office data links was required, fixed group delay equalisers were designed and manufactured to suit specific links. This had the disadvantage of long delivery time, although actual design was carried out by computer, and required a new equaliser to be made each time a data link composition was altered. The possibility of a range of standard fixed equalisers was considered, but it was decided to develop a fully variable group delay equaliser for universal application. This new equaliser has been designed by the A.P.O. (Ref. 1), and comprises active equaliser sections with variable group delay characteristics at selected frequencies. The facility of attenuation equalisation within a limited range is also provided.

When required for a voice bandwidth data link, group delay equalisers are installed at the end of the receive path, at the last carrier terminal in each designated patching section. Measurement and adjustment of equalisers is relatively straightforward where intermediate V.F. connected sections are involved. However, for the terminal carrier section on a data link, the equaliser is situated at a point remote from the data modem installation, and tests are first made on the carrier section, then test instruments are transferred to the data modem installation, and any further adjustment of the equaliser is then arranged by order wire. In the majority of situations, since the pair cable section from the carrier terminal to the data modem installation does not normally introduce significant group delay distortion, and as initial attenuation equalisation has been carried out, only minor readjustment is necessary in order to meet specification limits. This arrangement is recognised to be somewhat cumbersome, and a new version of the variable equaliser, which includes separate equaliser elements for the physical sections, and therefore simplifies initial equalisation and subsequent maintenance, is under consideration.

Equalisation of each data link is usually carried out to a fraction of the nominated specification, to provide a margin for drift in line transmission equipment, alterations to the composition of the data link, and drift in the variable equalisers involved. Where several patching sections are involved, equalisation to an apportioned fraction of the specification is carried out in each section, and in most cases the end-to-end specification requirement is met when the sections are connected.

Group Bandwidth Links

Group delay equalisation of group bandwidth links is currently carried out with fixed delay equalisers specifically designed and constructed for a particular application. Similarly to the case of voice bandwidth links, the fixed equalisers are located at the output of the group demodulator, at the last carrier terminal for each direction of transmission.

ALLOCATION OF SECTIONS

General

The provision of a data link between two data modem installations involves a combination of many types of plant. It is therefore essential that particular characteristics and limitations of each type are understood in order that a suitable format to meet the requirements for the data service is obtained. The A.P.O. is presently conducting an extensive research programme into all aspects of plant likely to affect transmission of data.

The significant parameter of group delay distortion in **voice frequency** facilities is caused mainly by the reactive characteristics of transformers and amplifiers at the lower frequencies, and by loading coils and line capacitance at the higher frequencies. In **carrier transmission** facilities, transformers and filters in channel, group, and supergroup modulation equipment are the main causes of group delay distortion.

Plant Characteristics

Voice Bandwidth Modems: A relatively high uniformity in transmission parameters is achieved by modern voice bandwidth modems, however tolerances in channel bandpass characteristics result in a typical variation of 100 microseconds in relative group delay between different units (See Fig. 1).

In general, however, group delay distortions add systematically, and experience indicates that one carrier section meets one half of M102, two voice frequency connected carrier sections just meet M102, and group delay equalisation is necessary for voice frequency connection of three or more carrier sections. Interconnection at group frequencies is therefore preferable where a number of carrier sections is involved.

Other factors concerning voice bandwidth modems include:—

Restricted Bandwidth: Modern 3 Circuit Open Wire Carrier Systems have a bandwidth from 300 to 3000 Hz, however some earlier types are restricted to an upper frequency limit of 2800 Hz (see Fig. 3). Where these latter types are encountered, group delay distortion in the upper frequency region of the voice frequency range renders equalisation extremely difficult, and such data link sections should be strictly avoided for special quality links.

On certain intercapital city routes in Australia, "Channel Doubling" (Ref. 2) equipment has been fitted to 12 circuit open wire carrier systems. The narrow band voice channels so derived are unsuitable for data transmission at speeds of 1200 bits per second and above.

Oscillator Stability: Certain types of voice bandwidth modems may employ individual channel carrier oscillators of inferior stability and unless frequent maintenance checks are made, the frequency error can exceed specification limits. Frequency errors of between 5 and 10 Hz have been encountered in practice.

Through Group and Supergroup Filters: The characteristics of through group and supergroup filters occasion additional group delay distortion to edge channels of a group or edge groups of a supergroup. These channels or groups should therefore be avoided if possible, particularly where several group or supergroup connected carrier sections are involved (see Fig. 2).

In some cases, imperfections in through supergroup crystal filters have caused severe attenuation and group delay peaks in the passbands of groups 2 and 3 of associated supergroups. This could present considerable difficulty in selection of groups for group bandwidth data links, but provided that the occurrence is carefully monitored and alternative choices made or crystal filters changed, this restriction need not be a governing factor.

Companders: Rural carrier and some types of 12 circuit open wire carrier systems are fitted with compandors (compressor/expandor facilities) which

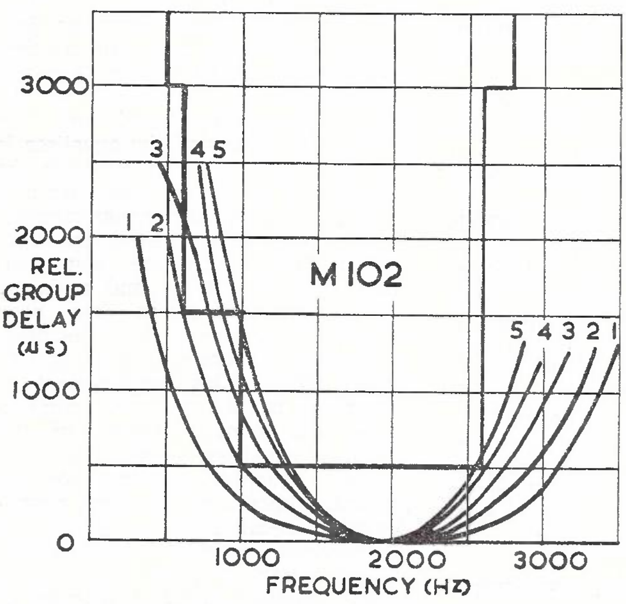


Fig. 1.— Group Delay of V.F. modems (Curves show Indicated Number of Modem Pairs Connected in Tandem).

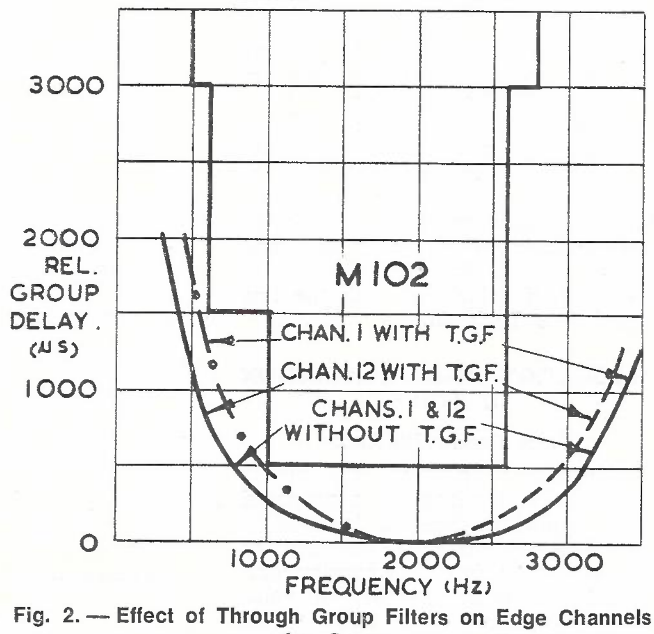


Fig. 2.— Effect of Through Group Filters on Edge Channels of a Group.

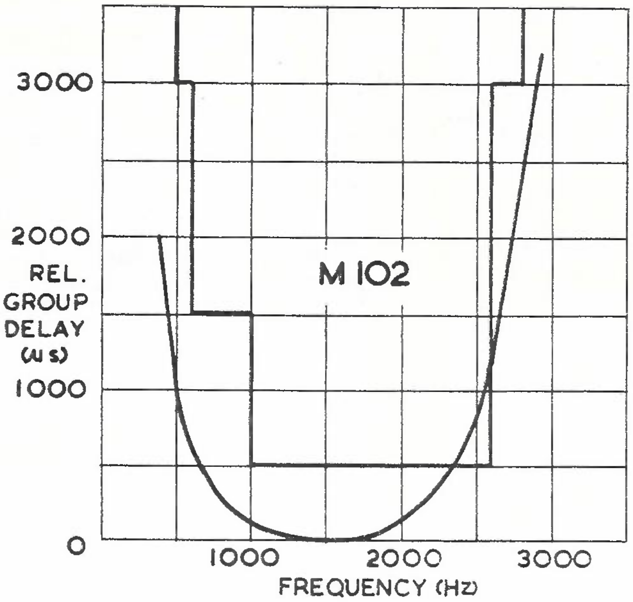


Fig. 3. — Group Delay of One Channel of a 3-Circuit Carrier System.

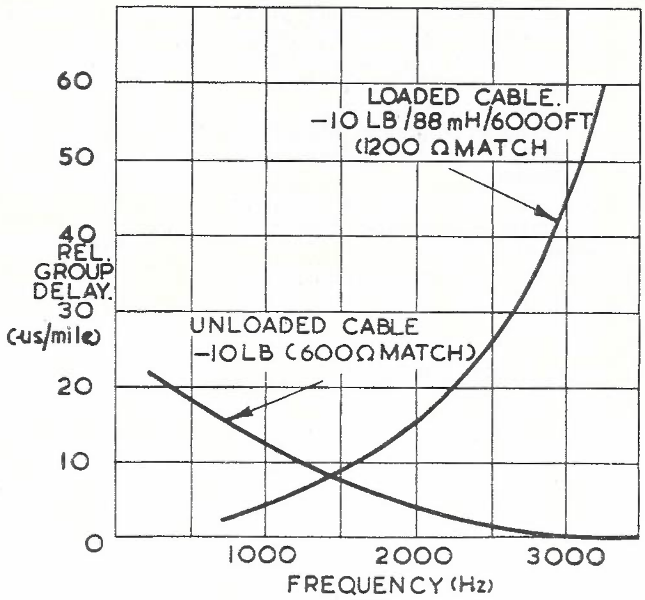


Fig. 4. — Group Delay of Loaded and Unloaded Cable.

afford improved signal-to-noise ratio under sub-standard conditions. Unless the compandor facilities are removed, data transmission over such carrier systems is only possible at low speeds since the compandor action varies at a syllabic rate, and therefore cannot follow signals varying in amplitude at data rates. Amplitude modulated data signals can also suffer significant distortion due to tracking error occurring between the compressor and expandor sections, particularly at low levels.

Echo Suppressors: Echo suppressors may be fitted to extremely long voice bandwidth links incorporating four-wire/two-wire conversion, since propagation delay can result in unacceptable echo. In some circumstances, it may be necessary to use such four-wire/two-wire links for data transmission, although four wire operation is usual. However, echo suppressor equipment has a finite "hangover" time for cessation of suppressor action, which severely limits the speed of bidirectional data transmission. Further, by insertion of high loss in the return path during forward transmission, simultaneous return data transmission at frequencies different to those used for forward transmission is blocked. For these reasons, facilities are provided to disable echo suppressors by means of a discrete tone during periods of data transmission.

Pair Cable Systems: No special problems are encountered with transmission of data via frequency division multiplex carrier systems operating on balanced pair cable. The A.P.O. is presently conducting trials on time division multiplex pulse code modulation systems for pair cable. Such systems are ideally suited to transmission of digital data provided access can be obtained to the digit stream, otherwise this type of system introduces a further noise factor as a result of the quantizing process of level assignment.

Voice Frequency Amplifiers: Some effect on group delay can be expected at the limits of the frequency range of voice frequency amplifiers. This is due to the controlled amplitude characteristics introduced for reasons of stability.

Negative Impedance Repeaters: N.I.R.'s are used on 2-wire loaded cable pairs, and may further degrade the return loss, giving rise to excessive echo (see Ref. 3).

Characteristics of Physical Sections

Cable: Loading of cable sections with 88 millihenry inductors spaced at 6000 feet intervals is often carried out to reduce attenuation in the junction cable network. Group delay distortion is introduced by the loaded sections, but a large number of sections can be tolerated before group delay equalisation is necessary (see Fig. 4).

Care must be taken to avoid discontinuities such as joining unloaded to loaded cable, and inadequate terminations arising from cable diversions, exchange transfers and unwanted teed cable. These factors severely accentuate attenuation and group delay distortion, and increase echo.

Impulsive noise spikes appearing on cable sections due to crosstalk couplings between pairs carrying high energy dialling or teleprinter signals can be very significant. In *voice bandwidth* data links, some attenuation is given by loading coils, however, the most effective measure is improvement in the balance of data equipment to earth, which affords longitudinal suppression. In *group bandwidth* data links, impulsive noise in pair cable sections between data modems and group bandwidth modems is a critical factor, and for this reason underground cables dedicated to group bandwidth links, and carefully selected pairs, are necessary to achieve satisfactory operation.

Open Wire: No significant effect on voice bandwidth data transmission is encountered, except where physical/carrier separation filters are employed. Relatively high impulsive noise can be experienced at certain times of the year, and careful transposition design is required to obtain satisfactory crosstalk attenuation to adjacent pairs.

Broadband Line Links

Total signal loading on broadband line links must be carefully controlled in order that overloading of common amplifier equipment, and generation of significant levels of inter-channel, group and supergroup interference does not occur. For this reason, the A.P.O. has presently standardised the maximum V.F. data transmission send level at —13 dBm0, which represents a compromise with the loading produced by speech.

Phase instability is being experienced in master oscillators associated with broadband line links due to several complex factors including:—

unsuitable techniques of carrier generation involving frequency multiplication,

lack of circuitry to ensure phase synchronism of normal and standby generators in some early type carrier generation equipment.
the use of electron tubes, with attendant microphonic difficulties, in early type carrier generation equipment,
transients caused by the operation of early type crystal oven temperature controls,
excessive hum modulation arising from certain early type power supplies,
lack of purity in the output of some carrier generators.

These factors and others are being isolated as techniques of measurement are improved, and action is accordingly being taken to upgrade and plan suitable facilities. In the interim, as more experience is gained in the problems involved, unsuitable equipment can generally be bypassed when link sections are being allocated.

Frequency asynchronism between master oscillators in main stations and between capital cities is still being experienced to varying degrees, and action is being taken to develop a system of routine manual checking, using special equipment at stations concerned. Automatic frequency locking is not regarded as desirable since this may introduce phase instability problems.

Line Links for broadband systems may utilize:—

Coaxial Cable: Short interruptions which cause phase hits and dropouts do not occur frequently on data links provided via coaxial cable systems. However, damage to the coaxial cable can result in a complete outage for a significant period until suitable patch facilities are provided, or repairs are effected.

Radio: Radio systems are subject to the effects of path fading which causes frequent switching to the associated standby link. This produces interruptions which may be as short as 5 milliseconds (for a single link with permanent standby), or as long as 35 milliseconds (for more complex link arrangements) in duration. Speech or direct relay television (excluding television relays being recorded for later transmission) is not significantly affected, however, the resultant phase instability severely degrades transmission of digital information. Careful system design and propagation path selection along the route can help to minimise these effects.

Satellite Links: In cases where data transmission via satellite links is involved, and four wire/two wire conversion is unavoidable, echo suppressors fitted to reduce talker echo during speech transmission will be disabled by a special tone during data transmission. However, propagation delay may be such that operation of block retransmission error control systems in data equipment is severely limited. Control of absolute delay is not feasible, and care must therefore be taken to assess all factors before allocating such links.

MAINTENANCE ASPECTS

Need for Maintenance

A check of characteristics of special quality links used for data transmission is desirable at infrequent intervals to detect and correct ageing in equipment, and is essential whenever the composition of the data link is altered, or when failure occasions insertion of alternate modulation equipment. C.C.I.T.T. Recommendation M102 suggests annual maintenance checks of attenuation and group delay distortion for special quality voice bandwidth data links.

Performance Criterion

The factor of paramount importance to the data transmission subscriber is error rate. However, the relationship between error rate and the many transmission factors is complex, and great care must be taken in drawing conclusions. Poor error performance has in fact frequently been observed with data links where the transmission parameters were within specification limits, and conversely low error rates have been reported from time to time with data links where the transmission factors have been outside specification limits.

Reports of data transmission difficulties will first be referred to data test centres being established in most capital cities in Australia. Following coordination of corrective action to restore service, firstly by provision of a patch link if practicable, these centres can check error rate performance over sections of the data link. Should this prove satisfactory, further end-to-end error rate tests may then be carried out at the subscribers data terminals via the respective data modems, and the source of the data fault can then be localised. Only when the fault is shown to be in the data link sections, and not in data equipment, is action taken to carry out checks on the various transmission parameters which may affect performance, since this involves several items of complex test equipment.

Maintenance Test Equipment

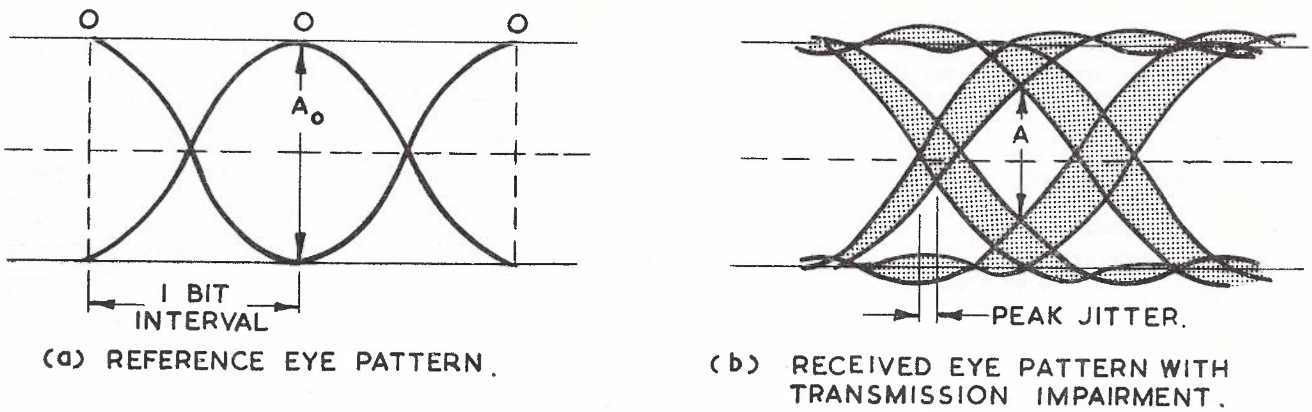
Several types of test equipment may be required to assess the performance of data services. These include:—

Data Test Sets: Items (a) and (b) below are used for bit and or block error rate tests, and for primary fault location on data services.

(a) Error Count and Distortion Test Set: The present A.P.O. test set for data services via *voice bandwidth* links comprises a data transmitter and receiver, with measuring facilities for peak telegraph distortion and block error count. The transmitter generates a range of data blocks including a 511 bit psuedo-random sequence, at rates from 50 to 4800 bits per second. For data services via *group bandwidth* links, the present A.P.O. test set counts bit errors in a psuedo-random stream with 2×10^{11} combinations, transmitted at a rate of 40.8 kilobits per second.
The use of data test sets of this type involves interruption to the service, and the sets are generally confined to commissioning and surveillance of corrective measures following catastrophic faults.

(b) On-Line Monitors: These devices enable the performance of data transmitted on a link to be monitored at any access point or time by extracting, decoding and analysing an error detection pattern fixed to the main data stream. No interruption to service is involved. Individual devices may be programmed to reject data blocks in error and initiate re-transmission, or to continuously record statistics on data performance in a selected format.
Such devices are not currently employed by the A.P.O. since data links are randomly allocated, and are not routed through a common point of access. Further, standardisation and implementation of an error pattern to be fixed to a wide range of customer data streams would pose a complex problem. However, the use of such on-line monitors could prove extremely beneficial to maintenance activities since most customers naturally prefer to avoid interruption to service unless serious impairment to data transmission is experienced.
Several types of on-line monitoring devices are employed by N.A.S.A. in their worldwide communications network, where data links are conveniently routed through switching centres, and data format is under close control (Ref. 4).

Storage Oscilloscope: Used for examination of the "eye" pattern of a succession of data pulses. Overlapping of successive pulses produces a distinctive "eye" shape whose opening is governed by the signal to noise ratio, bias, peak distortion of transitions, and delay distortion. The objec-



$$\text{TRANSMISSION IMPAIRMENT} = 20 \log_{10} \frac{A_0}{A}$$

Fig. 5. — Eye Pattern.

tive is a clean wide-open eye, which represents error-free operation (see Fig. 5).

Group Delay Measuring Set: A variable frequency and a selected reference frequency are alternatively modulated by a low frequency sine wave. If the phase slope is non-linear, there will be a frequency-dependent group delay which is used as a measure of phase delay. *Absolute* group delay cannot usually be measured unless the input and output of a data link are at the same location, and is therefore usually carried out on a loop-back basis (Ref. 5).

Using the above measuring technique, attenuation distortion can also be measured by detecting the amplitude variation which occurs at the point of changeover from selected to reference frequency.

Facilities are provided in some instruments of this type for variations in modulating frequency, which gives flexibility in measurement resolution.

Impulsive Noise Counter: This counts the number of noise voltage peaks exceeding a selected threshold level over a selected period of time. The bandwidth of the instrument must be compatible with the type of link to be tested.

Phase Jitter Meter: This instrument detects the phase difference between a stable reference frequency and a test frequency by use of a phase detector. Measurement bandwidth is typically 10-250 Hz which covers the major jitter energy spectrum. Facilities are also provided to count phase hits occurring above a selected threshold.

Available instruments are primarily designed for voice bandwidth data links, however by employing a modulation technique using a highly stable oscillator, measurements on wider bandwidth data links and at elevated frequencies may be readily carried out.

PAR Meter: This instrument (see Ref. 6) measures the ratio of peak to average value of a full wave rectified pulse signal, which is a weighted measure of attenuation and delay distortion of a data link. Such distortion causes the peak to average ratio to be reduced, by spreading the pulse out in time, and a PAR reading less than 100% is thus obtained. The instrument can be useful for routine comparison checks of voice bandwidth data link transmission performance.

A recently developed version of the PAR meter also enables absolute attenuation distortion and flat noise to be measured.

Fault Reporting

Control stations are established for data links, to maintain performance, receive and analyse fault reports, and to co-ordinate corrective action. The A.P.O. control station for a data link is normally nominated as a staffed carrier terminal nearest to one end of the data link. However, where a data link network control centre has been established by the lessee (e.g., N.A.S.A. switching centre in Canberra) the A.P.O. control station will be established as a staffed carrier terminal nearest to this point. For international data links, the A.P.O. control station is nominated as the staffed carrier terminal nearest to the international traffic switching centre, e.g., O.T.C. Paddington.

Alternative Patch Facilities

Each subscribers service is classified according to priority for restoration in the event of major transmission link failures. In the case of classified high priority services, such as civil aviation or defence, alternate patch facilities are normally provided for links or link sections, and these are usually specially equalised to have the same characteristics as the normal link. For example, the extensive NASCOM data network within Australia has complete 100% backup of normal links with specially equalised patch sections, and operational reliability is thereby maintained at a high level.

The nominated A.P.O. control station is responsible for substituting the designated patch facilities wherever available or practicable, according to the priority classification allotted to the subscriber. Where such patch facilities are unavailable, the control station is responsible for advising classified high priority lessees of the estimated period of outage, and anticipated time of restoration.

For subscribers with classified normal priorities, alternate patch facilities are provided if possible, but there is no guarantee that this can always be achieved, due to the demands placed on communications facilities during major failures. In these circumstances, service is restored with a minimum of delay.

Difficulties in arranging patching facilities are caused by random distribution of leased links throughout the A.P.O. communications system, and consideration is being given to reservation of special groups (or supergroups) specifically for this application. This is of particular value in the case of classified high priority links, when the use of automatic patching arrangements can be considered with a view to further minimising the duration of interruption to service.

Alternate patch facilities currently provided normally carry telephone traffic when not required, thereby increasing the efficiency of usage of available facilities. A trend noted overseas, however, is to provide totally dedicated patch facilities for leased links which are not used for other purposes, and these are automatically patched in the event of failure of the normal links. In principle, this patching arrangement is most desirable, however great demands are placed on the capacity of the communications network, and the arrangement could be restricted to only the most favourable situations.

RELIABILITY

Objectives

The following figures are indicative of the reliability likely to be obtained in operation of typical leased data links.

Interruptions:
Average number of interruptions (5 —300 ms) per 100 route miles per day (sustained bursts excluded). : 2

Outages:
Average number of outages (> 300 ms) per 100 route miles per month.
(i) Planned (maintenance) : 0.2
(ii) Unplanned : 1.3
(iii) Total : 1.5

Percentage Availability:
(i) Excluding planned outages :99.5%
(ii) Including planned outages :99.25%

Typical Reliability Statistics

(i) Average Performance of several broadband (coaxial cable and radio) line links:
Outages (> 300 ms) per 100 route miles per month : 0.7
Percentage Availability (for 500 route miles) :99.9%

(ii) NASCOM Network in Australia (classified high priority network with special patching arrangements):
Percentage Availability (average over 2 years) :99.825%

(iii) Melbourne-Adelaide radio link:
Interruptions (5-300 ms) per day (average over 2 years) : 1.2

TESTS ON TYPICAL LINKS

Standard V.F. Link

This link was provided for a 1200 bits per second data service between Charters Towers (Q) and Woomera (S.A.). Since the link comprised 4 V.F. connected carrier sections (3 on broadband and 1 on 12 circuit open wire), an 80 mile section of open wire physical, and considerable lengths of pair cable psysical, transmission tests were carried out to determine if equalisation of attenuation and group delay distortion was required even for 1200 bits per second. Error count and distortion tests were carried out simultaneously to investigate correlation between the various parameters.

Transmission tests on the data link showed that both attenuation and group delay distortion were considerably in excess of M 102 limits. Impulsive noise met C2 limits and frequency error was less than 1 Hz end-to-end. Data tests showed nil error count on a pseudo-random pattern and peak distortion was 18%.

In further data testing, the following aberrations were introduced:—

Substitution of a carrier section derived from a 3-circuit open wire carrier system (300-3000 Hz bandwidth) between Townsville and Charters Towers.

Insertion of two further looped back carrier sections derived from the 3-circuit system between Townsville and Charters Towers.

Placing the 3-circuit system 3.5 Hz out of synchronism.

In all cases, data tests showed nil error count and negligible change in peak distortion.

Only when the data modem send level was reduced 23 dB below normal (for the normal link) was an error count of 1 in 0.4 x 10^5 bits recorded. When three additional carrier sections derived from a 3-circuit system were included between Townsville and Charters Towers, a reduction of 18 dB in send level produced 1 in 0.45 x 10^5 errors.

It may be concluded that 1200 bit per second data transmission over standard quality data links will be generally satisfactory provided that adequate signal to noise margin is maintained.

Special Quality Link

This data link was required for a 2400 bit per second data service between Paddington (N.S.W.) and Carnarvon (W.A.) and equalisation to meet FCC conditioning specification C2 was required. The link comprised 5 carrier sections, on broadband and open wire line links, and appreciable cable pair sections. Using a fixed equaliser, correction of attenuation and delay distortion was carried out to a fraction of C2. However, great difficulty was experienced in group delay measurement due to fluctuations of up to ±100 microseconds. This was found to be caused by a low signal to noise ratio, primarily occurring in the open wire carrier sections between South and Western Australia.

Group Bandwidth Data Link

The following results were obtained in tests using the first group bandwidth equalized data link (for 40.8 kilobit per second data transmission over a basic group occupying a nominal spectrum of 6-54 kHz) placed in service by the A.P.O. between Melbourne and Sydney; minor variations to the interim objectives quoted previously were made to suit the particular data modem employed:

(Data signal level -5 dBm0)

Attenuation Distortion	:	1dB over range 15-45 kHz	
Group Delay Distortion	:	10 μs over range 15-45 kHz	
Basic Noise	:	< -37dBm0	
Impulsive Noise (measured on carrier section of link)	:	Threshold	Hits in 30 min
		-22dBm0	393
		-18dBm0	43
		-14dBm0	15
		-10dBm0	8
Single Tone Interference	:	< -41dbm0	
Loss Variation	:	0.25dB over working day	
Harmonic Distortion for -5dBm0 fundamental	:	2nd harmonic	-39 dBm0
		3rd harmonic	-49 dBm0
		4th and 5th harmonic	-55 dBm0
Phase Instability	:	Average 3.5°, Peak 8°. 10°, 33 hits in 20 min. 15°, 1 hit in 20 min.	
Data Tests	:	Single error rate better than 1 in 10^6.	

CONCLUSION

This paper has reviewed some of the problems involved in provision and maintenance of leased data links, and has stressed the need for close attention to a number of transmission parameters. As new techniques are developed to increase the information capacity of data links, emphasis on previously unimportant parameters is necessary. For example, data transmission at rates of up to 9600 bits per second is now technically feasible using voice bandwidth links, by means of multi-level, frequency, and phase coding (Ref. 7), but sensitivity to various forms of phase impairment is relatively high.

The range of test equipment necessary to carry out measurements of parameters such as phase impairment is not extensive and considerable scope exists for development of new instruments for a wide range of conditions (Ref. 5). It is apparent that testing and fault location methods for leased links, particularly those involving data transmission, must be reviewed to keep pace with the rapid expansion being experienced. In this respect, the use of on-line monitoring devices would appear to have a number of advantages provided that application to the A.P.O. network is feasible. Investigations into the characteristics of A.P.O. communications facilities must be pursued in order that new and valuable transmission techniques can be fully exploited.

Special attention will have to be given to reduction of phase instability problems, for example by a programme of replacement or modification of unsuitable carrier generator equipment and sub-units. A more sophisticated system of checking carrier supplies in and between carrier stations is necessary to reduce the incidence of carrier supply asynchronism. More detailed specification of parameters which are critical in respect to data transmission, combined with careful planning, installation and maintenance of broadband line links is vital if the full capabilities of the A.P.O. communications network are to be realised.

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AUTOMATIC BACKBUSYING OF JUNCTION CIRCUITS

C. R. GROAT, B.E., M.B.A.*

INTRODUCTION.

Telecommunication staff who have been at all involved in the maintenance of telephone exchanges will be familiar with the service difficulties that occur in multiple exchange networks where there is inadequate backguarding of junction circuits. An example of this difficulty is the 'no progress' call that results when a repeater is seized and a call initiated either before the incoming selector is completely free from the previous call, or while it is faulty. Automatic backguarding systems that eliminate this type of service problem have been under consideration for a number of years by the Australian Post Office, and it is the particular purpose of this article to describe the introduction of one such system into the Melbourne metropolitan network.

The basic concept of automatic backbusying is relatively simple, although there were a number of problems in applying the system to the existing metropolitan network. So much so that the work which commenced early in 1962 was not completed until mid 1970.

The protracted nature of this work resulted partly from the many different types of equipment that needed to be modified, and partly because the network is dynamic, requiring continual re-arrangement to accommodate growth. During the course of the project there has been some tendency, particularly with the less common combinations of junction terminals, for the modifications to be carried out on an ad hoc basis. This has resulted in some difficulty in recording and reporting on the many variations that have been made to the one basic circuit. However, for the purposes of this article it has been possible to select several typical modifications that adequately illustrate the mechanism involved.

The basic combinations of junction terminal equipment that were modified may be categorised as:

(a) Junction guard and repeater relay sets outgoing to crossbar equipment.

(b) Junction guard and repeater relay sets outgoing to bimotional equipment, and

(c) Incoming bimotional selectors from crossbar equipment.

The modification of these combinations was confined within the metropolitan area and did not include incoming selectors from auto trunks and subscriber dialled trunks (S.T.D.), nor outgoing circuits involving multimetering repeaters.

ALTERNATIVE SYSTEMS.

The principal service difficulties that have been observed in telephone networks as a result of inadequate backguarding may be summarised by:

(a) Junctions that are held on switch trains due to a 'stop on busy' condition.

(b) Incoming selectors that fail to release when a test link is accidentally removed or falls out.

(c) Incoming selectors that fail to release due to an abnormally short private unguard period (release blink) from the final selector.

(d) Distant repeaters that have not been manually backbusied when the incoming selector is worked on in situ or removed from the bank for servicing.

(e) Incoming 2000 type selectors that fail to latch.

(f) Short guard repeaters (repeaters with no re-guard feature) that are seized before the 2000-type incoming selector has fully released.

In order to completely eliminate these service difficulties a system of full automatic backbusying has been proposed where the repeater is not available until the incoming selector is positively detected as being in the normal position. This system can be provided by connecting the positive leg of the incoming selector to +50 volts via a mechanical off-normal spring set and connecting a 10,000 ohm sensing relay on the outgoing side of the repeater. This sensing relay will distinguish between 100 volts from the incoming selector and 50 volts from subsequent selectors.

An alternative proposal to this is a system of partial backbusying provided by a guard relay which simply detects 50 volts as distinct from an open circuit or a short circuit on the junction. Under this system the repeater becomes available when it detects battery and ground from a selector over a junction pair. The disadvantage of this system is that it will provide adequate guarding on only the last three service difficulties of the above list.

It is doubtful whether the extra complication of providing 50 volts on the incoming selector to give full backbusying is justified by the first three difficulties listed, especially since these can be reduced by other means. It was therefore proposed in 1962 by the Central Administration of the A.P.O. that the partial system should be the one adopted in all major networks.

PARTIAL BACKBUSYING.

The basic system of automatic backbusying shown in Fig. 1 provides a high resistance sensing relay 'BS' across the outgoing junction terminals. This relay is normally held operated by the battery behind the incoming selector's 'A' relay and will release if for any reason this battery cannot be sensed. On release an earth potential is applied to the relay set private wire thereby 'busying' the circuit to testing selectors. This system effectively isolates a circuit into a faulty junction (e.g., one that is open or short circuited or one with low insulation resistance) and into an incoming selector that is off-normal or removed from the bank.

The principal features of this system are:

(a) It facilitates maintenance work on junction switching equipment;

(b) It facilitates temporary removal of junction circuits during installation and re-arrangement works; and

(c) It fails safe in the event of a switching fault thus improving switching performance.

As these facilities already exist on crossbar equipment, the circuit modifications carried out during the course of the project only involved bimotional incoming selectors and the older types of junction relay sets.

INCOMING SELECTORS MODIFICATION.

The unmodified SE50 selector incorporates mechanical off-normal springs in the A relay circuit so that backbusying will result if the switch is stepped off-normal and held this way by removing the release link from position 11, 12. If the junction is already in use, this action prebusies the circuit, which will then backbusy after the call is completed and the release blink from the associated relay set has occurred. It was originally proposed by the Central Administration that incoming selectors should be exclusively of the SE50 type; however, it became clear at an early stage of the Melbourne project that less than half the required number of SE50 selectors could be made available for this purpose. It was therefore necessary to develop modifications for other types of incoming selectors.

The bulk of incoming selectors, about 40,000 are of the 2000-type and

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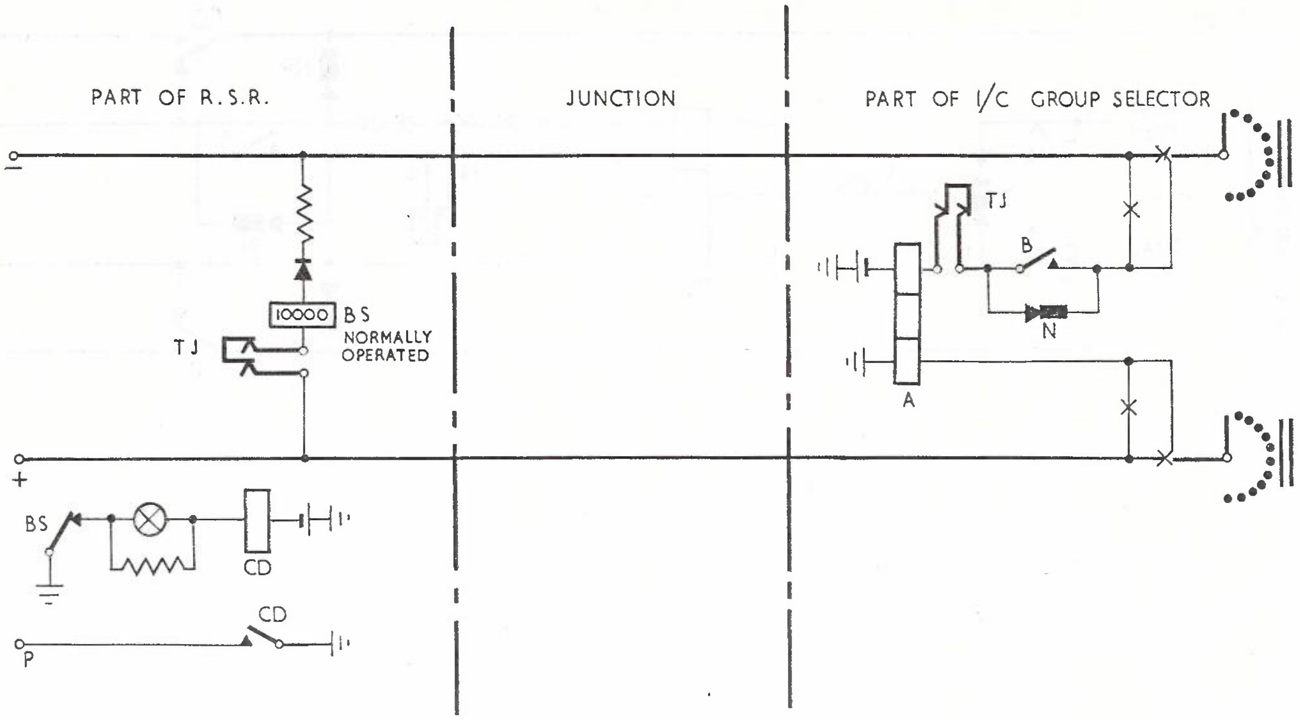

Fig. 1. — Elements of Automatic Backbusying.

an early modification proposal for these required that the A relay circuit should be wired via off-normal springs and a test link. The test link was subsequently deleted from the modifications so that backbusying occurred when the shaft was lifted off-normal as with the SE50 selector.

During the course of the project it was observed that false release alarms were occurring when two or more SE50's in paired shelves were back-busied with the release link removed, and a third selector released normally. It therefore became necessary to modify SE50 switches so that pre- and backbusying was accomplished by removing a test link from the A relay circuit without any need to disturb the release link.

To re-establish a consistent back-busying procedure between switch types, an A relay circuit test link was also re-introduced into the 2000-type modifications.

Since the test link is best parked in position 7, 8 after backbusying, it was necessary to insulate terminal 8, which is normally connected to the switch private wire. This modification effectively prevents the earthing of the private wire through the earth connected to terminal 7, and eliminates the possibility of held up switch trains whenever a switch is pre-busied.

Two alternatives were considered for the normal positioning of the test link. The first (Fig. 2a) eliminated the possibility of faults caused by removing the link between loop and cut-through but unfortunately rendered the backbusying inoperative when a fault permanently operated the B relay. This deficiency was considered a serious one and the second test link position (Fig. 2b) was the one finally adopted. It should be noted that the addition of a B relay contact was required to shunt the off-normal springs and to permit normal A relay impulsing and subsequent holding.

Typical modifications adopted are shown in Fig. 3 for 2000-type selectors and Fig. 4 for SE50 type selectors. Pre- and backbusying occurs by removing a link from test jacks position 13, 14 (i.e., open circuiting the A relay) and parking it in 7, 8. Because of the imminent removal of all pre-2000-type selectors from the switching network they were not modified, although they will backbusy if the shaft fails to restore to normal.

OUTGOING RELAY SETS MODIFICATION.

The general modification on the outgoing end of a junction required a high resistance relay BS across the junction terminals via an HA contact, a test link, a resistor and a diode. Whilst the junction is free, BS operates to battery and earth via the distant A relay, and the repeater tests free to preceding selectors.

If BS releases for any of the reasons previously discussed, a CD relay operates, lights a lamp and busies the repeater. The diode in series with BS ensures that this relay releases and busies the repeater if the junction is reversed or if the intruding party of a 'triple connection' (i.e. a 'stop on busy') releases his call.

2000-Type Repeaters: The typical modifications carried out on 2000-type

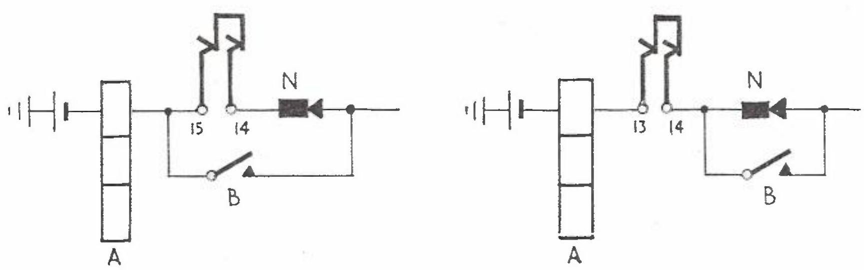

Fig. 2. — Selector Test Link Position.

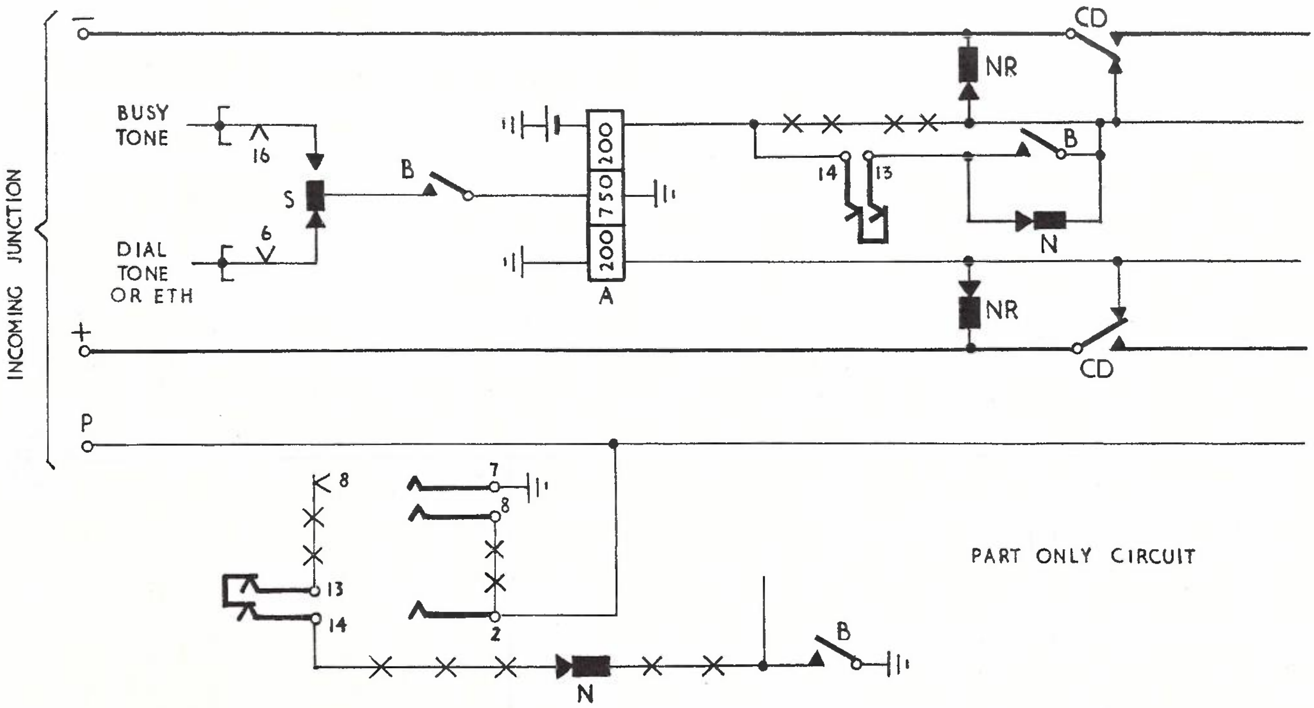

Fig. 3. — 2000 Type Selector.

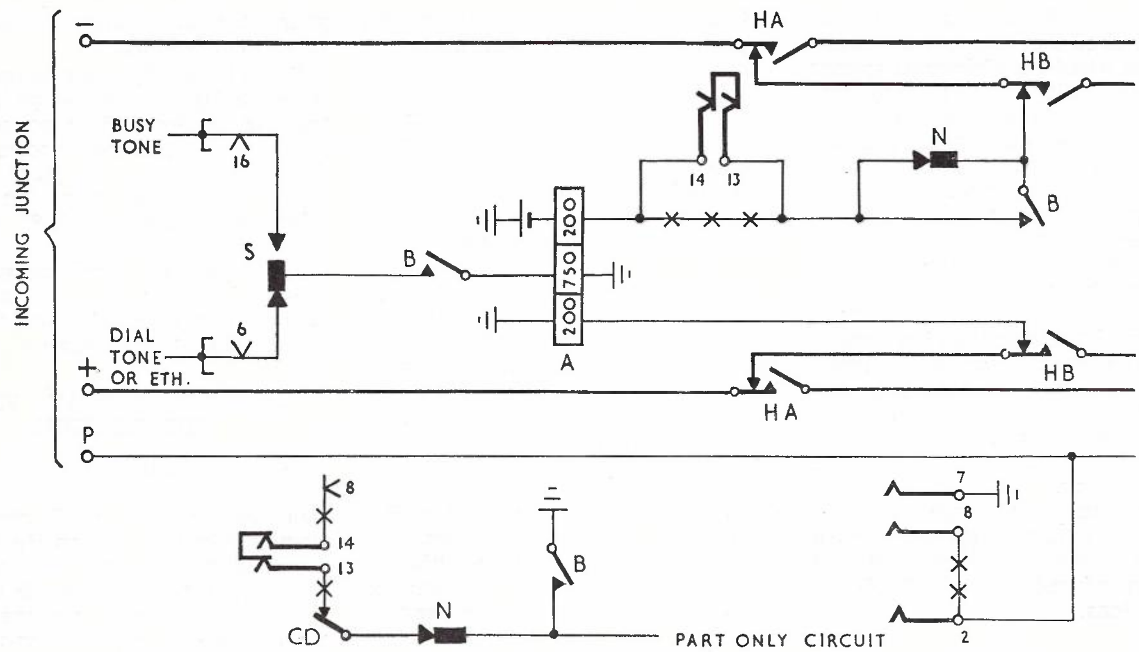

Fig. 4. — SE 50 Type Selector.

repeaters are shown in Fig. 5. Where 2000-type selectors (which will stop on open trunks) have access to the repeater, drop out can occur if the repeater is tested and seized during the release blink. This happens when BS2 open circuits the A relay, and the B relay cannot return a holding earth on the private wire. To overcome this problem it has been proposed to shunt the BS contacts allowing the A relay to operate in such circumstances. However, as wrong numbers may then occur due to the late release of an incoming switch train at the distant exchange (repeater B relay releasing faster than the incoming switch train) this proposal was rejected. Automatic backbusying would also have been ineffective where an incoming switch train was held to a subsequent repeater with the BS2 contacts shunted out. In this case a loop to the subsequent repeater allows the incoming held up switch train to be seized.

These repeaters may be manually busied by removing the test link 13, 14 (which opens the BS relay circuit) and parking it in position 1, 2 (with the

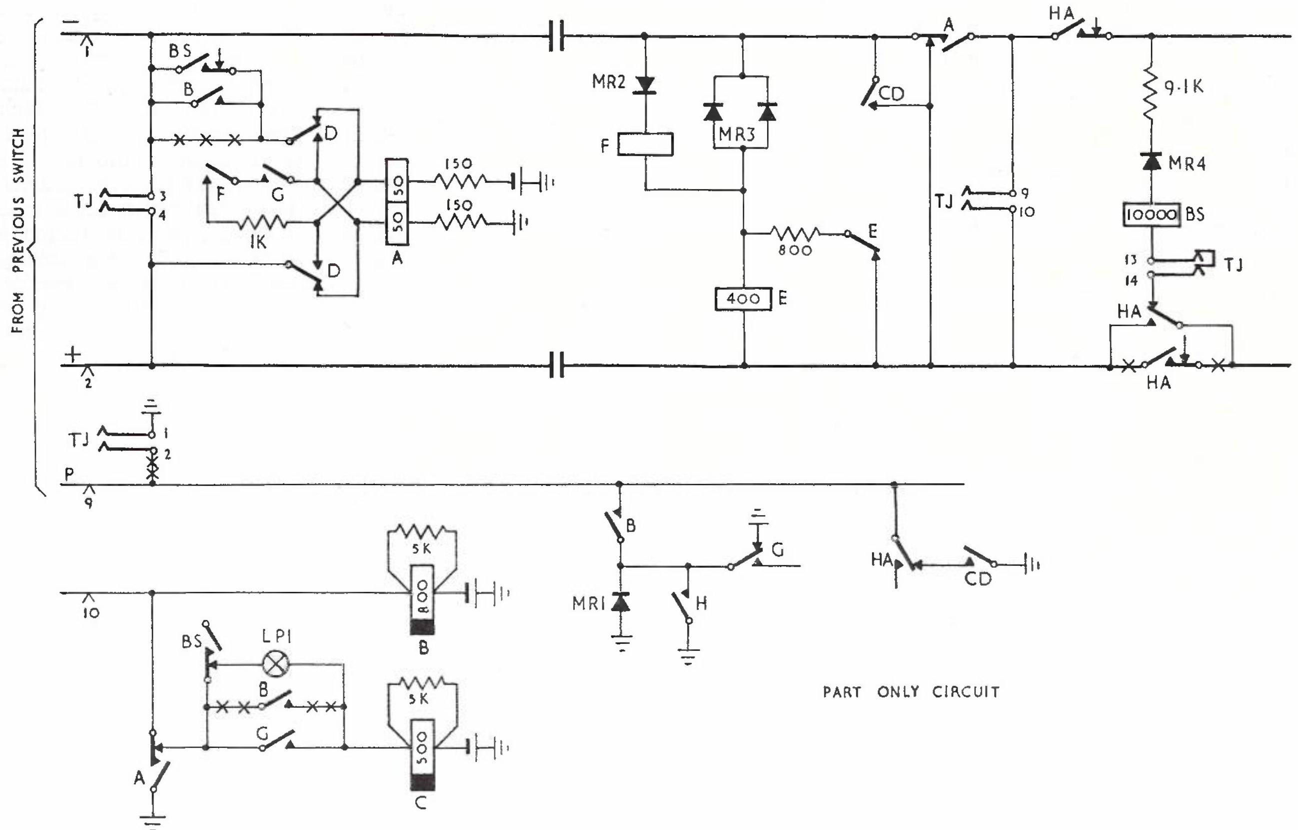

Fig. 5. — 2000 Type Repeater.

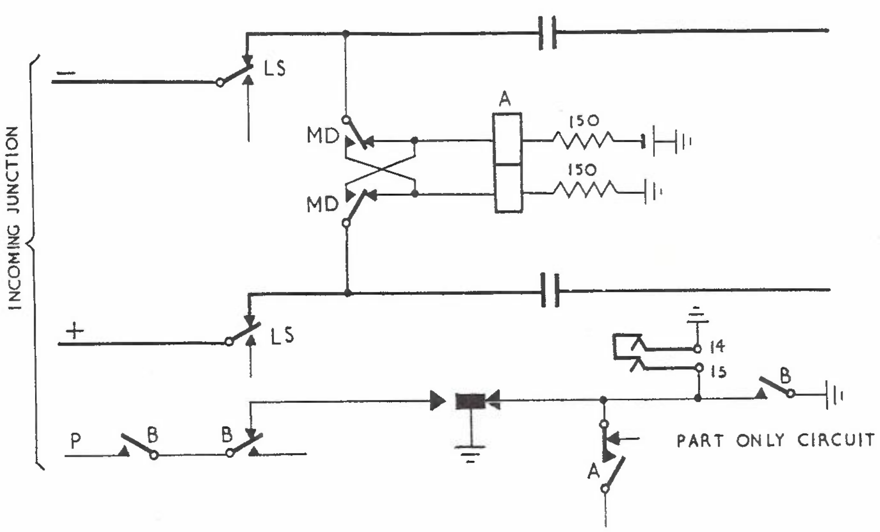

Fig. 6 — Incoming D.S.R.

private insulated from terminal 2).

Discriminating Selector Repeater: A small number of incoming D.S.R.'s were modified to provide automatic backbusying as in Fig. 6.

Digit Absorbing Repeaters: Some D.A.R.'s were modified although very few of these are extant in the Melbourne network.

Pre-2000 Type Repeaters: Some pre-2000 type selectors were modified, but they are generally considered to be unsuitable for circuit alteration and are to be shortly removed from the switching network.

Junction Guard Circuits: The modification to the junction guard circuits associated with discriminating selector repeater (D.S.R.) junction hunters, required replacement of a single coil JA relay with a double coil, and the addition of a rectifier. The modification for circuits off the D.S.R. switch banks and all switching selector repeaters (S.S.R.'s) junctions required provision of two relays JA and JB, and a rectifier. Typical additions are shown in Fig. 7. The JA relay in this circuit is red label and has a tendency to fail to operate if only standard mechanical adjustment has been made. It has been suggested as a solution that the indicator lamp could be dispensed with eliminating the need for one springpile, and critical relay adjustment.

COSTS.

The long-term operating costs associated with the back-busying circuits are expected to be negligible, so that the modification costs incurred during the period 1962-1970 may be taken as the total costs of the project. To account for the time value of money and to provide a base for comparing costs with project benefits it has been found convenient to compound forward the historic costs in Table 1 in order to provide a present value equivalent at the 30th June, 1970. A 7 per cent. interest rate has been used as the opportunity cost of the capital invested in the project.

From Table 1 it will be seen that the present value of costs at 30th June, 1970, was **$976,860.** (1)

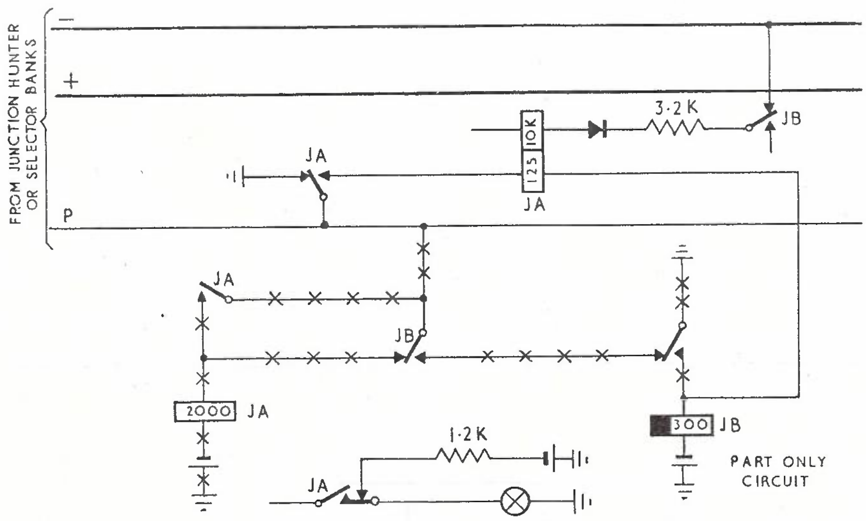

Fig. 7. — Junction Guard Relay.

BENEFITS.

The project modifications discussed in this article involve virtually all outgoing repeaters and junction guard relay sets and all bimotional selectors in the Melbourne metropolitan network. The benefits resulting from this work will flow while any of these modified units remain in service. Their obsolescence will be controlled mainly by the programmed rate of introduction of crossbar equipment into the network as summarised in Tables 2 and 3.

It will be recalled that the principal aim of the project was to remove a potential fault condition known to result in service difficulties for the subscriber. The benefits resulting from this service improvement tend to be intangible and are therefore difficult to quantify and compare with the project's cost. However, a concurrent benefit that can be set down in money terms is the maintenance labour saved when working on junction terminal equipment that has been modified.

Fault Removals.

Prescribed maintenance procedure (Ref. 1) requires that incoming selectors without automatic backbusying shall not be removed or worked on unless the outgoing exchange is contacted and the junction manually isolated. There is therefore an implicit tangible saving in automatic backbusying of the technician's time previously associated with each selector removal. A sample survey of the removal of selectors for fault attention in 1969, summarised by the skewed distribution in Fig. 8, indicates that these savings will be associated with an expected annual removal rate of 0.3 times per switch per year and a maximum rate of around 0.6 - 0.9 times.

Routine Removals.

In addition to removals for fault attention, bimotional selectors are removed for routine maintenance (e.g., cleaning and oiling) every 0.5 to 3 years depending on local conditions (Ref. 2); the actual rate in the Melbourne network varying between once and twice per selector per year.

For the purposes of the benefit calculation it has been assumed that incoming crossbar equipment will also need to be backbusied at about the same rates as a result of equipment re-arrangement and routine testing. The crossbar selector is expected to remain relatively maintenance free and no allowance has been made for routine cleaning and oiling.

Total Selector Removals.

Summing the switch removals for fault and routine maintenance attention we would expect a normal removal rate

TABLE 1. TOTAL COMPONENTS COSTS.

Repeaters, workshops modified	(15,825 at $13.6; 11,225 at $14.05)	$372,931
Repeaters, new and field modified	(11,690 at $14)	$163,660
Junction Guards modified	(8,255 at $ 9.2)	$75,946
Junction Guards provided	(4,280 at $11.5)	$49,220
Selectors modified	(36,781 at $ 3.0)	$110,343
Test Jacks modified	(51,627 at $ 0.70)	$36,139
		$808,239

Modified Units.

Year Ending June 30	1963	1964	1965	1966	1967	1968	1969	1970	Total.
Repeaters	300	250	2,750	9,200	13,240	13,000	—	—	38,740
Junction Guards	—	—	1,900	787	4,280	4,000	950	618	12,535
Selectors	500	500	2,850	4,000	5,564	2,300	10,050	11,017	36,781
Test Jacks	—	—	—	—	—	3,000	28,000	20,627	51,627
Costs $	$5,580	$4,900	$63,430	$144,360	$240,594	$234104	$60,675	$54,597	$808,240*
Compound Factor at 7 p. cent.	1.606	1.501	1.403	1.311	1.225	1.145	1.070	1.0	
Present Value 30/6/70	$8,961	$7,355	$88,992	$189,256	$294,728	$268,049	$64,922	$54,597	$976,860

*Rounding Error.

Source: Estimated from a physical count of units in situat 16/8/68; cost summaries taken from work authorities issued during the period.

TABLE 2. MELBOURNE NETWORK DEVELOPMENT SUMMARY.

F.Y. Ending June 30	1970	1971	1974	1977	1980	1985	2000	2015
Crossbar Lines	172,649	205,452	358,910	463,070	578,600	738,925	1,298,930	1,691,140
Bimotional Lines	349,725	331,145	276,010	254,745	225,120	203,380	30,360	—
Others	14,760	14,450	14,750	15,050	15,150	15,150	15,150	—
Total	532,334	551,047	649,670	732,865	818,870	957,455	1,344,440	1,691,140
Crossbar Percentage	32.5%	37.3%	55.2%	63.2%	70.7%	77.2%	96.6%	100%

Source: Estimated from the 'Melbourne Metropolitan Summary'.
Supervising Engineer Internal Planning (Metropolitan) 9/11/67, E-HD5/11.

TABLE 3. MODIFIED UNITS REMAINING.

F.Y. Ending 30th June.	1963-1970	1971	1974	1977	1980	1985	2000
Relay sets outgoing to crossbar	Not	5,597	5,212	5,567	5,795	6,505	2,385
Relay sets outgoing to bimotional	broken	43,667	40,014	36,620	31,056	26,139	3,283
Bimotional selectors incoming from crossbar	down	6,920	7,147	7,759	8,062	9,961	4,745
Total	222,120	56,184	52,373	49,946	44,913	42,605	10,413

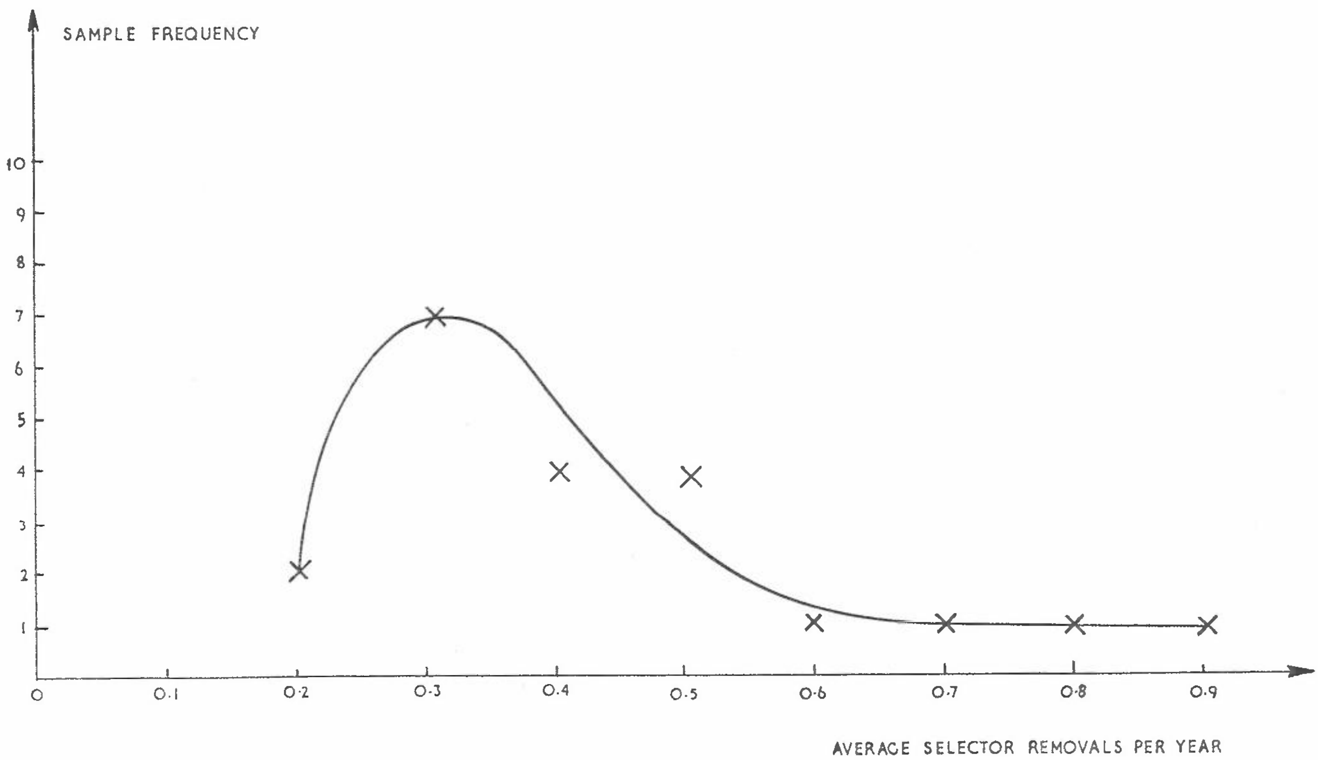

Fig. 8. — Incoming Selector Removals.

of 1.3 removals per switch per year and a maximum rate of about twice this. If we now assume that manual backbusying consumes 0.25 man-hours per removal then the expected benefit based on 1970 labour rates will be:

Normal expected benefit = $1/ selector / year.

It might be noted that the 0.25 hour estimate is a conservative one that will be exceeded for most actual removals. It therefore represents the probable minimum time spent telephoning the originating exchange to request that the junction be busied out, and the time waiting in many cases due to the particular junction being in use; and finally the time taken to telephone advice that the junction may be let into service again, when work on the circuit is completed.

The product of this normal expected benefit and the sum of the modified units in Table 3 provides an indication of the total dollar benefits that can be expected from the project. If it is assumed (conservatively) that the units existing in one of the reference years (e.g., 49,946 for 1977) also existed in the previous years not explicitly calculated (i.e., 1975 and 1976), then the sum of the benefits for all years up to the year 2000 is:

Total normal expected benefit, $1,089,220 (2)

and the maximum likely benefit (as

defined above) will be twice this:

Maximum likely benefit,

$2,178,440 (3)

From the above results the normal expected benefits / cost ratio is 1.1 and the maximum likely ratio is 2.2. As both ratios are higher than the break even of 1, the project can be justified on the labour saving benefit alone.

Other Benefits.

While a direct return on investment is important in determining the efficient use of capital resources, it is not uncommon, particularly in the public sector, that the worth of a project will depend in the final analysis on non-economic considerations (Ref. 3).

Since 1962, considerable improvement has occurred in the network's switching performance, due at least in part to automatic backbusying. An analysis of more than one million aural observations of calls originating in Melbourne indicates that 'no progress' faults reduced from 3 per cent. to 1 per cent. over the period to 1970 and 'wrong numbers' from 0.3 per cent. to 0.1 per cent. Based on call meter registrations this indicates some 50 million fewer call failures than would have occurred without service improvement. The benefit from this is intangible, but nevertheless quite important, and might be expected for example to encourage greater use of the network.

Intangible improvement can be expected in staff morale due to greater facility in removing or working on incoming switches and in a reduced need to visit unmanned exchanges in order to isolate faulty outgoing junctions.

Considerable improvement in public relations is also expected to accompany automatic backbusying in unmanned smaller rural exchanges where previously it was possible for one faulty junction circuit to completely isolate the exchange. By their very nature statistics of this phenomenon are difficult to find, but by all accounts the occurrence was not uncommon prior to automatic backbusying.

Some national saving may result from the saving of time previously lost by the business community and others in dialling into faulty junctions. Although this amounts to only about 15 seconds or so for each lost call and there is doubt that this time-saving would be usefully re-employed.

CONCLUSION.

Despite a historic cost of nearly one million dollars, the project to partially backbusy the Melbourne metropolitan junction network promises a worthwhile reduction in network maintenance costs and an improvement in the service provided. It will also facilitate the provision and re-arrangement of telephone exchange equipment. These benefits will flow for several decades (to about the year 2000) until all modified units have been replaced by crossbar equipment.

The project has been a notable example of sustained administrative effort and excellent co-operation between a number of engineering division sub-sections, throughout nearly a decade of modification work.

REFERENCES.

1. Metropolitan Service Instruction No. 9, issued 27th June, 1962.

2. A.P.O. Engineering Instructions MO115; MO120; Metropolitan Service Instruction No. 21.

3. Commonwealth Treasury White Paper, 'Supplement to Treasury Information Bulletin; Investment Analysis,' July, 1966, P.16.

THE MEASUREMENT OF VOLUME REFERENCE EQUIVALENTS

*E. J. KOOP, B.E.**

INTRODUCTION.

In order to plan and develop a telephone network with transmission characteristics which will provide subscribers with at least a specified minimum standard of satisfaction, it is necessary to be able to describe the transmission performance of a complete connection or parts thereof, in quantitative terms related closely to subscriber reactions to that connection.

The most realistic method in current use for assessing the transmission performance of an overall connection, is in terms of subscribers' opinions. (Ref. 1). However this method is unwieldy and time consuming, lacks the necessary precision for discriminating small differences, and is generally unsuitable for rating individual parts of a complete connection.

More precise methods, used extensively in the past, have been concerned with the articulation rating of the connection relative to a reference transmission circuit. One such method which gives an Articulation Reference Equivalent (A.E.N.)** rating of the connection has been recommended by the C.C.I.T.T. and described in their Recommendation P41, "Description of the A.R.A.E.N." (Ref. 2). On modern high quality connections, such a method of rating tends to provide insufficient loudness to provide subscriber satisfaction, and it has fallen into disfavour with most telephone administrations as a means of rating telephone connections.

In the period just prior to 1960, the C.C.I.T.T. recognised that modern telephone designs provided sufficient bandwidth with sufficiently low levels of distortion and sidetone to make it easy to obtain adequate intelligibility in a telephone connection. They therefore proposed that a volume or loudness rating (volume reference equivalent) as had been in limited use in the past, become the preferred method of rating telephone circuits for network planning purposes.

By C.C.I.T.T. definition, the reference equivalent of a subscriber's telephone connection is the volume inferiority, measured in a voice-ear comparison, of that telephone circuit relative to the New Master System for the determination of reference equivalents (N.O.S.F.E.R.), or with a working standard system already compared with N.O.S.F.E.R. or S.F.E.R.T. (the old master reference system). N.O.S.F.E.R. replaced the Master Reference System (S.F.E.R.T.) used in the old C.C.I.F. Laboratory (in Paris) when this laboratory was transferred in late 1950 to the new I.T.U. building (in Geneva).

It is therefore evident that the measurement of reference equivalents is basically a subjective comparison of the test telephone circuit against N.O.S.F.E.R., the New Master Reference System.

This paper is intended to survey the methods and associated problems in the measurement of reference equivalents. A brief description will be given of a number of Master Reference Systems which have been defined and used by the C.C.I.F. and the C.C.I.T.T. including the now obsolete S.F.E.R.T., the A.R.A.E.N. and the N.O.S.F.E.R. and relationships existing between these three reference systems. Details will be presented of the N.O.S.F.E.R. set up in the A.P.O. Research Laboratories and the techniques associated with the actual measurement of volume reference equivalents.

A number of instrumental systems intended for the objective measurement of volume reference equivalents have been developed in the last decade or so and the characteristics of one such system will also be described.

S.F.E.R.T.

The oldest international Master Reference System of interest is S.F.E.R.T., known as either "The European Master Reference System" or "The Master Transmission Reference System". It was installed for many years in the C.C.I.F. Laboratory in Paris and was used for the measurement of volume reference equivalents until the late 1950's. When the C.C.I.F. became the C.C.I.T.T. and the Laboratory moved into the new I.T.U. building in Geneva, S.F.E.R.T. was replaced by N.O.S.F.E.R. and became a museum piece.

The S.F.E.R.T. reference system which is described in detail in Ref. 3, included a fairly crude looking condenser microphone of about two inches diameter, an electro-dynamic receiver, and a rack of amplifiers using early type triode valves, inter-connected to provide a speech transmission system with specified characteristics. In common with the other reference systems to be described, it comprised a sending end, a 600 ohm junction attenuator and a receiving end.

The characteristic sensitivity of the sending end was based on a pressure calibration of the microphone using a closed coupler and a thermophone acoustic pressure standard, and was specified to be sensibly flat up to about 7 kHz. The microphone which was enclosed in a housing with an overall diameter of about 3.5 inches presented an appreciable obstacle to high frequency sound waves and had a free-field response which rose significantly with frequency. In actual use, the sending response was therefore not flat as suggested by the pressure calibration, but increased with frequency to a boost of about 11 dB in the region of 3 to 4 kHz.

The characteristic sensitivity of the receive end was somewhat representative of a medium quality, unequalised, dynamic receiver. This response was not necessarily the real ear sensitivity of the receive end because it was calibrated using a special artificial ear comprising a specified coupler and the calibrated S.F.E.R.T. condenser microphone, rather than an artificial ear designed to approximate the characteristics of a real human ear. The S.F.E.R.T. receiver was estimated to be about 7.3 dB more sensitive on a typical real ear than when coupled to the S.F.E.R.T. artificial ear.

The S.F.E.R.T. microphone was fitted with a 48 mm diameter guard-ring which defined the speaking distance of 43.5 mm from the microphone diaphragm. The dynamic receiver had a deep ear cap which contained a volume of 11.5 cc between the ear cap and the ear cap plane.

The send and receive responses were specified between 100 and 5000 Hz. in terms of the specified measuring technique, and were intended to be controlled with a tolerance of ±1dB.

In adjusting the send and receive sensitivites, the respective amplifier gains were adjusted so that the mean value of sensitivity for a number of frequencies between 200 and 3,600 Hz was equal to the nominal specified sensitivity:—

- nominal send sensitivity, — 31.5 dB re 1 volt/microbar*
- nominal receive sensitivity, + 24.2 dB re 1 microbar/volt.

The overall sensitivity from microphone to receiver with 0 dB attenuation in the junction was —7.3 dB as calibrated, or about 0 dB when the receiver was terminated with a real ear.

When used as a reference system for volume reference equivalent determination, an operator spoke into the microphone at the speaking distance of 43.5 mm at a constant level indica-

*Mr. Koop is Engineer Class 3, Research Laboratories, Headquarters. See Vol. 18, No. 1, p. 69.

**See Appendix for description and origin of abbreviated names.

*Note: 1 microbar = 1 dyne/sq. cm = 74 dB sound pressure level. Sound pressure level is the pressure ratio expressed in dB of the absolute sound pressure in microbars to the reference pressure of 2 x 10^{-4} microbar (2 x 10^{-5} N/m^2).

ted by the S.F.E.R.T. speech voltmeter connected across the input to the junction circuit. The speaking level indication was intended to be —16 dB. As the speech voltmeter is calibrated to read 0 dB for 6 mW into 600 ohms, this speaking level is equivalent to a speech voltage at the junction of —10.5 dB re 1 volt, and in turn corresponds to a mean speech pressure at the microphone of + 21.0 dB re 1 microbar, or a sound pressure level of 95.0 dB.

In practical use, the close speaking distance of about 4 cm caused problems with condensation of breath moisture on the microphone diaphragm, particularly during the winter months; the thermophone acoustic standard was a delicate device and was not a simple thing to use and the amplifier valves became obsolete and replacements were difficult to obtain. Although the system was originally designed to have a flat response, the large physical size of the microphone actually resulted in the free field speech response being substantially different from its nominally flat pressure calibration.

A.R.A.E.N.

A.R.A.E.N. represents the abbreviation for the French title for the Master System which is translated as "Reference Apparatus for the Determination of A.E.N." (Articulation reference equivalents).

The basis of this reference system which is described in C.C.I.T.T. Recommendation P41 (Ref. 2) is that overall it presents the acoustic transmission properties of one metre of free space between the talker's lips and the listener's ear, and in effect represents typical person-to-person direct conversation conditions. This reference system, developed by the United Kingdom Post Office, utilises essentially modern components and is so specified that with a reasonable understanding of the calibration procedure, it is possible to reproduce the essential performance, using either the recommended components, or any reasonable selection of alternative high quality components. Although the U.K. P.O. Research Department uses the A.R.A.E.N. as a reference system for determining relative volume ratings of telephone circuits, for the C.C.I.T.T. it forms the basis of the S.R.A.E.N. which is used for the determination of articulation reference equivalent ratings, i.e. A.E.N. ratings, which have now almost ceased to be used, except for special purposes.

The speaking distance is 33.65 cm (sometimes quoted as 33.5 cm) and the A.R.A.E.N. represents electro-acoustically the 66.35 cm remaining of the one metre air path. Nominally this 66.35 cm path has an acoustic loss of 9.5 dB, but this loss is reduced at the higher frequencies by the obstacle effect of the listener's head (i.e. the head diffraction effect) to give an effective mean loss (of volume) of about 7.8 dB. The theoretical overall response of A.R.A.E.N. is shown in Fig. 1. I would particularly like to point out that the A.R.A.E.N. is equivalent to the acoustic transmission of a one metre air path only when the A.R.A.E.N. junction attenuator is set at 30 dB.

The transducers recommended for use in this system are the S.T.C. type 4021E electro-dynamic microphone and four S.T.C. type 4026A electro-dynamic receivers.

The performance specification of the system requires a free field calibration of the microphone, and a calibration of the head receivers on the British Standard Artificial Ear (Ref. 4), using a calibrated probe microphone. The receivers are normally fitted with rubber ear pads and the calibration procedure is intended to provide a measure of their sensitivity on an average human ear.

This reference system (in common with most) is arbitrarily divided into a send end, a 600 ohm junction (of 30 dB attenuation), and a receive end. The send sensitivity is adjusted to give a mean value of one volt at the junction for a sound pressure of one microbar at the microphone, averaged for the three frequencies of 100, 300 and 900 Hz. The sensitivity of the receive end is set for a mean value of +22.2 dB re one microbar per volt, averaged over the four frequencies, 100, 300, 1000 and 2000 Hz. It will be observed that with 30 dB junction attenuation, the mean overall loss of volume between the microphone and ear (representing 66.35 cms of the one metre airpath) is 7.8 dB.

The speaking level as measured at the junction with the A.R.A.E.N. speech voltmeter is 0 dB (rel. to one volt) and hence the mean speech pressure at the microphone is one microbar, or 74 dB sound pressure level.

It is not proposed to describe in detail the method of A.E.N. rating

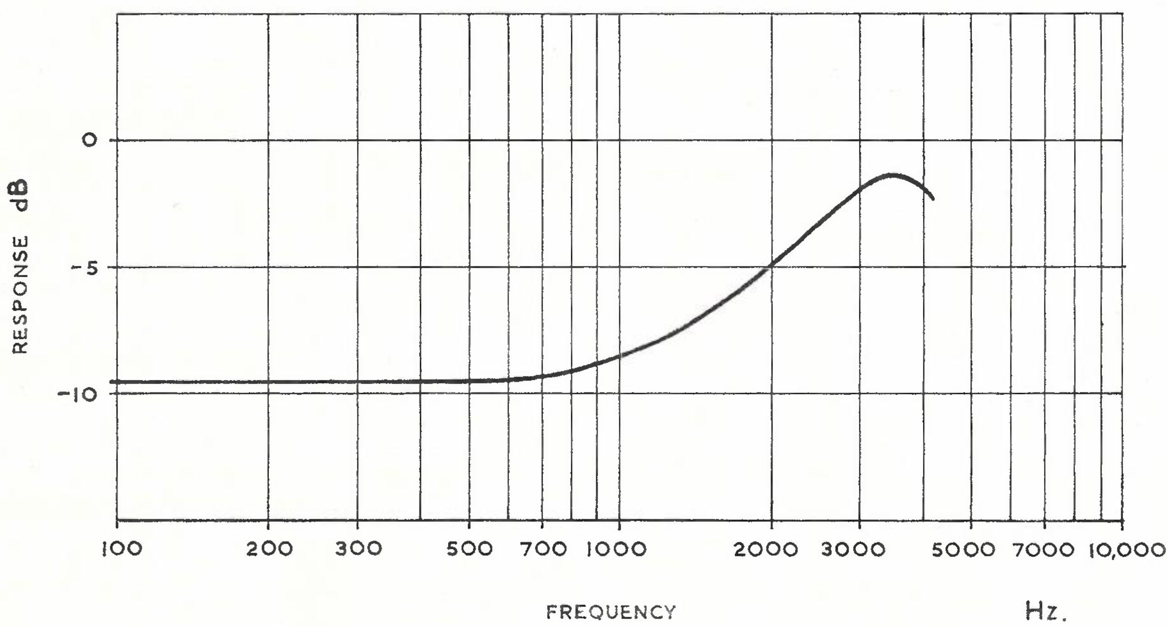

Fig. 1. — Overall Response of A.R.A.E.N.

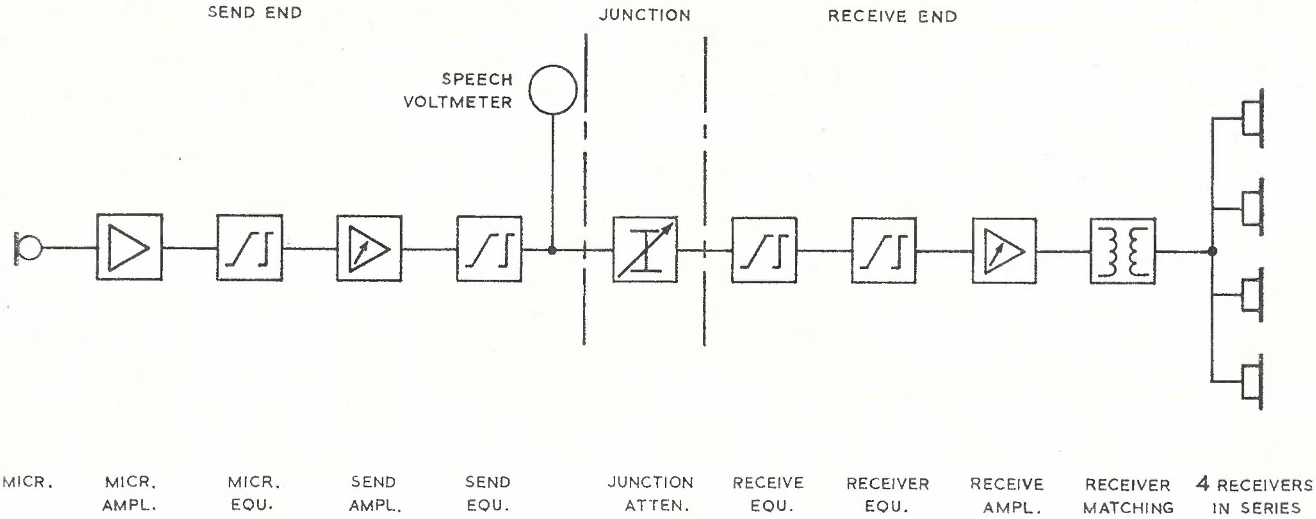

Fig. 2. — N.O.S.F.E.R. Block Schematic.

(see Ref. 2). However when used with mono-syllabic logatoms (inserted in a carrier phrase) for the determination of A.E.N. ratings of telephone circuits, the A.R.A.E.N. has a 300-3400 Hz bandpass filter inserted in the junction and has electrical or room noise added. It is then known as the S.R.A.E.N., i.e. the system for the determination of A.E.N. The A.E.N. rating corresponds to the difference in junction attenuations for an 80% sound articulation score for the S.R.A.E.N. and a similar articulation score for the respective telephone receive or send end coupled to the balance of the S.R.A.E.N.

It may be noted that when the S.R.A.E.N. is used for the A.E.N. rating of telephone circuits the absolute junction attenuation is no longer necessarily 30 dB, and in fact is not part of either the send or receive end of this system. The reference system is therefore no longer representative of a one metre airpath but has a volume transmission which is 30 dB better.

N.O.S.F.E.R.

N.O.S.F.E.R. is also known as the New Master Reference System, and is the reference system currently recommended as the basis for the determination of reference equivalents.

Due to difficulties experienced in operating, maintaining, and calibrating S.F.E.R.T., the C.C.I.T.T. decided to set up the equivalent of the S.F.E.R.T. Master Reference System using modern high quality components as already used for the A.R.A.E.N., with the addition of appropriate equalisers and amplifier gain adjustments, and then to define the characteristics in such a way that the system performance specification could always be met regardless of the continued availability of the original components. Thus was born the "New Fundamental System for the Determination of Reference Equivalents" — called N.O.S.F.E.R. It was developed as a result of extensive tests and experimentation with modifications to the A.R.A.E.N., carried out in the C.C.I.T.T. Laboratory during the years 1957 to 1959. The system is described in detail in C.C.I.T.T. Recommendation P.42 (Ref. 2).

In the C.C.I.T.T. Laboratory and also in the transmission laboratory of L.M. Ericsson of Stockholm, the A.R.A.E.N. is so set up that it can be readily converted to N.O.S.F.E.R. or vice-versa. In the A.P.O. Research Laboratories, we have all the essential components of A.R.A.E.N., but due to the lack as yet of a specific need for it, it has not yet been set up and tested. Fig. 2 shows the overall block schematic of the N.O.S.F.E.R. system.

The following are the main differences between A.R.A.E.N. and N.O.S.F.E.R.

(a) The speaking distance to the standard microphone is 14 cm for N.O.S.F.E.R. compared to 33.65 cm for A.R.A.E.N. (c.f. 4.35 cm for S.F.E.R.T.).

(b) The A.R.A.E.N. sending end has added to it a special send equaliser which simulates the free field response of the S.F.E.R.T. microphone, and, this together with the reduced speaking distance provides the necessary N.O.S.F.E.R. send sensitivity without having to change the amplifier gain. The mean send sensitivity based on the three frequencies of 100, 300, and 900 Hz now becomes —11 dB re one volt per microbar.

(c) At the receive end, the head diffraction equalising required for the A.R.A.E.N. is removed and is replaced by a N.O.S.F.E.R. receive equaliser which is intended to simulate the S.F.E.R.T. receive response. Receive amplifier gain adjustment is required. The mean receive sensitivity based on 100, 300, 1000 and 2000 Hz becomes +25.4 dB re one microbar per volt.

(d) The calibration of N.O.S.F.E.R. requires the same facilities and techniques as used in the calibration of A.R.A.E.N. The A.R.A.E.N. speech voltmeter (U.K. P.O. type 3) is also used at the input of the N.O.S.F.E.R. junction where the speech volume is intended to be —10 dB relative to one volt. This means that the mean speech pressure at the microphone is +1 dB relative to one microbar (or 75 dB sound pressure level). With zero attenuation in the junction, the mean overall acoustic gain from microphone to receiver is approximately +14.4 dB.

The nominal junction attenuation of N.O.S.F.E.R. is 24 dB, but this is mainly used as a means of controlling the listening level during measurements of send or receive reference equivalent and can be varied over a wide range with a recommended minimum value of 15 dB. Only when determining overall reference equivalents or sidetone reference equivalents, does the junction attenuation become a direct part of the N.O.S.F.E.R. system.

Measurement Technique

The voice-ear comparison between the volume efficiencies of the N.O.S.F.E.R. and the telephone circuit under test, which by definition gives the volume reference equivalent of the telephone circuit, is carried out under strictly defined conditions which include the following:

(a) special test phrases are used
(b) the speaking level is held constant at a specified level
(c) during sending efficiency comparisons telephone side-tone is not permitted to be heard by the talker
(d) the sending microphone and telephone are housed in a quiet acoustically treated room separately located from another similar room housing the N.O.S.F.E.R. receiver and receiving telephone
(e) speaking positions for both the standard microphone and the telephone handset are defined, and are located by fixed guard rings
(f) a team of trained speakers and listeners are used — nominally five — usually a minimum of three and not more than six.

Generally the comparison involves either the send or the receive end of N.O.S.F.E.R. against the telephone circuit, using the remaining part of the N.O.S.F.E.R. as a common listening or talking circuit. Fig. 3 shows the circuit arrangement for a sending reference equivalent determination using a technique known as the "Hidden Loss" method. This is the most widely used technique. It involves the listener in the adjustment of a balance attenuator to provide equality of loudness for the two circuits. The hidden loss attenuator is set by a third operator to a different value for each successive balance in order to ensure that the listener balances only as a result of his listening comparison. Fig. 4 shows the circuit arrangement for a receiving reference equivalent determination, while Fig. 5 shows the circuit arrangement for sidetone reference equivalent measurement. For the latter measurement, the volume efficiency of the complete N.O.S.F.E.R. is compared against the sidetone transmission of the telephone, with the telephone instrument appropriately terminated and with its receiver, electrically connected, but physically removed into an identical handset located in the listening room. The junction attenuator is normally divided into a balance attenuator located with the listener, and a hidden loss attenuator set by the third operator.

An alternative technique, which is commonly used by the U.K. P.O. Research Department, is the "Quantal

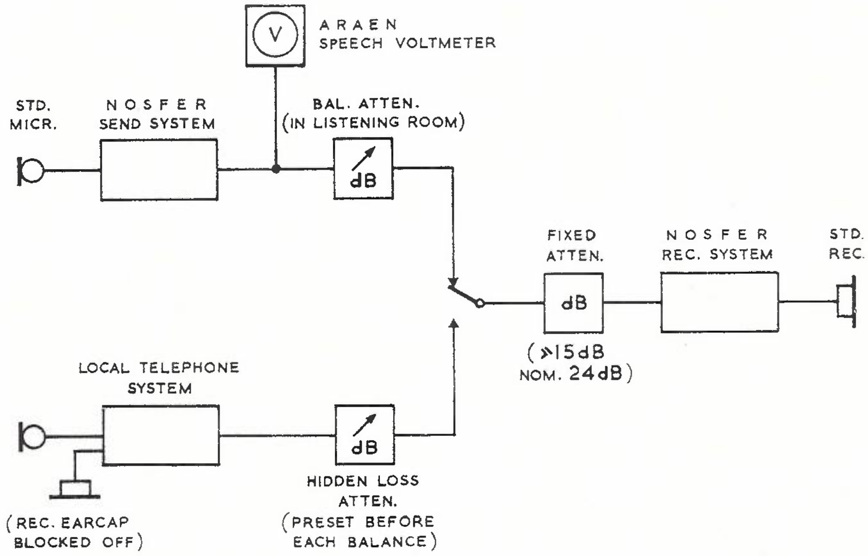

Fig. 3. — Sending End Reference Equivalent Determination.

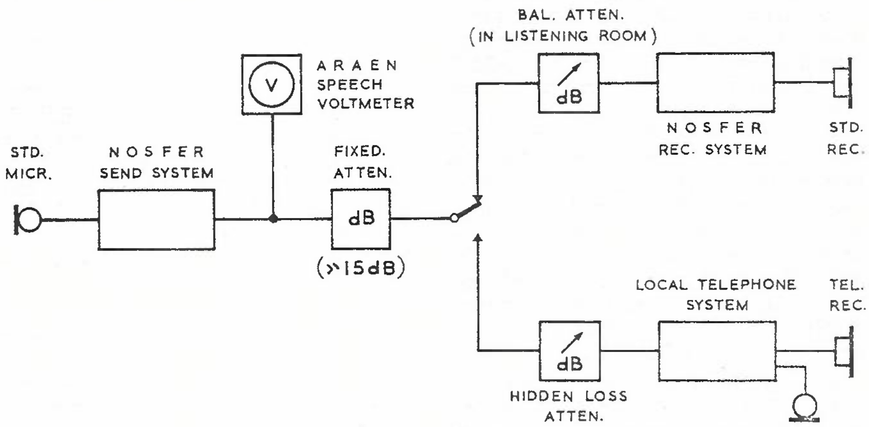

Fig. 4. — Receiving End Reference Equivalent Determination.

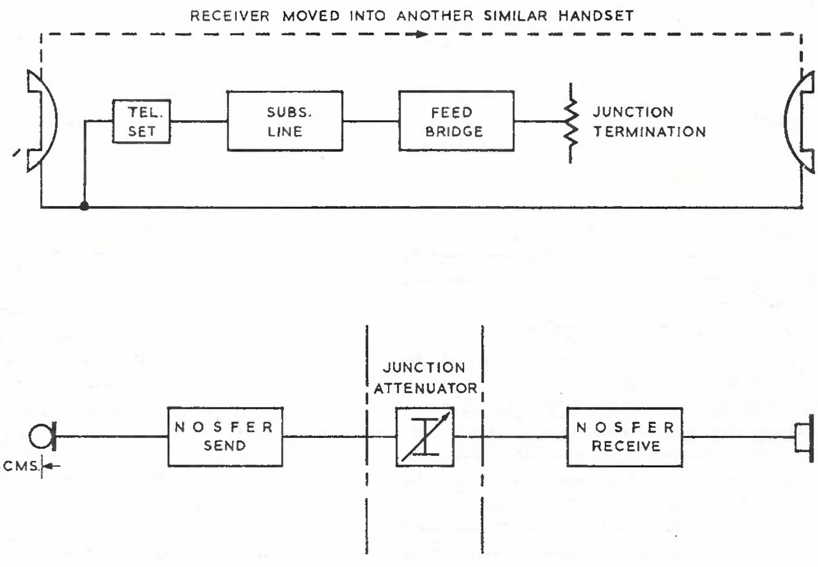

Fig. 5. — Sidetone Reference Equivalent Measurement.

Response" method. Here the listener does not have a balance attenuator to control and is not required to make a balance. He is however required to indicate which of the two conditions, "standard" or "test" is louder. He is normally given about six separate settings of the N.O.S.F.E.R. junction attenuator, spaced at 1 or 2 dB apart, and these are presented in a random order. From his responses it is possible to determine the balance point. It is necessary to first establish roughly the balance point in order that the chosen junction attenuator settings range around the nominal balance point. The U.K. P.O. claim that the "Quantal Response" method is less prone to listener bias that the "Hidden Loss" method.

In the C.C.I.T.T. Laboratory, Geneva, and also in the C.N.E.T. Laboratory in Lannion, France, the French phrase "Paris, Bordeaux, Le Mans, Saint-Leu, Leon, Loudon" is used and is spoken in a very rapid monotone. Other phrases recommended by the C.C.I.T.T. are the German phrase "Berlin, Hamburg, Munchen, Koblenz, Leipzig, Dortmund", the two American phrases "She was waiting at my lawn" and "Joe took father's shoe bench out" and the British phrase, "one, two, three, four, five".

In other laboratories such as those of S.T.L. Harlow, and L.M. Ericsson in Stockholm, test phrases which are considered to be more typical of telephone conversation phrases are used. For example, phrases in use at S.T.L. include "Don't go near the wet paint" and "Keep yourself slim at all costs".

As mentioned previously, the talking distance to the N.O.S.F.E.R. microphone is 14 cm, and this position is defined by a small metal guard ring with a diameter of one inch, against which the speaker is required to brush his lips when talking. The speaking distance for the telephone handset is also defined and fixed by a similar guard ring. Fig. 6 shows how this speaking point is fixed with respect to the ear-cap of the handset and shows the difference between the speaking point for N.O.S.F.E.R. and for A.R.A.E.N. Both speaking positions are based on early measurements of telephone user's head dimensions. The N.O.S.F.E.R. speaking distance was originally determined in America but has since been abandoned by them. The A.R.A.E.N. speaking point was based on measurements made in Britain and on the Continent. This N.O.S.F.E.R. speaking distance is not very practical with modern telephones featuring short handsets. Figs. 7 and 8 show the handset profiles of two current A.P.O. telephones. On each profile the shaded rectangles represent the N.O.S.F.E.R. guard ring position and the open rectangles represent the A.R.A.E.N. guard ring. In both cases, the guard rings are one inch in diameter.

It will be observed that a N.O.S.F.E.R. guard ring can be fitted to the A.P.O. 800 Series handset but not to the L.M. Ericsson telephone. A N.O.S.F.E.R. guard ring can also not be fitted to the Western Electric Type 500 Telephone or U.K. P.O. 700 series handsets and can be fitted only with difficulty to the A.P.O. 400 series handset. In all these cases, there is no difficulty in fitting a guard ring to comply with the A.R.A.E.N. speaking distance.

Because carbon microphones, and in particular those with plane electrodes like the No. 13 transmitter, are very sensitive to the inclination of the handset, it is necessary to roughly fix the handset position during tests. The C.C.I.T.T. recommend that the ear-cap plane be vertical and that the axis of the handset be inclined 45° to the vertical. This is approximately the normal position of the handset when speaking with the head inclined slightly forward.

All carbon microphones suffer to some degree from packing of the

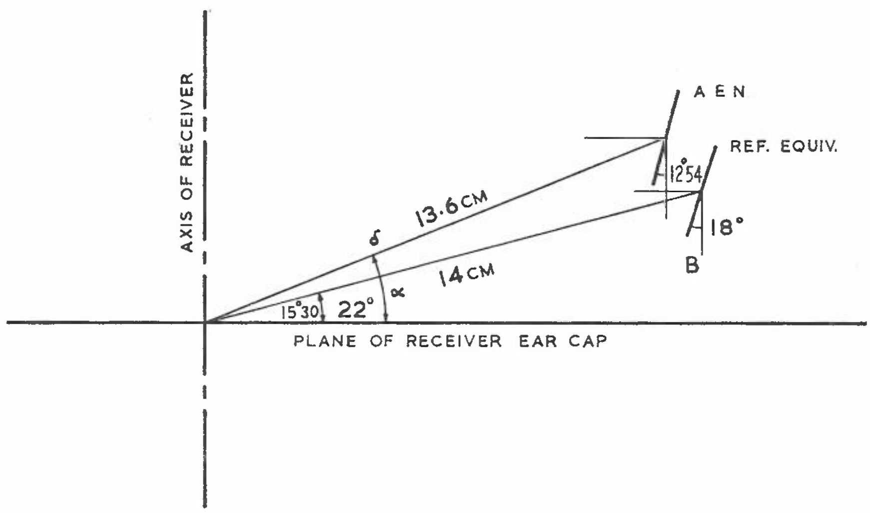

Fig. 6. — C.C.I.T.T. Talking Distances (for Transmission Rating of Telephone Instruments).

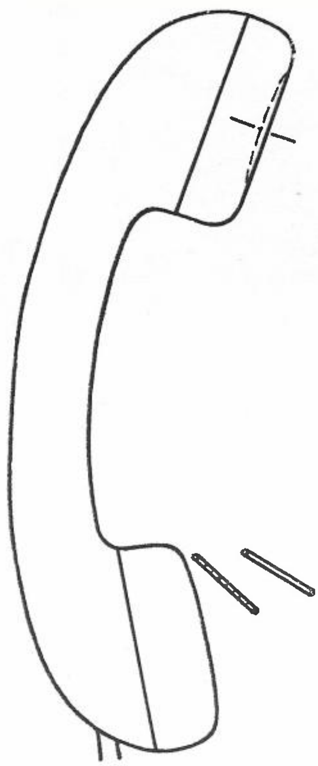

Fig. 7. — 800 Series Telephone (with N.O.S.F.E.R. and A.R.A.E.N. Speaking Guard Rings).

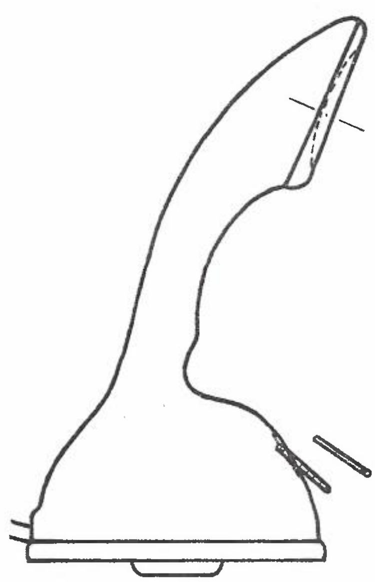

Fig. 8. — Ericofon (with N.O.S.F.E.R. and A.R.A.E.N. Speaking Guard Rings).

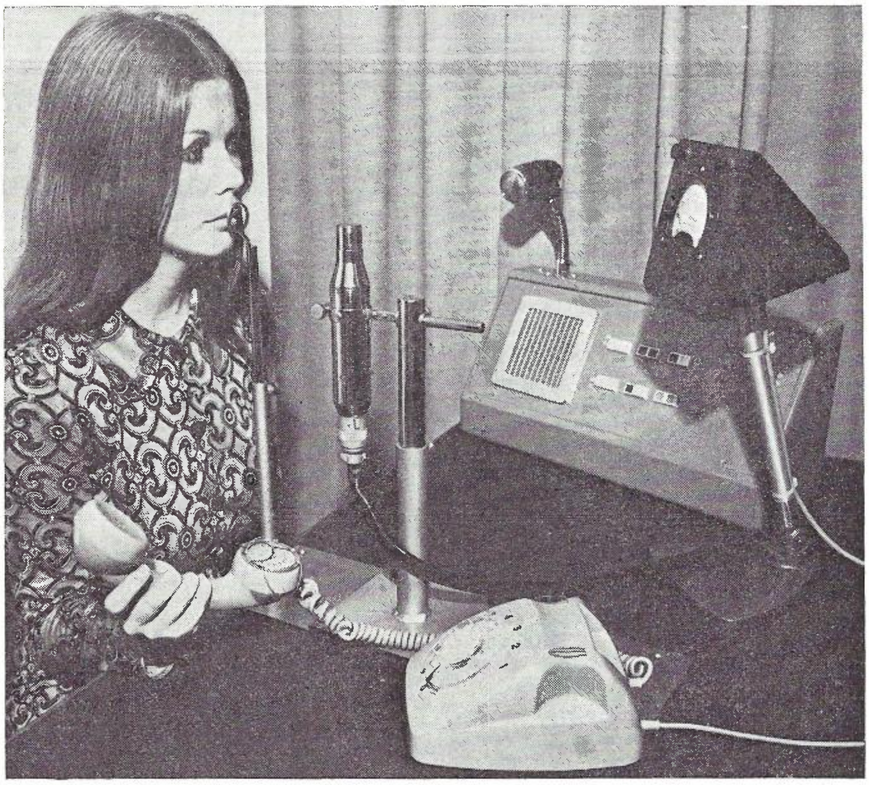

Fig. 9. — A.P.O. N.O.S.F.E.R. — Sending End Comparison.

Fig. 10. — A.P.O. N.O.S.F.E.R. — Receiving End.

carbon granules which causes a reduction in sensitivity and a decrease in microphone resistance. Precautions are necessary to ensure that the carbon granules are completely free of packing before commencing tests and that certain conditions which encourage packing are avoided as far as possible during the tests. The A.P.O. method for conditioning carbon microphones for subjective testing is to rotate the handset slowly, three times forward and backward from its final test position through an angle of 90°, either side of its final position. Tapping or vibrating the handset in a fixed position or subjecting the microphone to a sustained single frequency signal at the low end of the audio spectrum all cause rapid packing of the carbon granules and should be avoided. While a smart rap will generally dislodge packed granules, it is not recommended as a microphone conditioner, because there is little likelihood that this technique will always leave the carbon granules in the same condition. A proper microphone conditioning technique is most essential in carrying out either subjective or objective measurements on carbon microphones, and it must be repeated at regular intervals during the measurements.

The A.P.O. N.O.S.F.E.R.

The speaking and listening ends of the A.P.O. N.O.S.F.E.R. are illustrated in use in Figs. 9 and 10 respectively. Both the speaking and listening rooms are acoustically treated to control noise levels and reverberation times.

Because of the initial unavailability of the recommended S.T.C. transducers, the A.P.O. N.O.S.F.E.R. was originally set up using a W.E. 640 AA condenser microphone, and a set of Iwasaki moving coil head receivers. Using the British Standard Ear in the specified manner to calibrate these receivers, initial reference equivalent measurements made using the Laboratories N.O.S.F.E.R. gave receive reference equivalents approximately 8 dB pessimistic compared to C.C.I.T.T. Laboratory ratings on the same telephones. These receivers had exceptionally deep ear caps fitted with very soft ear pads. The Iwasaki receiver movements were then fitted into S.T.C. receiver cases, in place of faulty S.T.C. receiver movements which were the only ones on hand at that time. When equalised and calibrated using the same technique as before, laboratory ratings of receive and send reference equivalents agreed with C.C.I.T.T. ratings within 0.5 dB average for 5 telephone instruments, which is considered to be very good correlation.

S.T.C. 4012A receivers have since become available, and have been fitted with rubber ear pads, to bring the receive end of the N.O.S.F.E.R. up to C.C.I.T.T. specifications. Although varying slightly with team composition, recent reference equivalent determinations generally are within 1 dB of C.C.I.T.T. determinations for receive and within 2 dB for send.

The send system utilising the WE 640 AA condenser microphone has been calibrated for free field response in an anechoic room and there is no reason to suspect that it performs in any different way to the recommended S.T.C. moving coil microphone similarly calibrated. Although we now also have the specified S.T.C. microphone, the condenser microphone is more convenient to calibrate and check with our existing facilities so that it is not intended to change the microphone of the system.

Secondary Standard Reference Systems

As mentioned earlier, in addition to using N.O.S.F.E.R. for reference equivalent rating, it is permissible to rate telephone circuits against a secondary standard providing it has been itself rated against N.O.S.F.E.R. C.C.I.T.T. Recommendation P.42, Annexe 2, (Ref. 2) describes such a stable reference system which is called S.E.T.E.D. If such a system is to be used for rating of telephone circuits, an annual check of the system against N.O.S.F.E.R. is recommended.

Such secondary standards as S.E.T.E.D. feature the use of stable microphones and receivers, generally have only a nominal control of frequency response, and have a simple means of checking amplifier gains and transducer sensitivities without resort to the complex fundamental approach necessary for N.O.S.F.E.R.

OBJECTIVE MEASUREMENT OF REFERENCE EQUIVALENTS

Around 1952, Dr. Braun of the Post Office Telecommuncations Engineering Centre of the Federal Republic of Germany, together with the West German firm of Siemens and Halske, developed a set of equipment for the objective measurement of reference equivalents. This equipment, which became known as the O.B.D.M. (Objective Bezugsdampfungsmesser) was adopted by the West German Post Office for the transmission rating and testing of telephones and telephone circuits.

Around 1963, Siemens and Halske discontinued production and the Danish firm of Bruel and Kjaer was requested by the West German Post Office to produce a replacement. The new equipment which they subsequently offered incorporated many items in the standard range of B. & K. acoustic equipment, and this resulted in a significant reduction in cost as well as improved versatility. It is now not only in use by the West German Post Office, but also in the laboratories of most telephone administrations and manufacturers throughout the world. In recent years, (1969/70), B. & K. have released an improved version of the earlier system, although there is no significant change in the principle of operation.

Called "Electro-acoustic Transmission Measuring Sets", they both function in a similar way to that of the O.B.D.M. and each comprises four basic units, plus a number of accessory items.

The four basic units are:

(a) Source — a beat frequency oscillator swept mechanically (or electronically in later units) over a frequency range of from 200 to 4000 Hz, and back to 200 Hz. in one second. To get an approximation to a speech-weighted signal, the frequency sweep is logarithmic, which reduces the effectiveness of each unit bandwidth of the sweep as the frequency is increased.

(b) Artificial voice — a special artificial voice fitted with a small condenser microphone in its throat and coupled to the sweeping oscillator to control the sound pressure level in the throat in such a way that at a point about 4 cms from the throat an average sound pressure level of 94.6 dB is measured by a simulated S.F.E.R.T. microphone. (Response flat within ±2 dB).

(c) Artificial ear — three separate ears are provided, all utilising a one inch condenser microphone as the sensing element. The recommended ear is the Braun 4 cc ear which is intended to simulate the impedance of a real ear. A compensating attenuator with a value of 3.6 dB loss is used with this ear to compensate for its lack of volume. This compensation is switched out when either of the alternative 6 cc hard coupler ears are used (N.B.S. or A.S.A. standard ears). The later system includes a fourth artificial ear — an I.E.C. Standard Audiometric Ear, which utilises a half-inch condenser microphone.

(d) Loudness level indicator — this is a special circuit which sums all the individual frequency components arriving over the sweep half cycle ($\frac{1}{2}$ second duration — the remaining half cycle is a mirror image sweep and has similar frequency components although in a reversed order) and gives an indication of the relative loudness level. It comprises a special rectifier circuit, indicator, and scale such that the deflection y for a voltage x follows the law $y = kx^{0.6}$.

By integration with electrical time constants and meter mechanical time constants, the meter indication becomes a summation of the individual components in the sweep. The relationship $y = kx^{0.6}$ is based on the well known relationship that if there is a 10 dB increase in sound pressure level, there is a doubling (i.e. 6 dB increase) in loudness level. The indicator does not provide any frequency discrimination and frequency weighting is provided on an effective duration basis by the logarithmic sweep.

The accessories include a response tracer, a response recorder, octave band filters, 5 kHz high pass filter, d.c. supply for telephone feed bridge and an acoustic calibrator or pistonphone. They assist in viewing and recording transducer responses, analysing noise and distortion products and calibrating the system. During send reference equivalent determinations and during system calibration, a S.F.E.R.T. filter is included in the artificial voice circuit. This compensates the obstacle effect of the large S.F.E.R.T. microphone which causes a rise in pressure at the microphone above the free field pressure of up to 11.5 dB at about 3 to 4 kHz, and ensures that the calibration adjustment effectively takes into account only the pressure response of the microphone (as in S.F.E.R.T.).

The system sensitivities are set as follows —

Send —31.5 dB re one volt per microbar

Receive +31.5 dB re one microbar per volt

When the artificial voice produces a mean pressure of 10.75 microbar (or +20.6 dB relative to one microbar or 94.6 dB sound pressure level) at a point 4.35 cms from its throat, and a voltage of 285 mV (= —10.9 dB re one volt or one Neper below 1 mW) is produced by the test telephone across the 600 ohm junction, this is read as 0 dB reference equivalent (R.E.) send.

Correspondingly if 285 mV is fed into the junction of the telephone system, and results in a pressure of 10.75 microbar in its receiver, it will produce 285 mV from the artificial ear and will be read as O dB R.E. (receive).

Fig. 11 shows the essential components involved in a send reference equivalent determination, while Fig. 12 illustrates the corresponding set-up for a receiving reference equivalent determination. A study of these two figures, plus a study of Fig. 5 showing the general arrangement for the measurement of side-tone reference equivalents, will suggest how this system can also be used for side-tone measurements.

With the objective measuring equipment, it is possible for one operator to measure send, receive and sidetone performances of a telephone for four

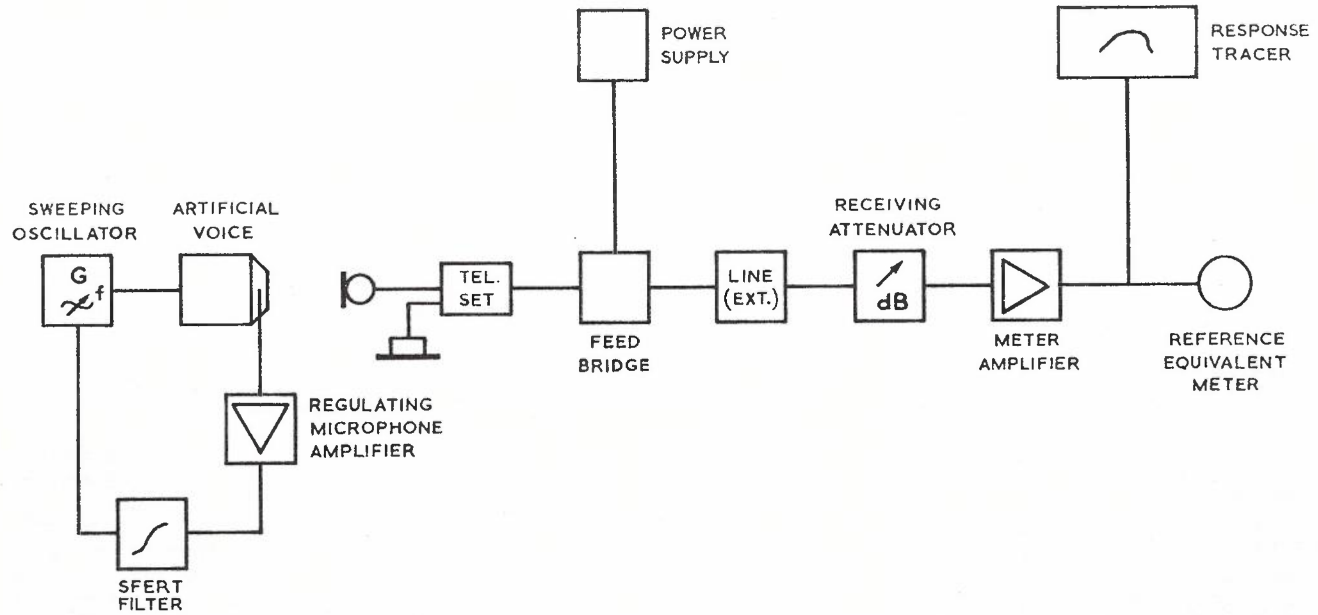

Fig. 11. — Objective Measurement of Send Reference Equivalent (with B. & K. Electro-acoustic Telephone Transmission Measuring Set).

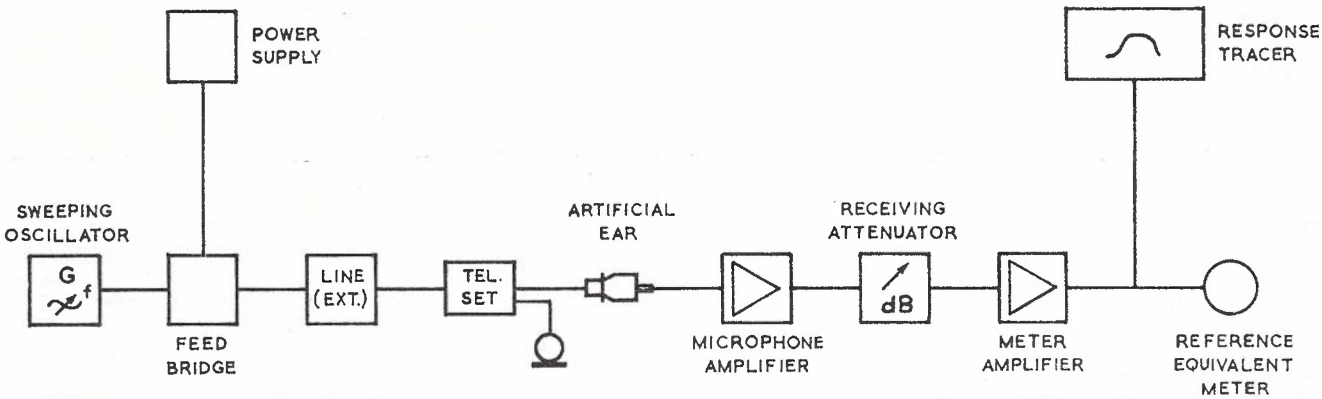

Fig. 12. — Objective Measurement of Receive Reference Equivalent (with B. & K. Electro-acoustic Telephone Transmission Measuring Set).

or five lengths of local line in perhaps an hour or two. Similar measurements made subjectively would involve a team of four or five operators working for one to two weeks. The results of objective measurements on a typical 801 regulated telephone corrected for minimum acceptable efficiency transducers are shown in Fig. 13. While the absolute values of reference equivalents obtained objectively may still be suspected, this graph shows readily a number of important characteristics of the 801 telephone —

(a) good receive regulation, particularly between zero line and two miles of $6\frac{1}{2}$ lb/mile cable,
(b) sidetone performance on $6\frac{1}{2}$ lb/mile cable which although poor at zero line, improves rapidly with line length to a satisfactory value for lines of approximately one mile and longer,
(c) compared to the receive performance, the send regulation is poor and is quite inadequate in compensating the high feed current loss of the carbon microphone.

CORRELATION BETWEEN OBJECTIVE AND SUBJECTIVE DETERMINATIONS

In general the correlation between subjective and objective measurements of reference equivalent is not as good as would be desirable. Some of this difficulty is due to the variability of the results obtained in subjective testing. With a given telephone instrument and a given team, repetitions of subjective determinations of send and receive reference equivalents typically differ by up to 1 dB. With a change of team composition a further change in the mean value of up to at least 1 dB is common. The poor stability of carbon microphones and the great influence of the conditioning procedure on the results also limits the degree of correlation possible.

In objective testing, one of the major factors causing difficulty in correlating the results with subjective measurements is the difference in the bandwidths of the two systems. Objective testing usually involves only the frequency range of 200 Hz to 4000 Hz while N.O.S.F.E.R. has an effective bandwidth of 80 Hz to 8000 Hz. When a 200 to 4000 Hz bandpass filter is inserted into the junction of the N.O.S.F.E.R., it produces a loss of volume of the order of 3 to 4 dB, the actual value of which varies with the listening level.

Handset length, frequency response, and non-linear distortions in the tele-

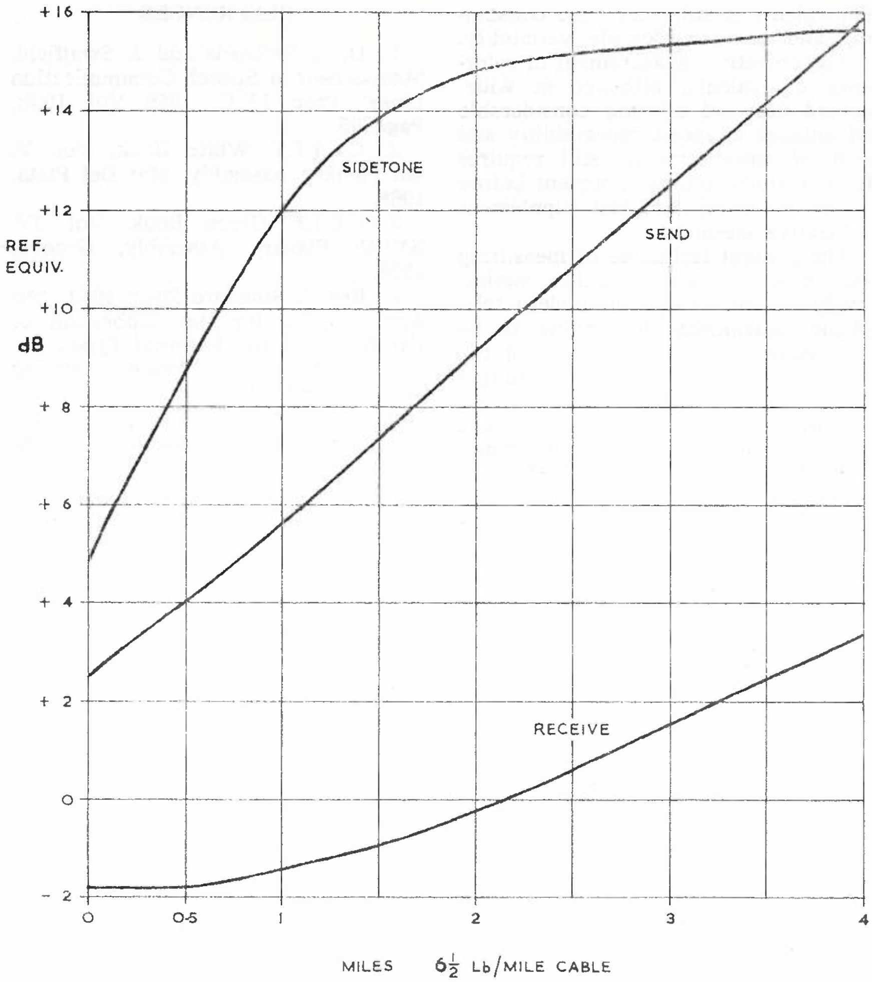

Fig. 13. — Objective Reference Equivalents of a Typical 801 Telephone. (Measured on B. & K. Electro-acoustic Telephone Transmission Measuring Set).

TABLE 1 — REFERENCE EQUIVALENT OF 801 TELEPHONES

Sending Instrument No.	C.C.I.T.T. Value (dB)	A.P.O. Value (dB)	Objective Value (dB)
1	+16.7	+17.2	+13.9
2	+16.7	+16.7	+13.7
3	+17.9	+16.9	+13.7
4	+17.4	+17.4	+13.9
5	+18.6	+17.3	+14.7
Mean	+17.5	+17.1	+14.0
Receiving Instrument No.	C.C.I.T.T. Value (dB)	A.P.O. Value (dB)	Objective Value (dB)
1	+3.7	+4.8	+2.9
2	+2.7	+3.3	+1.8
3	+3.5	+3.4	+2.6
4	+4.1	+3.2	+3.1
5	+2.6	+2.9	+2.3
Mean	+3.3	+3.5	+2.5

phone instrument need also be taken into account when correlating objective and subjective determinations of reference equivalents. A study of the effect of various factors affecting correlation has been made in the Standard Telecommunication Laboratories and the results are given in Refs. 5, 6 and 7. Corrections have been determined for bandwidth restrictions, calibration methods, handset length and listening level, and when applied to most telephone sets provide reasonable correlation between objective and subjective determinations of send, receive and sidetone reference equivalents (within 1 to 2 dB maximum).

For the 801 telephone, objective measurements of reference equivalent using the B. & K. Electro-acoustic Transmission Measuring Set without corrections, produce values compared to C.C.I.T.T. Laboratory subjective determinations which are typically similar (within 1 dB) on receive, about 3 to 4 dB lower on send and about 6 dB lower for sidetone. These differences vary with change of transducer types and with telephone set types.

Table 1 illustrates results of reference equivalent determinations made subjectively in the C.C.I.T.T. Laboratory, and both subjectively and objectively in the A.P.O. Research Laboratories on five separate 801 telephones measured on 3.4 miles of $6\frac{1}{2}$ lb/mile cable. The figures given have been corrected for minimum acceptable transducer efficiencies.

A.P.O. TELEPHONE EFFICIENCY TESTER

To standardise the performance of telephone instruments and transducers in production, the A.P.O. has developed a Telephone Efficiency Tester (T.E.T.) which utilises a sweeping oscillator, an artificial voice and an artificial ear, and in these and other respects it resembles equipment such as the B & K Electro-acoustic Measuring Set, designed to measure volume reference equivalents. (Ref. 8).

The T.E.T. however has a frequency sweep linear with time and does not incorporate a loudness integrating device, and can therefore not measure relative volume performances. It does not provide facilities for holding the handset in the normal talking position and the position of the artificial voice in relation to the microphone is not related to the N.O.S.F.E.R. speaking distance. It is unsuitable for comparing the relative volume transmission performances of two telephone instruments which have differences in frequency response or handset shape. It is however a reasonably satisfactory tester for monitoring production performances of the one type of telephone instrument, when transducer frequency responses are unlikely to show much variation. Where there are occasional gross changes in frequency response, the T.E.T. tends to favour those transducers having response peaks towards the high frequency end of their range.

CONCLUSION

In reviewing what has been written in this paper about the development of transmission reference systems and rating methods, it can be seen that to obtain an understanding of the methods currently in use for both subjective and objective measurement of reference equivalents it is helpful to understand the role once played by the now obsolete reference system S.F.E.R.T.

Providing that the telephone frequency response is reasonably broad and flat, that its harmonic distortion is low and that its sidetone is not excessive, then a measure of its volume transmission, viz, volume reference equivalent, is a satisfactory basis for planning and implementing a telephone network. Although a volume reference equivalent rating is obtained with less effort than an articulation rating, the subjective measurement of reference equivalents is still very time consuming and has considerable variability.

The objective measurement of reference equivalents, although in widespread use and offering considerable advantages in speed, repeatability and cost of measurements, still requires further study and development before it can do more than just supplement subjective methods.

The general technique of measuring reference equivalents (either subjectively or objectively) of modern telephone instruments is tending to be increasingly restricted because of the incompatability of the standard N.O.S.F.E.R. telephone speaking distance with the trend towards short compact handsets. The shorter handsets also tend to provide send reference equivalents which are unduly optimistic relative to their real performance in the telephone network.

The C.C.I.T.T. (Study Group XII) is currently studying new techniques of measurement which are aimed at improving the reliability of both subjective and objective determinations of reference equivalent with a view to developing an objective method giving results which correlate well with subjective methods, and which might become an internationally agreed method of measurement.

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APPENDIX

DESCRIPTION OF ABBREVIATED TITLES

Abbreviation	Description	Original Title
A.E.N.	Articulation Reference Equivalent.	Affaiblissement Equivalent pour la Netteté.
C.C.I.T.T.	International Telephone and Telegraph Consultative Committee.	Comité Consultatif International Telegraphique et Téléphonique.
A.R.A.E.N.	Reference Apparatus for the Determination of A.E.N.	Appareil de Référence pour la Determination de l'Affaiblissement Equivalent pour la Netteté.
N.O.S.F.E.R.	New Master Reference System.	Nouveau Système Fondamental pour la Detérmination des Equivalents de Référence.
S.F.E.R.T.	European Master Reference System or Master Transmission Reference System.	Système Fondamental Européen de Référence Téléphonique.
I.T.U.	International Telecommunications Union.	
C.C.I.F.	International Telephone Consultative Committee.	Comité Consultatif International Téléphonique.
S.R.A.E.N.	Articulation Reference System.	Système de Référence pour la Determination de l'Affaiblissement Equivalent pour la Netteté.
C.N.E.T.	National Centre for Telecommunications Studies (France).	Centre National des Etudes Télécommunications.
S.T.L.	Standard Telephone Laboratories (Harlow, Essex).	
S.E.T.E.D.	Working Standard Reference System having Electro-dynamic Microphone and Receiver.	Système étalon de travail avec microphone et récepteur électromagnetique.
O.B.D.M.	Objective Reference Equivalent Meter.	Objective Bezugsdampfungsmesser
N.B.S.	National Bureau of Standards (U.S.A.).	
A.S.A.	American Standards Association (U.S.A.).	
U.K.P.O.	United Kingdom Post Office (formerly B.P.O. — British Post Office).	
A.P.O.	Australian Post Office.	
T.E.T.	Telephone Efficiency Tester (A.P.O.).	

THE COMMISSIONING AND MAINTENANCE OF ARM EXCHANGES (Part 2)

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

INTRODUCTION.

Part 1 of this article, which appeared in the previous issue of this journal, described commissioning tests and procedures for the common control equipment, switching stages, registers and analysers in the ARM exchange.

Part 2 in this issue describes Incoming circuits and Tariff Equipment and Outgoing circuits.

Part 3 describes Service Aids and the Maintenance of ARM Exchanges.

COMMISSIONING AND MAINTENANCE OF INCOMING CIRCUITS.

Functional Tests on FIR's.

It will be seen later that a full functional and (if required) tariff test is performed on every FIR in the exchange prior to connection to the transmission media. Most faults encountered are cleared in situ, but for more difficult ones the FIR tester is used.

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** Mr. Liubinas was Engineer Class 2, Metro. Exchange Installation, Victoria and is now with L. M. Ericsson Pty. Ltd. See Vol. 21, No. 2, Page 192.

The FIR tester is mounted on a rotissery, as shown in Fig. 37.

The survey diagram in Fig. 36 shows the elements of the tester as they are applied to test a FIR-ZTM-H1. The basic philosophy of the tester is similar to the register test rack in that the normal boundary conditions are simulated. Thus we have elements simulating the distant end equipment, tariff setting equipment, register equipment, etc. The procedure to test this FIR is as follows:—

Operate SW1 to position 1 and momentarily depress the short pulse key. FPG in the tester will generate a 150 ms pulse to seize the FIR. 1F2 and 2F2 in the FIR should operate. The FIR will call for a RSM by connecting negative to the 'm' wire and the "RS call" and "amplified" lamps will light.

Operate the "connect register" key to simulate the connection to an H1 register. The call towards RSM will be broken and the "RS call" lamp will extinguish. At the same time the "RS hold" and "Incoming Stage" lamps will light indicating that these functions have been performed by the FIR.

To test the tariff setting element, pre-operate the "Tariff Test" key and then operate the "Tariff Set" toggle switch the required number of times to set the desired tariff rate. Relays F7 to F10 in the FIR should count the operations of the toggle switch.

Operate the C wire key and then restore the "Tariff Test" key to simulate the 'C' wire test, which should operate the F1 in the FIR. The incoming stage marking lamp will now extinguish and the 'C' wire lamp will light.

Momentarily depress the "Pad Switch" key to check the operation of F29 in the FIR (Pad switching function).

Operate the "End of Selection" key to simulate the ready connection of register. The "F4" lamp will light and all other lamps except the 'C' wire lamp will extinguish.

Turn SW1 to position 2 and operate the "short pulse" key to simulate the transfer of an "answer" condition from the ARM exchange. F20 in the FIR should release for 150 ms, causing the operation of F5 and F6. The "M" lead lamp should flash twice for approximately 150 ms, indicating the "answer" pulse and the first meter pulse transmitted by the FIR.

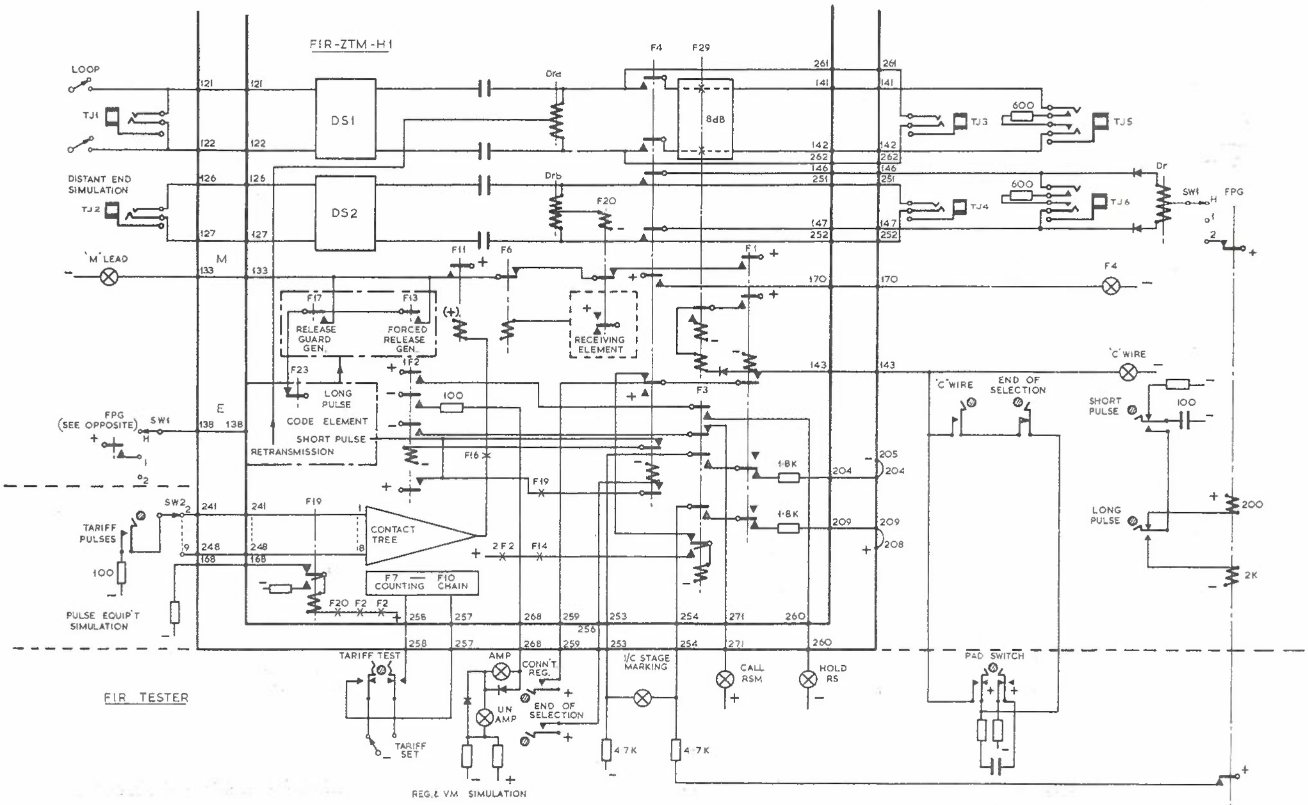

Fig. 36. — FIR Tester Survey.

To test the blanking of the next regular meter pulse, and transmission of further pulses, set SW2 to the previously set tariff rate. There should be no flash on the M lead lamp during the first operation of the tariff key and a flash for each further operation.

Clear the FIR by operating the "short pulse" and the "long pulse" keys simultaneously. FPG will generate a 600 ms pulse, which will result in the operation of F17, and the release of 1F2 and 2F2 relays in the FIR. A "release guard" pulse generated in the FIR will be seen as a flash of the 'M' lead lamp.

To test forced release conditions turn SW1 to position 2 and generate a long pulse. Relays F19 and F13 will operate and relays F1 and F4 will release.

Line Signalling in ARM.

For line signalling via carrier channels the A.P.O. adopted the L.M. Ericsson pulse signalling system, otherwise known as 'T' signalling system.

Fig. 38 shows the pulses which are transmitted via the signalling leads in either direction and their meaning. To overcome some shortcomings of the system in step-by-step networks

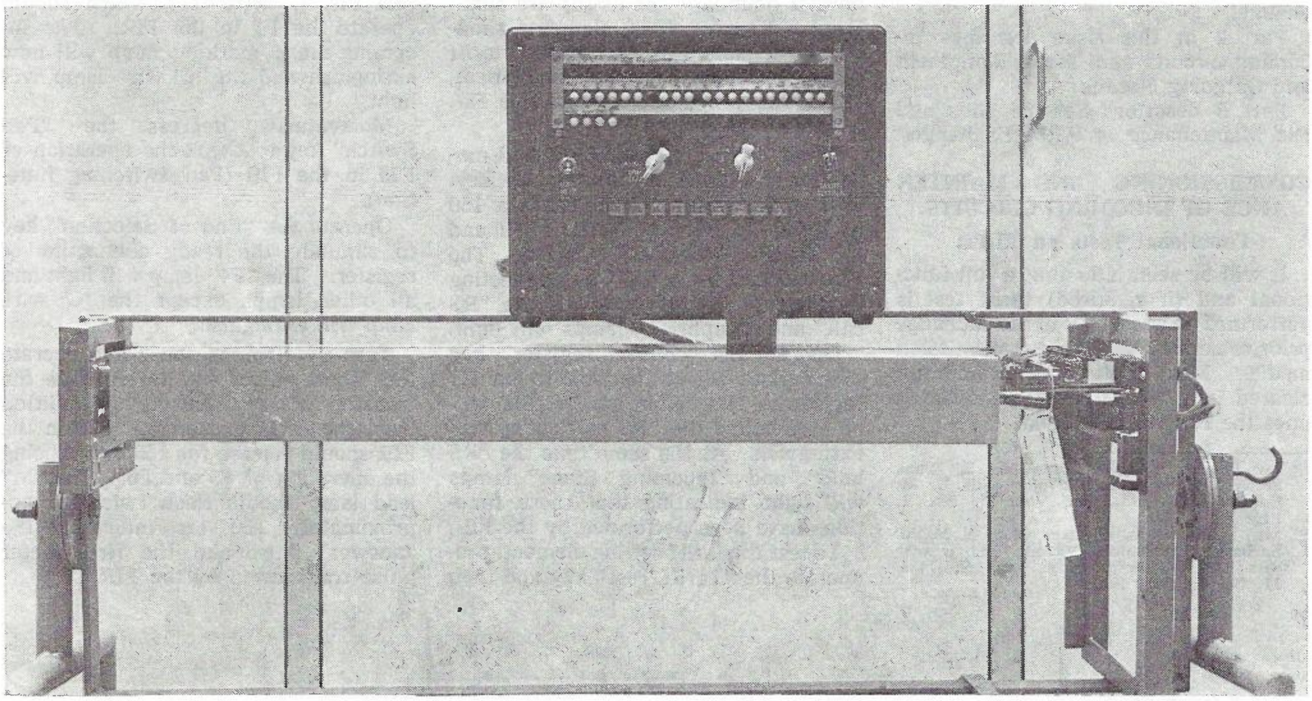

Fig. 37. — FIR Tester.

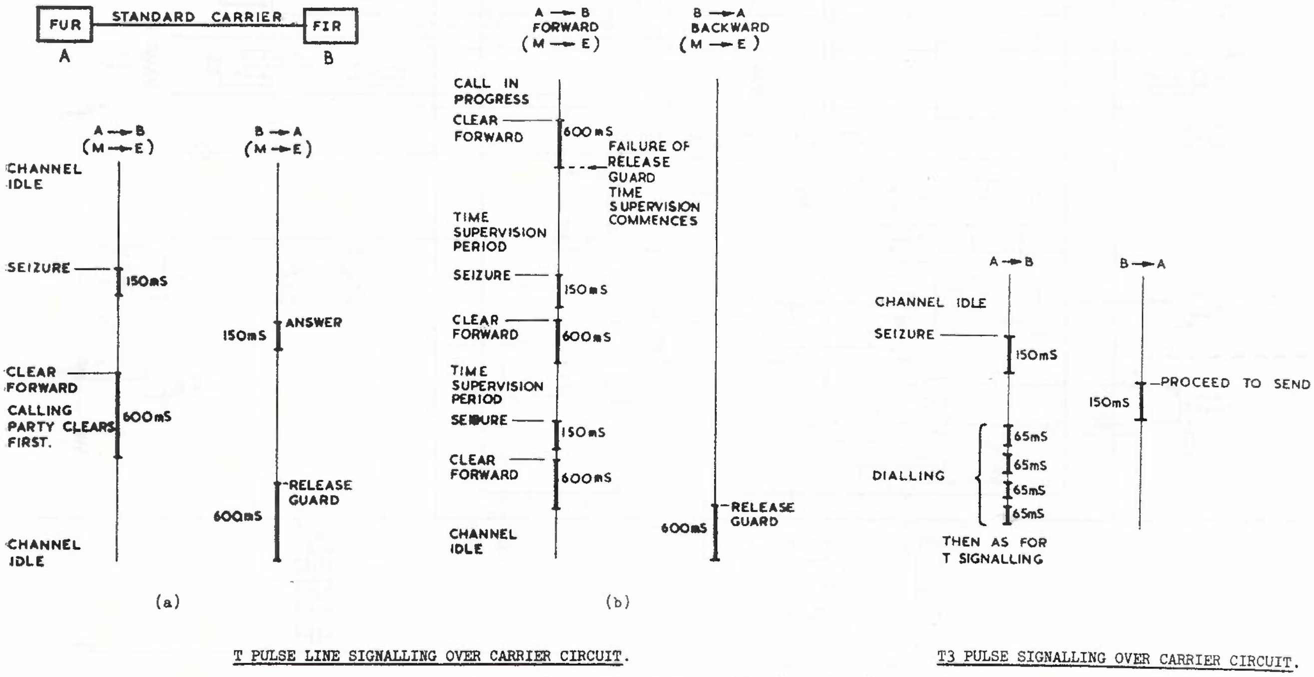

Fig. 38. — Pulse Signalling on Carrier Circuits.

the A.P.O. developed an improved version known as the T3 signalling system, by adding to the scheme the "proceed to send" signal. Line signals requiring transfer through an ARM exchange are converted to "Positive off" conditions on the cailho circuits of the speech wires, i.e., T signalling "pulses" are converted to "pauses" within the exchange. Two types of pulses (or pauses), distinguished by time length, namely, 150 ms and 600 ms, are employed and a requirement exists, therefore, to discriminate between these pulses both when receiving and generating.

The survey diagram in Fig. 39 provides an overall picture of line signalling in the ARM system. Let us consider a call from the FUR-TM-C (1) via the FIR-TM-Y1 (2), the ARM exchange, the FUR-L1M-C (3), to the FIR-L in a distant ARF ex-

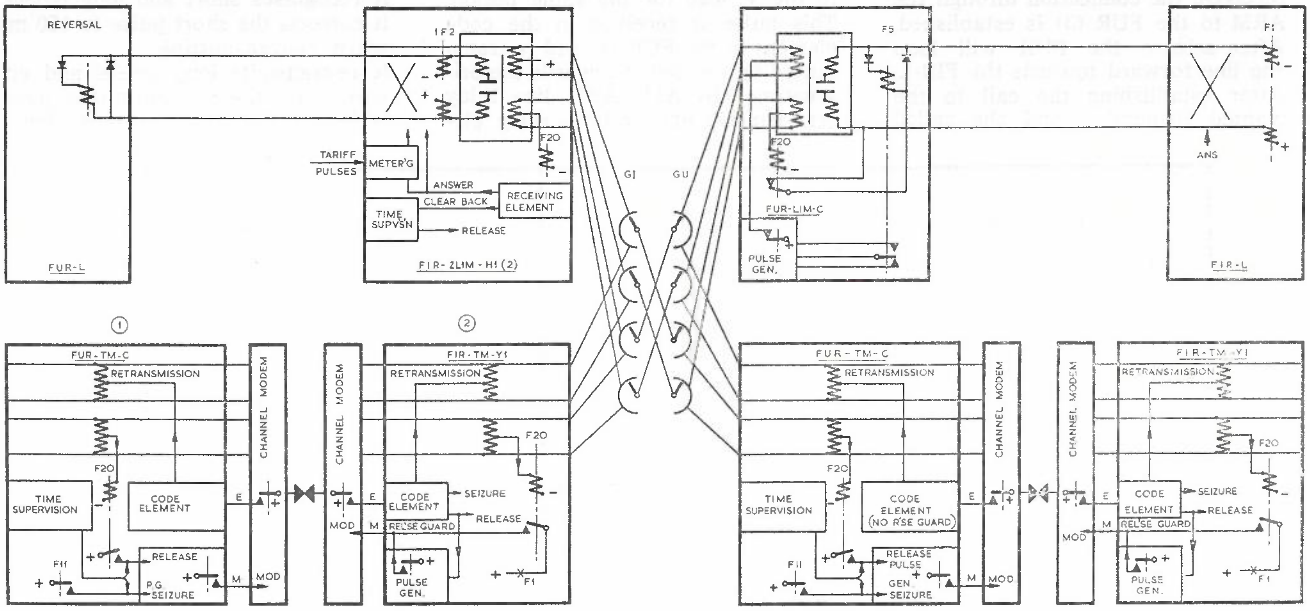

Fig. 39. — Line Signalling Survey.

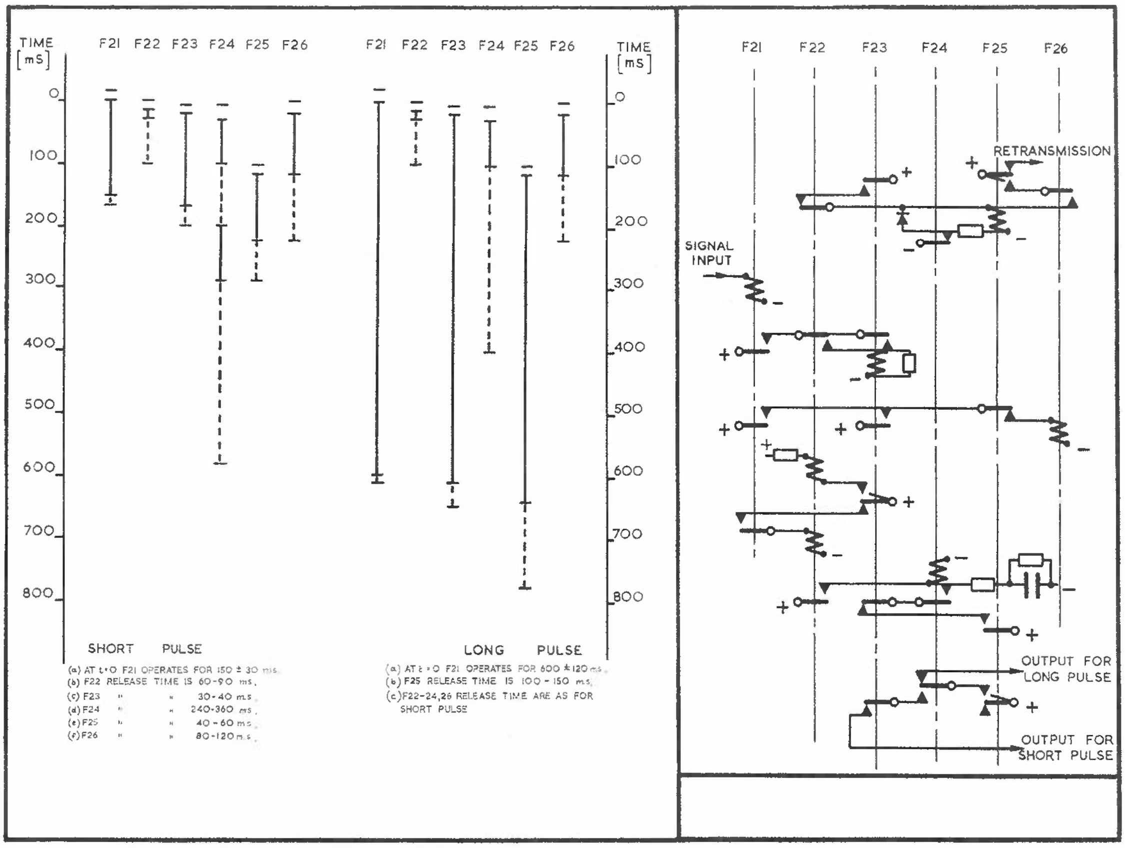

Fig. 40. — Line Relay Sets Code Element.

change (4). The FUR (1), when seized, causes a 150 ms pulse to be transmitted on the M lead to the FIR (2). Here the pulse is recognised in the code element and causes seizure of the FIR. A REG-Y1 is connected, and after sufficient information signals have been received, the connection through the ARM to the FUR (3) is established. After seizure the FUR will loop the line forward towards the FIR-L. After establishing the call to the wanted B number and the called party answering, the answer condition is transferred from the ARF as a polarity reversal on the line to the FUR (3). This operates F5, which causes the pulse generator to open the cailho to the FIR for 150 ms. In response F20 in the FIR (2) releases for 150 ms and positive is connected to the M lead for the same period. This pulse is received in the code element in the FUR (1) and re-transmitted on the cailho towards the originating FIR A11. ARM line relay sets contain one or both relay elements to recognise these line signals. The code element consists of six relays, is always connected to a carrier "E" lead and performs the following functions:—

It receives pulses from the carrier system, but disregards any spurious signals of less than 60 ms duration.

It recognises short and long pulses.

It corrects the short pulse to 150 ms when re-transmitting.

It re-transmits long pulses and ensures that the re-transmitted pulse is longer than the received signal.

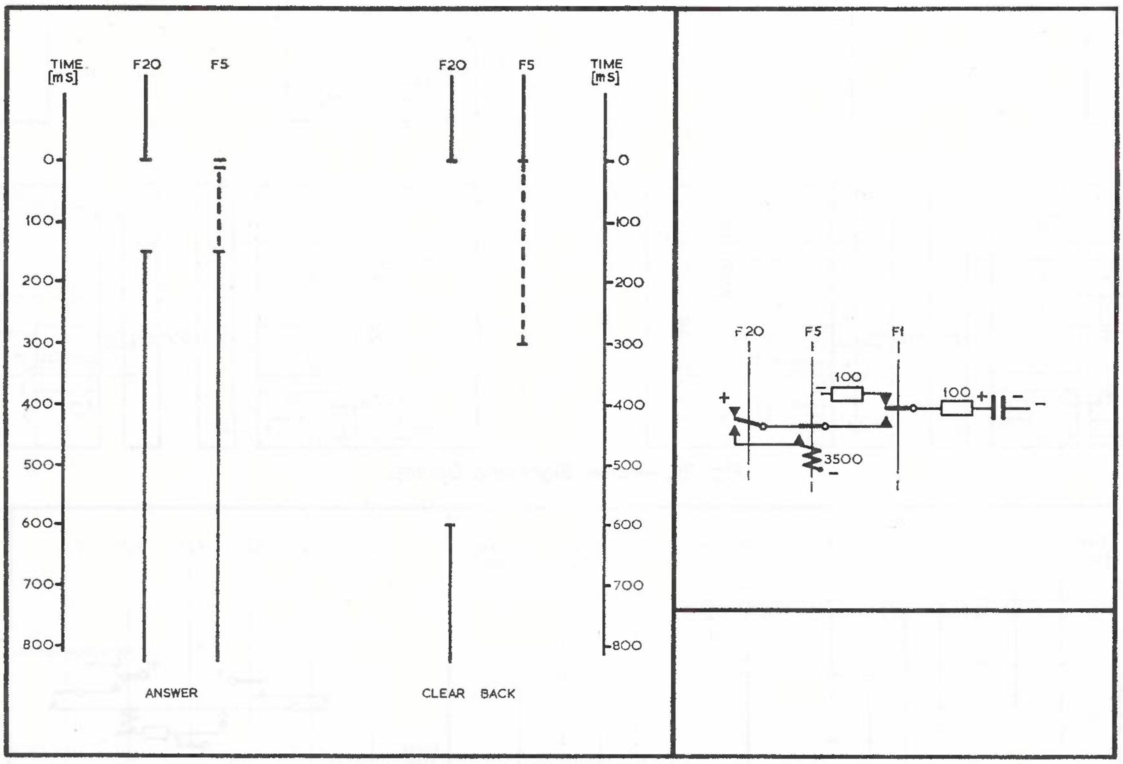

Fig. 41. — Receiving Element.

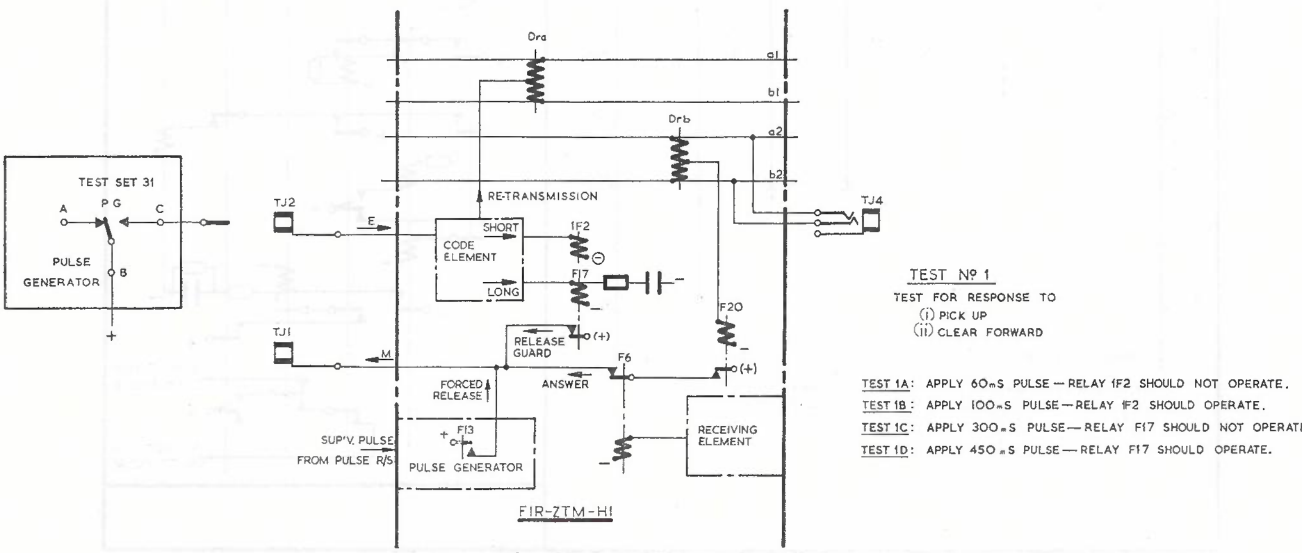

Fig. 42. — Pulse Test No. 1.

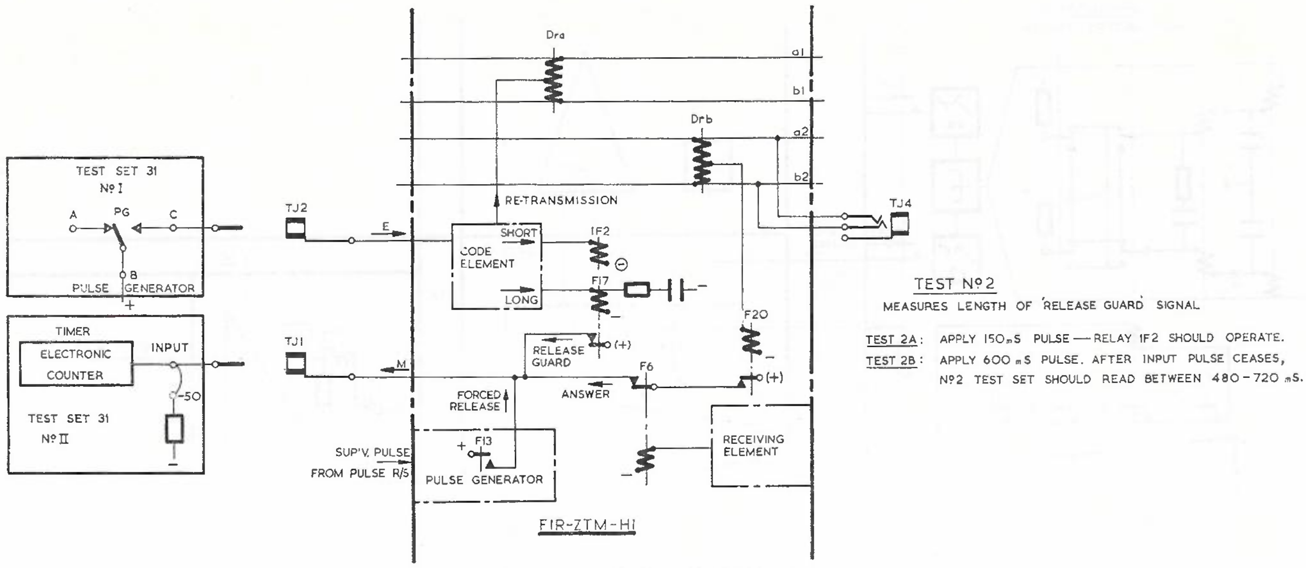

Fig. 43. — Pulse Test No. 2.

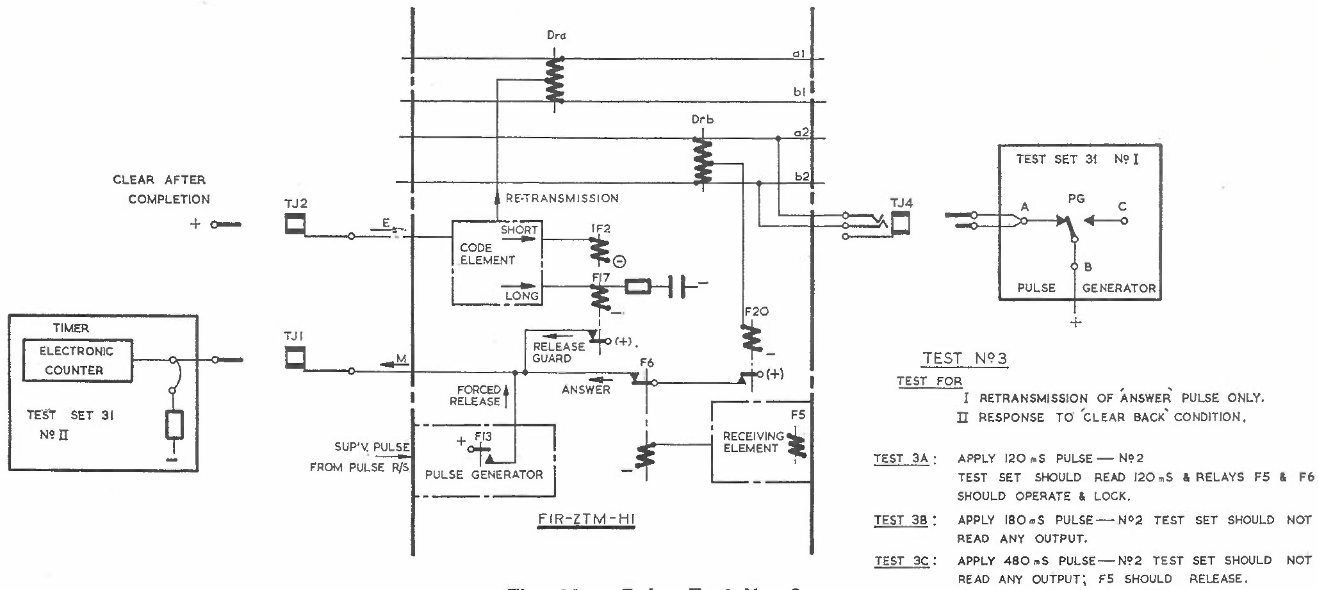

Fig. 44. — Pulse Test No. 3.

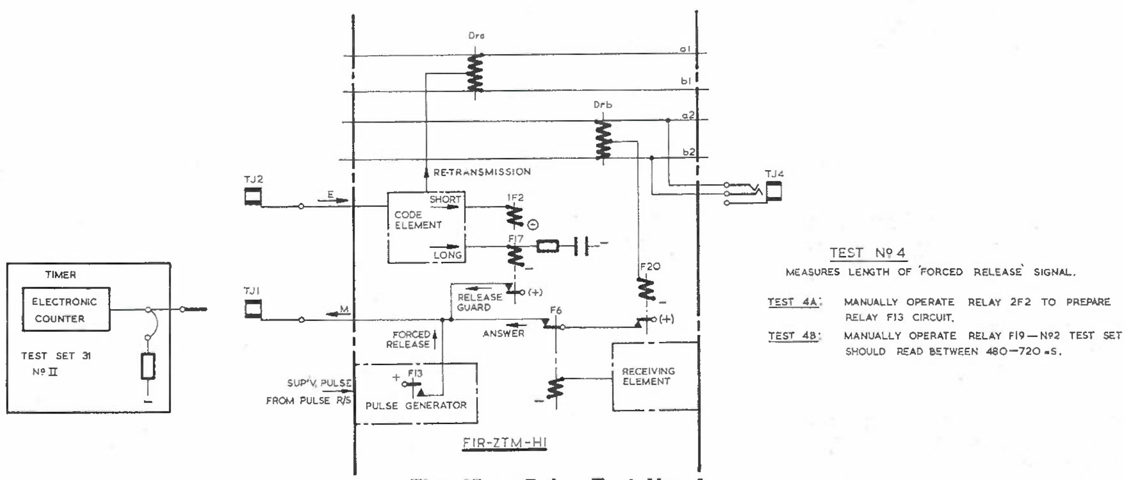

Fig. 45. — Pulse Test No. 4.

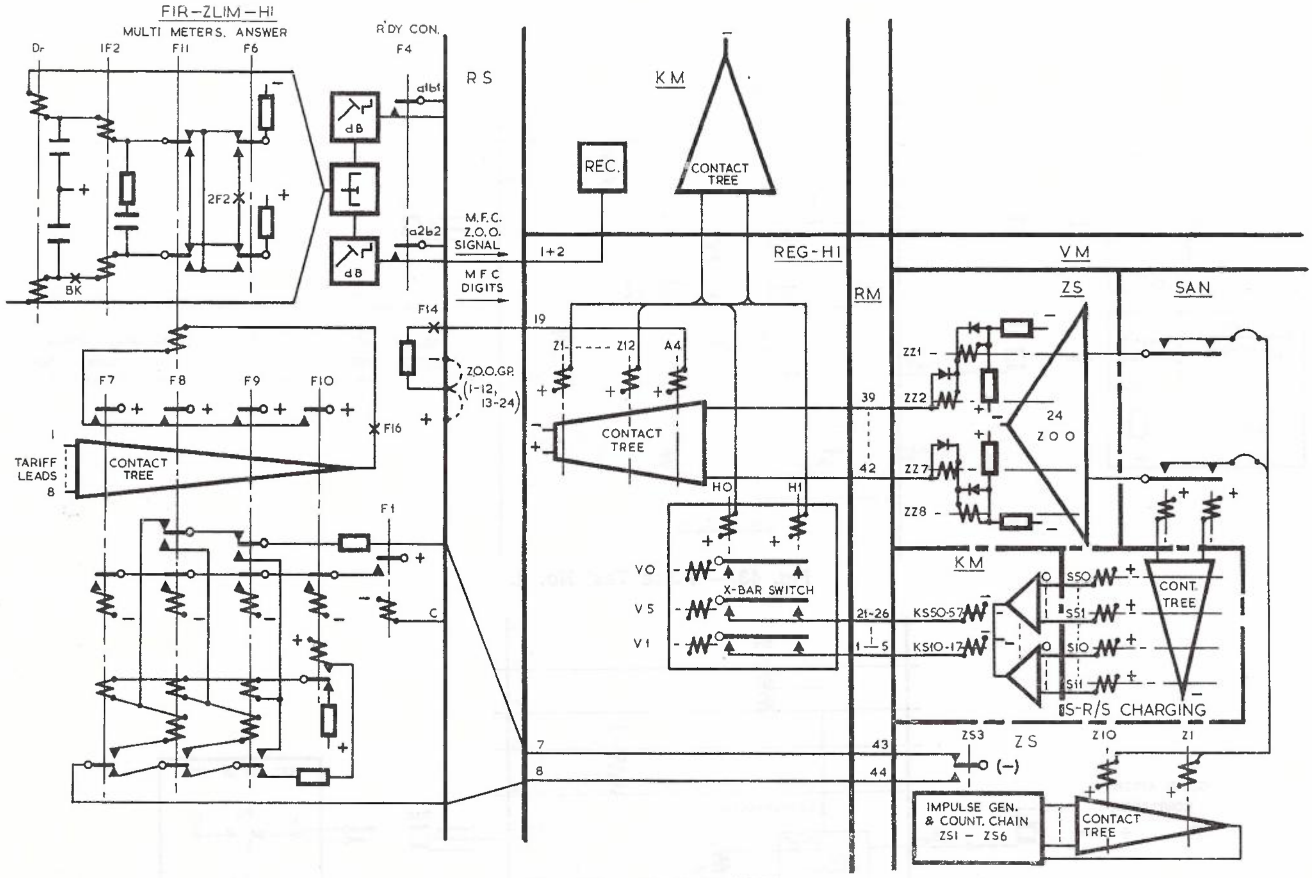

Fig. 46. — Tariff Setting.

Fig. 40 shows the schematic circuit of, as well as timing diagrams, for the code element. The circuit operation is as follows:—

Rejection of Spurious Pulses: +ve on the "E" lead operates F21, which operates F22,

F22 operates F23, which releases F22 slowly. F25 controls all outputs from the code element and F25 is operated only when F22 has released again. Thus the 60-90 ms release lag of F22 prevents any output from the code element unless F21 remains operated for longer than this period.

Discrimination between Short and Long Pulses: F22, when operating after F21, operates F24. After the release of F22, F24 releases slowly (300 ms approx.)—because of the capacitor. If F24 is still holding when F23 releases, it is re-energised from F25. At the same time a "Short Pulse" output appears. If F24 is released when F23 releases, F25 cannot hold or re-operate F24 and a "long pulse" output appears.

Correction of Short Pulses: The operation of F25 provides retransmission of the signal. F23 operates F25 when F22 is released and F25 releases F26 which was previously operated by F21. F26 holds F25 operated via its own contact. The combined release lags of F25 and F26 are 150 ms. Thus provided F21 is operated for less than 200 ms approximately, F23 is released when F26 releases and F25 operates for 150 ms. The same occurs if F21 is operated for only 100 ms as F25 is controlled by F26.

Lengthening of Long Pulses: If F21 is operated for approximately 500 ms, F23 will be operated for the same period. F23 allows F24 to release, and with F24 released the release lag of F25 is increased to 150 ms approx. Thus F25 will be operated for 570 ms or 70 ms longer than the incoming signal duration.

Where line signals are received through the ARM exchange, no screening for spurious signals is necessary, nor is re-transmission required. In this case, a much simpler "receiving" element is used.

Fig. 41 shows the circuit and timing of the various relays. The capacitor is normally charged with F1 and F20 operated. When F20 releases for 150 ms, F5 will operate and hold to the charge until F20 re-operating locks F5 via its own contact. If F20 releases for 600 ms, the capacitor will discharge through F5 and the relay will release before F20 can re-operate and lock F5.

The timing of the relays in the code and receiving elements is critical and all line relay sets are "pulse tested" prior to any other functional testing.

Pulse Testing: Installation staff at Lonsdale developed a pulse testing guide which specifies certain test setups and procedures (see Ref. 3). Figs. 42-45 detail these tests. The limits laid down are the nominal pulse lengths ± 20 per cent. If test specifications are not met, re-trimming of certain relays is necessary. Most of the relay set faults that exist in new equipment are found during this procedure and only few faults are located by functional testing.

Tariff Testing.

Tariff Determination and Setting (see Fig. 46): The ARM exchange is capable of determining the charge rate for any call by relating the 'B' address to a subscriber's zone of origin. Meter pulses are transmitted from FIR-Z's in accordance with the rate set.

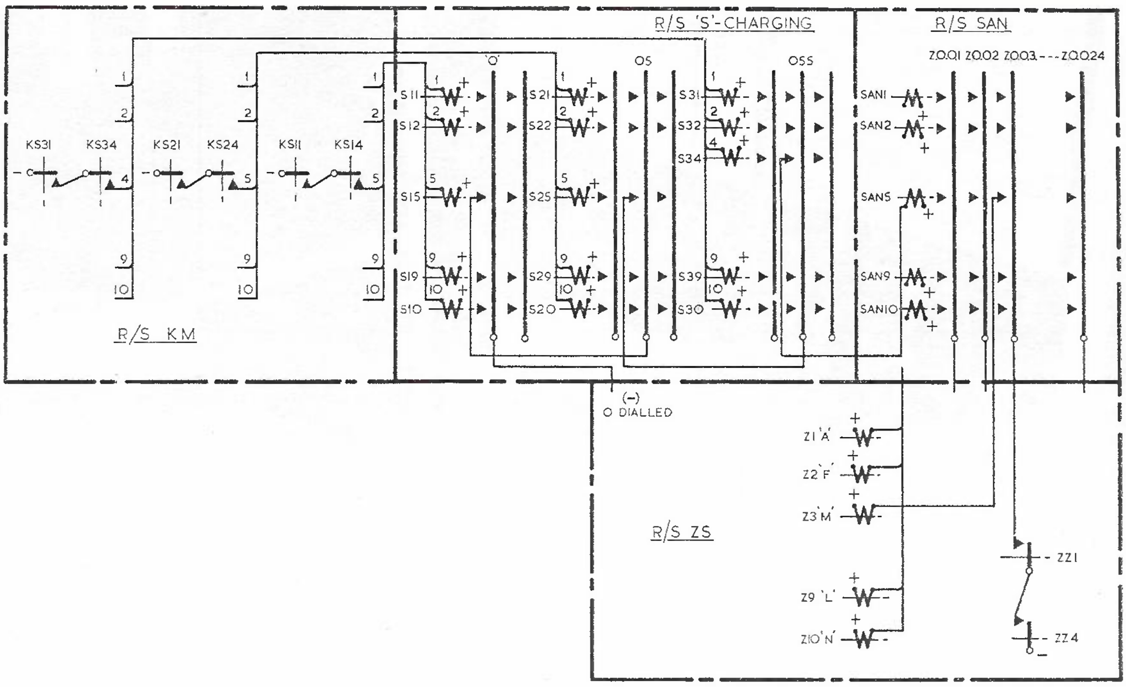

Fig. 47. — Operation of Call Charge Relays During Call from Geelong (Z.0.0.3) to Colac (0554).

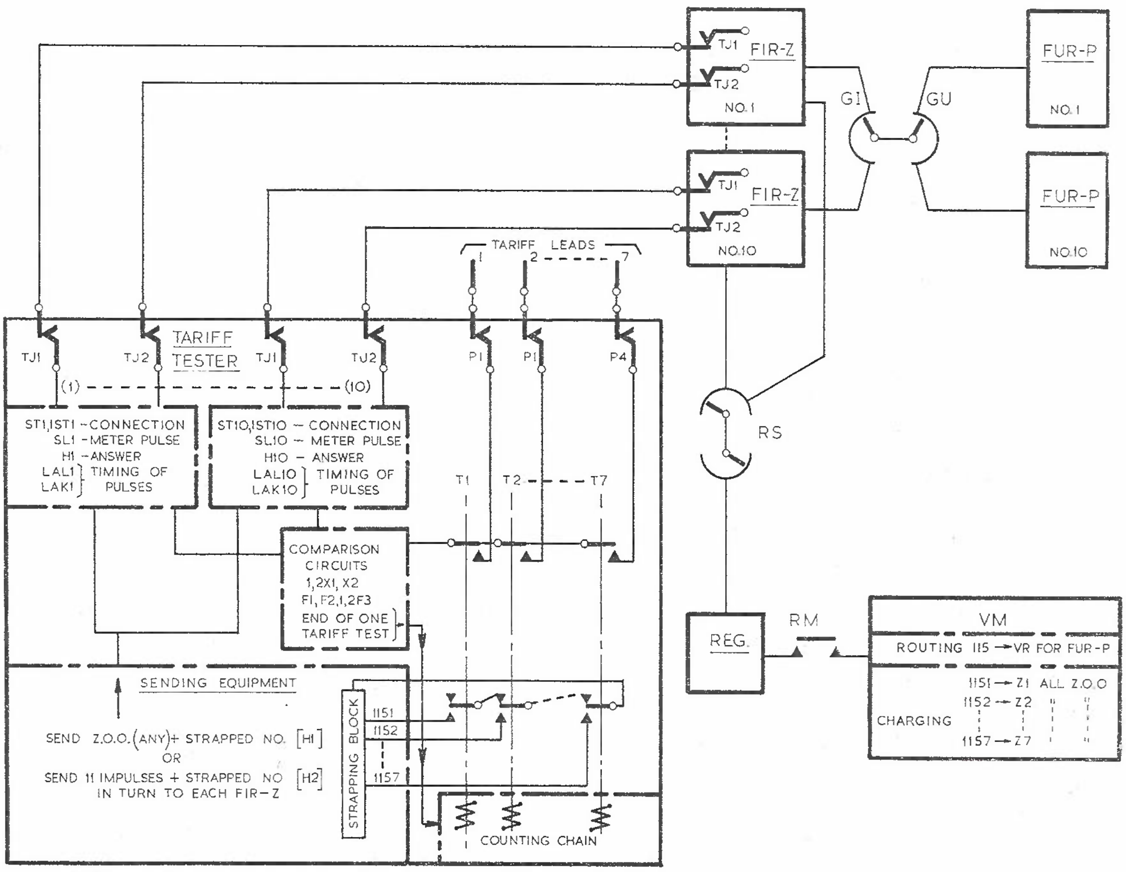

Fig. 48. — Auto Tariff Test.

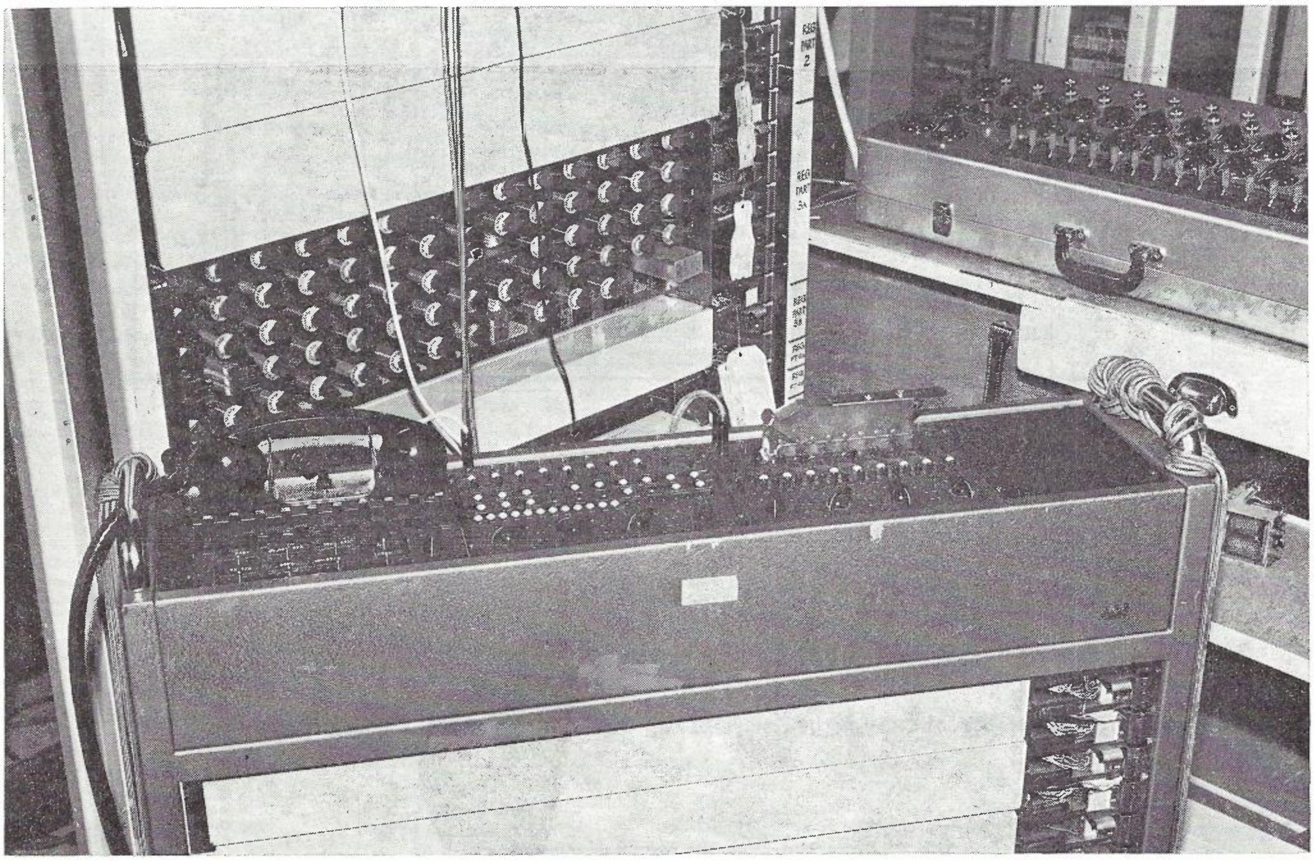

Fig. 49. — ARM Tariff Tester.

The FIR-Z, when seized, from the originating exchange, will connect to a free register via the RS stage. The register will receive the originating charging zone number (Z.O.O. digit) and the wanted 'B' party's number. When sufficient digits for routing and charge determination have been received, the register calls for a free route marker (VM) and forwards the zone of origin and the 'B' number to the VM. The zone digit is stored on ZZ relays in the ZS relay set, while the 'B' number, after decoding in KM, is stored in the S relay sets, with one S relay set each for routing and charging. The S relay set for charging is strapped up for each possible code and two SAN relays are operated when a particular code is received. The SAN relays have 24 make contacts representing 1-24 zones of origin. With a negative extended to the appropriate SAN contact strip via a ZZ relay contact tree, Z.O.O. and 'B' number are related to arrive at the correct charge rate for the call (operation of relays Z1-Z10 in ZS relay set).

Fig. 47 shows, in greater detail, how the Z relays are operated. When a Z relay has operated, an inter-action is set up in relays ZS1-ZS6 under control of the particular Z relay.

Negative is connected alternatively to wires 43 and 44 towards RM. These negative pulses pass through the register and are counted on relays F7 to F10 in the FIR. The appropriate combinations are as follows:—

Z1 — F7
Z2 — F7 and F8.
Z3 — F8.
Z4 — F8 and F9 .
Z5 — F9.
Z6 — F10.
Z7 — F10 and F7.
Z8 — F10 and F7 and F8 (not used in A.P.O.).
Z9 — F10 and F8.
Z10 — Nil operated.

When the connection through the exchange is established, F1 operates during the "c wire control test" and locks the combination of F relays operated, prior to the release of the VM.

Tariff Testing on FIR-Z's: One of the standard L.M. Ericsson testing aids, supplied with each ARM exchange is the tariff tester. This device simulates a distant originating exchange and can interwork with all types of ARM FIR'S and registers.

A block schematic survey diagram of the tariff test is shown in Fig. 48. The tariff tester is connected to 10 FIR-Z's simultaneously. The FIR's must all be of the same type and must be mounted on the same rack. The tariff tester is capable of setting up seven different pre-strapped numbers in sequence via these FIR's. To facilitate auto testing the 115X codes were allocated, on a trial basis, to the different rates in the VM strapping, for tariff testing purposes, with test calls routed to a group of 10 answering bases (FUR-P) on code 115. When testing to REG-H1 the tariff test proceeds as follows:—

The tariff tester seizes FIR No. 1.

The zone of origin digit and code 1151 are transmitted to REG-H1. This will cause a connection to be set up to FUR-P No. 1.

When answer is received and recognised in the FIR and transmitted to the tariff tester the call is held and FIR No. 2 is seized.

Code 1151 is again transmitted and this process continues until a call has been set up via all 10 FIR's.

The regular meter pulses, which should be received at the "A" rate in the tester, are compared with the "A" rate pulses from the rack supply.

If pulses received from the two sources are co-incident and are of correct length (150 ms), the tariff test

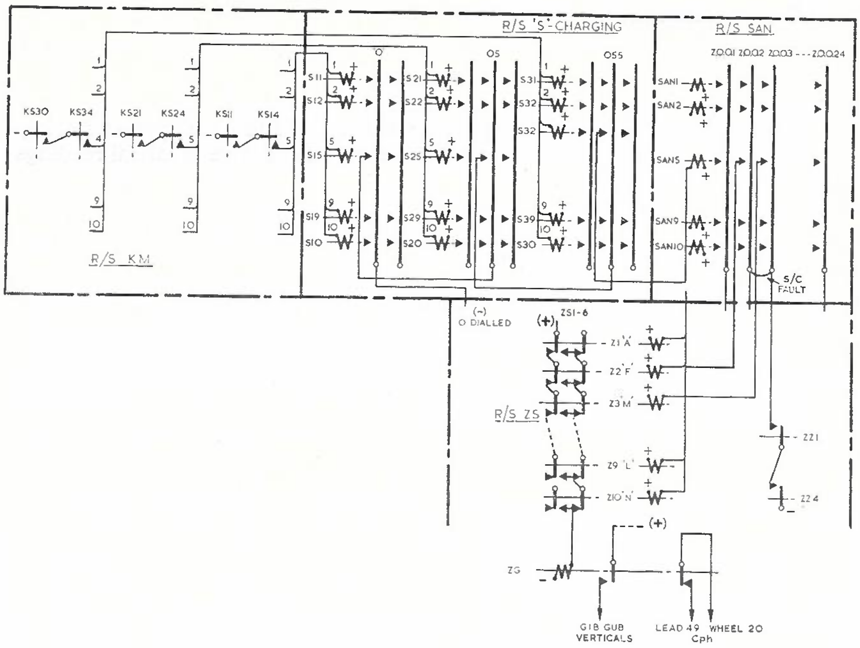

Fig. 50. — Cph Printout of Tariff Strap Fault.

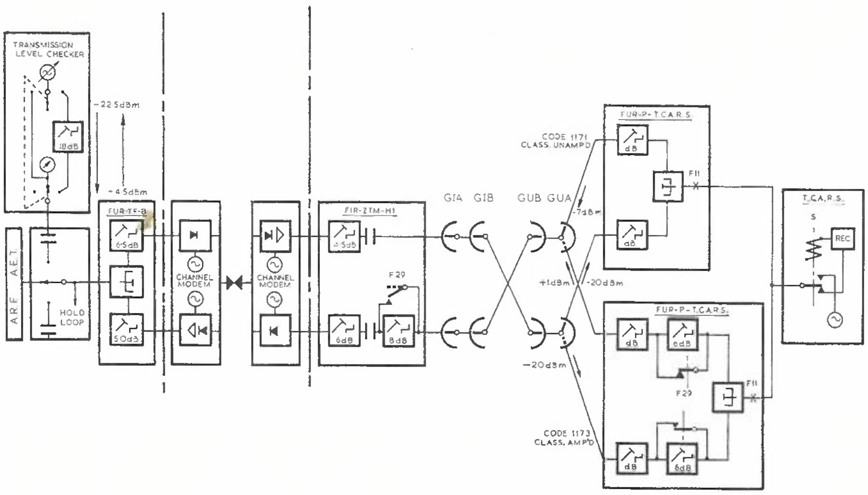

Fig. 51. — Test Codes 1171 and 1173.

of the "A" rate is completed. The T chain is stepped-on, T2 operates and all FIR's are released.

10 calls to code 1152 are now set up. These calls are again terminated on the same FUR-P's, but the "F" rate is now set in the FIR'S. The rack supply pulses are again compared with those received from the FIR's and step-on to testing the third charge rate occurs.

After checking the seven tariff rates successfully, the end of test signal is given and the tester is now set up on 10 different FIR's.

Testing via REG-H2 is similar, except that decadic pulsing is employed and digit re-insertion must be cancelled by transmitting a train of 11 impulses.

The automatic tariff test checks—

That the VM can correctly set the charge in each FIR, and

That the FIR's transmit meter pulses in accordance with the set rate.

Fig. 49 shows the tariff tester. Keys, lamps, etc., can be clearly seen.

Tariff Setting Supervision: The above tests do not, in any way, check the charge strappings in the VM, which have been tested at the installation stage by means of the manual strapping tester. To maintain an automatic surveillance of these strappings, the maintenance staff at the North Melbourne ARM have developed a modification to the VM to enable it to call the Centralograph when a no-charge or two or more charge rates have been set.

This check is achieved by the addition of a simple "one and only one" contact chain on Z relays to prevent the connection from being completed and to give a characteristic "charge fail" Cph print, when none or two Z relays operate (see Fig. 50). The print is characterised by the fact that the figure "9" appears in both the M and VM lines. When such a failure occurs all relevant details, e.g., REG number, FIR number, VM number, digits dialled, etc., are printed and lead to a quick location of the trouble. When additions or alterations are made to the charge analysis strappings they are again tested by means of a manual strapping tester. Most tariff faults that develop later are detected by the Cph, as is borne out by the very low level of metering complaints at North Melbourne ARM.

ARM Test Numbers.

For testing of circuits incoming to the ARM from other exchanges a range of test numbers has been provided. These test numbers fulfil various functions as outlined in Table 3.

Test Code 1171 and 1173 (see Fig. 51): These test codes have been provided for transmission and pad switch testing in the ARM. Outlets on both routes are connected to a test call answer relay set (TCARS) and thereby the following checks can be carried out:—

A testing officer calls 1173, which is classified as an amplified outlet. In our example the call was made via a carrier circuit and therefore the ARM register will not transmit a pad switching pulse. The testing officer now checks the transmission equivalent in both directions by means of the transmission level checker — for detailed description of this type of equipment see Ref. 4. In our example, the testing officer would read a far end receive level of –0.5 dBm on the red scale and a near end receive level of –4.5 dBm on the black scale. He notes these readings and releases the call.

A call is now set up via the same circuit to code 1171. This outlet is classified as unamplified and accordingly the register transmits a pad switching pulse. This will operate F29 in the FIR, thus removing the 8 dB pad. The TCARS reached via code 1171 triggers at –20 dBm, but transmits a level of –7 dBm instead of +1 dBm. If the pad in the FIR has been correctly switched out, the readings obtained by means of the transmission level checker should be identical to those obtained previously. This checks the pad switching function of registers and the FIR.

TABLE 3 — ARM TEST NUMBERS.

Test Number	Classification in VM	Tariff Set	Function
1171	Manual unamp.	L	Used in association with transmission test to 1173 to check pad switching. Tests to 1173 and 1171 via the same circuit should give identical readings at the originating end.
1172	Manual amp.	L	Call Manual Test Position to meet testing officer.
1173	Manual amp.	L	Transmission and Poling test.
1174	Manual unamp.	Y	Functional testing of S.T.D. equipment in terminal exchanges.
1175	——	L	Testing of correct return of congestion conditions from ARM exchange.
1176	Manual unamp.	A-N	Access to tariff route, i.e., same as 1151-1150, gives "Answer" condition and "Route Failure" announcement.

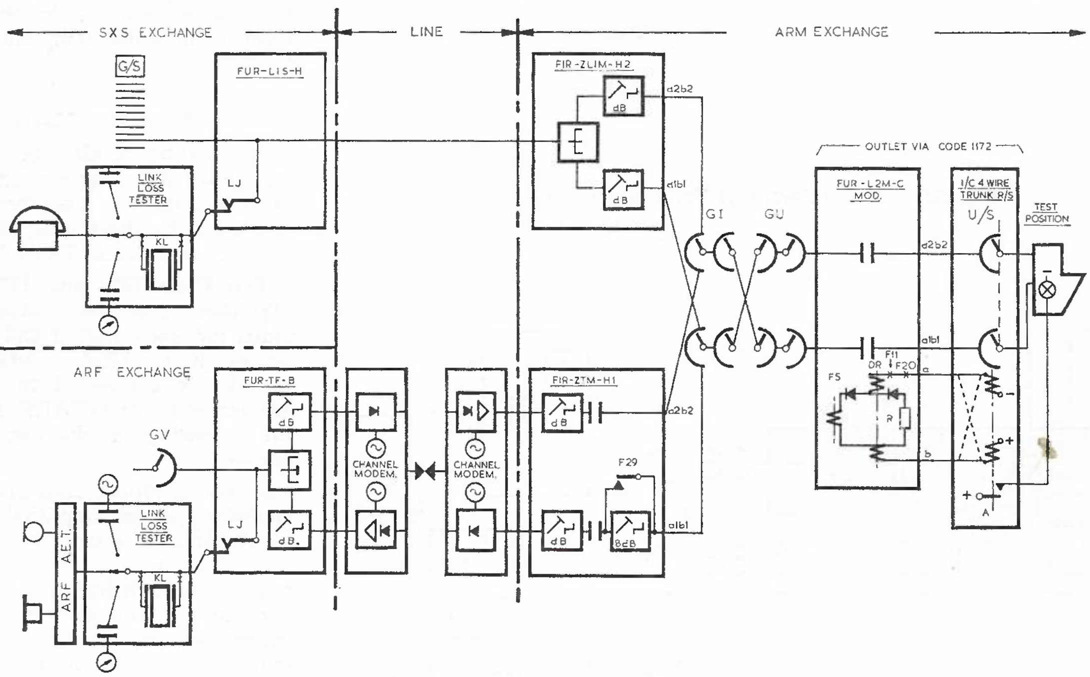

Fig. 52. — Test Code 1172.

As the FUR-P-TCARS relay sets connected to these outlets contain hybrid transformers, correct poling of the a1, b1 and a2, b2 wires is checked. These two test codes therefore test for the following:—

Transmission Equivalent.
Correct Pad Switching.
Poling of the Speech Wires in the ARM exchange.

Test Code 1172: This outlet is provided to call the manual test positions in the ARM (see Fig. 52). The outlet is classified as amplified and pad switching does not take place if incoming carrier circuits call this number. When the connection through the ARM is established, a modified FUR-L2M-C is seized, which loops forward on the a and b wires to the incoming 4-wire trunk relay set. Relay A, in operating, lights the "incoming call waiting" lamp on the test position. The testing officer at the position operates the "incoming 4-wire trunk" key and this causes the uniselector to find the calling line.

Test Code 1174: Outlets reached via code 1174 provide the following facilities (see Fig. 53):—

The answering base provides the sequence required by traffic route testers, and therefore serves as a TRT terminating base.

If charging takes place, the tariff is set at Y rate for metering checks.

The circuit is returned to the unanswered state after approximately eight seconds, and serves to check time-out conditions on FIR's.

When the self-answering relay set (modified FUR-L1M-C) is seized, the call is answered after a delay of four seconds, when F2 releases and reverses the line potentials. After release of F3 the line potentials are returned to normal (clear back condition), and 820 Hz tone interrupted at 1.5 second intervals is connected. During the period between the release of F2 and F3, a record announcement identifying the ARM exchange is transmitted. A typical functional test can thus be carried out on a FUR-L1S-K as follows:—

Dial 5 followed by 11 impulses to cancel 05 previously inserted into REG-H2, and finally code 1174.

On answer, the FIR-ZL1M-H2 will re-transmit the answer condition and then metering reversals at the Y rate. These conditions can be monitored on the test set at the terminal.

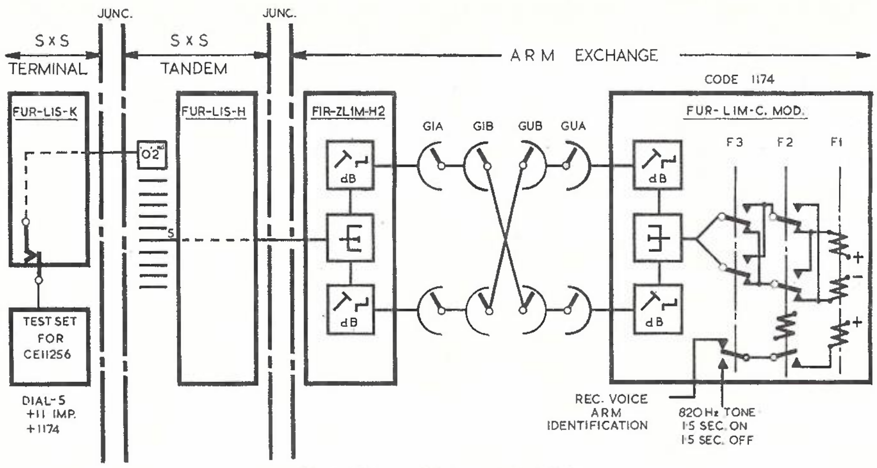

Fig. 53. — Test Code 1174.

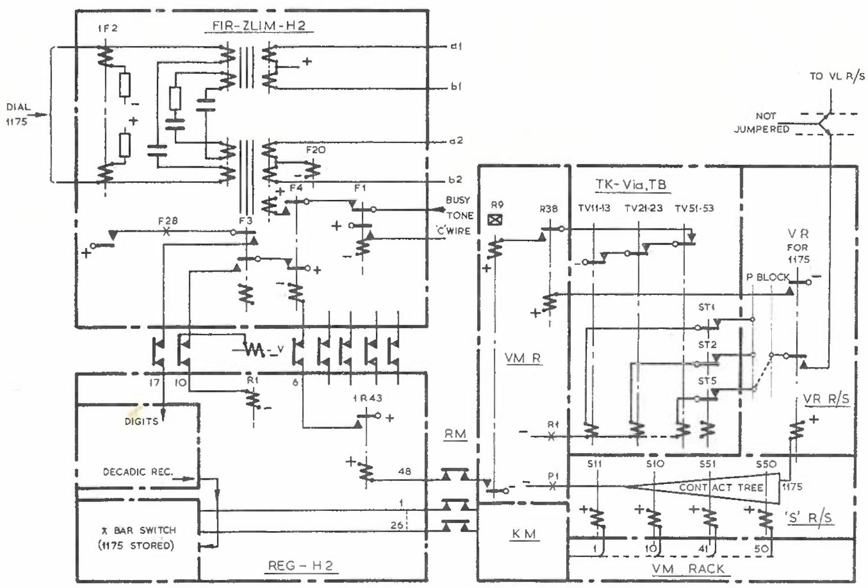

Fig. 54. — Test Code 1175.

Holding the call will result in a "forced release" condition being applied backwards from the ARM after 72-144 seconds.

Code 1175: This test code is provided to check that congestion conditions are correctly returned by the ARM in one of two ways:—

With MFC signalling, A3 + B4 are returned.

With decadic signalling, busy tone is transmitted from the ARM FIR.

The survey diagram in Fig. 54 shows that code 1175 is strapped to operate a VR relay. However, as there are no outlets allocated to this code the TV relays in the VM will not operate, and after the operation of R9 in relay set VMR congestion will be signalled to the register by operating relay 1R43. 1R43 will operate relay F4 in the FIR, releasing the register, and causing busy tone to be transmitted from the FIR to the 'A' party.

Commissioning and Maintenance of Echo Suppressor Pools.

The ARM20 system provides the facility of switching A-end and B-end echo suppressors into the circuit, should the overall connection exceed 2400 miles in length. The echo suppressors are concentrated in pools and use is made of re-entrant trunking. If, within a particular ARM, an echo suppressor is required, the call is routed from a FIR to a SNA-ES with the echo suppressor attached, and from there again through the ARM switching stages to an FUR on the wanted route. A fairly complex MFC signalling scheme had to be introduced to cater for these requirements.

Fig. 55 is a survey diagram of installation tests to be performed on the SNR-ES rack to prove that all functions of these devices are performed correctly. Under service conditions, automatic testing of the signalling and switching functions was designed to check the following:—

Register functions in regard to echo suppressors and special MFC signalling.

SNR switching.

That echo suppressors are not locked in a suppression mode.

The gain of amplifiers in the SNR-Es relay sets.

Fig. 56 shows how the TCARS can be reached from an originating FIR through A-end and B-end echo suppressors in tandem. Code 117X is allocated as the echo suppressor test code. This route is established with one circuit only. This circuit is a re-entry connection leading back into another ARM register. Code 117X overflows to the TCARS on code 1173. Thus when the call is switched via the B-end echo suppressor the single outlet available via 117X is busy and the call is terminated in the TCARS. The MFC signalling sequences are also given in the surveys. Fig. 56 shows the process with REG-Y1 (the feature is called for by code 13) and Fig. 57 shows the sequence when a call is set up via an H1 register (REG-KV analysis initiates ES switching).

COMMISSIONING AND MAINTENANCE OF OUTGOING CIRCUITS.

Commissioning Tests.

All circuits outgoing from the ARM are tested prior to placing them into service. These tests consist of:—

Functional tests, including Pulse Tests.

Load Tests.

Transmission Tests.

Functional Tests: Pulse testing is carried out on each FUR prior to any other commissioning tests to check the code element and the associated relays: The pulse test guide describes these tests in detail for most common types of FUR'S, and the testing procedure is similar to that described previously for incoming circuits. After pulse testing and the establishment of connection to the distant end, functional tests can be carried out, using functional test procedures for all types of ARM circuits developed by installation staff at Haymarket ARM, an example of which is given in Table 4.

It should be noted that the impulsing test must include a read-out check at the far end to ensure the correct operation of the fixed-break impulse correctors in the FIR'S.

Load Testing by means of the Tariff Tester: When all circuits on a given route are operational, load testing is applied as in Fig. 58.

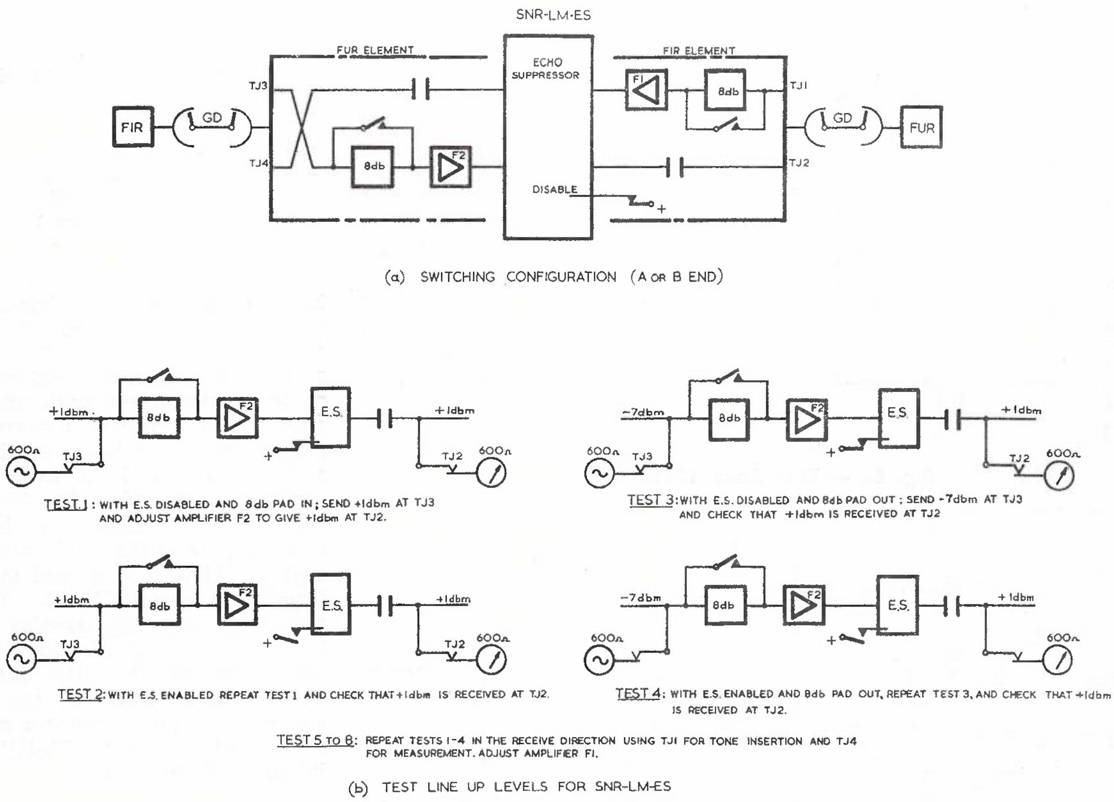

Fig. 55. — Installation Tests Performed on Echo Suppressors.

The tariff tester has been modified for this purpose to function as an exchange tester, which involved the inclusion of a "repeat after answer" key allowing the tester to re-set when answer was obtained from the 10 FIR's connected. The tester can now also be used with FIR-TM-Y1 relay sets. Statistical meters were provided to allow recording of the call details. In the different centres self-answering circuits, such as time, weather, sporting results, etc., can be used for this purpose.

If such service codes are not available, special groups of telephones must be provided in smaller exchanges using a PBX group (as shown in Fig. 58). and a technician must manually answer the calls as follows:—

All lines on the route except 10 (maximum) are blocked.

The tariff tester is connected to 10 FIR's and is started.

The first call will be connected to the first telephone at the far end where the technician lifts off and hangs up again.

The tester, after sensing "answer," holds the call and originates the next call via the second FIR.

The second telephone is rung and answered.

This process continues until 10 calls have been connected through the route under test to 10 lines in the test exchange.

This procedure checks that all FUR's can be picked up correctly through the exchange equipment, whereas functional testing via test jacks only proves the functioning of the FUR.

Transmission Testing: Transmission commissioning tests have already been adequately described in this Journal (see Ref. 5).

Maintenance of Outgoing Circuits ARM Test Access: The current policy is not to install jack type trunk test boards at carrier terminals because:

Signalling systems have become too complex to be simulated from a trunk test board, inserted between a line relay set and the transmission medium.

A complex and important part of the circuit, namely, the outgoing relay set, is bypassed in any tests performed via trunk test boards.

Therefore the trunk test boards have been replaced with automatic test access equipment, which allows a testing officer, situated at a centrally located console, to connect himself to any desired outgoing circuit via the FUR.

Fig. 59 shows the trunking diagram of the ARM test access system. Equipment necessary to connect the test console to lines outgoing from an ARF exchange in the same building is also shown. This allows the ARM testing officer at the ARM test console to test all circuits outgoing from the particular building, and is particularly suitable for country areas, where all exchanges in a building are under the control of one Supervising Technician. The ARM test access system, already described in Ref. 6, provides the following facilities:—

Pick-up and signal through any type of outgoing relay set. A special test access register has been developed which can send MFC or decadic signalling under control of instructions from the trunk test console.

Speak 4-wire over the circuit.

Monitoring equipment for the line signalling leads (see below).

Blocking of circuit under test with fault and occupation lamp indications appearing on the console in lieu of the remote blocking rack.

Equipment to send tones of 200, 300, 400, 600, 820, 1600, 2400,

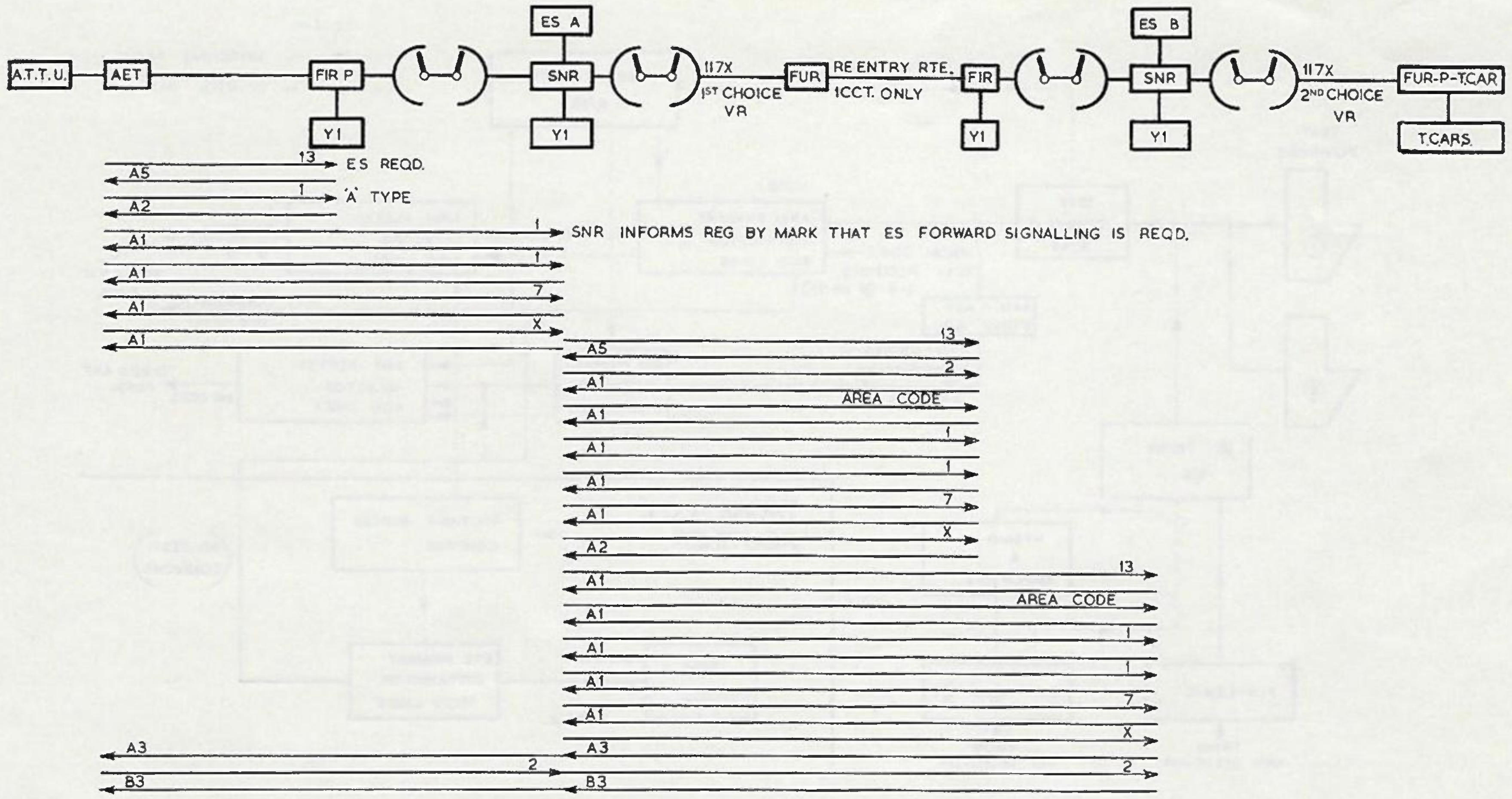

Fig. 56. — Automatic Testing of Echo Suppressors — Reg. Y1.

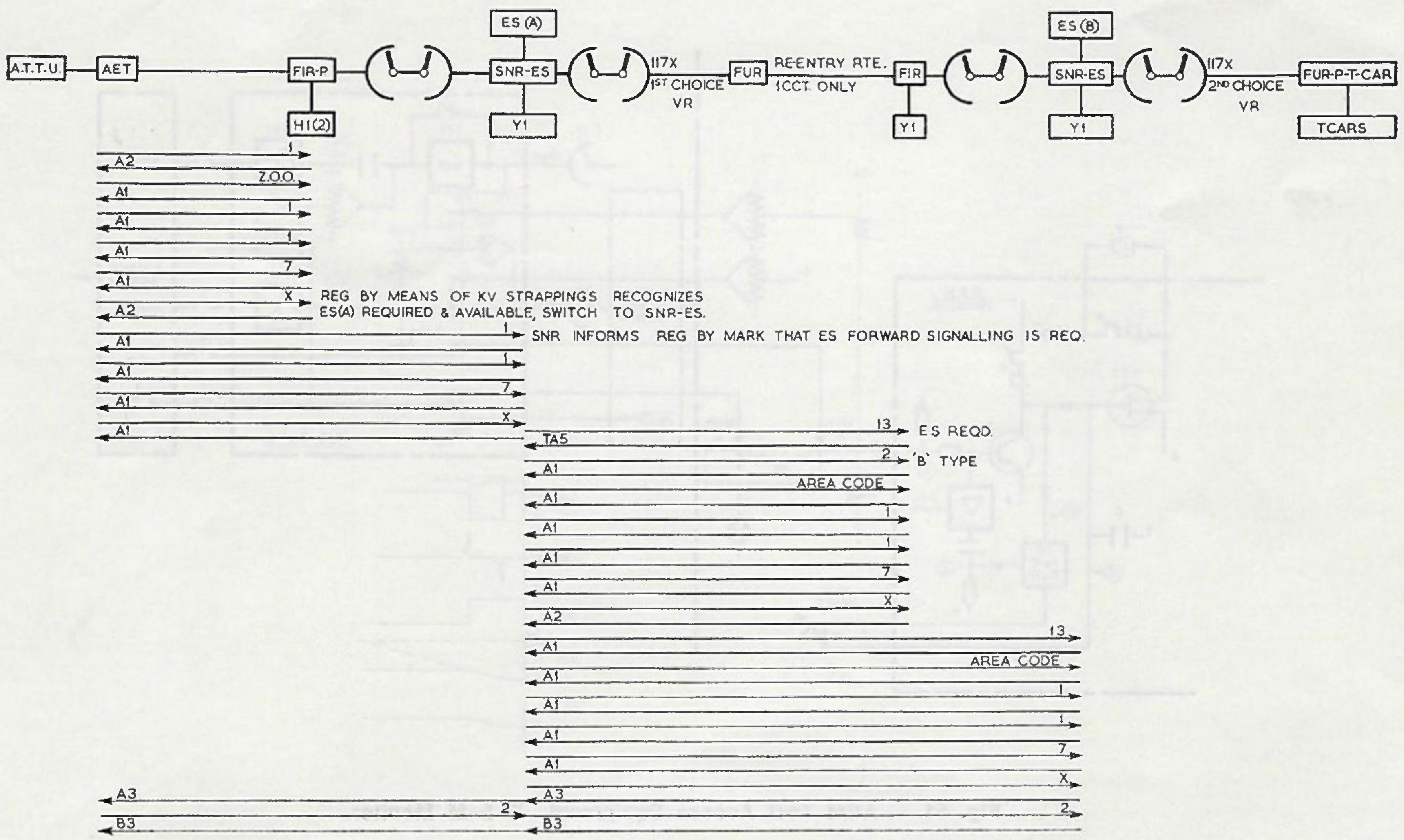

Fig. 57. — Auto Testing of Echo Suppressors — Reg. H1.

TABLE 4 — FUNCTIONAL TESTS ON OUTGOING CIRCUIT.

No.	Test	Method	Observation
1	Idle Condition	——	Check all FUR relays are in the released condition.
2	Seize Forward (S x S routes)	Use Test Box	Check F20 operates. Check F17 operates and then releases.
3	Pulsing S x S routes)	Use Test Box	Check F20 releases and operates in step with the pulses.
4	Seize Forward and Information Signalling) (mfc routes)	Use AET	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 hang-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 & M leads O/C) and both ends clear	Check F19 operates and after time supervision pulse, check F17 operates and releases, followed by the release of F16 and F13.
		Allow FUR to repeat sequence, then restore channel.	Check FUR and distant end equipment clear, after time supervision period. Check BL lamp on FUR rack for full glow flash.
13	Busy Tone (S x S routes)	ARM makes call and D/E Tech. to force selector to 11th step.	Check for busy tone.
14	Deleted		
15	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.
16	Impulsing	(a) Connect test set No. 31 to TJ4 of FUR-TM-C. (b) Connect radio test set No. 30 to TJ3 of distant FIR. (Note: Calibrate test set 30 as per instruction on panel. Operate F3 to obtain short circuit loop.) (c) Set test set No. 31 to send continuous pulses. (d) Send continuous pulses from test set 31 at 10 pulses per second. Record reading on Test Set 30. (e) Reading must be 34-38% make under this condition. If the readings are out of limits the fixed break corrector in the FIR should be investigated.	

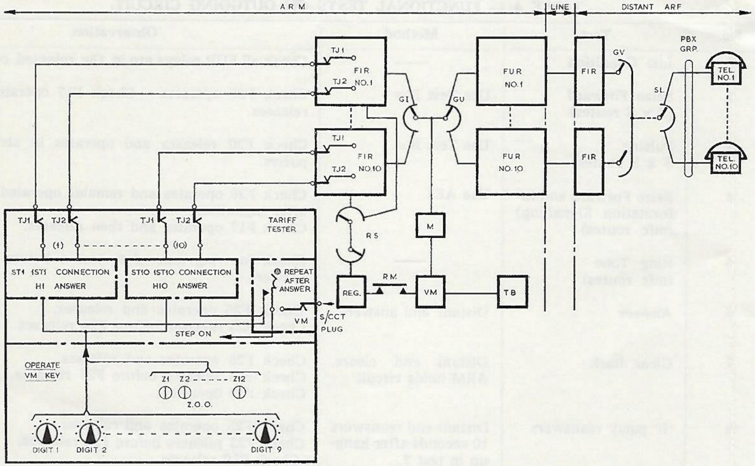

Fig. 58. — Load Testing with Tariff Tester.

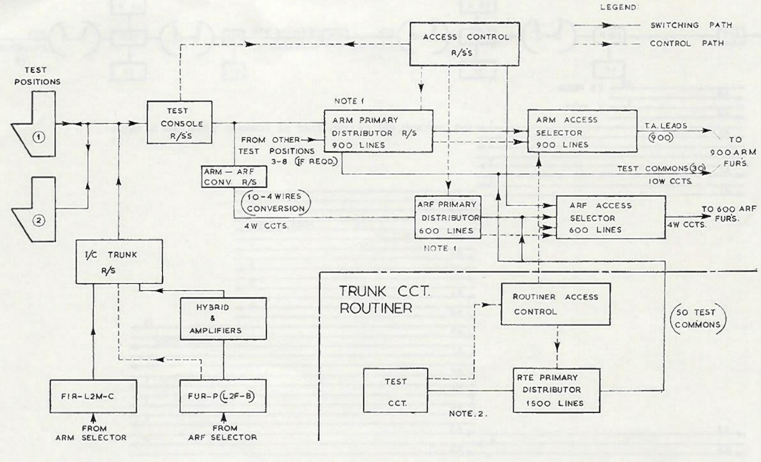

Fig. 59. — ARM Test Access — Trunking.

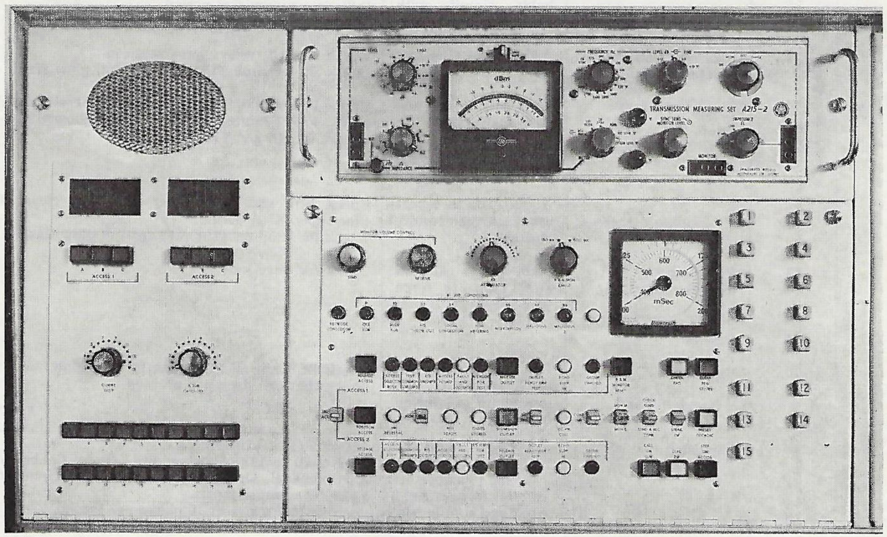

Fig. 60. — ARM Trunk Test Position.

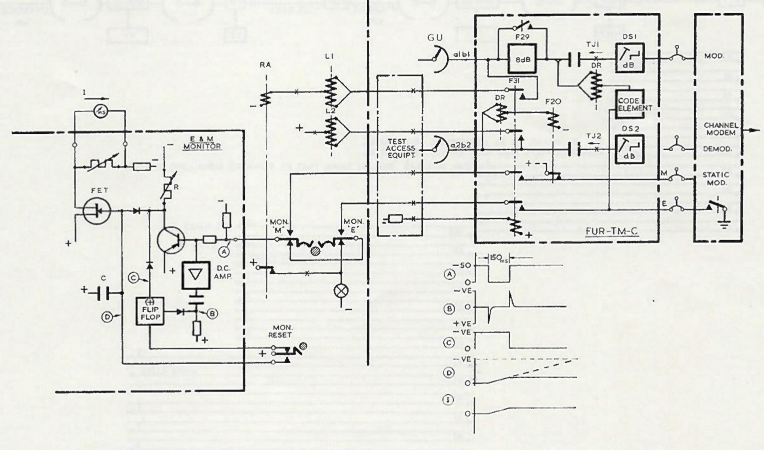

Fig. 61. — ARM Test Access Equipment. E & M Monitor.

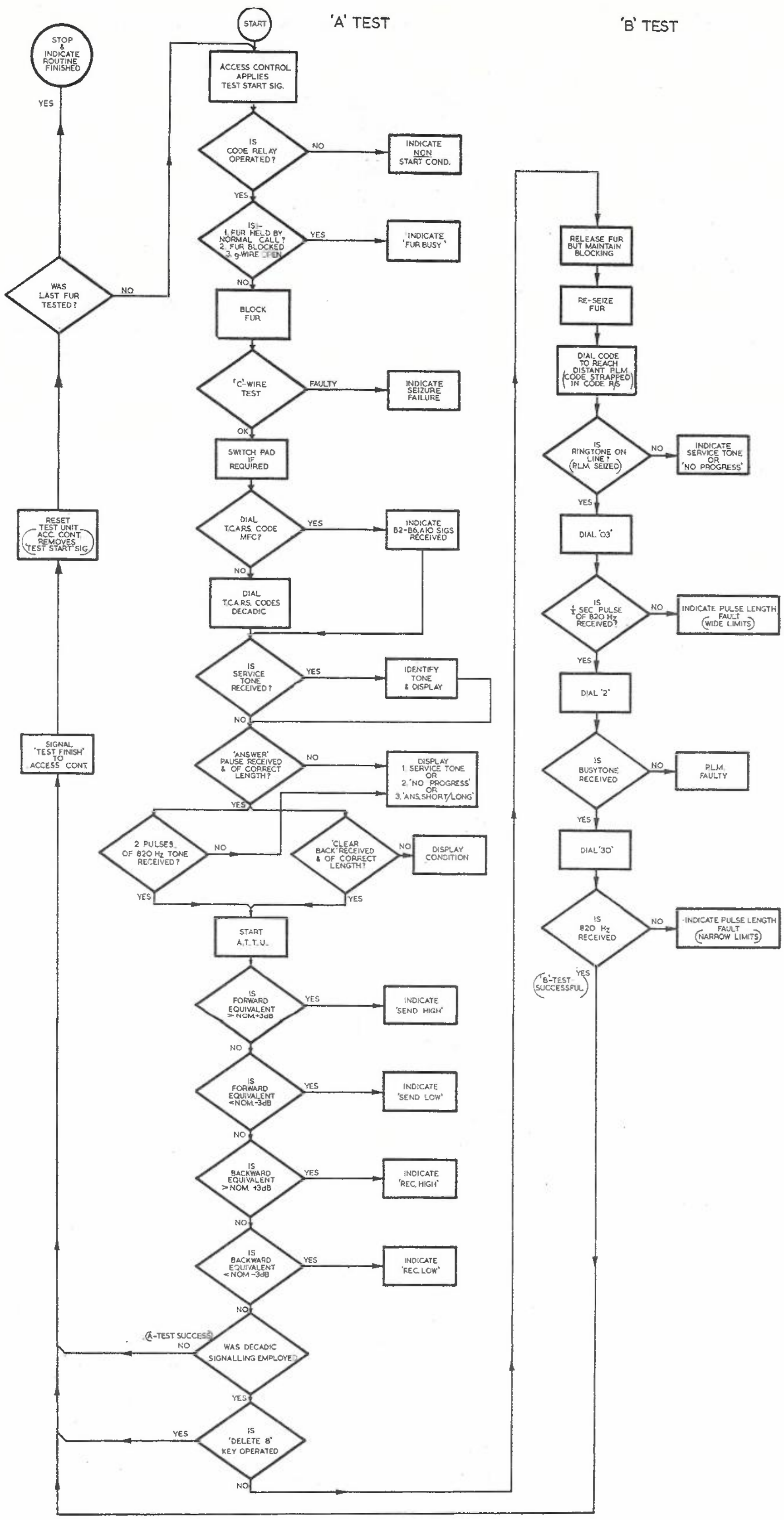

Fig. 62. — Flow Diagram of Trunk Routiner Test Functions.

2600, 3000, 3400 and 3600 Hz at any required level. The 8 dB switchable pad in the relay set can also be switched from the test console.

Equipment to receive and measure VF tones in the range of –50 dBm to +20 dBm, with facilities to make a return loss check.

Special access jacks to permit connection to the test common, of any special test equipment which may be needed to test a circuit.

Order wires as required.

A monitor amplifier and speaker.

Fig. 60 shows the control panel of one test position. The provision of a 270 degree meter, calibrated in milli-seconds, will be noted. This meter is attached to an electronic E and M monitor, developed by maintenance staff at Haymarket ARM, to provide a ready means of measuring the length of line signalling pulses on the E and M leads and the cailho of the a1, b1 wires.

The survey diagram in Fig. 61 shows the E and M monitor connected to a FUR-TM-C and ready to measure a 150 ms answer pulse. The pulse is received via the E lead by the code element and re-transmitted via the a1, b1 cailho. This causes RA in the test console to release for 150 ms, producing wave form A as shown on the diagram. The transistor is cut off, allowing capacitor C to charge through variable resistor R. (Wave form D.) The potential across the capacitor will be proportional to the length of the pulse. When RA re-operates, the transistor is made to conduct again and a pulse is transmitted to the flip-flop circuit (wave form B).

The flip-flop is triggered short-circuiting the transistor, and further pulses received will not register in the monitor circuit until the circuit has been re-set. The Field Effect Transistor, connected across capacitor C, senses the potential due to the charge and allows current to flow through the meter depending on this potential. As the voltage across the capacitor is proportional to the pulse length, so the current through the meter is also proportional to this time. The meter can therefore be calibrated directly in milli-seconds and gives a direct indication of pulse length.

The Automatic Trunk Routiner: Telephone Equipment Section, Headquarters, has developed an automatic trunk routiner for rapid in-service testing of all circuits outgoing from the ARM exchange. The routiner is able to test large numbers of circuits and indicate those in need of attention.

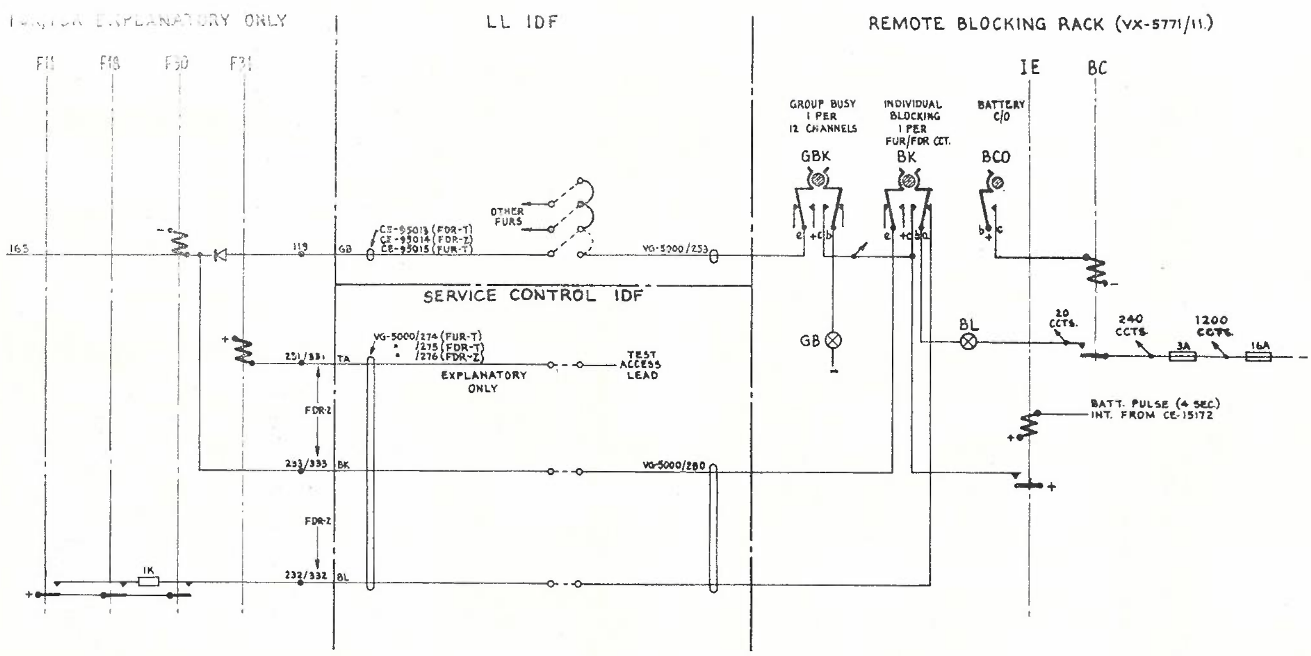

Fig. 63. — Trunk Circuit Supervision.

The flow diagram of the routiner operation is shown in Fig. 62, its mode of application and operation is as follows:—

Access Control:

The routiner has a capacity for 1500 R/S.

Shares the common access switches with Trunk Test Consoles, and tests for free conditions before seizing each access switch.

Records a busy access switch or a busy individual outlet after time-out period of 45 sec., and then steps on.

Can be "thrown-off" if access switch is required by a Test Console. On dialling a code should the access switch busy signal be returned, testing officer operates the "throw-off" key. If the access switch is in use by another console the busy signal will persist. Should the access switch be in use by the Routiner then the access switch is released and busy signal is removed. On releasing the access switch the routiner access control may:

Wait until "throw-off" key is restored at Console, seize the access switch when free and re-position to the outlet previously in use by the routiner and re-commence testing.

OR

Release the access switch and step to next access switch after recording that the access switch was seized by Trunk Test. Choice of (a) or (b) is by means of a key. Note: This facility was not provided on ARM test consoles.

Operates a code relay associated with the route served by the FUR. One code relay is provided for each group of FUR's serving the same route.

Relay sets serving the same route may be routined by operation of a master Route Control key and also the route key (press-button) of the route to be tested. Access control will step over any R/S not associated with the required group.

Can be used for Tone Tracing and will cycle over the R/S's until an FUR bearing "Trace Tone" is found. Control stops and indicates the R/S by means of the lamp display.

Incorporates the printer read out elements required for recording the access code, etc. One printer cct. is shared between up to 10 routiners and associated access controls.

Provides all normal facilities such as Continuous Routine, Re-set, Step-on, manually setting to any desired position under the control of keys, and a lamp display.

All keys and lamps required for the access control and test circuit are mounted on a Control Panel which is remotely located.

Complete circuit comprises 4 parts:
Parts 1 - 2: Access Control Circuit.
Parts 3 - 4: Connection of test commons.

Routiner Test Circuit:

General:

Brought into use by test start signal from access control and returns a test finish signal at the end of the test cycle on each R/S.

By means of the code relay operated at the same time as the TA relay, the Routiner is advised of the code to be sent and the transmission equivalents of the bearer, together with the type of distant exchange whether crossbar or step-by-step (a hybrid exchange is treated as a crossbar exchange or a step exchange according to the signalling used).

Seizes FUR's in cyclic order, unless route testing is required, if free. Should a busy be encountered the fact is recorded and access stepped to next outlet.

All faults, causing the routiner to stop, may be recorded before the access control is stepped. Time-out, with recorder in use, is 45 seconds.

Provides lamp display for faults—mounted on the remote Control Panel —and incorporates the read-out elements for recording the fault code.

If recorder is not switched in, it will stop and actuate the non-urgent alarm after a time-out of 60 seconds.

MFC signalling:

Will send up to 9 pre-strapped digits to gain access to a distant TCARS.

Employs a special test register, used only by the routiner, together with a standard KSR which is mounted on the KSR rack and wired direct to the test register. The test register employs MFC signalling only.

Will record as a fault if any other than a B1 signal is returned after code is sent. (Fault Code provides for B2-B6 and A10.)

Monitors the answer signal from TCARS. Two periods of tone, a 150 ms answer and 600 ms clear signal.

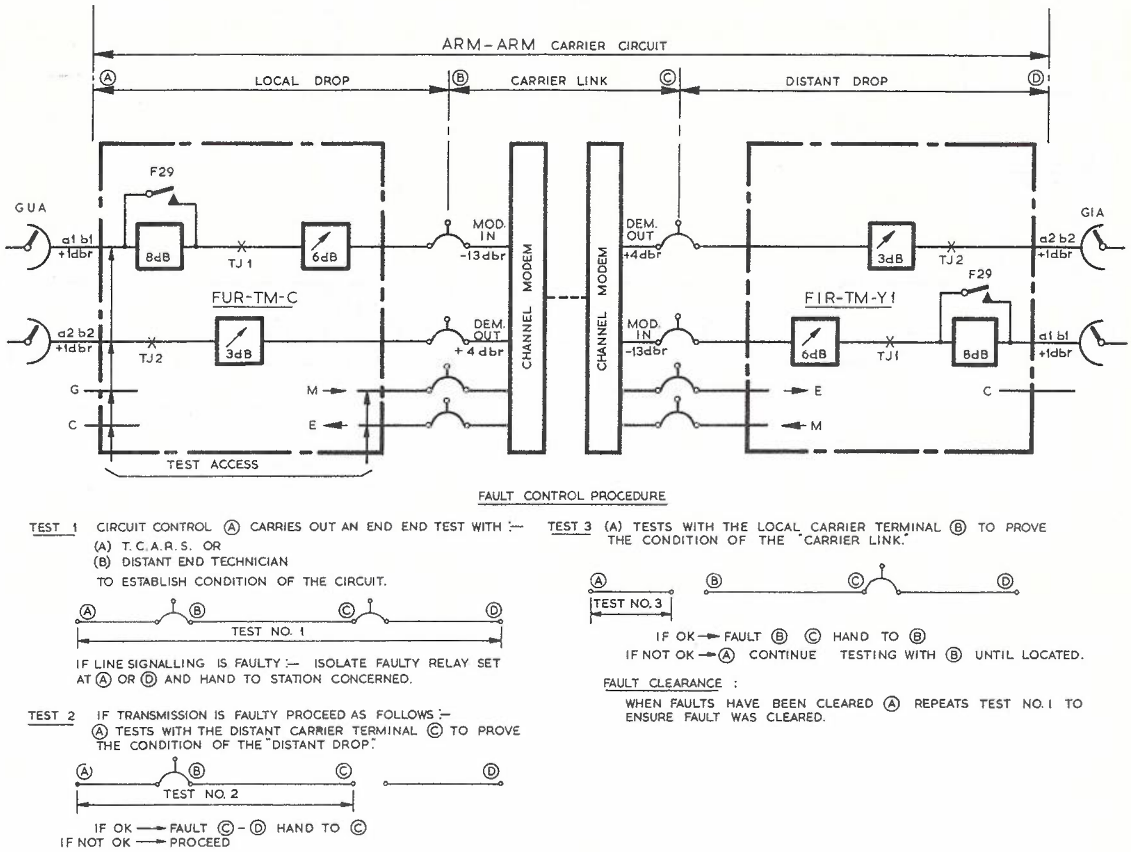

Fig. 64. — Fault Control Procedure.

Will record as a fault:—
- (a) Answer short.
- (b) Answer long.
- (c) Clear short.

Switches to transmission test at end of a second period of tone.

Carries out a transmission test in collaboration with the distant TCARS. Will record as a failure:
- (a) Send high.
- (a) Send low.
- (c) Receive high.
- (d) Receive low.

Transmission equivalent information is provided by the code relays.

On completion of a successful transmission test releases the FUR and provides the test finished signal.

Decadic Signalling:

Will send up to 7 digits pre-strapped on the code relays for access to a distant TCARS. The decadic signalling circuit is housed in the routiner and the test register is not employed.

Monitors the T.C.A.R.S. answering signal as in the MFC case. If answer signal is not received, will detect the returned tone as Busy or N.U. Absence of tone is also detected. Record is made and access stepped. (Tone detection takes place in 4.25 seconds.)

Carries out transmission test, then releases the connection. FUR is blocked to prevent seizure from traffic.

Re-seizes and sends up to 5 digits (the first 3 being common to the T.C.A.R.S. code) for access to a distant PLM.

Monitors the PLM answer signal, then sends the digits "03." Monitors the reply and if O.K. responds with the digit "2" to change the PLM limits. On receipt of the recognition signal, sends "30" as a final test. Records each step if a fault occurs.

Releases the FUR and returns the test finished signal.

Hybrid Exchange:

If MFC signalling is employed throughout, it behaves as explained previously under MFC signalling.

If decadic signalling is requested, it is advised by the test register regarding starting point for decadic signalling, then switches over to decadic signalling cct, releases the test register and sends decadic from the routiner.

Recognises the fact that decadic signalling was requested and follows on with a "B" test (PLM) after the transmission test as above in Decadic Signalling.

The routiner is also included in the trunking diagram shown in Fig. 59, and it can be seen that only the access selectors are common to both routiner and test consoles. The routiner contains its own access control and primary distributor. If ARF extension equipment has been installed the routiner will also test ARF circuits.

Trunk Circuit Supervision: For remote control and fault supervision a busying button and a lamp are provided for each outgoing and both-way circuit with the lamp at a half glow when the circuit is busy and at full glow, if it is blocked (see Fig. 63). These lamps and keys are provided on a panel near the trunk testing positions in addition to those on the relay set rack. Supervision of the outgoing routes from the ARM exchanges can thus be done visually at any time, permitting the identification of:
- No. of circuits which are busy in traffic on any particular route.
- Any circuits which are not picked up even in heavy traffic.
- Large numbers of blockings revealing bearer failures.
- Any circuits which have been blocked.

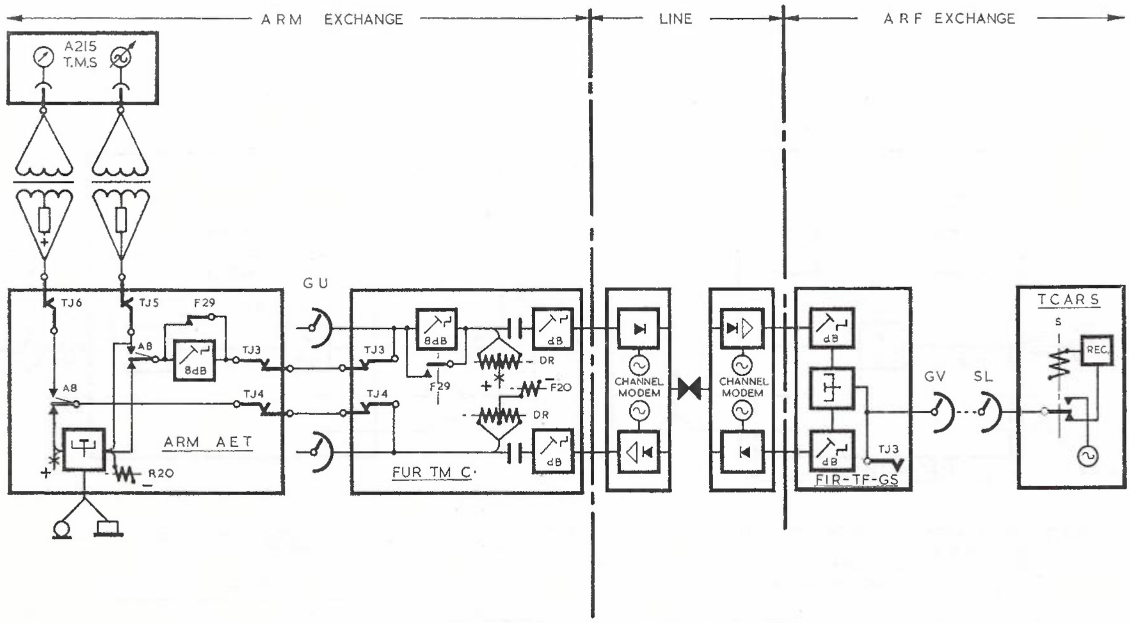

Fig. 65. — Transmission Measurement with A.E.T.

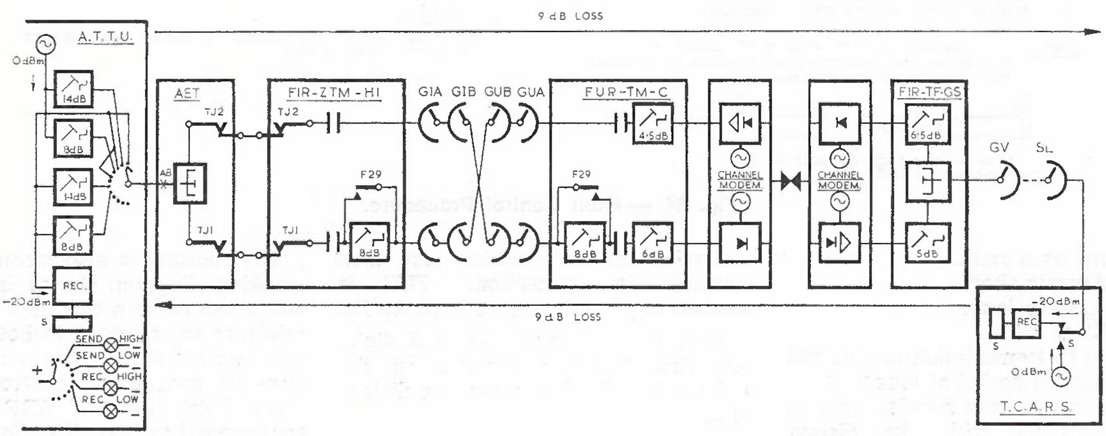

Fig. 66. — Automatic Transmission Test with A.E.T. and A.T.T.U.

Those which are not recorded as faulty are followed up, so that the number of circuits out of service is kept at a minimum. It has been found overseas that at any one time some 5 per cent. or more of circuits can be out of service for various reasons.

Transmission Measurements under Service Conditions: If a trunk circuit has been identified as faulty in regard to transmission performance further testing to enable fault location is necessary. The outgoing ARM exchange is the circuit control station and is responsible for locating a transmission fault into one of three sections, i.e.,either end section or the carrier link in between. To achieve this the step-by-step procedure shown in Fig. 64 is followed.

Fig. 65 shows how an ARM automatic exchange tester (AET) can be used to make a bothway transmission level measurement to a TCARS at the far end, where ARM test consoles have not been installed.

The AET trolley has been extended to house a transmission measuring set A215 and suitable interface equipment and the process is as follows:—

The FUR of the faulty circuit is tested in situ, with the connections between AET and FUR, established as shown.

The AET is set to call the TCARS at the far end and the identification sequence can be observed on lamps.

After the second pulse of tone the "transmission test" key is thrown, operating relay A8. The speech wires are extended to the interface equipment and TMS, but line supervision is maintained via the sleeve of TJ5 and the cailho of the a1, b1 wires.

The TMS is caused to send a low level tone to line (less than -25 dBm) and this level is slowly increased.

Triggering of the TCARS will be observed by a sudden deflection of the dB meter needle.

The oscillator is switched off and the meter reading of the received level noted.

The level to which the oscillator had to be adjusted to trigger the TCARS should now be measured, and the forward loss can then be calculated from the formula — dB loss = 20+ oscillator output level (dBm).

Where a trunk circuit routiner is not available, the AET can also perform an automatic transmission test by addition of an automatic transmission test unit (ATTU) on the extension frame.

Fig. 66 shows how a call can be set

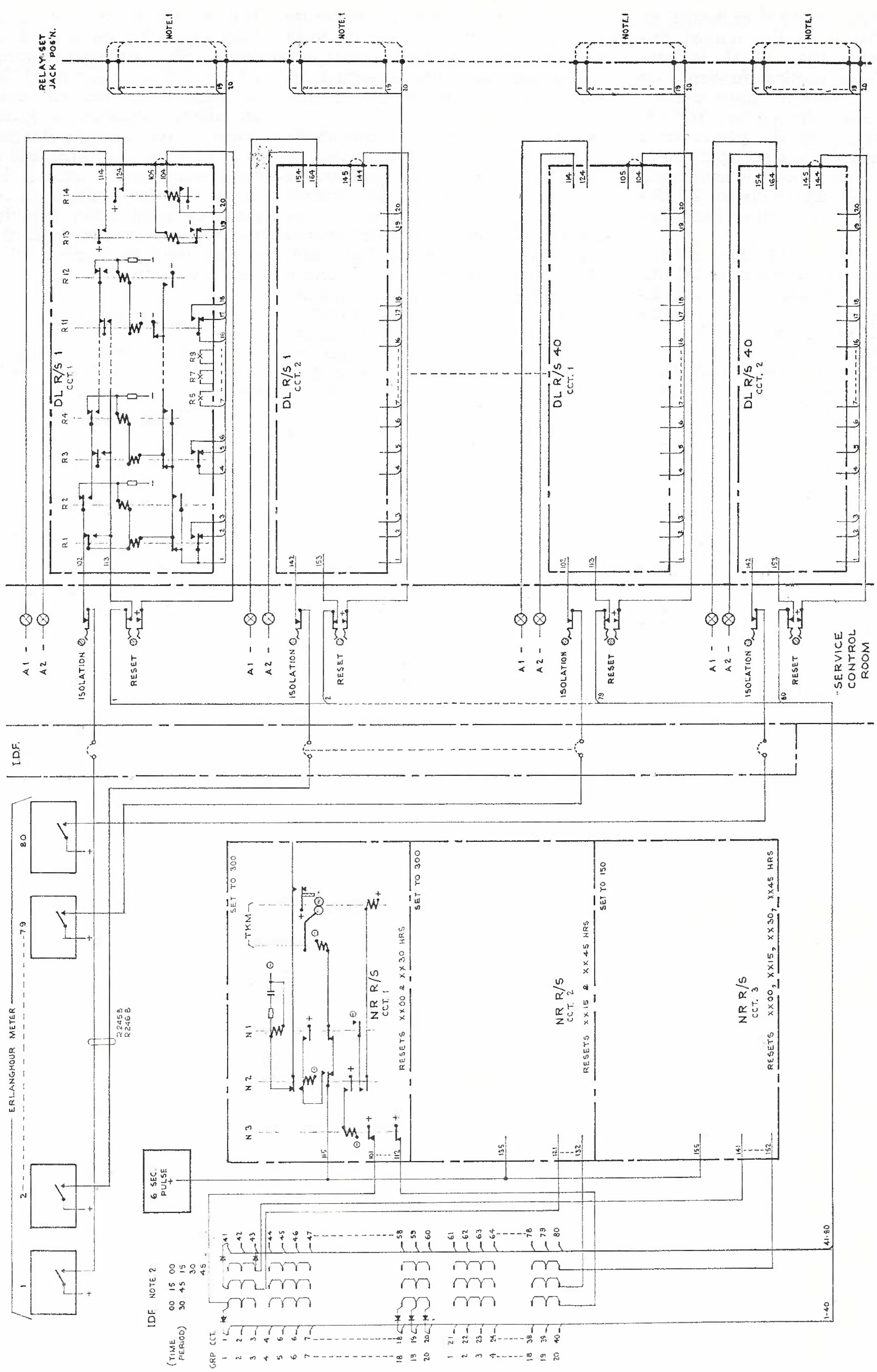

Fig. 67 — Survey of Automatic Traffic Surveillance.

up via an FIR, the ARM exchange, an outgoing circuit to the wanted distant TCARS. The ATTU is programmed for a nominal forward loss of the whole connection and a nominal incoming level from the TCARS. Fault limits at ±3 dB points from these nominal settings are applied. In our example the process is as follows:

The AET calls up the distant TCARS and starts the ATTU after identification.

The ATTU sends –14 dBm into the AET and monitors whether the TCARS does trigger. Because of the 9 dB nominal loss forward, the level reaching the TCARS should be –23 dBm, thus insufficient to trigger.

The ATTU now transmits –8 dBm, which should reach the distant TCARS as –17 dBm. S should operate, and tone is returned from the far end.

The tone receiver in the ATTU is now connected to the incoming tone level via a 14 dB pad and should not operate as –9 d Bm should be nominally received.

The pad attenuation is reduced to 8 dB and the receiver should operate.

If the four tests are successfully passed, the ATTU will transmit a "test finish" signal to the AET, which releases the call and proceeds to set up another one.

Automatic Traffic Surveillance: It is considered a service function to ensure that the traffic on particular outgoing routes will not exceed safe limits, and to this end such routes should be identified before congestion is actually encountered.

For this purpose, accumulating erlang hour meters are connected to the TKTu leads of all final choice outgoing routes (Ref. 7). The original proposal was to read these meters daily and plot the "busy hour" erlangs on a graph with a line at 5 per cent. below route traffic capacity drawn across the graph to set the action limit. However, in large ARM exchanges daily meter readings and the necessary calculations would require a considerable effort, and for this reason a service alarm system has been devised in Victoria giving an automatic indication when safe traffic limits on a route are exceeded. The system employs the standard service alarm relay sets DL and NR (see Part 3, A Maintenance Plan for ARM Exchanges) and makes use of the tele-metering contacts in the erlang hour meters.

Fig. 67 shows the survey diagram of the system. The tele-metering pulses are counted in the DL relay sets, and six second pulses are used to drive the NR's. There is one DL circuit per erlang hour meter and one NR per 15 or 30 minute time cycle. The DL's are re-set by one of the three NR's depending on busy hour conditions. Should the pulse count in the DL exceed a pre-strapped limit for the route within the NR time period, an alarm indication is given. Because of the inherent design of the DL, two alarm levels (A2 and A1) may be pre-strapped. Once it has been discovered that limits on a route are being exceeded, action is initiated and the route is isolated from the alarm system until the remedial action has been completed.

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A VARIABLE GROUP DELAY AND ATTENUATION EQUALIZER FOR TELEPHONE CIRCUITS

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INTRODUCTION

The implementation of the plan of the American National Aeronautics and Space Administration (N.A.S.A.) for a world-wide chain of telephone circuits which can be used both for speech communication and also for data transmission at 2400 bits/second has been carried out in the Australian territory since 1964 by the Australian Post Office (A.P.O.) (Ref. 1).

The voice band data transmission systems used up to date in this service employ phase modulated carrier signals with a signalling rate of 1200 bauds and four phase levels of the carrier signal. The spectrum of the line signal has, for random data input, primary nulls at 600 Hz and 3000 Hz, with the majority of the spectrum energy lying between 600 Hz and 2800 Hz. For a low error rate, most long distance telephone circuits have the capability to provide sufficiently high signal to noise ratios but need both amplitude and delay equalization. Circuits having the performance laid down in C.C.I.T.T. Recommendation M.102 (Ref. 2) are satisfactory for the purpose and, currently, the whole of the distortions permitted in this Recommendation are permitted for the N.A.S.A. circuits within Australia (the signals are regenerated for onward transmission over international connections). However, on the assumption that transmission without regeneration may be necessary over six links connected in tandem and that each link will be individually equalized, the equipment described in this paper is capable of equalizing circuits to within limits which are 1/6 of those set down in Recommendation M.102.

When the design work on the delay equalization of the N.A.S.A. circuits was first undertaken by the A.P.O. in 1964, it was thought to be most economical to use specially designed fixed equalizers for each circuit. Later, experience showed that better overall economy would be obtained by the use of a carefully designed variable equalizer.

The design described in this paper was inspired by a similar equalizer described by the Overseas Telecommunications Commission (Australia) (Ref. 3). However, it incorporates features which A.P.O. experience with fixed equalizers had shown to be desirable in order to deal with the Australian inland telephone circuits. This design, described in more detail in Ref. 4, is in current production and substantial numbers are now being installed by the A.P.O. staff throughout the Commonwealth.

Data transmission on the special quality circuits to M.102 specification is normally performed with data modems supplied by the customer and which are, therefore, outside of the control of the A.P.O., except in regard to type approval of their general characteristics. Consequently, it is not practicable to take account of the data signals actually transmitted when the telephone circuit is equalized. (In future, this may no longer be the case.) Because telephone circuit performance requirements such as Recommendation M.102 were, and are still, specified in the frequency domain and because all of the maintenance measurements are made in the frequency domain, it was logical to execute the variable equalizer design in that domain.

DESIGN FEATURES

The C.C.I.T.T. Recommendation covers matters such as noise, circuit stability, attenuation and delay distortion. If the delay distortion limits of the Recommendation are divided by six, the values given in Table 1 are obtained.

The characteristics of the circuits to be equalized (formed mainly from frequency division multiplex carrier systems with 4 kHz carrier spacing, together with a variety of voice frequency connecting circuits) made it necessary that the equalizer should be capable of dealing with up to 3000 μs of delay distortion and 6dB of attenuation distortion between the extreme limits of frequency quoted in Table 1. To cater for a wide range of attenuation and delay distortion curve shapes and to achieve an economic design, the equalizer was made "expandable" by the use of plug-in circuit cards, each with two second-order equalizer sections mounted thereon. Moreover, the resonant frequency of each equalizer section is adjustable to any one of 25 different values through a nominal range of 800 to 3600 Hz by the use of plug-in capacitors associated with fixed inductors on each card. The capacitor tolerance scheme used makes it possible, if necessary in exceptionally difficult cases, to select individual capacitors to permit closer control of the resonant frequencies.

As the major part of the group delay to be equalized arises in the frequency division multiplex terminals of the carrier equipment used, and because at carrier stations suitable staff, space, and testing equipment would be available, the equalizer was designed to be connected to the demodulator output terminals of the carrier equipment (+4 dBr point) and equalizer level range, noise performance and impedances were chosen accordingly. Although basically intended for the equalization of group delay, an adaptation of the delay circuit permits a small amount of amplitude equalization which is not independent of the delay equalization. However, as will be explained, a careful choice of circuit configuration minimizes alignment difficulties due to the interdependence of the two adjustments.

Physically, the equalizer comprises a small rack mounted box with a knob for delay adjustment and a knob for attenuation adjustment associated with each equalizer section. In each section, a delay adjustment of 0.3 to 2.0 ms and attenuation adjustment of ±3dB is possible. Unlike earlier designs of variable equalizer, the test equipment

TABLE 1: DELAY DISTORTION OBJECTIVES

Frequency Range	Group Delay Relative to the Minimum Group Delay
Below 500 Hz	Not less than 0 μs
500 - 600 Hz	Not exceeding 500 μs
600 - 1000 Hz	Not exceeding 250 μs
1000 - 2600 Hz	Not exceeding 83 μs
2600 - 2800 Hz	Not exceeding 500 μs
Above 2800 Hz	Not less than 0 μs

*Messrs. Gray (See Vol. 20, No. 3, Page 281) and Rumpelt are Engineers Class 4 and Class 3 respectively, Research Laboratories, and Mr. Ward (See Vol. 20, No. 3, Page 281) is Engineer Class 3, Telephone Exchange Equipment, Headquarters.

needed to adjust the equalizer has not been incorporated into the equalizer design. Consequently, it is possible to use sophisticated test equipment which allows automatic tracing of circuit response but which can be transported from job to job as required.

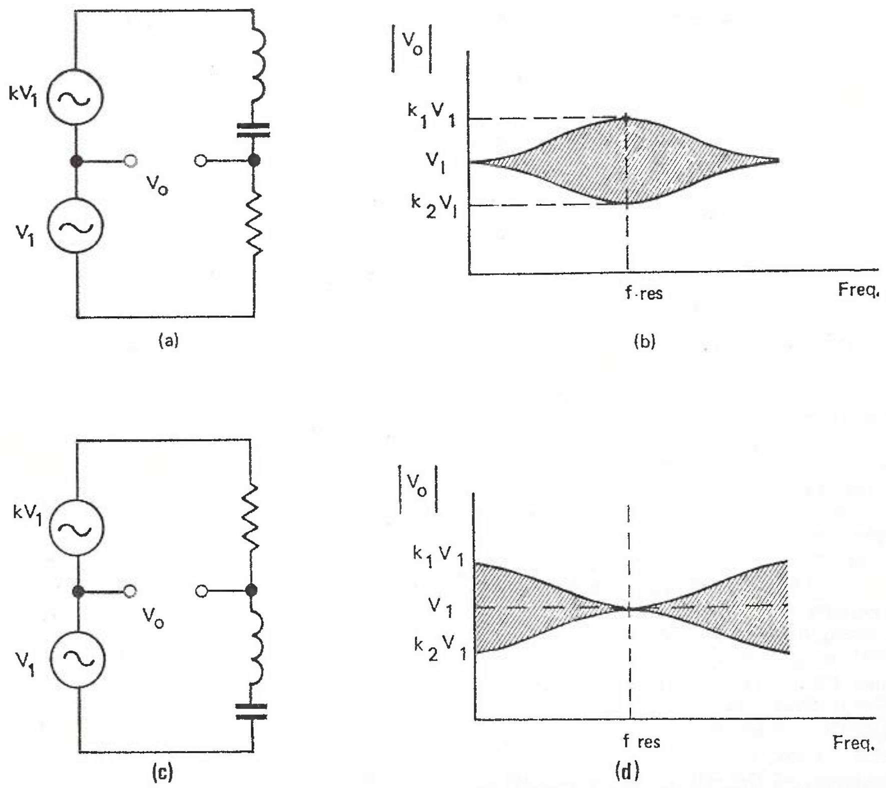

Fig. 2. — Two Possible Circuit Configurations and Their Amplitude Characteristics.

OPERATIONAL PRINCIPLES

Fig. 1(a) shows two identical voltage sources V_1 which cause current to flow through a series combination of a network having a pure reactance X and a resistance R. The output open circuit voltage V_0 may be shown vectorially as in Fig. 1(b). The value of X is negative in this figure. The voltages iX and iR are 90° out of phase so that, as X varies with frequency, the head of the vector V_0 will lie on a circle of diameter 2 V_1. The magnitude of V_0 is, therefore, constant and equal to the magnitude of V_1, and the circuit acts in an all-pass manner.

If a single reactive component is used, the reactance X varies monotonically between minus infinity and zero, or between zero and plus infinity, as the frequency of V_1 varies between zero and infinity. When X is equal to infinity, V_0 is in phase with V_1 (i.e. $\beta = 0$) and when X is equal to zero V_0 is in antiphase with V_1 ($\beta = 180°$). Thus, with a single reactive component, a phase shift of 180° can be produced as the frequency of V_1 is varied. In a second-order circuit either a series or a parallel LC combination may be used in the reactive arm. Either of these networks will produce a 360° change of phase of the output voltage as the frequency of V_1 is varied from zero to infinity. In each case, the maximum rate of phase occurs approximately at the resonant frequency of the combination and so the group delay of the circuit is a maximum near the resonant frequency.

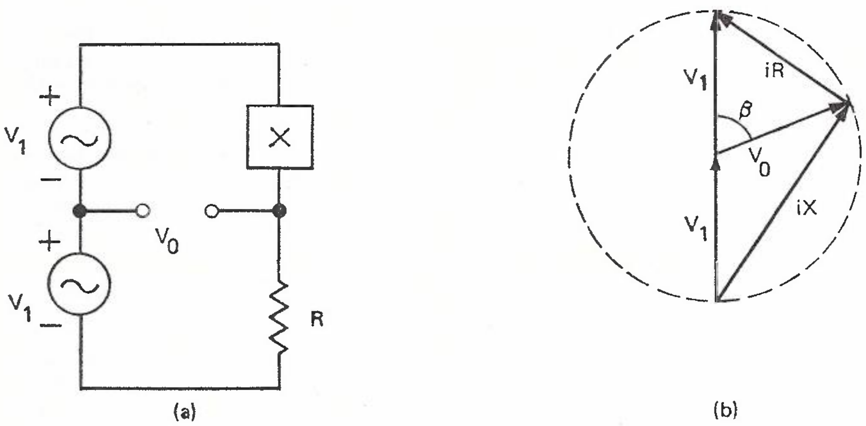

Fig. 1. — Basic Phase Shifter Operation.

If the voltage sources are of unequal magnitude, V_1 and kV_1, then the magnitude of V_0 will vary with frequency. As the reactance X varies between the limits of zero and infinity, the amplitude of V_0 will vary between the amplitudes of the two sources V_1 and kV_1. Hence, by making the factor k variable, the circuit may be used as an attenuation equalizer.

In principle, the reactive network may have any desired degree of complexity, but adjustment is most conveniently carried out if a pair of reactances is chosen with resonant frequency within the nominal frequency band. There are four possible circuit configurations using a single inductor-capacitor combination. The two reactances may be connected in series or parallel and the combination may be included in the circuit arm associated with the generator kV_1 or with the generator V_1. The two possibilities with series-connected reactances are shown in Fig. 2(a) and (c) and the revelant amplitude characteristics in Fig. 2(b) and (d). In Fig. 2(b), which shows the performance of the circuit adopted, the amplitude adjustment has its maximum effect near the resonant frequency but in Fig. 2(d), it will be seen that the amplitude adjustment has little effect near that frequency.

In the series resonant circuits shown in Fig. 2, the maximum value of the group delay is proportional to the inductance value and independent of capacitance value; the resonant frequency may, therefore, be varied by changing capacitance values without altering the range of the group delay. (With a parallel resonant circuit, the inductance values would have to be changed.) Furthermore, the capacitor in the series resonant circuit can function simultaneously as a resonant element and as a d.c. blocking capacitor.

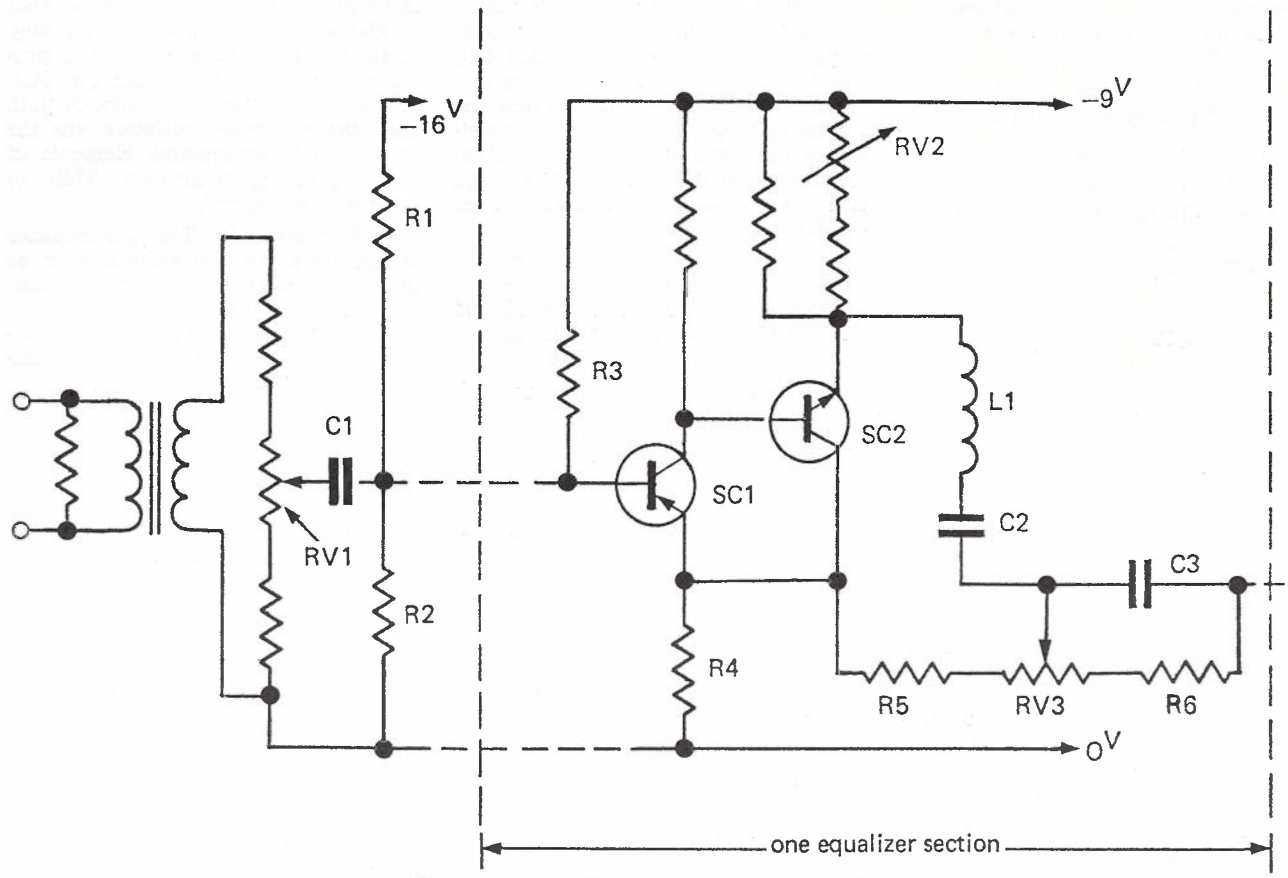

Fig. 3. — Input Circuit and Equalizer Section.

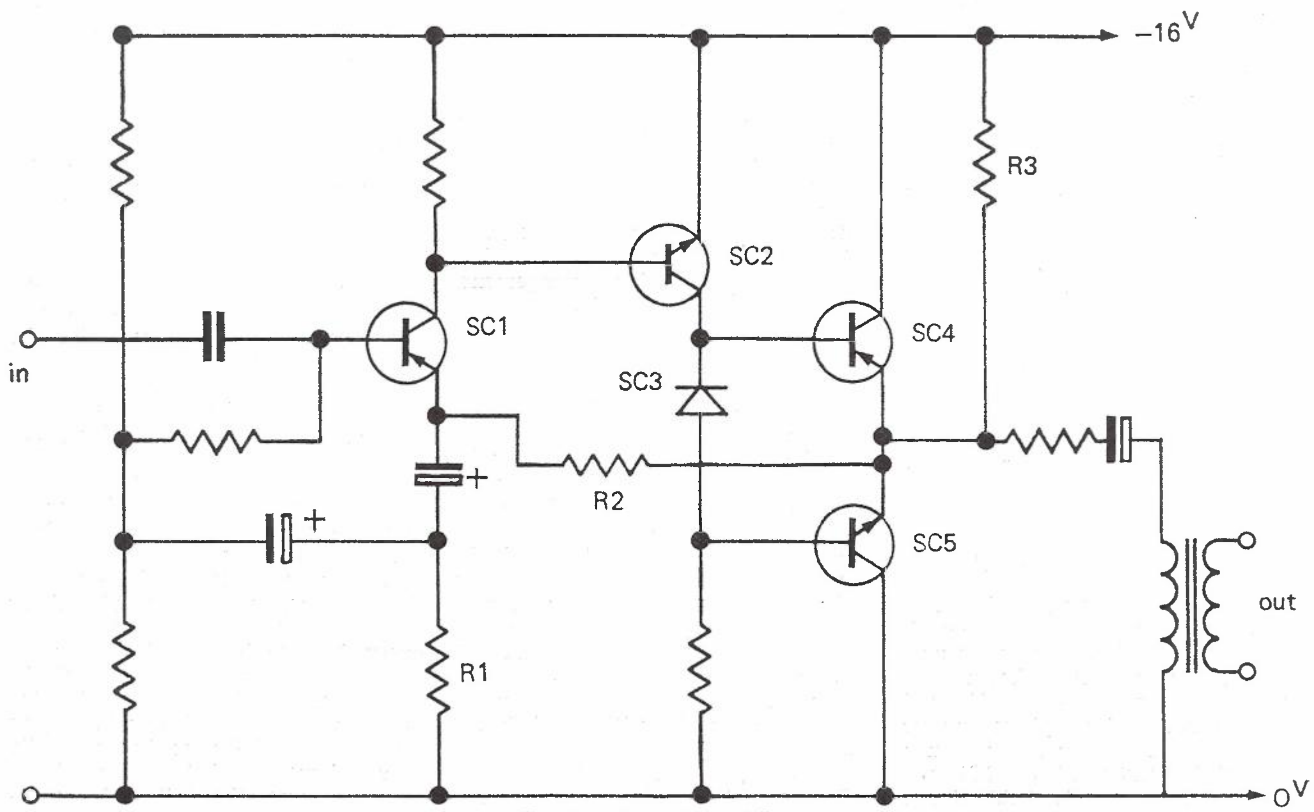

Fig. 4. — Output Amplifier.

An analysis of the equaliser configuration selected for use shows that the voltage gain $A = 20 \log |V_0/V_1|$ is:

$$A = 10 \log \frac{[k^2 + Q^2(fn^2 - 1)^2]/fn^2}{[1 + Q^2(fn^2 - 1)^2]/fn^2} \ldots (1)$$

and the group delay is derived as

$$tg = \frac{1}{2\pi fo\, Q}\left[\frac{k(fn^2 + 1)}{k^2 fn^2/[Q^2 + (fn^2 - 1)^2]} + \frac{(fn^2 + 1)}{fn^2/[Q^2 + (fn^2 - 1)^2]}\right] \ldots (2)$$

where $fn = f/fo$, $fo = 1/(2\pi\sqrt{LC})$, $Q = 2\pi fo\ L/R$.

Equation (1) shows that the circuit exhibits all-pass behaviour when the two voltage sources are of equal magnitude (k equal to unity) and that it exhibits a frequency dependent loss or gain when the voltage sources are of unequal magnitude ($k \neq 1$).

The presence of the factor k in equation (2) indicates that the attenuation A and the group delay tg are interrelated functions. Thus, achieving attenuation equalization by varying k will cause the group delay characteristic to change to some extent and, consequently, equalization is an iterative process. Group delay equalization is performed first with k set equal to one and, then, attenuation equalization is carried out by varying k. Minor changes in R will then be necessary to correct the delay equalization, after which the attenuation equalization should be re-adjusted, if required, and so on. Since the dependence of the group delay on k is not strong, only two or three iterations are required.

By considering equation (2), it may be seen that the maximum value of the group delay will occur when the frequency is approximately equal to the resonant frequency f_0 (provided Q is greater than unity). Thus,

$$(t_g)_{res.} = \left(1 + \frac{1}{k}\right)\frac{2L}{R} \quad \ldots (3)$$

and in the all-pass condition, when $k = 1$,

$$(t_g)_{res.} = \frac{4L}{R} \quad \ldots (4)$$

The peak group delay value may conveniently be made variable by making R variable $(t_g)_{res.}$ will take its largest value when R is set to its minimum value.

CIRCUIT REALIZATION

The circuit realization is shown in principle in Figs. 3 and 4. In Fig. 3, one equalizer section (out of the possible maximum of ten) is shown.

The two voltage sources V_1 and kV_1 are produced by a phase splitter circuit using an emitter follower in a "superbeta" configuration (SC1 and SC2, Fig. 3). An analysis of this circuit is given in Ref. 5. The variable factor k which determines the amplitude response of the circuit is controlled by the resistor RV2 in the emitter circuit of SC2, the maximum and the minimum values of which are controlled by the associated series and shunt resistors so that k is variable between 0.71 (A = —3dB) to 1.41 (A = +3dB).

The elements of R and X of the equalizer section are shown in Fig. 3 as RV3 and R5 in series, and L1 and C2 in series, respectively. The chosen combination of R5 and RV3 gives a resistance range from 1.5 to 11.5 kilo-ohms, which yields the required variation range of the group delay and, at the same time, avoids excessive loading of the phase splitter outputs and excessive generation of non-linear distortion in the inductor L1. The potentiometer RV3 has an inverse logarithmic resistance/rotation law, giving approximately linear variation of maximum group delay over the range of rotation.

Since the superbeta circuit presents a very high input impedance, it is a suitable load for a variable equalizer section of the type described above and allows such equalizer sections to be connected in tandem. It is essential that this property of having a high input impedance is not lost when producing the required d.c. bias voltage for the base of the first transistor in the superbeta circuit. This d.c. voltage is, therefore, derived from the d.c. emitter voltage of the corresponding transistor in the previous section. As up to ten of such sections may have to be connected in tandem, it is important that the voltage drop from the base to the emitter of this transistor is compensated in each section. This is achieved by the resistance chain R3 (in the following section), R6, RV3 and R5. In this arrangement, only R3 causes additional a.c. loading to the output of the preceding section and as its value is 470 kilo-ohms, its loading effect is negligible.

The input circuit has a loss of about 30dB (on a voltage basis) to ensure that the signal loading on inductor L1 is sufficiently small to make non-linear distortion negligible and this loss must be made up in the output amplifier (Fig. 4). This amplifier has a high-impedance input stage (SC1) feeding a driver stage (SC2) for the push-pull output stage (SC4 and SC5). The diode SC3 between the bases of SC4 and SC5 reduces crossover distortion in the output stage. Crossover distortion is further controlled by R3 which introduces asymmetry in the output stage. For low signal levels, only transistor SC5 is operative and crossover occurs at relatively high signal level so that its distorting effects are comparatively small. Resistor R2, in addition to providing a d.c. emitter return for SC1, forms with R1 the a.c. feedback path and hence these resistors are the primary gain-determining elements of the circuit. Approximately 35dB of feedback is applied.

Performance. — The performance specification covered factors such as input and output impedance, return loss values, noise, distortion, surge protection, and temperature coefficients, which are not specifically mentioned in this paper. The equipment manufactured so far has performed in accordance with the design objectives, within the limits set initially to ensure satisfactory operation in telecommunication buildings without air-conditioning in any part of Australia.

Adjustment Procedures (See Fig. 5). — The equalizer having been designed to meet criteria which are specified in the frequency domain, it is appropriate that its adjustment should be performed using frequency domain measurement techniques. Present practice is to use a swept-frequency sine-wave source operating through the telephone circuit and equalizer to a receiving set which measures both envelope delay and amplitude responses (Wandel & Golterman Measuring Set for Group Delay and Attenuation). These circuit properties are measured relative to a constant but adjustable reference frequency which, for convenience in equalizer adjustments, is set to the resonant frequency of one of the sections.

The choice of the number of equalizer sections to be used is made with the help of a table showing the number of sections required in relation to the difference between minimum and maximum delay in the frequency band of interest. Having chosen the number of sections, the resonant frequencies are then selected with the help of a second table. Some modification of the resonant frequencies may be needed after the first delay equalization cycle. Guidance is also given in the operator's handbook in the selection of the initial delay settings.

Adjustment of delay is first made at the resonant frequencies of each of the sections only and afterwards a recording is made of the complete delay/frequency response and a check made to ensure that the response is everywhere within the target limits. If not, further re-adjustment will be necessary. The attenuation equalization is then performed and the whole cycle repeated. The full procedure normally takes about one half to one hour, depending upon the skill of the opera-

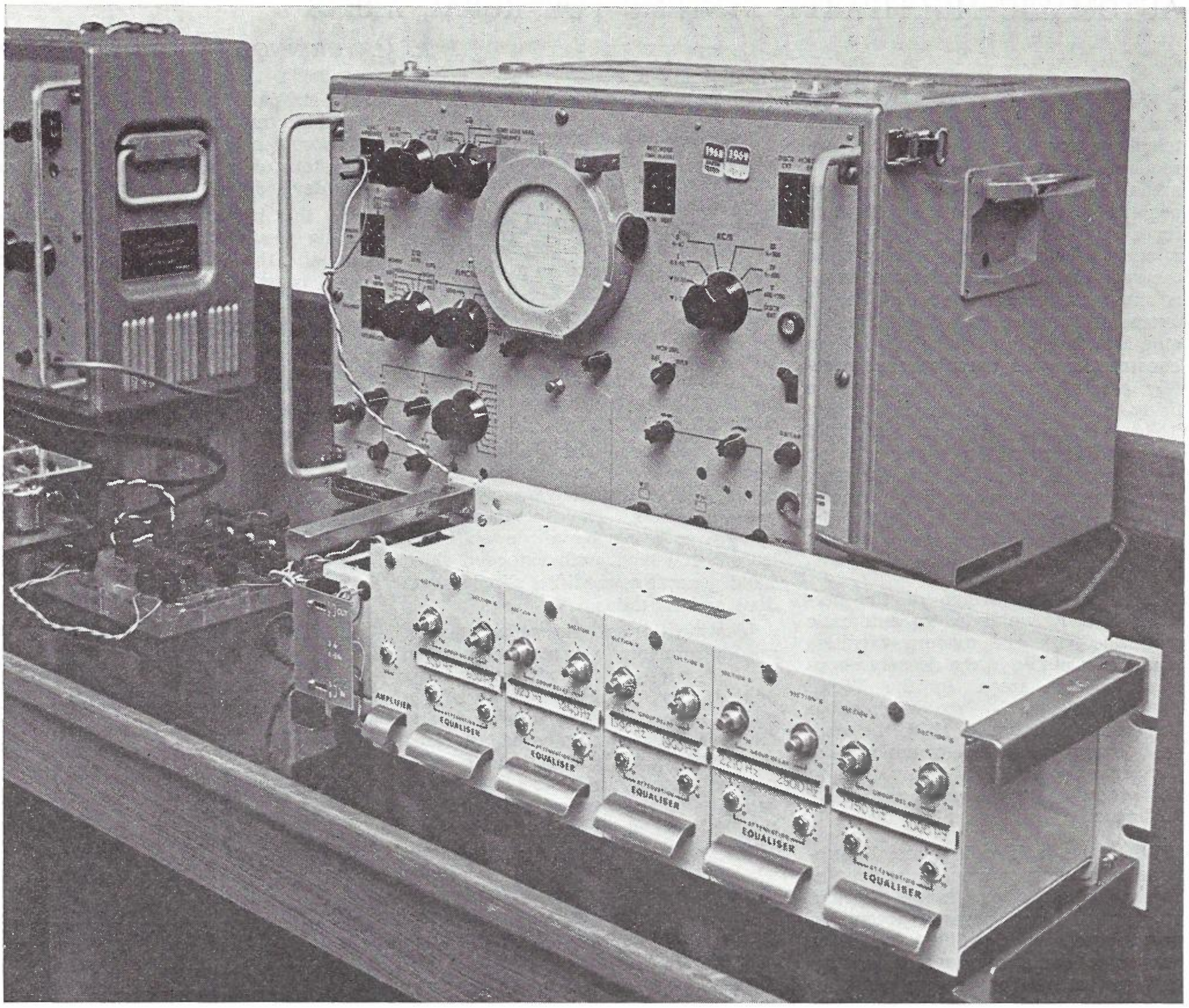

Fig. 5. — The Equalizer under Test.

tor, the complexity of the circuit response, and the degree of equalization desired.

FUTURE DEVELOPMENTS

The circuit design, which has been described, was carried out in 1966 when the cost of integrated circuit blocks was such that it was more economical to construct the equalizer from discrete circuit components. The first production units were put into service late in 1969, and the experience now being gained throughout the Commonwealth will, undoubtedly, be used in due course for the preparation of a new design, which may well be very different from the present one.

The decision of the A.P.O. to permit only the use of its own data modems in the commonly used speed ranges could mean that it may be desirable, in future, to perform delay equalizations end-to-end in the time domain, perhaps, with adaptive equalizers. Nevertheless, it is considered that there will still be a widespread need for circuits, the terminal equipment for which is supplied by the user of the service, and these circuits are probably best dealt with in the frequency domain by variable equalizers such as the one described in this paper.

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AUTOMATIC MULTIPARTY SYSTEMS FOR RURAL AREAS

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

For many years it has been Australian Post Office policy to provide telephone services wherever they are required, even in the most remote areas. This goal is virtually being achieved, as nearly all applications for a service have been fulfilled. The minority fringe of the network, in the sparsely populated areas commonly has subscribers' line lengths in excess of 20 miles, and there is a 168 mile line in Queensland. Often cheap construction was used on the privately erected section of the lines to bring them within the means of these isolated people. Magneto signalling gave greater reliability under adverse conditions of bushfire or flooding, with concentration of lines usually being performed by switchboards, privately operated during restricted hours at station homesteads.

Currently, this fringe of the network is being upgraded to automatic working, with the modern facilities that are available in the densely populated coastal areas. In the White Paper presented by the Minister to Parliament in August, 1969, the residual manually served component of the network was 11.5%, which was to be reduced to 9.6% during the 1969/70 financial year.

When the decision is made to automate a particular area, a review of external plant often reveals a small number of lines beyond acceptable transmission or signalling limits for automatic equipment, which are an embarrassment, for service must be maintained to these subscribers. The lines may be constructed of 8 S.W.G. galvanised iron wire which is favoured on privately erected lines for its reliability, high strength and long span capability, or they may require rebuilding because of unreliability. In any case the decision to change the wire to copper-cadmium with a shorter span in order to improve the transmission and signalling characteristics can be very expensive. In Queensland there are almost 1,000 lines longer than 20 miles, with 280 of these exceeding 50 miles. Most are party lines, for subscribers in these areas readily accept party sharing as an economic compromise. However, the cost of building a new line in 70 lb. c.c. wire pairs can be $700 per mile, which is still very expensive per party past the 15 mile radial distance now provided by the Department.

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THE DESIGN OBJECTIVE

Against this background, it was decided to design a new multiparty system, which would work over metallic lines outside normal limits. The telephone was to be passive and cheap, so that electronic elaborations would not increase its price to a point competitive with the C.E.21510 tone dialling system, which is still the preferred system for earth return lines. It was also to be compatible with all automatic exchange systems. which incidentally made it compatible also with C.B. switchboards.

The previous metallic multiparty line systems had only moderate signalling limits, and conventional transmission limits. The telephone was expensive, being based on an obsolescent 400 type, with extended skirt, hand generator, modified slipping cam dial, and batteries.

Identification of the caller was by masking an impulse on one leg when the '0' prefixed to all codes was dialled. Even if the sensitivity of the parent relay set were improved, and other disabilities eliminated, the current working limit of 850 ohms could not be extended because the shunt capacity of the parties' bells multilated the masked identification impulse. Therefore the problem was approached by minimising the effect of the three principal limitations of poor lines — the signalling resistance, leakage resistance, and transmission attenuation.

Three path signalling is necessary in any DC multiparty caller identification systems i.e. the line pair and earth. To obtain a high ratio of signalling current to leakage current, line battery was passed down both legs of the line, using an earth return. When compared with the loop condition, this cailho mode of signalling in practice triples the line current drawn. When used in conjunction with 3/412 type high speed relays, which have a low ratio of operate to release currents, discrimination against leakage is excellent.

Conventional ring tripping is not practical because of the large capacity across the line. Tripping is possible in every silent period, by the same pair of relays which always sense line current. Thus if a line fault is not bad enough to cause a P.G. condition, then it will not falsely trip ring or cause false identification.

Identification is a problem with long lines. If we consider a 2500 ohm line, with six parties, each with an extension bell, the time constant to sensing DC would be about 50 ms. Therefore a system of pushbutton identification was devised, and is described later.

As this high current mode of signalling results in more than 40 mA through the telephone under the worst conditions, this is used for the transmitter current rather than a local battery. Because the voltage output of a carbon transmitter is proportional to the current through it, and the line current is triple that of a loop mode telephone, a substantial lift in transmitted level is achieved.

Ease of installation was considered, and at the parent end, connection to the exchange line circuits does not involve rearrangement of the manufacturer's wiring.

The lifting of these primary limitations, of course, causes secondary limitations to performance to become apparent on longer lines. Firstly, reception attenuation may become too great. However, in remote areas, the ambient noise level is low, and a reduced standard may be acceptable to rural subscribers. Secondly, the disproportionate attenuation of high frequencies by long lines may cause a loss of intelligibility. Only active equalisation could remedy this. Thirdly, the ring may be weak. Fitting a bell amplifier as an ancillary unit is a standard solution for this, but will probably not be necessary with this system.

THE TELEPHONE

In appearance, the instrument is an 801AT telephone, on a plinth, with a pushbutton labelled "Press for Dial Tone". Electrically, the speech and ring appear transversely across the line pair, and are received in the normal fashion by the conventional telephone circuit. Line current is decoupled from both legs by a centre-tapped choke. This current is smoothed with a capacitor, which also bridges a voltage limiting zener diode. The potential across this zener is applied to the transmitter and the primary of a transformer, and the current drains through the dial and hookswitch contacts to earth. The secondary of this transformer couples into the induction coil in the normal position for the transmitter.

The identification pushbutton connects each leg of the line separately to a network to earth, which forms the identification of each party. Thus each leg could be coupled to earth through a strap, a diode, or not at all. Conduction occurs on both legs when in use, and on neither when idle. Depressing the pushbutton breaks conduction of negative current on one leg only. Upon receipt of this condition, the parent equipment removes negative polarity from both legs, and with a reversed capacitor, applies positive polarity to both legs. Conduction may occur on either leg. These four permutations, coupled with the original two, allow eight parties to be identified. Auxiliary straps or diodes in the speech circuit give the same response to positive battery as this network, so false identification cannot be gained by restoring the pushbutton quickly.

SUBSCRIBER'S OPERATION

To originate a network call, the subscriber lifts the handset, and presses the pushbutton. Dial tone is returned, and the wanted number is dialled.

To originate an interparty call, the subscriber lifts the handset, dials a digit from 3 to 0 corresponding to the wanted party, and replaces the handset. The parent equipment then sends three cycles of coded ring back down the line. This can be tripped, but if it is not the caller lifts the handset to await the called party's answer. If no answer results then the process may be repeated.

A terminating call rings out in coded patterns, as Fig. 1 shows. Ring may be tripped in any silent period. The parent equipment guards the other line circuits until last party release.

PARENT EQUIPMENT FACILITIES

The basic relay set provides facilities for four parties. This is Part 1. Part 2 is required only if the system needs to be extended to eight parties. As Part 1 contains 28 relays and a uniselector, it is too complex to be reproduced entirely in Fig. 2.

Each party is coupled to his own line circuit for all calls, so metering is not passed through the relay set. Outlets of the parent relay set are directly tapped onto the a, b and c or P wires. Earth is passed out on the c wire when an outlet is to be busied, and an incoming earth is taken as indication of a terminating call. Originating calls onto line circuits are held under loop control. Therefore, this system is compatible with ARF, ARK Step and C.B. exchanges.

Each party has a separate directory entry, appearing as a normal service. There is no limitation on allocation of line circuits to various parties, and each party can be separately categorised or added to or removed from the system without number change.

The ring codes used are those preferred for magneto services. Part 1 uses D, U, K and R, and Part 2 S, W, G and 5, in Morse coding.

The party line must be metallic, and a loop resistance of 2500 ohms is tolerable with full safety factor on the line relays. A leakage of 14,000 ohms is safe.

TECHNICAL DETAILS OF PARENT EQUIPMENT

Fig. 2, a skeleton sketch showing only 11 of the 28 relays in Part 1, illustrates the principle of operation. The X and Y relays, type 3/412AAB, sense line current on each leg. Their readjust sensitivities are 10.6 mA operate, 5.6 mA release, which gives good response to impulsing, and immunity to leakage.

On an originating call, when the identification button is pressed, X or Y releases, thus operating K or J respectively. These lock and store the first stage of identification. PB operates, and applies positive battery to line. The states of X and Y are transferred to L and M respectively. After this timed impulse of positive potential, the stored identification is transferred from the J, K, L and M relays to one of the connecting relays, P, Q, . . . This connects the subscriber to his own line circuit, and removes the earth which the guard relay G had been applying to the c wire. After a pause sufficient for the line circuit (LR/BR) relays to release, the loop is passed forward. The earth which then returns on the c wire also holds the connecting relay, and ensures guarding until the last party releases.

On an interparty call, operation of J or K does not occur, as the first signal received is dial train. The first two impulses are absorbed to guard against hookswitch flicks, and subsequent ones are passed into the P, Q, . . . connecting chain which doubles as a counter, as well as a ring coding device. As soon as the count enters the chain, the outgoing looping facility is disabled, and the connecting relay belonging to the wanted party remains operated. Restoration of the caller's handset starts the ring generator, and a miniature uniselector makes three sweeps of 12 steps. The outlets of its bank, through contacts of the connecting relay, pulse RR in the appropriate code. After three codes, the circuit restores to the idle condition.

On a terminating call, an earthy potential on a c wire operates a connecting relay. This operates the guard relay G, which guards the other c wires. The ring code generator is started, and sends continuous codes to line. Operation of X and Y by an answering subscriber locks out the

PARTY	PHONE STRAPS				IDENTIFYING RELAYS				CONNECT RELAYS	RING PATTERN	
	'A' LEG	'B' LEG	X - Y	X - Z	J	K	L	M		MORSE	CODE
1	O	——‖	—▷|—	——		X		X	P	D	— • •
2	—▷|—‖	—|◁—‖	——	—▷|—		X	X		Q	U	• • —
3	O	—|◁—‖	—▷|—	—▷|—		X			R	K	— • —
4	—▷|—‖	——‖	——	——		X	X	X	S	R	• — •
5	——‖	O	——	—▷|—	X		X		T	S	• • •
6	—|◁—‖	—▷|—‖	—▷|—	——	X			X	U	W	• — —
7	—|◁—‖	O	—▷|—	—▷|—	X				V	G	— — •
8	——‖	—▷|—‖	——	——	X		X	X	W	5	• • • • •

Fig. 1.

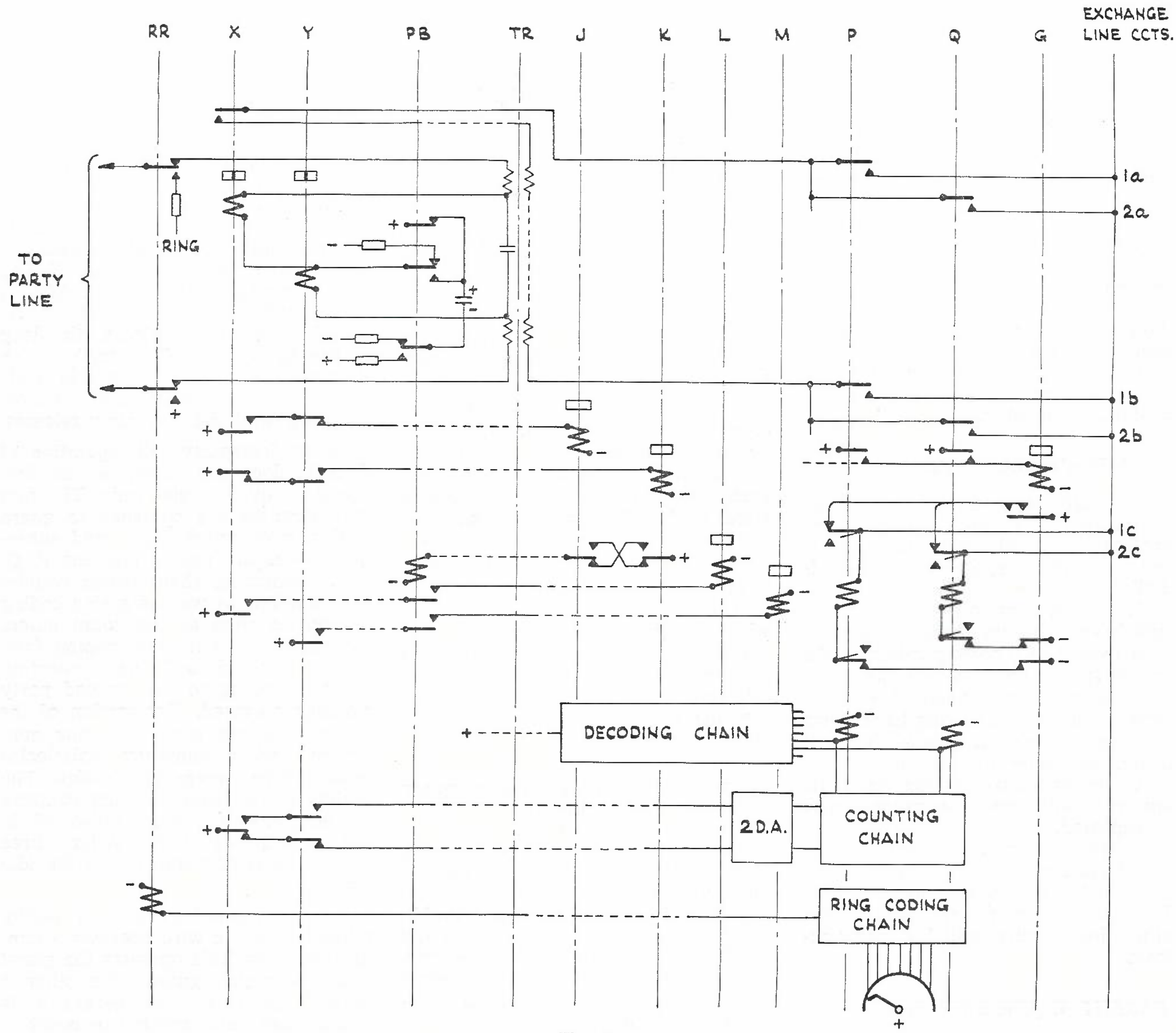

Fig. 2.

ringer circuit, and loops the exchange line to trip the ring coming from the exchange. The call then proceeds normally, with last party release of the exchange equipment.

PROTOTYPE TESTING

The prototype was developed and tested by the Queensland Telephone Equipment Design Group, interworking with ARF and Step Equipment. The Victorian Equipment Design Co-Ordination Division also tested it extensively with ARK equipment. A second prototype was then installed on a long part privately erected line with a poor fault history off an ARK exchange at Billa Billa. The field trial was successful and this equipment has been adopted as the preferred item in this application.

FURTHER DEVELOPMENTS

Following the demonstrated success of this earth current system, the Design Group developed two similar systems. The first is a simple one for exclusive services, for use where a normal loop signalling telephone would be unsatisfactory. The second is a two party system, employing cheaper exchange equipment than the multiparty system. It is basically a simplification of this system, but gives exclusive rather than coded ringing to line, and pushbutton ringing of the other party.

It is expected that when the development of the Long Line telephone is finalised, it will be used to extend the transmission limit of this party line system and the exclusive service system will then be redundant.

CONCLUSION

It is felt that this signalling technique, whether in the exclusive, two-party, or multiparty systems, extracts as much performance as is practicable from a passive instrument at the substation, and passive lines. In order to commission lines which are outside the limits which even these systems can accommodate, it is currently necessary to use more complex equipment with receiving and sending amplifiers. The costs are decreasing but there are still problems to be solved before connection of very remote subscribers becomes technically and economically viable.

CANTOT — COMPUTER ANALYSIS OF TROUBLES ON TRUNK CIRCUITS

*N. J. RYAN, M.I.E., Aust.**

INTRODUCTION.

The Australian Post Office, in common with other telecommunications authorities, is faced with the problems of spiralling costs, shortage of skilled labour, and at the same time, satisfying the increasing demand for the provision of reliable telecommunications facilities. A corollary to these problems is the need to maintain the facilities at an acceptable standard of service while effecting economies in the use of manpower and other resources. In order to achieve this, it is necessary that management be provided, on demand, with a current assessment of the condition of the telecommunications network. Automatic data processing, which provides an efficient method of collecting, storing and analysing data to supply this assessment, will fulfil this requirement.

The previous manual trunk circuit faults and analysis system (Ref. 1) produced some general statistics of fault incidence on long line plant. Trunk circuits with a fault report level exceeding a specified figure were identified by manual means and remedial action initiated. However, there was no assessment of the effects of faults on the quality of the service. At the present rate of growth of the network (the number of trunk circuits is doubling every five years), manual methods of analysing faults and deriving service indicators were too slow and costly. Therefore, in order to handle efficiently the large volume of recorded fault data (15,000 dockets per month) and disseminate the processed results quickly, CANTOT (Computer Analysis of Troubles on Trunk Circuits) was developed.

* Mr. Ryan is Engineer Class 2, Maryborough Division, Queensland.

PURPOSE OF THE CANTOT SYSTEM

The new system is service oriented in that its primary function is to provide information concerning the overall service performance of trunk and junction circuits. CANTOT is aimed at providing a quantitative assessment of the integrity of trunk telephone facilities with the following objectives:—

- Supply the information in a form which will permit problem areas to be located and assist with the identification of causes.
- Supply the data in sufficient time to be effective as a management aid.
- Provide information with sufficient frequency to permit performance trends and the effects of the implementation of decisions to be observed.

The output information is arranged to suit the requirements of management at the following levels:—

- The officer in charge (O.I.C.) of a maintenance district in regard to the services and plant under his control.
- The Regional Engineer in so far as services and plant (internal and external) under his control are concerned.
- State and Commonwealth engineering administrations in regard to

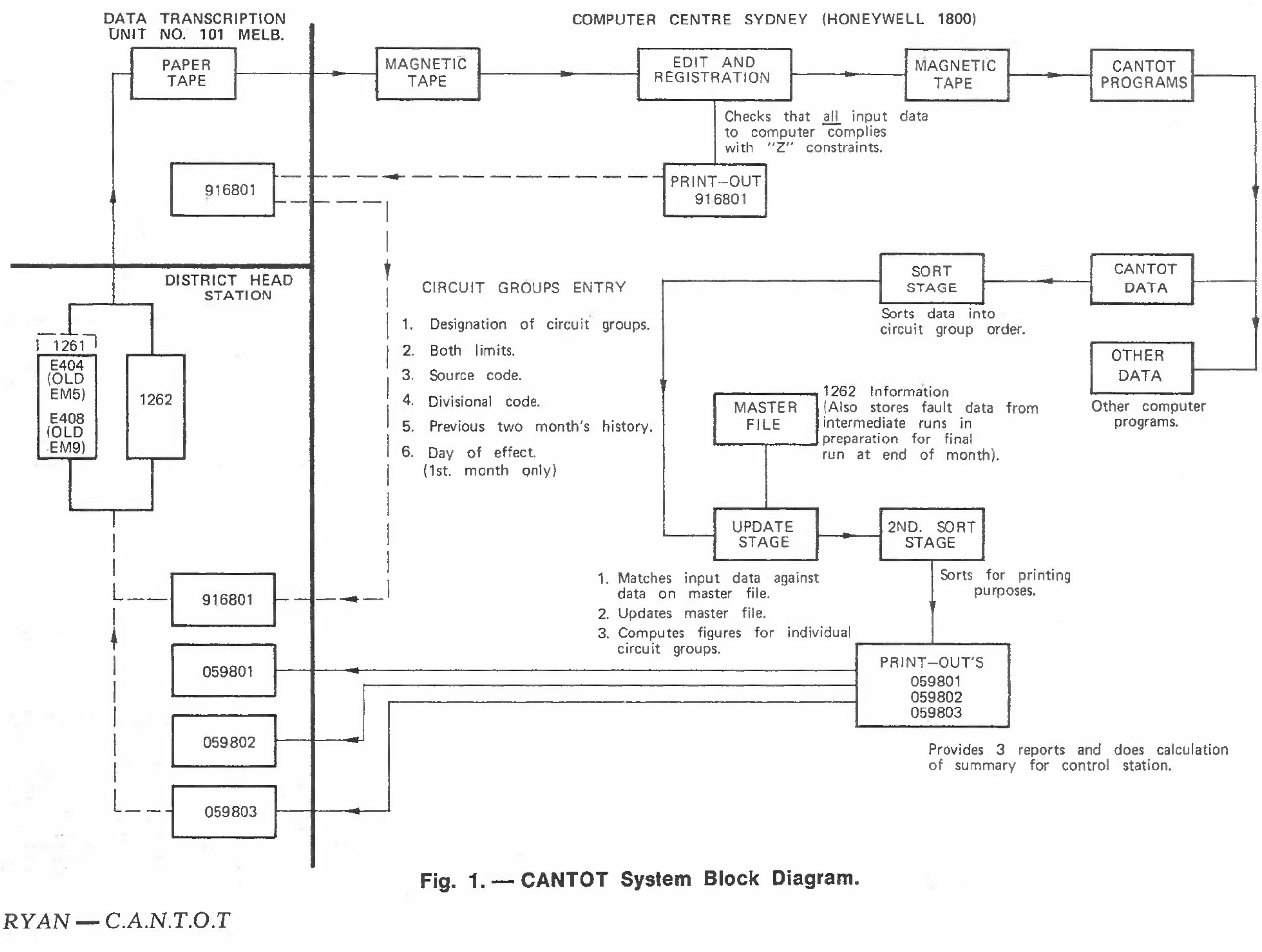

Fig. 1. — CANTOT System Block Diagram.

P.M.G.'S DEPT.
E 441 (EM41)
(Aug. '69)

CANTOT PROJECT

CIRCUIT GROUP DETAILS

A.D.P. MESSAGE HEADER		
Message Type	1262	101
Source Code	28411	102
Sequence No.	0124	103
Date of Despatch	120271	104
Control Station Division	223	105
HASH-TOTAL	150291	113

All fields MUST have an entry

ANALYSIS MONTH FEBRUARY

STATION STAMP:

Officer-in-Charge,
Telephone Exchange,
ALBURY, NEW SOUTH WALES. 2640

NOTES: 1. To CREATE or AMEND a CIRCUIT GROUP, each field on the form MUST have an entry.
2. (i) To CREATE NEW GROUP(S), enter "2" in the CODE column (204).
(ii) To AMEND the PERFORMANCE LIMITS and/or the NUMBER OF CIRCUITS (fields 205, 210 and 211) of an EXISTING GROUP, enter "4" in the CODE column (204).
N.B.: The entry in field 211 is the total number of circuits in the group after amendment.
(iii) To CANCEL AN EXISTING GROUP, enter "6" in the CODE column (204).
N.B.: Fields 205, 207, 210 and 211 MUST BE LEFT BLANK.
3. To AMEND he "CIRCUIT GROUP DESIGNATION" (fields 202 and 203) of an EXISTING GROUP, CANCEL (CODE "6") the group, and re-CREATE (CODE "2") using the NEW DESIGNATION. N.B.: The transactions may be consecutive entries on the one message form.
4. To CHANGE the SOURCE CODE and/or DIVISION CODE relating to a CIRCUIT GROUP:
(i) CANCEL (CODE "6") the group using the OLD SOURCE CODE and DIVISION CODE.
(ii) CREATE (CODE "2") the group, using the NEW SOURCE CODE and/or DIVISION CODE on a separate message form. N.B.: THE SEQUENCE NUMBER USED ON EACH MESSAGE FORM MUST BE TAKEN FROM THE APPROPRIATE SEQUENCE REGISTER.
5. In fields 205 and 210, if there is no figure after the decimal point, enter zero, e.g. 2.0, 98.0.

202 Control End Code	203 Terminating End Code	204 Code	205 Av. No. Outages Limit	207 Day of Effect	210 % Availability Limit	211 No. of Circuits
(Use Codes from 'CANTOT-INDEX OF EXCH.')						
ALBY	BALR	2	1.5	01	99.0	007
	BNAH	2	1.5	01	99.0	004
	KEWA	6	.		.	
	HOLB	4	1.5	14	99.0	008
	WAGA	2	1.0	01	99.5	012
KHAN	ALBY	6	.		.	
BRBK	BROC	2	1.5	01	98.5	001
BROC	BRBK	2	1.5	01	98.5	001
602	3	4	1.0	01	99.5	015
	602030	2	1.5	01	99.0	005
	MELB	4	1.0	17	99.5	008
602020	ALBY	6	.		.	

Fig. 2. — CANTOT Sample Message Type 1262.

P.M.G'S DEPT.
E440 (EM 40)
(AUG. '69)

CANTOT PROJECT

MESSAGE HEADER – FAULT DOCKETS

A.D.P. MESSAGE HEADER		
Message Type	1261	101
Source Code	28411	102
Sequence No.	0123	103
Date of Despatch	120271	104
HASH-TOTAL (incl. Message Type)	150066	113

ANALYSIS MONTH FEBRUARY

STATION STAMP:

Officer-in-Charge,
Telephone Exchange,
ALBURY, NEW SOUTH WALES. 2640

NOTES: 1. In the Message Header, all fields must have an entry.
2. Date of Despatch must be entered DAY, MONTH, YEAR, e.g. 040869.
3. This form must be placed on the top of each bundle of FAULT DOCKETS. Each bundle of 50 and header must be secured by a rubber band.

Fig. 3. — CANTOT Sample Message Type 1261.

the general level of circuit performance and the identification of inferior routes.

THE A.P.O. COMPUTER SYSTEM AND CANTOT

The A.P.O. computer operation is a pool system which is planned to encompass the various computer programmes into a totally integrated data processing system (code-named Z). Therefore, any data to be processed by the A.P.O. Data Processing Centre (D.P.C.) in Sydney must comply with the general constraints of the Z programme, as well as the CANTOT programme. The block diagram of the complete system to obtain the CANTOT reports is shown in Fig. 1.

Source Data.

The source of basic data for the programme is the fault dockets E404 (old EM5), the route failure reports E408 (old EM9) and the message type 1262 (Fig. 2). The E404 and E408 (see Ref. 2) are used to forward input data for the programme, whereas the 1262 is to create, alter or delete information on the master file of the computer.

The message type 1261 (Fig. 3) is attached to all batches of E404 fault dockets submitted as input data to the programme, and is the means by which the computer recognises the data as belonging to the CANTOT programme and validates the legitimacy of the data source.

Reporting Procedure.

All data from the district head stations is forwarded to the Data Transcription Unit (D.T.U.), Melbourne, and is transcribed on to paper tape. The tapes are forwarded weekly to the Data Processing Centre (D.P.C.) Sydney. From the weekly run the 916801 and 059803 reports are produced (Figs. 4 and 7), and provide details of errors in submitted data. The input data accepted by the computer is stored in the master file of the CANTOT programme until the end of the month, when a full production run of the programme is carried out. The 059801 and 059802 reports (Figs. 5 and 6) are generated in the production run.

An explanation of the various reports is given below.

Parameters.

The output information for the Exchange O.I.C. and Divisional levels comprises an evaluation of two parameters for each circuit group, namely, service availability and the average number of fault reports per circuit.

The formulae for calculating the parameters are:—

```
REPORT TYPE : 916801        REJECTED INPUT MESSAGES FROM OPERATING SOURCES        REG-S-N 00044 OF 04FEB71   PAGE 0017

TO  101

MESSAGE HEADER      SOURCE   SEQ    TYPE   DATE     DTU  DMI   OPI   PUNCHED   MS   SYSTEM ACTION
                    38641    0011   1261   710129   101  156   119   030271    0    ITEM PARTIALLY REJECTED

HEADER DETAIL       105    106    107    108        109          110       111      112
                    0000   0000   0000   0000000    000000000    000000             0

TRANSACTION DETAIL  202            203            204   205     206       207    208   209    210    211    212       SER V
                    MORW           HEYF           000   00002             0000   U            2801   1120   A         053 2

                    302          303    304    .305      306      307        308       309        310
                    0000000000   3301   1130   R         000001   HEYF       NX        00000000   00000000

ERROR COMMENT       FIELD 303 ILLEGAL DATE

TRANSACTION DETAIL  202            203            204   205     206       207    208   209    210    211    212       SER V
                    MORW           HEYF           000   00002             0000   U     0      2101   1020   A         054 2

                    302          303    304    .305      306      307        308       309        310
                    0000000000   2301   1120   R         000000   HEYF       EA        00000000   00000000

ERROR COMMENT       REQUIRED FIELDS NOT PRESENT

TRANSACTION DETAIL  202            203            204   205     206       207    208   209    210    211    212       SER V
                    MORW           COWW           000   00006             0000   U     0      2801   1320             058 2

                    302          303    304    305       306      307        308       309        310
                    0000000000   2801   1330   F         001000   COWW       NA        00000000   00000000

ERROR COMMENT       FIELD(S) OUTSIDE LIMITS
```

Fig. 4. — CANTOT Rejected Input Messages, Report Type 916801.

```
REPORT TYPE : 059801          TRUNK NETWORK PERFORMANCE ANALYSIS      CAN-S-N 051 OF 8JAN71     PAGE 1

                              CIRCUIT GROUP PERFORMANCE SUMMARY       DISTRICT : MORWELL VIC

CANTOT PROJECT                                                        ANALYSIS MONTH : DECEMBER 1970
```

CIRCUIT GROUP	NR. OF CCTS. IN GROUP	PERCENT SERVICE AVAILABILITY ACTUAL	LIMIT	AVERAGE NO. OUTAGES PER CCT. ACTUAL	LIMIT	
MORW TO :						
* BAIR	3	99.1 ..*	99.0	4.0 ***	1.5	
COWW	4	99.0	99.0	1.3	1.5	
* HEYF	9	98.3 *.*	98.5	1.5 *.*	1.0	
KRBA	6	99.2	99.0	1.2	1.5	
MELB	16	99.4	99.0	1.1	1.2 A	
* RDLE	2	97.0 *	99.0	2.8 *	1.5	N
SALE	14	99.3	99.0	1.0	1.5	
WGUL	4 A	99.8 .*	99.0	0.5 ..*	1.5	
YRAM	7	99.7	99.0	0.3	1.0 A	
YALL TO :						
MOEE	6	99.9	99.5 A	0.1	1.0	
MORW	15	99.5	99.0	0.3	1.5	

```
  N = NEW CIRCUIT GROUP THIS MONTH
  A = ALTERED SINCE PREVIOUS MONTH
  * = CCT. GRP. OUTSIDE LIMITS THIS MONTH
 .* = CCT. GRP. OUTSIDE LIMITS PREVIOUS MONTH
..* = CCT. GRP. OUTSIDE LIMITS PREVIOUS MONTH
      BUT ONE
```

Fig. 5. — CANTOT Circuit Group Performance Summary, Report Type 059801.

REPORT TYPE : 059802 — TRUNK NETWORK PERFORMANCE ANALYSIS — CAN-S-N 051 OF 08JAN71 PAGE 1

FAULT DETAILS FOR CIRCUIT GROUP OUTSIDE LIMITS — MORW - HEYF

CANTOT PROJECT — ANALYSIS MONTH : DECEMBER 1970

CIRCUIT NUMBER	SYSTEM NR.	CHAN. NR.	NO. OF CIRCUITS	FAULT CODE	STN. FAULT FOUND	REPORTED DATE	REPORTED TIME	RESTORED DATE	RESTORED TIME	OUTAGE (MINS)	SOURCE	EFFECT	RESTORATION CODE
	V0087		4	NX		5 DEC	0930	6 DEC	0830	780	0	U	R
	"		4	EA	TRAR	23 DEC	0840	23 DEC	1000	80	0	U	F
	V0035		4	EA	TRAR	27 DEC	1020	27 DEC	1230	130	0	U	F
1			1	LC13		1 DEC	0757	1 DEC	0825	25	0	U	Y
"	V0035	1	1	NA		1 DEC	2030	2 DEC	0820	110	0	U	R

Fig. 6. — CANTOT Fault Details for Circuit Group Outside Limits, Report Type 059802.

REPORT TYPE : 059803 — CAN-S-N 051 OF 8JAN71 PAGE 1

ERRORS DETECTED AT UPDATE PHASE — DISTRICT : MORWELL VIC

CANTOT PROJECT — ANALYSIS MONTH : DECEMBER 1970

MESSAGE TYPE : 1261 — THE FOLLOWING FAULT DOCKETS WERE REJECTED FOR THE REASONS SHOWN AND NOT INCLUDED IN THE CIRCUIT GROUP PERFORMANCE SUMMARY. CORRECTED DOCKETS SHOULD BE RESUBMITTED BEFORE THE SEVENTH DAY OF THE NEXT MONTH.

CIRCUIT GROUP	CCT. NR.	SYSTEM NR.	REPORTED DATE	REPORTED TIME	RESTORED DATE	RESTORED TIME	NR. OF CIRCUITS	MESSAGE SEQUENCE	REASON FOR REJECTION
MORW-BOOL	1	V0755	0812	1321	0812	1252	1	0051	FAULT RESTORED BEFORE REPORTED
MORW-ERIC	2		1512	0815	1512	0920	1	0052	CCT. GROUP NOT ON MASTER FILE
MORW-MELB		V3128	2212	1118	2212	1231	27	0052	NR. OF CCTS. TOO LARGE
MORW-KRBA			2811	1522	0312	1155	1	0051	REPD MONTH NOT ANALYSIS MONTH

MESSAGE TYPE : 1262 — THE FOLLOWING CHANGES TO THE CIRCUIT GROUP FILE WERE INEFFECTIVE FOR THE REASONS SHOWN.

CIRCUIT GROUP	CODE	AV. NR. OUTAGES LIMIT	DAY OF EFFECT	PERCENT AVAILABILITY LIMIT	NR. OF CIRCUITS	REASON FOR REJECTION
MORW-KORR	6					CCT. GROUP NOT ON FILE
MORW-TRAF	4	1.5	02	99.0	6	CCT. GROUP DETAILS SAME AS THOSE ON FILE
MORW-ROYS	4	1.5	08	99.0	17	SOURCE CODE NOT SAME AS THAT ON FILE

Fig. 7. — CANTOT Errors Detected at Update Phase, Report Type 059803.

$$\text{Service availability: } \left\{ 1 - \frac{\text{Total Circuit Minutes Outage}}{14 \times 60 \times \text{Number of Days in Analysis Month} \times \text{Number of circuits}} \right\} \times 100\%$$

(Service availability is calculated 8 a.m. to 10 p.m. seven days per week.)
Average Number of Fault Reports per Circuit:

$$\frac{\text{Summation of Number of Circuits Affected by Each Fault}}{\text{Number of Circuits in the Group.}}$$

This information is supplied monthly in the form of the printed report 059801. Action limits for both parameters are set by the Regional Engineer and a supplementary statement gives full details only of every fault affecting those circuit groups which do not meet one or both limits (report 059802). For those groups which meet the preset limits, no further details are necessary. Although the system is designed primarily for the trunk network, it is also applicable to junction groups in country areas where required.

Output Data.

Four reports are currently produced by the CANTOT programme. They are:

916801 — Input Edit Reject Report (Fig. 4).
059801 — Circuit Group Performance Summary (Fig. 5).
059802 — Fault Details for Circuit Group Outside Limits (Fig. 6).
059803 — Errors Detected at Update Stage (Fig. 7).

A copy of each report produced for his district is sent to the Maintenance District O.I.C.

The Regional Engineer receives copies of the Circuit Group Performance Summary (059801) and the Fault Details for Circuit Group Outside Limits report (059802) for all district head stations within his division.

The 916801 report (Fig. 4) is a product of the general programme. It is sent to the O.I.C. of the District head station when data submitted by him does not meet the constraints of that programme.

The 059801 (Fig. 5) report is the main print-out of CANTOT. It provides information on the monthly fault performance of each circuit group on the master file, and whether for the previous two months the circuit groups were within the limits of the two parameters. If they are exceeded, an asterisk is printed against the limit exceeded, and the circuit group involved for the current month. Asterisks are also printed beside the appropriate limit if it has been exceeded for either or both the previous two months. This provides a three months fault history of the circuit group performance.

Where poor performance figures of a circuit group appear to be due to distributed or random factors, it is probable that no remedial action would be initiated on the basis of a single bad result, but the peerformance of the circuit group over three or four consecutive months would be observed and consistently poor results investigated.

It is considered that action need only be taken on a circuit group when its performance figures exceed the established limits for its parameters; therefore the 059802 report (Fig. 6) is produced for a circuit group, only when either or both limits are exceeded within the month of analysis.

It should be noted that an individual circuit with a high fault incidence will not be shown up, in the output reports if the average performance of the circuit group is within the specified limits. This can occur when the faulty circuit is in a large circuit group, and to provide for this situation a supplementary system of manual flagging and filing of the fault dockets is necessary (see Ref. 3). The 059803 report (Fig. 7) is only produced when data on the E404 or E408 or 1262 does not conform with the constraints of the CANTOT programme.

PROBLEMS IN SETTING-UP SYSTEM.

When submitting data for a computer programme it is essential that key information be correct. The mechanics of the CANTOT system require the direct submission of input data to a computer system by the field technical staff. As the transcription of this data on paper tape is performed by non-technical female staff, remote from the data source, it is essential that the data entries should be not only accurate, but also legible, as verification of the entries is not practicable at the transcription stage. Further, the submitted input data must comply with the constraints of the Z and CANTOT input programmes. These aspects of the CANTOT system requirements were the subject of considerable staff education effort prior to introduction of the system.

As a standard list of abbreviations did not exist, it was common practice to abbreviate exchange names when recording faults and in designating circuit jacks on trunk switchboards with local abbreviations. A list of the names and suggested 4-letter codes for all exchanges, long line equipment terminals and repeaters was therefore compiled. A computer was used to sort the information into two lists; one in alphabetical order of exchange names and the other in alphabetical order of 4-letter codes. The first list was produced on a State basis so that the 4-letter code of any exchange in a particular State could easily be found. The second list was compiled on a Commonwealth basis to eliminate duplication and to enable the exchange name for any 4-letter code to be readily obtained. Both lists were printed in book form under the title "Index of Exchanges in the Trunk Network."

FUTURE DEVELOPMENTS.

For use at the management level responsible for the oversight of the country trunk and junction network, it is proposed to provide a further series of output reports. A brief outline of the content of these statements is supplied below.

Statement A: A State and Commonwealth quarterly summary of the per cent. distribution of circuits in six categories of per cent. service availability.

Statement B: A State and Commonwealth quarterly summary of the per cent. distribution of circuit fault incidence under the primary classifications of plant type, viz., external plant, exchange equipment, long line equipment, radio, power plant and cause unknown.

Statement C: A State and Commonwealth quarterly summary of the duration of circuit outages as a per cent. distribution of plant type.

Statement D: A State oriented quarterly print-out of circuit groups which fail to meet a predetermined level of performance. This level, in terms of availability and fault incidence, will be established by the relevant State Engineering Administration and may be so controlled (adjusted quarterly) as to reveal the circuit groups comprising the tail of the performance distribution curve.

Statement E: A State oriented quarterly print-out of the per cent. distribution of circuit groups in four categories of average time taken to effect service restoration. eg., $\leqslant$ hour, $\leqslant$ day, $\leqslant$ 2 days, $\leqslant$ 4 days.

Although CANTOT is primarily service oriented, a further proposed extension of the programme would enable some of the basic input data to be used to obtain statistics of the performance of various items of plant for the information of procurement sections. This can be done by means of the system number which should be entered on every fault docket issued for circuits operating over carrier systems. It is proposed to create a master file for the plant analysis programme which will contain all the information on each unit of plant (e.g., manufacturer, contract number, date of purchase, location and previous fault history). As the system number will be the key to obtain this information or other analysis, it will be imperative that the correct system number be used in all instances.

As service performance is one of the parameters used in determining staff levels in the Position Estimating Procedure (P.E.P.) for technical staff, these proposed reports and other information produced by the CANTOT programme should be of assistance to Regional Engineers in determining staff requirements and performance standards within their Divisions.

CONCLUSION.

The application of data processing to the trunk network has assisted field engineers to assess quickly the performance of circuits in their area and pinpoint trouble spots. It will also provide a feedback of the performance data of equipment to design engineers and manufacturers.

Being the first time that field staff have been directly involved with data processing and computers, it has provided a basic training ground for the future. A by-product of the system is the considerable reduction in time spent on clerical duties by the technical personnel enabling them to devote their energies to the ever-increasing complexity of equipment being installed in our exchanges.

REFERENCES.

1. A.P.O. E.I. General Works M3410. "Fault Recording Procedures — Trunk Channel Equipment."

2. W. Stirling, "Fault Recording in Country Area Exchanges'; Telecom. Journal of Aus., Oct. 1971, Vol. 21 No. 3, p. 280.

3. A.P.O. E.I. Telephone Exchanges, M0114; "Fault Recording Procedures for Country Maintenance Districts."

FURTHER READING.

A.P.O., E.I., Long Line Equipment, P 0115; "Computer Analysis of Trunk Circuit Faults — CANTOT."

Network Performance Information Bulletin, No. 1.

POWER DISTRIBUTION IN HIGH-RISE DEPARTMENTAL BUILDINGS

K. A. G. McKIBBIN, M.I.E. (Aust.)*

INTRODUCTION

The purpose of this paper is to discuss and set out the general requirements for the supply of electrical energy, its distribution and control, in high rise buildings housing telecommunications equipment and other allied specialised equipment. Particular attention is given to the reliability of power supplies, economy in switching and distribution, overall efficiency, co-ordination of control, and minimal maintenance.

Current examples of the class of buildings being considered are Lonsdale Telephone Exchange in Melbourne, Pitt in Sydney and Waymouth in Adelaide, all of which have a potential load demand of at least two megawatts. The power plant at Lonsdale is already installed; the Pitt plant is being installed; and at Waymouth the design is finalised.

FUNCTION

The function of the power system is to provide adequate power at all times and in all areas within the building to meet efficiently the operational needs of all the installed equipment. At the centres under discussion the electrical supply requirements can be itemised as follows:—

The incoming commercial supply.
The consumer load requirements.
The mains distribution and switching.
The standby generating plant.
The power plant within the building to provide complete continuity of a.c. and d.c. supplies to the various equipments — telephone exchange; computer complex; long line; radio and miscellaneous specialised items.
Supply to essential services — equipment, environmental control, lifts, fire protection, and selected lighting, etc.
Centralised supervision and control of the power system.
House supplies — lighting, miscellaneous power, canteen, etc.

These items govern all aspects of the power system from the planning and design stage, through layout and installation to the operation and maintenance needs. It follows that care in the complete integration of all power plant items coupled with collective experience in power engineering is very necessary in the production of a satisfactory system.

In addition, the allocation of floors to the various functions for which the building is designed has a bearing on the economics of power provision.

INCOMING A.C. MAINS

Due to the magnitude of the load, the incoming a.c. mains will be at high tension. Indications are that 11 kilovolts will be standard for all capital cities.

It is usual to have two sources of incoming supply, each capable of carrying the full load of the building. Normally any one source is used, the other remaining as a standby.

The consumer may accept power at the incoming high tension voltage and provide step-down transformers as required. Under this condition, the consumer would receive a discount on the tariff of at least five percent. Sydney County Council have recently increased this discount to 8%. A high load factor as in the case of electronic telephone exchanges, may be a point for discussion with the Supply Authority in obtaining a further reduction in energy costs.

The use of "dry" transformers gives a 50% reduction in mass compared with oil filled transformers, reduces fire risk and maintenance, and allows ease of unit construction whilst the transformer and switchgear forms one packaged unit. These reduced installation costs more than offset the slightly higher cost of the dry transformer.

CONSUMER LOAD REQUIREMENTS

The fully developed peak load demand in the class of building under discussion could range between two and four megawatts. At any stage during the development, the standing load can be taken as half the peak load. In general at telephone exchanges, the load peaks for 1½ hours during the morning, 1½ hours in the afternoon and one hour in the evening. Load changes are not in large steps but rather on a gradual increase and decrease according to traffic conditions.

MAINS SWITCHING AND DISTRIBUTION

The telecommunication centres at Sydney, Melbourne and Adelaide, mentioned earlier in this paper accept the incoming a.c. mains at low tension, namely 415 volts from a sub-station located at one corner of the building in the basement area. The main switchboard is in the same area close to the sub-station. A multiplicity of individual power risers extend from the switchboard to power and lighting distribution points at the various floor levels. For example at the Pitt Exchange, the sum of the heights between the switchboard and the floor levels connected by individual risers is approximately 4,500 ft. Because of the switchboard being located at the front of the building and the power plant at the rear, the overall length of the risers is more than double its vertical component.

The changeover switching on the main switchboard at Pitt Exchange consists of twenty-seven switches, thirteen of which are automatic and fourteen manually operated. At Lonsdale and Waymouth Exchanges similar changeovers are made by twelve automatically operated, low tension, heavy current, circuit breakers.

Undesirable features of the present mains switching and distribution system at low tension are:—

(i) The point of transformation from the incoming high voltage mains to the low tension supply, namely the sub-station, is located in the worst possible position with regard to the load copper centre.
(ii) Because of (i) the copper requirements are high. In addition it may be necessary to run cable at a current density below the economic value to minimise voltage drop.
(iii) Copper losses can be a significant charge in the energy tariff.
(iv) The heavy currents introduce magnetic coupling and electrical noise problems.
(v) Distribution installation costs are very high.
(vi) An extensive main switchboard is required to meet the L.T. distribution and emergency switching requirements.

The undesirable features of the present L.T. switching and distribution

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system can be eliminated by extending the incoming high voltage mains to various load copper centres within the building (see Fig. 3). Simplification of the system is further aided by past and recent developments in the cable and switchgear fields, the use of dry transformers and the availability of high tension HRC fusegear. In addition, the larger a.c. motors and power rectifiers could be fed direct from high voltage which eliminates double transformation in these areas. The advantages to be gained by extending the distribution of high voltage within the building are:—

A reduction of at least 10 to 1 in copper requirements for the main distribution. The modern trend in high tension cable and busbar is to use aluminium conductors, resulting in a further reduction in cost.

A reduction of at least 2 to 1 in copper requirements for localised low tension distribution due to the placement of dry type step down transformers at the copper centres of the various load areas. Distribution cable installation costs reduced by at least 75%. Simplification of distribution switching with particular reference to emergency conditions. For example, at Pitt Exchange, twenty-seven changeover switches are used, thirteen of which are automatic in operation. At Lonsdale and Waymouth Exchanges, twelve heavy current low tension circuit breakers are operated in changeover from mains to standby supply and vice versa. In a high voltage system only a simple circuit breaker is used.

Significant improvement in mains voltage regulation within the building.

Magnetic coupling problems are minimised due to the very big reduction in distribution amperes. Fault currents on the low tension side of the step-down transformers are limited by their capacity and reactance. Choice of suitable transformers reduces low tension switchgear costs to a minimum. Increase in reliability.

Reduction in maintenance. Operational staff requirements are a minimum with centralised control.

Reduction in energy tariff.

An additional feature of high tension distribution not always appreciated is that due to standard H.T. switchgear ratings, a single design of system can cope with a wide range of loading with little or no modification. At Pitt Exchange, for example, the changeover from crossbar to electronic operation during the design and construction stage resulted in major changes to the power system, including a complete new low tension switchboard. With a high tension system such changes if any would only apply to localised power distribution.

There is no doubt at this stage that the extension of the incoming high voltage mains to load centres at various levels in the high rise buildings under discussion leads to a more efficient electrical power system. A closer examination will indicate that such an arrangement can be designed to give greater reliability, higher efficiency, economy in switching and distribution, better co-ordination of control and minimal maintenance.

The general requirements for H.T. mains distribution and switching are shown in Fig. 1. Incoming mains are at 6.6 or 11 kV depending on the electricity supply distribution.

In general, circuit breakers are the same for both voltages. The high voltage can be used direct on the higher powered air conditioning motors and on the input to high power rectifiers, thus eliminating the need for interposing transformers. Synchronous motors could be introduced in some air conditioning drives to effect power factor improvement.

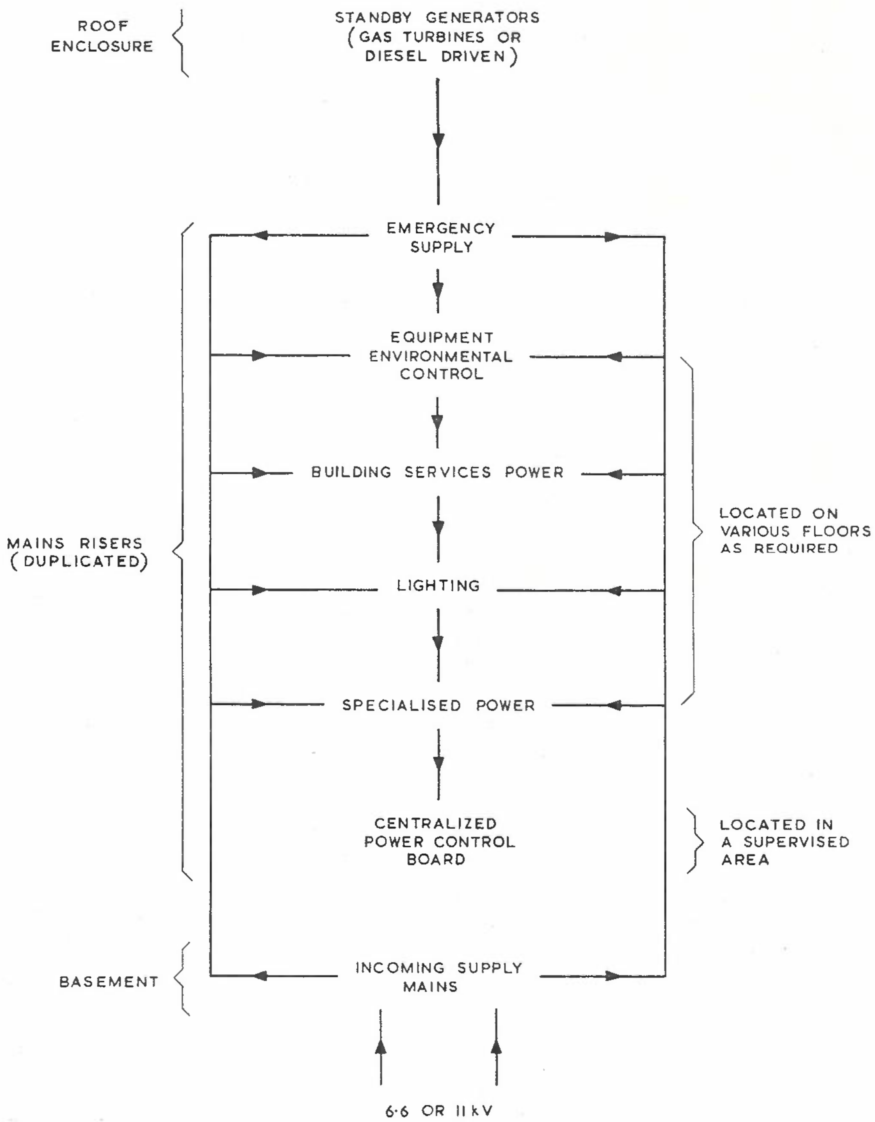


Fig. 1. — Functional Diagram of H.T. Distribution.

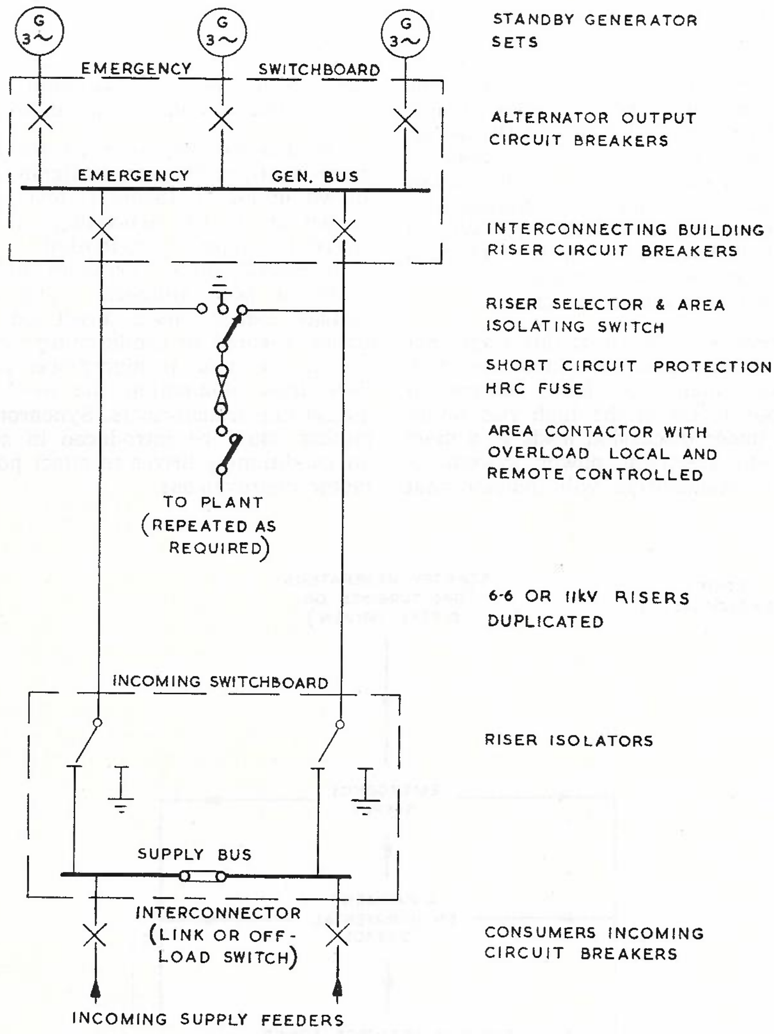


Fig. 2. — Basic Switching Diagram for H.T. Distribution.

Low tension requirements at 415/240 volts are provided by "dry" type transformers located at various levels to suit equipment, miscellaneous power and lighting needs.

Before discussing the switching arrangements associated with the main distribution, it should be stressed that switchgear can take a wide variety of forms, layout and make-up, and yet achieve the same object, namely the efficient and safe control of electrical power. The importance of switchgear making and breaking capacity and all that is implied and also safe control are vital factors in deciding the switching arrangements.

The proposed switching arrangements as indicated in Fig. 2 are based on two incoming supply feeders, with duplicated building risers at H.T. each capable of carrying full load. These risers are switchable to the emergency generating plant.

With the mains healthy the following conditions apply:—

Only one incoming feeder circuit breaker is closed, the other acting as a standby to the feeder on load. Interlocks prevent both incoming breakers being closed simultaneously.

Both riser isolators closed, allowing the area loads to be switched to either riser. Alternatively only one riser isolator closed and the area loads all switched to this riser.

Both riser circuit breakers open: These switches are interlocked with the incoming feeder circuit breakers to prevent closing unless the latter are open.

Failure of both incoming mains allows switching as follows:—

Incoming feeder circuit breakers open.

The emergency generator bus is energised from the emergency generating sets via the alternator circuit breakers.

The riser circuit breakers are both closed. Alternatively, if all the area loads are connected to the same riser, only the circuit breaker associated with this riser need be closed.

The proposed mains distribution and switching at H.T. forms the simplest possible system and is reflected in the low switchgear requirements. Fig. 3 lists the switchgear details, which are as follows:—

Basement:

Supply Authority switchgear and ing —

Consumers switchgear comprising —

2 — Incoming mains circuit breakers.

2 — Riser isolators.

1 — Bus tie.

Top Floor:

The standby generating set switchboard comprising three or more alternator circuit breakers with control cubicles, and two building riser circuit breakers.

Equipment environmental plant—air conditioning switchgear.

Various Floors:

A.c. input switchgear associated with the power suites, a.c. and d.c. for the telecommunication equipment, computer and other specialised plant.

A.c. input switchgear for miscellaneous power and lighting.

Referring to the mains distribution diagram (Fig. 2), the total of seven H.T. circuit breakers, comprising two incoming feeders, the riser units and the alternator output switches, are all similar. These breakers are electrically operated with provision for local/remote closing and tripping. In addition, the interlocking facilities cover the operational requirements of the power system in the building.

The two riser isolators may be air break switches of the off load break type, manually operated with locking "in" or "out", and electrically interlocked on a trip basis with the supply circuit breakers.

The area selectors and isolating switches are "off load" type with locking "in" and "out" facilities, and are manually operated. Short circuit protection of the load area is provided by H.T. HRC fuses, with input switching and overload protection covered by vacuum contactors. The latter units are fitted with facilities for local/remote closing and tripping. A feature of this contactor is long contact life capable of up to two million operations at rated current with little or no maintenance.

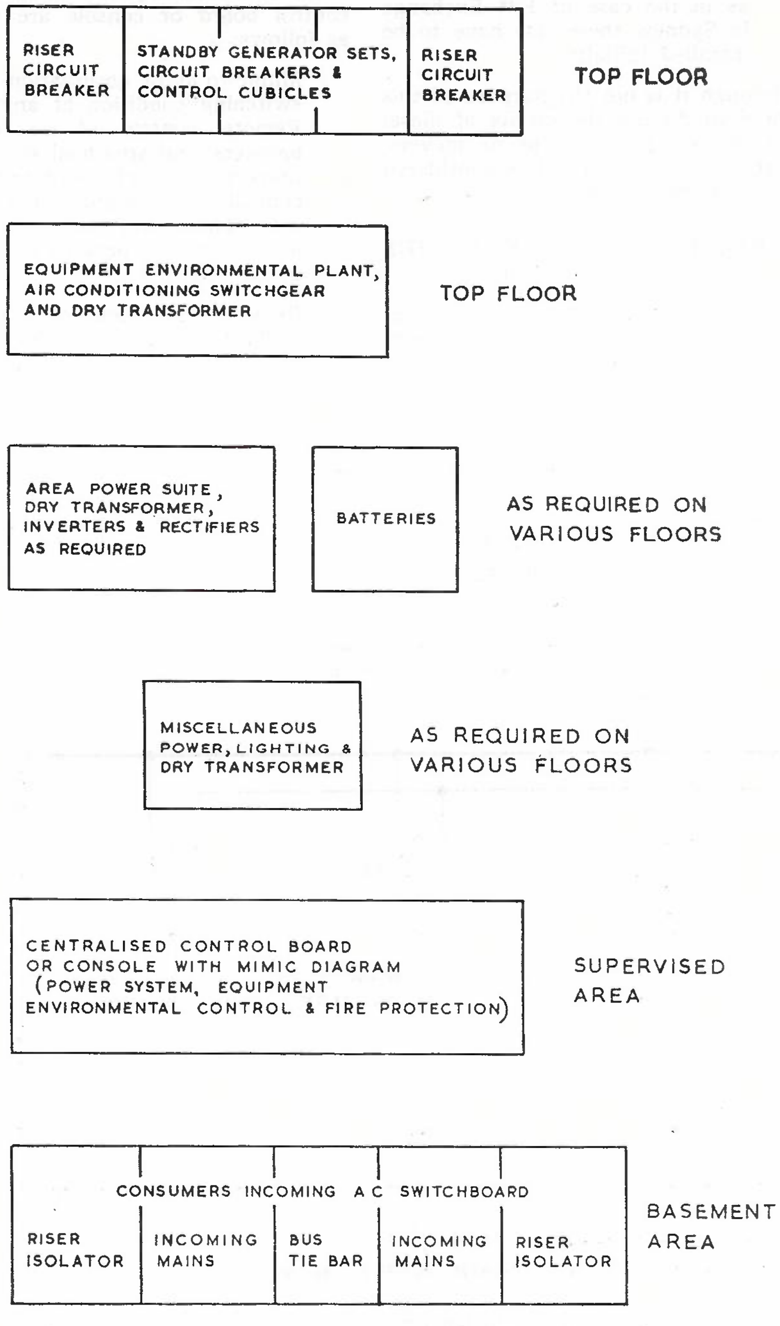


Fig. 3. — Switchgear Requirements for H.T. Distribution.

EMERGENCY GENERATING PLANT

In high rise P.M.G. buildings to date, the location of the emergency generating plant is in the basement area. This arrangement poses many problems, the two most vital and costly being cooling and disposal of the engine exhaust gases. In addition the space requirements in the basement form a large proportion of overall cost, and the fact that such space could be very usefully used for other purposes.

Locating the generating plant on the roof of buildings is receiving much attention both here and overseas. Its adoption results in a very considerable reduction in cost due to the elimination of the problems associated with such plant in the basement. An example is the 750 kVA standby diesel-alternator plant on the roof of the new multi-storey A.M.P. building in Melbourne. The supply and installation of this plant was less than half the cost of the equivalent set in the basement. In the case of gas turbine driven generators where exhaust gas back pressure must be minimal and the attenuation necessary of high frequency noise, the advantages of a roof installation are more pronounced. A list of the advantages of installation on the roof are:—

- Elimination of very costly engine exhaust stacks, back pressure problems and condensation.
- Elimination of water tower cooling, and its associated water piping and valves running between the basement and roof. This does not apply to gas turbines.
- Considerable cooling air requirements in the basement for the removal of engine radiated heat and alternator heating are eliminated.
- Engine room noise problems associated with ducting, wall opening, doors, etc., are eliminated.
- Release of valuable basement space for other purposes.

In general the roof of high rise buildings requires little reinforcing to carry the dead weight of generating plant. The use of antivibration mountings eliminates all vibration from the building.

A sheet iron structure with a three foot clearance between the sides and the roof to allow for air circulation is satisfactory for housing diesel alternator sets. A short engine exhaust pipe with an efficient snubber provides sufficient silencing. Engine cooling can be radiator or heat exchanger depending on the size of set and on the water cooling facilities provided on the roof for other purposes.

Gas turbines require inlet and exhaust silencers but no radiator or heat exchanger.

As the generating sets are the standby power source and must cover short and prolonged failures of commercial power, the reliability and flexibility of the system must be the best possible within reasonable limits of cost. The number of generating sets installed to meet the fully developed load requirements should therefore not be less than three, preferably four. The reasons for this are:—

Flexibility of operation — with one set out due to its failure or for maintenance it must be possible to carry on the essential services. Careful load selection may be required under this condition. Parallel operation gives flexibility of control plus power for motor starting.

Selection of set capacity in association with available prime movers is of importance. For example, the prices per kilowatt for a range of diesel driven generating sets less control gear and external cooling are of interest —

600 kW	— $66 per kW
700 „	— „
1400 „	— „

It will be noted from these figures that four smaller sets would cost no more than two larger sets to meet the same load. Suitable gas turbine driven sets at present available cost approximately $120 per kW.

With smaller sets, the floor loading is more evenly distributed and lifting requirements are less.

Capital expenditure can be spread over the full development period when smaller sets are used — two sets initially, plus additional sets up to four to meet load requirements. When two sets are used to meet the fully developed load as in the case of Pitt Exchange in Sydney, these sets have to be installed initially.

Although it is not the purpose of this paper to discuss the merits of diesel versus gas turbine as prime movers, both types of set should be considered for roof installations.

CENTRALISED CONTROL OF THE POWER SYSTEM

Centralised control of the power system is very necessary to ensure continuity of supply and efficient operation under normal and emergency conditions. As the air conditioning and fire control are closely linked operationally with the power system, and their function is essential in the environmental control of the telecommunication and computer plant areas, all these functions should be supervised in a single area. Such an arrangement reduces the electrical and mechanical staffing requirements, and minimises the possibility of confusion and mis-operation which could arise in an emergency.

The functions required on the power control board or console are briefly as follows:—

Mimic to allow observation of the switching condition at any time.

Remote control of all circuit breakers, and area load switching.

Start/stop and synchronising control of the standby generating sets. These functions may also be automatic depending on operational conditions.

Remote indication of the kW loading at various loading points and on the standby generator out-

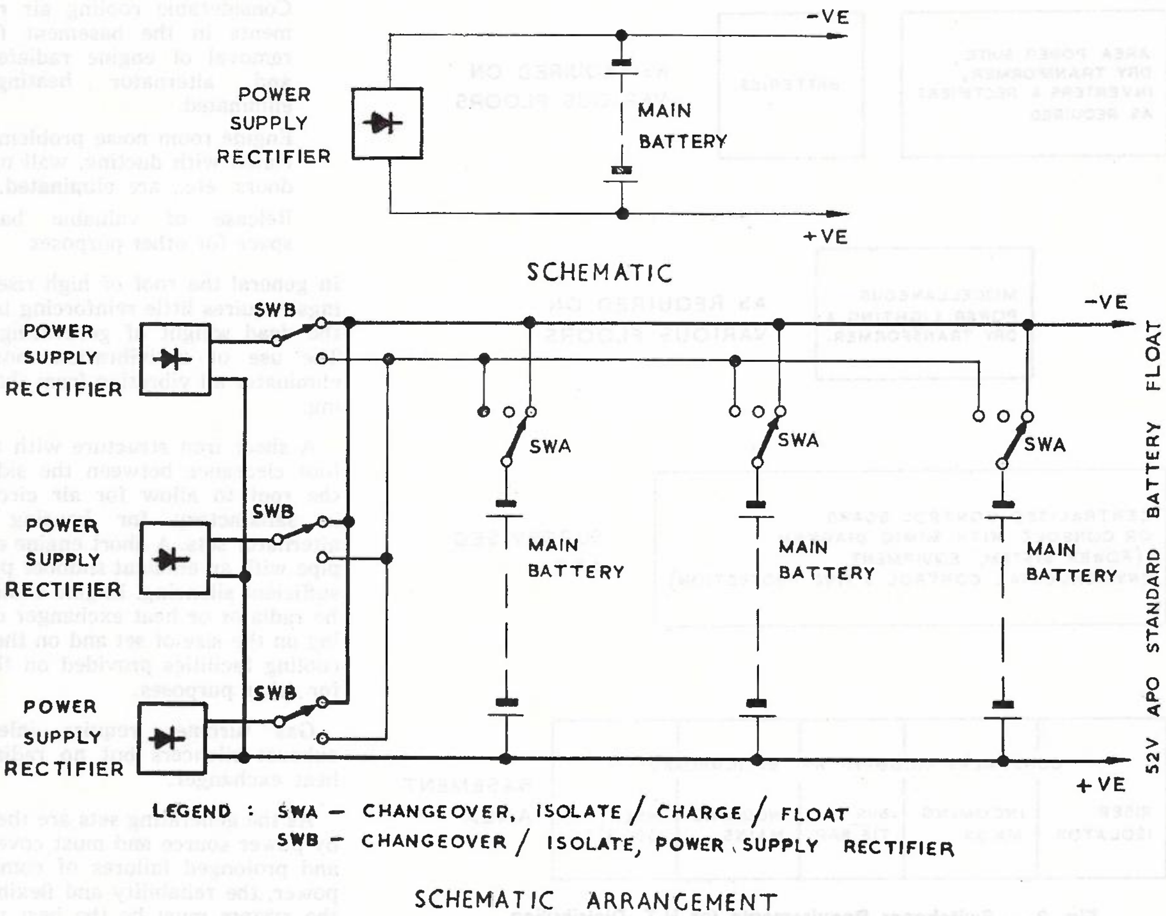


Fig. 4. — Current A.P.O. Switching Arrangements for Small and Large D.C. Supplies.

puts, to facilitate switching operations.

Alarm extensions from all power plant associated with the telecommunication and computer equipment.

Lighting in the central supervised area should be continuous at all times, and not subject to a break on mains failure. The power for such lighting can be supplied from a small local inverter system or from the building a.c. no-break power supply. It is likely that continuous lighting may be required in other areas and therefore the latter supply may be more convenient.

POWER PLANT FOR EQUIPMENT D.C. AND A.C. SUPPLIES

General

At present the d.c. supplies to equipment are provided by static rectifiers with parallel connected lead acid batteries operating on full float to ensure continuity of supply during a.c. failure. The d.c. busbar voltage is maintained at the minimum required to make up battery losses, namely 2.17 volts per cell. A nominal 48 volt d.c. supply uses twenty-four 2 volt cells, giving a load busbar of 52.08 volts. Similarly, a nominal 24 volt system operates at a busbar voltage of 26.04 volts.

At large centres where standby generating sets are installed in multiples, the battery provides continuity of the d.c. power during periods without a.c. supply. These periods would not extend beyond the time taken to bring the standby generators on load after a mains failure. A battery capacity sufficient to meet one hour on peak load is considered satisfactory. One of the advantages of centralised control of the power system is that this period could safely be reduced to thirty minutes.

No-break a.c. supplies are provided in the main by rotary inverters of the 2-machine and 3-machine types. Static inverters are used for supplies up to 1½ kVA loading. The latter type is now being extended into the areas covered by rotating machines, for example at Pitt and Waymouth electronic exchanges, and the C.U.D.N. installations. The d.c. input voltage to these larger inverters depends on the economics of the overall power system. The current electronic exchanges use 48 volts d.c. and C.U.D.N. 240 volts d.c.

The a.c. supply to the power rectifiers can be direct at H.T. or at 415 volts via a step down transformer. The choice of voltage will depend on the power system design.

The analysis of the d.c. and a.c. power supplies which follows these general remarks is based on the present practice of providing peripheral power plant to meet the needs of the telecommunication, computer and other specialised equipment installed in a single building. The future trend may be to a single supply to meet all requirements and the provision of the necessary diversified supplies inbuilt into the equipment. The C.U.D.N. equipment operates on this basis except that the a.c. supply must be "no-break". It is understood that in future the d.c. supplies to telephone exchanges, and transistorised radio and long line equipment will be at 48 volts d.c. nominal.

Loading

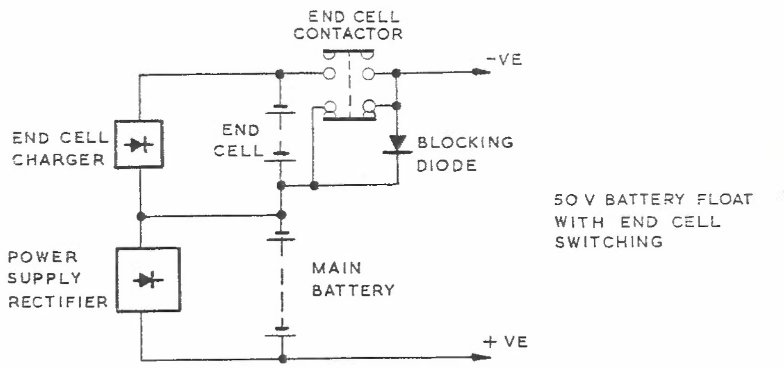
Load swing is an important factor in rectifier design, especially when associated with lead acid batteries on float. With limited swing or fixed load it is possible to provide a more simple plant with increased operational efficiency, than is necessary for wide load swing.

Latest information indicates a standing load figure of 55% peak load for electronic telephone exchanges. In practice therefore, maximum load swing of 45% peak load can be effected. For practical purposes the loadings for C.U.D.N., long line equipment and broadband radio can be assumed constant.

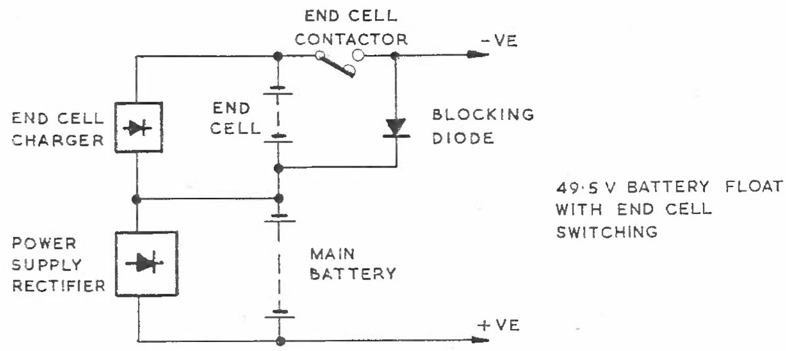
D.C. Supplies

For the purpose of this paper it is assumed that nominal 48 volts d.c. is all that is required from the peripheral d.c. power plant. Any other d.c. voltage requirements within the equipment is provided by inbuilt devices.

In considering the various methods of d.c. supply provision it is very desirable from the power consumption and heating points of view, particularly

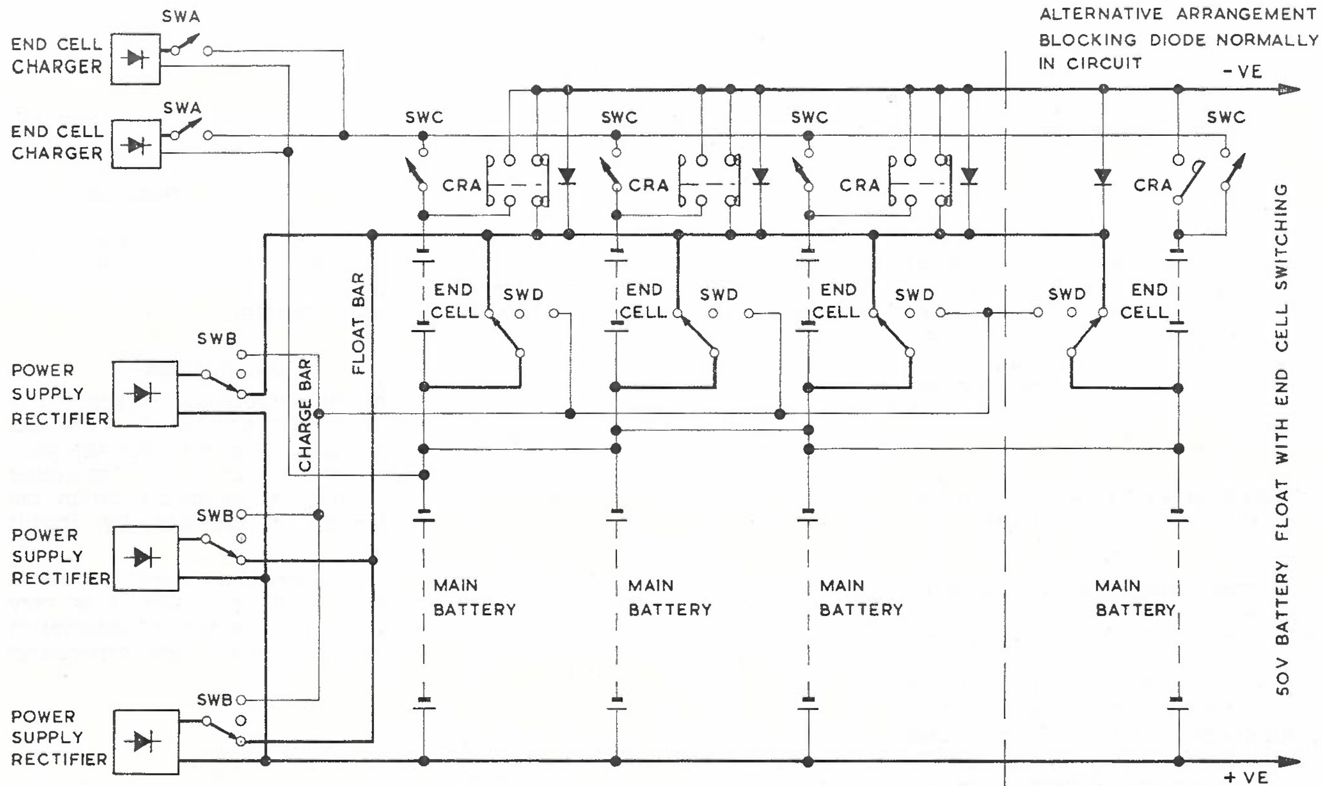


BLOCKING DIODE ONLY IN CIRCUIT DURING END CELL SWITCHING



BLOCKING DIODE NORMALLY IN SUPPLY CIRCUIT

Fig. 5. — Alternative Arrangements for End Cell Switching.



LEGEND : SWA - OUTPUT, END CELL FLOAT/CHARGE RECTIFIER SWD - CHARGE/ISOLATE/FLOAT, MAIN BATTERY
SWB - CHANGEOVER/ISOLATE POWER SUPPLY RECTIFIER CRA - END CELL CONTACTOR
SWC - CHARGE FLOAT, END CELL

Fig. 6. — Switching Diagram for End-Cell D.C. Installations.

on heavy continuous loading that the equipment d.c. supply voltage is maintained constant under all conditions at the optimum design value. Continuity of d.c. supply is required during breaks in input a.c. power or failure of conversion plant. It is essential in such breaks, that the d.c. voltage is maintained within the working voltage limits of the equipment. The various methods of provision based on the present A.P.O. standard float voltage of 2.17 volts per cell for lead acid batteries and end of discharge lower voltage limit of 1.85 volts per cell, are as follows:—

Present A.P.O. standard (See Figs. 4 & 8): Constant potential rectifiers operating in parallel provide d.c. power. Automatic switching "in" and "out" of individual rectifier units to suit load requirements ensures operation over their most efficient load range and power factor. Continuity of the d.c. supply during a.c. power interruptions or rectifier plant failure is provided by lead acid batteries connected in parallel with the d.c. supply and operated on the "full float" system. Details of the "float" arrangements are:

Number of cells in series per battery	24
D.c. busbar voltage	52.08
Voltage range at battery terminals on discharge	48 to 44.4

Floating Battery with End Cell Switching (See Figs. 5, 6 & 8). The power supply rectifiers can be similar to the present A.P.O. standard, except that the number of lead acid cells on "float" are reduced to 22 or 23 in series per battery. The number of end cells, 2, 3, or 4, can be switched "in" in steps or all at once. A small float-charge rectifier is necessary for maintaining the end cells. The float and switching details covered in Figs. 5 & 6 are as follows:—

Number of cells in series per battery	23
No. of end cells	3
D.c. busbar voltage	50 or 49.6
Voltage range at battery terminals on discharge. Momentary drop to 45 volts	52 to 45

Total capacity of batteries in parallel is about one half the requirement for the A.P.O. standard float system with equivalent loading. In this instance as there are 26 cells in series per battery during discharge, the end voltage can be lowered to 1.73 volts per cell.

Floating Battery with Series Voltage Regulators. (See Figs. 7 & 8). The power supply rectifiers operate at a d.c. voltage suitable for floating the main battery. The number of cells in series per battery can range from 24 to 28 depending on the discharge requirements. The load busbar voltage is maintained at 48 volts d.c. by a buck-boost regulator irrespective of whether the power is supplied by the power rectifier or by the main battery on discharge. In other words the load bus is continuously maintained at constant voltage. The float and switching details shown in Fig. 7 are as follows:—

Number of cells in series per battery
24 to 28
depending on load requirements.
D.C. busbar voltage
48
continuously.
Total capacity of batteries in parallel,

is about one half the requirement for the A.P.O. standard float system with equivalent loading.

Comparing the three d.c. systems already described, indicates that the present A.P.O. battery floating system is uneconomic, especially at the heavier loadings encountered in the new high rise buildings. The main points of comparison are as follows:—

Capital Cost. All three systems are are about equal as the additional switching and plant costs on the end cell switching and constant potential systems would be covered by the large reduction in battery capacity over that necessary for the current A.P.O. system. Space requirements are greater for the latter system due to larger requirement in battery capacity.

Operation. The A.P.O. system from the power switching point of view is simple. The other two systems require additional power switching (See Figs. 4, 5, 6 & 7). In all three cases the rectifier control circuits are similar. The constant voltage d.c. system using a series voltage regulator meets the ideal requirements for maximum reliability and design performance of the connected equipment. In other words the equipment operates continuously at its mean designed voltage, heating is a minimum for ideal operation, operating temperatures are constant and power consumption is a minimum.

Power Consumption. Very considerable savings in power can be achieved by operating the equipment at the optimum design voltage. Comparing the A.P.O. system with the other two systems, shows a power reduction of $7\frac{1}{2}\%$ for end cell switching and 15% for the series regulated constant voltage system. The reduction in power on the latter two systems is also applicable to the equipment air conditioning load. It may be possible to lower the load busbar voltage on the end cell system to 48 volts, depending on the end cell switching time. The following calculation indicates the savings that could be made when operating at a load busbar voltage of 48 volts in lieu of 52 volts.

Assume a combined equipment and air conditioning load of 1 MW and a kWh cost of 2 cents.

Total annual bill	$175,200
15% annual saving	$26,380

General Comments on d.c. Supplies

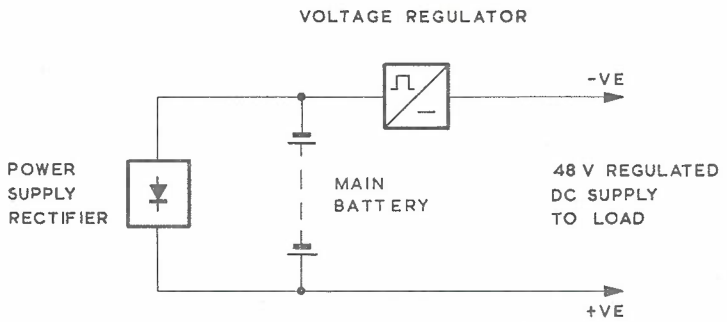
At present individual rectifiers are designed completely self contained, with voltage regulation and parallel operating facilities in-built. Automatic switching "in" and "out" of rectifier units in parallel to suit varying load conditions is also provided. Rectifier units complete with d.c. power switching board are installed in the form of a power suite to suit equipment load requirements. (See Fig. 9.)

Usually the power suite and associated batteries are located in rooms convenient to the equipment area. Power distribution to the equipment and to d.c./a.c. inverters for a.c. nobreak supply is direct from the d.c. output board. Battery charge/float switches are also located on this board.

Due to the considerable reduction in load swing at the new large centres, coupled with the high efficiency of modern rectifiers over a wide load range, the automatic switching "in" and "out" of units in parallel does not reduce power consumption. The facility could be eliminated with advantage as it simplifies circuitry and allows a wide tolerance on load sharing.

The 48 volt d.c. loading at the large telecommunication centres presents distribution volt drop problems and the minimising of the busbar impedance to assist in the reduction of electrical noise. Locating the d.c. power suite and batteries in rooms at one end of the equipment area does not lend itself to an efficient distribution layout. An alternative arrangement is to locate suitably sized rectifier and battery groups at convenient points on the long side of the equipment area (See Fig. 9). This layout reduces the length of distribution, lowers volt drop and impedance, and eliminates the need for a d.c. output cubicle.

It is not the purpose of this paper to go into detail on power design, operation, and maintenance problems, but rather to highlight areas where



NOTE : THE OUTPUT VOLTAGE OF THE POWER SUPPLY RECTIFIER IS REGULATED BY THE SERIES BUCK/BOOST DEVICE (VOLTAGE REGULATOR) TO GIVE CONSTANT DC SUPPLY VOLTAGE. IN EVENT OF POWER RECTIFIER FAILURE THE SERIES BUCK/BOOST DEVICE REGULATES THE MAIN BATTERY DISCHARGE VOLTAGE.

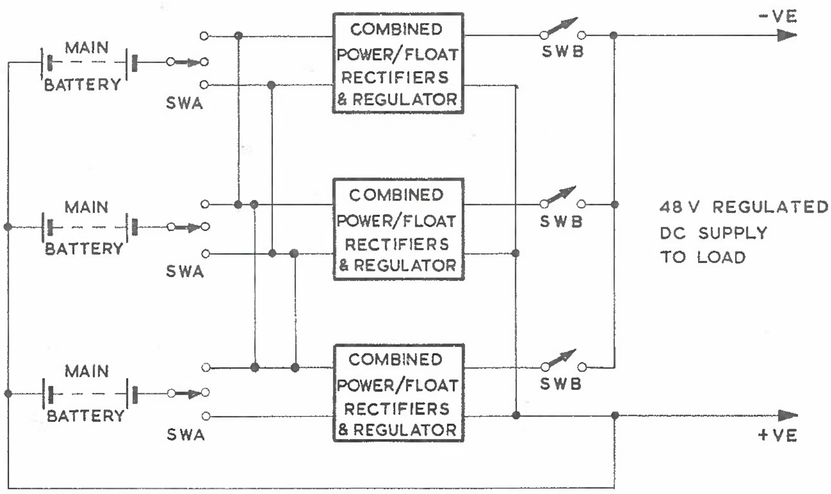


Fig. 7. — Schematic Diagram for Series Regulated D.C. Installations.

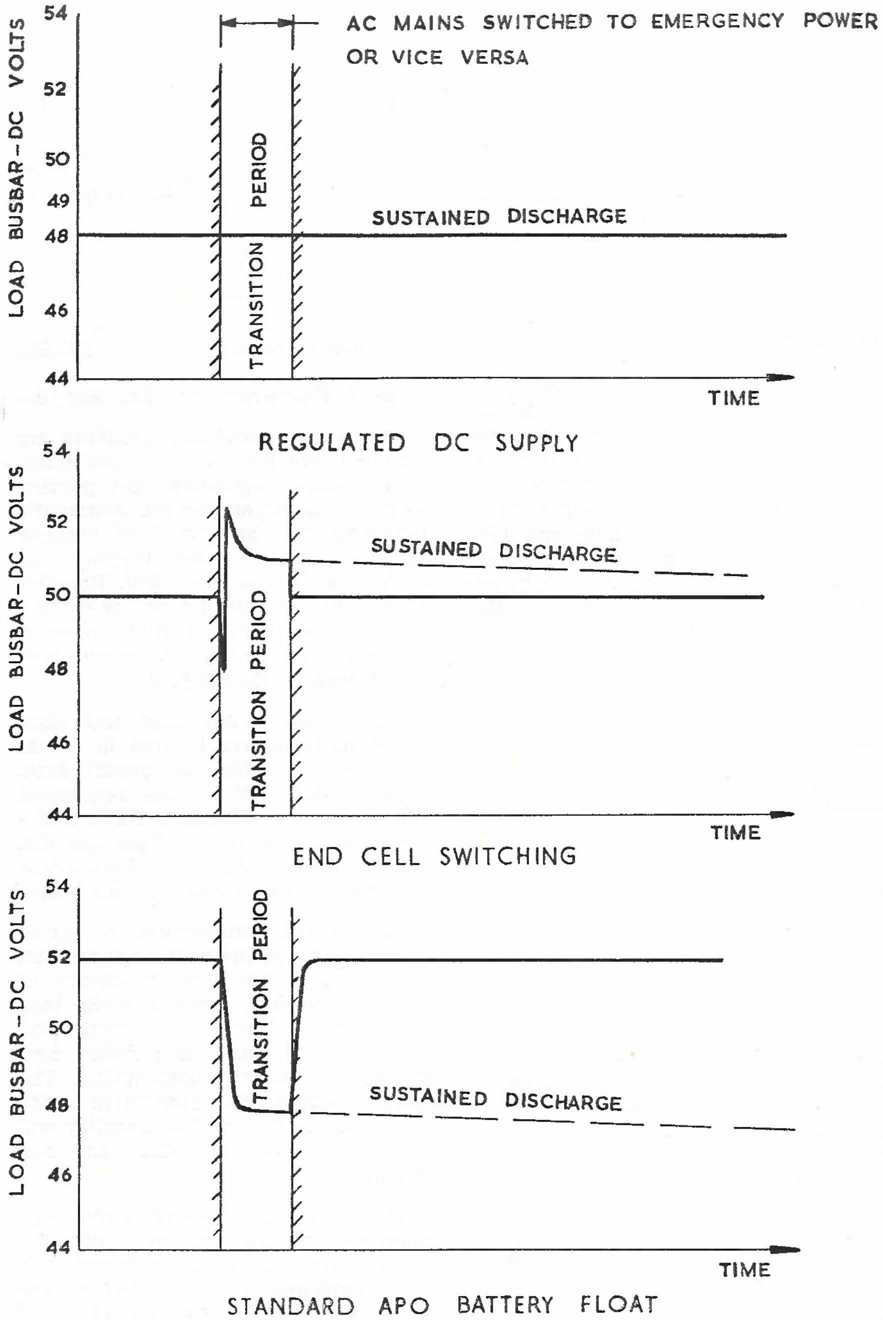


Fig. 8. — Busbar Voltage Characteristics for Various Control Methods.

considerable improvements could be achieved over present practice. D.c. supplies and distribution is one of these areas. For example, at the new Pitt Exchange, Sydney, there is at least 100 ft. of busbar between the rectifier suite output and the nearest point in the equipment area. Under battery discharge conditions the length of bar is further extended by the distance between the rectifiers and the battery.

Regulating the a.c. input voltage to rectifier modules at large electronic exchanges and the acceptance of a small variation in battery floating voltage would reduce design complexity. Such an arrangement reduces capital cost, simplifies circuitry and operation, increases efficiency and reliability, and reduces maintenance to a minimum. The rectifier module would consist of a transformer with input taps for setting and matching d.c. output voltage, a rectifier diode assembly and output smoothing. The transformer requires a derating factor to obtain a no-load/full-load registration of about 4%. Such an arrangement gives a variation of one volt d.c. in output over a 50% load swing in the upper half of the load range. In practice, at an electronic exchange, this would mean that the battery floating voltage would be maintained within one volt over the twenty four hours. Any additional constant d.c. loading such as long line equipment would result in closer regulation.

A.C. NO-BREAK SUPPLIES

General

D.c./a.c. inverters both static and rotating are normally powered from rectifiers fed by the a.c. mains. Continuity of d.c. supply to the inverters during interruptions to mains power is provided by a battery floating across the rectifier outputs. Flywheel inertia can also be used on both d.c. and a.c. driven alternators to cover short mains interruptions up to about 30 seconds. On this class of set, quick start diesel-alternators are required to maintain the motor drive during prolonged mains breaks.

It is generally accepted that the economic limit in size for single static inverters operating at 50 volts d.c. input is about 5 kVA due to commutation and other problems at heavy current. Inverters fed from the equipment d.c. system require considerable smoothing on their d.c. input to prevent electrical noise being reflected back into other equipment circuits fed from the same bus.

Inverters above 5 kVA output for 415/240 volt a.c. no-break supplies are best operated from a separate d.c. system at 100 to 400 volts depending on the size of load.

Application

The need for no-break a.c. plant at the large centres under discussion will depend on the input power requirements to the various installed equipments. Present trends are towards a single voltage supply a.c. or d.c. with all the diversity in supplies provided by inbuilt a.c./d.c., d.c./d.c. and d.c./a.c. power conversion devices.

Metaconta equipment now being manufactured for the A.P.O. is powered by 48 volts (nominal) d.c. supply. The a.c. no-break power and other d.c. voltage needs for this equipment are provided by in-built power inverter and converter packs.

C.U.D.N. computers currently being purchased by the Department are designed for a 415/240 volt 3-phase a.c. input at 50 cycles. As complete continuity of power supply is required for this equipment, the input a.c. power is provided by separate a.c. no-break plant. In-built power packs in the computers provide the necessary d.c. power.

Figs. 10 & 11 cover the various alternatives for a.c. and d.c. supplies.

SUMMARY OF RECOMMENDATIONS WITH COMMENTS

1. Incoming a.c. mains supply, 2 feeders at 11 kV. Availability of the two feeders will depend on the supply authority's H.T. distribution system. Electrical energy should be purchased at high tension. The savings in energy costs over purchase at low tension would enable the cost of stepdown transformers to be written off in about three years.

2. Main distribution of electrical power within the building at high tension with duplicate risers, one circuit breaker per riser and area distribution covered by vacuum type contactors or other suitable switchgear backed by HRC fuse gear for short circuit protection. gear for short circuit protection. loss to a minimum; savings of at least 10 to 1 in copper requirements over L.T. distribution are achieved and switching is minimised.

3. Standby high tension generating sets located on the roof, minimum of three sets. Gas turbines should be considered particularly since future costs may be more advantageous. Supply and installation costs of diesel driven generating plant on roof is about one half the cost of similar plant in the basement.

   The quantity of engine fuel stored at large telecommunication centres should be sufficient for at least one week's running on the station load.

4. Dry transformers to be used at various levels for plant power, miscellaneous supplies and lighting. These transformers must be integrated with the power plant design; for example in the power rectifier and inverter areas, the dry transformers in cubicles form part of the power suites.

5. Large size a.c. motors in the air conditioning plant fed direct at high tension.

6. Centralised control and supervision of the power system. It is strongly recommended that this facility and the environmental and fire control are combined in a single supervised area. This arrangement is considered essential from the staffing point of view and efficient operation of the plant. Essential lighting in the supervised areas should be immediately switched to battery

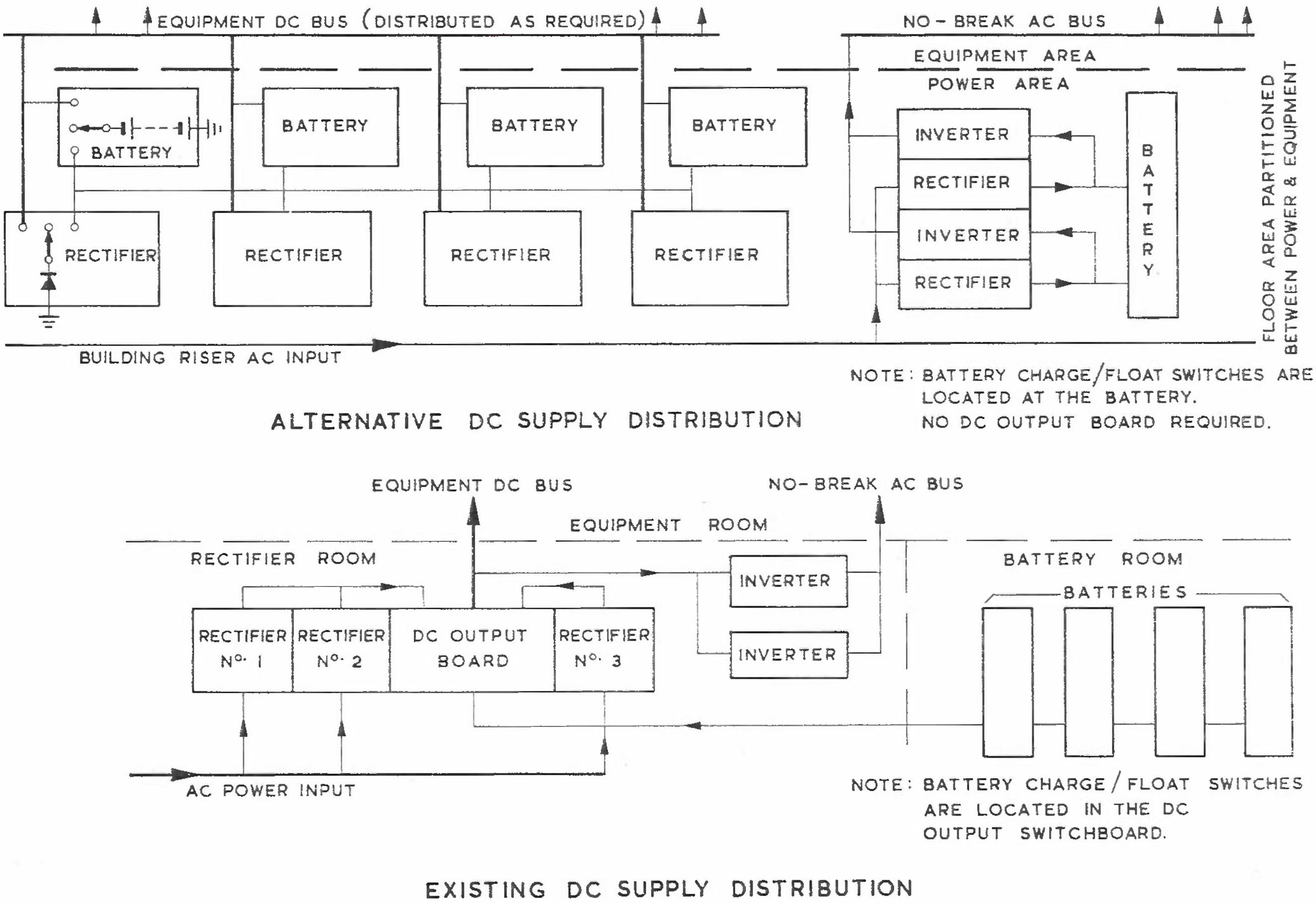


Fig. 9. — Current Arrangements for Battery/Rectifier/Inverter Installations.

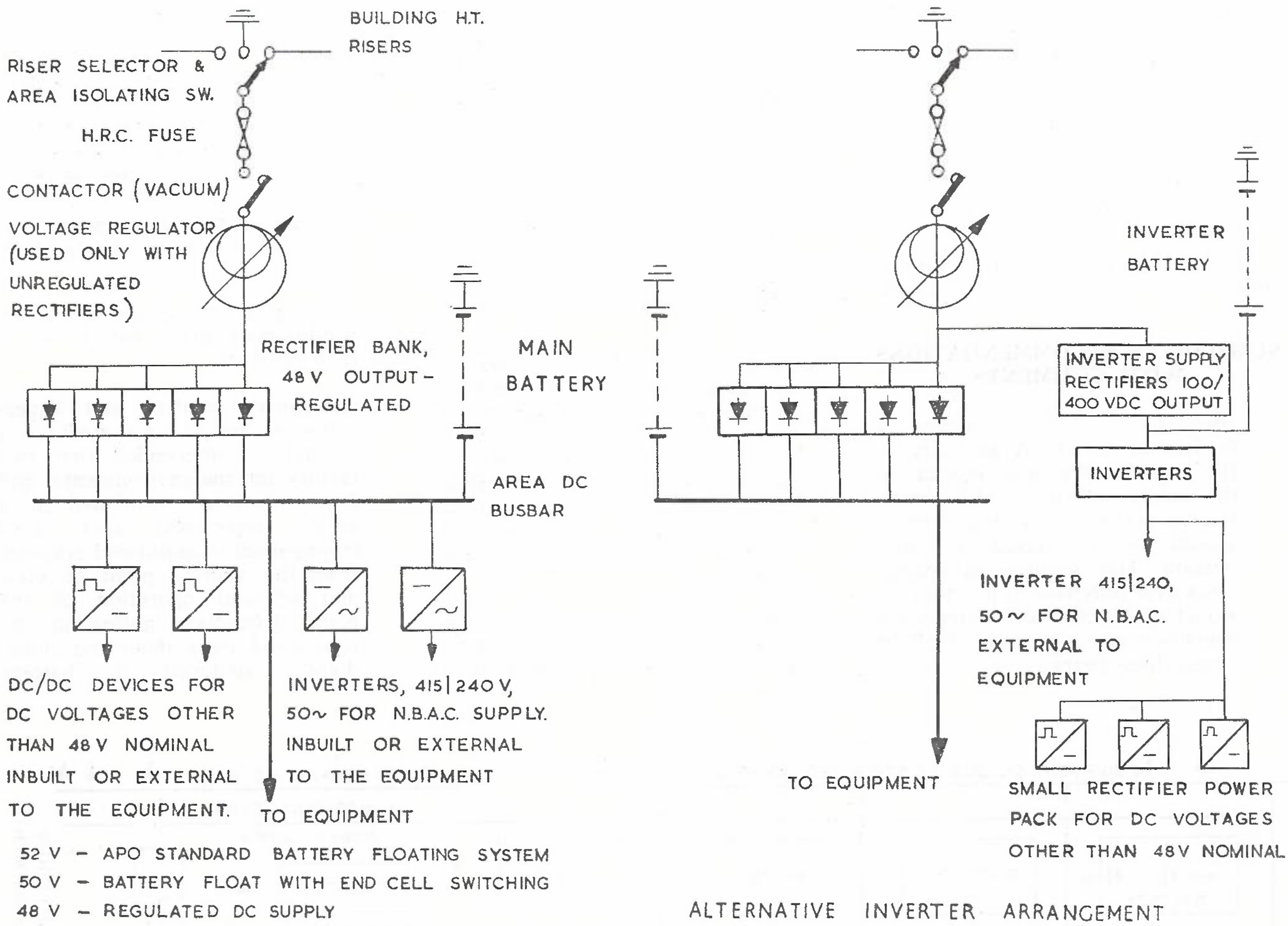


Fig. 10. — Current Combined D.C. and N.B.A.C. Rectifier and Inverter Installations.

inverter units during any interruptions to a.c. supplies. Commercial units of this type are available. An alternative is to feed essential lighting from the a.c. no-break system.

7. The economics of d.c. supply provision in relation to savings in power consumption by reduction in operating voltage, should be examined.

   Conversion plant and battery layout in relation to the equipment must be arranged to facilitate a short run distribution system to reduce conductor requirements and volt-drop to a minimum. For example, at the Pitt Exchange, Sydney, there is 100 ft. of busbar between the rectifier suite and the nearest point in the equipment room. A further 30 ft. exists between the rectifiers and the battery, giving an overall bar length of 130 ft. between battery and equipment. At Waymouth, Adelaide, the rectifiers and battery are located adjacent to the long side of the equipment room, and this results in a very considerable reduction in distribution length.

   The design of the rectifier plant in relation to the operation and loading conditions should be closely examined with a view to increased reliability, efficiency simplification of circuitry and operation, reduced maintenance, and lower capital cost.

8. At this stage it is not possible to forecast no-break a.c. requirements, as this will largely depend on equipment manufacturer's policy in relation to power supply requirements, a.c. or d.c. and to the extent of inbuilt power supplies.

9. Equipment environmental control plant needs will depend on equipment design. The trend in this area is for inbuilt environmental control within the equipment itself. This arrangement when extended to the ultimate would mean that the building air conditioning would only supply any necessary air changes in the equipment area.

CONCLUSION

The discussions and recommendations made in this paper indicate that not enough attention is given to overall design and integration of power plant in high rise telecommunication buildings with heavy energy demands. There is no doubt that more design concentration in this area could result in greater reliability, reduction in costs and increased operational efficiency with lowering of running costs.

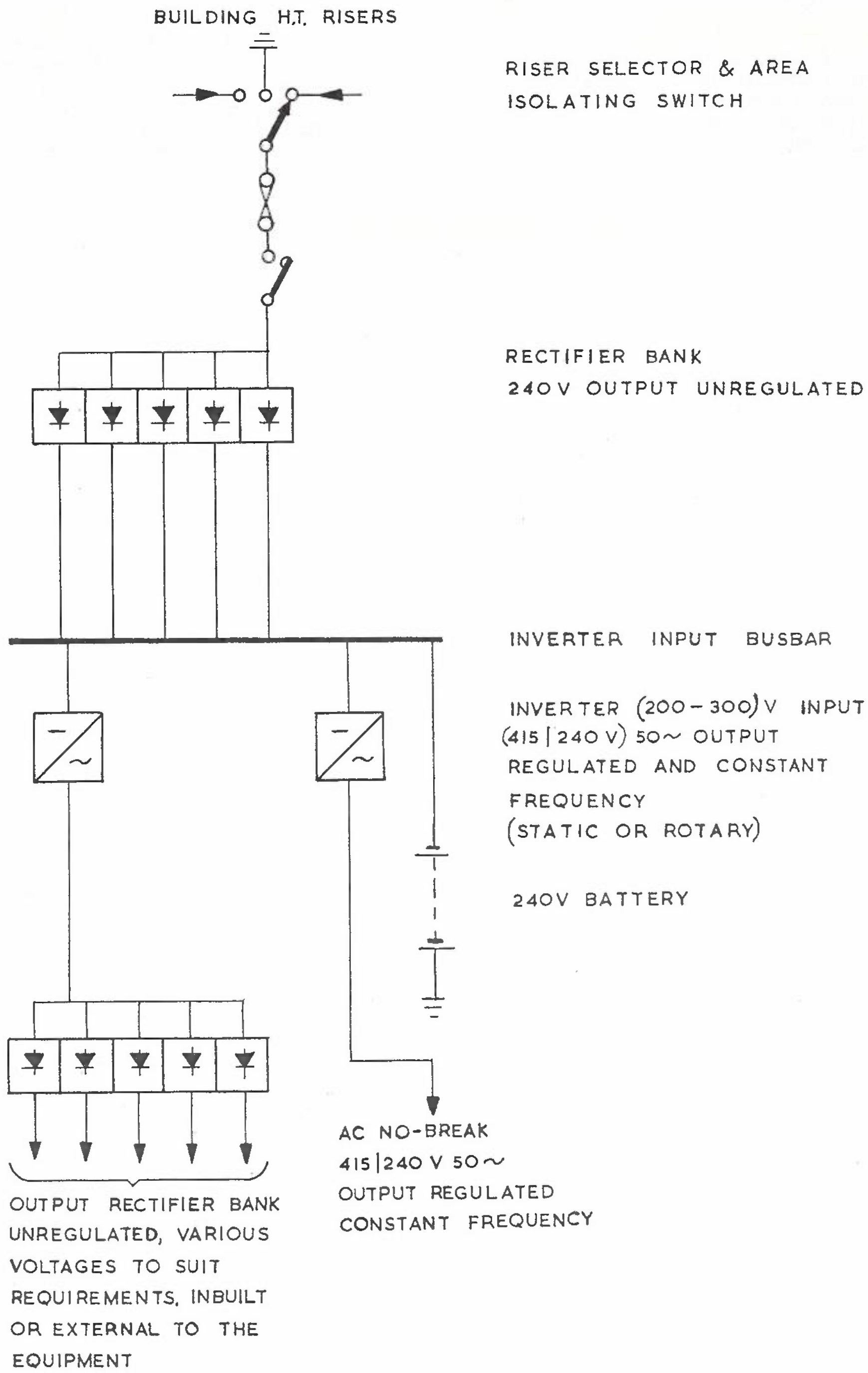


Fig. 11. — Total Inverter Type Distribution for D.C. and N.B.A.C. Supplies.

FAULT RECORDING IN COUNTRY AREA EXCHANGES

*W. STIRLING**

INTRODUCTION

This article outlines new procedures for recording and analysing fault report on telecommunication plant in country areas.

Early in the 1960's, following overseas investigations into exchange maintenance practices, new maintenance techniques were introduced in automatic exchanges and networks in the Australian metropolitan areas. This new maintenance concept was called Qualitative Maintenance (Q.M.), because it was largely based on quality control methods using sampling techniques to determine the standard of service being given to the customer and the operating efficiency of the plant. It implies an analytical approach to plant maintenance, activity being concentrated in areas where the need is greatest, as determined by indicators such as the analysis of subscribers' trouble reports, testing of equipment and recording and analysis of faults.

To more effectively utilise the information available to determine where maintenance activity should be concentrated, a new fault docket (EM 301A) for automatic exchanges was introduced (Fig. 1). This fault docket catered for a system of filing which gave a visual indication of plant performance and highlighted areas requiring investigation and possible attention.

At this time it was also determined that a great deal of information supplied by subscribers in the form of complaints was not being effectively acted on, these being of a type indicating trouble in the switching network rather than the individual subscribers' service. This led to the establishment of Service Co-ordination Centres now known as Network Performance and Analysis Centres (N.P.A.C.). The function of these centres is to analyse all subscribers' reports of the type where a visit by a technician was not required, but which indicated that the subscriber had experienced some trouble in establishing a call via the automatic network.

With the rapid development of the trunk network in the 1960's, including the spread of automatic working and S.T.D. to a large number of the country districts, it became necessary to investigate methods whereby performance information relating to country networks and exchanges could be collected and analysed.

A system identical to that in use in the metropolitan areas could not be used in country areas because it did not cater for all the different sources from which reports were generated. In country areas trouble reports are received from operators at local and distant manual exchanges, as well as from subscribers and technician's stations; and they relate to manual, common battery, and automatic exchanges and to long line equipment, Tress, broadcasting, broad band radio, Telex, etc.

The problem of recording and analysis was further heightened in country areas by the need to evaluate the performance of trunk and junction circuit groups in relation to their availability and fault history because of their high revenue earning capacity.

Existing fault recording procedures in use in country areas did not cater for all these requirements, as they provided information in a form which was not readily interpreted and far too detailed to be of ready use. This system was entirely plant oriented with little emphasis given to overall service quality which is an essential part of qualitative maintenance. It was clear that any system envisaged for country areas must be capable of being integrated with the system in use in the

* Mr. Stirling is Senior Telecommunications Technical Officer Grade 3, Albury, N.S.W. See Vol. 12, No. 5, p. 365.

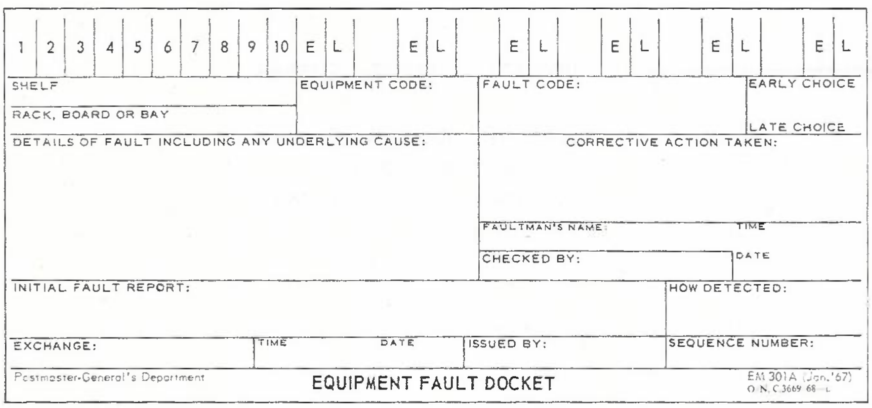


Fig. 1. — Fault Docket EM 301A.

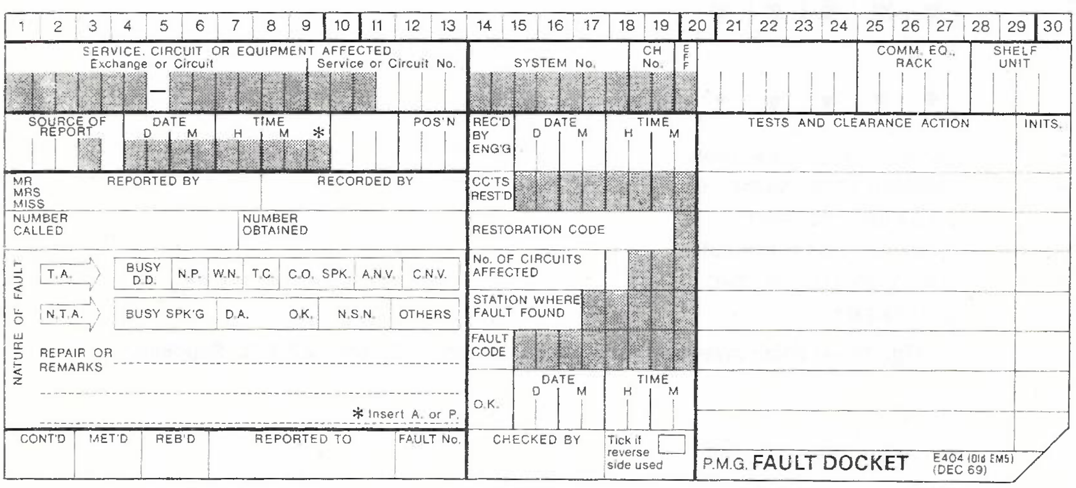


Fig. 2. — Fault Docket E 404.

metropolitan areas, and at the same time provide information in a form suitable for automatic data processing The fault reports for telephone circuits are now processed by a computer (CANTOT — Computer Analysis of Troubles on Trunks).

Ideally, information relating to all aspects detailed in the preceding paragraphs should be recorded on a single common form which can be used as input data for computer analysis, and at the same time provide a quick and accurate indication of plant performance and service quality at the work face. A new fault docket E404 (previously known as EM5) was designed on this basis (Fig. 2).

OUTLINE OF NEW PROCEDURES

Service difficulties and faults reported by subscribers and operators are handled by Repair and Assistance operators of the Telecommunications Division. These reports are divided into three basic categories.

(a) Non Technical Assistance. (N.T.A.)

(b) Technical Assistance. (T.A.)

(c) Repair.

Categories (b) and (c) are passed onto the Engineering Division for attention. The flow lines shown in Fig. 3 indicate the possible source of a report and the action taken to initiate rectification.

The three main classifications depicted by the flow lines are as follows:—

(a) Non Technical Assistance classifies a report where the called party is D.A. (Does not Answer), Busy, etc. In these cases no assistance to establish the connection is provided by the Repair and Assistance Operator.

(b) Technical Assistance reports are those where a satisfactory connection to the called party cannot be obtained due to no progress, wrong numbers, triple connection, cut off speaking, busy during dialling etc., and

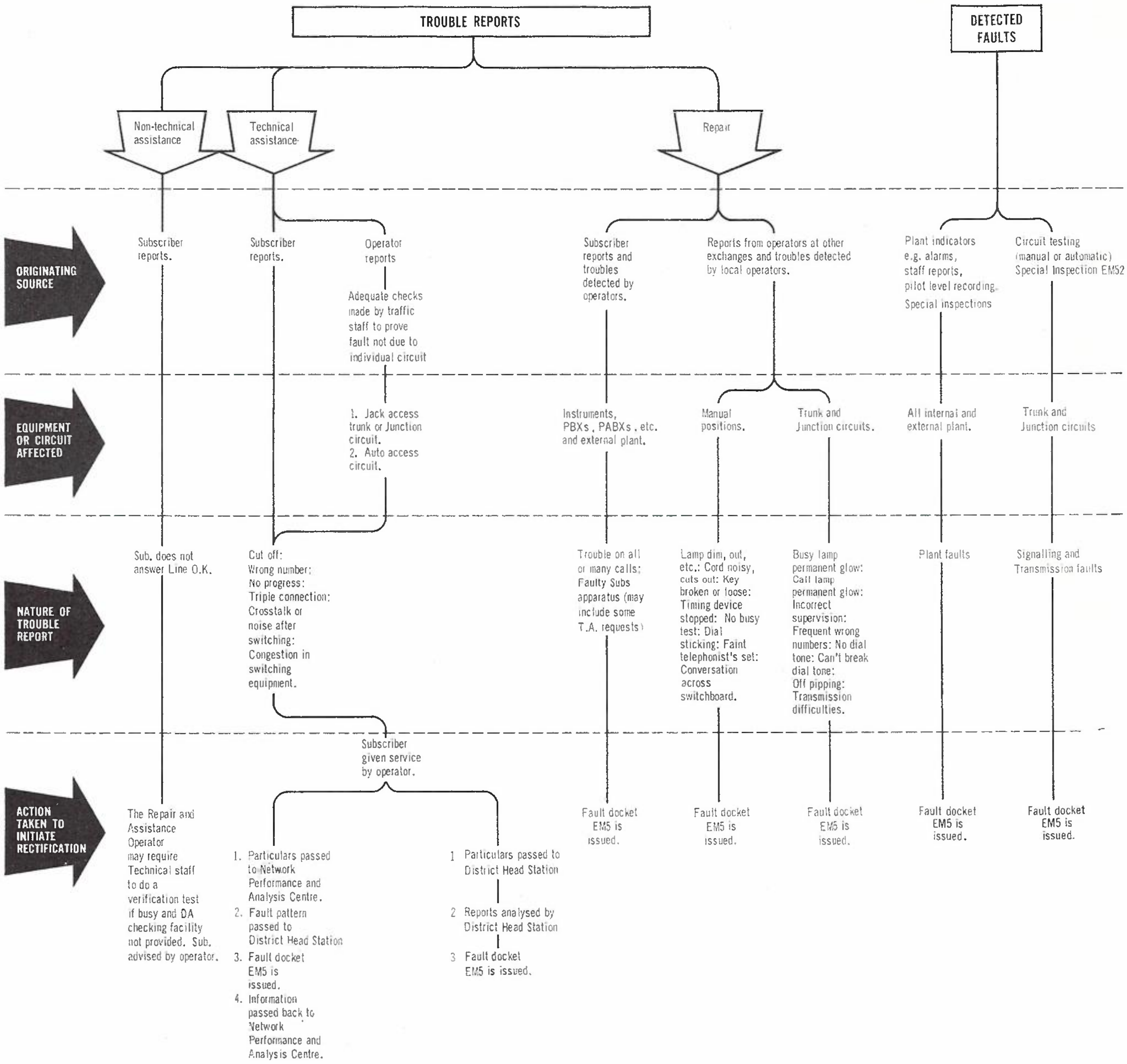


Fig. 3. — Trouble Report Flow Chart.

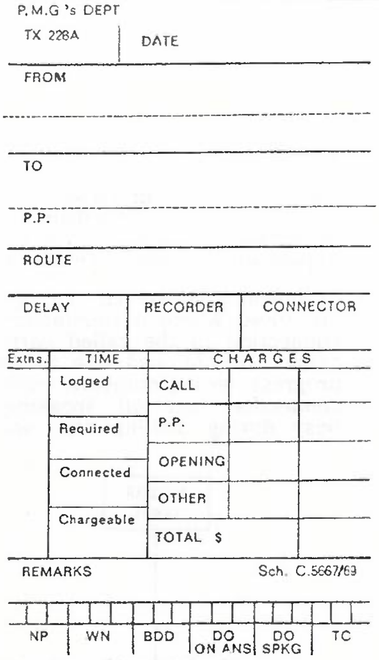


Fig. 4. — Operator's Charge Docket, TX 228.

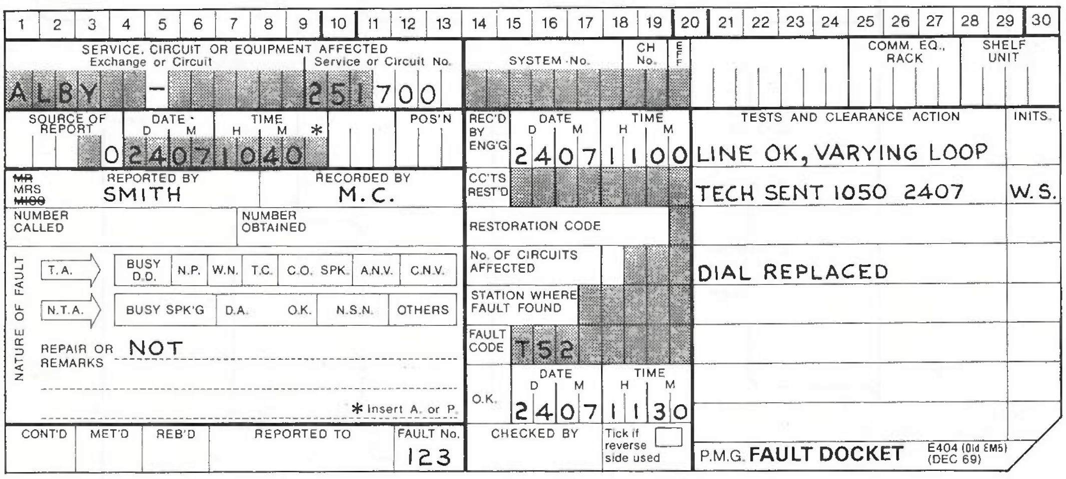
the Repair and Assistance Operator is in some circumstances able to complete the connection. As operator access to the S.T.D. network increases, the analysis of service difficulties encountered by operators will provide valuable additional information for the supervison of the network. Trunk Operator Technical Assistance reports will be catered for by a new charge docket shown in Fig. 4 where provision has been made at the bottom of the docket for the operator to record in the appropriate space the type of difficulty encountered, these reports subsequently being passed to the N.P.A.C. for analysis.

(c) Repair includes reports where a fault condition is evident or suspected on an individual subscribers' service or manually operated trunk or junction circuits and associated equipment. Examples are — can't break dial tone, not receiving rings, switch hooks sticking, etc.

In all cases of repair reports an E404 fault docket is issued and appropriate action taken by the Section concerned to rectify the fault. After details of the tests and fault found have been entered and the final fault code inserted, the docket is filed in the sorting box against the particular item or group of plant, and flagged to indicate details such as the component and type of fault, if required. With this type of filing a build up of fault reports on various items of plant can be seen immediately and patterns detected indicating possible need of maintenance attention.

At predetermined periods the current dockets are counted and recorded on a form under various categories and control limits are set to indicate the need of special attention to areas of equipment if these limits should be exceeded.

EXAMPLE OF SUBSCRIBER'S REPAIR REPORT



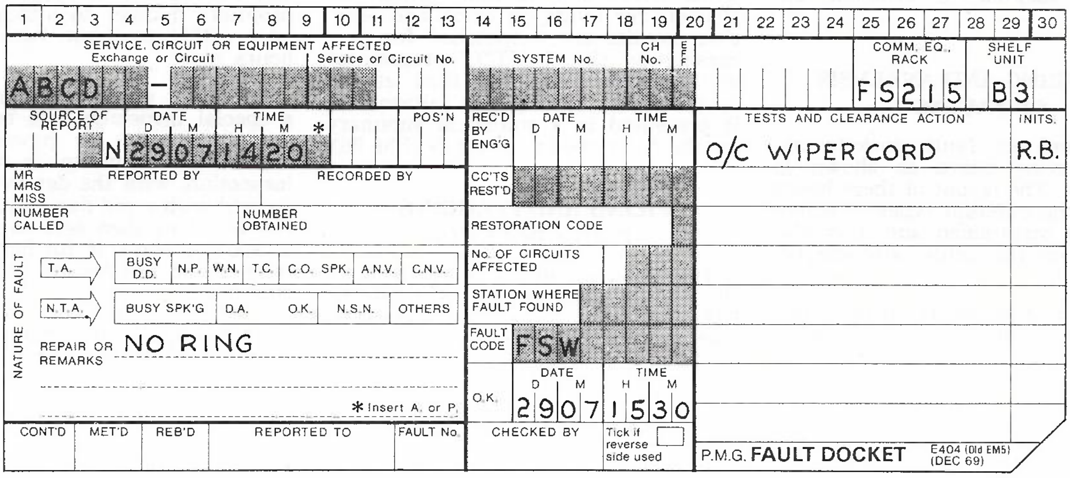
TYPICAL FILING BOX LAYOUT FOR REPAIR REPORTS FOR HEAD STATION OR LARGE EXCHANGE

	FAULT CLEARED WITHIN: 1 HR. (1), 2 HRS. (2), 3 (3), 4 HRS. (4), 5 (5), 6 HRS. (6), 7 (7), 8 HRS. (8), 12 HRS. (9), 24 HRS. (10), 48 HRS. (11)	ANY OTHER FORM OF ANALYSIS AS REQUIRED, e.g. FAULT CODE TYPE OF INSTRUMENT, SET REPLACED ETC. 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30	EM 96
EXCH.&NET			COLUMN 7
MDF			8
RWT			11
90X			12
TELE.INSTS			15
PBX			16
PABX			17
INTERCOM.			18
EXTERNAL			20
PT FAULTS			23
PT RWT			24

Fig. 5.

STIRLING — Country Fault Recording

EXAMPLE OF EXCHANGE FAULT DOCKET



TYPICAL FILING BOX LAYOUT FOR AUTOMATIC EXCHANGE EQUIPMENT

EQUIPMENT OR RACK ETC.	FLAG TO INDICATE SWITCH OR RELAY SET FLAG TO INDICATE FAULT CODE	
U/S 1		STEP EXCHANGE
GS 1		
FS 1		
ETC.		
LR/BR		CROSSBAR EXCHANGES
SLM 1		
SLM2		
SR		
RS		
REG.		
ETC.		

Fig. 6.

At the end of the week, fault dockets relating to trunk and junction faults are posted to the Automatic Data Processing (A.D.P.) Centre for computer analysis to evaluate the performance of circuit groups. Details of the computer analysis known as CANTOT are described in Ref. 1. Following return of the fault dockets from the A.D.P. Centre, they are flagged and filed to provide an immediate visual indication of groups and individual circuits which are in need of maintenance attention.

DESIGN OF THE FAULT DOCKET

The new fault docket was designed to meet the following requirements:—

(a) Cater for reporting and recording of faults on all types of equipment.

(b) Contain only relevant detail in a pre-printed form but allow adequate space for additional information.

(c) Physical separation of "reporting" and "action" information.

(d) Cater for the provision of input data for automatic data processing.

(e) Provide a ready distinction between information on individual items of plant e.g., selector, carrier system, and on trunk and junction telephone circuits.

(f) Give flexibility to allow any form of manual analysis to be undertaken with a minimum of effort on the part of technical staff.

To enable these objectives to be achieved a review of the procedures pertaining to all plant areas was carried out, and as a result a new fault docket was produced as shown in Fig. 2.

The docket is similar in size to that used in Metropolitan exchanges, because a similar method of filing and flagging is used to give an immediate visual indication of fault patterns by the use of the standard fault filing boxes. (This system is described in A.P.O. Engineering Instruction, Telephone Exchanges M 0112). It will be seen from the two dockets (Figs. 1 & 2) the EM 301A and the E 404, that the numbering along the top edge of the docket has been changed. This was done to allow for greater flexibility of analysis by means of metal flags in the numbered spaces. The EM 301A was essentially designed for step exchanges with switches in shelves of ten and the grading being such that it allowed for an indication to be given of whether the switch was an early or late choice, and therefore could not be easily adapted to crossbar exchanges.

RECORDING AND ANALYSIS OF FAULTS

The completed fault dockets are filed in sorting boxes as shown in Figs. 5 to 8. The layout of these boxes varies for the different types of equipment being maintained and it is also dependent on the actual statistic being recorded.

Initially it is necessary to lay down fundamental guide lines stating what information is needed to be recorded. These are primarily statistics which are required by Engineering management, but also which will be meaningful to all levels of supervisory staff. For example in the case of subscribers' trouble reports, it is necessary to be able to categorise repair requests in the primary classifications of internal, external and sub-station plant. This information is then further divided to show the number of faults on various types of sub-station equipment, e.g., instruments, switchboards, also right when tested and no fault found etc. Dockets for faults on trunk and junction circuits are despatched for processing by the CANTOT programme and then returned and filed at the local station. Finally this information is presented in a statistical summary on the form shown in Fig 9 (EM 96).

FILING AND FLAGGING FAULT DOCKETS

The illustrations in Figs. 5 to 8 show the various methods of filing the EM 404 fault docket in association with Long Line Equipment, Exchange Equipment, Subscribers Equipment, Radio Broadband and Telegraph, etc.

The dockets may be flagged by the use of a metal signal in any of the numbered squares 1 to 30 along the top edge of the docket. The purpose of this is to allow any desired form of analysis to be carried out in accordance with a predetermined programme; for example, clearance times on subscribers faults may need to be analysed to indicate the efficiency in the rectification of sub-station faults. The docket can be flagged on an appropriate number to indicate a clearance within one hour, two hours, four hours, etc.

A further example would be where a special inspection has been carried out on a trunk or junction circuit; the docket resulting in the special inspection, with the details entered, is flagged with a red flag, say, in position No. 20. This then acts as a ready indicator to show if further faults are reported or detected on this particular circuit.

The flagging and filing system is completely flexible, and allows for any predetermined programme of analysis to be arranged with a minimum effort, a programme which can be changed once it has highlighted a particular trouble, or furnished the desired information.

The fault dockets are filed in the sorting boxes and retained for as long a period as possible with the exception of subscriber repair requests which are kept for a period of six

EXAMPLE OF TRUNK OR JUNCTION SERVICE FAULT REPORT

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

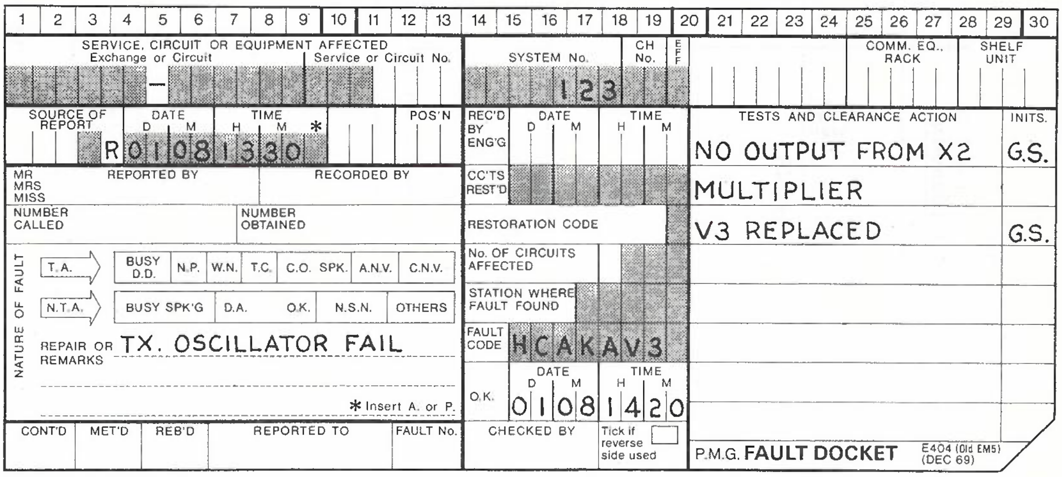
SERVICE, CIRCUIT OR EQUIPMENT AFFECTED — Exchange or Circuit: BREN – ADAL; Service or Circuit No.: 23
SYSTEM No.: VO631 — CH No.: 9 — EFF: U — COMM. EQ. RACK — SHELF UNIT
SOURCE OF REPORT: 0 — DATE D M: 2407 — TIME H M: 1205 * — POS'N
REC'D BY ENG'G — DATE D M: 2407 — TIME H M: 1230
TESTS AND CLEARANCE ACTION — INITS.
VF 7502 Hz LOW LEVEL
R/S TO BE CHECKED
TECH A.B. ATTENDING 2407 AT 1235 — WS
FAULTY TONE PASSING CONTACTS
MR MRS MISS — REPORTED BY — RECORDED BY: M. R.
CCT'S REST'D: 2407 1300
NUMBER CALLED — NUMBER OBTAINED — RESTORATION CODE: F
No. OF CIRCUITS AFFECTED: 1
NATURE OF FAULT: T.A. — BUSY D.D. — N.P. — W.N. — T.C. — C.O. SPK. — A.N.V. — C.N.V.
N.T.A. — BUSY SPK'G — D.A. — O.K. — N.S.N. — OTHERS
STATION WHERE FAULT FOUND: BREN
REPAIR OR REMARKS: N. P.
FAULT CODE: 171RSCD
O.K. — DATE D M: 2407 — TIME H M: 1300
* Insert A. or P.
CONT'D — MET'D — REB'D — REPORTED TO — FAULT No.: 345 — CHECKED BY: R. B. — Tick if reverse side used
P.M.G. **FAULT DOCKET** E404 (Old EM5) (DEC 69)

TYPICAL FILING BOX LAYOUT FOR TK/JN SERVICE REPORTS

CIRCUIT GROUP	CIRCUIT, OR SYSTEM CCT NUMBER 1 2 3 4 5 6 7 8 9 10 11 12	ALL	CARRIER: LOCAL EQ	CARRIER: DISTANT EQ	DISTANT EXCH. EQ	LOCAL EXCH. EQ	EXTERNAL	RWT	BEARER	SPECIAL INSPECTION	SYSTEM NUMBER
B											PHYSICALS
R											VN1234
E											VNO12
N											VN1821
A											PHYSICAL
D											VO162
A											V1862
L											V3585

Fig. 7.

EXAMPLE OF RADIO BEARER FAULT DOCKET


1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
SERVICE, CIRCUIT OR EQUIPMENT AFFECTED
Exchange or Circuit | Service or Circuit No.
SYSTEM No. 123 | CH No. | EFF | COMM. EQ., RACK | SHELF UNIT
SOURCE OF REPORT R | DATE D M 01 08 | TIME H M 13 30 * | POS'N
REC'D BY ENG'G | DATE D M | TIME H M
TESTS AND CLEARANCE ACTION | INITS.
NO OUTPUT FROM X2 | G.S.
MULTIPLIER
V3 REPLACED | G.S.
MR MRS MISS | REPORTED BY | RECORDED BY
CC'TS REST'D
NUMBER CALLED | NUMBER OBTAINED
RESTORATION CODE
NATURE OF FAULT
T.A. | BUSY D.D. | N.P. | W.N. | T.C. | C.O. SPK. | A.N.V. | C.N.V.
N.T.A. | BUSY SPK'G | D.A. | O.K. | N.S.N. | OTHERS
No. OF CIRCUITS AFFECTED
STATION WHERE FAULT FOUND
REPAIR OR REMARKS TX. OSCILLATOR FAIL
FAULT CODE HCAKAV3
O.K. DATE D M 01 08 | TIME H M 14 20
* Insert A. or P.
CONT'D | MET'D | REB'D | REPORTED TO | FAULT No. | CHECKED BY | Tick if reverse side used
P.M.G. FAULT DOCKET E404 (Old EM5) (DEC 69)

TYPICAL SORTING BOX LAYOUT FOR RADIO BEARER EQ

RADIO & B. BAND EQUIP.	FLAG TO INDICATE DESIRED INFORMATION	PILOT EQ	TRANS-MITTER	RECEIVER	OSC & MULT.	MOD.	DEMOD.	PWR. SUPPLY	SYSTEM NO.
RADIO BAY MODEM I.F. C/O. B.B. C/O.									123
RADIO BAY MODEM I.F. C/O. B.B. C/O.									124
300 CH. EQ.									151
60 CH. EQ.									186
SUPVY									120
PWR.PLANT									

Fig. 8.

months, a separate box being used for the current month.

Fault dockets for trunks, junctions, exchanges, subscribers, etc., are flagged either with a distinctive colour representing the month in the quarter, or flagged in a predetermined position for the current month. In this case the flags are removed after the statistics for the current month have been recorded.

THE EM 96 TROUBLE REPORT SUMMARY (Fig. 9)

The EM 96 summary provides an analysis of repairs requested by subscribers. A basic service indicator is the rate of subscribers' repair requests as shown in Column 6.

It can be seen from the EM 96 that the reports are sub-divided to indicate the number of reports which originated as a result of faults or potential faults in the exchange or network, the number of right when tested (R.W.T.), faults on subscribers' equipment, public telephones and faults in external plant.

Faults in the various types of automatic exchange equipment during the period of analysis are recorded in the columns shown. A more detailed analysis of the faults on any type of equipment can be undertaken on an Equipment Fault Summary form EM 92 (not shown).

Trunk and junction equipment faults can also be recorded on the EM 96 in columns which have been left spare for this and similar purposes.

This form now presents an overall picture of all faults and fault reports for a period and will allow an assessment to be made of all factors which have affected service to subscribers connected to a particular exchange, or in a nominated district. Care must be exercised in grouping exchange areas or districts in a country situation, as it will be found that there is a distinct difference in the fault reporting rate in rural areas as compared with the larger urban towns and cities. The fault rate for the smaller exchange areas up to 100 lines can be two to three times greater than the larger urban exchanges. It is therefore important that when comparing subscribers' repair reporting rates that exchanges of a similar type be considered.

The lower part of the EM 96 provides for control limits to be set to indicate when investigation is necessary to establish the need for maintenance work.

POSTMASTER-GENERAL'S DEPARTMENT

TROUBLE REPORT SUMMARY

EXCHANGE OR DISTRICT ONE SHEET PER EXCHANGE

~~MONTH~~ ~~QUARTER~~ YEAR ENDING 1970

EM96

1 PERIOD OR LOCATION (NOTE 1)	2 T.A. REPORTS: SUB.	3 T.A. REPORTS: OPRTR.	4 TOTAL SUBS. REPAIR REPORTS (P.T.'s EXCLUDED)	5 TOTAL TELEPHONE INSTRUMENTS	6 SUBS REPAIR REPORTS/100 INST./MONTH	7 SUBSCRIBER REPAIR REPORTS — EXCHANGE & NET.: TOTAL EXCH. & NET FAULTS & F.O.K's	8 M.D.F.	9	10	11 R.W.T.: TOTAL R.W.T.	12 90X	13	14 SUBSCRIBERS' EQPT.: TOTAL SUBS. FAULTS & F.O.K's	15 TEL. INST. FAULTS & F.O.K's	16 P.B.X. FAULTS & F.O.K's	17 P.A.B.X. FAULTS & F.O.K's	18 INTERCOM.INSTS FAULTS & F.O.K.	19	20 EXT. PLT.: TOTAL EXT. PLT. FAULTS & F.O.K's	21	22 P.T. REPORTS: TOTAL PT. REPAIR REPORTS	23 PT. FAULTS & F.O.K.	24 P.T. R.W.T.	25 VANDALISM	26 EXCHANGE EQUIPMENT — MAN. EXCH.: FAULTS & F.O.K's	27 R.W.T.	28 AUTO. EXCH.: SXS FAULTS & F.O.K.	29 X BAR FAULTS & F.O.K.	30 TRK. SWITCH FAULTS & F.O.K.	31 ARM FAULTS & F.O.K.	32	33 REMARKS (NOTE 3)
18-6-70	85	207	314	5886	5·35	14	9			55	2		170	99	47	4	20		75		110	23/29	37	21	100	15		33	28	5		
TYPICAL ENTRIES FOR A LARGE COUNTRY EXCHANGE																																
15-7-70			12	138	8·7	1	1			4			4	3	1				7		2	/2					1					
TYPICAL ENTRIES FOR A C.A.X.																																
22-5-70			4	80	5·0								3	3					1						1							
TYPICAL ENTRIES FOR A SMALL MANUAL EXCHANGE																																
COLUMN TOTAL →				X	X																											
TOTAL UNITS OF PLANT →				X	X																											
AVERAGE REPAIRS, R.W.T. FAULTS ETC. PER MONTH (NOTE 2) →					PER 100 TEL. INSTS.	PER 100 TEL. INSTS.				PER 100 TEL. INSTS.			PER 100 TEL. INSTS.	PER 100 TEL. INSTS.	PER 100 WKG. ENDS	PER 100 WKG. ENDS					PER 100 P.T.'s											
TARGET → (SPECIFIED BY ENGINEER)																																
UPPER CONTROL LIMIT (SPECIFIED BY ENGINEER)																																

NOTE 1. At small exchanges where statistics are counted quarterly instead of monthly, divide repair reports per 100 tel. insts. per quarter by 3 to derive repair reports per 100 tels. per month.

NOTE 2. The average repair reports per 100 tel. insts. per month for the year, is the column total divided by 4 if statistics are entered quarterly or 12 if entered monthly. The average for all other columns is given by $\frac{\text{Col. total}}{\text{No. of units}} \times \frac{100}{12}$

NOTE 3. Record as Note 1, 2 etc. on back of form reasons for significant changes in fault statistics. Indicate in this column the relevant note number. Columns are also provided for any additional analysis of statistics.

OS. 2605

O/N C.3818/69

Fig. 9. — Completed Trouble Report Summary.

Information provided by fault recording can be an effective tool in the hands of trained and experienced personnel and will provide valuable assistance in determining where a concentrated maintenance effort may be required.

CONCLUSION

All forms of recording and analysis require an amount of time to be expended to obtain the necessary results. It is, therefore, essential to carefully study the particular situation as applied to the area in question, and if possible predetermine what detailed information is required and the amount of effort that is needed to produce this information. Flagging of dockets can be time consuming and unnecessary flagging is economically wasteful.

It is stressed that fault recording and analysis both on a plant performance and service indicator basis, is a means to an end and not an end in itself. These statistics must be used in conjunction with all other available information before determining any policies related to the performance and reliability of the plant which is necessary to provide an economical and efficient service to the subscribers.

REFERENCES

1. N. J. Ryan, "CANTOT — Computer Analysis of Troubles on Trunk Circuits"; Telecom. Journal of Aust., Oct. 1971, Vol. 21, No. 3, Page 263.

TECHNICAL NEWS ITEM

WORLD ADMINISTRATIVE RADIO CONFERENCE FOR SPACE TELECOMMUNICATIONS — GENEVA, 1971

An administrative conference to consider the frequency spectrum requirements of space telecommunications services for about the next decade and to make such changes to the International Radio Regulations as were required to give effect to the conclusions which emerged, was held in Geneva over the period 7th June to 17th July 1971. The conference was under the auspices of the International Telecommunication Union and was attended by 102 countries. In total, these countries were represented by 740 delegates. The Australian delegation was led by Mr. L. M. Harris of the A.P.O. and contained representation from the A.P.O., the Departments of Supply, Defence, Civil Aviation and Interior, the Broadcasting Control Board, the Overseas Telecommunication Commission and the Commonwealth Scientific and Industrial Research Organisation; in all a total of 15 delegates.

The results of the conference are published in the form of Final Acts which will form an integral part of the Radio Regulations when they come into force on 1st January 1973. The main changes to be incorporated in the present Radio Regulations are explained in the following paragraphs.

Broadcasting — Satellite Service

Provision has been made for this service within the band 620-790 MHz by footnote, though there are some qualifications. Frequency modulation must be used, the power flux density must not exceed —129 dBW/m^2 for angles on arrival at the earth of less than 20° except by special agreement and in all cases, the agreement of Administrations which have services that may be affected is a necessary condition for the use of such assignments in this band.

No provision has been made in the Table of Frequency Allocations for satellite broadcasting in the band 845-935 MHz, which was the portion of the spectrum proposed for experimental broadcasting to community receivers by the satellite ATS-F now being built in America. One of the major experiments using this satellite is to be a 12 month trial of Instructional Television covering India. In recognition of the considerable investment of resources already committed to this experimental trial, the conference recommended to India that the Final Protocol should include a statement about use of this band for experiments in satellite broadcasting in that country. The Indian delegation accordingly included a statement covering this usage.

Broadcasting satellites for domestic and regional systems for community reception are allocated a band 2500 to 2690 MHz. Use of this band for this purpose is however subject to agreement among the administrations concerned and power flux densities are specified to protect fixed services using line-of-sight and tropospheric scatter techniques.

The major broadcasting satellite band allocated for Region 3, which includes Australia, is 11.7 to 12.2 GHz. This band is shared with the fixed, mobile and terrestrial broadcasting services but in a footnote to the table and a Resolution calling for a broadcasting frequency assignment planning conference, the Conference effectively established a somewhat privileged status for broadcasting satellites in this 500 MHz band of the spectrum.

Other bands allocated to broadcasting satellites are 22.5 to 23 (Region 3 only); 41 to 43; and 84 to 86 GHz. These bands are provided more for long term development rather than for immediate use.

Fixed-Satellite Service

This service is broadly equivalent to the present communication satellite service and extra provision was made in three distinct parts of the spectrum.

The portion below 10 GHz is already congested so only very limited new allocations were possible here. The most interesting are the two bands 2500 to 2535 MHz and 2655 to 2690 MHz. These are respectively for transmission in the directions space to earth (down) and earth to space (up) for domestic and regional systems. The bands are shared with the fixed, mobile and broadcasting-satellite services so there is a power flux density limit in the down direction and use of the bands is subject to agreement among the Administrations concerned.

Above 10 GHz, equipment development suggests that the portion of the spectrum between 10 and 15 GHz could be exploited in the very near future. In this portion, a total of 1250 MHz has been allocated to the fixed satellite service, split up into three bands of 250 MHz width for the down direction and one band of 500 MHz width for the up direction. These bands are all shared with other services, so sharing criteria have been specified but there are no other restrictions. The bands are therefore available for general purpose use in this service.

Rain attenuation is a problem that becomes increasingly serious as frequencies increase above 10 GHz and the constituent gases of the atmosphere cause absorption bands. Despite these drawbacks, adequate provision for growth of the fixed-satellite service required that allocations be made in the spectrum above 15 GHz. A total bandwidth of about 85 GHz was allocated in the range 15 to 275 GHz (275 GHz was the highest frequency allocated). Of the bands concerned, the ones of immediate practical interest are 17.7 to 21.2 GHz for the down direction and 27.5 to 31 GHz for the up direction.

Three other bands for each of the down and up directions and totalling in all 12 GHz and two bands totalling 20 GHz but with unspecified direction of transmission have also been allocated. A total of 45.95 GHz of bandwidth, split into four bands, has been allocated for satellite-to-satellite (i.e. intersatellite) use. Generally these bands are located around one or other of the gaseous absorption attenuation peaks which of course do not affect an intersatellite path. The rather generous allocation for this purpose looks forward to the time when satellite inter-connection on a large scale could make it possible for any earth station to communicate with any other without any restriction on mutual visibility. This would make a truly global system!

Aeronautical Mobile and Maritime Mobile Satellite Services

These are new services which are expected to be introduced in the foreseeable future. Their technical feasibility has been demonstrated in several trials, among which has been the series done as part of the Applications Technology Satellite programme. As a result, allocations have been made in the range 1535 to 1660 MHz. Two bands (1535 to 1542.5 and 1636.5 to 1644 MHz) have been allocated to Maritime Mobile-Satellite and two bands (1543.5 to 1558.5 and 1645 to 1660 MHz) to Aeronautical Mobile-Satellite. In addition, two bands (1542.5 to 1543.5 and 1644 to 1645 MHz) are allocated to both of these services to facilitate some inter-working between the two services for such purposes as, for example, search and rescue operations.

Amateur Satellite Service

Many countries were opposed to the use of space techniques by amateurs except for those bands which are allocated exclusively to them on a world wide basis. There was thus a great deal of opposition to this use of the band 435 to 438 MHz. However, strong representations in favour by Australia and other countries led to the compromise that the Amateur Satellite Service may be authorized in this band on condition that harmful interference shall not be caused to other services.

Other Allocations

Allocations to provide for other new services or the expansion of existing ones were made throughout the table. The most important of these were for the Space Research Service and for meteorological satellites and earth resources satellites. No earth resources satellite has yet been flown but there is active development going on and the first of this type is likely to be launched within the next few years. Such satellites are designed to view the whole of the surface of the earth at regular intervals with high resolution cameras and other sensors with the aim of making, and keeping up-to-date, an inventory of the resources of the earth so that complete information will be available to allow these resources to be managed efficiently.

Other Conclusions

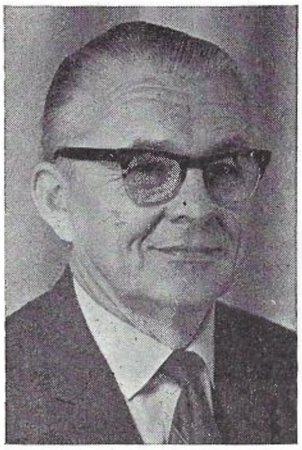
In addition to the changes to the Table of Frequency allocations, mention should be made of two other conclusions of the Conference.

A Resolution was agreed relating to the technical criteria recommended by the International Radio Consultative Committee (CCIR) for sharing frequency bands between space and terrestrial services. The effect of this Resolution is to allow CCIR Recommendations to be used to up-date the technical criteria specified in some of the Radio Regulations, provided the administrations affected agree to such use.

The new co-ordination procedures to regulate the sharing of frequencies by different satellites pay special attention to the conservation of the geostationary satellite orbit. The fundamental premises on which these procedures are based are that any satellite should be designed with orbit conservation in mind and should be capable of movement in position or antenna pointing direction if this is required to allow future satellites to be located near it.

The main consequences that follow from this World Administrative Radio Conference for Space Telecommunications are that national frequency usage must be reviewed in the light of the new International Table of Frequency Allocations and the implications of frequency sharing between types of terrestrial and space services not previously carried out must be taken into account in system design.

OUR CONTRIBUTORS



E. RUMPELT

N J. RYAN

R. M. TORKINGTON

E. RUMPELT, co-author of the article 'A Variable Group Delay and Attenuation Equalizer for Telephone Circuits', is an Engineer Class 3 in the Research Laboratories Headquarters. From 1937 to 1939 he worked in the Central Laboratories of Siemens and Halske, Berlin, and in the period 1940-1948 was on the staff of the Technische Hochschule at Munich. In this latter appointment he specialised in methods of filter design, in particular the then novel insertion loss method, working under the guidance of the late Professor H. Piloty, one of the pioneers of this method. Since 1948 Dr. Rumpelt has worked in Research Laboratories, Headquarters, where he is mainly concerned with network theory and design.

Dr. Rumpelt graduated from the Technische Hochschule, Munich, in 1937 with the qualification Dipl.Ing., and in 1947 gained the Dr.Ing. degree.

★

N. J. RYAN, author of the article 'CANTOT — Computer Analysis of Troubles on Trunk Circuits', is District Engineer, Maryborough, Queensland. He joined the Department in 1950 as a Technician-in-Training and after completing his training, was transferred to Trunk Test Room, Brisbane. In 1956 he qualified as a Senior Technician and was also appointed as a Trainee Engineer.

After spending 3 years as Engineer Class 1 in District Works No. 1 Division, Brisbane, Mr. Ryan transferred to Service Division in Long Line Equipment Section, Headquarters, where he was engaged on investigations of fault recording procedures and computerisation of statistics on the performance of the trunk network. He was also associated with the Australian N.A.S.A. communications network for the Apollo moon missions for which he received the Apollo Achievement Award.

Mr. Ryan is a member of the Institution of Engineers, Australia.

★

C. R. GROAT, author of the article 'Automatic Back Busying of Junction Circuits', joined the Postmaster General's Department as a Cadet Engineer in 1956. In 1959 he completed the degree of Bachelor of Engineering (Electrical) at the University of Melbourne and from 1960 to 1966 he was employed in the Metropolitan External Plant Section No. 2, mainly as a Group Engineer. In October 1966 Mr. Groat transferred to the Internal Plant Section where for three years he was the co-ordinating engineer for the Network Performance Analysis Centre and the Junction Control Centre. In 1970 he completed the degree of Master of Business Administration from the University of Melbourne and after short periods in the Metropolitan Cable Protection Division in District Works, Mr. Groat was transferred to Headquarters Postal Services Division where he is currently acting Controller, Long Range, and Business Planning.

R. M. TORKINGTON author of the article, 'Automatic Multiparty Systems for Rural Areas', joined the Postmaster-General's Department as Cadet Engineer in 1955. After graduation, he was Engineer Class 1 for five years in Metropolitan Exchange Installations, before promotion to Design Engineer, Telephone Equipment Design Group. He has occupied this position since, except for a period spent on the R.C.M.X. Design Project. He is also the Circuit Standards Engineer for Queensland. Mr. Torkington is a Member of the Institution of Engineers, Australia.

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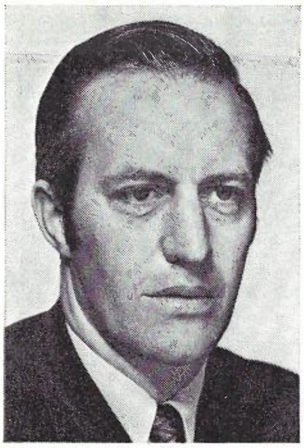
C. R. GROAT

M. A. RHEINBERGER



B. L. GRAHAM

K. A. G. McKIBBIN

M. A. RHEINBERGER, co-author of the article 'Aluminium Conductors in Paper Insulated Telephone Cables', joined the Postmaster-General's Department as a Cadet Engineer in 1958. After graduating from the University of New South Wales in 1962 he commenced duty with the N.S.W. Administration as Engineer, Class 1, Country Primary Works where he spent three years in installation and acceptance testing of trunk cable and aerial projects including the Wagga-Griffith coaxial broadband system. Mr. Rheinberger then joined the Central Laboratories of Siemens A.G. in Munich, West Germany, where he remained for two years mainly engaged in broadband microwave and cable system design. Returning to Australia in 1967, he joined Headquarters Staff as Engineer, Class 2, Cable Design, Lines Section.

During 1967-70, Mr. Rheinberger was associated with new developments in outdoor telephone cables, including single quad carrier, unit twin, moisture barrier sheath, aluminium conductor and insect resistant nylon jacketing. In 1970, he went overseas for twelve weeks to study developments in the design and manufacture of CATV cables and to review trends in high channel capacity analogue and digital bearer design. During this visit he presented this article to the 19th International Wire and Cable Symposium in Atlantic City, New Jersey.

In July, 1970, he was promoted Engineer, Class 3, and is currently Divisional Engineer, Trunk Network Design, Lines Section, Headquarters.

Mr. Rheinberger has the degrees of Bachelor of Engineering (Electrical) from the University of New South Wales and Bachelor of Arts from the University of Melbourne. He is a Graduate Member of the Institution of Engineers, Australia.

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B. L. GRAHAM, author of the article 'Transmission of Data Over Leased Links', joined the Postmaster-General's Department as a Technician-in-Training in 1949. Following training as a Cadet Draftsman and Trainee Engineer, he completed Associateship Diplomas in Radio and Electrical Engineering in 1959 and 1960. He was appointed as Engineer Class 1 in the Long Line and Country Installation Section, Victoria, in 1959, and was engaged in installation of line transmission and telephone exchange switching equipment in Northern Victoria. In 1960, he was promoted to Engineer Class 2, Long Line Equipment Section, Headquarters, where he worked on preparation of specifications for physical, environmental and component selection aspects of long line equipment; equipment design; evaluation of physical aspects of new equipment and provisioning of voice frequency equipment. Since 1968, Mr. Graham has been primarily responsible for assessment of the service performance and capabilities of various line transmission facilities, and for engineering liaison in provision of special quality leased data links. He was recently promoted to Engineer Class 3, Letter Systems Design, Postal Engineering Section, Headquarters. Mr. Graham is a Member of the Institution of Engineers, Australia.

K. A. G. McKIBBIN, author of the article on 'Power Distribution in High Rise Buildings', became a graduate member of the Institution of Electrical Engineers (London) in 1931 after completion of a five years apprenticeship in electrical engineering with Thomson Houston Co. Ltd., Rugby, England. He continued at this firm in the main drawing office on heavy electrical plant design until he joined Harland and Wolff, Belfast, on similar plant design for ships.

In 1936 he joined the British Broadcasting Corporation, North Ireland Region, and was associated with studios and outside broadcasting until the early war years, when he was transferred to the Power Branch of Planning and Installation at Headquarters in London. In this area he was mainly associated with the design, installation and commissioning of power plant at high power transmitting stations until the end of 1949, when he joined the A.P.O. and was posted to the Telephone Equipment Section, Headquarters, in February 1950. In September 1952 he was appointed Senior Engineer, General Engineering at Army Design, Department of Supply, and at the end of 1956 he transferred back to A.P.O. Headquarters.

Mr. McKibbin has been associated with several new power plant developments since joining the A.P.O. and is at present concerned with power system design and layout for large communication centres. He is a member of the Institution of Engineers (Aust.).

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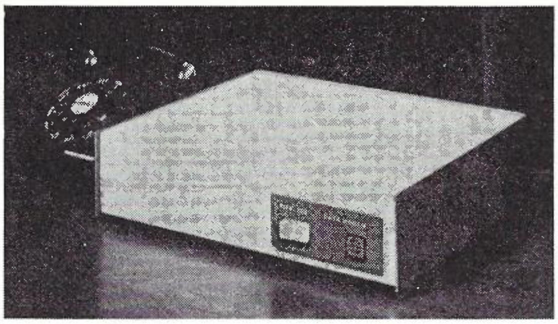

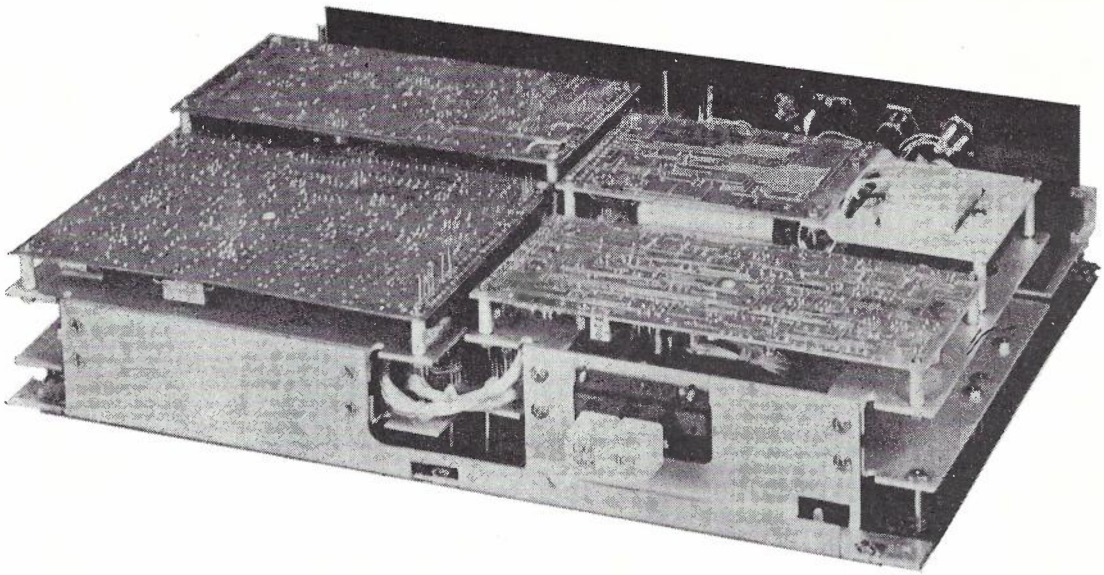

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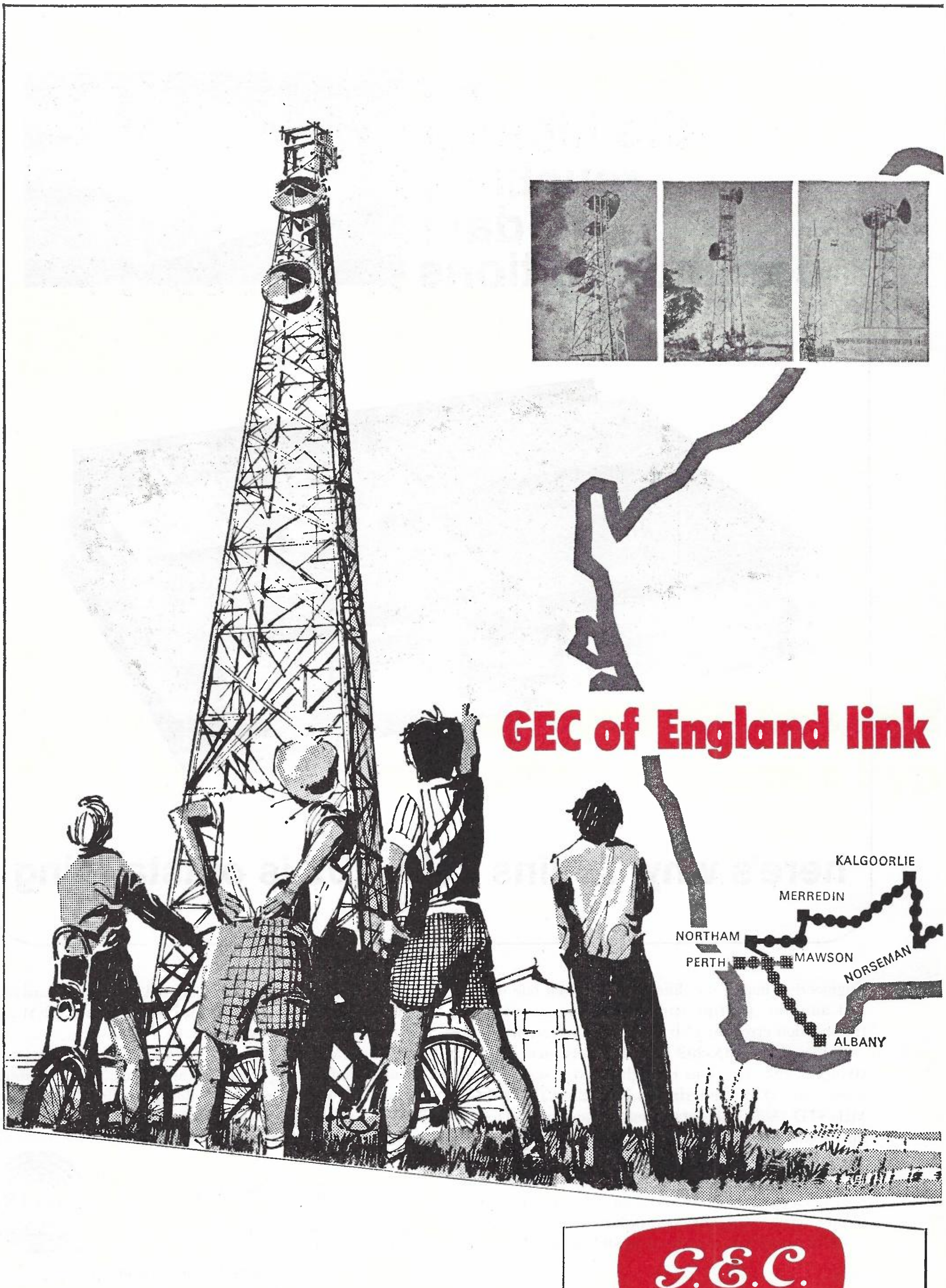
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THE TELECOMMUNICATION JOURNAL OF AUSTRALIA

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OCTOBER 1971

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The TELECOMMUNICATION JOURNAL of Australia

ABSTRACTS: Vol. 21, No. 3

CLARK, R. A., RHEINBERGER, M. A., and SISSON, A. W.: 'Aluminium Conductors in Paper Insulated Telephone Cables'; Telecom. Journal of Aust., October 1971, page 195.

The Australian Post Office believes that there is an economic application for paper insulated aluminium conductor cable in the city networks. The basis for this belief and the particular installation and maintenance practices applicable in such a network are discussed in this paper. The manufacture of cables and the results of field installations are also reported on.

FLETCHER, C. and LIUBINAS, A. E.: 'Commissioning and Maintenance of ARM Exchanges'; Telecom. Journal of Aust., October 1971, page 235.

In a series of three articles the authors describe testing procedures developed for the commissioning of ARM exchanges. The emphasis is on those tests which ensure satisfactory interworking of the ARM equipment with the telephone network. The principles of the maintenance of ARM equipment are also covered.

GRAHAM, B. L.: 'Transmission of Data over Leased Links'; Telecom. Journal of Aust., October 1971, page 208.

The characteristics of various transmission facilities are examined in relation to the practical problems of provision of leased data links. Critical factors in data transmission, performance specifications, methods of equalisation, maintenance techniques, and operational reliability are also reviewed.

GRAY, D. A., RUMPELT, E., and WARD, M. K.: 'A Variable Group Delay and Attenuation Equalizer for Telephone Circuits'; Telecom. Journal of Aust., October 1971, page 255.

The Australian Post Office provides long distance telephone bandwidth data transmission circuits for a number of users, of which the N.A.S.A. is, at present, the most important. To make good use of the potentialities of these circuits, they are equalized for delay and amplitude within limits prescribed by the C.C.I.T.T. Recommendation M.102. A variable equalizer design is described which makes use of up to ten second-order delay networks. The technique of circuit equalization is also outlined.

GROAT, C. R.: 'Automatic Backbusying of Junction Circuits'; Telecom. Journal of Aust., October 1971, page 218.

This paper describes measures taken in the Melbourne Metropolitan telephone network toward the provision of partial automatic backbusying of junction circuits in bimotional switching equipment. The heart of the system described is a guard relay which detects 50 volts as distinct from an open or a short circuit in the junction. The paper describes modifications to incoming selectors and outgoing relay sets, and discusses costs and benefits.

KOOP, E. J.: 'The Measurement of Volume Reference Equivalents'; Telecom. Journal of Aust., October 1971, page 225.

The volume reference equivalent of a subscribers telephone connection is by C.C.I.T.T. definition, the volume (or loudness) inferiority of that telephone circuit measured in a voice-ear comparison against the New Master Reference System (N.O.S.F.E.R.) or against a calibrated working standard system. The historical development of the N.O.S.F.E.R. reference system is outlined and the technique of measuring reference equivalents is described. Details are given of the N.O.S.F.E.R. set up and operated in the A.P.O. Research Laboratories. The essential components of a measuring system for the objective measurement of reference equivalents are described and some of the problems of correlating the results of objective and subjective measurements are outlined.

McKIBBIN, K. A. G.: 'Power Distribution in High-Rise Departmental Buildings'; Telecom. Journal of Aust., October 1971, page 268.

This paper discusses the general requirements for the supply, distribution and control of electrical energy in high-rise telecommunications buildings. Particular attention is given to the reliability of power supplies, economy in switching and distribution and overall efficiency.

RYAN, N. J.: 'CANTOT — Computer Analysis of Troubles on Trunk Circuits'; Telecom. Journal of Aust., October 1971, page 263.

This paper describes the application of automatic data processing to the analysis of fault data on trunk circuits. The system is service oriented and provides information to assist field engineers to pinpoint troubles. It also provides feedback information for design engineers and manufacturers.

STIRLING, W.: 'Fault Recording in Country Area Exchanges'; Telecom. Journal of Aust., October 1971, page 280.

This paper outlines new procedures for recording and analysing fault reports on Telecommunication plant in country areas. The system is designed to cover the particular sources of service information in a country area, and includes new recording procedures developed.

TORKINTON, R. M.: 'Automatic Multiparty Systems for Rural Areas'; Telecom. Journal of Aust., October 1971, 260.

A system of providing automatic telephone service to party line subscribers on long lines is described. The use of cailho battery feed, pushbutton identification, and earth return dialling extends the normal working limits of an exchange. It is intended for use in remote rural areas.

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