THE

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IN THIS ISSUE

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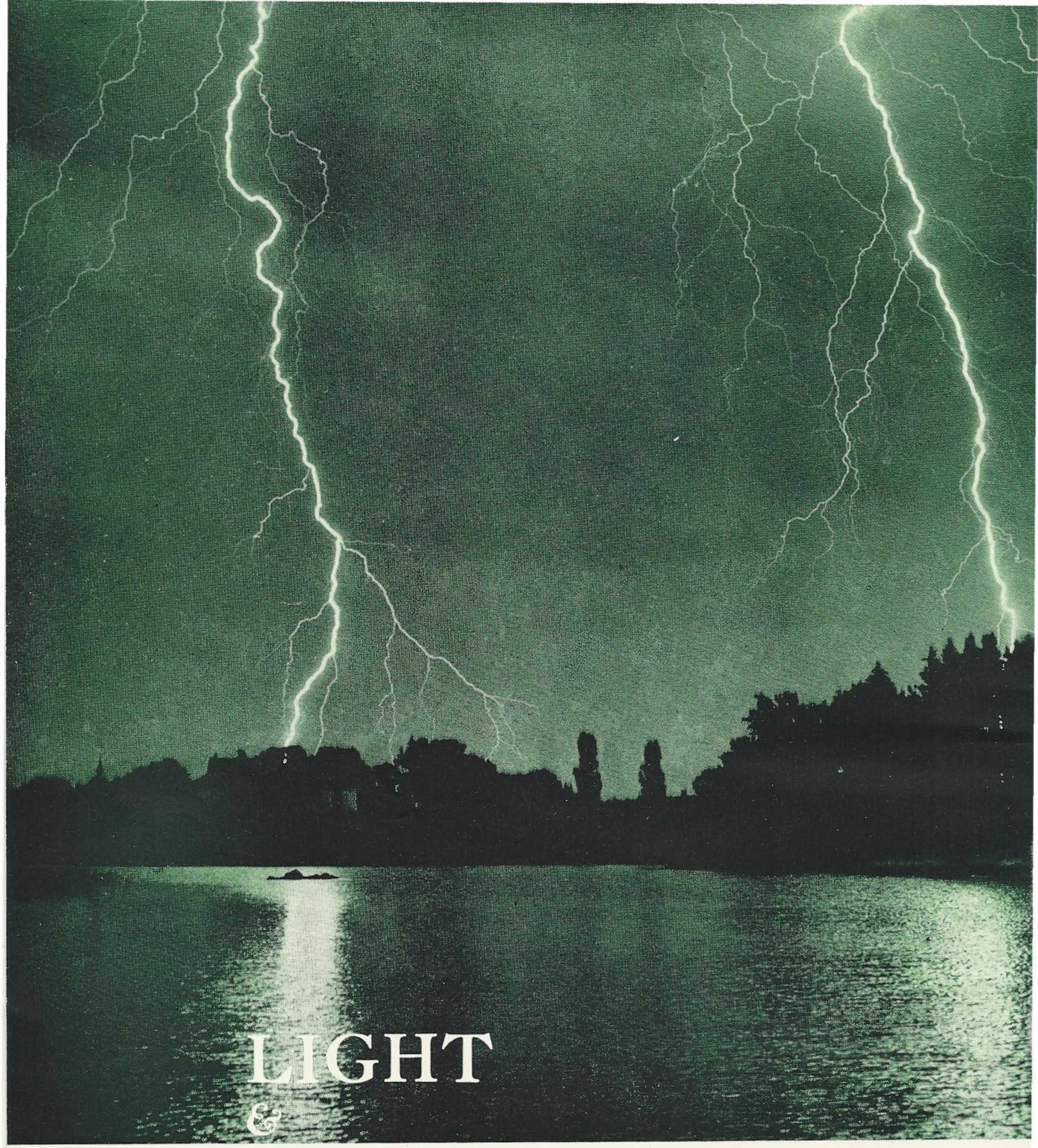

LIGHT & SOUND

Electrical energy and sound were associated in a familiar, elemental way long before Edison and Bell began to reorganise them.

Now less elemental, but increasingly familiar, the association has been turned to man's ends. President talks to Prime Minister; Jack talks to Jill. In the coming day when anyone can talk to anyone, anywhere, at any time, we shall be there, still helping.

Standard Telephones and Cables Pty. Ltd.

The

TELECOMMUNICATION JOURNAL

of Australia

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*For addresses see inside back cover.

COMPAC: VANCOUVER-SYDNEY 60/80 CHANNEL SUBMARINE CABLE SYSTEM

R. E. KNIGHTLEY, A.M.I.E.Aust.[*]

INTRODUCTION — HISTORICAL

Telegraph Cables

Intercontinental, or **trans-ocean** electrical communication began with the first trans-Atlantic telegraph cable. After three abortive attempts which failed, largely due to insufficient appreciation of the mechanical strength required for deep-sea cables, a successful cable linked the British Isles with Newfoundland in 1866. Response to this new form of communication was so rapid that by 1902 a system of telegraph cables and landlines ringed the world, including the 1872 cable to Port Darwin that linked with Australia's Overland Telegraph Line.

Up to 1926, British interests alone had installed a cable network grossing some 150,000 nautical miles. By this time, however, inter-continental radio systems were becoming economically attractive, and after a merger of British radio and cable interests in 1929, no new trans-ocean telegraph cable routes were opened by British establishments.

High Frequency Radio

When Marconi and others made trans-ocean radio communication a commercial possibility after the turn of the twentieth century, it became apparent that the new medium offered a number of advantages beyond the scope of cables. In addition to the economic aspects, radio enabled higher signalling speeds for telegraphy, while it was suitable for telephony and facsimile transmission as well.

A second era of inter-continental communications began with the establishment of a radio-telegraph link between England and the U.S.A. in 1907, and the first radio-telephone circuit between the same countries in 1927. By 1927, also, radio spread commercially to Australia with the opening of "Beam Wireless" between Victoria and Britain.

In the 1930's, however, it was realised that H.F. radio had three serious limitations: firstly, it rarely approached the quality of "wired" telephony, even over similar distances; secondly, propagation conditions were often unstable and at times impossible; thirdly, the useful frequency spectrum (3-30 Mc/s) was becoming so crowded by the expanding global network that international regulation of frequencies and emission processes was needed. Attention turned to other media—in particular, to "telephone" cables.

Coaxial Telephone Cables

As with telegraphy, the first trans-ocean **telephone** cable linked the Old World with the new, from Oban in Scotland to Clarenville in Newfoundland, in 1956. In addition to the usual difficulties of long-distance multi-channel telephony, submarine coaxial cable working presented many unexplored fields. Four of these were: the development of suitable cable; the development of wide-band repeaters which could be laid in deep oceans and left unattended for many years; design and production of equipment to supply power to the repeaters from land-based stations; and problems of equalisation and system loading in the absence of access to intermediate points when propagation characteristics changed with age and with variations of sea-bottom temperatures.

Considerable research into these problems occurred on both sides of the Atlantic, and this research found practical expression in numerous "short" cable systems. Notable examples were the Anglesey-Isle of Man cable of 1943, Key West-Havana in 1950, and Scotland-Norway in 1954.

By 1953 the American Telephone and Telegraph Company, the British Post Office and Canadian Overseas Telecommunications Corporation had sufficient confidence to contract for provision of the first **trans-ocean** telephone cable. Handed over for traffic in September, 1956, and now known briefly as "T.A.T. ONE" (Trans-Atlantic Telephone No. 1), the system was designed to carry three basic C.C.I.F. groups, that is, 36 voice-bands at 4 Kc/s spacing. Some details of the system are shown in Table 1.

Once again, the advent of a new technique gave a marked stimulus to traffic. High quality channels, 24-hour reliability and on-demand service caused such a sharp up-turn in trans-Atlantic telegraph and telephone activity that, within two years, the original 36 voice-bands became overloaded to the extent that bandwidth conservation techniques were applied and additional trans-Atlantic systems were under negotiation.

The history of T.A.T. 1 channelling arrangements is shown in Table 2, while the rapidity with which coaxial-cable systems are now being added to the world's inter-continental facilities is indicated in the map, Fig. 1.

Of particular interest to countries of the British Commonwealth are the two cables, COMPAC and CANTAT. The CANTAT system is a joint venture undertaken by the British Post Office (B.P.O.), Cable and Wireless Limited (Britain), and Canadian Overseas Telecommunications Corporation. Bandwidth has been reserved in this cable for extension of Pacific area circuits to Britain and beyond. From 1964 onwards, the COMPAC and CANTAT systems will be linked across Canada by high-grade micro-wave circuits and will then be treated as an integrated system from both engineering and economic viewpoints.

COMPAC — OVERALL PLANNING

Finance and Organisation

Following conferences in London and Sydney in 1958-59, the governments of Australia, New Zealand, Canada and Britain agreed to advance capital for a

TABLE 1: T.A.T. 1—COMPOSITION OF SYSTEM

System Terminals & Route Lengths	Submarine-Cable Links & Lengths	No. of Submarine Repeaters	Nominal No. of C.C.I.F. Voice-Bands
London-New York 4,078 miles	(i) Oban-Clarenville 1,950 naut. miles.	102*	36
London-Montreal 4,157 miles	(ii) Clarenville-Sydney Mines (Nova Scotia) 333 naut. miles	16†	60

* American (uni-directional) repeaters, 51 in each direction.
† British (bi-directional) repeaters.
London-New York and London-Montreal paths divide at Spruce Lake, N.B.

TABLE 2: T.A.T. 1—BAND-WIDTH CONSERVATION MEASURES

Date	Action Taken	Total Number of Voice-Bands Available
Sept., 1956	System opened with voice channels at standard C.C.I.F. spacing (4 Kc/s).	36
Dec., 1957	Narrow-band (2 Kc/s) voice channels introduced on London-Montreal circuits; 1½ "out-band" channels added.	44½
Jan., 1960	Narrow-band (3 Kc/s) voice channels introduced on London-New York circuits.	54
May, 1960	Time-Assignment Speech Interpolation (T.A.S.I.) added on London-New York circuits.	76

* See page 348.

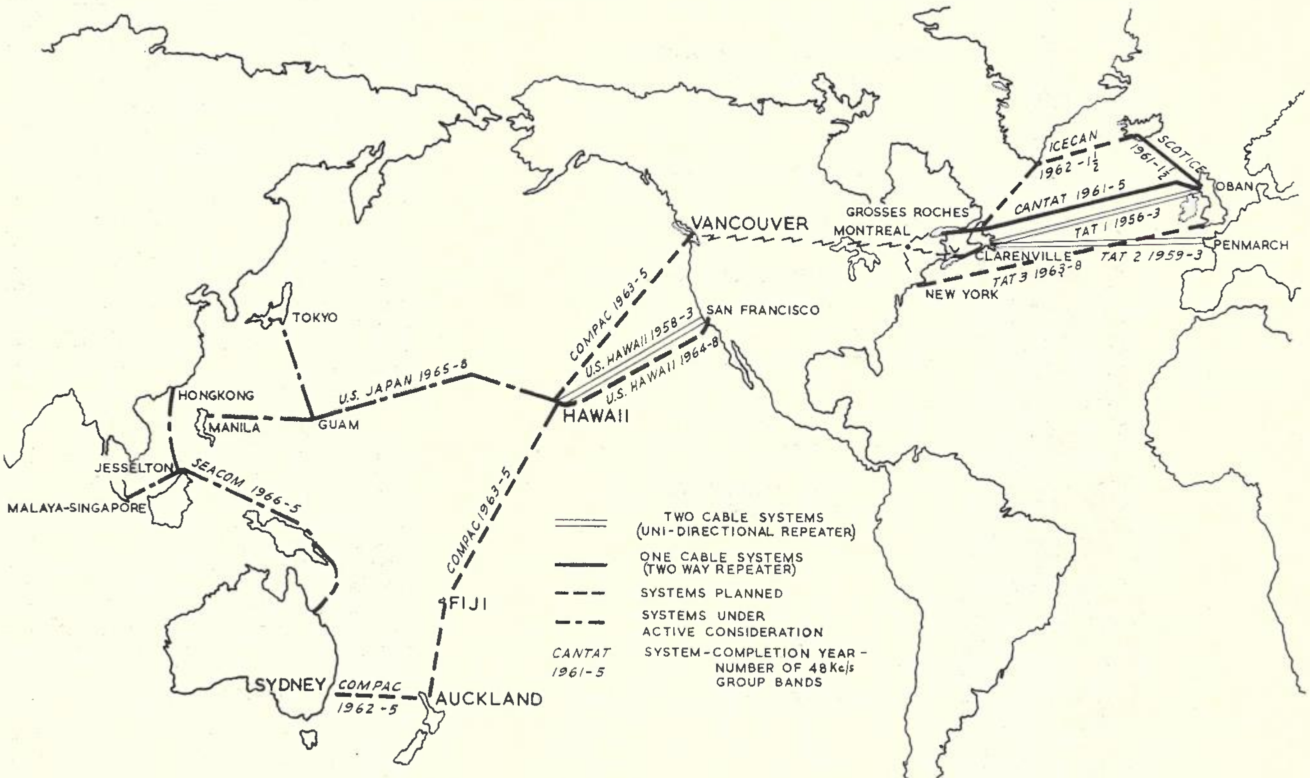


Fig. 1.—Existing and Projected trans-Ocean Cables.

(basically) 60-circuit system linking Vancouver Island and Sydney. Significant points in the agreement were:—

(i) **Capital:** Contributors to the capital cost of the scheme, amounting to £33 millions, would be:

The Overseas Telecommunications Commission (Australia).
Canadian Overseas Telecommunications Corporation.
Cable and Wireless Limited, Britain.
New Zealand Post Office.

As far as possible, contributions would be in kind, rather than in cash, and contracts so far placed in Australia include the terminal building, power plant, raw materials for cable manufacture, and installation of new ducts and cables between the O.T.C. building at Paddington (Sydney) and Bondi beach.

(ii) **Direction and Control:** Executive direction would be vested in a Management Committee composed of representatives of the four contracting partners, headed by a Convenor drawn from the Management Committee members. First Convenor of the Management Committee is Mr. T. A. Housley, C.B.E., General Manager of O.T.C. (Australia).

(iii) **Engineering:** Cable and repeaters would be produced under the supervision of the B.P.O., and laid by the B.P.O's 8,000-ton cable-layer, "Monarch". Special items of equipment specific to long-distance systems would be produced under the detailed supervision of the B.P.O., with installation to be effected by the partners. Other equipment would be the entire responsibility of the individual partners. System performance, engineering facilities and time-tables would be worked out by Joint Technical meetings in the various countries from time to time.

TABLE 3: COMPAC: ESTIMATED CAPITAL COSTS (Sydney, 1959)

Item	Quantity*	Price Per Unit in A£. *	Total Cost in A£M
Deep-Sea Cable	7,752 nauts	1,875	14.3
Other Cable	346 nauts	Various	0.7
Submarine Repeaters	312	22,500	7.0
Submarine Broad-Band Equalisers	30	15,000	0.5
Hire of H.M.T.S. "Monarch"	597 days	1,875	1.1
Other Shipping Costs	—	—	0.8
Buildings, Power Plant and Equipment	—	—	2.9
Engineering Office Costs and other Charges, including Spare Cable and Repeaters	—	—	2.6
Contingencies at 10%	—	—	3.1
			Total £33m.

*Figures used at Sydney conference; subsequently revised.

Economic Considerations

The capital cost of the system was estimated at £33 millions, assuming land-based stations at Vancouver Island, the Hawaiian Islands, Fanning Island, Fiji, Auckland and Sydney. The more significant items are shown in Table 3.

Annual costs were expected to total, over the 20-year estimating period 1964-84, some £80 millions. Conservative estimates of income were compiled on the premises that the Hawaiian Islands would form a cross-roads for interchange of British and U.S.A.-Asia traffic, and that traffic generally would receive a 100% stimulus from the provision of high quality, stable circuits, It was estimated that revenue over the 20-year period would be in the vicinity of £84 millions.

Subsequently, at joint conferences in Wellington in February 1961, capital cost estimates were revised downwards to £30 millions. This occurred after placement of orders for all cable and repeaters. At the same time, traffic forecasts are being revised upwards.

Choice of Route

In connection with CANTAT and other schemes, the B.P.O. research establishment at Dollis Hill had carried out extensive development of cable and repeaters, including deep-sea trials, and were able to offer the proposed CANTAT model as a basis for the 1959 Sydney conference to build from. Thus

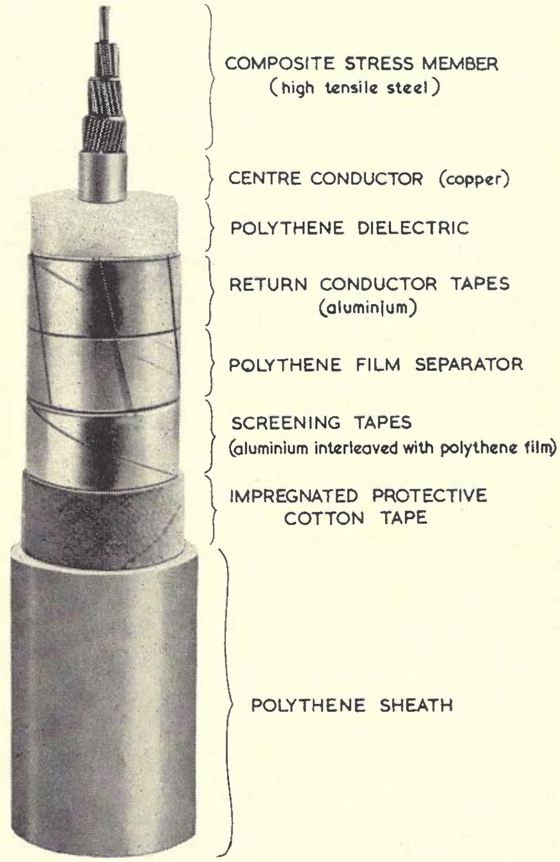


Fig. 2.—Light-weight Deep-Sea Cable (By Courtesy of Standard Telephones and Cables, Limited).

it was proposed to plan a system with the following characteristics:

Capacity: Five basic C.C.I.T.T. groups (each 48 Kc/s wide).

Repeaters: B.P.O. design, bi-directional.

Cable: "Lightweight" type, of appropriate configuration.

Sections: Up to 3,700 nautical miles for any individual section, assuming large-diameter cable.

At the time of laying T.A.T. 1, it had not been possible to use British repeaters on the long trans-ocean link, mainly because techniques for laying them in ocean waters had not been developed. By 1959, however, the problem had been effectively solved and thus it was proposed to provide a system using only one cable, with two-way repeaters, to carry both "go" and "return" transmission.

The maximum length of any individual section was limited primarily by the D.C. voltage that could be applied to the cable-end for the purpose of supplying power to the repeater valves. As at 1959, the maximum working voltage that could be applied across capacitors, in the repeater power-separating filters, was limited to 5 K.V.; larger capacitors to withstand higher voltages would mean extensive redesign of repeaters. In the context of this limitation, and after consideration of the relative economics of various diameters of cable, the following route was tentatively decided as being technically and economically feasible:

Section	Length Nautical Miles	Max. Depth Fathoms
Vancouver Island-Hawaii	2,310	3,400
Hawaii-Fanning Island	1,046	3,100
Fanning Island-Suva	1,867	3,000
Suva-Auckland	1,235	2,500
Auckland-Sydney	1,250	2,600

As it was realised that negotiations for landing cable and building a station in the Hawaiian Islands could take some years, evidence was produced to show that, if necessary, they could be by-passed to give a Vancouver Island-Fanning Island link (3,300 nautical miles) by using larger cable.

Subsequent to the 1959 conference, the Hawaiian landing rights have been secured by Canadian O.T.C., and the B.P.O. have shown that existing repeaters capacitors can, in fact, withstand working voltages of the order of 10 K.V. without significant impairment of performance. This led the joint conferences in Wellington in 1961 to decide upon the by-passing of Fanning Island so that the cable will follow the route shown in Fig. 1. At the same time, Canadian O.T.C. decided to place the Canadian terminal at Vancouver in lieu of on Vancouver Island. The longest link now becomes Suva-Hawaiian Islands, at 3,008 nautical miles, with an applied system power voltage in the vicinity of 6.3 K.V. at each end. The total route distance from Sydney to Vancouver is just over 8,000 nautical miles (9,320 statute).

Construction Time-table

At the time of the Sydney conference, the only ship in the world capable of laying long repeatered cables was the "Monarch", while the only factories producing suitable cable and repeaters were Submarine Cables Limited and Standard Telephones and Cables, both in England. From a study of availability of the ship and anticipated factory production, the tentative time-table agreed was:

Sydney-Auckland—complete by May, 1962.

Remainder—complete by early 1964.

Subsequently, Cable and Wireless Limited have contracted for the construction of a second ship. This, coupled with the decision to by-pass Fanning Island and later knowledge of repeater and cable production, led to the following target dates being agreed at the 1961 Wellington conference..

Link	*Installation Complete by:*	*Ready for Traffic by:*
Sydney-Auckland	May 1962	July 1962
Auckland-Suva	November 1962	December 1962
Suva-Hawaii Hawaii-Vancouver	October 1963	December 1963

CABLE AND REPEATERS

Cable

As indicated in the opening lines of this article, the failure of early cable systems was due largely to insufficient mechanical strength in the cables. This factor continues to be a dominant parameter in cable design, and all deep-sea cables up to and including T.A.T. 2 were steel-wire armoured. The purpose of the armouring was, not protection from accidental damage, but longitudinal strength. However, the steel armouring always presented considerable handling difficulties, and this led the B.P.O. and Submarine Cables Limited to investigate other forms of cable com-

TABLE 4: COMPARISON OF T.A.T. 1 AND COMPAC-TYPE DEEP-SEA CABLES

Cable	Diameter Overall	Weight in Water	Modulus	Attenuation at 608 Kc/s.
Light-weight (COMPAC)	1.30 inches	0.6 Tons/nm	12.5 nm	2.11 db/nm
T.A.T. 1	1.27 inches	1.8 Tons/nm	7.0 nm	3.21 db/nm

position having sufficient tensile strength, but with reduced rigidity and tendency to twist under strain.

By 1959, it was possible to offer "lightweight" deep-sea cable, the composition of which is shown in Fig. 2. The strength of the cable rests in a core of 43 high-grade steel strands, over which is a copper tube forming the central conductor of the coaxial transmission path. Between this and six helically-wound aluminium tapes forming the outer conductor, is an insulant of extruded polythene containing an admixture of anti-oxidant. A thin polythene tape separates the outer conductor from an electro-static screen of aluminium foil; this screen has no function in normal working, but reduces cross-talk between flakes of the cable while it is coiled in the tanks of the ship. The aluminium is protected by a lapping of cotton tape impregnated with a corrosion inhibitor (for example, barium/zinc chromate and butyl rubber), and an outer sheath of polythene. Between the cotton tape and the polythene sheath is a wrapping of polythene film, this being to protect factory staff from contact with the poisonous chromate during manufacture. The cable can be made in a range of sizes, that chosen for the deep-sea sections of COMPAC having a coaxial-tube diameter of 0.99 inches and an overall diameter of 1.3 inches.

Development of this type of cable represented a significant contribution to cable telephony. Not only was a cable produced which overcame the major mechanical difficulties of previous types, but it proved to have superior attenuation characteristics, as compared with armoured cable of similar external diameter (see Table 4); moreover, its characteristics appear to undergo only very small changes with handling, during laying activities and with ageing.

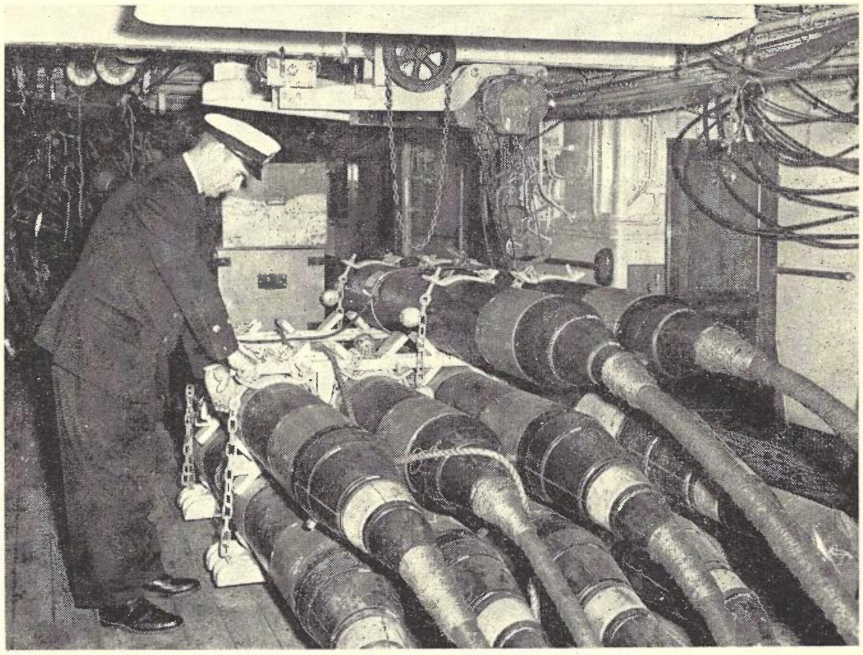


Fig. 4.—Submerged Repeaters on "Monarch".

Repeaters

At the time of laying T.A.T. 1, two types of broad-band repeaters had been developed. One type—American—consisted of a series of articulated containers which, when jointed into the cable, formed a flexible unit that could be run over the laying-sheaves of a ship. The other—British—was a single unit, housed in a heavy steel casing; it cannot be passed over the laying sheaves. The British repeater, however, is a two-way repeater, that is, it can amplify transmissions in both directions, while the American is a one-way only amplifier and must be used in conjunction with two separate cables.

Now that techniques for laying "rigid" repeaters in ocean waters have been developed on both sides of the Atlantic it is doubtful that two-cable systems of the T.A.T. 1 and T.A.T. 2 type will be installed in the future. CANTAT is the first example of a one-cable, two-way-repeater system in a trans-ocean link, and COMPAC will follow this pattern.

The repeater consists of an electronic assembly inside a heavy steel cylinder designed to withstand pressures of some 6 tons per square inch. Illustrated in Figs. 3 and 4, the completed repeater is some 10 feet long, 10 inches in diameter, and weighs over half a ton.

Because of the extremely high reliability requirements, great care is taken in the manufacture of the repeaters. Many components are hand-made under conditions of hygiene approaching those of a hospital operating theatre, and similar conditions surround all stages of repeater assembly. Exposed metal surfaces in the electrical units are gold plated against corrosion and the growth of whiskers, and the atmosphere inside each steel cylinder is replaced by dry nitrogen before the watertight bulkheads are fitted. There will be some 323 repeaters of this type between Sydney and Vancouver, spaced at nominal distances of 26.3 nautical miles.

A block schematic diagram of the transmission path of a repeater is shown in Fig. 5. In the A-B direction of transmission (low-frequency band), signals pass via hybrid H2 and low-pass filter F2 to the amplifier and thence via filter F3 and hybrid H1; in the B-A direction the signals pass via H1, F1 and the amplifier to F4 and H2.

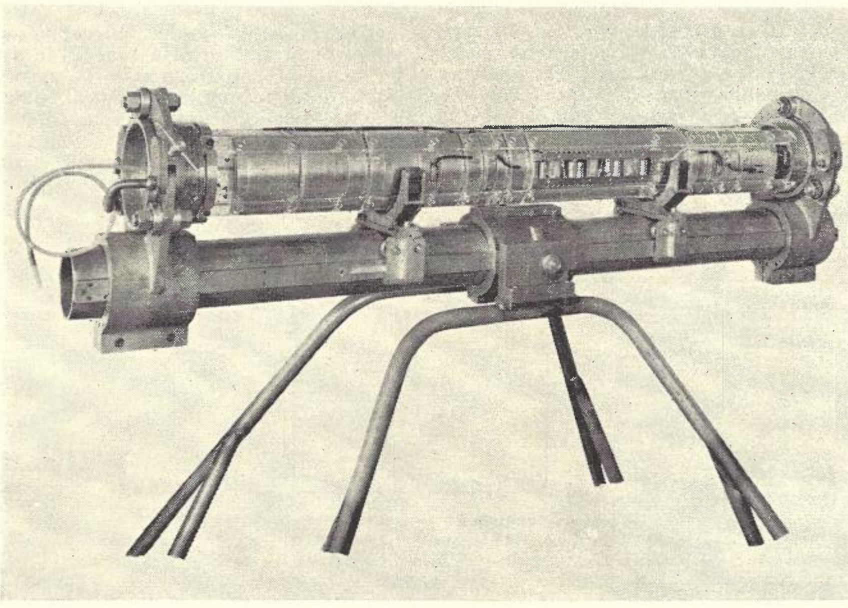


Fig. 3.—Submerged Repeater—Electrical Units (By Courtesy of Standard Telephones and Cables, Limited).

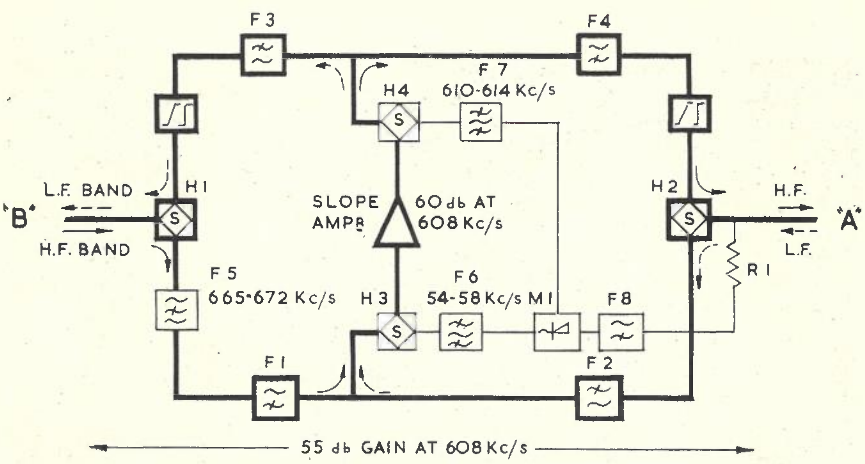


Fig. 5.—Submerged Repeater — Block Schematic Diagram.

A common broad-band amplifier is used for both directions of transmission.

The amplifier itself is a 6-valve unit, consisting of two three-stage amplifiers in parallel, with common feedback. The feedback arrangements are such that, should one of the two amplifiers fail, the change in gain would be only some 0.2 db, but the noise would rise measurably, for example by about 8 db in the case of second-order intermodulation products.

Other components shown in the diagram form supervisory circuitry by which the gain, noise, harmonic content and intermodulation products of each repeater may be measured from shore stations, some of these tests being possible while the system is carrying traffic.

Power Feed Equipment

As in many other coaxial systems, the repeater valves are powered by feeding a steady direct-current along the centre conductor of the cable, the return path normally being via sea-earth plates at each end of a link.

It is essential that the value of the D.C. between the ends of the cable be held within very close tolerances for a number of reasons, for example, the maintenance of constant filament temperatures and valve electrode potentials influences both valve life and transmission performance. Moreover, the highest possible protection is needed to guard repeaters against damage by excessive voltages and currents under a wide variety of possible system faults.

In addition it is essential for economic and repeater-life reasons to ensure a very low probability of interruption to power, and to maintain the service under conditions in which the actual "earth" potentials at the two ends of a link may vary greatly in a random manner.

The conditions are shown in the form of an equivalent circuit in Fig. 6. At the A and B stations, series-aiding e.m.f.'s are provided, with variable control elements to govern the current. Earth potentials are represented by uncontrollable variable e.m.f.'s which may in practice aggregate 1 K.V. under high earth-current conditions.

A highly simplified block schematic diagram of typical power-feed arrangements at a COMPAC shore station is shown in Fig. 7. Three independent no-break A.C. supplies power three rectifiers—A, B and C. Under normal conditions, two of these A.C./D.C. supplies are sharing load, with the other switched out of service. Any one A.C./D.C. supply can carry the required load; thus, with up to two supplies faulty there would be no interruption to service. Indeed, on the shorter links of COMPAC, cables can be powered from one-end-only for reasonable periods, allowing faults on four out of six A.C./D.C. converters.

The outputs of rectifiers A, B and C are connected in series, and between these and the power-separating filter are three separate current-control elements. Voltages from these elements are fed back individually to regulators (via calibrating circuits and magnetic amplifiers) in the input circuits to the rectifiers.

On COMPAC, cable current will be supplied at 430 mA $\pm$ 1%. As each repeater requires a voltage drop of 73.5V. across it, and the cable produces a voltage drop of 1.2V. per naut, the applied system voltages will be of the order of 2.5 K.V. per end on shorter links, rising on the long Fiji-Hawaii link to the 6.3 K.V. mentioned previously.

FREQUENCY SPECTRUM, CHANNELLING AND PILOTS

Frequency Spectrum

As indicated previously, the system is designed to carry five C.C.I.T.T. group bands, each 48 Kc/s wide. Their arrangement on the coaxial links and the frequency translation process at both A and B stations is indicated in Fig. 8.

In the A to B direction of transmission, standard C.C.I.T.T. translation processes are employed. The five basic groups are translated using carriers of 420, 468, 516, 564 and 612 Kc/s into the basic super-group band, 312-552 Kc/s. This is then modulated against the system translating carrier of 612 Kc/s into the Super-Group No. 1 band, 60-300 Kc/s. The reverse process applies at the B station.

In the B to A direction, non-standard translating processes are used. At the B station, the basic groups are translated directly up to the line frequencies, using carriers of 468, 516, 564, 612 and 668 Kc/s. This places groups 1 to 4 in the positions normally occupied by groups 2 to 5 in a standard Super-Group No. 2 — that is in the band 360-552 Kc/s. A gap of 8 Kc/s, for certain submerged repeater supervisory functions as mentioned earlier, is left between groups 4 and 5, placing the latter in the band 560-608 Kc/s.

Although not shown in Fig. 8, it is expected that at least two "out of main band" channels will be achieved, suitable for traffic on short links such as Auckland-Suva.

The gap of some 54 Kc/s between the A-B and B-A directions of transmission enables the provision of directional filters with very low basic loss (0.1 db) in submerged repeaters and shore stations.

Allocation of Groups

The proposed initial allocation of group paths is shown in Fig. 9. It will be seen that one group is to be carried right through from Sydney to London, a total route distance of some 16,000 statute miles. This group, and the Hawaii-London group, will traverse the internal network of Canada plus some

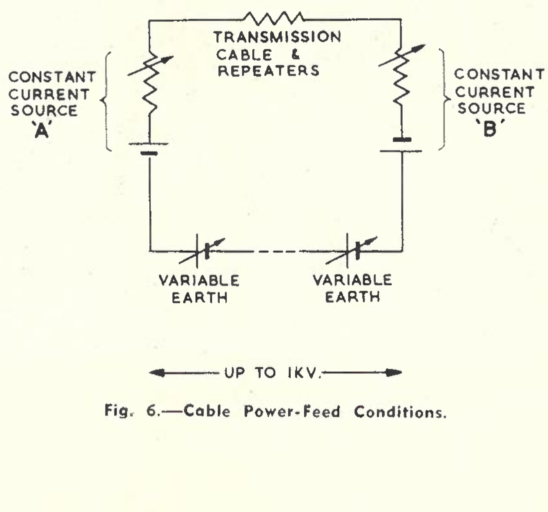


Fig. 6.—Cable Power-Feed Conditions.

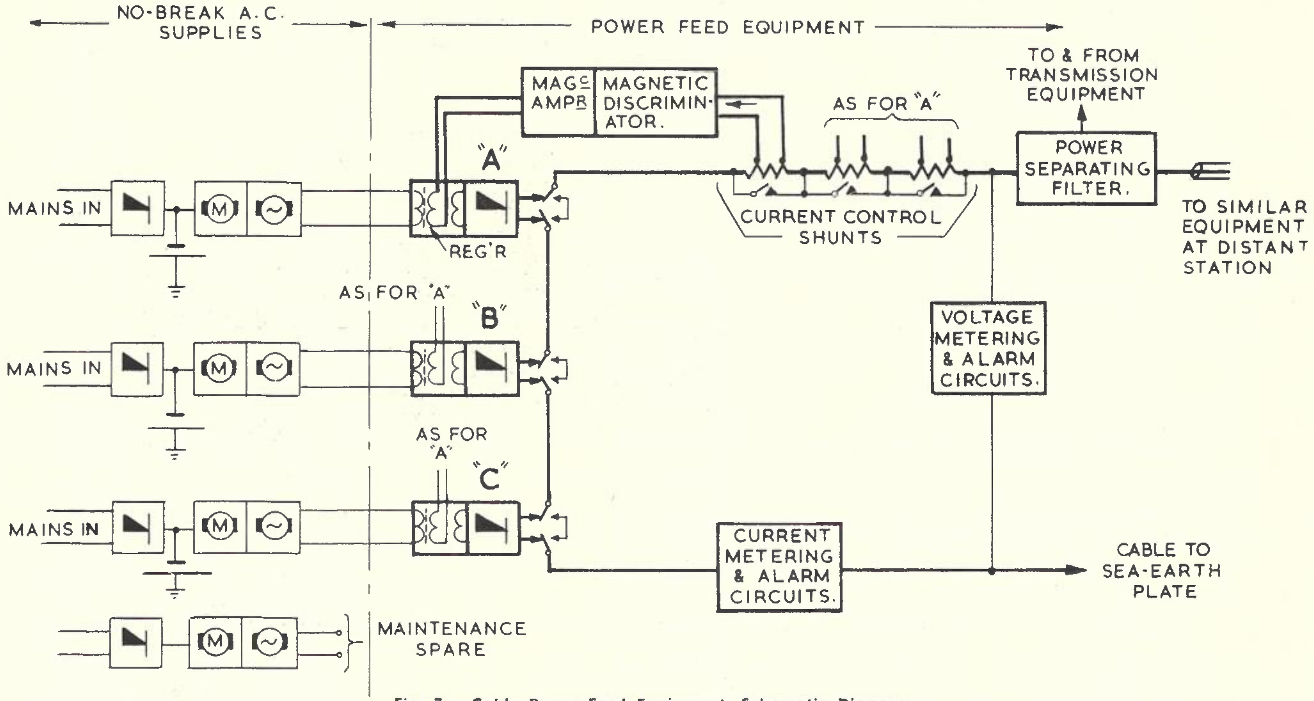


Fig. 7.—Cable Power-Feed Equipment, Schematic Diagram.

500 miles of the internal network of the U.K., between Oban and London. In addition, the proposed Hawaii-Montreal circuits will traverse a considerable portion of the 4,500 mile trans-Canada system.

Channelling Arrangements

When compared with a channel in a **national** network, a trans-ocean circuit is an economic unit with extremely high capital and maintenance costs. Thus, the inter-continental engineer is led to examine critically the advances which have taken place in frequency-translation processes, filter techniques, and so on since the 4 Kc/s channel spacing was adopted many years ago by the C.C.I.F. In particular, he is interested in the "unused" kilocycle which results when a voice-channel of nominal 300-3,400 c/s bandwidth is applied to a system at 4 Kc/s channel spacing.

While the submarine system designer may depart from accepted international standards on the submarine links, he faces a number of difficulties if he attempts to carry non-standard channel spacings on existing inland networks. For example, he finds pilots and carrier leaks within the channel bands instead of being placed conveniently at channel cross-over points. It was shown in Table 1 that T.A.T. 1 had become a mixture of channels at 2 Kc/s and 3 Kc/s spacings. The 2Kc/s channels are compatible with 4 Kc/s C.C.I.T.T. standards and are connected directly between London and Montreal. The 3 Kc/s circuits between London and New York, however, are reduced to audio at the submarine-system terminals, and the channels are then carried through the American and British national systems at 4 Kc/s spacings.

On COMPAC, as shown in Fig. 9, groups will traverse both Canadian and British national networks. Current plans are that groups which are not connected directly into these transmission networks (that is groups which are reduced to audio at the submarine-system stations) will each consist of 16 channels at 3 Kc/s spacing, while groups which traverse the national systems will be of 12 x 4 Kc/s characteristics.

It should be noted, however, that the transmitted voice-band of the 3 Kc/s channels is a nominal 250-3,050 c/s, as against 300-3,400 in C.C.I.T.T. standards, that is the voice band-width on the submarine links is nominally reduced by only 300 c/s with respect to C.C.I.T.T. Standards.

The most heavily loaded sections of the system will carry initially a total of 76 voice bands, which may be increased to 78 by the addition of out-band channels on short links.

Pilots

Three major systems of pilots will be employed to produce highly stable transmission: "Cable" pilots, "System" pilots and "Group" pilots.

On each submarine section, one "Cable" pilot tone will be transmitted in each direction, the tone being at the high-frequency end of the broad-band spectrum, as shown in Fig. 8 (305.25 Kc/s, A to B; 609.25 Kc/s, B to A). It will be injected into and extracted from the broad-band path at the nearest convenient point to the coaxial cable termination. Associated with a continuous level-recorder, it will perform the dual functions of recording any changes in level that occur due to ageing of cable and repeaters, and of giving positive indication of cable or repeater interruption.

Also on each section, two "System" pilot tones will be transmitted in each direction—one at the upper end of the broad-band spectrum and the other at the lower (59.25 and 304.75 Kc/s, A to B; 359.25 and 608.75 Kc/s, B to A). These tones will constitute "slope" pilots, will be continuously recorded, and observation of them will lead to periodic adjustment of shore-station broad-band equalisers, for example, for seasonal variations of sea-bottom temperatures.

"Group" pilots will be of two kinds. One "Group Section" pilot will be applied to each direction of each group on a link-by-link basis (60 Kc/s in each group) and will be continuously alarmed for variations from nominal group transmission equivalent exceeding ± 1 db. In addition, each group will carry a "Group Reference" pilot in each direction on an end-to-end basis (84 Kc/s in each group). At each group terminal, A.G.C. equipment with a nominal compression ratio of 10:1 will be actuated by the reference pilot, with alarm provision for variations from nominal overall transmission equivalent of 0.5 db.

Each section of COMPAC will thus carry a minimum of 26 pilots. Other pilots will, of course, occur, for example, V.F. telegraph system pilots.

PERFORMANCE OBJECTIVES

Although certain transmission performance objectives have been agreed at C.C.I.T.T. level, they have been limited to circuits 2,500 Km in length. The longest COMPAC group, however (London-Sydney via CANTAT and the trans-Canada microwave system), will be some 25,700 Km long, while the shortest groups in the system will be Sydney-Auckland at 2,300 Km.

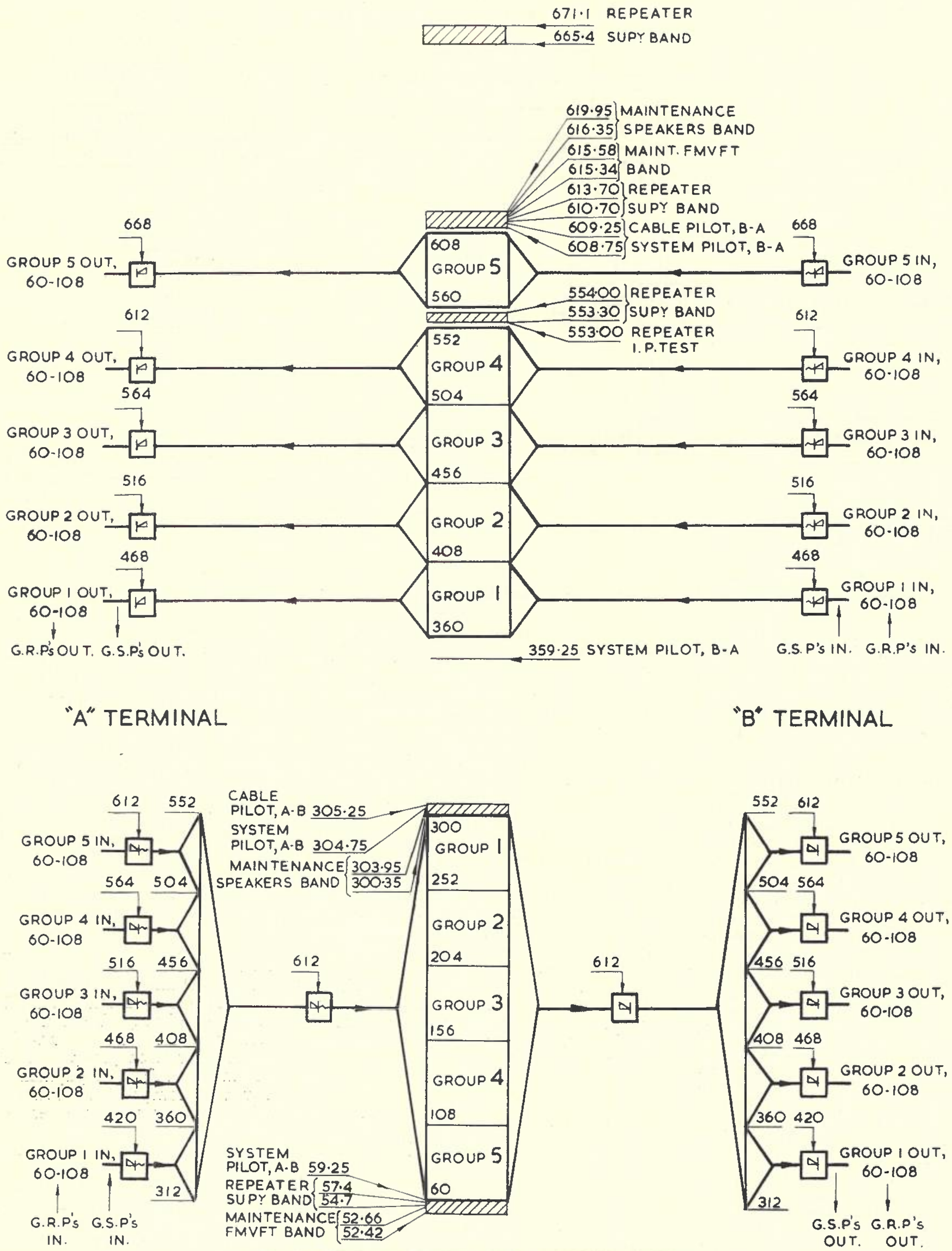


Fig. 8.—Frequency Spectrum and Translation Processes.

Switching and transmission objectives for global circuits are now under C.C.I.T.T. study. However, the current absence of broad international agreements has meant that each new trans-ocean system has been planned with a view to providing the best possible transmission performance within the framework of economics, current development and anticipated subscriber tolerance.

The author does not propose, in this article, to analyse all the clauses of the agreed objectives for COMPAC, but merely to state some of the most significant aims. It must be emphasised, however, that the objectives here stated are under continual review.

Variability of Circuit Loss: On COMPAC sections, the variation with time of circuit loss from the nominal figure will have an R.M.S. value not exceeding $\sqrt{0.3n}$ db, where n is the number of submarine groups connected in tandem at voice frequency—this means, for example, an R.M.S. value of 0.55 db for a channel which traverses only one pair of channelling equipments.

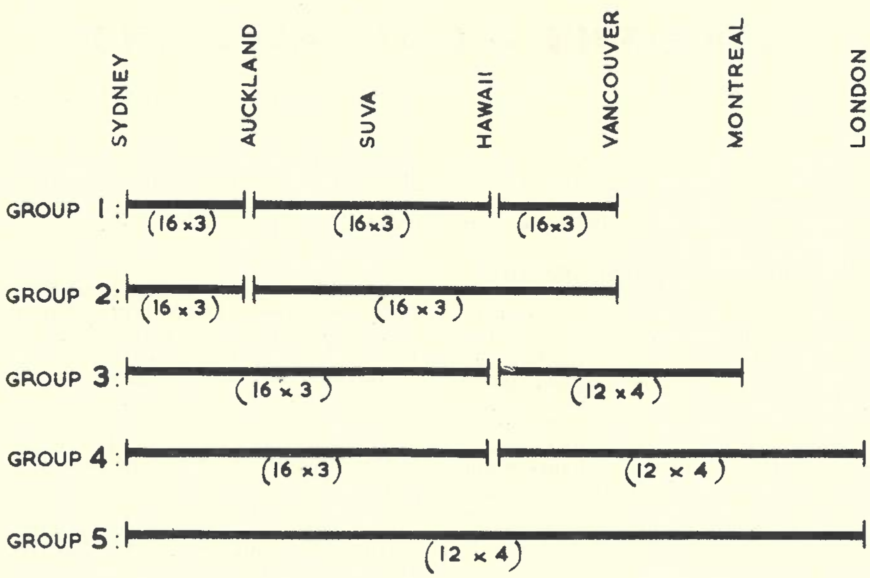


Fig. 9.—Allocation of COMPAC Groups.

A special case will be circuits in the Sydney-London group. Although there is only one audio-audio link, it traverses a mixture of submarine and overland group paths, and a provisional target of 1.8 db has been set.

It is of interest to note that the term "standard deviation" does not appear in COMPAC transmission objectives; this has been done in an endeavour to keep both absolute levels and variability within close limits.

Transit Loss: The four-wire loss between adjacent virtual switching points will be in conformity with C.C.I.T.T. objectives at 0.5 db. There is some room for conjecture as to whether this figure will be compatible, from a stability point of view, with the R.M.S. variability of 1.8 db for the Sydney-London circuits, and it is possible that the latter figure may have to be reduced.

Circuit Frequency Response: The specified frequency responses for channelling equipments are shown in Fig. 10. It will be noted that the 4 Kc/s, as well as the 3 Kc/s -spaced channels will have extended response at the low-frequency end, except for anticipated degradation of edge channels by through-group filters on long through-groups. The worst circuits will be the edge channels on the Sydney-London group, but by choice of high-grade through-group filters it is expected that these will approach half the C.C.I.T.T. standard, as stated for a 2,500 Km circuit.

Spurious Frequencies: No spurious frequencies in any group band will be at a level greater than –66 dbm0.

Envelope Delay Distortion: Individual circuit requirements vary, but a typical case is that of a channel to be used for photo-telegraphy, where maximum-minus-minimum delay within the band 1,300-2,500 c/s will not exceed 300 microseconds.

Noise: The general performance objective for a channel has been set at 1 pW/Km mean weighted noise in the busiest hour, with an upper limit of 3 pW/Km for the worst channel in any submarine section. Again, the worst overall performance will be on a Sydney-London channel, but by suitable choice of the location of the group in the broad-band path it is expected that the average mean weighted noise will not exceed –48 dbm0 (less than 1 pW/Km). As this figure approaches the anticipated limit of subscriber tolerance, consideration is being given to the installation of compandors.

Frequency Stability: Two sources of frequency error will occur. Firstly, shore stations will derive their carrier supplies from free-running master oscillators having a short-term frequency stability better than 1 part in 10^7; and secondly some channelling equipments will have free-running oscillators for the formation of sub-groups. Nevertheless, the agreed limits for audio-audio frequency errors are ± 0.45 c/s for a circuit involving only one pair of channelling equipments, and a maximum of ± 1.0 c/s for any channel regardless of the number of audio-audio stages in tandem. To enable each station to check the accuracy of its oscillators at will, an end-to-end frequency reference pilot will be available on the cable at all times, derived from the Australian National Standards Laboratories.

CONCLUSION

COMPAC represents an historic engineering project, and the extreme length of the circuits has led to performance objectives more stringent than those in normal use. The agreed construction time-table is such that, within five years from initial agreements, five independent organisations spread over more than half the circumference of the earth will have planned and executed the world's longest single telecommunications system.

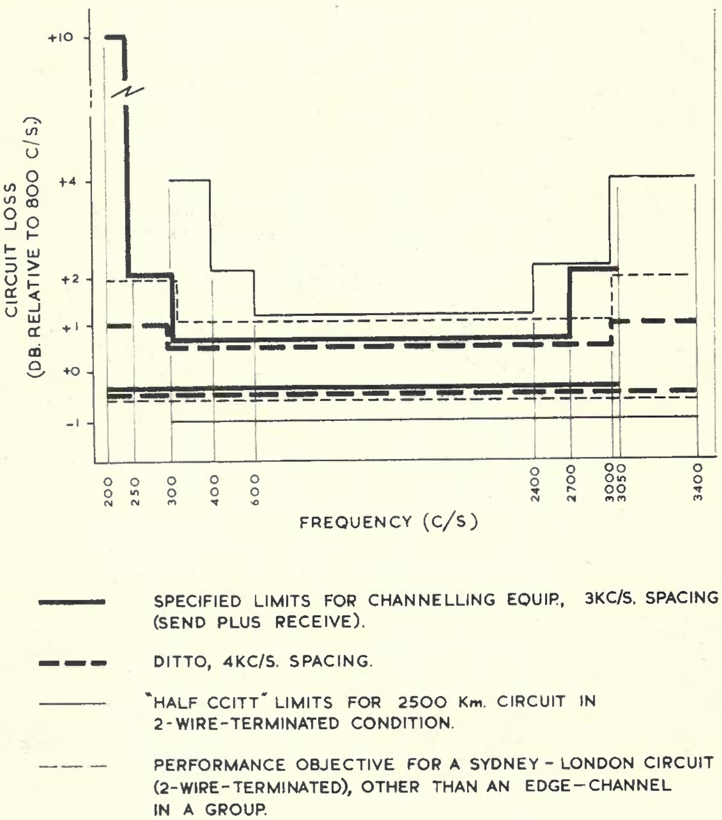


Fig. 10.—Circuit Frequency Response Objectives.

EMERGENCY TELEPHONE SERVICE — CIVIC EXCHANGE, CANBERRA

J. WHYBOURNE, A.M.I.E.Aust.*

INTRODUCTION

At approximately 1 a.m. on Friday 22nd September, 1961, a fire which originated in the air treatment wing of the pre-fabricated aluminium telephone exchange building at Civic, resulted in the complete destruction of a 2,000 type exchange, with 5,482 working lines and a capital value exceeding £500,000. It served the main Canberra commercial centre at Civic as well as the hospital, police and fire brigade, in effect over one-third of the Canberra network. The cause of the fire was not apparent, but it was determined later that it had been started deliberately by vandals. Figs. 1 and 2 illustrate the damage.

The organisation which was set up to meet the emergency and the manner in which works were carried out, resulted in the restoration of telephone services to virtually every subscriber within 14 days, an effort unequalled in the Department previously. It is the intention of this article to present a broad picture, drawn from a considerable number of personal reports, of how the emergency was met, and to discuss the organisation which made the relief possible as a stimulus to thinking should such an emergency arise again.

* See page 348.

FACILITIES EXISTING BEFORE FIRE

The Civic exchange and line depot shared a common site, as shown in Fig. 3, with a fence separating the two sections. The line depot building is approximately 40 x 80 ft. of clear span construction and was internally partitioned to provide office and storage spaces. The aluminium exchange building was centrally located on its portion of the site and a concrete coaxial cable repeater hut was located on the southern side.

A 2,000 type equipment installation of 6,000 lines, for which an extension to 6,800 lines was almost complete, existed in the exchange room together with an M.D.F. on which 12,000 subscribers and 1,200 junction cable pairs were terminated. Paper insulated to silk insulated cable pot-head joints were accommodated in a room parallel to the M.D.F. and separated by a timber and glass partition. Silk insulated cable tails fed the M.D.F. via metal cable chases provided on the basis of one chase per vertical.

Civic was trunked as a main exchange in a city network of three main exchanges, the others being Barton (1,800 lines) and Manuka (3,500 lines). There was also one repeater branch at Yarralumla, parented on Barton, and a semi-automatic trunk exchange at Central.

There was no separate equipment uncrating area in the Civic building and a quantity of material for the new extension had been stored in the air-conditioning plant room. The fire was started with this material. The air treatment installation included an automatically controlled oil fired boiler which was located in the room and contributed to the destruction.

DESTRUCTION BY FIRE

The fire started a fire bell, outside the Exchange building, which was heard ringing at approximately 12.48 a.m. A passing taxi driver also noticed the fire

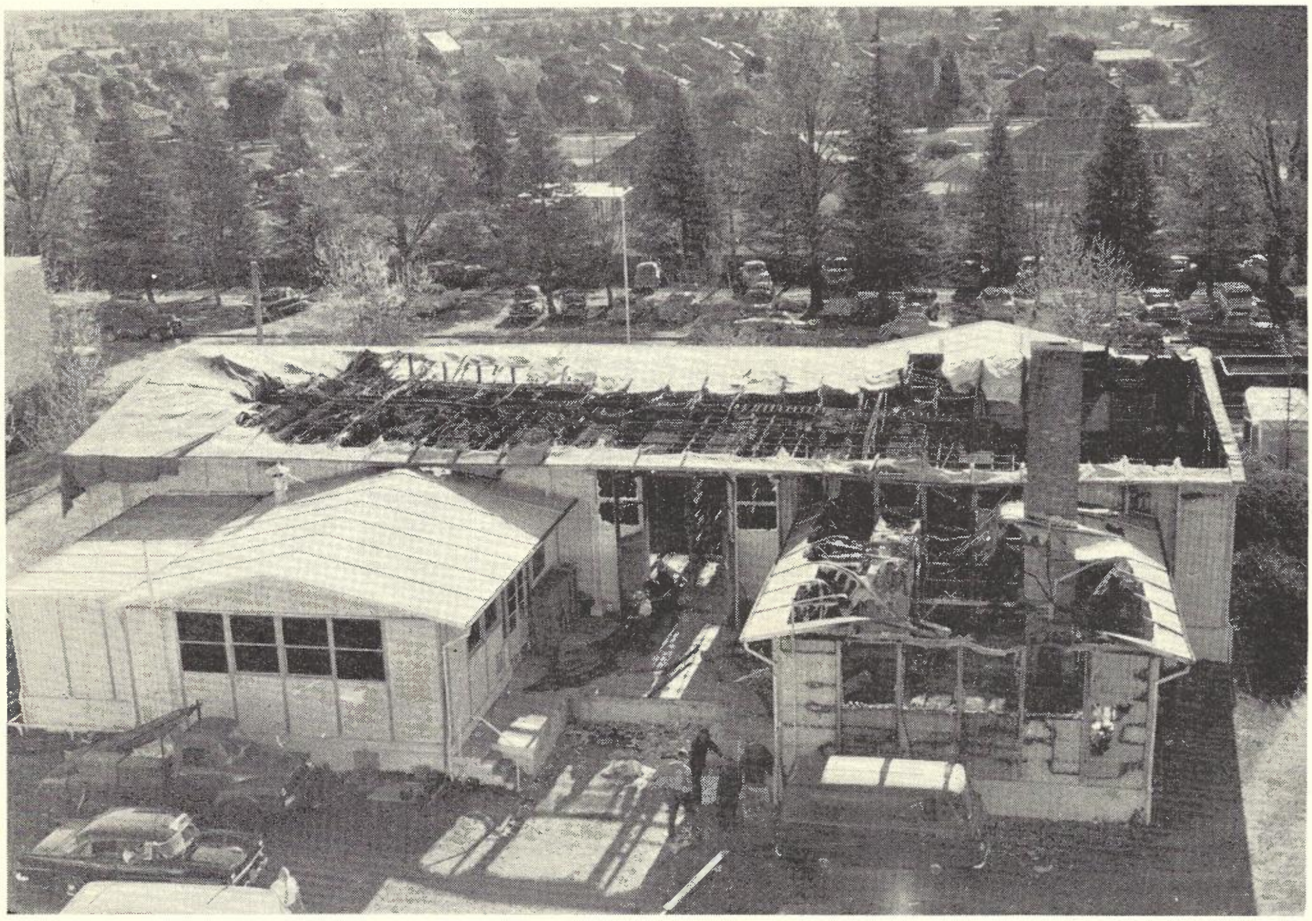


Fig. 1.—Looking down on Damaged Building, showing Destruction of Air Treatment and Equipment Areas.

burning in the air treatment room and raised an alarm via his radio to the Police. The Fire Brigade arrived a few minutes after 1 a.m. A local technician who was passing the building about that time went to the rear of the building, where the air treatment room was an inferno, and saw the windows of the room collapse. He then entered the power room when the fire, which had broken through the wall between the equipment and air-conditioning rooms, was advancing rapidly through the ceiling and cabling over the equipment area as shown in Fig. 3. The technician turned power switches off and arranged for a fireman to chop through the main exchange 50V power supply ammeter shunts which were glowing red hot at the rear of the power board. The fire was extinguished by 2 a.m.

Examination immediately after the fire was extinguished revealed that the switching installation was completely destroyed. Considerable portions of most racks were seriously damaged by fire and almost all equipment was saturated by water and covered with a sticky deposit. The upper part of the M.D.F. was badly damaged and lead-covered silk-insulated subscriber and junction cable tails were burnt through. The roof over almost the entire length of the 100 x 40 ft. equipment/M.D.F. room had disappeared. It was apparent that, as the walls were seriously damaged and structurally unsound, rehabilitation of the building would virtually require a completely new equipment room. The power and battery room installation was almost undamaged and the test desk, together with the power and test desk rooms, had suffered minor damage only. The M.D.F. and cable record cards were recovered intact, which was of considerable significance in the light of subsequent events.

RELIEF MEASURES

General Measures

The Divisional Engineer, Canberra, was advised of the fire within half an hour of the alarm and immediately alerted the local engineering organisation and advised the Assistant Director, Engineering, in Sydney, who, in turn, alerted the senior engineers of the State Engineering organisation. By 7 a.m. on the morning of the fire, these officers, together with supporting staff, had met in conference and the subsequent discussion, based on information passed from Canberra and on detail available in the State Headquarters, enabled four basic decisions to be taken:

(i) To provide all possible relief by connection of urgent services to Barton and Manuka over junction cable and to provide interception on the Civic "J" level at other network exchanges.
(ii) To abandon the damaged Civic exchange and M.D.F.
(iii) To divert to Canberra all possible portable exchange equipment for emergency telephone service provision.
(iv) To construct a new semi-permanent exchange, including M.D.F., in the line depot building at the rear of the Civic exchange building.

These decisions were discussed with the Engineer-in-Chief and other Headquarters Senior Engineers, and the agreement of Headquarters with the proposed course was obtained.

Connections to Manuka and Barton

Implementation of the first relief phase had begun in Canberra within hours, and emergency lines to the Hospital, Police and Fire Station were being arranged via the junction cable to Barton and Manuka. By 10 a.m. 37 of these lines had been connected. In view of the fact that the M.D.F. was substantially intact and particularly that the cable pot-heads were undamaged, a basic decision had to be made whether any cross connections for these emergency services should be attempted at this point. A significant factor was that the lead-covered cables from the pot-head joints to the frame were destroyed at the top of the M.D.F. Thus re-tailing would have been necessary to use the M.D.F. terminations as connecting points, although a limited amount of jumpering for the initial urgent services could have been carried out on the fanned silk tails. On the other hand, junctions and subscribers' cable pairs could be picked up in street manholes and cross connected, thus leaving the street cables immediately in front of the exchange site free for re-arrangement in conjunction with the proposed new M.D.F. The arrangement of cables is shown in Figs. 4 and 5, and the decision very early on Friday to leave the exchange entry cables free of active lines by carrying out cross connecting in street manholes, was shown subsequently to have advantages over-riding the disadvantages. The latter arose mainly from the damage which occurred to street cable joints as pairs were sought for cross connection. Problems did occur through this course of action as not all subscribers' cables paralleled the junction cable to Manuka and Barton and in one particular case, jumper wires

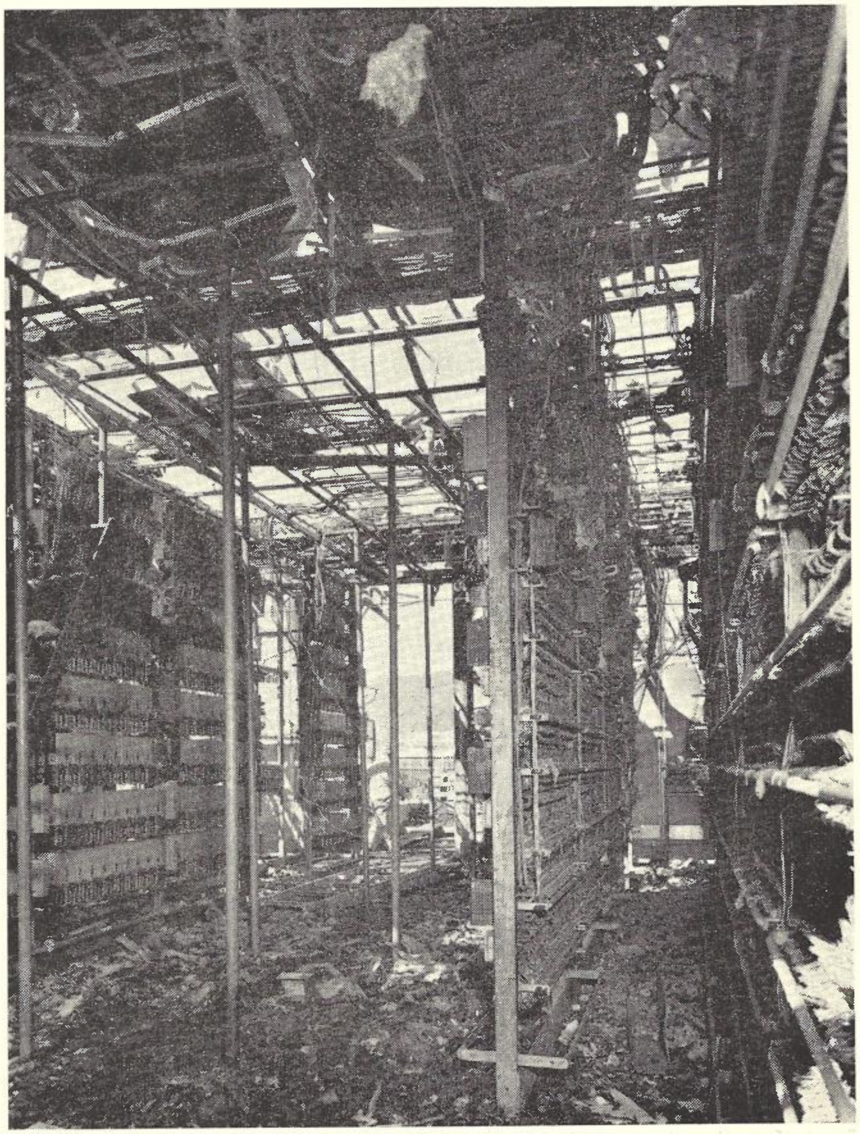


Fig. 2.—Scene inside Civic on the Morning after the Fire, looking towards Air Treatment Room.

were run from one manhole through trees to another manhole to restore two urgent services of high priority. Nevertheless for the first few days, the only way in which emergency services were provided from Manuka and Barton over junction cables was by cross connections in manholes. 352 services were provided in this way.

Interception

Concurrently with the connection of urgent services to spare exchange numbers in Manuka and Barton, interception facilities were being established for calls directed to the destroyed exchange. An early decision was to refrain from advertising a special code to call instead of a "J" number, and to rely on interception on the "J" level at main exchanges to provide the necessary information to telephone callers. This concentrated interception on one code only and avoided the need for interception on a new code as well as on "J".

Interception facilities were arranged on the "J" level at network exchanges on the Friday morning, by routing all early choices from selector junction gradings to interception positions consisting of 2 + 4 or 3 + 9 cordless switchboards established at the Barton and Manuka Local and the Semi-automatic Trunk Exchanges. These positions were staffed by Technicians and provided for the bulk of the interception traffic until it became known generally to local subscribers that "J" numbers could not be reached. A 12-track recorded announcement machine was installed at Barton, and served the three points of interception, Barton, Manuka and the Semi-automatic Trunk Exchange. This removed the necessity for staffing the temporary manual positions at each exchange and directed callers to "dial information" for further details of urgent services, etc. The machine provided all interception until 11 p.m. on Sunday, 24th, when a new installation of four lamp-signalling P.B.X. switchboards at the Trunk Exchange became available. At this time, "J" junctions after the third choice outlet from each exchange, were connected to the new switchboards and calls were cord switched to handset telephones. The first three choices were left on machine interception until 8 a.m., Monday, when the four manual positions were staffed and the machine removed from service. Subsequently machine in-

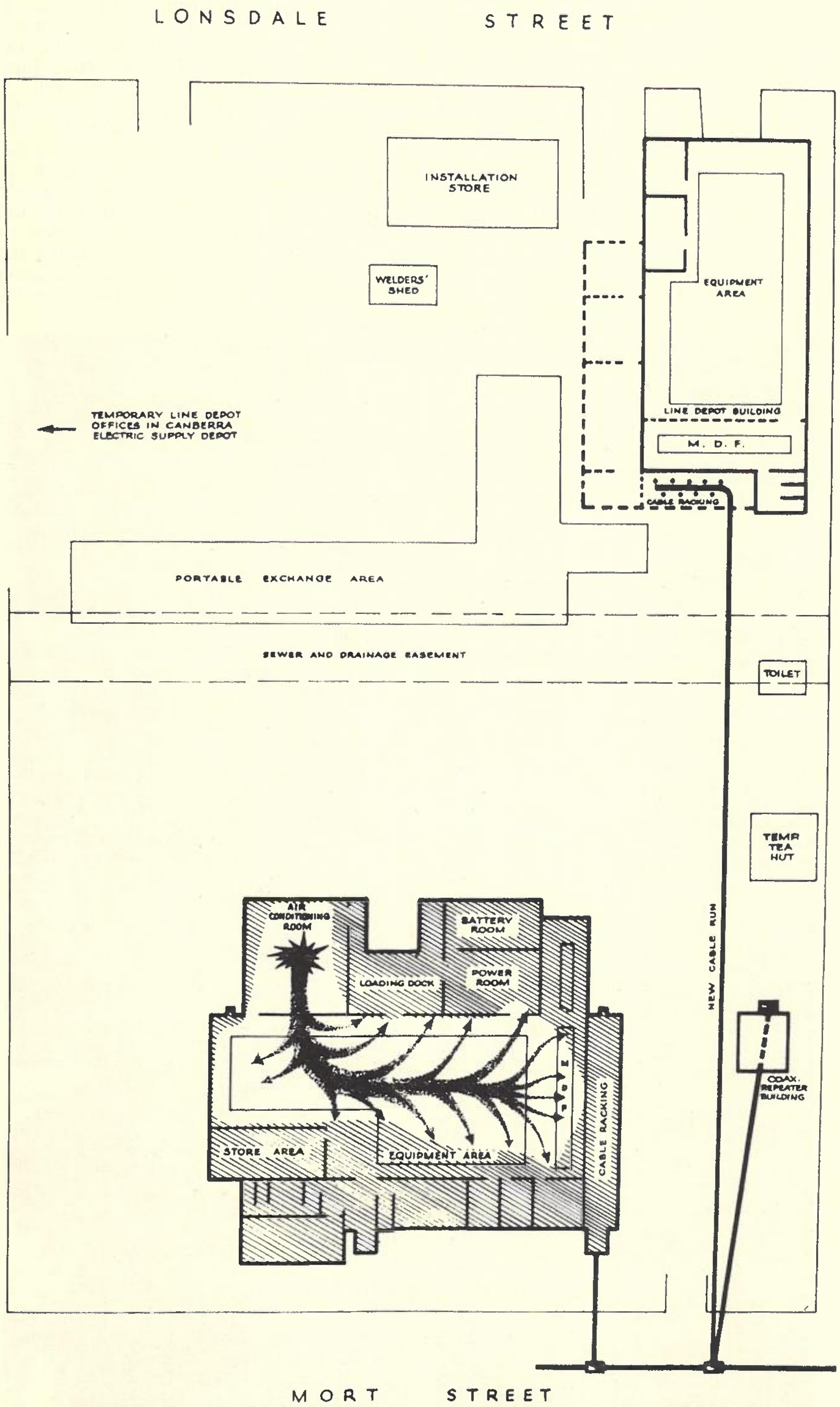


Fig. 3.—General Layout of Exchange and Line Depot at Civic. Temporary Buildings shown in Light Outline.

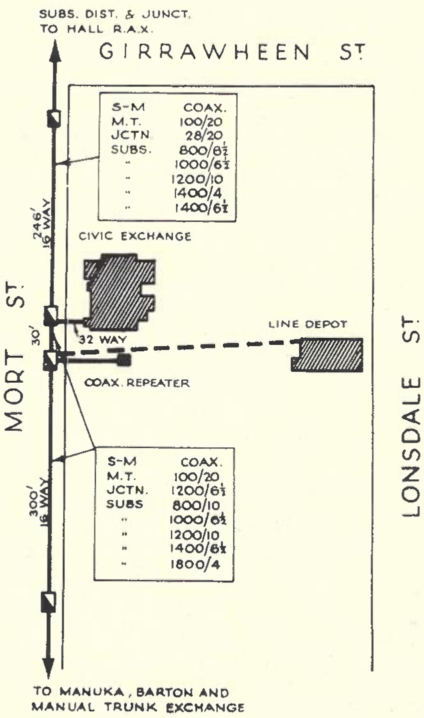


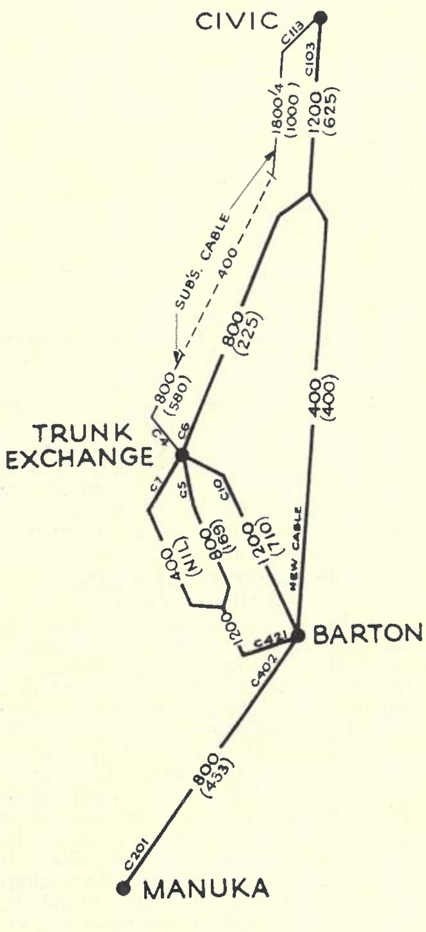
Fig. 4.—Ducts and Cables at Civic.

terception only on the first three choices from each exchange was used between 11 p.m. and 8 a.m. and manual interception during the day.

As emergency numbers were connected, suitable lists were prepared by the District Telephone Officer and published daily through the co-operation of the local press. In addition an interim Canberra directory of the emergency numbers was issued, during the week ending 21/10/61, to all Canberra subscribers and all trunk centres, and this greatly reduced interception traffic. A few days later machine interception and redirection only was found to be adequate on the "J" level.

Abandonment of Damaged Installation

The decision to abandon the damaged building came before noon on the day of the fire, after a detailed examination of rehabilitation work necessary had been made by the Works Director, Canberra, and discussed with the Superintendent, Buildings Branch. It was the considered opinion of that group that erection of a roof over the area would take two weeks, and that the completion of walls would take additional time. Renovation of such a seriously damaged building is obviously fraught with difficulty and it appeared likely that unforeseen delays could upset this optimistic estimate. A usable temporary building structure could not be made available for three weeks, and there would be obvious difficulties in attempting any major exchange re-establishment whilst building work was in progress.



NOTE: (400) INDICATES SPARES AS AT 22.9.61

Fig. 5.—Junction Cables in Canberra at 22/9/1961.

The decision to abandon the installation was therefore influenced by two major factors:

(i) Appreciation of the delays which could occur to prolong completion of the emergency buildings rehabilitation beyond two weeks.

(ii) An acceptable building in the form of the Line Depot was available and reconstruction of the Civic exchange could commence immediately.

In the light of the subsequent achievements made possible by establishing a replacement exchange and M.D.F. in a new building, the decision was proved to be a good one.

PORTABLE EXCHANGES

From a quick assessment, it was apparent that at least 2,400 lines of portable exchange equipment (Ref. 1) could be diverted to Canberra and could be absorbed into augmented trunking of the co-main exchanges of Manuka and Barton as repeater branch units. New exchange numbers could be provided by this means as emergency lines to priority subscribers until a replacement "J" exchange was built.

The initial survey of portable exchanges on 22/9/61 showed that the units in Table I, Part A, could be made available immediately or within a short period, and transport arrangements were set in motion. The first units from Unanderra and Ingleburn were loaded and en route to Canberra by mid-day. Intensive installation effort released the Wallsend unit by 6 a.m. on Sunday, 25th, and the first Rydalmere unit by Tuesday, 26th.

A preliminary trunking scheme was prepared on the Friday for the 2,400 lines but by Monday, 25th, as a result of Headquarters asking the Victorian and South Australian administrations to investigate the availability of portable exchanges, a further 1,700 lines of equipment was in sight. On the same day the New South Wales Engineering Division decided to release a 600-line unit from Morriset East and a modified trunking diagram was completed on Tuesday, 26th, for 4,700 lines total. By Wednesday, 27th, however the Sydney Metropolitan Installation section had devised a method of releasing a second unit of 600 lines from Rydalmere and the trunking scheme was amended to include the total of 5,300 lines.

At this point it was clear that emergency service could be provided to every Civic subscriber, either from 5,300 emergency numbers in portables at Civic or via junction cable to spare numbers in Barton and Manuka. It was expected that provision of these emergency lines would be completed within three weeks. The complete relief within such a short time was a matter of great satisfaction to all concerned and a very real example of co-operative effort in meeting a major emergency. The additional portable units to take relief from 2,400 to 5,300 lines are listed in Part B of Table 1.

It was the intention to cutover the Morriset East exchange by stages, leading to the eventual amalgamation into a single exchange area of two existing manual exchanges and an R.A.X. The first stage cutover was to take place approximately one month after the fire. All external cables had been terminated with the final testing of equipment about to take place. Disconnection of these cables was completed by 9 a.m. on Tuesday, 26th, and the exchange was loaded and on its way to Canberra by mid-day.

Subscribers' lines on the 500-line portable exchange at Elizabeth, South Australia, had been cutover to the permanent exchange one month earlier, but cables were still connected to the M.D.F. As soon as it was confirmed that the units available in South Australia should be sent to Canberra, work was commenced to release the exchange. It was loaded and despatched from Adelaide on Wednesday, 27th, together with the second unit which had been free at Osborne.

In the case of Drouin, Victoria, the exchange was being prepared for cutover as a 900-line repeater branch of Warragul following the replacement of a magneto exchange at Warragul in February, 1962 by an 1,800-line automatic exchange. The Victorian administration agreed to the release despite the considerable inconvenience involved, and after a concentrated effort the unit was cleared of cables and loaded on Friday, 29th.

The release of the second 600-line unit from Rydalmere involved extensive re-arrangements to transfer the subscribers working on the portable exchange equipment to the same numbers made available on the incomplete permanent exchange installation. The effort involved was justified as utilisation of the portable exchange for emergency numbers at Civic just allowed all services to be restored. The unit was loaded and on the way to Civic by Sunday, 1/10/61.

ADDITIONAL JUNCTION PROVISION

It was fortuitous that the existing junction cable was adequate for the connection of the 352 subscribers to Manuka and Barton and the establishment of 3,800 lines of portable equipment, since cable extensions had been completed only a short time before the fire. However it was clear that to provide adequate junctions for the full 5,300 lines of portable exchange equipment, additional junction provision would be necessary. As shown in Fig. 5, spare subscriber cable capacity existed from Barton via the Trunk Exchange M.D.F. towards Civic and vice versa, and a decision was taken on Tuesday 26th to bridge the gap with S.T.A. (steel tape armoured) and P.I.Q.L. (lead-covered paper insulated) cable which was in stock.

Two cables, each of 200 pairs, were laid for one mile across the bed of the proposed Canberra Lake, and an additional one-third of a mile of cable was

TABLE I — PORTABLE EXCHANGE UNITS DIVERTED TO CIVIC

PART A — FIRST EVALUATION 22/9/61 — 2,400 LINES

No.	LOCATION	LINES	TRUNKING	STATUS	SITED	ESTAB-LISHED
1	Ingleburn	600	2,000 Type—Sels. + F.S./U.S.	Unencumbered	23/9/61	25/9/61
2	Unanderra	300	Pre 2,000 Type — F.S./U.S.	Unencumbered	23/9/61	25/9/61
3	Wallsend (including Annexe)	500 + 300	Pre 2,000 Type — Sels. + F.S./U.S.	Being prepared for cutover to new building on 7/10/61 without number change. In final testing stage. Released by intensive lines effort.	27/9/61 28/9/61	29/9/61
4	Rydalmere I	700	2,000 Type + 100 lines pre 2,000 — Sels. + F.S./U.S.	Being prepared for cutover to new building without number change in few weeks. Released by intensive installation effort.	28/9/61	29/9/61

SUB-TOTAL — 2,400 LINES

PART B — ADDITIONAL UNITS 25/9/61

No.	LOCATION	LINES	TRUNKING	STATUS	SITED	ESTAB-LISHED
5	Morriset East	600	2,000 Type — Sels. + F.S./U.S.	Being installed as a new exchange amalgamating several small exchanges and an R.A.X. Released by lines re-arrangements.	28/9/61	30/9/61
6	Elizabeth, S.A.	500	2,000 Type — Sels. + pre 2,000 F.S./U.S.	Lines recently cutover to permanent exchange but cables still on M.D.F. Released by line works.	1/10/61	3/10/61
7	Adelaide, S.A.	300	Pre 2,000 Type — F.S./U.S.	Unencumbered.	1/10/61	3/10/61
8	Drouin, Vic.	900	2,000 Type — Sels. + F.S./U.S.	Being prepared for February, 1962, cutover as repeater branch of new Warragul. Working lines through M.D.F. Released by line works.	3/10/61	5/10/61
9	Rydalmere II	600	Pre 2,000 Type — Sels. + F.S./U.S.	Being prepared for cutover to new building January, 1962. Released by line and installation works.	2/10/61	5/10/61

COMBINED TOTAL — 5,300 LINES

laid in existing ducts. The S.T.A. route followed the line of a proposed coaxial cable (which it had been intended to lay in the current financial year) necessary for local Canberra TV programmes, and a suitable length of a 6-tube cable was rushed from Melbourne for laying in the trench opened across the lake bed.

This work was completed on 7/10/61 and provided the necessary increase in junction cable plant to permit the establishment of all portable exchanges as repeater branches of Manuka and Barton. This would allow subscribers connected to those exchanges to remain on their temporary numbers and allow some 250 external extensions and private lines to remain in the junction cables.

TRANSPORT OF PORTABLE UNITS

Possible difficulties involved in transporting the portable exchanges were avoided by the outstanding co-operation of the New South Wales Police Department in providing escorts for the vehicles on the road. At one stage there were five portable exchanges converging on Civic simultaneously.

The two units from South Australia were transported on a single low loading semi-trailer, the unit being 66 ft. overall and the load width 13 ft. 4 in. The preferred route for the 900 mile trip was through Victoria via Murray Bridge but the load height exceeded the capacity of the river bridge at that point and the alternative route via the Murray Valley to Mildura was taken. A problem existed at Blanche Town vehicular ferry which has a 58 ft. deck, and at low river levels involves a fairly steep descent from the roadway. With the cooperation of the South Australian Highways Department, the unit was loaded with the end gates on the ferry open, and moved safely across the Murray River. The semi-trailer averaged 200 miles per day on the long haul to Canberra. A mixture of Commonwealth and private contractors transport facilities was used in moving the portable exchanges, and no difficulties were experienced, all units arriving at Canberra without damage.

One interesting facet was the examination by the Newcastle Engineering Division, in conjunction with the R.A.A.F. at Williamtown, of the possibility of transporting a portable exchange by Hercules aircraft. However, while the weight lifting capacity of the transport was adequate, the rear loading opening was only 10 x 10 ft. and would not take the building which was 12 x 13 ft. The principle of using the large capacity aerial transport facilities, which are undoubtedly now a permanent feature of our defence forces, for emergency communications relief works, is one which merits serious consideration. The aircraft in question can transport a weight equal to a 600-line exchange and physical dimensions are the only limit. Portable exchange units suitably dimensioned to fit these aircraft, which are capable of landing on natural surfaces, could be a valuable asset as automatisation of country areas proceeds.

LINE DEPOT BUILDING MODIFICATION

Implementation of the decision to use the Line Depot building for a replacement M.D.F. and exchange started on the morning of Friday, 22nd, and building work to make the structure suitable for this purpose was commenced immediately. As shown in Fig. 6 it was of fabricated steel truss construction with a corrugated asbestos cement roof, no ceiling, and a concrete floor which was raised 4 in. under the offices along the northern side. It was clear that temperature fluctuations and condensation problems would be severe unless thermal insulation was installed beneath the roof. This work was carried out immediately as the restricted ceiling height would have made it difficult after equipment was installed. A hardboard covering was provided as a ceiling.

The speed with which the building alterations were made was no less remarkable than all other aspects of the emergency project. The floor layout of the new exchange was determined generally by 11 a.m. on the Friday of the fire, and the removal of line depot stores and demolition of unwanted office and amenity partitioning, chain wire safe areas and pipe stands commenced without delay. Plumbers and electricians cleared unwanted water, drainage and electrical services. By 4 p.m. the area required for initial M.D.F. and equipment installation was clear. Two of the existing offices were retained for use by the installation team.

While the clearance of partitioning was proceeding, supplies of insulating and ceiling material were being secured and erection of this commenced at 4.30 p.m. Because of the urgency of establishing the M.D.F. and the low roof clearance which would have made subsequent building work most difficult, the ceiling was completed over the M.D.F. area first. The remaining ceiling area was then completed progressively, avoiding conflict with the installation of racks which, by this time, was taking place concurrently. At the same time the Works Department also carried out a considerable amount of minor building work in the form of cutting away concrete kerbing, filling drainage holes and levelling uneven sections of the floor. All minor building works inside the new exchange building were completed during Sunday, 24th.

In addition to the internal re-arrangements necessary, external additions shown dotted in Fig. 3 were required to make an effective exchange. A room was built about the cable racking, which was erected during Saturday, the 23rd, at the rear of the line depot building, and an extension along the side of the building 13 ft. wide provided a 27 x 13 ft. Test Desk Room, 15 ft. 6 in. x 13 ft. Lunch Room, Locker Room and Supervising Technician's Office. A temporary shelter of galvanised iron had been erected over the cable joints on the Saturday, and construction of the permanent extension along the side of the main building commenced on Tuesday, 25th. This was of timber frame, asbestos cement roofed construction on a concrete floor. The target of having a complete, acoustically treated Test Desk Room available by 2/10/61 was bettered by a day. The completion of the extension to include the Lunch and Locker Room and, finally, replacement of the temporary roof over the cable joints followed.

NEW M.D.F. AND CABLE ENTRY

The erection of the M.D.F. was commenced at 9 p.m. on Friday, 22nd, using cut-down 200/300 verticals and ironwork which had arrived from Sydney a matter of hours before. Forty-five verticals were erected by 6 a.m. the following day and this established a reference for the location of the new cable terminating frame to carry the paper to silk insulated cable joints. The urgent need to have silk insulated cable tails for the M.D.F. available as soon as the cable jointing could commence, resulted in a decision to make these locally, and 13,200 pairs of cable tails were made in the open from 100 and 200 pair lead covered plastic insulated cable. This work continued round the clock under specially erected flood lighting.

The cable trench from the coaxial cable Mort Street break-off manhole, to the location of the new pot-head joints at the rear of the line depot building, was dug during Friday and was completed by 2 a.m. Saturday, 23rd. Ironworkers had been despatched from Sydney early Friday, 22nd to construct the new cable racking, which was completed during the night of Saturday, 23rd and 13,200 pairs of street and junction cables were brought up ready for terminating by 6 a.m. Sunday, 24th.

From this time there was a clear programme of line works ahead; the 13,200 pairs had to be connected via pot-head joints and silk tails to the new M.D.F. and the new lead-in cable had to be jointed to the existing cable available in the Mort Street manhole (Fig. 3). The first tails were dropped on to the M.D.F. at 8 p.m. on Saturday, 23rd, and forming, lacing, fanning out, identification and terminating of the 13,200 pairs were completed in 7 days. At one stage five cables were being jointed simultaneously at the rate of 200 pairs/cable/12 hr. shift, and three of the cables were being identified and terminated on 8 adjacent M.D.F. verticals. With the simultaneous dropping, terminating and jumpering of cables to the first portable exchanges, the M.D.F. became a scene of almost indescribable activity.

Fig. 6.—Scene inside the Line Depot Building on the Day of the Fire. New M.D.F. is being Erected and Roof Insulation is in Progress.

ESTABLISHMENT OF PORTABLE EXCHANGES

The portable exchanges (1) and (2) (Table I) together with an empty long line equipment portable building, which had been despatched from Sydney early on the 22nd for possible use as a cable terminating cabinet, were at the Civic site at daybreak on Saturday morning but, because of the siting requirements, it was necessary to secure the services of suitable cranes before these buildings could be placed in position. These three units were sited by 5.30 p.m., the empty long line equipment unit being located beside the line depot building to accommodate a temporary 50V power supply for the portable exchanges. A panoramic photograph of the site is shown in Fig. 7.

Experience with the first three buildings made it clear that because of the restricted space and careful siting necessary to accommodate all portables, a single crane capable of lifting a complete unit would be most useful. A 25 ton capacity crane which was engaged in bridge construction work in Canberra was made available, and this greatly simplified the siting of later arrivals. It was possible for one man to rotate a portable unit supported by the crane through 360°, and siting time was reduced to an average of 20 minutes.

Lack of time and the temporary nature of the portable exchange installation made the provision of normal portable exchange foundations and piers impracticable and unnecessary, and all buildings were located on piers built up with 16 x 8 x 8 in. concrete blocks which were purchased locally. Subsequent levelling and height adjustment was made by jacking and fish plate insertion while installation work was in progress.

The buildings were located so that they used a common cable trench for cabling to the new M.D.F. with 50 pair

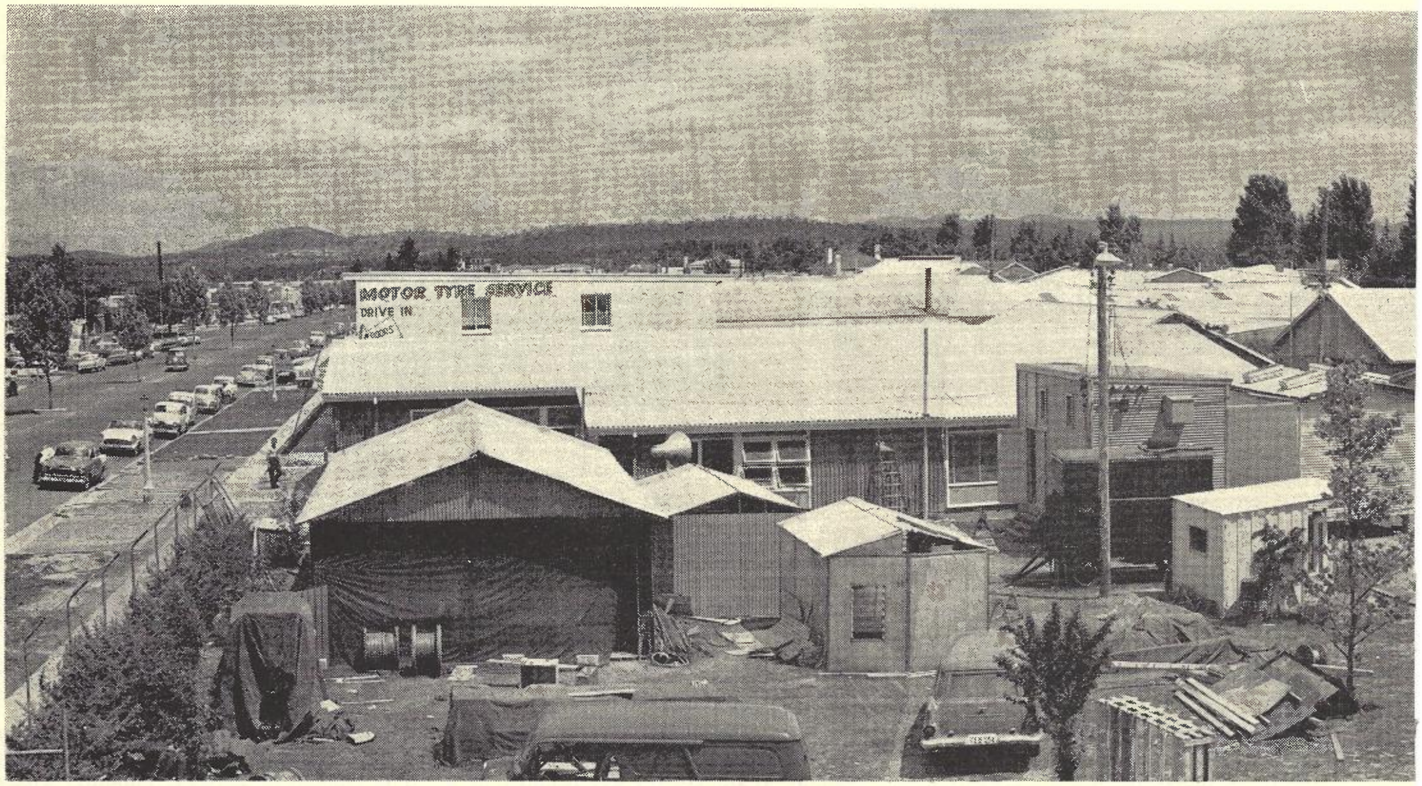


Fig. 7.—General View of Civic Site on 30/10/1961. Line Depot Building is in Centre Left with Extensions Complete, Temporary Installation Store is in Bottom Left, with Ironworkers Shop adjacent. Portable Exchanges are in Centre Foreground.

P.V.C. sheathed and insulated subscriber distribution cable run in 4 in. asbestos cement ducts buried approximately 18 inches. Two ducts per portable exchange were necessary and heavy plastic conduit was used in the final run from the rigid asbestos ducts into the portable buildings.

All portable exchanges had M.D.F. arrestors cabled to final selector-uniselector numbers and in most cases these arrestors were jumpered permanently to an equal number of fuses. In normal use, subscriber cables terminated on pin strips to conserve space in the portable exchanges, and protected numbers were jumpered as required to cable pairs. At Civic the protected numbers were connected via the tie cables to allotted pin strips on the M.D.F., appearing as normal exchange numbers, and these were then jumpered as required to cable pairs. Because of this arrangement it was possible in the later stages of the project to terminate the M.D.F. end of tie cables to portables and to jumper allotted emergency numbers to the appropriate cable pairs before the portable exchanges with the numbers were on site, considerably expediting relief.

For dispersion of effort on the M.D.F. and to conserve equipment side space, the portable exchange tie cables were split into two feeds with approximately half terminating on the equipment side link strips and half on line side link strips. A.C. power was reticulated in G.I. pipe from a central distribution associated with the power supply portable, and 50 V.D.C. was fed to portable exchanges without power equipment from the power portable via the tie cable ducts.

ADDITIONAL TRUNKING AT BARTON AND MANUKA

In the final scheme, three of the four available first selector levels in Canberra were used for emergency numbers of four or five digits as shown in Fig. 8. The levels '2' and '3' were used in conjunction with penultimate switches in portable exchanges, to provide 1,100 emergency 4 digit numbers, while three racks (240 switches) of '5' level second selectors were installed at Barton, and by trunking outlets direct to final selector units gave 500 additional 4 digit numbers. Five '5' selector outlet levels were trunked to penultimate switching in portable units and provided a further 3,700 five digit numbers. The subscriber uniselector outlets were trunked to spare first selectors at Manuka (173 junctions) and to first selectors increased by one additional rack at Barton (184 junctions). A total of 411 level '2', '3' and '5X' junctions were provided from Manuka and Barton to Civic.

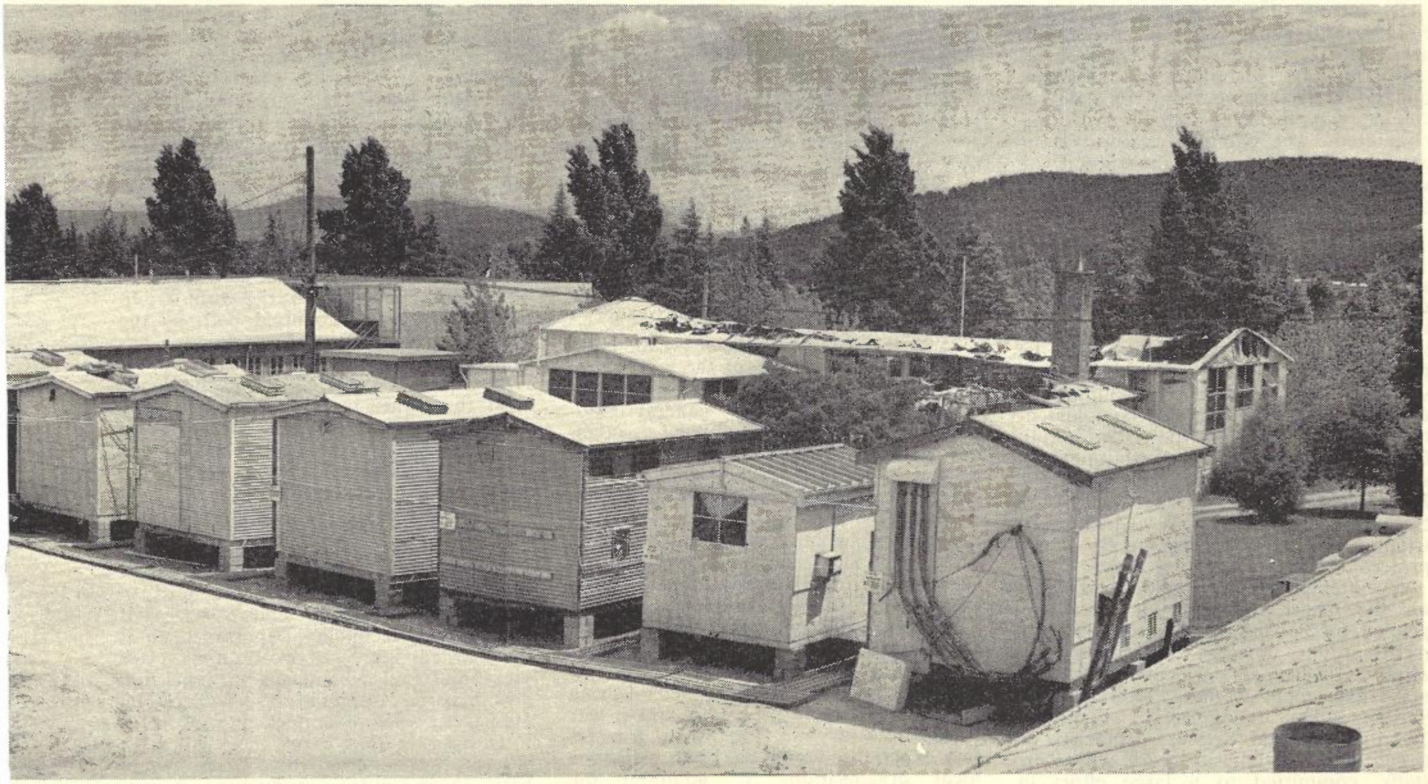
A compromise approach was used in regard to the semi-automatic trunk exchange where network first selectors were incorporated in the trunk exchange equipment. Instead of providing additional gradings to levels '2', '3' and '5', from the first local motor uniselectors at the trunk exchange, a recently vacated 20 outlet group accessible by the operators on a '13' code was trunked to Barton first selectors, and operators were instructed to prefix all emergency numbers with '13'. This arrangement worked well, and avoided additional work in the trunk exchange.

The connection of over 300 urgent subscriber services to spare numbers in Manuka and Barton resulted in a traffic unbalance on some uniselector gradings and necessitated regrading work to overcome traffic blocks. However, the adequacy of junction cables and the relative ease with which it was possible to increase trunking at Barton and to utilise spare lines at both Manuka and Barton, was a basic factor in enabling implementation within such a short time of a relief scheme giving full emergency service to all subscribers.

The installation of the additional first selector and three level '5' second selector racks was commenced on Friday, 22nd, and was completed ten days later. The gradings had to be modified progressively as the number of portable exchanges was increased during this period.

ALLOCATION OF EMERGENCY NUMBERS

It was estimated initially that 2,400 emergency numbers would be provided in portable exchanges, and a list of subscribers who would be given such service had to be prepared. The District Telephone Officer commenced this task early on the Friday morning by reference to the Subscribers' Service Cards held in his office. An emergency number satisfying certain requirements, referred to later, was allocated and lists prepared in the form Old Number-New Emergency Number. Engineering officers provided subscribers' cable locations for these urgent services from the



M.D.F. cards and cable records, by working from the old Civic number.

The clerical task at this stage was of considerable magnitude and was complicated by the fact that several hundred priority subscribers had been allocated spare numbers in Barton and Manuka but a large number of these connections had not been implemented because of the delay in locating the subscribers in cable joints and cross connecting to junction pairs, or for technical reasons such as excessive loop resistance. This information had to be fed back so that alternative service could be given from Civic.

In addition, as all subscribers' cables, Fig. 4, had to be established on the new M.D.F., it was obviously desirable to determine a priority order in which termination could be effected to provide the greatest yield in emergency services provided. This required an analysis of yield per cable and even an analysis of yield distribution within a cable. One 1,800 pair cable, for example, served the greater part of the business area of Civic, but most urgent services were in the last 500 pairs.

By mid-day, Wednesday, 27th, it had been established that a full 5,300 emergency numbers would be provided and this made largely redundant the priority allocation based on limited 2,400 number relief. Schedules were then prepared for all subscribers to be given emergency numbers and this was completed by Friday, 29th, one week after the fire. From this point the yield of each cable was determined by total services included in the cable and not the relative priorities.

In the initial allotment of emergency numbers under the 2,400 line relief scheme, some order was introduced to facilitate possible later re-allocation of equipment (perhaps with new numbers) to subscribers still without service, as permanent exchange equipment became available. In addition the scheme allowed the possible recovery of complete portable exchanges with the completion by stages of the permanent exchange.

The numbering plan followed the form shown in Table II.

TABLE II

Emergency Numbers	Old 'J' Number
3,100-3,199	J1XXX
3,200-3,299	J5XXX
3,400-3,499	J4XXX
3,700-3,799	Mixed

In this scheme the re-establishment of a 'J' 1,000 number group would release complete 100 number blocks in the portable exchanges, which could then have been re-allocated with the same or different numbers to subscribers still without service. By retrunking it was envisaged that complete portable exchanges could have been recovered if necessary. It was impossible to introduce complete order into this scheme, and hence it was necessary to allocate some mixed groups. However the problems which would have arisen in clearing up the relatively few such groups were not comparable to the difficulties which would have arisen in re-allocating number blocks if all emergency number groups had served subscribers from the complete 'J' range.

In the final scheme with full emergency number provision it was not necessary to re-allocate emergency numbers to subscribers still without service or to recover portable exchanges progressively, as it became apparent that the replacement exchange could cutover from emergency numbers in one action. However, the orderly number allocation would have been useful in different circumstances.

ESTABLISHMENT OF REPLACEMENT CIVIC EXCHANGE

It was decided that a basic layout providing for 8,400 new 'J' numbers was practicable in the line depot building, and such a floor plan was available at the site by the afternoon of Friday, 22nd. Installation duplicating the destroyed unit commenced as soon as the line depot building was cleared. Survey and marking of the floor was completed by 12 mid-day, Saturday 23rd, and the laying of plinths commenced.

At 1 a.m., Sunday, 24th, the first load of racks arrived from Sydney Stores, and these were stored temporarily on the footpath outside the exchange and covered by tarpaulins. By 6 a.m., Sunday, the laying of plinths was completed and the first racks were stood in position. In all, 86 racks weighing approximately 60 tons were erected between 6 a.m., Sunday, 24th, and 8 a.m. Monday, 25th. The first drum of cable was used on Tuesday, 26th, and all cabling was completed by Monday, 9th October.

The initial target date for completion of installation and cutover was 18/11/1961, which date allowed for normal testing safeguards and an abnormally large amount of checking of cable records and subscribers master cards. However as the work progressed, it proved possible to advance this date by one week to 11 p.m., Saturday, 11/11/1961.

By means of removing links on the M.D.F. and cords used to open-circuit arrestors, a cutover was achieved in approximately 1½ minutes on that date, and no faults arising from the new exchange equipment or cutover were encountered. The complete restoration of almost 5,500 'J' numbers to subscribers within 51 days of the fire was a remarkable achievement.

ORGANISATION

The extensive organisation which was set up at Canberra to meet the emergency covered a wide field of activity and is set out in the Organisation Chart, Fig. 9. At its peak, some five days after the fire, the project directly involved a total staff in Canberra of 536, including 21 engineers. In addition, the complementary effort shown on the Organisation Chart involved a large commitment in staff and resources, not only from the Postmaster-General's Department but from other organisations, which contributed materially to the success of the project.

No attempt has been made to indicate on the Chart the level of effort expended by Postmaster-General's Department groups outside Canberra or by other Government Departments and non-Government bodies. However the Superintending Engineers, Planning, Metropolitan and Services Branches of the Engineering Division were, with their staffs, committed to a large effort in ensuring the smooth flow of work on the engineering project. At the same time the Assistant Director, Telecommunications Division and the Superintendent, Buildings Branch had large responsibilities in the handling of subscriber records, priorities and emergency services in the first case and the determination and oversight of building and allied works in the second instance. In the same manner, a large complementary effort flowed from bodies outside the Department.

The engineering works at Canberra were under the direct control of two Supervising Engineers whose areas of responsibility fell into the broad categories of External and Internal Plant. However, because it was impossible in a 24-hour a day project of the magnitude involved for a single individual to be present all the time, there was a considerable overlap of functions in the managerial sense. This greatly facilitated operations in that decisions were reached under the guidance of the alternate Supervising Engineer if the one directly concerned was not available.

With the passing of time and the completion of some phases of the work there were naturally changes within the organisation. However, the general principles outlined in Fig. 9 applied throughout the period of maximum effort and proved to be most effective. The very close co-operation between the Telecommunications and Engineering Divisions necessitated what amounted to a composite staff for some functions, and this is covered by side-ways ties between engineering officers and the District Telephone Officer at several points in the chart.

The influx of over 400 men augmenting the normal Canberra engineering staff created many problems, and it was found necessary to temporarily transfer two experienced staff clerks to assist the local organisation. In addition, the Staff and Industrial Officer personally visited Canberra to assist with advice on industrial matters such as accommodation, transfers, leave and pay arrangements, as well as the maintenance of harmonious staff relationships.

It has been demonstrated many times that in an emergency all staff will give of their best, but it is human nature that if maximum effort is maintained for more than a few days there must be compensating factors to make up for the diminishing novelty and sense of urgency as the work task becomes more defined. Temporary, and perhaps mediocre to poor, accommodation receives a closer scrutiny, regular meal times and tea breaks are looked for and there are the inevitable requests for leave and assurances on pay arrangements.

The availability of the Staff and Industrial Officer and the attentions of experienced clerical staff to all aspects of the issues referred to achieved a notable degree of smooth staff relations and would always be of great assistance at any similar project in the future. In addition, it was recognised both by the Postmaster-General's Department administration and the industrial unions represented at Civic, that on emergency work there must be a degree of flexibility in the application of regulations and principles. It was a source of encouragement to both parties that no friction occurred on this score.

CONCLUSIONS

In meeting a major emergency in the communications system, the first target is restoration of service, and cost in manpower, materials and services is generally of secondary importance. It is only when increased restoration costs yield marginal advantages in time that cost may be a significant consideration. However, when examined in retrospect it is possible that experience will have shown that alternative courses would have been more productive in results or less costly in effort and materials. The particular circumstances existing at the site and time of occurrence of an emergency are of course fundamental, and decisions will have been based on such considerations as:—

(i) The speed with which relief can be provided.

(ii) The ease of implementation of relief measures from the point of view of availability of materials, manpower and general resources.

(iii) The departures from standard prac-

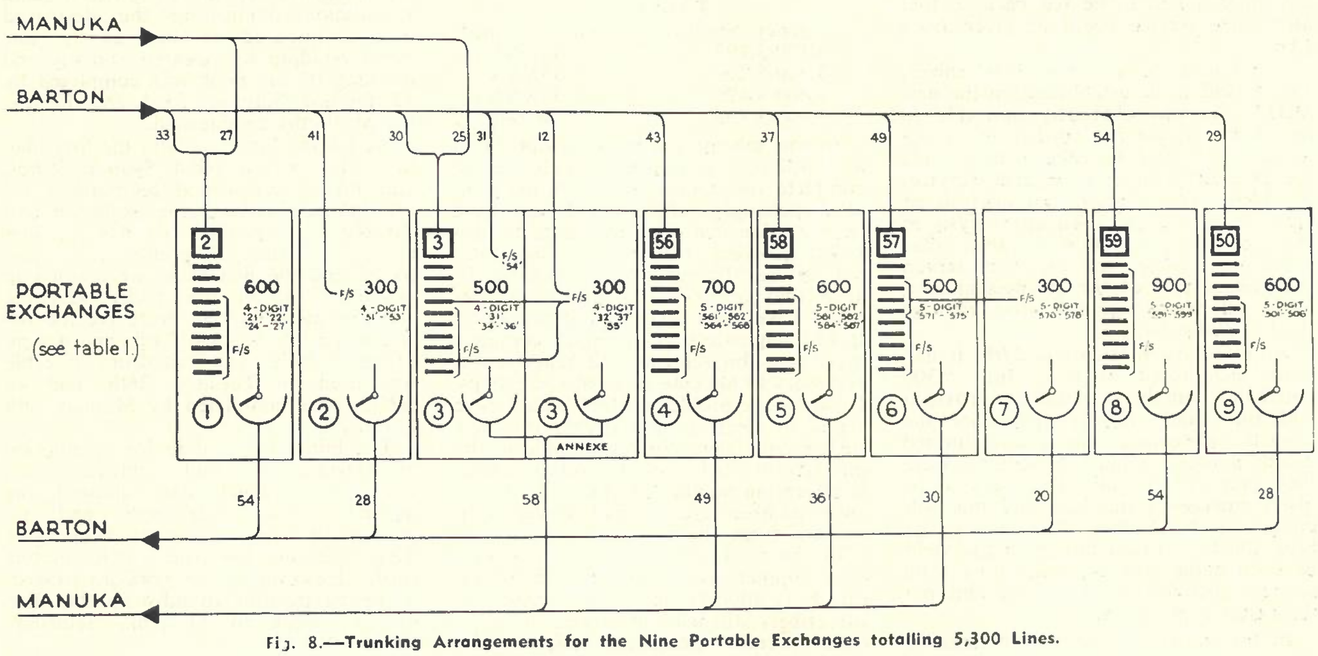


Fig. 8.—Trunking Arrangements for the Nine Portable Exchanges totalling 5,300 Lines.

tices which could require considerably increased direction and result in lower productivity.

(iv) The permanency of relief.

(v) The cost.

It was most significant that, after a critical examination in retrospect of the course of relief measures adopted at Civic, no one involved in its initial determination could see any better alternative. Any changes which seemed desirable were in matters of detail rather than basic action and this was a source of considerable satisfaction to all concerned. It was apparent that, in the engineering organisation existing at this time, there was an inherent capacity to mount a large-scale emergency relief operation. Of equal significance is the skillfullness with which this was done. This skill was undoubtedly obtained from experience in the handling of materials, machinery and staff made necessary by the large expansion in scale of engineering works carried out by Departmental staff during the last 10-15 years.

There were no significant bottlenecks in the Civic project and it was not necessary for any individual to carry out functions any different from his normal duties — the only difference was an increased sense of urgency of completion of each task. In this particular case, the emergency was met by the Engineering Division, Country Branch, within whose sphere of control it arose, complemented to the degree necessary by the diversion of additional planning, installation, maintenance, external plant, materials and staff resources. Each of the complementing sections was self supporting in that it brought its own key staff of manipulative, supervisory and engineer grades and arranged generally for its own material supplies. Because of this, the additional load placed on the normal Country Branch organisation was kept to a minimum. This is a logical arrangement and should occur naturally in any similar circumstances.

Because of the great number of decisions which have to be made during the progress of a major relief work, the dispersion in the nature of concurrent activities and the considerable diversity in the problems encountered, there is good justification for adopting the Civic procedure of not attempting to enforce a too rigid line of command and to permit a degree of overlapping of responsibility.

For example, the Supervising Engineer, Regional Works and Services, under whose control the Canberra Regional Engineering Division came, was naturally involved in many discussions and conferences not directly related to the execution of relief works. These concerned such aspects as the Fire Committee investigations, co-ordinating conferences with the Telecommunications Division and Assistant Director, Canberra, discussion on re-siting of the Line Depot and co-operation with other Commonwealth organisations assisting in the relief measures. At the same time, the Supervising Engineer, Long Line and Country Installation, was frequently involved in material conferences, discus-

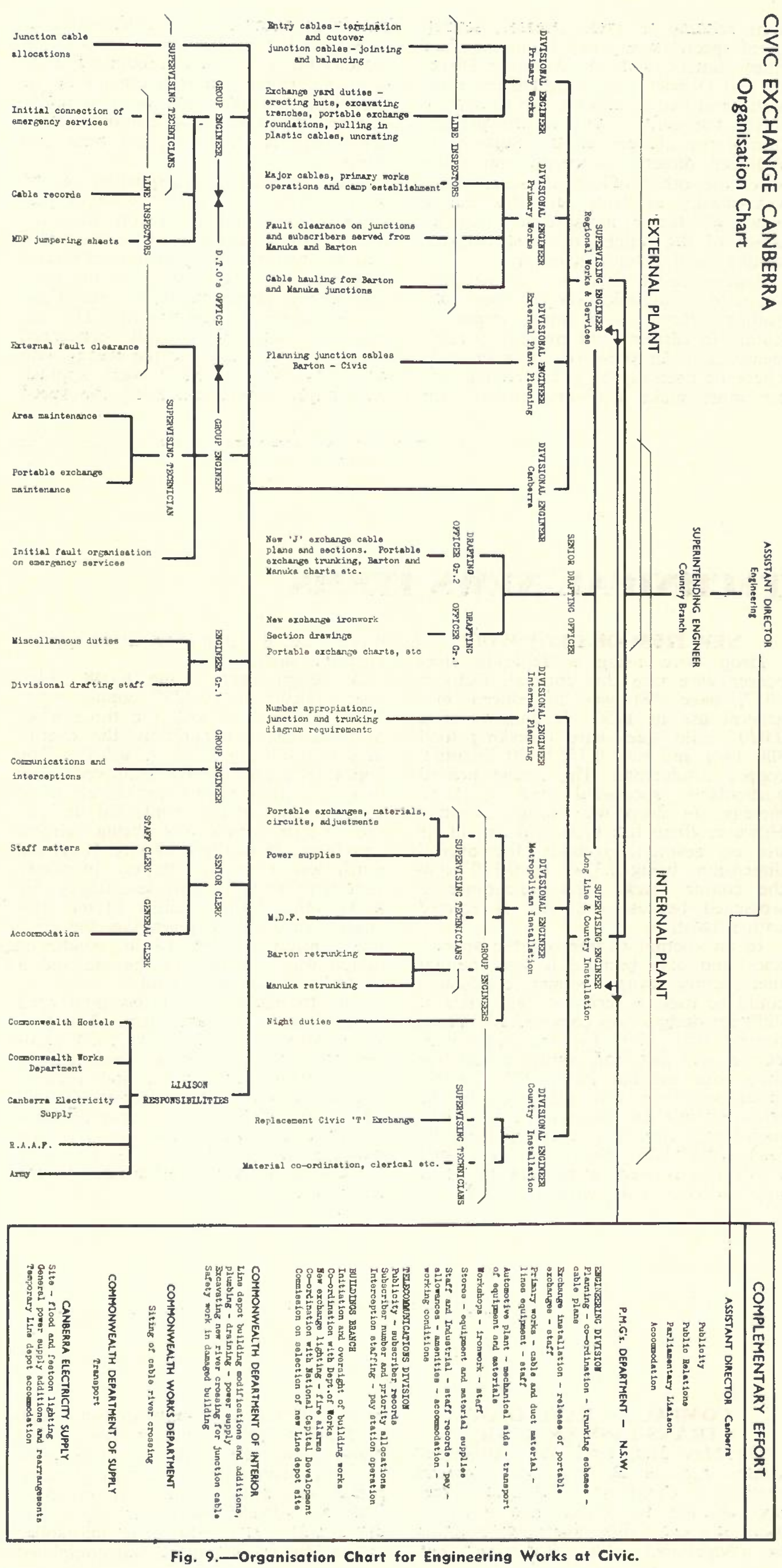


Fig. 9.—Organisation Chart for Engineering Works at Civic.

sions relating to press releases, setting up of special emergency telephones and other matters, with the Assistant Director and District Telephone Officer, Canberra, and had to make a trip to Sydney during the early course of the project. During the absence of the Supervising Engineer directly concerned on some issue, the other officer of equal status was usually available and this was a significant factor in ensuring that no aspect of the relief work was delayed, waiting high level discussion.

Experience at Civic has shown that adequate communication between controlling officers is a most important feature in carrying out emergency relief measures under pressure. In a situation where of necessity each controlling officer must make decisions without the benefit of discussion and deliberation, it is essential that he know exactly the reasons for a particular section of work and its inter-relation with other parts of the project. Unless this is so, a faulty concept through weak communication can easily result in wasted time and effort.

After an objective inspection of the works carried out, examination of personal reports and discussion with the officers concerned, it must be concluded that the restoration of telephone service at Civic can be grouped with the most outstanding achievements of the Postmaster-General's Department. The enthusiasm with which all concerned approached the task and the energy with which the various skills were applied, was amply demonstrated by the speed with which emergency service was given to all subscribers and the very short time involved in complete restoration of all telephone numbers.

ACKNOWLEDGEMENTS

Acknowledgement is made to the Superintending Engineer, Country Branch, New South Wales, and his staff, and the many other Departmental Officers for their assistance in preparing this report. The conclusions reached are not necessarily those of any individuals concerned in the relief works.

REFERENCE

1. C. G. Hammersley, "Removal of 600 Number Portable Exchange from Sydney to Launceston"; The Telecommunication Journal of Australia, Vol. 10, No. 4, page 115.

TECHNICAL NEWS ITEMS

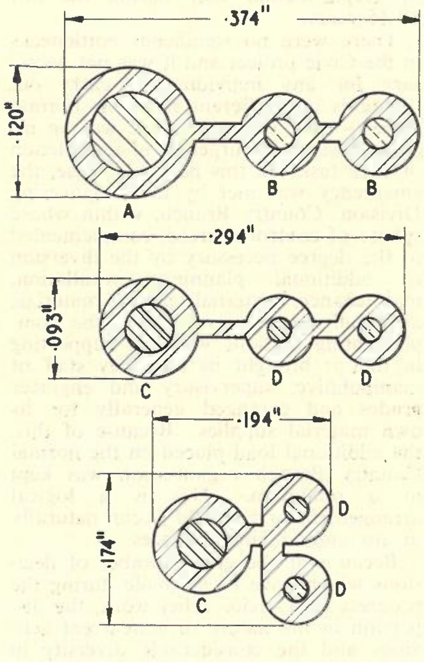
NEW ITEM OF DROP WIRE

Drop wire using a separate steel bearer wire (see this Journal, October 1957, page 58) was introduced into general use in 1956. It consists of a 0.080″ mild steel wire (breaking load 300 lbs.) and two 0.355″ (20 lb./mile) copper conductors. The design proved particularly successful and a large increase in drop wire usage resulted. However there has been criticism of its use on aesthetic grounds, the overall dimensions being 0.374″ by 0.120″ and the colour black. The appearance is worsened because the wire is erected with a twist.

In an attempt to improve the appearance and also because it was thought that lighter gauge copper conductors could be used, a series of field trials of different designs was commenced. These proved that .020″ (6½ lbs./mile) conductor was not sufficiently robust for drop wire use but that .025″ (10 lb./mile) conductor was adequate. In the trials, a triple flat design using an 0.048″ high tensile steel wire (breaking load 300 lbs.) and 0.025″ (10 lb./mile) copper conductors proved satisfactory for most applications. This wire is 0.0294″ x 0.100″, but the improvement in appearance was slight.

A design again using 0.048″ high tensile steel and 0.025″ copper wires was then evolved with the three wires in triangular configuration, the overall dimensions being 0.193″ x 0.170″. The appearance was greatly improved. The new design also gave improved electrical balance compared to triple flat designs, the copper conductors being almost equidistant from the steel wire. It proved much less prone to "flutter" in windy conditions and therefore less susceptible to vibration fatigue failure of the steel bearer wire. For a given sag, the erection tension for the 10 lb. conductor design was half that of the old and it could be tensioned by hand.

The triangular design has now been adopted as a standard item. The purchase price is £3.10.0 per 1,000 yards less than the old design, resulting in annual savings of £15,000 and, because of reduced weight and dimensions it will be supplied on 500 yards disposable reels instead of 220 yard reels, thus reducing wastage of short ends. The following sketches show the three designs to the same scale.



	DESCRIPTION
A	·080" MILD STEEL (30 T.S.I.)
B	20 lb. COPPER CONDUCTOR
C	·048" HIGH TENSILE STEEL (90 T.S.I.)
D	10 lb. COPPER CONDUCTOR

COMPAC — LAYING OF TRANS-TASMAN LINK

On May 21st, 1962, the "Monarch" commenced laying the trans-Tasman section of COMPAC. "Monarch" was accompanied by Cable and Wireless Limited's cable-ship "Retriever", acting as navigational pilot. "Retriever" had previously laid shore-ends at Bondi and at Muriwai (N.Z.), plus radar-reflector buoys along the cable route to assist accurate navigation. "Monarch" completed the trans-Tasman lay on May 30th, but adverse weather caused a two-day standby, after which the final splice to the Muriwai shore-end was completed on Saturday, June 2nd. The first conversation between Sydney and Auckland took place at 8.30 a.m. (Sydney time) that day. Transmission tests are now in progress and will be completed before the link is officially opened by the Prime Ministers of Australia and New Zealand on July 9th.

THE MELBOURNE-MORWELL COAXIAL CABLE SYSTEM—PART I

L. A. WHITE*, R. K. EDWARDS, B.E.E.†, I. L. McMILLAN†, and J. R. WALKLATE, B.Sc.‡

INTRODUCTION

On 16th September, 1961, the second coaxial cable multichannel telephone system in Australia was placed in service between Melbourne and Morwell on a coaxial cable installed by the Postmaster-General's Department (Refs. 1 and 2). The equipment for this project was supplied by Siemens and Halske A. G., West Germany, through Siemens Halske-Siemens Schuckert (A'asia) Pty. Ltd. The installation of the system was carried out by Country Branch staff of the Victorian Engineering Division of the Postmaster-General's Department under guidance of an Installation Supervisor and a Lineup Engineer from Siemens and Halske. Assistance in specialised testing was also rendered by the Central Office Long Line Equipment Laboratory of the Postmaster-General's Department. The system is of type V.1260, the prefix "V" representing the German word "vierdraht-system" meaning a four-wire system using the same line frequency range for the go and return directions of transmission, while the number indicates the ultimate number of speech channels which can be provided, in this case 1,260 on one pair of coaxial tubes. A bandwidth of approximately 6 Mc/s is employed.

The initial contracts for the basic items of equipment were placed in July/September 1959 based on tenders received in February of that year for general broadband carrier equipment. Immediately after the placement of these contracts a visit was made to Germany by the Central Office co-author of this article, and discussions were held with Siemens and Halske in Munich on all aspects of the engineering of the system in order that the final equipment requirements could be determined and that Departmental preparatory work could proceed. The final complete contracts were placed in May 1960 and shipment of equipment commenced shortly thereafter. By early 1961 sufficient equipment had been delivered for installation to be commenced and the Siemens and Halske Installation Supervisor arrived in February for a period of ten weeks. He was followed in May by the Lineup Engineer whose services extended until shortly after the system was commissioned in mid-September.

Fig. 1 shows the overall route of the system, which is approximately 100 miles in length, and the location of the repeater stations. There are two attended repeater stations equipped with supergroup drop-out facilities, and a total of 15 unattended repeater stations. The initial installation has provided two supergroups of channels Melbourne-Morwell, one supergroup Melbourne-Warragul and one supergroup Melbourne-Dandenong. In addition, supergroup equipment only was installed for additional supergroups Melbourne-Dandenong, Dandenong-Warragul and Warragul-Morwell and the other equipment for these supergroups will be added shortly. The allocation of the initial supergroups in the system is shown in Fig. 2 together with a possible future allocation.

Power is fed to the unattended repeater stations from the attended repeater stations at Dandenong and Warragul, which are equipped with no-break A.C. supply plant as also are the terminal stations. The power feeding sections are shown in Fig. 3, which also gives details of the arrangement for remote supervision of the high frequency line equipment and for service order-wires. The latter consist of a long haul 4-wire amplified circuit between Melbourne and Morwell and the intermediate attended stations Dandenong and Warragul, and a short haul 2-wire unamplified order-wire with magneto signalling, connecting the unattended repeater stations to the attended stations over each main repeater section. The order wire and remote supervision facilities are provided on voice-frequency paper insulated pairs in the composite coaxial cable (Ref. 1).

The coaxial cable system may be considered in two main parts, these being the terminal modulating equipment for

*—See Vol. 13 No. 1, page 80.
†—See page 348.
‡—See Vol. 13, No. 3, page 269.

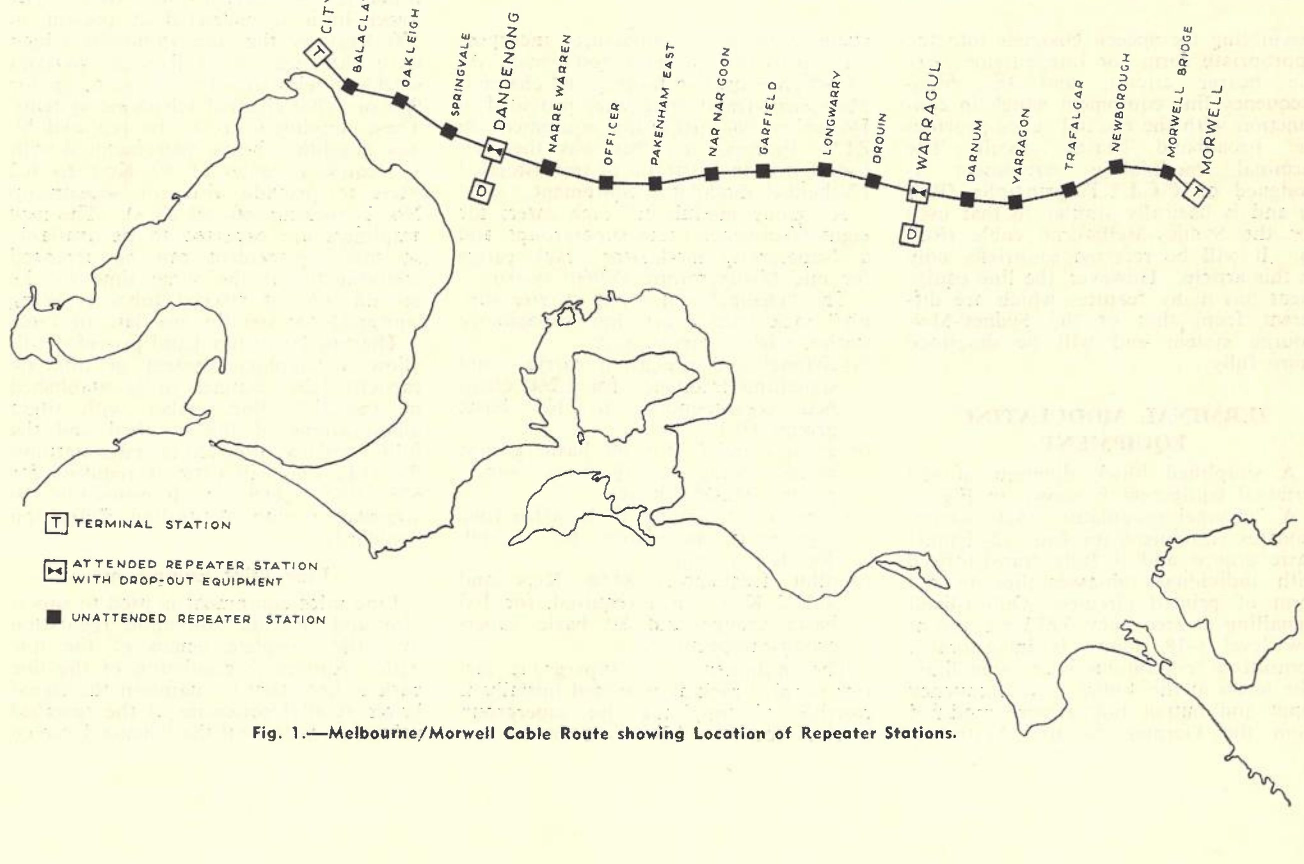


Fig. 1.—Melbourne/Morwell Cable Route showing Location of Repeater Stations.

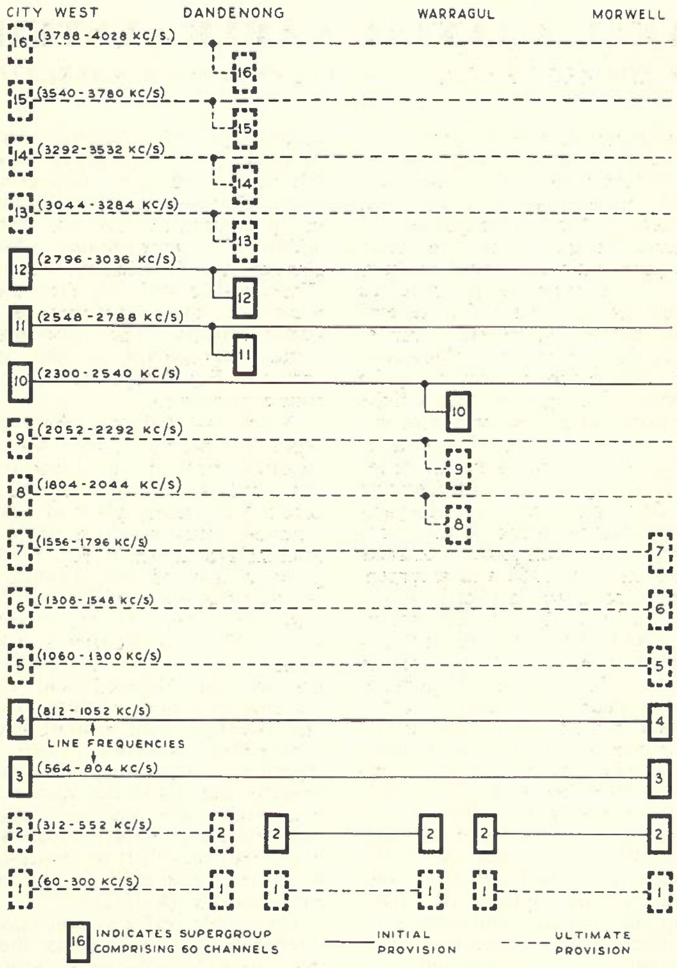


Fig. 2.—Allocation of Supergroups.

assembling the speech channels into the appropriate form for transmission over the bearer circuit, and the high-frequency line equipment which in conjunction with the coaxial tubes provides the broadband bearer circuit. The terminal modulating equipment is designed on C.C.I.T.T. principles (Ref. 3) and is basically similar to that used for the Sydney-Melbourne cable (Ref. 4). It will be referred to briefly only in this article. However, the line equipment has many features which are different from that of the Sydney-Melbourne system and will be described more fully.

TERMINAL MODULATING EQUIPMENT

A simplified block diagram of the terminal equipment is shown in Fig. 4.

A "channel modulator" rack accommodates equipment for four 12-channel basic groups and is fully transistorised with individual sub-assemblies in the form of printed circuits. Out-of-band signalling at frequency 3,825 c/s and at low level (−18 dbm0) is incorporated permitting "continuous tone" signalling. The levels at the 4-wire voice frequency input and output points were modified from the German to the Australian standard by the manufacturer incorporating pads in the central test panel. As an advance interim measure 60 channels Melbourne-Dandenong were provided in December 1960 using this equipment on Z12N bearers, and this was the first installation in Australia of transistorised 12-channel modulator equipment.

A "group modulator" rack caters for eight 60-channel basic supergroups and a "supergroup modulator" rack caters for one 16-supergroup (V960) system.

The "channel and group carrier supply" rack with short, low capacitance station wiring, can supply:

(a) channel and pre-group carriers and signalling frequency for 1,260 channels corresponding to 105 basic groups 60-108 Kc/s,
(b) group carriers for 80 basic groups corresponding to 16 basic supergroups 312-552 Kc/s,
(c) supergroup carrier 612 Kc/s for four supergroup modulators No. 1 (60-300 Kc/s.), and
(d) pilot frequencies 84.08 Kc/s and 411.92 Kc/s, when required, for 105 basic groups and 80 basic supergroups respectively.

The equipment of a "supergroup carrier supply" rack as provided initially is capable of supplying the supergroup carriers for four V960 systems or one V1260 system. Expansion to three V1260 systems and one V960 system is readily possible however by increasing to seven the number of decoupled outputs of the supergroup carriers 4-8, which are used to assemble basic mastergroups, and by providing an additional (8th) output of the supergroup carrier 7 used for mastergroup modulation in the Siemens and Halske scheme, which is an alternative to that outlined in Reference 3.

HIGH FREQUENCY LINE EQUIPMENT

General Facilities

The term "H.F. line" refers to a facility which transmits a given frequency band from one terminal station to another with a certain stated loss or gain, which is normally constant over the frequency band, and in which the overall distortion lies within fixed limits. The H.F. line equipment for each coaxial tube comprises the transmit line amplifier rack at the sending terminal station and the receive line amplifier rack at the incoming terminal station, together with the intermediate line amplifiers at the partly regulated unattended and the fully regulated attended repeater stations. The remote power supply equipment and route remote supervision facilities are also part of the H.F. line equipment. Fig. 5 is a simplified block schematic of the H.F. line equipment at the repeater stations, excluding the remote supervision facilities, while the terminal equipment is included in Fig. 4.

The line frequency band available in each direction with the equipment installed initially on the first pair of tubes on the Melbourne-Morwell coaxial route is 300 Kc/s to 6.2 Mc/s. The lower limit is restricted at present to 300 Kc/s by the line amplifiers which were designed originally for vestigial sideband television transmission, or for 900 or 1,200 channel telephone systems. These amplifiers are to be replaced by new amplifiers being manufactured with a frequency range of 60 Kc/s to 6.2 Mc/s to provide also for supergroup No. 1 working (60-300 Kc/s). The new amplifiers are expected to be available so that replacement can be arranged conveniently at the same time as the second pair of coaxial tubes is being equipped for standby use late in 1962.

The line frequency band provided will allow a telephone system of ultimate capacity 1,260 channels to be established on the H.F. line. Also, with slight modifications of the terminal and the fully regulated attended repeater stations, the H.F. line will cater if required for 625 line television transmission in accordance with Australian Television Standards.

Line Pilot Equipment

Line pilot equipment is used to supervise and provide automatic regulation over the complete length of the line path. Automatic regulation of the line path is necessary to maintain the signal levels at all frequencies at the specified values, in order that the balance between

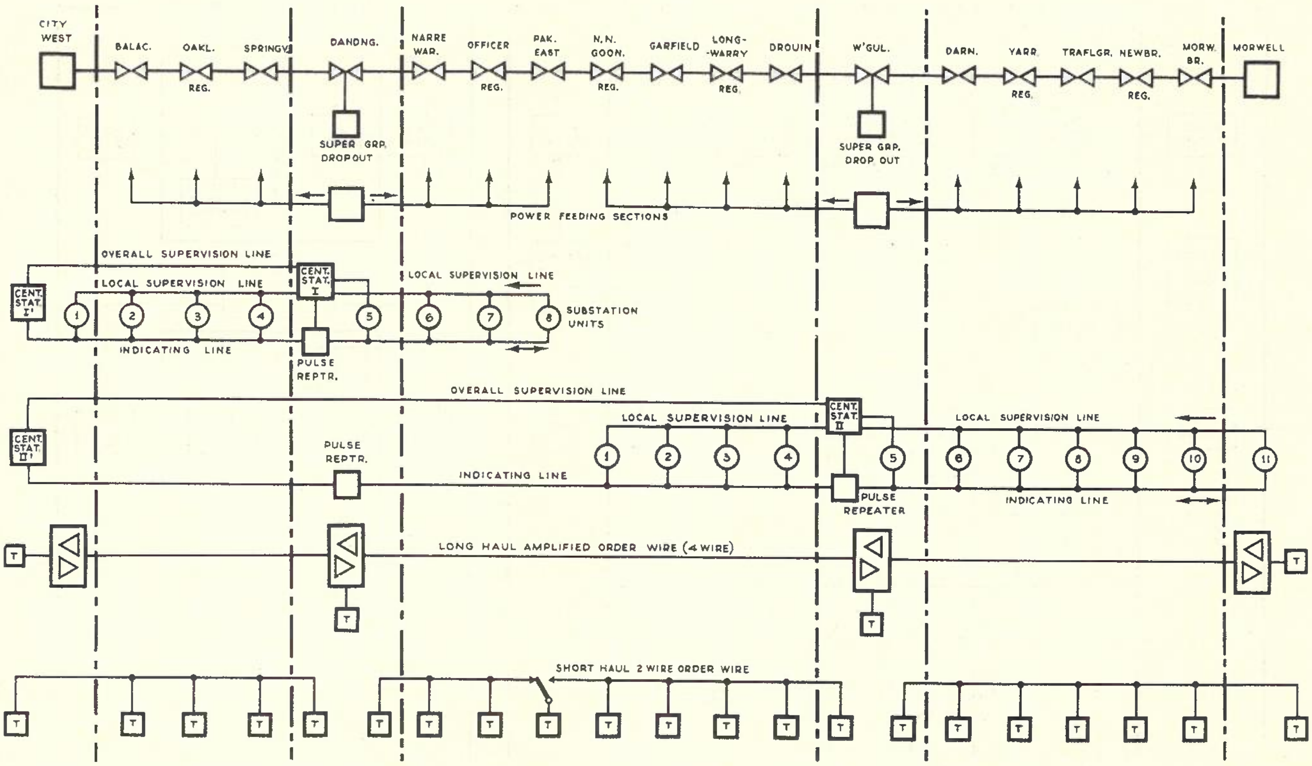


Fig. 3.—Power Feeding, Remote Supervision and Order Wire Arrangements.

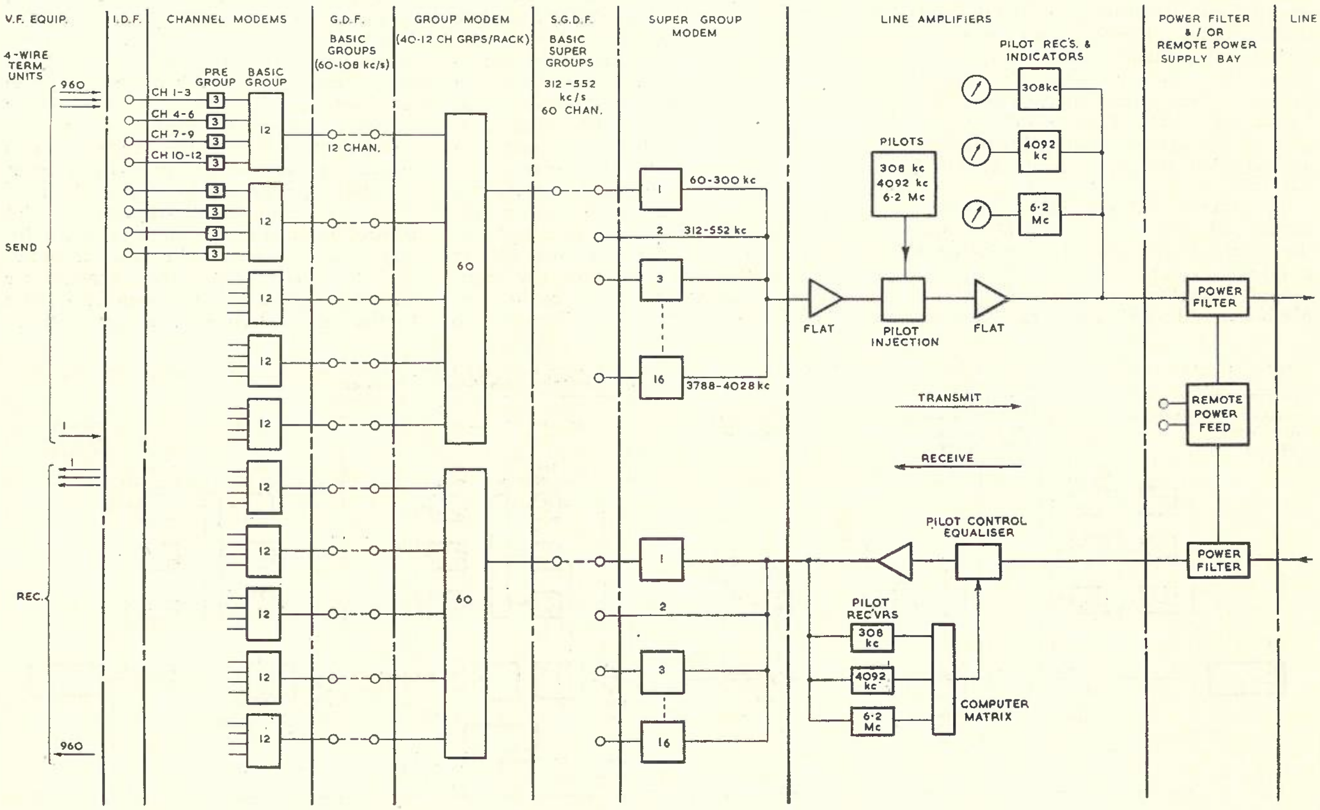


Fig. 4.—Block Diagram of Terminal Equipment.

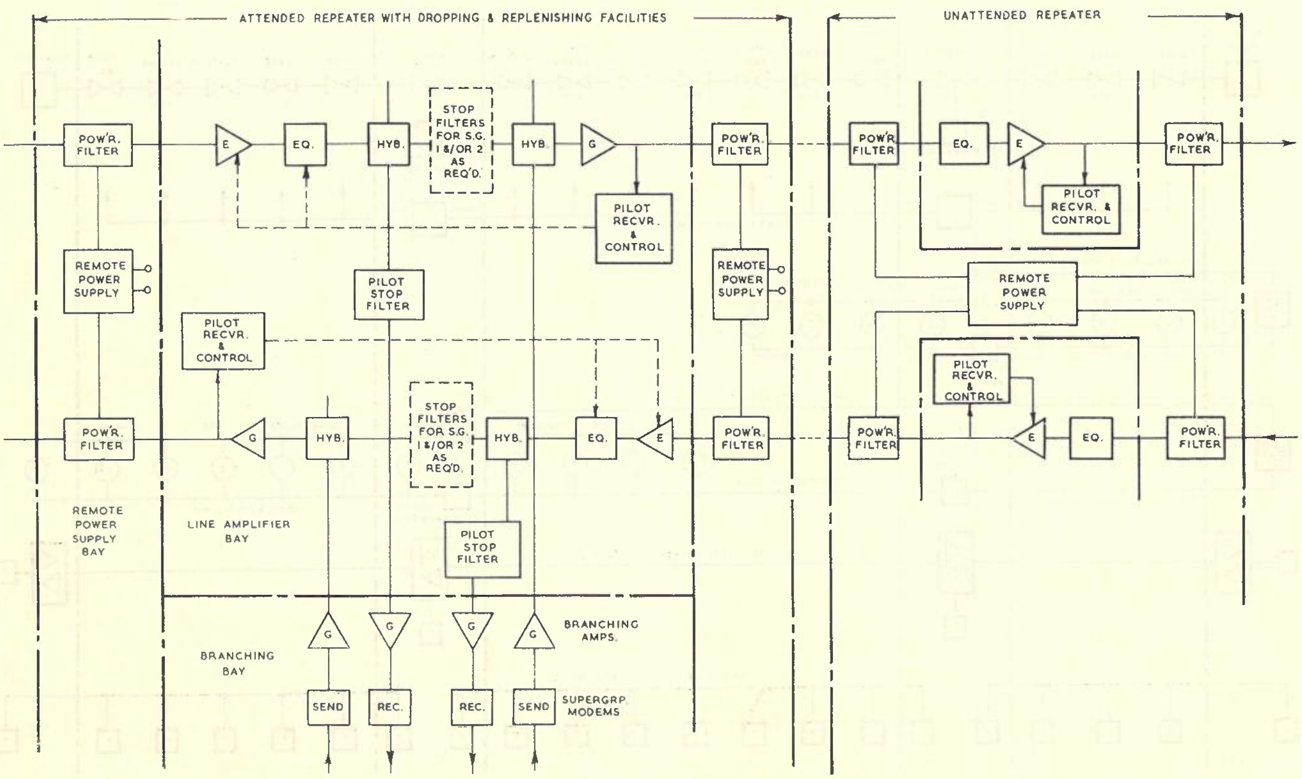


Fig. 5.—Simplified Block Diagram showing Repeater Equipment for Coaxial Cable System.

thermal noise and intermodulation noise is not upset with a resulting increase in total noise, and to avoid variations in attenuation distortion over the line frequency band. Fig. 6 shows, in simplified block schematic form, the pilot supervision and regulating facilities of the high frequency line. Three pilot frequencies (308 Kc/s, 4092.453 Kc/s and 6.2 Mc/s) are generated, distributed and injected at the transmit line amplifier rack.

The unattended repeater stations are supervised only by the 6.2 Mc/s pilot; the level of this pilot is monitored by a pilot receiver connected to the pilot output from the line amplifier. On the Melbourne-Morwell route each alternate unattended station is equipped with automatic gain regulators which are controlled by the pilot receiver output to adjust the gain of the slope line amplifier "E" (Fig. 7) to offset the attenuation changes of the cable due to temperature variations in the preceding two repeater sections. At the unattended stations not equipped with pilot controlled motor regulators, the gain can be set by hand, the pilot level being observed on a portable measuring instrument. Routine manual adjustment should definitely not be necessary however according to the planning of the system, as the range of automatic regulation is adequate to cover cable temperature changes of ± 12°C over one repeater section and the actual cable temperature changes on the Melbourne-Morwell route are not expected to exceed ± 6°C.

All three pilots are used for supervision and automatic gain control at the fully regulated attended repeater and terminal receive stations. At these stations, automatic regulation is provided to take care of the effects of valve ageing and ambient temperature changes on the repeater equipments. Both of these corrections are effected by pilot controlled equalizers. In addition, automatic regulation of the line amplifier "E" to correct for cable temperature changes is provided in a manner similar to that at unattended repeater stations.

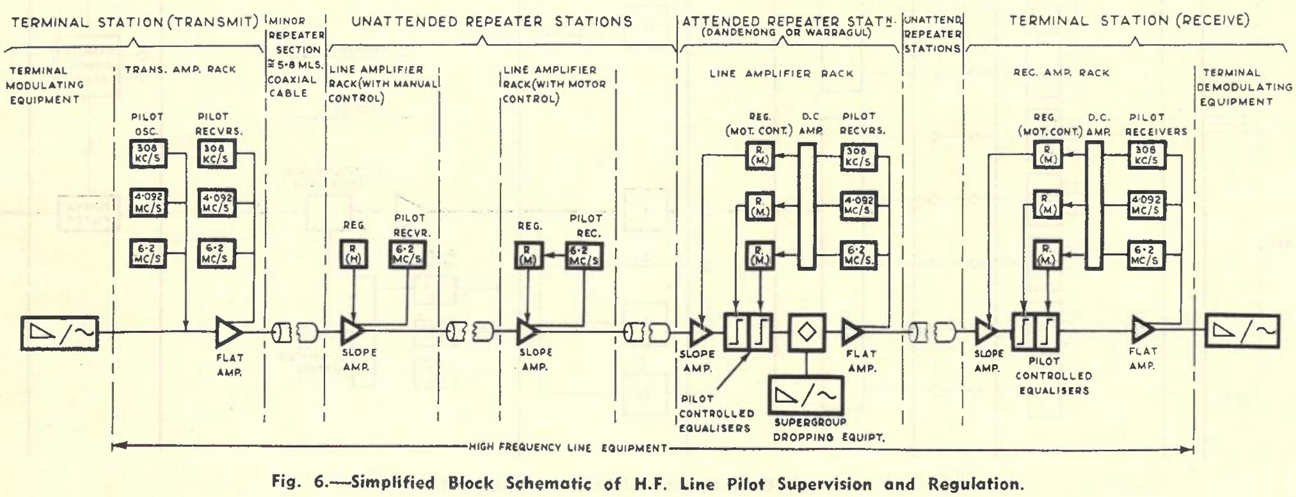


Fig. 6.—Simplified Block Schematic of H.F. Line Pilot Supervision and Regulation.

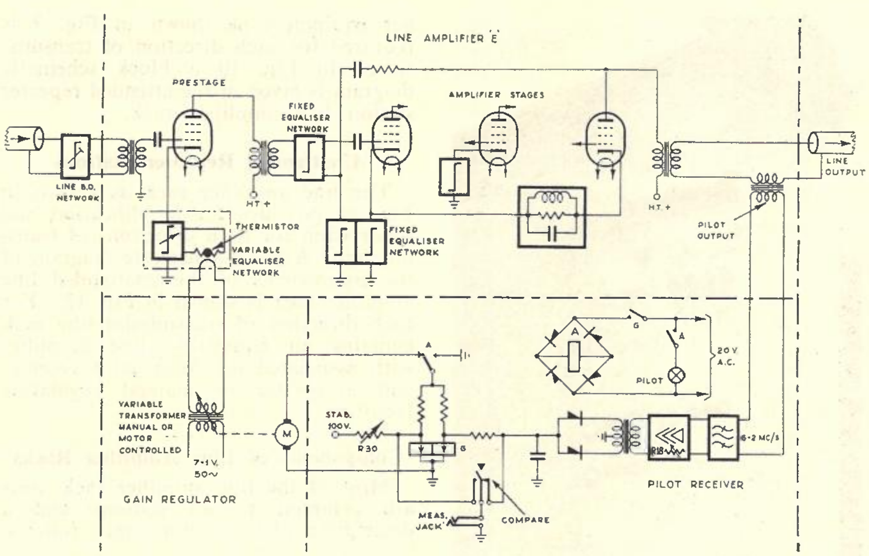


Fig. 7.—Simplified Schematic of Line Amplifier "E" and Pilot Receiver Showing Principle of Automatic Control of Amplifier Gain.

To prevent interaction between the three pilots, a voltage distributor followed by D.C. amplifiers is provided between the pilot receiver outputs and the motor regulators, and ensures that upon a certain level variation, only the appropriate regulation takes place and "hunting" is avoided. With failure of one or more of the pilots, the pilot control action is disabled so that the system is maintained in an unchanged condition. An alarm is also given on pilot failure.

Principle of Pilot Regulation

This is shown in schematic form in Fig. 7 and although this diagram is for the 6.2 Mc/s pilot regulation at an unattended repeater station, the same principle applies to all three regulators at an attended repeater station or terminal receive station. The pilot frequency is extracted from a separate output circuit of the line amplifier and applied to the pilot receiver where a sharp cutoff crystal filter selects the 6.2 Mc/s pilot for application to a three stage amplifier. After amplification, the pilot voltage is rectified and the resultant D.C. voltage compared with a highly stabilised reference voltage of 100 volts. With correct amplifier output level the magnitude of the rectified pilot voltage equals the standard voltage, which results in no voltage being applied to the gain regulator and there is no motor drive. The regulating motor is of the permanent magnet type and is therefore easily reversible; it responds to very small voltages and drives, via a reduction gear, a rotary transformer which applies an A.C. voltage to heat a thermistor in the variable equaliser network of the line amplifier, so controlling the gain. Depending on whether the pilot level increases or decreases, there is applied to the motor regulator a positive or negative voltage which drives the motor in the correct direction. The regulating process continues until the level variation is reduced to zero. The level difference can be read on a meter plugged into the appropriate jack of the pilot receiver. The stabilised reference voltage is adjusted by observing a reading on the meter plugged into the same jack, after pressing a key. Should the pilot level drop by more than 4.34 db, the regulating circuit is disabled and an alarm given. This disabling prevents the line amplifier gain from being increased to maximum when there is a pilot failure. When the end of the range is reached, limit switches prevent the regulating motor from driving on and an alarm is given.

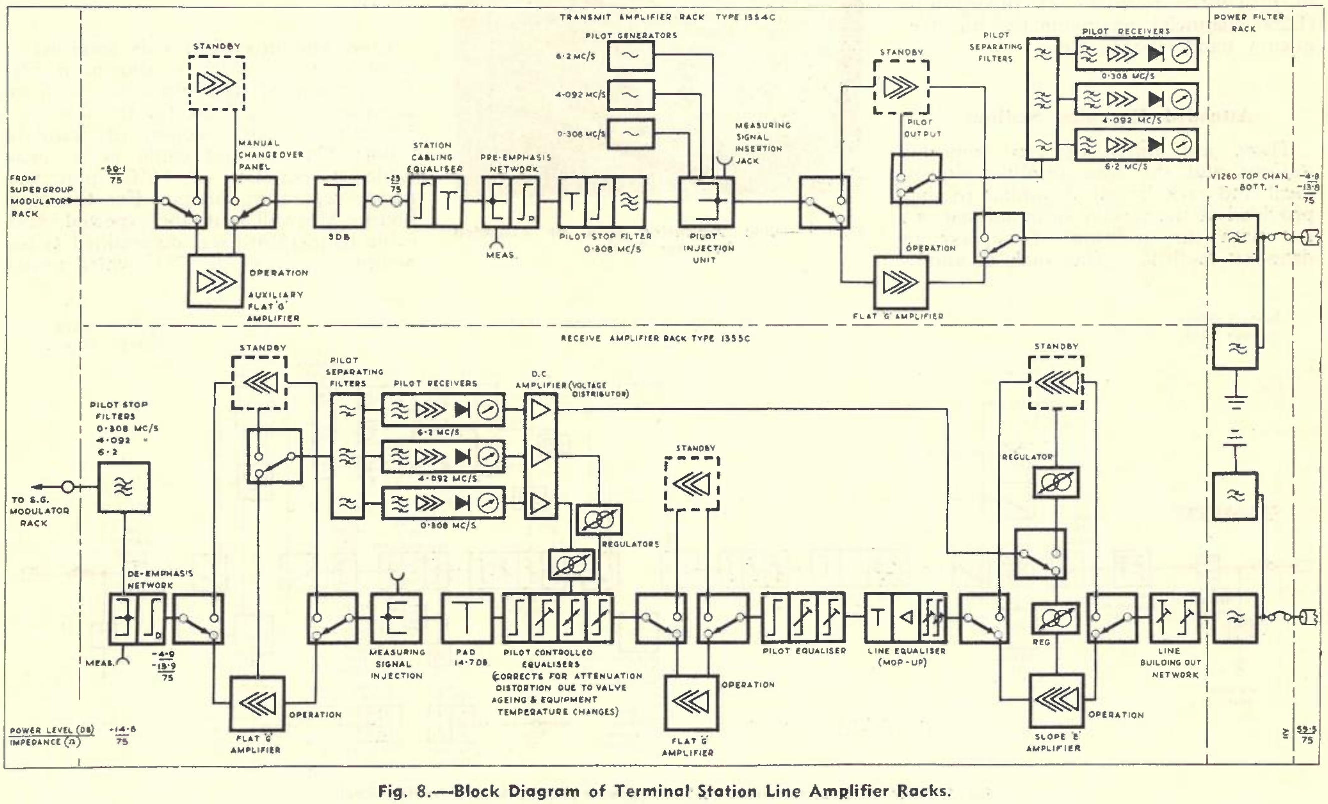


Fig. 8.—Block Diagram of Terminal Station Line Amplifier Racks.

LINE AMPLIFIER EQUIPMENT DESIGN

Terminal Stations

In Fig. 8 is shown a block schematic diagram of the terminal amplifier equipment for a terminating V.1260 line. This equipment is mounted on two racks, these being a "Transmitting Amplifier Rack V.1260" which can accommodate the station cabling equalisers, pre-emphasis networks and pilot and amplifier equipment (excluding the auxiliary "G" amplifier) for three transmitting directions, and a "Receiving Amplifier Rack V.1260" which accommodates the building out network, equaliser, pilot and amplifier equipment for one receiving direction.

The transmitting amplifier rack V.1260 was originally designed for vestigial sideband television transmission, and in the initial Melbourne-Morwell installation the auxiliary "G" amplifier necessary to correct the level difference between the output of the supergroup modulator rack and the input of the line transmitting amplifier equipment has been installed in the transmitting amplifier rack in one of the two spare transmitting direction spaces. Subsequently the auxiliary "G" amplifier will be accommodated in a "Master Group Modulator Rack" which will be necessary to combine the first stage installation of 16 supergroups (960 channels), occupying the line frequency band 60-4028 Kc/s, with a second stage installation of a master group comprising 5 supergroups (300 channels), occupying the line frequency band 4280-5512 Kc/s, to provide a resultant 21 supergroups (1,260 channels) occupying the line frequency band 60-5512 Kc/s.

Attended Repeater Stations

These are fully regulated repeater stations and the line amplifier equipment and rack layout is similar to that provided at the receive terminal stations but with the addition of supergroup drop-out facilities. One rack of amplifier equipment as shown in Fig. 9 is required for each direction of transmission. In Fig. 10 a block schematic diagram is given of the attended repeater station line amplifier rack.

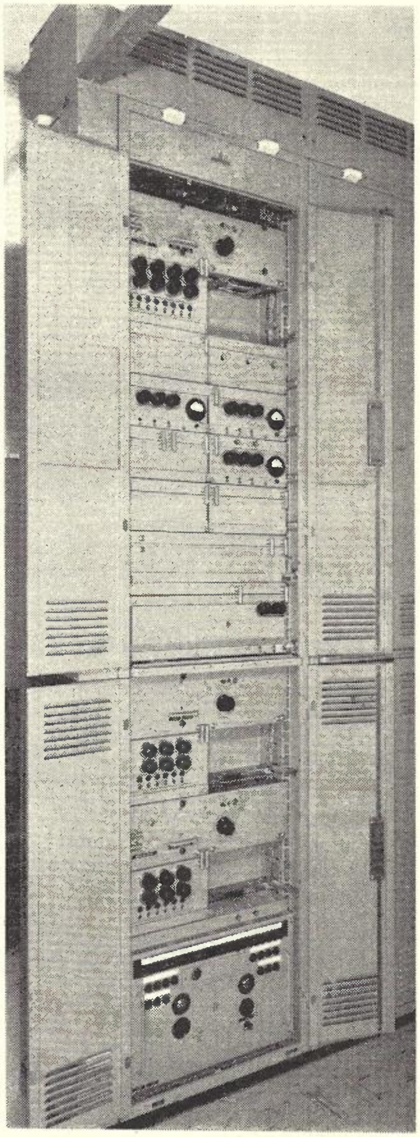


Fig. 9.—Line Amplifier Rack at Attended Repeater Station.

Unattended Repeater Stations

The line amplifier rack as shown in Fig. 11 provides for amplification and supervision for both directions of transmission. A block schematic diagram of the components of the unattended line amplifier rack is shown in Fig. 12. For each direction of transmission the rack contains an equalizing line amplifier with associated 6.2 Mc/s pilot receiver and automatic or manual regulating facilities.

Components of Line Amplifier Racks

Most of the line amplifier rack units are common to all stations and a description of the various units follows.

Line Building-Out Network: This allows short repeater sections to be extended so that they fall in the regulating range of the slope line amplifier "E". The network consists of sections that simulate the loss, over the full frequency range, of 0.25, 0.5, 1 and 2 miles of coaxial cable. The sections may be brought into circuit singly or several at a time thus allowing a "building-out" of short repeater sections up to a maximum of 3.75 miles. This network is mounted in the line amplifier "E" changeover panel and the line frequency band is brought direct to this panel via rack cabling from the line amplifier rack terminal panel coaxial connections "F IN".

Line Amplifier "E": This amplifier, a front view of which is shown in Fig. 13, is provided to compensate, with an accuracy of ± 0.5 db, for the loss of a 5.8 mile repeater section of standard 0.104/0.375" coaxial cable at a mean cable temperature of 15°C, plus two power separating filters. For the Melbourne-Morwell route the expected mean cable temperature was determined at the planning stage to be 17°C which meant

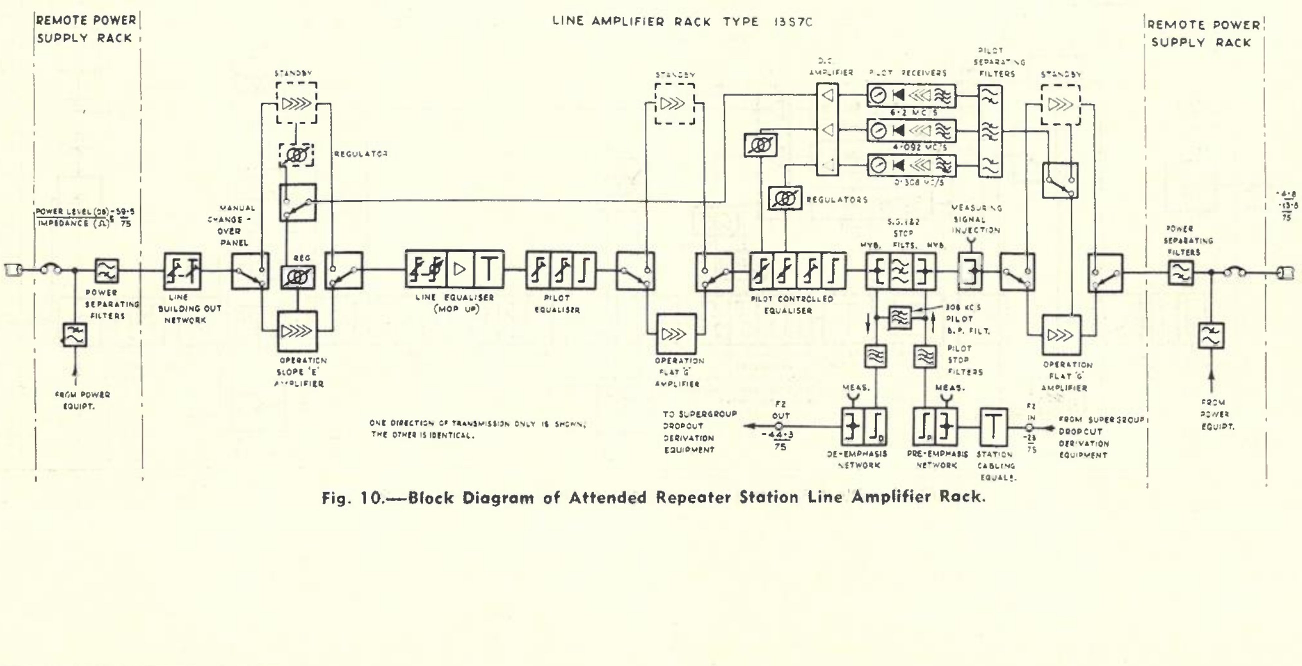


Fig. 10.—Block Diagram of Attended Repeater Station Line Amplifier Rack.

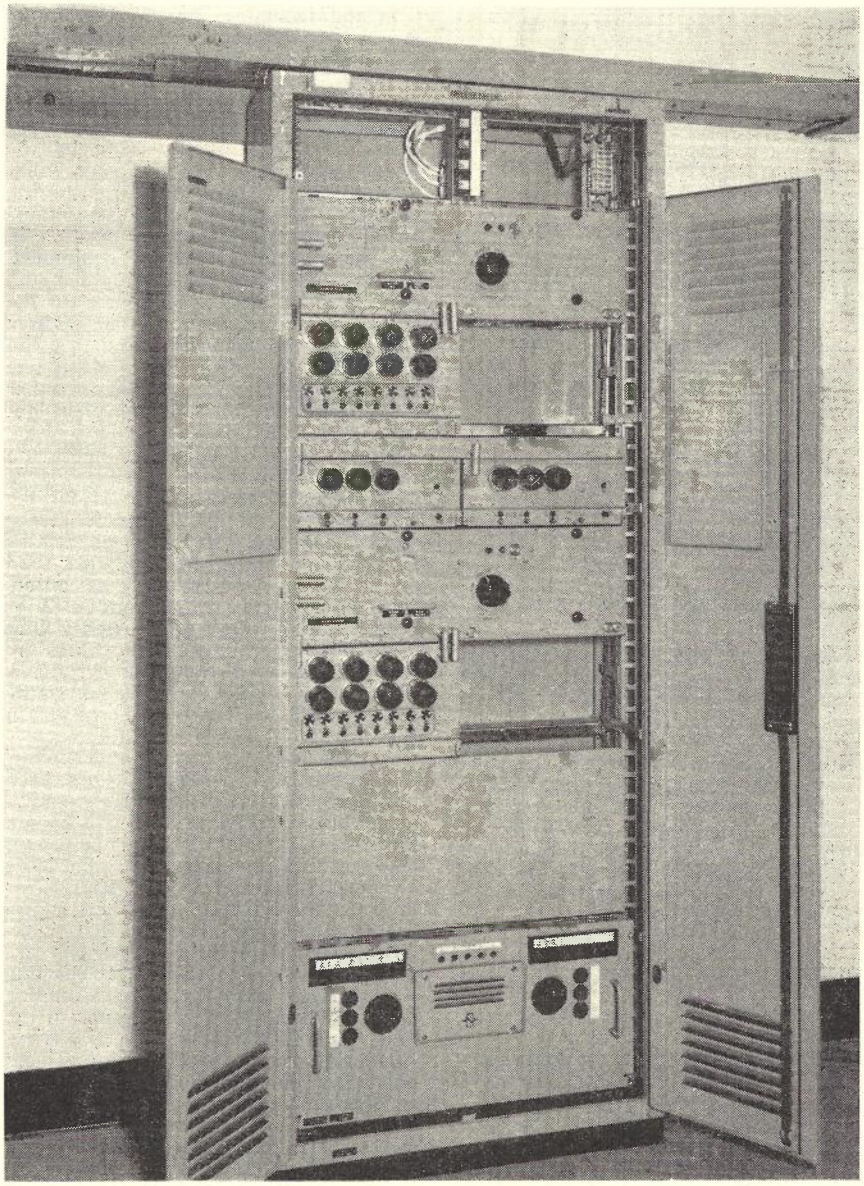


Fig. 11.—Unattended Repeater Station Line Amplifier Rack.

reduction of the actual repeater section planning length to 5.72 miles. The gain versus frequency response of the amplifier matches approximately the attenuation versus frequency curve of the coaxial cable. The desired sloping frequency response of the amplifier is obtained by incorporating fixed equalizers and a variable equalizer in the amplifier circuitry.

The amplifier consists of four stages each with parallel valve operation to ensure a high degree of reliability from service interruption. The variable equalizer network which is in the pre-stage of the amplifier, contains a thermistor element which allows the gain of the amplifier to be adjusted continuously within certain limits. This control serves for offsetting loss variations due to temperature changes in the cable and also allows, within its range of control, for fine adjustment to the correct gain after adjustment of the building-out networks for different repeater section lengths. The essential elements of the amplifier were referred to previously in Fig. 7, and Fig. 14 shows its regulating range. At 6.2 Mc/s the available gain variation is from 50.8 to 58.6 db which is more than adequate for fine adjustment of building out (approximately ± 1.2 db) and for cable temperature changes of ± 12°C (approximately ± 1.4 db). In isolated cases, therefore, a repeater section may be increased by up to approximately 0.26 miles (mean cable temperature 17°C) beyond the planning length, provided care is taken not to prejudice overall noise performance. On the Melbourne-Morwell route, 15 of the 18 repeater sections were established well within the planning length of 5.72 miles but in three cases this length was exceeded by 0.04, 0.06 and 0.13 miles respectively.

Line Amplifier G: This amplifier which is used as a transmitting amplifier, level compensating amplifier or for offsetting loss due to equalizer networks, has a flat gain of 39 db in the frequency range 60 Kc/s to 6.2 Mc/s. It is a 3 stage amplifier with feedback applied over all three stages; each stage is equipped with parallel valves for greater reliability of service.

Line Amplifier Changeover Panels: These are provided for standby switching of the line amplifiers. It is possible by means of these panels to take any desired amplifier out of the communication path and substitute a standby unit in the line without interruption to service. During the changeover the inputs and outputs of the operating and standby units are connected temporarily in parallel. Fading resistors minimise the accompanying level changes. A rotary switch in the changeover panel serves for no-break transfer. Space is left beside each operating amplifier for the insertion of the spare amplifier when a changeover is to be effected. In addition, when changing over line amplifiers E, a spare gain regulator must also be inserted in the space provided.

Station Cabling Equalizer: This is provided to offset the frequency response of the station cable between the output of the supergroup modulating equipment and the input of the transmitting amplifier rack. Seven different types of station line equalizers, corresponding to different lengths of cable, are available to build out the station cable to a flat loss of 3 db. The maximum length of station cable allowed is 310 feet. A 3 db attenuator is provided for station cable lengths up to 33 feet only.

Pre-emphasis and De-emphasis Network: A pre-emphasis network is included in the transmit line amplifier rack where it precedes the transmitting amplifier to give a frequency-dependent output level to line. The pre-emphasis network has a slope of 9 db and the output levels to line for the lowest and highest channels of the V.1260 system are −13.8 and −4.8 dbm respectively. The output level at the highest frequency is determined by consideration of the signal to thermal noise ratio at the amplifier input of the next repeater station and effectively determines the nominal repeater spacing. Pre-emphasis allows a reduction in the output level of the lower frequency channels which results in a lower system loading than with a flat transmitting level over the line frequency band, and thus allows an improvement in intermodulation noise. The output levels are chosen so as to achieve a reasonable balance between thermal and intermodulation noise in all channels. A de-emphasis network is provided in the receive amplifier rack. This network has inverse characteristics to the pre-emphasis network and restores the levels to a flat characteristic. A pair of these networks is also included

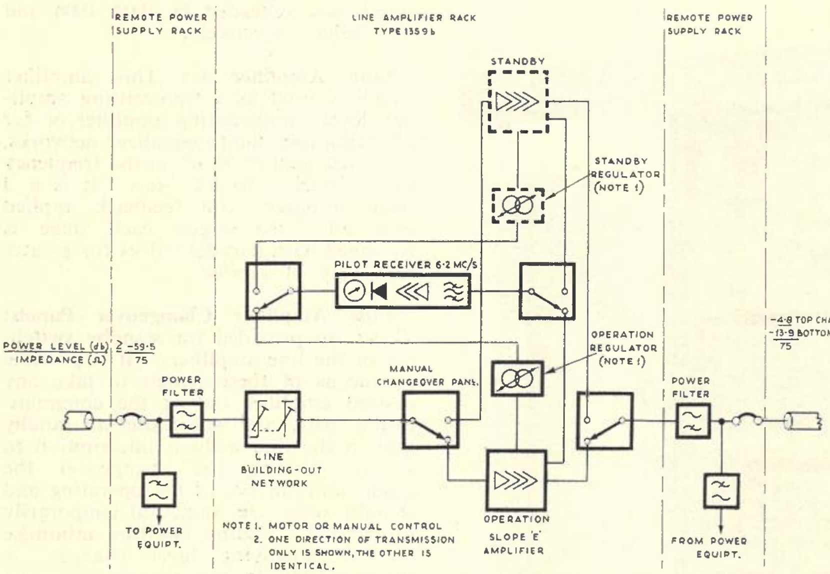


Fig. 12.—Block Diagram of Unattended Repeater Station Line Amplifier Rack.

in the attended repeater station line amplifier rack in the supergroup drop-out path.

Pilot Stop Filters: Band stop filters are equipped in the transmit and receive terminal paths. The transmit filter prevents extraneous signals from the terminal equipment reaching the line where they might interfere with the pilot signals. The receive filters suppress the pilot frequencies to prevent interference with television signals or with pilot signals of other systems. For telephony, only one pilot stop filter for 308 Kc/s is necessary but three pilot stop filters, one for each of the line pilot frequencies, are necessary for television programme transmission.

Pilot Injection Unit: Before the transmit line amplifier G, at a point of low level, the pilot injection unit adds the three pilots (308, 4,092 and 6,200 Kc/s) to the line frequency band. It is accommodated in the changeover panel of the line amplifier G. A jack is also provided on this unit for injection of measuring signals.

Pilot Separating Filters: These are band pass filters for the pilot frequencies 308, 4,092 and 6,200 Kc/s and are

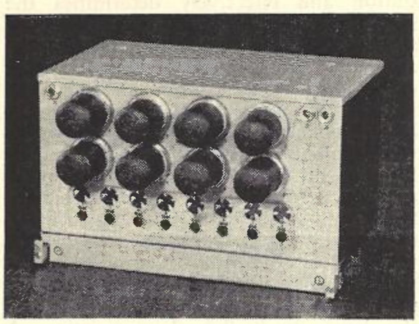


Fig. 13.—Line Amplifier "E" Front View.

placed at the pilot output of the line amplifier G on transmit, attended repeater and receive amplifier racks to feed the three pilot receivers.

Pilot Receivers: These are provided to supervise the pilot output level of the line amplifiers. The pilot receivers contain a sharp cutoff crystal filter, 3 stage tuned amplifier and rectifier. At attended stations a meter is provided on the pilot receivers to show the respective pilot level deviations.

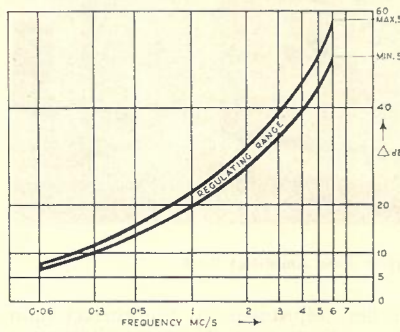


Fig. 14.—Regulating Range of Line Amplifier "E".

System, Pilot-Controlled, and Mop-Up Equalizers. These units are described later under "High Frequency Bearer Lineup—Equalization".

SUPERGROUP DROPPING FACILITIES

Portions of the line frequency band may be dropped and in some cases replenished at attended main repeater stations. This is arranged by providing a hybrid assembly in the line amplifier rack for each direction of transmission at these stations (Refer to Fig. 10).

In the incoming direction of transmission the entire line frequency band is applied to the supergroup modulators at the drop-out station from the separating hybrid, via a flat G amplifier. The supergroups to be dropped are selected from the line frequency band by the filters associated with the supergroup demodulators. In the transmitting direction the supergroups, after translation to the line frequency position in the supergroup modulator equipment, are amplified by a flat G amplifier and applied to the combining hybrid for the appropriate direction of transmission. Except for the frequency band that can be blocked by stop filters, the full line frequency band is transmitted in either direction, and each terminal picks out that portion that is allotted to it.

By providing an additional hybrid on each repeater rack and inserting band-stop filters between the hybrids, the supergroups 1 and/or 2 (line frequency band 60-300 and 312-552 Kc/s) may be dropped and replenished and thus used separately on both sides of a station. With stop filters for supergroup 2 or 1 and 2, a 308 Kc/s pilot by-pass filter is necessary. Also, pilot stop filters are required to keep the pilot frequency from being applied to the dropping station. These details are shown in Fig. 10.

At Warragul a special "dropping" rack, as shown in Fig. 16, has been provided and incorporates all the equipment necessary to translate, with certain limitations, a total of six supergroups between line frequency and the basic supergroup position 312-552 Kc/s. This rack contains the flat G amplifiers, supergroup modulators and associated supergroup carrier supplies. Facilities are provided for dropping and replenishing supergroups 1 and 2 and for dropping a total of two other supergroups in the range 3-16 from one or both directions. A block schematic of the initial and possible ultimate dropping arrangements at Warragul is shown in Fig. 15.

At Dandenong, because of the larger number of supergroups to be dropped, standard terminal station type supergroup modulator and carrier supply racks have been provided. Initially, both the flat G amplifiers required for the initial stage of dropping on the Melbourne side only, have been installed in a transmitting line amplifier rack provided for this purpose. In the next stage of provision a mastergroup modulator rack is to be provided which will accommodate the outgoing G amplifiers for dropping on both sides of the station, while the incoming G amplifiers for both sides will be accommodated on the "transmitting line amplifier" rack.

REMOTE POWER FEEDING OF UNATTENDED REPEATERS

General Description

The power required to operate the line amplifiers and supervisory equipment at the unattended repeater stations is fed over the inner conductors of the coaxial tubes from an attended station equipped with no-break A.C. power sup-

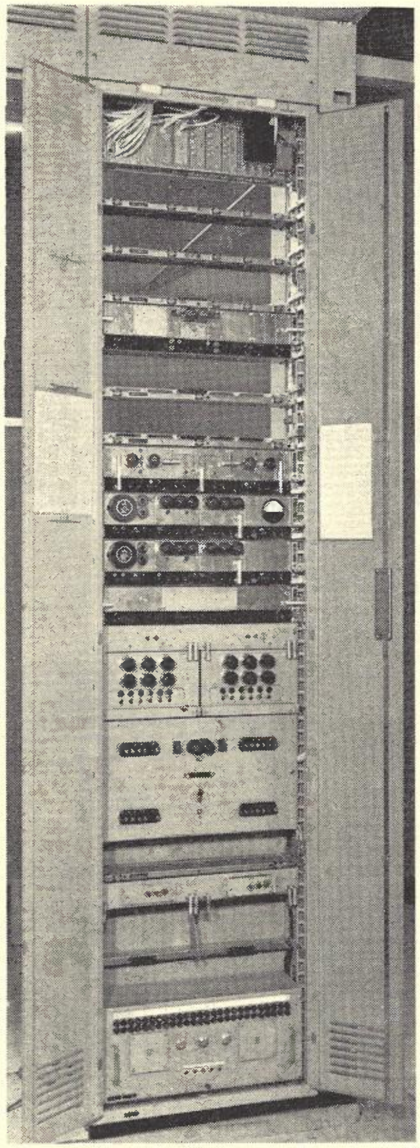


Fig. 16.—Supergroup Dropping Rack — Attended Repeater Station.

ply plant. Fig. 17 shows how the remote power feeding is arranged for the main repeater section between Dandenong and City West.

This method of feeding power to the unattended repeaters provides for reliability in operation and economy. It is more reliable and economic to supply a number of repeater stations from a common source of regulated no-break A.C. power in an attended station where it can be centrally monitored, than to generate the power in each unattended repeater station or to use the local public A.C. mains supply. The use of A.C. at mains frequency provides the simplest method of obtaining the different voltages required at the unattended stations for operation of the line equipment, and allows power to be transmitted at the most suitable voltage which can be stepped up at each repeater station before transmission to the next station.

As each pair of coaxial tubes is equipped for bearer use, a separate power feeding system is installed to feed power to the unattended station amplifier equipment which is associated with the pair of coaxial tubes providing the H.F. bearer. Hence the power feeding system is associated directly with the communication system on a pair of coaxial tubes. For each power feeding system the inner conductors of a pair of coaxial tubes form a high voltage, 50 c/s, single phase power transmission line. The outer conductors of the coaxial tubes are at earth potential as well as the cable sheath, and the power feeding transformers are earthed at the centre tap, this being shown in Fig. 18. The voltage used on the Melbourne-Morwell system is 1,200 volts between the inner conductors of the two coaxial tubes, and 600 volts therefore exists between the inner and outer conductor of each coaxial tube.

It should be noted that power separation filters are still installed on cable sections where there is no power feeding. This is mainly to protect the transmission equipment from longitudinal voltages that may be induced in the cable due to nearby power line faults or lightning strikes, and also maintains standard conditions for line equalisation and cable termination.

At the feeding station the regulated 240 volt A.C. obtained from the no-break A.C. supply plant is supplied via a 240/220 volt auto transformer to the power feeding rack. There the voltage is stepped up and applied to the inner conductors of the two coaxial tubes via the low pass section of power separating filters which separate the transmission equipment from the power supply as shown in Fig. 17. The power separating filters are suitable for 1,000 volts operation with a maximum current of 3 amps., and the stopband loss of the high pass section at 50 c/s is greater than 95 db. At the unattended repeater (fed station) the high voltage power is extracted from the inner conductors of the coaxial tubes via power separating filters and fed to a step-up transformer which offsets the voltage drop introduced in the preceding section and restores the voltage to the original value (2 x 600 volts) for onward transmission to the following power section. A secondary winding on the transformer steps down the voltage to provide the 220 volts A.C. required for the local power circuits.

Power Feeding Supervision Equipment

A general schematic of the power supervision equipment is shown in Fig. 18. This equipment is provided on the remote power supply racks at the feeding and fed stations, and is required to protect the equipment and coaxial cable from damage due to large feeding currents or unbalanced currents in the two tubes, and high voltages under fault conditions. At the power feeding station the supervisory panel provides the following facilities:

(a) An alarm when an underload greater than 0.4 KVA exists; power feeding continues under this condition.
(b) An alarm and automatic disconnection of power feeding for an overload greater than 0.4 KVA. The disconnect time is similar to that of a 2 amp. circuit breaker and varies from about 30 secs. for an overload of 1 KVA to 6 secs. for an overload of 3 KVA, and 100 m.s. for an overload of greater than 4 KVA.
(c) Mains interruptions of less than 100 m.s. do not result in disconnection of the remote power feeding.
(d) Simple adjustments for setting the sensing circuits, depending on the normal power feeding load of the route section.
(e) Push button "on" and "off" switches to control the remote power feeding. During cable repair operations, inadvertent or unauthorised reconnection of the power feeding is prevented by a key locked power switch.

The supervisory panel at the fed stations (unattended repeaters) detects (i) unbalances of the current greater than 10% in each coaxial tube due to

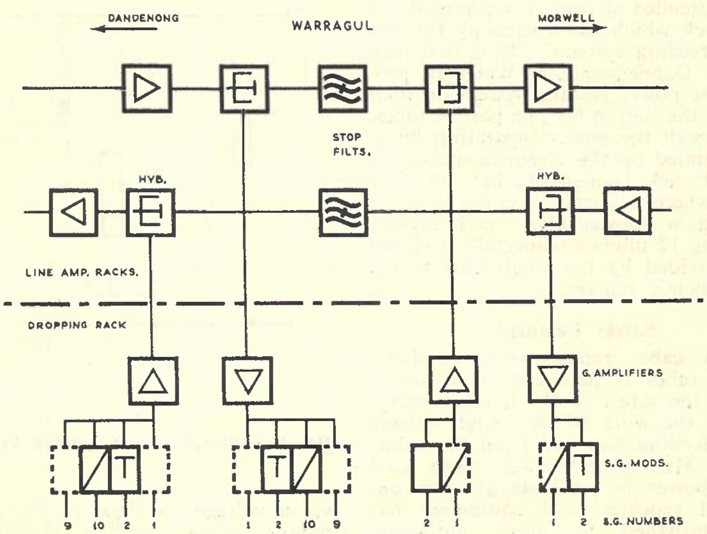


Fig. 15.—Supergroup Dropping Arrangements at Warragul.

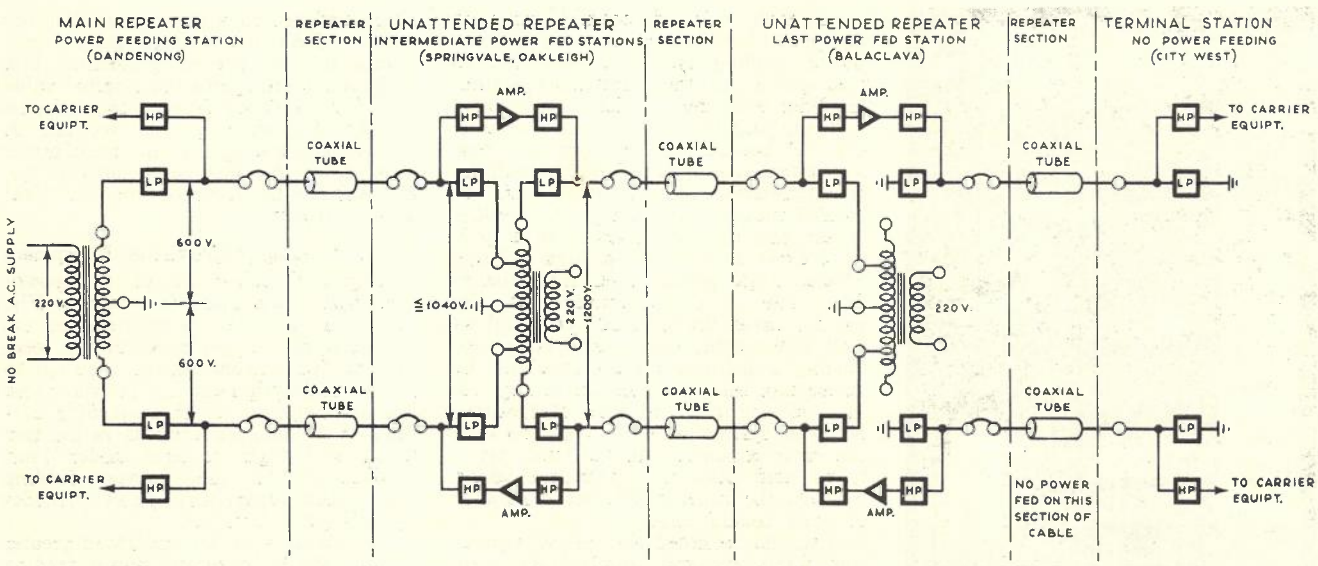


Fig. 17.—Typical Remote Power Feeding Arrangements; Dandenong/City West Main Repeater Section.

a cable or equipment faults or to induction, and (ii) a voltage supply to the station equipment higher than 10% above normal, which could be caused by the disconnection of other stations along the route resulting in a voltage rise. In either event the supervisory equipment places a 2 ohm load on the secondary of the transformer feeding the station where the fault condition is detected. This causes an increase in the power fed from the power feeding station and a resultant disconnection due to the supervisory panel sensing the overload.

At an unattended station, all the equipment for the power supply on a pair of tubes on both sides of the station is mounted on one remote power supply rack. As each pair of tubes is equipped, an additional remote power supply rack is installed. The "first-in" rack, however, contains the order wire and remote supervision equipment for the station.

The remote power feeding equipment at an attended station is accommodated on a rack which has a capacity for two power feeding systems. Thus one rack each at Dandenong and Warragul provides the power feeding system on both sides of the station for one pair of tubes. At Morwell the power separation filters are mounted on the Departmental cable pothead rack framework, but for City West, where a larger number will be involved, a "power filter" rack accommodating 12 filters was specially designed and provided by the Contractor at the Department's request.

Safety Features

When cable repair work involving coaxial tubes is necessary, it is essential for the safety of the linemen carrying out the work to have high voltage power feeding removed from the cable. On the Melbourne-Morwell route local mains power is available at each unattended repeater, and equipment has been provided to allow automatic changeover to the local mains supply

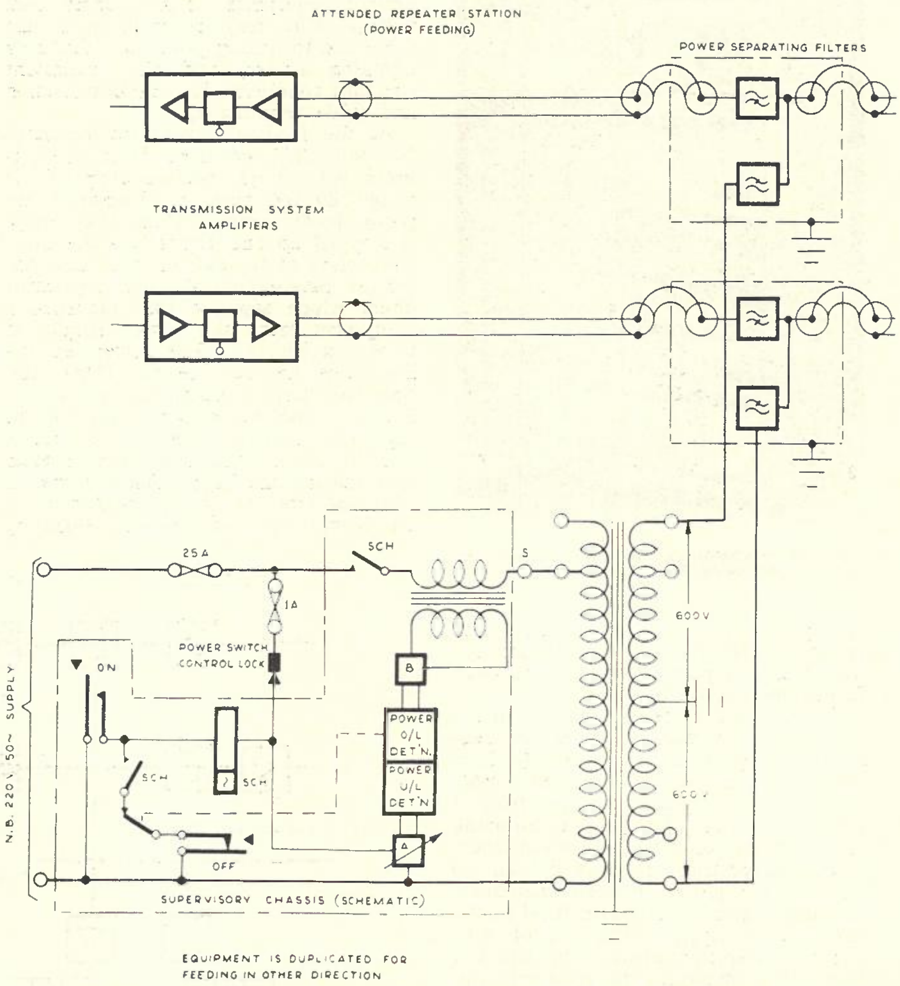


Fig. 18.—Remote Power Feeding System; Block Schematic of Power Feeding and Power Fed Stations.

via a voltage stabiliser in the event of remote power feeding disconnection. Alternatively the equipment will also allow the use of a mobile power feeding plant (Ref. 5). The power feeding racks at Dandenong and Warragul incorporate a power switch lock which prevents the power feeding being connected unless the special key is in the lock. Separate keys are provided for each power feeding system and these keys are not interchangeable. When cable repair operations are necessary, the lineman in charge visits the appropriate power feeding station and requests disconnection of the high voltage power feeding from the cable section where work is to be performed. After disconnection of the power he is handed the key from the power switch lock which he places in a metal box provided at the station and then locks the box with his own padlock. When cable repair work has been completed, including cable tests, the lineman in charge revisits the power feeding station and returns the key to the officer in charge at the station, who proceeds to reconnect the remote power feeding. By this method the high voltage power feeding cannot be accidentally reconnected to the pair of coaxial tubes until field operations are completed.

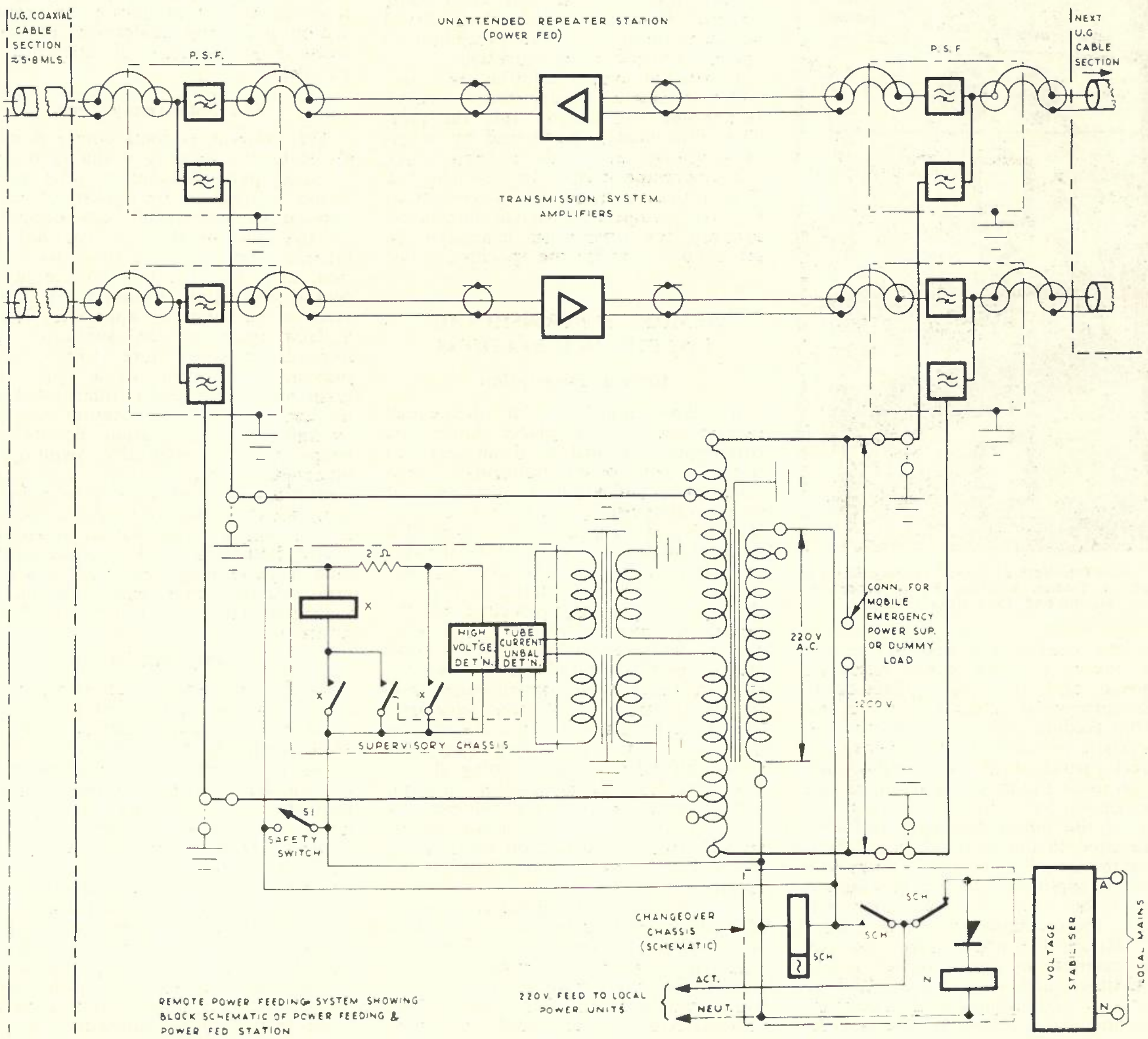
At both the power feeding and power fed stations all the equipment containing high voltage connections has cover plates marked with a red "lightning" symbol. These plates can be removed only with tools. All control elements outside the cover plates marked with the lightning symbol are safe to touch, for example, the supervisory slide-in chassis and fuse panel, which are behind cabinet doors. As an additional precaution, each power rack at unattended repeater stations contains a safety switch which can be used to short-circuit the station supply voltage, so that the supervisory equipment at the power feeding station disconnects the high voltage power feed.

The remote power supply racks for power feeding and power fed stations are shown in Figs. 19 and 20.

Line-up of the Remote Power Feed System

The general method of adjusting the power feed system involves a process which begins at the substation furthest from the feeding station and works back systematically towards the feeding source, adjusting in succession each substation transformer (see Fig. 17) so that the voltage fed to line is always constant (2 x 600V) and the secondary voltage is always 220V.

Before the actual line-up can commence, several preliminaries are necessary at each substation. The local mains supply is switched on from the start and should not be subsequently disconnected. This permits steady operation of the equipment in general and of the valves in particular, by means of the automatic changeover of power facilities, despite the frequent interruptions necessary to the high voltage remote power feeding during line-up adjustment. When the substation local mains supply (regulated to 220V by the constant voltage transformer) has been checked, adjustments are made to the amplifier rack power supply to establish the correct voltages for the equipment. Fur-



REMOTE POWER FEEDING SYSTEM SHOWING BLOCK SCHEMATIC OF POWER FEEDING & POWER FED STATION

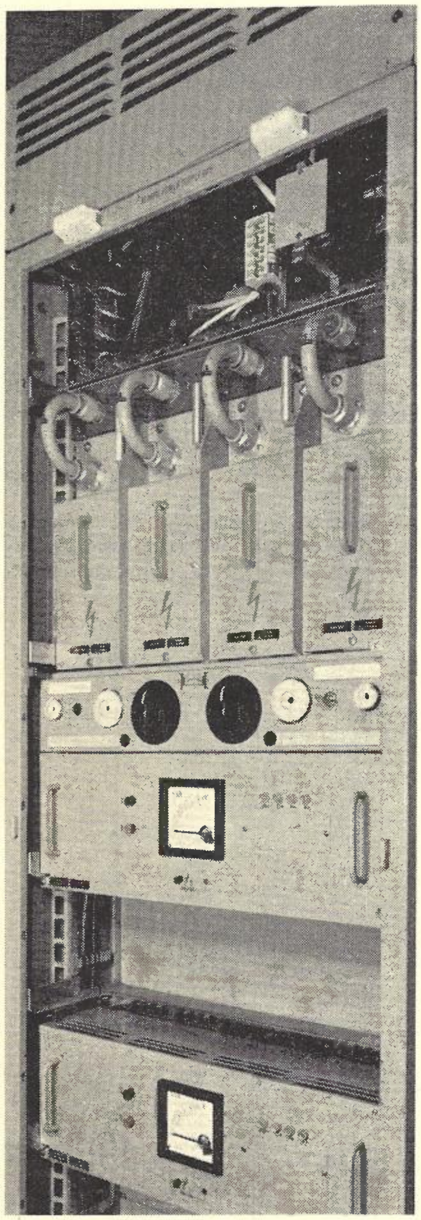


Fig. 19.—Top Half of Power Feeding Rack at Attended Station showing Power Separating Filters and Supervision Panels.

ther, the coaxial U-connectors on the line side of all four power filters are removed, and the "over voltage/unbalance" supervision chassis is withdrawn. At the feeding station, the power feed supervision chassis is first tested for correct operation of the overload protection using the inbuilt checking device. Also, the output voltage from the secondary of the power feeding transformer is adjusted to the nominal value. With the substation line connectors removed, power is applied to the first feeding section of the cable. At the nearest substation, the incoming voltage is checked for balance, the appropriate links are then inserted to apply power to the transformer, and the resultant 220V is measured and adjusted if necessary. The on-going voltage is checked for balance and then the other two line connectors are inserted to apply power to the next cable section. This procedure is repeated at each station.

Beginning at the distant end power fed sub-station in the particular power feeding section, the process of correcting the transformer tappings can now proceed. Referring to Fig. 17 as a typical example, and designating the power feeding station as Number 1, and successively numbering the Substations 2 to 4, the following is the line-up procedure:

At Substation 3, the substation immediately preceding the most remote power fed substation, the primary of the high voltage transformer is set to give 2 x 600 volts outgoing to line. At Substation 4, the secondary is set to give 220 volts. The next step is to set the primary at Substation 2 to feed 2 x 600 volts to line, followed by readjustment, if necessary, of the primary at Substation 3 to maintain the output at 2 x 600 volts. The secondary at Substation 3 is now set to 220 volts, and so the process continues back to the feeding station. Moving-iron voltmeters should be used throughout this procedure to ensure accuracy of measurement.

Finally, at each substation the "over voltage/unbalance" supervision chassis is adjusted and inserted into the rack. The adjustment is performed by means of a special testing device into which the supervision chassis can be plugged. This device simulates various conditions of over voltage and current unbalance, enabling the supervision chassis to be set to operate within the specified limits.

REMOTE SUPERVISION OF UNATTENDED STATIONS

General Description

All line equipment at unattended repeater stations is placed under the continuous supervision of an attended station. This system transmits, over a cable pair, indications in the form of 50 c/s A.C. pulse telegrams from a "substation" unit located at the unattended repeater station to a "central station" unit located at an attended repeater station or terminal station. Fig. 21 shows the operating principle of the remote supervision system. The substation units and the central station unit contain step-by-step selector switches which run in synchronism during the transmission of pulse telegrams. The pulse telegrams contain the indications to be transmitted, beginning with an identification of the sending station from the first set of contacts (station identification contacts) and followed by identification from the second set of contacts (fault identification contacts) of the fault or unstandard condition at the unattended station.

Circuit safeguards prevent the display of false information due to non-synchronous stepping of the selectors or simultaneous sending of pulse telegrams from two or more stations on the route, which would mask each other. The pulse telegram is received by all other substations and is used to block the substation units from sending pulses until the transmission path is clear again. Any indications about to be transmitted are stored and transmitted subsequently; time delay circuits set for different periods at each station ensure that, should there be more than one station waiting to send a telegram, they transmit their telegrams in sequence.

Each central unit can cater for either 10 substations each sending 25 signals, 11 stations each sending 24 signals, or 12 stations each sending 12 signals. On the Melbourne-Morwell route the panels are arranged to cater for 11 stations; with this arrangement, it is necessary to leave the first fault position on the indicator panel blank.

The basic remote supervision system requires two cable pairs, one pair being for an indicating line and the other for a supervisory line.

The Indicating Line

This is in effect a party line, and is used to send the 50 c/s pulse telegrams from the substation units to the central station indicating equipment, of which more than one may be connected in parallel.

The Supervisory Line

This is used to continuously monitor the state of readiness of the substations to send pulse telegrams. The supervision is arranged by sending 50 c/s at approximately 18 to 50 volts, depending on the line length from the last unattended station in the supervision section, and receiving this voltage at the central controlling station to operate a relay in the indicating apparatus. Should a fault occur at any substation, for example, power failure, which would prevent transmission of a pulse telegram, the 50 c/s feed is interrupted and the central controlling station responds by lighting all the station identification lamps and automatically sending an interrogation signal. This causes all substations to send a pulse telegram in turn, which extinguishes the associated station lamps. The station where the power failure has taken place cannot send a pulse telegram, and the appropriate station lamp remains lit on the indication panel to identify the faulty substation.

Interrogation

So that the central station can make a check of the unattended stations, an interrogation signal consisting of a long pulse (approximately 1,500 m.s.) of 50 c/s is sent from the central station to initiate the sending of pulse telegrams from the substation units. A time delay circuit, which is set for a different period at each substation unit, ensures that the indicating pulse telegrams are sent in sequence from unattended stations. The interrogation signal is sent automatically on failure of the supervisory line, and also on reconnection of power at a central station following a power failure at the central station. A push button key allows for manual operation of the interrogation when required.

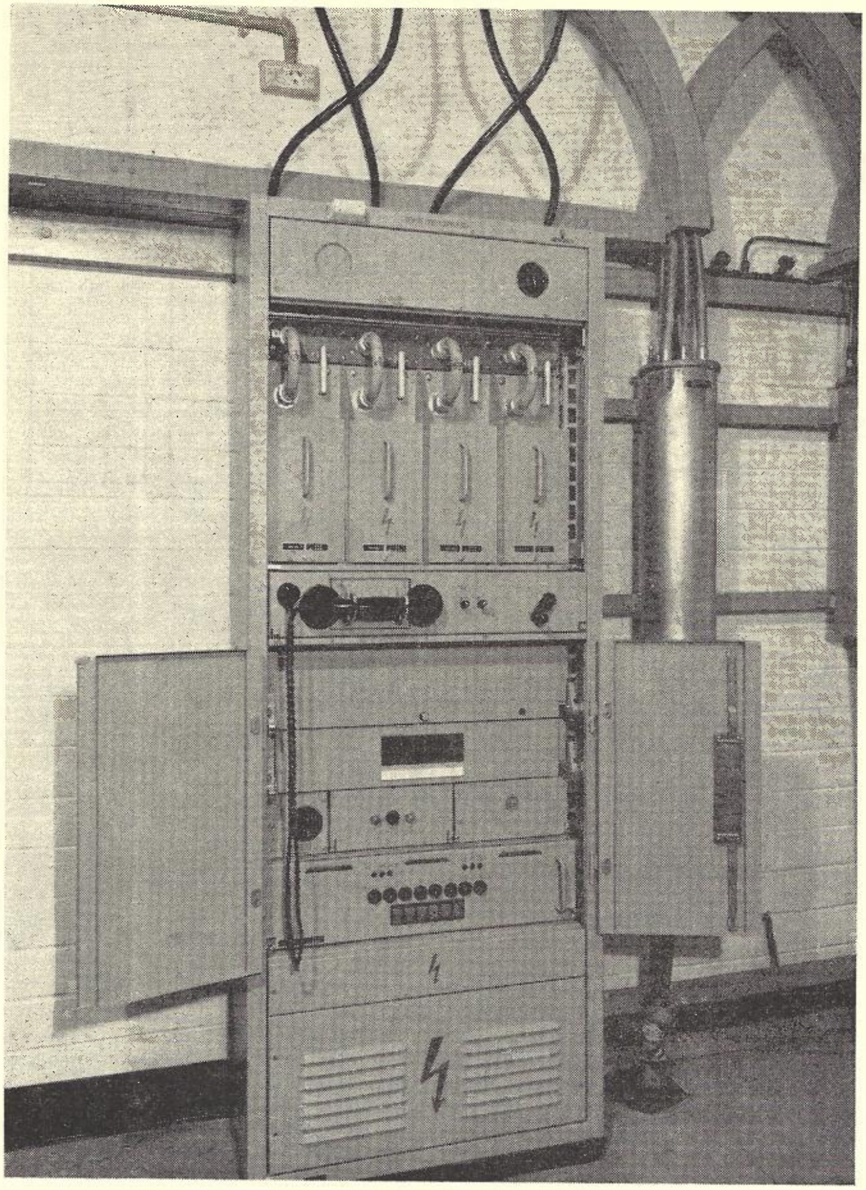


Fig. 20.—Remote Power Supply Rack at Power Fed (Unattended) Station.

Transmission and Evaluation of Impulse Telegram

Each item of equipment at an unattended station requiring alarm extension facilities, is equipped with a relay which extends an earth under fault conditions to a contact of the selector device, and initiates the start condition which results in stepping of the selector and application of pulses of 50 c/s to the indicating line. These pulses are received by the central station monitoring equipment where a selector steps in synchronism with the substation selector. At each step, the selector switch at the substation tests a contact. Should there be an earth present on the contact, the pause before sending the next pulse is lengthened from the normal 60 m.s. to 210 m.s. At the central station, this lengthened pause is sufficient to allow the release of a relay which holds over the normal 60 m.s. interval. This results in operation of the G or P relay connected to the contact of the selector on which the wiper is resting, thus allowing evaluation of the calling station and fault condition. A typical impulse telegram is shown in Fig. 21 in which station 2 has sent fault condition 3.

For station identification, an earth is permanently connected to the station identification contact assigned to the particular station.

Alarm Extension Details

The following alarm conditions are sent from the unattended repeater stations to the central monitoring stations on the Melbourne-Morwell coaxial cable route:—

1. Repeater hut door open
2. Remote power supply fail
3. Local mains supply fail
4. Signal voltage fail
5. Anode or heater voltage fail
6. Valve fail A-B direction
7. Valve fail B-A direction
8. Pilot fail A-B direction
9. Pilot fail B-A direction

Testing and Lineup of Remote Supervision

This consists of the adjustment and measurement of time delays on each substation and central unit, followed by correct adjustment of the 50 c/s voltages on the indicating and supervision line and check of overall transmission of impulse telegram trains.

In testing the substation units, the various time delays necessary for correct operation of the equipment are measured on a pulse recorder at test links specially provided. The desired time delays on the pulsing relays are obtained by suitable adjustment of associated variable resistors.

The 50 c/s transmitting voltage for pulse transmission and supervisory line is determined by the voltage drop on the lines between the stations to be supervised. It can be adjusted to any value between 18 and 50 volts A.C. The lowest possible value is chosen in each case to minimise interference with other circuits on the same route. At each station the transmitting voltage should be adjusted so that a voltage of approximately 6 volts A.C. (operating voltage of the receiving circuits) is received at the station on the line most distant from the sending station.

Following adjustment of the substation units and transmitting voltages at all stations, a record of the indicating telegrams is made at the central station on a pulse recorder and the pulse sequence of a telegram from each substation is checked for correct "on" and "off" times. This provides an overall check of the line which includes the send equipment, pulse repeaters and the receiving relay. At the time the indication telegram is recorded on the pulse recorder, it is evaluated simultaneously by the central station unit.

The pulse recorder used for these tests is a Siemens and Halske twin-track tape machine running at a constant speed of 0.25 m.m. per milli-second. The actual on/off time of each impulse is therefore directly proportional to the length of the recorded impulse and can be measured on the tape recording. A typical pulse telegram is shown in Fig. 21.

ROUTE REMOTE SUPERVISION AND POWER FEEDING LAYOUT

In the initial planning and engineering of the system it was necessary to determine a remote supervision and power feeding layout which would be the most suitable for this particular route. Firstly, a general rule applied that from maintenance considerations, the remote supervision and power feeding sections should coincide. Consideration then had to be given to the implications of power feeding on no-break

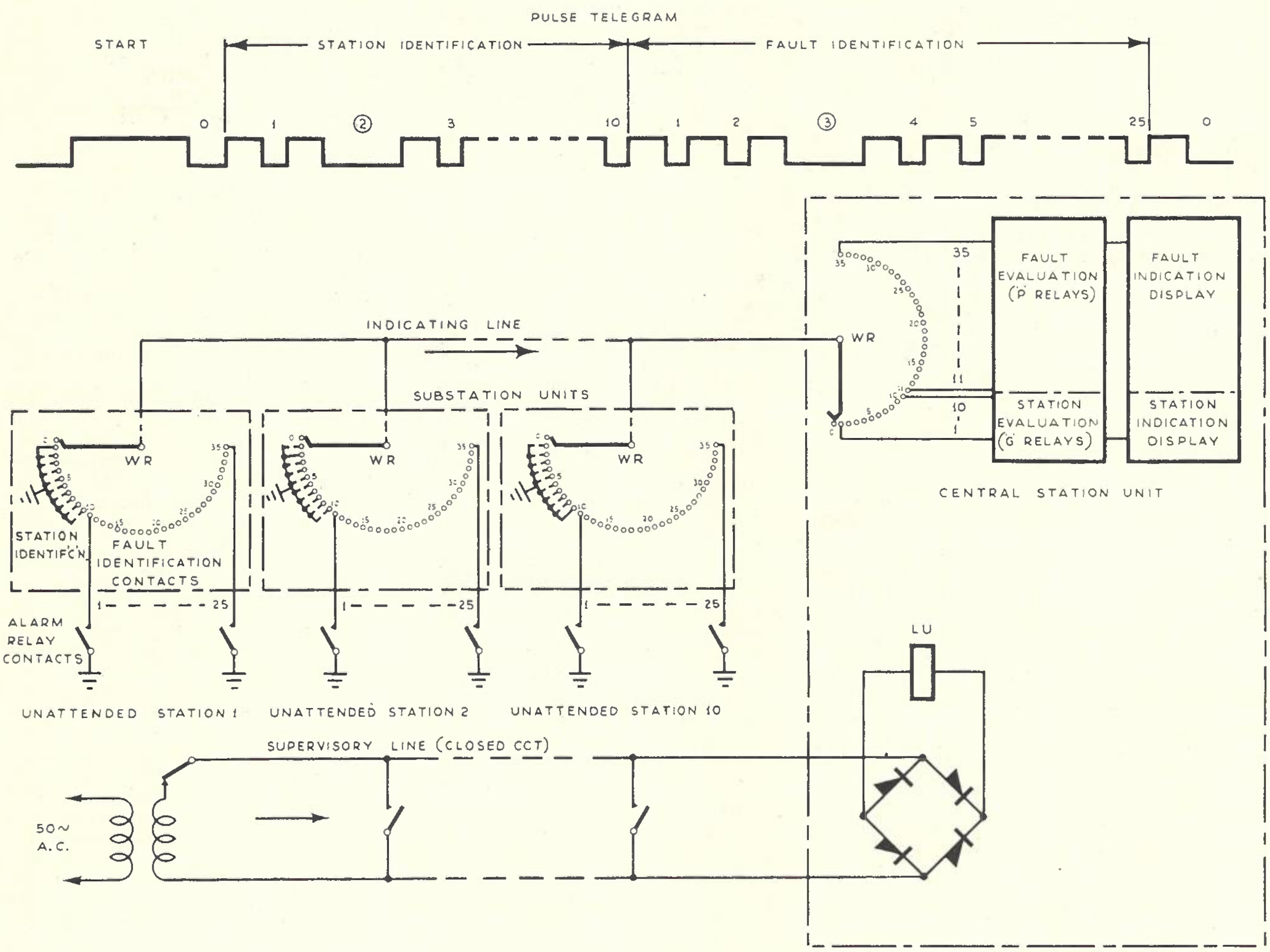


Fig. 21.—Principle of Operation of Remote Supervision System.

A.C. power plant requirements, and to distance limitations of the remote supervision and order wire systems. A particular problem on this route was that between Dandenong and Morwell, it was desired to retain all the paper-insulated 20 lb/mile interstice and core pairs of the 4 tube coaxial cable for short-haul carrier working, leaving only 10 lb/mile pairs of the 80 pair layer for remote supervision and order-wire circuits. Also it was not desired to install amplifiers for the order wire circuits in other than the four attended stations.

The arrangement which was finally adopted is shown in Fig. 3. This arrangement, with the use of parallel 10 lb/mile pairs for remote supervision and short haul order wire between Dandenong and Morwell, provided a very satisfactory solution with minimum outlay of equipment. Division of the Dandenong-Warragul section between Pakenham East and Nar Nar Goon will allow Pakenham East, a probable future dropout station, to be established as such, when required, with its repeater equipment still power fed from Dandenong. It is expected that by the time this is done all terminal equipment will be available in transistorised form allowing battery operation, so that no-break A.C. power plant should not be required at Pakenham East. The short-haul order wire unit at Pakenham East at present requires to be switched towards either Dandenong or Warragul as required. However, when a second remote power supply rack is installed at Pakenham East at a later stage for the second pair of tubes, a second order wire unit will also be installed to allow permanent connection to both end stations of the main repeater section.

The arrangement adopted also provides overall supervision of the whole route from City West, using two central station equipments installed in the one rack at City West and connected in parallel to the central stations at Dandenong and Warragul respectively.

The numbers of cable pairs used for the remote supervision and order wire arrangements provided, are shown in Table I.

TABLE I

Route Section	Remote Supervision (unloaded cable pairs)	Order Wires (loaded cable pairs)
City West-Dandenong	5-20 lb.	3-20 lb.
Dandenong-Pakenham East	8-10 lb.	
Pakenham East-Nar Nar Goon	4-10 lb.	4-10 lb.
Nar Nar Goon-Warragul	6-10 lb.	
Warragul-Morwell	4-10 lb.	

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2. C. H. Hosking, "Installing the Melbourne-Morwell Coaxial Cable"; ibid, Vol. 12, No. 6, page 402.

3. J. R. Walklate, "Broadband Telecommunication Systems — Part 5. The Transmission of Telecommunication Traffic over Broadband Bearers"; The Journal of the Institution of Engineers, Australia, Vol. 33, No. 6, page 224.

4. J. R. Walklate, "The Sydney-Melbourne Coaxial Cable Project: Design of Transmission Equipment"; The Telecommunication Journal of Australia, Vol. 13, No. 3, page 245.

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TECHNICAL NEWS ITEM

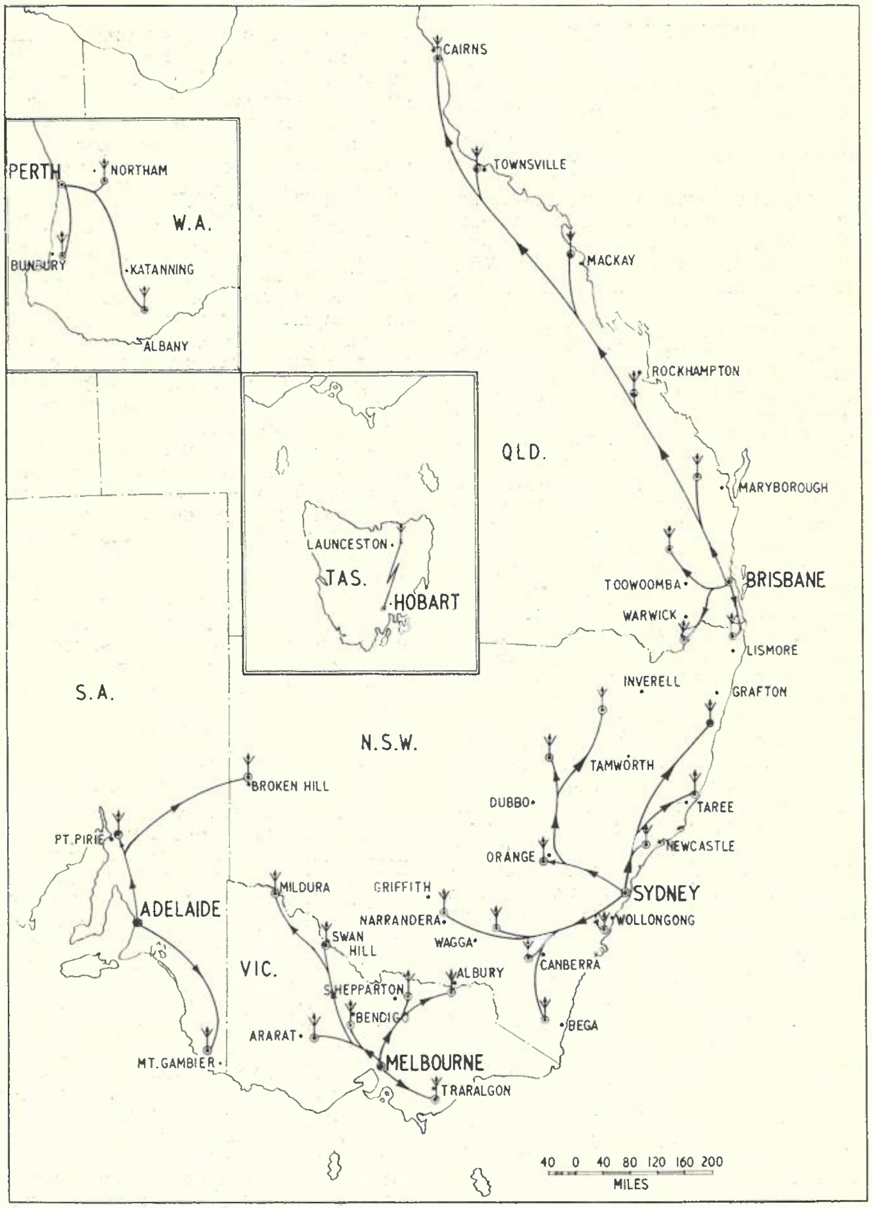
LONG-DISTANCE TELEVISION RELAY

Work is already in hand in the Australian Post Office to connect the Australian Broadcasting Commission's television studios to the 13 National television transmitters proposed under Phase 3 of television expansion in Australia for completion over the period 1962-1964. Information on the relay facilities for that Phase was given in an article in the October, 1961 issue of this Journal.

The Post Office is now preparing detailed plans to provide television relay facilities from A.B.C. capital city studios to the 20 further stations proposed under Phase 4 of the programme, with a view to completion over the period 1964-1966. While the provision of relay facilities is a general objective, it is possible that local studios' facilities will be provided initially in a few instances. The initial plans generally provide for several transmitters to be connected to a common programme source for reasons of economy, but with independent relays serving different groups of stations in each State (see figure). This arrangement will provide some facilities for independent regional news and other programmes, if required. The following table shows the facilities proposed for both Phases of the programme:

A.B.C. TV Studios	Route	Serving Transmitters near
Sydney	South	Wollongong, Canberra, Bega, Wagga, Narrandera / Griffith (5 stations).
	West	Orange, Dubbo, Tamworth (3 stations).
	North	Newcastle, Taree, Grafton (3 stations).
Melbourne	North-west	Ballarat, Bendigo, Swan Hill, Mildura (4 stations).
	North	Shepparton, Albury (2 stations).
	South-east	Latrobe Valley (1 station).
Brisbane	West	Toowoomba, Warwick (2 stations).
	North	Maryborough / Bundaberg, Rockhampton, Mackay, Townsville, Cairns (5 stations).
	South	Lismore/Tweed Heads (1 station).
Adelaide	North	Port Pirie, Broken Hill (2 stations).
	South-east	Mt. Gambier (1 station).
Perth	East	Northam, Albany (2 stations).
	South	Bunbury (1 station).
Hobart	North	Launceston (1 station) (by off-air pick-up: not relay).

Total: 33 stations.



The long-distance facilities will, with one exception, be by microwave line-of-sight radio systems to which it will be possible to add equipment to provide trunk circuits for the telephone network where required. The exception will be the Perth-Bunbury link, which will be provided by a vestigial sideband system over a coaxial cable. The relay systems will be planned as an integral part of Australia's trunk network. In capital cities, the television relay channels between studios, television switching centres and radio relay terminal stations will be coaxial underground cables, also co-ordinated with the telecommunications network.

AN AUTOMATIC TRAFFIC RECORDER

R. SMITH,* M.E., Grad.I.E.E., A.M I.R.E.Aust.

INTRODUCTION

To date, the measurement and recording of traffic within automatic telephone exchanges in the Australian Post Office has been by means of manually-operated equipment. This paper describes an automatic recorder which can be used in conjunction with the existing equipment to facilitate these measurements. The results are punched out on paper tape in any desired five unit code. With telegraph code, subsequent page-printing is possible.

Telephone traffic in automatic exchanges is measured by current summation of the battery supply using resistors connected to bimotional switch private wires. The existing equipment used for traffic measurement, which is described in Ref. 1, employs a recording process which is both slow and tedious. It requires an operator to manually select the group of switches to be observed, to read at regular intervals the number of switches busy as indicated on a meter, and to record these results by hand. It is possible to provide an automatic stepping of the recording equipment over groups of switches via a motor uniselector, but the reading and recording must still be performed by the operator.

An automatic recorder has been developed which will perform this function in one half-second, punching the results on paper tape, and also giving a signal which steps the motor uniselector of the manual equipment to the next group of switches. It will continue this sequence of read, punch and step until a stop signal is obtained from the last position of the uniselector. An automatic start facility is included in the equipment, allowing the recording cycle to be restarted every three minutes. This provides that up to 350 groups can be read in one three-minute period, the recorder then stopping, and restarting to re-read the same groups, at the beginning of the next three-minute interval.

In principle, the function of the recorder can be divided into two parts, a measuring and read-out function, and a control function. A block diagram is shown in Fig. 1. The actual measurement is performed by a digital voltmeter, (Solartron type LM901), which measures the voltage developed across a small resistor connected in series with the exchange equipment. This voltage is a measure of the traffic flowing, and is encoded and fed to a five hole parallel punch, (Creed Model 25 Mk IV). The control circuitry provides the timing sequence necessary for the operation of this equipment. It should be noted that the results are presented in such a way that they can be fed directly to a digital computer for processing. When telegraph code is used, subsequent page-printing is possible.

The prototype recorder, shown in Fig. 2, is built into an equipment 13 inches square by 33 inches high, and is mounted on castors to provide mobility. The punch is seated on top of the unit, and can be removed for transport. Included in the circuitry (excluding the voltmeter and encoding matrix) there are 40 transistors and 53 diodes. For telegraph code, an additional 27 diodes are required. 15 high-speed relays are also included. No expensive or critical components are used.

OPERATION

Measurement of Traffic:

In the exchange, a 510 k-ohm resistor is connected to each switch in a group whose traffic is to be measured. Fig. 3 shows that when the switch is operated, one end of the resistor is earthed via the private, the free ends of the resistors being tied together and connected to the exchange battery via the small resistor in the automatic recorder. The total current then flowing from a group will be approximately n.52/510 mA — i.e. approximately n/10 mA, where n is the number of operated switches in that group. The small resistor in the automatic recorder carries this current when the group is being read; its value (approx. 100 ohms) is adjusted so that the voltage developed across it is 10 mV for each operated switch. The voltmeter reads in steps of 10 mV, hence the voltmeter output will be a direct reading in Erlang. The resistor is variable over a small range to provide calibration, allowing for variation of the exchange battery voltage.

* See page 349.

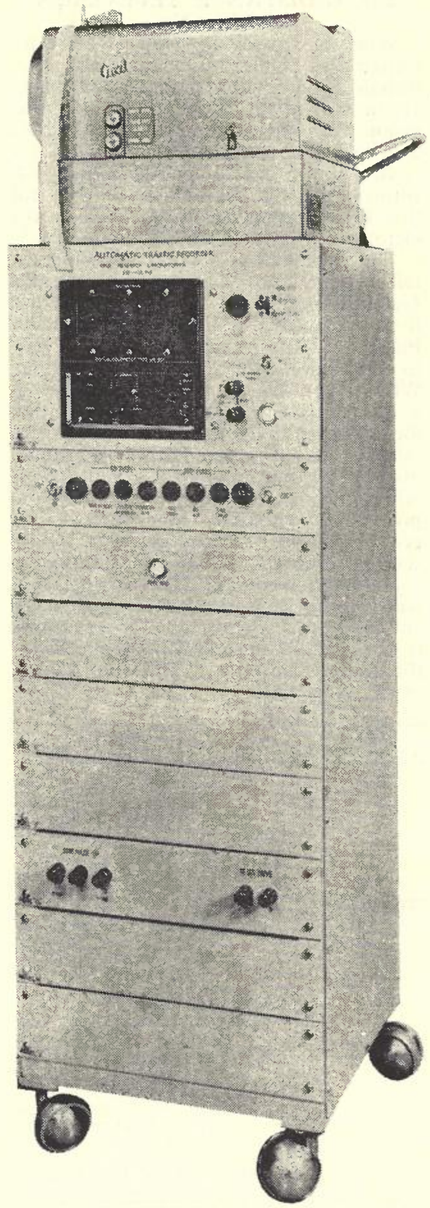


Fig. 2.—The Automatic Recorder.

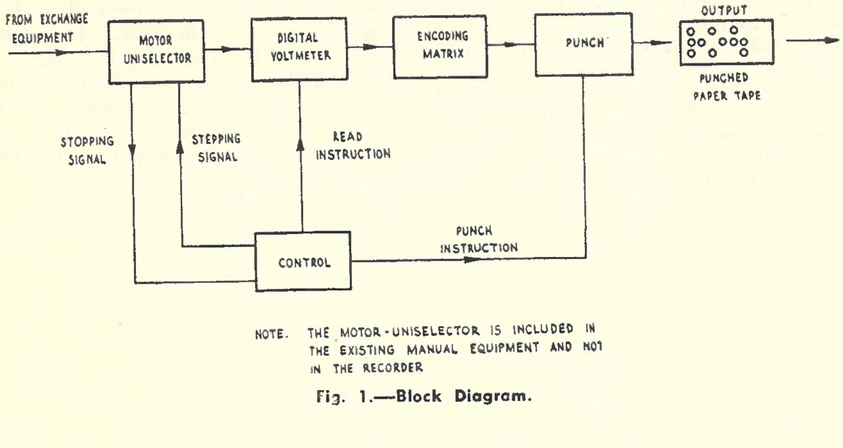


Fig. 1.—Block Diagram.

Encoding and Print-Out:

The digital voltmeter output is presented in decimal form on three groups of ten wires. The wires representing the given output are indicated by relay contacts inside the voltmeter which connect them to a common return lead. A lamp display originally provided has been discarded.

The corresponding output wires are paralleled for the hundreds, tens, and

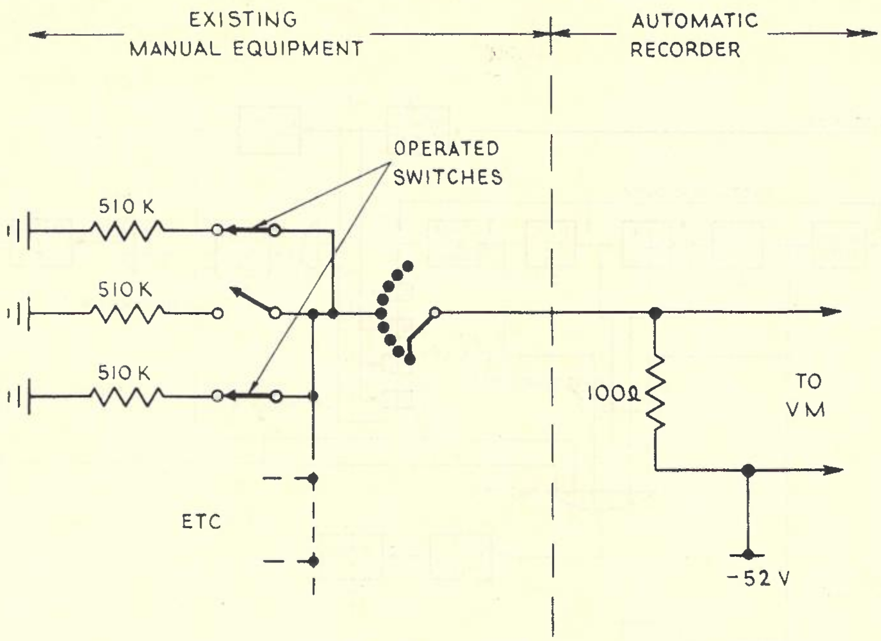


Fig. 3.—Measurement of Traffic.

units groups; seaparate sequentially switched relay contacts select the required group when the voltage is actually being printed. This is performed in the order, hundreds, tens, units, and space, (the space providing a gap between successive readings). Fig. 4 shows the voltmeter output circuitry, the encoding matrix, and the slave relays, which in turn operate the punch. The matrix is shown connected for WREDAC code, although any other five unit code may be used, providing the code elements are binary in nature. (WREDAC is a digital computer operated by the Department of Supply in South Australia).

Two matrices have been provided with the prototype model, one wired with WREDAC code, the other in Telegraph code. They are connected on a plug-in basis.

The Control Circuitry:

A block diagram of the control equipment is shown in Fig. 5. A sequence diagram is shown in Fig. 6. The basic components are a half-second oscillator, a control bistable multivibrator (flip-flop), and chain of monostable multivibrators (monos). In addition, for operation with telegraph code, a 16's counter is incorporated, (this is treated in more detail later in this section).

The oscillator is an asymmetrical astable multivibrator which provides a positive going pulse every half-second, which can be considered as the time origin to which every other operation in a read/punch cycle can be referred.

The control flip-flop, when set by a start signal, enables positive pulses to be transmitted from the oscillator to the chain of monos; when reset, it inhibits these pulses. Hence the operation or non-operation of the control equipment depends on the state of this flip-flop. It can be set manually, using the Manual-Step key, or electrically by a pulse initiated by the last position of the uniselector.

The Read mono is triggered by the positive going trailing edge of the oscillator output pulse. Relay A is normally held operated and is released during the pulse period of the mono. This is adjusted to 15 msecs. The relay change-over contacts are connected to the external sampling circuitry of the digital voltmeter, and hence the operation of this mono is an instruction to the voltmeter to commence reading the voltage applied to its terminals.

The voltmeter requires at least 280 mS delay after the read instruction is given before the result is presented; this is provided by a 300 mS delay before any further action is taken. This delay is devised from a similar mono triggered by the positive going trailing edge of the Read pulse.

The 300 mS delay mono is followed by a chain of four 35 mS monos entitled "set 100's", "set 10's", "set 1's" and "set space", each mono being triggered by the positive going edge of the output pulse of the previous mono. This is most clearly shown in the sequence diagram (Fig. 6). The first three of these monos present the hundreds, tens, and units groups of the voltmeter output to the encoding matrix in turn, (see Fig. 4). The fourth sets up the space code on the matrix.

Simultaneously with these last operations, the Punch Delay (5 mS) and the Punch (25 mS) monos operate. The punch delay mono is triggered by the positively going trailing edge of each of the output pulses of the 300 mS delay, the set 100's, the set 10's, and the set 1's monos, via OR Gate 2. This provides an instruction to the tape punch to operate at a time centrally situated in the "set" periods, thus punching out the required information.

At the completion of the 300 mS delay, the voltmeter has the required voltage stored at its output, and the

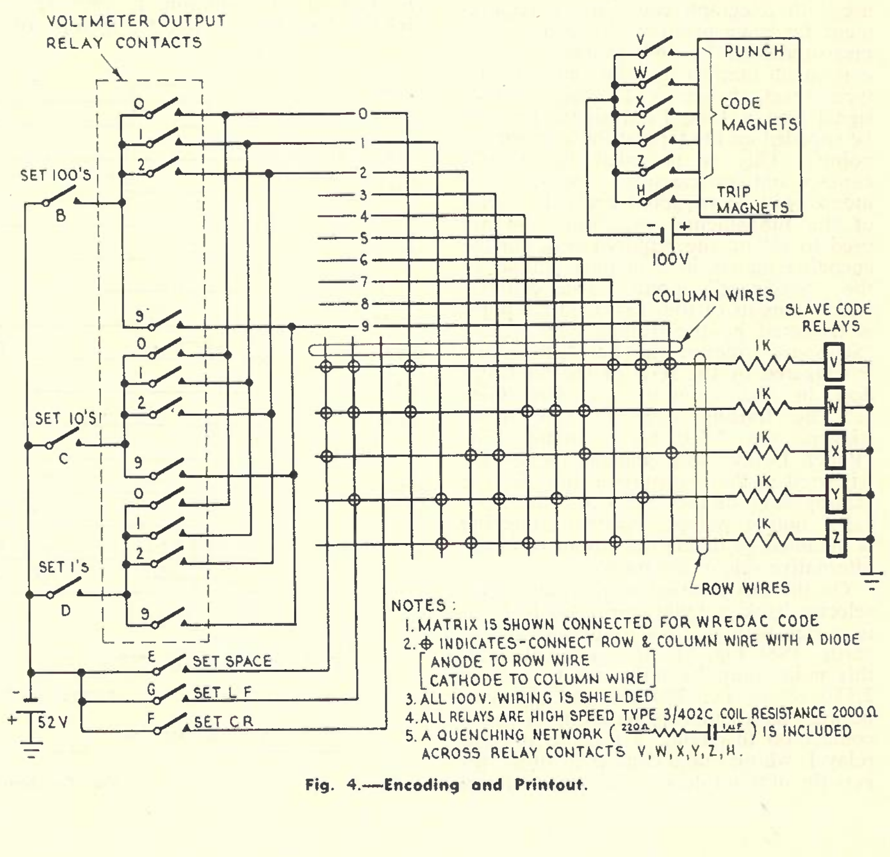


Fig. 4.—Encoding and Printout.

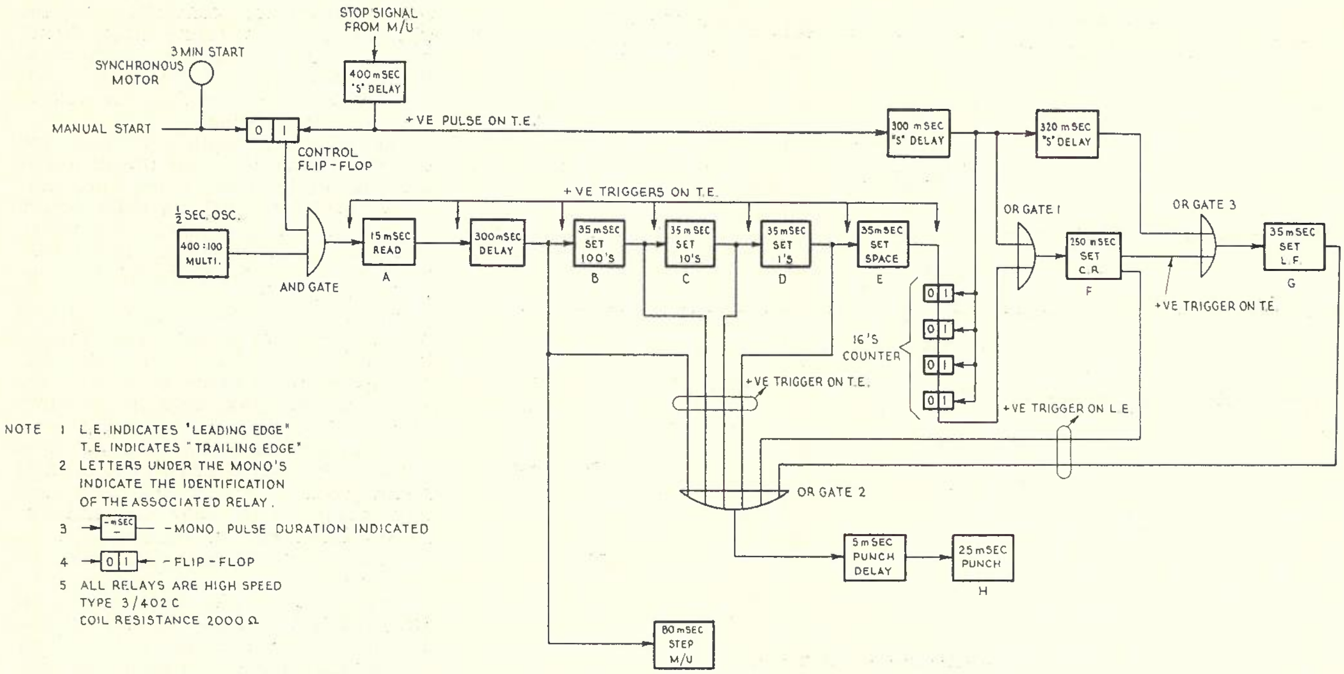


Fig. 5.—Block Diagram of the Control Equipment.

motor uniselector may be stepped to its next position. The voltmeter output will not change until the next read instruction is given. The "Step M/U" mono is triggered from the trailing edge of the 300 mS delay output pulse, and is adjusted so that the pulse duration is 80 mS.

The remaining circuitry is mainly for use with telegraph code, and a requirement for page printing. Sixteen voltage measurements, i.e. 64 characters, is a convenient number to print across a teletype sheet, hence a Carriage Return signal and a Line Feed signal have to be encoded on the tape at the appropriate points. This is provided by a 16's counter and two cascaded monos. These monos will be triggered every 16 cycles of the fundamental oscillator, and are used to set up the required code on the encoding matrix in a manner similar to the "Set-Space" mono. The counter, which consists of four cascaded flip-flops, is triggered by the trailing edge of the "Set-Space" mono; the Set C.R. mono is triggered by the reset of the final flip-flop in the counter, via OR Gate 1. The trailing edge of this mono triggers the "Set L.F." mono. The "Punch Delay" and "Punch" monos are triggered at the appropriate times by the leading edge of the "Set C.R." and "Set L.F." output pulses. Positive triggering is obtained by taking the output from the alternative side of the mono.

On the last position of the motor uniselector bank, a 1,000 ohm relay is wired in series with a 1,500 ohm resistor, to earth. (See Fig. 7). If it is so desired, this point may be built out to exactly 2,550 ohms, i.e. 200 erlangs, and can be used as a calibrate position. A make contact on this relay is used to operate relay L whose make contact in turn triggers the 400 mS delay. This delay allows the voltage appearing at the uniselector contact to be read before the recorder is stopped. The trailing edge of this mono output pulse resets the control flip-flop, and also triggers a further delay of 300 mS. This allows the last voltage information to be punched out. The trailing edge of this mono in turn triggers the "Set C.R." and "Set L.F." monos via OR Gate 1. In addition, to provide a division between consecutive groups of readings, an additional Line Feed is included. This is obtained via a 320 mS delay, OR Gate 3, and the "Set L.F." mono.

Because of the uncertainty of the delay incurred by the motor uniselector (M/U) stepping circuits in the existing manual equipment, the "stopping" monos have been adjusted to allow for a maximum delay of 150 mS between the commencement of the Step M/U pulse, and the

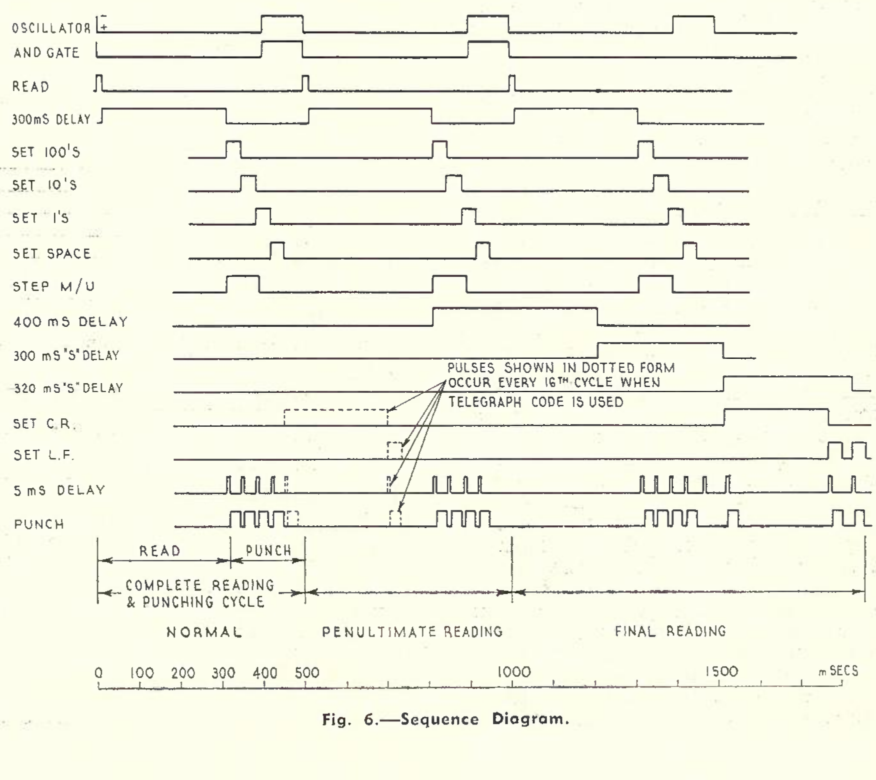


Fig. 6.—Sequence Diagram.

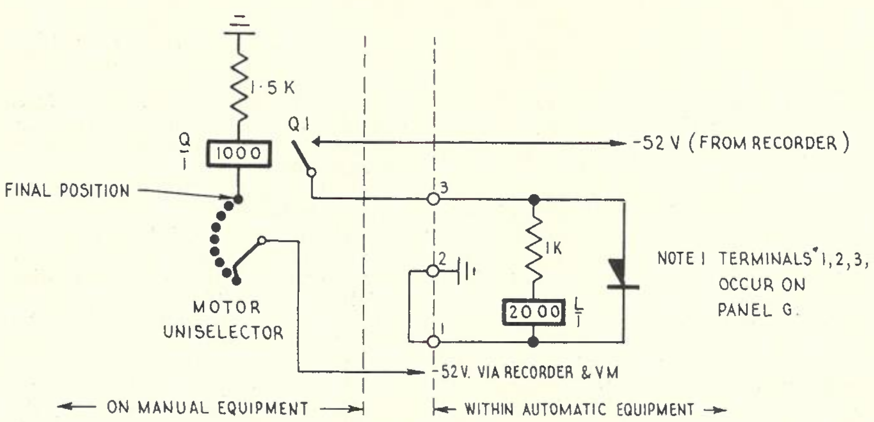


Fig. 7.—Stopping Circuit.

triggering of the 400 mS "stop" mono on the last position of the M/U. The pulse duration of the "Set C.R." mono has been adjusted to 250 mS to offset the effects of this variation in the case where the number of positions of the M/U is an exact multiple of 16; in this case the counter will trigger the "Set C.R." mono, the pulse received from the stopping circuit, will arrive during the set period of this mono, and hence it will be ineffective. The additional "Line Feed" will be obtained from the stop pulse via the 320 mS delay, as usual.

At the completion of the 300 mS "stop" delay, the 16's counter is reset, preparing it for the commencement of the next train of pulses. The counter is also reset when the "Manual Stop" key is thrown.

Where it is desired to use a code other than Telegraph, it is possible to use the "Carriage Return" and "Line Feed" equipment to provide some other facility. For example, when using WREDAC code, both inputs to the "Set C.R." mono are disconnected and earthed. (This connection is actually effected when plugging in the appropriate encoding matrix). The Set L.F. mono can now be connected to the matrix in such a way that an encoded Z is punched out. This Z will occur only at the end of a group of readings; WREDAC will recognize the Z as such and can act accordingly.

The three minute automatic start provision consists of a microswitch operated by a cam revolving one revolution in three minutes. The cam is geared down from a synchronous motor, hence operation from 50 cycle mains is desirable, rather than from an engine driven alternator, or equivalent.

The motor uniselector stepping is obtained by applying battery, via the contacts of relay K in the "Step M/U" mono, to a relay in the manual equipment, relay K taking over the function of the "Manual Step" key in this equipment. Due to the heavy contact loading of the latter relay, and the operating time of the remainder of the uniselector stepping circuit, it is necessary for the "Step M/U" mono to have a pulse duration of at least 80 mS. If it is required that the uniselector should drive over busied out contacts, then it will be necessary to increase this. 150 mS is the maximum allowable pulse duration.

EXTENDED MEASURING PERIOD

The basic measuring cycle of the equipment occupies three minutes. If, however, it is desired to measure more than the 350 groups readable within the three minutes, then it is possible to operate on a 3.n minute cycle, where n is an integer. The basic cycle relies on a stop signal being received during the cycle, the synchronous motor restarting the equipment at the end of the period. If a stop signal is not obtained during the cycle, then the equipment will continue to function, the automatic start being rendered ineffective as the control flip-flop is already set. If a stop signal is received after $3n + x$ minutes, say, where $x < 3$, then the equipment will stop, restarting at the next whole multiple of three minutes, i.e. after $3(n + 1)$ minutes from the commencement of the reading.

This facility allows any number of groups to be read in one reading cycle. However the time taken is increased in rough proportion.

POWER SUPPLIES

The automatic recorder is operated from the 52 volt exchange battery and the 230 volt A.C. mains. The mains supply drives the voltmeter, the synchronous motor and the punch motor. The exchange battery is fed via a noise filter to the transistorised equipment and the encoding matrix. The stepping relay of the manual equipment is also driven from the filtered battery.

A separate isolated 100 V. D.C. supply is derived from the mains supply to operate the punch magnets.

CONCLUSION

A device has been developed which, in conjunction with existing manual equipment, will automatically record up to 350 traffic groups within a three minute period in a conventional telephone exchange employing electromechanical switching. These results are obtained periodically and are punched out on paper tape in any five unit code desired. The maximum reading obtainable is 999 Erlang.

ACKNOWLEDGMENT

The Author wishes to acknowledge the work of Mr. F. W. Arter of the P.M.G.'s Research Laboratories, who was responsible for the initial design of this equipment.

REFERENCES

1. L. M. Wright, "A Direct Reading Traffic Recorder"; Telecommunication Journal of Australia, Vol. 10, No. 2, page 51.
2. I. A. Newstead, "Review of Telephone Traffic Engineering — II"; Telecommunication Journal of Australia, Vol. 13, No. 1, page 38.

Errata Vol. 13, No. 3

Page 166, 6th paragraph:

"N.V. Phillips Telecommicatie Industrie" should read "N.V. Philips Telecommicatie Industrie".

Page 186, last paragraph:

"1032 tube joints" should read "10032 tube joints".

VIBRATION TESTING

*H. L. C. READ.**

INTRODUCTION

Electronic equipment, by its very nature, contains large numbers of components and very large numbers of soldered joints. Unless each of these is perfect trouble can occur. A perfect soldered joint has a very low and very stable resistance value but an imperfect or dry joint has a higher and generally unstable value of resistance. Dry or imperfectly soldered joints are also mechanically unstable and any vibration at all can cause movement which results in variations of the resistance of the joint. This variation of joint resistance is effectively a variation of circuit resistance which can cause unwanted variations of signals passing through the circuit.

Because factory operatives and inspectors, and field inspection, operating and supervisory staff are human, some imperfect joints do occur and do pass inspection. These joints are very difficult to detect when they are newly made because the joint between the mating metal surfaces is new, clean, and tight. However, with the lapse of time, corrosion products form and the mechanical stresses are relaxed. This results in the joint resistance becoming higher and less stable as time goes on.

Many intermittent faults can be attributed to dry joints as every technician and lineman knows but they are extremely difficult to find by deductive fault finding means because they are intermittent.

VIBRATION TESTING

Since variation of dry joint resistance causes variation of signal strength in the circuit, it can be looked on as a modulating element which impresses on a steady state signal a modulation or variation at the frequency of variation of the joint resistance. A technique has been developed for sending a signal through items of transmission equipment and applying this signal to a special test set. The equipment is then carefully probed and vibrated using standardised techniques. Any faulty joints or components will cause modulation of the test signal when they are disturbed.

The test set consists essentially of a detector to detect the modulation of the test signal, followed by filters to reject the test signal (or carrier) and pass the modulation, and a high gain amplifier to raise the level of the modulation products to the point where they will operate a loudspeaker or headphones. The clicks and noise produced when a faulty joint is disturbed are clearly audible and the source can be traced readily. This technique has been known to electronics technicians since the very earliest days but it is only recently that proper instruments and standardised methods have been developed.

This article describes the Philips type of instrument, shown in Fig. 1, which is that purchased by the Department and used by the author. Other similar instruments giving equivalent results are available from other manufacturers.

THE FAULT DETECTOR

The fault detector consists of an oscillator and a receiver, and a block schematic of the instrument and the equipment under test is shown in Fig. 2. The oscillator has a low impedance output and the frequency is continuously variable beween 0-700 Kc/s, the output level being controlled by a coarse and fine adjustment.

The receiver consists of a two-stage pre-amplifier, detector, level indicator, 3.2 Kc/s low pass filter, two-stage final amplifier and loudspeaker. The input impedance may be varied by an external switch, which alters the input transformer taps to give 150 ohms or 600 ohms, loss or high impedance. In the later model of the fault detector, STM 206/21, a narrow band elimination filter is provided with maximum attenuation at 1.9 Kc/s; this allows a mid-band (1.9 Kc/s) test frequency to be used when testing audio equipment without the test tone reaching the final stage amplifier and loudspeaker after detection and thus swamping crackles due to a fault condition. In the earlier model, STM 206/20, testing of audio frequency equipment could be accomplished only at 3.2 Kc/s, the low pass filter having maximum attenuation (90 db) at 3.2 Kc/s.

Setting Up:

(a) The equipment for test is connected between output and input terminals of the Fault Detector. For example, suppose it is desired to test the A to B direction of a "J" repeater. After observing the normal precautions, the output terminals of the Fault Detector are connected to the "J" equipment jacks on the south filter bay and the input terminals of the Fault Detector are connected to the "J" equipment jacks on the north filter bay; this places the whole of the "J" repeater between input and output terminals of Fault Detector.

(b) The frequency of the oscillator of the Fault Detector is set somewhere in the pass band of the equipment under test (say, 100 Kc/s for the example given above), and the level adjusted to approximately 10 db below the normal operating point of equipment to prevent "burning out" of any fault. It is desirable to keep the test signal level as low as possible without impairing the sensitivity of the receiver to crackles due to a fault in the unit under test. Station noise has generally been the limiting factor in this regard.

(c) The receiver input selector S1 is set at either H.F. or L.F. (600 ohms or 150 ohms) input, appropriate to circuit under test.

(d) The input attenuator of the receiver is set to give a central reading (black section) on M1. This indicates that the detector is operating at the optimum point.

(e) Potentiometer S3 controls noise suppression and is adjusted to minimise background noise.

(f) A test of sensitivity may be made by introducing an artificial fault condition or by moving the fine control of the test oscillator. This will be heard as a crackling noise as the wiper arm of the potentiometer passes over each turn of resistance wire.

Operation: The test frequency passes via the output terminals of the Fault Detector, equipment under test, input termi-

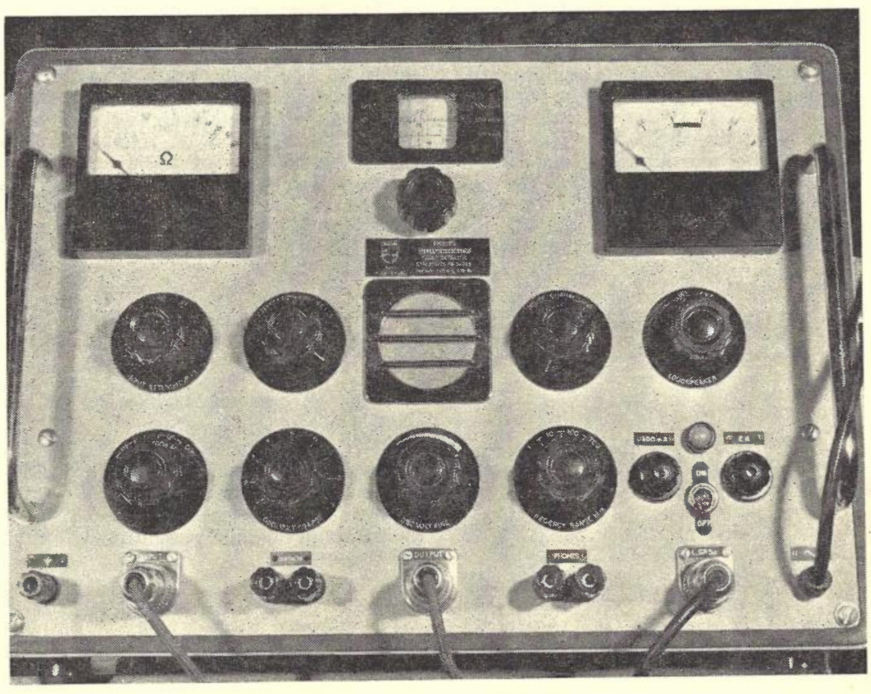


Fig. 1.—Philips Fault Detector Type STM206/21.

* See page 348.

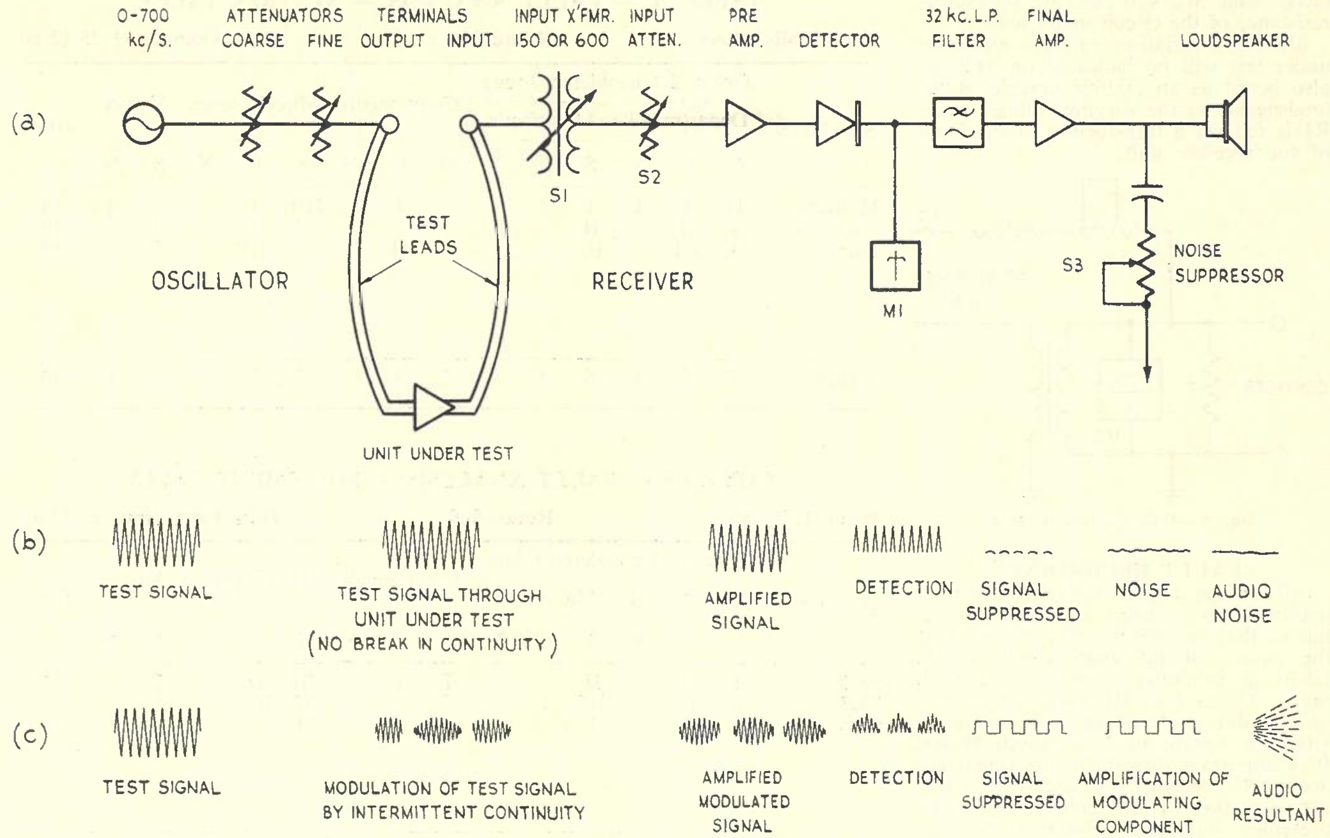


Fig. 2.—Block Schematic of Fault Detector.

nals of the Fault Detector, and preamplifier to the detector where the signal is rectified. The frequency of the test signal will be such that it will be blocked by the 3.2 Kc/s low pass filter, or in the case of audio testing with equipment type STM 206/21 by the 1.9 Kc/s band stop filter, and only the output amplifier thermal noise will be heard in the loudspeaker.

A careful and systematic examination is made of all visible soldered and screwed connections, and wiring and components are moved or vibrated using a piece of insulating material such as a length of fibre rod ⅛ inch in diameter. Valves should be moved in their sockets to detect any bad connections, and sealed cans are given a sharp bump to disturb any internal unsoldered or dry joints or loose components. Fig. 3 shows the instrument in use.

Any break or partial break in the continuity of the test signal can be likened to a mechanical modulation of the signal and after detection in the receiver will be passed by the low pass filter to the final amplifier stages and loudspeaker and heard as a crackle. The process is illustrated in Fig. 2.

D.C. Continuity Tests: An additional feature of the Fault Detector is the provision of terminals marked "Contacts" whereby a low resistance path may be tested for continuity, for example, switch or jack contacts. With reference to Fig. 4, the application of this test is as follows:

(a) S1 is set at position marked "Contacts."

(b) S4 is varied to give full-scale deflection on M2. M2 is calibrated in ohms but is sensitive to a voltage drop across R1.

(c) The circuit under test is now connected across terminals marked "Con-

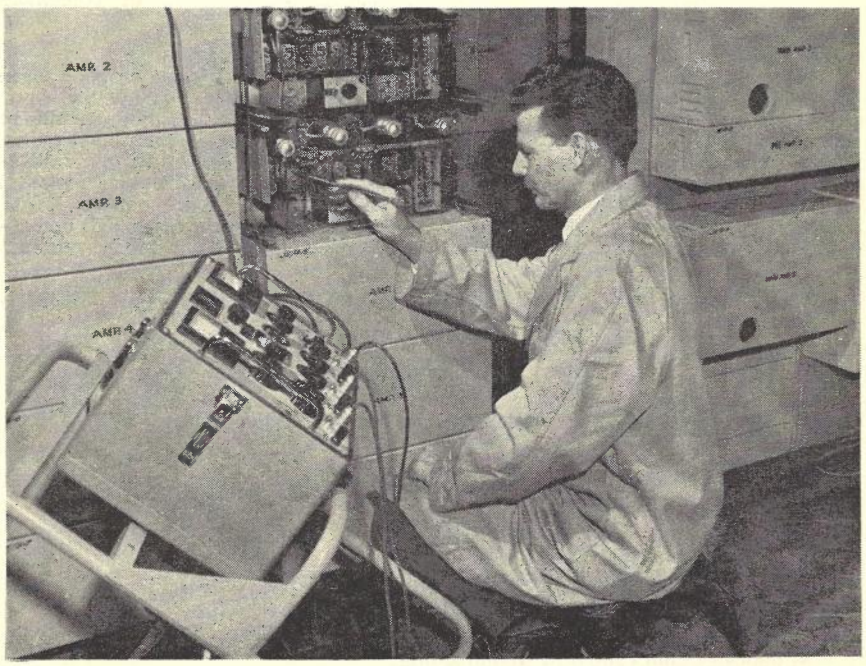


Fig. 3.—Vibration Testing in Progress.

tacts," and M2 will indicate the actual resistance of the circuit under test.

(d) Any variation of the resistance under test will be indicated on M2 and also heard as an audible crackle in the loudspeaker as the varying voltage across R1 is fed via a transformer to the input of the receiver unit.

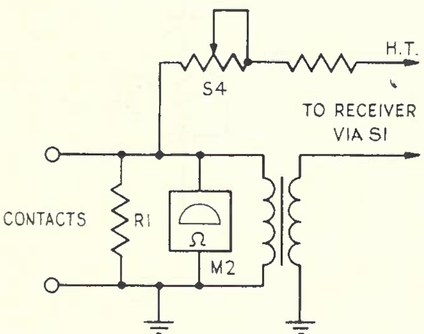


Fig. 4.—D.C. Continuity Test.

TABLE II — FAULT ANALYSIS — STATION TALLY

Fault Tally Sheet **Route 900** **Date Completed 25/12/60**

STATION	Dry and Unsoldered Joints						Components			Miscellaneous			Valves		Total
	Departmen'l			Manufact'r											
	S	C	N	S	C	N	S	C	N	S	C	N	S	N	
Maitland	II	I	I	I	I			I		IIIII	I			I	14
Cessnock	I	II		II			I			II	I		I		10
Taree	I	III		III			I	II			IIIII		I		16
Totals	4	6	1	6	1		2	3		7	7		2	1	40

TABLE III — FAULT ANALYSIS — EQUIPMENT TALLY

Fault Tally Sheet **Route 900** **Date Completed 25/12/60**

SYSTEM	Dry and Unsoldered Joints						Components			Miscellaneous			Valves		Total
	Departmen'l			Manufact'r											
	S	C	N	S	C	N	S	C	N	S	C	N	S	N	
5005	I	II		II			I	I		III	II		I		13
5007	II	II	I	III	I		I			II	IIII		I		17
5006	I	II		I				II		II	I			I	10
Totals	4	6	1	6	1		2	3		7	7		2	1	40

FAULT RECORDING

All defects found during a vibration overhaul are recorded and coded in detail so that an analysis may be made of the causes of interruption and action taken to minimise recurrence of such faults. Tables I to III show the method of recording and coding faults found by vibration testing in New South Wales. It is important that the faults found are accurately recorded and coded to enable a true picture of the fault pattern to be presented and thus allow corrective action to be initiated and directed at the source of the trouble, whether it be due to workmanship, component failure or design weakness. The fault record will also serve as a gauge for evaluating the effectiveness of the overhaul.

FAULT INCIDENCE

From the results of vibration testing to date, dry and unsoldered connections constitute by far the greatest factor contributing to fault incidence. The analysis has shown also that many of these bad connections have been found visually and not by vibration testing, that is, they could have been found without the aid of the Fault Detector. On stations where a visual inspection has been made prior to a vibration overhaul, the reduction in faults found by vibration testing is estimated to be as high as 60 per cent. This indicates that a careful and systematic examination of an installation is worth while and will result in a general improvement of equipment performance.

CONCLUSION

The importance of making good clean electrical connections cannot be overstressed. Particular attention should be given to soldering, screw connections, busbar take-offs, fuses and fuse mountings, valve sockets, valve pins and grid clips. Relay and jack contacts should be clean and properly tensioned. Potentiometers and switches which are not being frequently moved, for example, carrier leak potentiometers, but require adjustment, should be rotated back and forth sharply to ensure a clean contact surface before being set at a new position. All the points mentioned above have been causes of interruption to service and have been detected during the course of a vibration overhaul.

Valuable information on the performance of a carrier system can often be obtained by making an examination of the Station Log Book, provided the entries are accurate and complete. For example, it may be noticed that the local V.F. Telegraph system is being continually patched to another bearer circuit because of "bumping" without any fault being found on the normal bearer. This is a clear indication of the existence of a fault of intermittent and short duration. Steps could be taken to isolate the trouble to a particular section or repeater with the aid of decibel recorders, and when isolated to a particular section of equipment, steps taken to locate the source of trouble, firstly by a visual inspection and if this is unfruitful then perhaps a vibration overhaul would be desirable.

Vibration Testing is not claimed as a "cure for all complaints" procedure, but where complaints of unsatisfactory service are frequent and no satisfactory cause can be found, then a vibration overhaul may prove very beneficial.

TABLE I—RECORD OF FAULTS REVEALED DURING VIBRATION TESTING

System: 5005. Station: WEST MAITLAND.

Panel	Description of Fault	Code
J12 GROUP BAY		
Regulating Amp.	Unsoldered Joint Pin 4 T2 (Soldered)	P/S/M
CHAN MODEM BAY		
Chan 6 Mod.	Faulty Rectifier (Replaced)	P/C/-
Chan 8 Demod.	Faulty Carrier Leak Pot (Replaced)	P/S/M

Legend

V indicates fault found visually.
P indicates fault found by percussion.
S indicates fault affecting service.
C indicates fault conditionally affecting service.
N indicates fault not affecting service.
D indicates fault caused by Departmental Staff.
M indicates fault caused by Manufacturer.

B. TIDE, Supervising Technician. 3/4/61.

EARTH FAULT LOCATION TEST SET

*J. E. SANDER, B.Eng., Grad.I.E.E.**

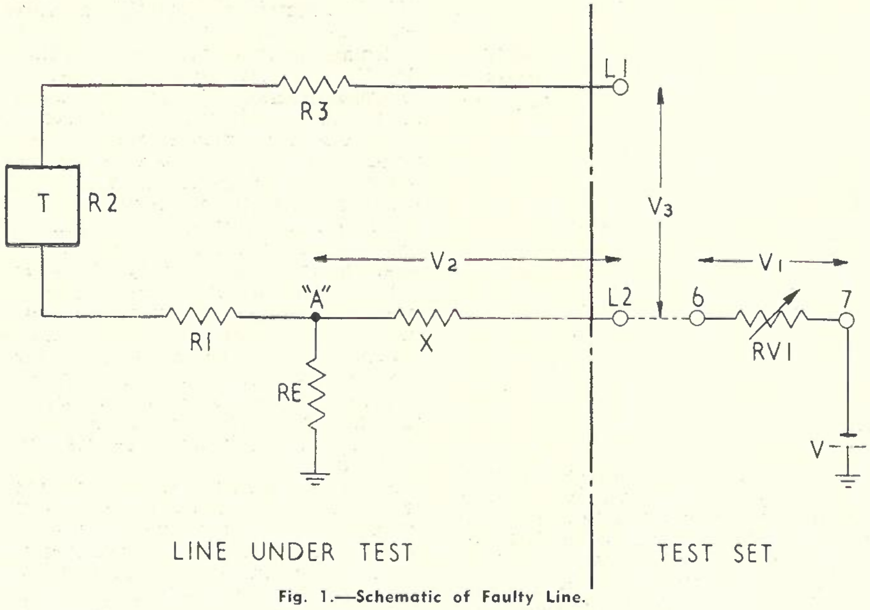


Fig. 1.—Schematic of Faulty Line.

INTRODUCTION

For many years earth faults on telephone cables and aerial wires have been located using Varley Bridge, or sometimes Murray Bridge, techniques. Varley and Murray Bridge techniques are capable of considerable accuracy if the particular fault conditions are favourable, but their application is slightly tedious and sufficiently complex to generally warrant the use of skilled staff for the work. The earth location tester described in this paper operates on a basically different (and apparently previously unused) principle, and, over the usual ranges of commonly encountered earth (or contact) faults, it has proved to be at least equal to the Varley Bridge in accuracy, and decidedly simpler to operate. Only one single balancing operation is required before being able to read off the line resistance to the fault **directly on a decade resistor box.** This simplicity of operation should prove advantageous in field use.

* See page 349.

PRINCIPLE OF OPERATION

Consider the schematic arrangement shown in Fig. 1. It represents a faulty line, with a telephone at the distant end, connected to a resistor (RV1) and test battery (V) in such a way that the test resistor RV1 is in series with the faulty conductor. Current flows through RV1, the faulty conductor X, and the earth fault resistance RE. Now if RV1 is adjusted (by means to be discussed later) to have the same value of resistance as the faulty conductor X, then the voltage drops shown as V1 and V2 will be equal because the same test current is flowing in each. Terminal "A" at the earth fault is normally inaccessible so special means must be adopted in order to measure the voltage drop V2 and check it against V1 for equality, as it is only when V1 equals V2 that the value of resistance RV1 equals the resistance of X. The resistance of X is what is required in order to compute the location of the earth fault at point "A".

Imagine for the moment that a voltmeter which draws no current whatsoever is connected across L1 and L2, and that the line is looped at the telephone (or distant) end. As no current flows into the voltmeter there will be no current flowing through resistances R1, R2 and R3 and therefore there will be no voltage drops across R1, R2 and R3, and the voltage that will be measured by the voltmeter across L1 and L2, that is V3, will be equal to V2.

The problem now remaining is to discover a means of testing the voltage appearing across L1 and L2 and compare it with the voltage V1 across RV1, without drawing any significant current from L1 or from terminals 6 or 7 in the process. This, at first sight, seemingly difficult task can be performed easily by the circuit shown in Fig. 2, and also by the circuit shown in Fig. 3.

Examine for the moment the simple circuit of Fig. 2. It contains amongst other things a test battery V and a decade resistor box RVI. Imagine terminal 2 being connected to line terminal

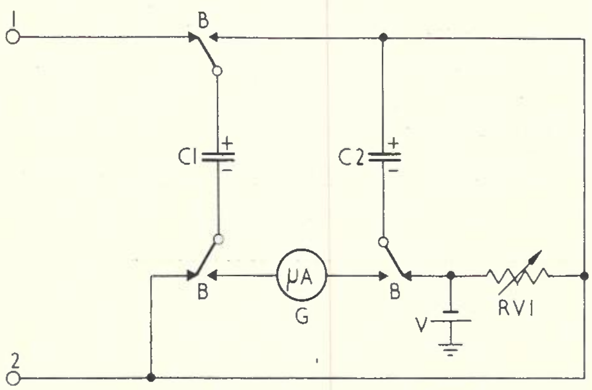


Fig. 2.—One Form of Earth Location Tester.

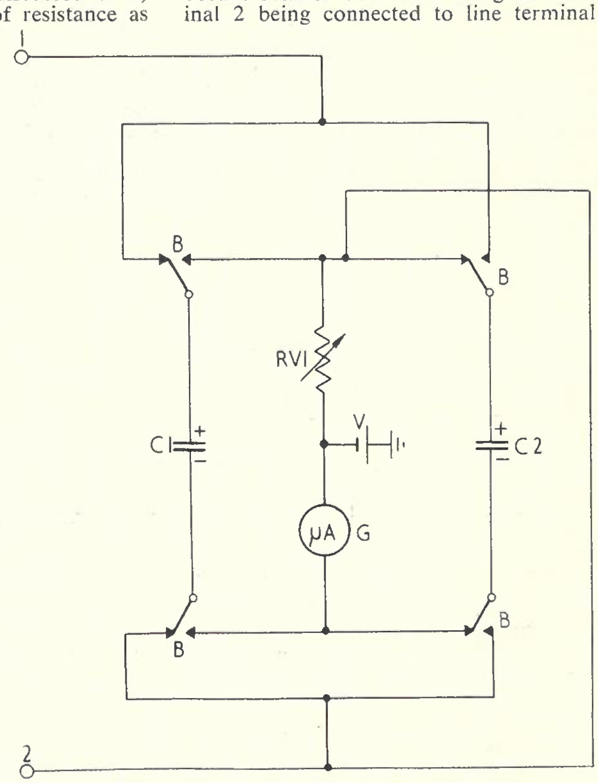


Fig. 3.—Preferred Form of Earth Location Tester.

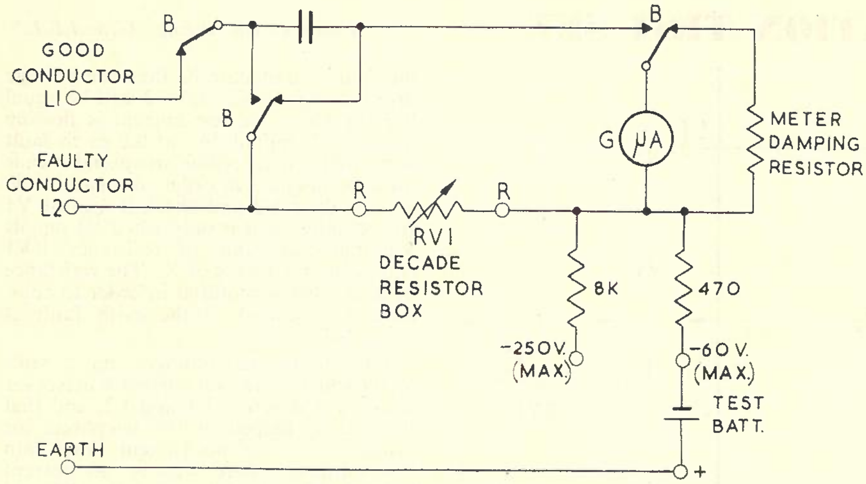


Fig. 4.—Basic Tester Circuit.

L2 (in lieu of the connection shown dotted in Fig. 1), and terminal 1 connected to line terminal L1. Now, given sufficient time, capacitor C1 will charge to the voltage appearing across L1 and L2, that is V3, and capacitor C2 will charge to the voltage appearing across RV1. After the charging process, these capacitors will not draw any significant current from their charging sources, and, so, C1 will charge fully to voltage V3 (that is voltage V2), and C2 will charge fully to voltage V1. The polarities will be as indicated on the drawing assuming that the test battery has its positive pole earthed.

If now changeover contacts B are operated synchronously, the capacitors C1 and C2 will be connected in series opposition across the test galvanometer G. If the voltages on C1 and C2 are equal no deflection will occur on the galvanometer. If they are not equal then a momentary deflection of the galvanometer needle will be observed in one direction or the other depending on whether V1 is greater than, or less than, V2.

By operating the changeover contacts B regularly (at any reasonable speed) a steady deflection on the galvanometer can be obtained which allows RV1 to be easily adjusted until it equals X. It is important to realise that at balance (that is zero deflection on the galvanometer), no current is being discharged from C1 and C2, and therefore no charging currents are being drawn, and hence no errors can be caused by the resistances R1, R2 and R3, irrespective of the values they may have. In actual fact tests have shown that a telephone can be used to complete the line loop and accurate balance can still be obtained in spite of the uncertainty (and general variability) of the telephone resistance R2. Random fluctuations in the value of R2 due to the carbon transmitter of the telephone have no effect on the actual balance point because, as explained above, at balance no current whatsoever flows through R2 when the value of RV1 is adjusted to exactly equal X. Likewise, even though the speed of repetitive operation of the B changeover contacts is made very high, no errors are brought about by the short charging times available, as, irrespective of the speed, capacitors C1 and C2 will still draw no charging currents when RV1 is adjusted to equal X. Extensive tests have confirmed that neither the switching speed nor the value of resistors R1, R2, R3, or RE affect the **accuracy** of the final balance, although, particularly in the case of RE, very high values of these resistors do adversely affect the **precision** with which a balance can be obtained by effectively reducing the sharpness of the balance point.

The testing circuit of Fig. 2 is simple, and it works reasonably well, but the arrangement shown in Fig. 3 works rather better in that approximately a three-fold increase in galvanometer sensitivity can be obtained for the same switching speed, using the same size test capacitors, C1 and C2, and the same galvanometer. The only additional cost is the extra changeover contact and wiring and this adds negligibly to the total cost of the unit.

After preliminary bench tests had proved the value of the test set, a very simple unit was made up for trial in order to check the actual capabilities of the principle against a standard Varley type test set under field conditions. A schematic of the basic circuit used in the trial test set is shown in Fig. 4. The actual detailed circuit in Fig. 5 incorporates resistors and diodes to protect the decade box and the galvanometer against possible damage. It will be seen that this field trial tester uses only one capacitor and in fact is equal only to one half of the favoured circuit shown in Fig. 3. This was done for simplicity and minimum cost reasons only, as, until the principle was thoroughly proven in field use, it was naturally desired to keep costs to a minimum. For these reasons also manually operated changeover contacts (B) were used.

DESCRIPTION OF TEST SET

The panel layout of the test set as used in the initial field trial is shown in Fig. 6 and it will be seen that a separate decade resistor box and a separate test

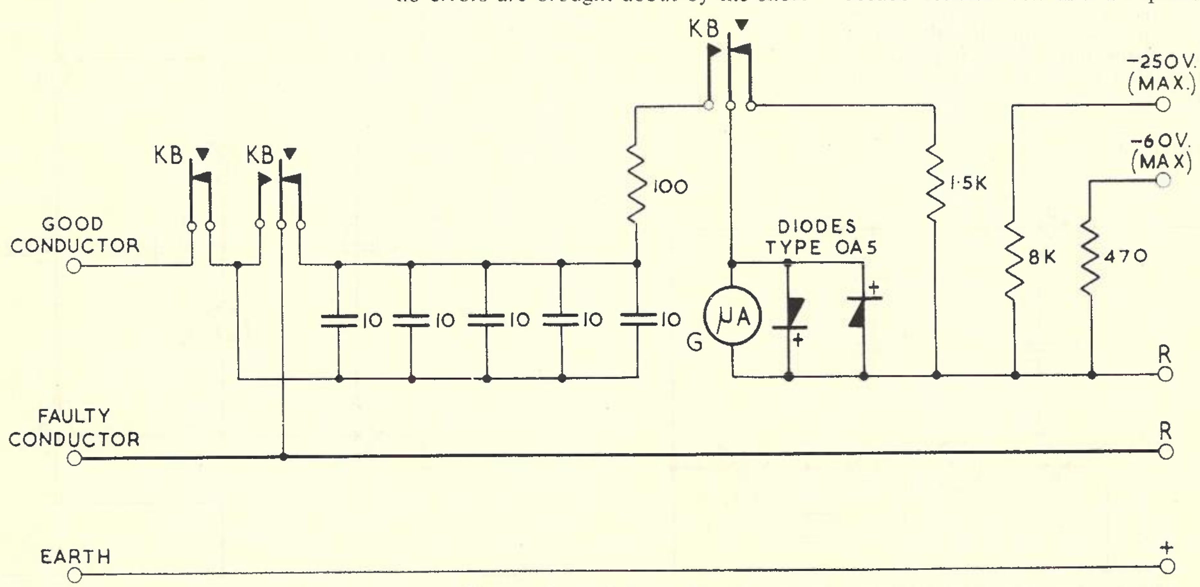


Fig. 5.—Detailed Tester Circuit.

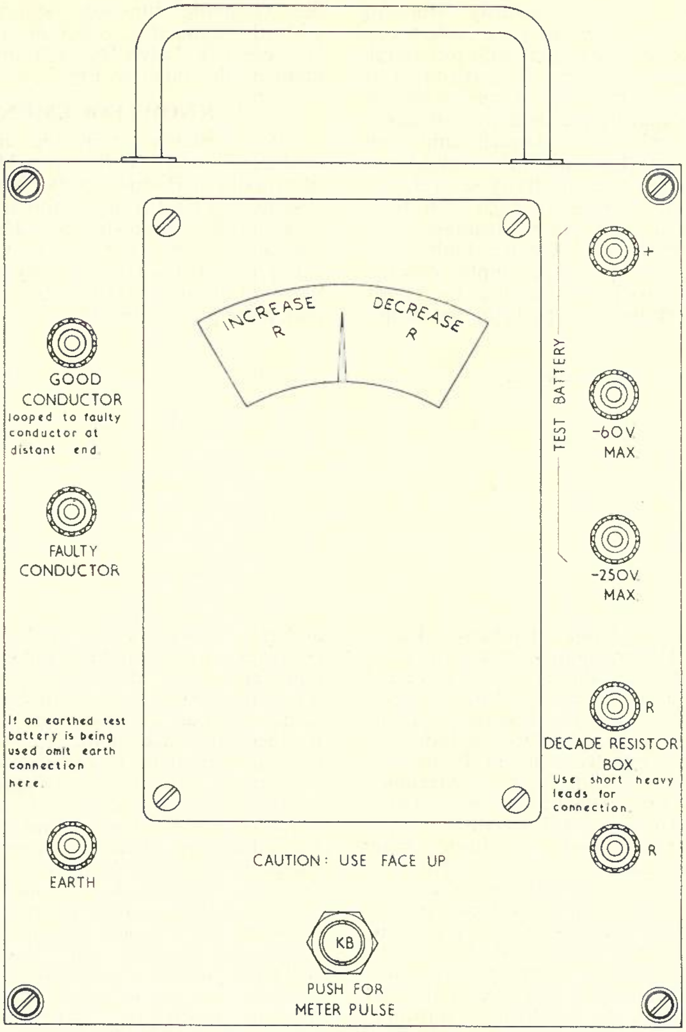


Fig. 6.—Panel Layout of Tester.

battery power supply are needed. This makes the setting up of the unit rather clumsy but separate units were necessary in order to keep down the initial costs as indicated previously.

When operating the test set, non-locking key KB is depressed occasionally and the resulting momentary meter deflection is used to indicate the direction of the next adjustment of R. It proved to be quite a simple process in practice to adjust the decade resistor box properly and determine the desired value of X. In the cases where it was difficult or impossible to get a zero deflection on the galvanometer it was also difficult or impossible to get a bridge balance when a normal Varley tester was tried. These field difficulties are discussed further in the following paragraphs.

FIELD TEST RESULTS

For the initial field trial a standard Varley Bridge tester and the new tester were each used to locate a number of faults which occurred in a Melbourne District Works Division. In every case where it was possible to get a good Varley location it was also possible to get a good test with the new tester, and the location test results shown in Table I illustrate generally the similarity of the two results obtained in each case.

Trials 5 and 17 indicate significant discrepancies but unfortunately in neither of these particular cases was the location of fault (as actually found by the jointer) measured out accurately and it is impossible to say now which of the measurements was the more accurate. Due to uncertainties in the actual cable conductor resistance per unit length (cable temperature and manufacturing tolerances cause significant variations), and in the precise length of cable coiled up in each of the jointing pits along the route, absolutely perfect earth location tests are rarely obtained and indeed, highly precise tests can be seen to be rather pointless when the uncertain value of the actual cable resistance per unit length of ground distance is considered.

TABLE I — COMPARATIVE FIELD TEST RESULTS

Trial Number	Conductor Size	Varley Test Result	New Tester Result
1	10 lb.	19.77 ohms	19.76 ohms
2	10 ,,	1.31	1.30
3	10 ,,	11.49	11.78
4	10 ,,	0.77	0.68
5	6½ ,,	0.58	0.4 *
6	10 ,,	7.95	7.98
7	6½ ,,	28.13	28.08
8	6½ ,,	2.4	2.48
9	10 ,,	5.22	5.18
10	10 ,,	1.95	1.98
11	10 ,,	11.2	11.3
12	10 ,,	0.66	0.64
13	10 ,,	22.27	22.2
14	10 ,,	0.64	0.64
15	10 ,,	41.4	40.6
16	10 ,,	2.04	2.08
17	4 ,,	0.04	0.08 *
18	10 ,,	7.04	7.0
19	10 ,,	1.75	1.8

FOREIGN BATTERY INTERFERENCE

Whilst carrying out the field trials it became apparent that many serious insulation breakdowns were associated with an amount of foreign battery which was varying in a random manner. This random (and often quite rapid) variation in the amount of foreign battery picked up on the faulty conductor, frequently made a steady balance on the tester impossible to obtain irrespective of the type of test set which was used. Theoretically it should be possible to overcome such interference by supplying the faulty conductor from a constant current source instead of from a constant voltage source, but initial trials using a transistorised

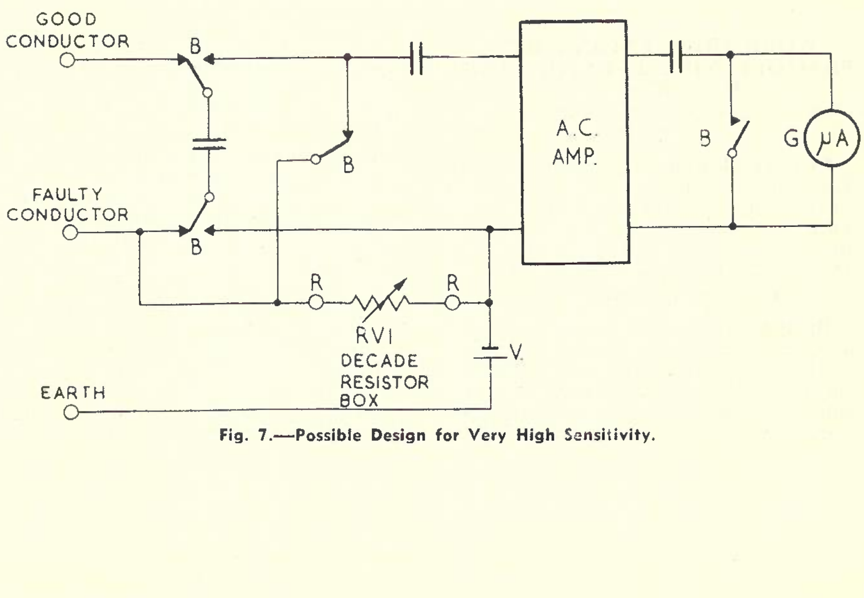


Fig. 7.—Possible Design for Very High Sensitivity.

constant current power supply have not been very successful. There is obviously room for further work on the matter as faults which cannot easily be located electrically, can in some circumstances prove to be very expensive in terms of manpower and lost revenue.

FUTURE DEVELOPMENTS

Now that the principle employed in the new test set has been supported successfully by field trials, further use will be made of test sets similar to that described above, and the development of further models employing two switched capacitors and continuously vibrating changeover contacts may be undertaken. Trials have indicated that with this simple improvement, it is possible to obtain an increase in sensitivity of approximately ten times that of the field trial model.

More sophisticated models employing chopper type D.C. amplifiers could possibly increase the sensitivity several hundred fold, and such high sensitivity would be of very great advantage when locating very high resistance faults. One particular chopper type amplifier design which appears interesting uses the vibrating contact units to perform the amplifier chopping functions synchronously with the capacitor switching functions. One possible design for such an arrangement is illustrated in Fig. 7.

ACKNOWLEDGEMENT

The assistance given the author by engineers and staff of Melbourne Metropolitan District Works No. 2 Division during field trials of this instrument is gratefully acknowledged. Thanks are due also to the staff of the Telephone Equipment Circuit Laboratory who participated in the initial tests of the circuit principle late in 1959.

BOOK REVIEWS

TELECOMMUNICATIONS — PRINCIPLES AND PRACTICE

W. T. Perkins. Second Edition 1961. Publisher — George Newnes Ltd., London. p.p.377. Australian price 34/9, post and packing 1/9. Copy from — Technical Book and Magazine Co. Pty. Ltd., 295-9 Swanston St., Melbourne.

Chapter Headings: City and Guilds Examination Syllabuses — Formulae for Telecommunications — Fundamentals of Electricity — Resistance — Electromotive Force, Potential Difference, Ohm's Law, Power — Cells — Heating Effect of Electric Current — Direct Current Experiments — Electrolysis — Electrostatic Field and Capacitance — Magnetism — Electromagnetism — Motors and Generators — A.C. Theory and Transformers — Measuring and Testing Instruments — Relays — Principles of Telephony — Public Telephone Systems — Manual Exchange Equipment — Underground Cables and Overhead Line Conductors — Telegraph Circuits and Codes — Valves, Semiconductors and Radio Frequency Transmission — Special Features of Inductors, Capacitors and Resistors at Radio Frequencies — Soldering — Graphical Symbols and Detached Contact Drawings — Tables and Logarithms.

Review: The book has been written primarily for the United Kingdom Student who is preparing for the examinations in Elementary Telecommunications Practice of the City and Guilds of London Institute. It deals with the basic principles of Magnetism, Electricity, Telephony, Telegraphy and Radio Communication by listing formulae, describing basic experiments and giving short explanations of principles together with answers to typical questions. The text is adequately illustrated by diagrams and circuits and well indexed. However, as a very wide syllabus is covered, the main purpose of the book is to provide a revision text in fundamental principles. A new chapter on valves and transistors has been included in this second edition but the treatment is cursory with only four pages, inclusive of diagrams and circuit, devoted to transistors. The chapters on Telephony and Exchange Equipment could be confusing to the Australian student because of the differences between A.P.O. and overseas practice. These differences are also apparent in the chapter on Graphical Symbols which does not conform to A.P.O. Standards. The book is of little value as a reference work to the Australian student preparing for local examinations; for this purpose the Course of Technical Instruction is more appropriate.

P.L.W.

WORKSHOPS ENGINEERING PRACTICE VOL. 2—LATHE WORK

H. G. Rider, 1959

Iliffe and Sons Ltd., pp. 133, Australian Price 15/9

Chapter Headings: The Lathe—Lathe Tools and Cutting Speeds — Measuring Instruments — Marking Out — Plain Turning between Centres — Turning a Bush from a Bar — Using Chucks and Mandrel — Face Plate Work — Tapers — Safety in the Workshop.

Review: This book is the second in a series dealing with various aspects of workshop engineering and is intended for United Kingdom students taking the subject at Secondary Modern and Junior Technical Schools, or studying for the craft examinations of the City and Guilds of London Institute. The author is Chief Instructor in Workshop Engineering at Borough Polytechnic, London.

The subject matter is presented in a straightforward manner and is adequately illustrated by 340 drawings. The drawings are clear and are particularly effective where a sequence of operations has to be demonstrated. To enable teachers to take full advantage of the visual method of presentation used in the book, accompanying sets of coloured filmstrips are available.

In the first chapter, the lathe and its main parts are described, including methods of holding work in the lathe. A discussion of lathe tools and calculation of cutting speeds follows. The effect of correct and incorrect tool angles is adequately covered. The 30 pages of Chapter 3 deal with the rule, callipers, micrometer, dial indicator gauge, protractor and try square. The chapter concludes with a series of test questions on measuring instruments. Chapter 4 deals with marking out and is followed by three chapters devoted to practical exercises. Finally, face-plate work and the production of tapers are dealt with. An adequate index is provided.

The book uses standard conventions and terminology and would be a valuable reference text for instructors in Australian technical schools. (Our copy from Technical Book Co. Melbourne.)

—A. N. BIRRELL, B.E., A.M.I.E.Aust.

METHODS OF NUMERICAL FILTER DESIGN — PART IX

*E. RUMPELT, Dr.Ing.**

14. SOME DESIGN PROCEDURES FOR INSERTION PARAMETER FILTERS

14.1. Determination of the Parameters of the Characteristic Function. In order to demonstrate a systematic way of determining the parameters of the characteristic function in Eq. (13.8), a type of insertion loss specification will be chosen which is encountered frequently in practice: In the pass-band the insertion loss is required not to exceed a given small and constant maximum value, whereas in the stop-band some irregular contour may be specified as the permissible minimum boundary of the insertion loss. The shape of this contour is determined by the particular purpose of the filter.

It is often more realistic to prescribe the pass-band performance in terms of minimum return loss instead of maximum insertion loss, and in the case considered, the specified minimum return loss would be constant throughout the pass-band. As we are dealing with reactance four-poles, return loss and insertion loss are related via Eq. (4.11) and any return loss specification can be converted directly into an equivalent insertion loss specification.

This type of loss specification can be met with best efficiency if the characteristic of the insertion loss in the pass-band has maxima of equal height between its zero values at the angular velocities a_ν in Eq. (13.8). An insertion loss characteristic of this kind is shown in Fig. 23. Filters with such performance are said to have Tchebycheff behaviour in their pass-bands.

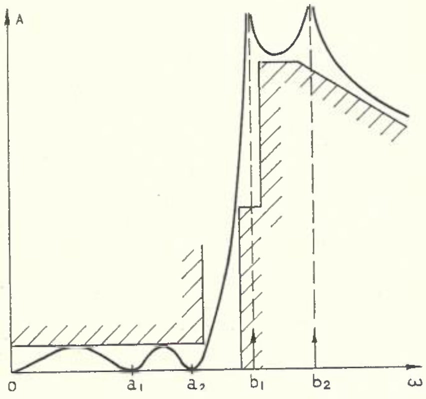


Fig. 23.

S. Darlington has devised a method by means of which Tchebycheff behaviour in the pass-band can be obtained for an insertion parameter filter in a very easy way and without placing any restrictions on the stop-band performance of the filter. He achieved this by deriving the characteristic function of the insertion parameter filter from the image transfer constant of a related image parameter filter which he calls the reference filter. The method makes use of the relationship between the image parameters, Z_{I1}, Z_{I2} and Θ, on the one hand, and the open-circuit driving-point and transfer impedances, Z_{11}, Z_{22} and Z_{12}, on the other hand, of a passive four-pole network. From this relationship the following formulae can be derived:

$$\sinh \Theta = \frac{\sqrt{Z_{I1} Z_{I2}}}{Z_{12}},$$

$$\cosh \Theta = \frac{Z_{11}}{Z_{12}} \sqrt{\frac{Z_{I2}}{Z_{I1}}} \quad \ldots \quad (14.1)$$

In case of a reactance four-pole, such as an image parameter filter, the open-circuit impedances are odd, real, rational functions of the complex frequency parameter "s". If the image parameter filter is antimetric, we have:

$$Z_{I1} Z_{I2} = R_0^2$$

and hence:

$$\sinh \Theta = \frac{R_0}{Z_{12}} \quad \ldots \ldots \ldots \quad (14.2)$$

This is an **odd,** real, rational function of s and is therefore permissible as the characteristic function of an insertion parameter filter.

If the image parameter filter is symmetrical we have:

$$Z_{I1} = Z_{I2}$$

and hence:

$$\cosh \Theta = \frac{Z_{11}}{Z_{12}} \quad \ldots \ldots \ldots \quad (14.3)$$

This is an **even,** real, rational function of s and is therefore also permissible as the characteristic function of an insertion parameter filter.

In both cases the function can be expressed in the general form of Eq. (13.8). It remains to be seen how the image transfer constant, $\Theta = \alpha + j\beta$, of the reference filter, has to be chosen to meet the insertion loss specifications with the insertion parameter filter.

In the pass-band of an image parameter filter the image attenuation, α, is zero and we have therefore:

$$\sinh \Theta = \sinh j\beta = j \sin \beta \quad \ldots \quad (14.4)$$

$$\cosh \Theta = \cosh j\beta = \cos \beta$$

In the pass-band the image phase-shift, β, rises steadily with the frequency between two limits depending on filter type and complexity. In the same frequency band the magnitudes of the functions of Eq. (14.4) oscillate between 0 and 1. Consequently, if the function of Eq. (14.2) or (14.3) is used as a characteristic function and is introduced in Eq. (13.7), the condition of equal insertion loss maxima between zero values is fulfilled throughout the pass-band of the reference image parameter filter right up to its theoretical limits. It is then only necessary to multiply the function by a properly chosen constant factor, say K_0, in order to obtain the specified maximum insertion loss or minimum return loss in the pass-band of the insertion parameter filter. With the help of Eqs. (13.7) and (4.11) this constant factor is found to be:

$$K_0 = \sqrt{10^{0.1 A_{L_{max}}} - 1} \quad \ldots \quad (14.5)$$

or

$$K_0 = \frac{1}{\sqrt{10^{0.1 A_{e_{min}}} - 1}} \quad \ldots \quad (14.6)$$

where $A_{L_{max}}$ is the maximum permissible insertion loss and $A_{e_{min}}$ is the minimum permissible return loss in the pass-band of the filter.

The desired characteristic function is then given either by

$$K = K_0 \sinh \Theta \quad \ldots \quad (14.7)$$

where Θ is the image transfer constant of an **antimetric** image parameter filter and yields an **odd** function of s,

or by

$$K = K_0 \cosh \Theta \quad \ldots \quad (14.8)$$

where Θ is the image transfer constant of a **symmetrical** image parameter filter and yields an **even** function of s.

The specification for the insertion loss, A_L, in the stop-band of the insertion parameter filter can now be transformed to a corresponding specification for the image attenuation, α, in the stop-band of the reference filter, by means of Eqs. (13.7) and (14.7) or (14.8). The evaluation of the latter two formulae is, however, somewhat cumbersome, and for specified insertion loss values greater than 20 db, the whole transformation can be simplified on the basis of the following approximations:

$$A_L \doteqdot 20 \log |K| \quad \text{(in db)}$$

$$\sinh \alpha \doteqdot \cosh \alpha \doteqdot \tfrac{1}{2} e^{\alpha} \quad (\alpha \text{ in nepers})$$

which yield:

$$A_L \doteqdot \alpha + 20 \log K_0 - 6 \quad \ldots \quad (14.9)$$

$$(A_L \text{ and } \alpha \text{ in db})$$

For ordinary pass-band insertion loss or return loss specifications the value of 20 log K_0 is within the range from about –6 to –20 db and the required image attenuation of the reference filter is therefore always larger than the specified minimum insertion loss in the stop-band.

The problem of finding the characteristic function of an insertion parameter filter with Tchebycheff behaviour in the pass-band has thus been reduced to the design of an image attenuation characteristic enveloping as closely as possible an attenuation contour which can easily be derived from the insertion loss specifications. The design process is best carried out with the help of the template design method described in Chapter 6.

The result of this design is a series of attenuation peak frequencies or

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*See page 298, Vol. 12, No. 4.

corresponding m-values from which the image transfer constant, θ, as a function of ω can be calculated. This in turn yields the characteristic function through Eqs. (14.7) or (14.8) after some algebraic manipulations. S. Darlington and others have derived direct conversion formulae. From these the characteristic function is obtained in the general form of Eq. (13.8) except that the numerator polynomial appears in its expanded form instead of in factorized form.

This is a disadvantage if a method of finding first approximations of the roots of the polynomial E(s)E(–s) is to be applied, which will be described in Section 14.3, because herein the knowledge is required of the roots of both numerator and denominator polynomials of the characteristic function, that is, the values of the parameters a_ν and b_ν in Eq. (13.8). The parameters b_ν are already known as the angular velocities of the image attenuation peaks of the reference filter(*). The parameters a_ν are those angular velocities where the expressions in Eq. (14.4) become zero, that is, in the case of an antimetric reference filter where the image phase-shift β is an even multiple of $\pi/2$ (including 0), and in the case of a symmetrical reference filter where the image phase-shift is an odd multiple of $\pi/2$. The parameters a_ν can therefore be found by evaluating the phase-shift function of the reference filter. This can be done graphically with the help of the template design method described in Chapter 7.

If necessary, the results of such a graphical design can be improved by numerical evaluation and linear interpolation of the phase-shift in the vicinity of the values obtained graphically. For this purpose a table may be prepared representing the function of the phase template in sufficiently small steps of β (0.01 radians). Finally, the constant factor of the characteristic function is determined by evaluating the latter at any one of its maxima in the pass-band (where the image phase-shift is an odd or even multiple of $\pi/2$ in case of an antimetric or symmetrical reference filter, respectively) and equating the result to K_o.

14.2. Some General Considerations Concerning the Roots of E(s)E(–s). It has been mentioned in Chapter 13 that the numerator polynomial, E(s), of the transfer factor is obtained by solving the polynomial equation

$$E(s)E(-s) = F(s)F(-s) + G(s)G(-s) = 0$$

and combining in E(s) all those roots of E(s)E(–s) which have negative real parts, that is, which are situated in the left half of the s-plane. Only with very simple filters can the above equation be solved by purely algebraic operations. In most practical cases some iterative approximation method must be applied, and it is desirable to keep the number of roots which must actually be determined in this way as small as possible.

(*) For the numerical calculations the angular velocities are normalized by using a suitably chosen angular velocity as a reference value, for example, the cut-off in case of a low-pass filter, or the band centre in case of a band-pass filter.

If the characteristic function has the general form of Eq. (13.8), that is, if it is either an even or odd function of s, then Eq. (13.9) can be written in one of the following two forms:

If K(s) is even, both F(s) and G(s) are even polynomials of s and we have:

$$E(s)E(-s) = [F(s) + jG(s)]\,[F(s) - jG(s)] \quad \ldots (14.10)$$

If K(s) is odd, either F(s) or G(s) is an even polynomial, the other one is an odd polynomial of s and we have:

$$E(s)E(-s) = \pm\,[F(s) + G(s)]\,[F(s) - G(s)] \quad (14.11)$$

In both Eq. (14.10) and (14.11), one half of the roots of E(s)E(–s) is contained in the left bracket expression, the other half is contained in the right one, and the two groups of roots are symmetrical to one another with respect to the imaginary axis of the s-plane. It is therefore sufficient to find the roots of one of the two bracketed polynomials only, for example, the roots of F(s) + jG(s) in case of an even characteristic function, or the roots of F(s) + G(s) in case of an odd characteristic function.

Every calculated root, s_o, of a polynomial, $P_a(s)$, can be removed from the polynomial by division:

$$P_a(s) \div (s - s_o) = P_b(s)$$

and the next root can be calculated from the polynomial $P_b(s)$ which has reduced degree. Proceeding in this way, approximation methods need be applied only until the degree of the remaining polynomial is so small as to permit the rest of the roots to be calculated by a straightforward algebraic operation.

In the polynomial F(s) + jG(s) of Eq. (14.10), the coefficients are complex, and so are the values of all of its roots. Calculation with complex numbers is therefore unavoidable, but as both F(s) and G(s) are even, their degree can be reduced by half by substituting for s^2 a new parameter, say z.

In the polynomial F(s) + G(s) of Eq. (14.11) all the coefficients are real, but with practical filters all of its roots are conjugate complex, excepting one real root if the degree of the polynomial is odd. Calculation with complex numbers can, however, be avoided by combining each conjugate complex pair of roots in one real quadratic expression:

$$(s + a + jb)\,(s + a - jb) = s^2 + ms + n \quad \ldots\ldots (14.12)$$

with $m = 2a$ and $n = a^2 + b^2$, and finding for each pair of roots the values of m and n, instead of those of a and b.

Only those pairs of roots of F(s) + G(s) need be calculated which are situated in the right half of the s-plane, that is, those with negative values of m when expressed in the manner of Eq. (14.12). This means that only about half of the roots of the polynomial must be determined. After these roots have been removed by division, the residual polynomial has only roots in the left half of the s-plane, and E(s) is obtained by multiplying this residual polynomial with all those factors $s^2 + ms + n$ which have been removed, after changing the sign of the m's from negative to positive. In this way roots are added which are symmetrical to the removed ones with respect to the imaginary axis.

It can easily be verified from Eqs. (14.10) and (14.11) that at the roots of the bracketed polynomials, it must hold that $|F(s)| = |G(s)|$ and the arguments of F(s) and G(s) must differ by odd multiples of $\pi/2$ in Eq. (14.10), where the characteristic function is even, and they must differ by even multiples of $\pi/2$ in Eq. (14.11), where the characteristic function is odd. In the case of practical low-pass and band-pass filters, the loci $|F(s)| = |G(s)|$ in the complex plane are curves with shapes somewhat similar to an ellipse enclosing the roots of F(s). The other conventional filter types can be derived from low-pass filters and need therefore not be considered.

Along a locus $|F(s)| = |G(s)|$ the roots of F(s) + jG(s) alternate with those of F(s) – jG(s), and the roots of F(s) + G(s) alternate with those of F(s) – G(s).

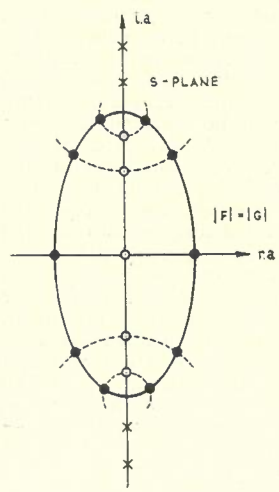

Fig. 24.

Fig. 24 shows the root pattern in the case of a simple low-pass filter with odd characteristic function. The roots of F(s) are marked by small circles and the roots of G(s) by small crosses on the imaginary axis. The roots of E(s)E(–s) are marked by small black dots on the locus of $|F(s)| = |G(s)|$. Those in the left half of the s-plane belong to E(s) and those in the right half belong to E(–s).

It can be seen that there is a certain co-ordination between the roots of F(s) and those of E(s)E(–s). This is due to the fact that the roots of E(s)E(–s) are the intersections of the locus $|F(s)| = |G(s)|$ with those of its orthogonal trajectories, which pass through single roots of F(s) at right angles to the imaginary axis. In Fig. 24 these trajectories are indicated by broken lines. This co-ordination makes it comparatively simple to guess the approximate positions of the roots of E(s)E(–s) once the locus of $|F(s)| = |G(s)|$ is known, and it is used in a method of obtaining approximate values of these roots, which will be described in the following section.

14.3. A Semi-Graphical Procedure of Root Finding. Among simple iterative approximation methods of determining the roots of a polynomial, Newton's method is one which converges very rapidly provided that adequate approximations to the roots are already known. Newton's method has therefore been chosen in the present case, and it will now be shown how good approximations to the roots of E(s)E(–s) can be obtained by means of a systematic and fundamentally simple semi-graphical procedure. It is based on the following considerations:

Let a general polynomial P(s) of n-th degree be given in its factorized form: $P(s) = C (s - \alpha_1) (s - \alpha_2) \ldots (s - \alpha_n)$ where $\alpha_1, \alpha_2, \ldots \alpha_n$ are the n roots of the polynomial. They may have real, imaginary or complex values, and the same applies to the constant factor C. The individual factors, $(s - \alpha_\nu)$, of the polynomial are equal to the vectors from the points α_ν to the point s in the complex s-plane. (See Fig. 25).

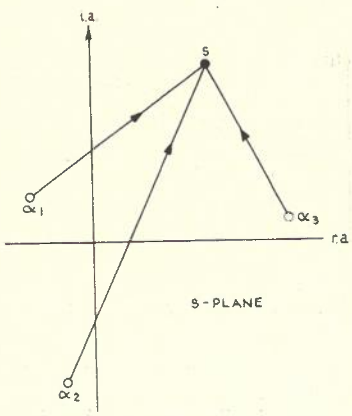

Fig. 25.

The polynomial P(s) can therefore be evaluated at any point s in the complex plane by marking its roots on this plane, by drawing the vectors from the roots to the point s, and by measuring the lengths of these vectors and their angles with the positive, real axis. The magnitude of the polynomial is obtained by multiplying all vector lengths together with |C|, and the argument of the polynomial is obtained by adding the angles of all vectors and the argument of C. (In the cases under consideration only positive or negative, real or imaginary constant factors occur, whose arguments are respectively, 0, π and $\pm \pi/2$).

This evaluation method is used to find the roots of F(s) + jG(s), that is, the points in the complex plane where F(s) = – jG(s), or alternatively, to find the roots of F(s) + G(s), that is, the points where F(s) = – G(s). The procedure is best demonstrated by means of a simple example.

A low-pass filter will be considered whose polynomials F(s), G(s) and E(s)E(–s) have the principal root pattern of Fig. 24. In accordance with Eq. (13.8), the polynomials F(s) and G(s) are given in general terms by the expressions:

$$F(s) = s\,(s^2 + a_1^2)\,(s^2 + a_2^2)$$

$$G(s) = \frac{1}{c}\,(s^2 + b_1^2)\,(s^2 + b_2^2)$$

The constant factor, c, of the characteristic function is assumed to be positive and has been combined, for convenience, with the denominator polynomial G(s). As the characteristic function is odd, Eq. (14.11) applies, and to obtain E(s) the roots of F(s) + G(s) in the right half of the s-plane are determined.

Among the roots of E(s)E(–s) shown in Fig. 24, the root on the positive, real axis must belong to the polynomial F(s) – G(s) because both F(s) and G(s) are real and positive for real and positive values of s. The next root along the locus |F(s)| = |G(s)| belongs therefore to F(s) + G(s), and this root together with its conjugate complex counterpart are the only roots of F(s) + G(s) in the right half-plane of the case in hand.

In order to simplify the graphical evaluation of F(s) and G(s), a new variable, z, is substituted for s in these polynomials:

$$z = s^2$$

This substitution gives:

$$F = \sqrt{z}\,(z + a_1^2)\,(z + a_2^2)$$

$$G = \frac{1}{c}\,(z + b_1^2)\,(z + b_2^2)$$

and it halves the number of roots of F(s) and G(s). There is, however, a slight complication because the odd polynomial F(s) has now an irrational factor, $\sqrt{z}$. The root at s = 0 becomes a branch point and F is no longer a polynomial. But, as far as the graphical evaluation is concerned, it only means that, instead of the vector from the origin of the z-plane to z, its square root has to be used, that is, the square root of the vector length for calculating the magnitude of F, and half of the vector angle for calculating the argument of F.

The arrangement of the roots of F and G in the z-plane is shown in Fig. 26. All the roots are situated on the negative, real axis.

The detailed procedure is as follows: The required root(†) of F + G is co-ordinated to the point $-a_1^2$. Its position is estimated on this basis and marked on the z-plane, say, at z_1 in Fig. 26. A straight line is drawn from the point $-a_1^2$ through z_1 and, as a first step, the point z_c on this line is determined where |F| = |G|. For this purpose the magnitudes of F and G at z_1 are evaluated as described earlier in this section giving, say, $|F_1|$ and $|G_1|$. Usually the result is $|F_1| \neq |G_1|$, that is, z_1 is not the correct point z_c on the line. It is evident from Fig. 26 that any small displacement of z_1 along the line changes $|F_1|$ much more than $|G_1|$ because the lengths of the vectors from the roots of F are altered much more than those from the roots of G. Therefore, if $|F_1| > |G_1|$, the point z_c is closer to $-a_1^2$ than z_1, and vice versa. Denoting the distance between z_1 and $-a_1^2$ with l_1, a substantially improved approximation to z_c is obtained with a point z_2 on the line whose distance from the point $-a_1^2$ is:

$$l_2 = l_1 \sqrt{|G_1| / |F_1|}$$

This procedure may have to be repeated several times unless z_1 is already close to the point z_c. If in this way two points are obtained, say z_3 and z_4, which are on opposite sides of z_c on the line, that is, if for example $|F_3| > |G_3|$ and $|F_4| < |G_4|$, then the point z_c can be obtained with good accuracy by linear interpolation as shown on an enlarged scale in Fig. 27. The point z_c is the intersection of the line through $-a_1^2$ and z_1 with the locus

(†) The term "root" is not strictly correct in this connection because F + G is not a polynomial in the z-plane.

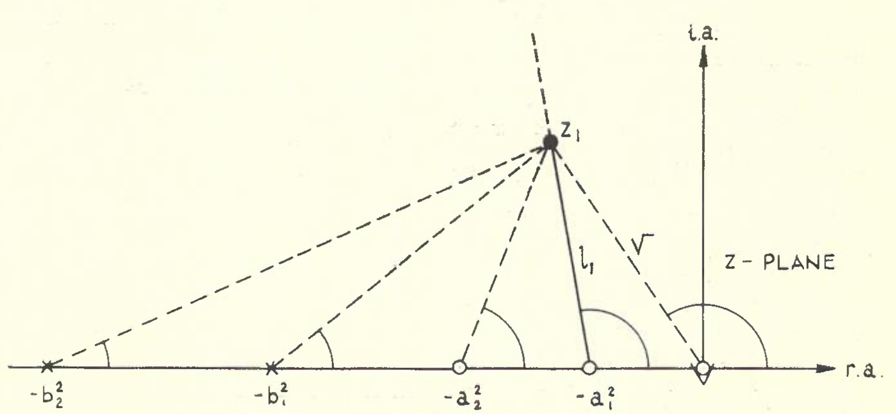

Fig. 26.

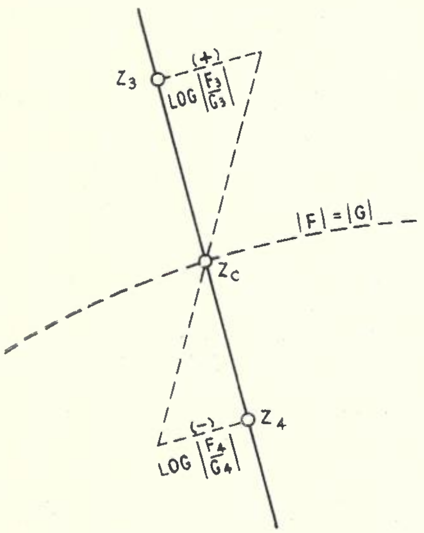

Fig. 27.

$|F| = |G|$, and the approximate curve of this locus in the vicinity of z_c can now be estimated and drawn into the diagram.

The next step in the procedure is the determination of the arguments of F and G at the point z_c in the way described earlier yielding, say, arg F_c and arg G_c. If these arguments differed by π, that is, by 180° (meaning that $G = -F$) then z_c would be the required root, z_o, of $F + G$. Usually, however, we have: arg $F_c \neq$ arg $G_c + 180°$. It is evident from Figs. 26 and 27 that a small displacement of z_c along the locus $|F| = |G|$ changes arg F_c much more than arg G_c because the angles of the vectors from the roots of F are altered much more than those from the roots of G. Therefore, if arg $F_c >$ arg $G_c + 180°$, the root z_o is to the right of z_c on the locus $|F| = |G|$ in Fig. 27, and vice versa. Assuming that

$$\arg F_c - (\arg G_c + 180°) = \delta,$$

a point much closer to the root z_o than the point z_c is obtained by drawing a new line through $-a_1{}^2$, with an angle of $-\frac{1}{2}\delta$ to the original line, and by finding the intersection of this new line with the locus $|F| = |G|$ in the same way as before. If the curve section through z_c in Fig. 27, representing this locus, has been correctly estimated, then the intersection of the new line with this curve already yields the new point, say, z_c'. After determining the arguments of F and G at this point, a new angle of deviation

$$\delta' = \arg F_c' - (\arg G_c' + 180°)$$

is obtained having substantially reduced size compared with δ. Further improvements, if necessary, may be achieved by repeating this process. When in this manner two points on the locus $|F| = |G|$ are found with small δ-values of opposite signs, that is, situated on opposite sides of the required root z_o, the latter is found by linear interpolation.

The accuracy of this semi-graphical procedure is limited only by the precision with which the various roots and other points are plotted, and the lengths and angles of the vectors are measured. In most cases it is not necessary to go to the limit of the obtainable accuracy in the way described above, because the object is only to get root approximations which are near enough to the exact positions for continuation with Newton's method.

The value of the root z_o thus obtained is complex:

$$z_o = u + jv$$

The parameters m and n in the real, quadratic expression of Eq. (14.12), which is to be removed by division from $F(s) + G(s)$, can now be calculated from u and v by means of the formulae:

$$n = \sqrt{u^2 + v^2} \;;$$

$$m = \pm\, v / \sqrt{\tfrac{1}{2}(n - u)}$$

or

$$m = \pm \sqrt{2(n + u)} \quad \ldots . \; (14.13)$$

The parameter m of Eq. (14.12) must be negative in this case because the conjugate complex pair of roots to be removed is in the right half of the s-plane. The accuracy of the parameters m and n correspond to that of u and v.

14.4. Newton's Method Combined with Horner's Scheme

The basic formula of the Newton method (more precisely, the Newton-Raphson method) is the equation:

$$x_2 = x_1 - \frac{f(x_1)}{f'(x_1)} \quad \ldots . \; (14.14)$$

x_1 is a first, rough approximation to a value x_o where the function f(x) passes through zero, $f(x_1)$ is the value of the function at x_1, $f'(x_1)$ is the value of the derivative of the function at x_1, and x_2 is an improved approximation to x_o. All these values may be real, imaginary, or complex numbers. The process is repeated with x_2 instead of x_1 in Eq. (14.14) yielding a further improved value x_3, and so on, until adequate accuracy is achieved.

In Fig. 28 the method is demonstrated graphically for a real function of a real variable x. The curve in the figure represents the function, f(x), which has a zero value at $x = x_o$. The point x_1 on the x-axis is a first estimate of the zero x_o. The value of the function at x_1 is $f(x_1)$. The tangent to the curve is drawn at the corresponding point of the curve with the co-ordinates x_1 and $f(x_1)$. The intersection of this tangent with the x-axis at x_2 gives an improved approximation to x_o. Eq. (14.14) can be obtained directly from the following trigonometric relationship read from Fig. 28:

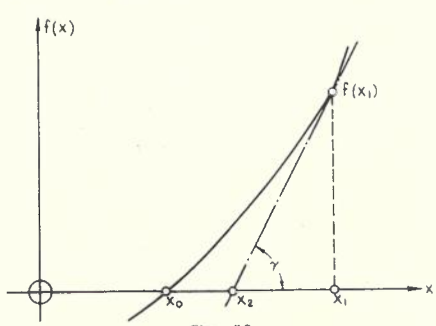

Fig. 28.

$$f'(x_1) = \tan\gamma = \frac{f(x_1)}{x_1 - x_2}$$

The example of Fig. 29 shows that the method does not necessarily converge unless the starting point is close enough to the zero. However, if the method converges at all, the rate of convergence increases rapidly as the distance from the zero is reduced. It is therefore desirable to start with a fair approximation to a zero.

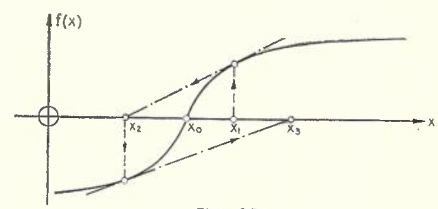

Fig. 29.

When the function is a polynomial, its derivative is also a polynomial, and the main labour in applying Newton's method is the evaluation of polynomials. This labour can be alleviated by a procedure of polynomial evaluation which is called Horner's scheme and which operates as follows:

A polynomial $P_a(s)$, which is to be evaluated at $s = s_1$, is divided by $(s - s_1)$ yielding a quotient polynomial $P_b(s)$ and leaving, in general, a remainder r_a. This process is described by the equation:

$$P_a(s) \div (s - s_1) = P_b(s) + \frac{r_a}{s - s_1}$$

Multiplying this equation by $(s - s_1)$ gives:

$$P_a(s) = (s - s_1)\, P_b(s) + r_a \quad \ldots . \; (14.15)$$

If now s_1 is substituted for s in this equation, the first term on the right-hand side becomes zero and we have:

$$P_a(s_1) = r_a$$

In other words, the remainder of the division of a polynomial in s by the divisor $(s - s_1)$ is equal to the value of the polynomial at $s = s_1$. The remainder is zero if s_1 is a root of the polynomial.

The differentiation of Eq. (14.15) with respect to s yields:

$$P_a'(s) = P_b(s) + (s - s_1)\; P_b'(s) \quad \ldots . \; (14.16)$$

By introducing s_1 for s in this equation we get:

$$P_a'(s_1) = P_b(s_1)$$

This means that the value of the derivative of the polynomial $P_a(s)$ at $s = s_1$ may be obtained simply by evaluating the quotient polynomial $P_b(s)$ at $s = s_1$. This can be done with the same method as used for evaluating $P_a(s)$.

Thus, when applying Newton's method for computing a root of a polynomial, starting from an approximate value s_1, it is only necessary to divide the polynomial a first time by $(s - s_1)$, which yields the remainder r_a, and then a second time, which yields the remainder r_b. An improved approximation to the root is obtained with

$$s_2 = s_1 - r_a/r_b \quad .$$

This procedure is repeated using $(s - s_2)$ as divisor, and so on, until the size of the remainder r_a is as small as one unit of the last significant digit of the constant term in the polynomial.

The two polynomial divisions which have to be carried out for each iteration of Newton's method can be expedited by means of the scheme shown in Table V. In the top row of this table the coefficients, p_ν, of the polynomial whose roots are to be determined, are entered in inverse order of their subscripts indicating the pertaining powers of s. The elements of the third row, p_ν', are the coefficients of the first quotient polynomial. They are given by:

$$p_{\nu-1}' = p_\nu + s_1 p_\nu'$$

and are obtained, together with the elements of the auxiliary second row, by the following successive operations:

Starting at the left of the third row, the element in the first column is $p_{n-1}' = p_n$. This is multiplied by s_1, entered in the second row of the second column, and added to p_{n-1} in the top row of the same column.

The result, $p_{n-2}' = p_{n-1} + s_1 p_{n-1}'$, is entered in the third row of the same column, then multiplied by s_1, entered in the second row of the third column, and added to p_{n-2} in the top row of the same column giving

$$p_{n-3}' = p_{n-2} + s_1 p_{n-2}',$$

and so on. The last element of the third row is the required remainder, $r_a = p_o + s_1 p_o'$. This series of computation is particularly suited for a desk calculating machine.

The elements of the fifth row, p_ν'', are the coefficients of the second quotient polynomial and are obtained, together with the elements $s_1 p_\nu''$ of the auxiliary fourth row, in a way similar to the coefficients of the first quotient polynomial by successive operations, this time applying the formula

$$p_{\nu-1}'' = p_\nu' + s_1 p_\nu''$$

The last element in the fifth row is the remainder of the division,

$$r_b = p_o' + s_1 p_o'' \quad .$$

The method which has been described for evaluating a polynomial is always applicable, and is independent of whether the values of the polynomial coefficients or of s_1 are real, imaginary or complex. Computation with real numbers only is, of course, much easier and is therefore always to be preferred under otherwise equal circumstances if there is a choice.

Assuming that the polynomial coefficients are real, the benefit of a computation restricted to real numbers is lost if Eq. (14.15) is used for evaluating a polynomial at a complex value of s_1. This disadvantage can, however, be avoided if the polynomial division is not carried out with the divisor $(s - s_1)$ but instead with a real, quadratic divisor of the type of Eq. (14.12), say, $(s^2 - m_1 s + n_1)$ containing s_1 as one of its two conjugate complex roots.‡ The division is represented by the equation:

$$P_a(s) = (s^2 - m_1 s + n_1)\, P_c(s) + c_1 s + c_o \qquad \ldots . (14.17)$$

where $P_c(s)$ is the quotient polynomial and $c_1 s + c_o$ is the remainder of the division. The latter is now a polynomial of first degree. When s_1 is substituted for s in Eq. (14.17) the first term on the right-hand side becomes zero, because s_1 is a root of the quadratic factor, and we get,

with $s_1 = a_1 + jb_1$:

$$P_a(s_1) = c_o + c_1 a_1 + jc_1 b_1 \qquad \ldots . (14.18)$$

(‡) A negative sign has been chosen for m_1 assuming that the two roots are situated in the right half of the s-plane. Both m_1 and n_1 are then positive, real numbers.

Differentiating Eq. (14.17) with respect to s yields:

$$P_a'(s) = (s^2 - m_1 s + n_1)\, P_c'(s) + (2s - m_1)\, P_c(s) + c_1 \qquad \ldots . (14.19)$$

When s_1 is substituted for s in this equation the first term on the right-hand side again becomes zero. Considering that $m_1 = 2a_1$ and therefore $(2s_1 - m_1) = j2b_1$, we get:

$$P_a'(s_1) = j\,2b_1 P_c(s_1) + c_1$$

This expression shows that the derivative of $P_a(s)$ at s_1 may be obtained by evaluating the quotient polynomial $P_c(s)$ at s_1. This can be done in the same way as before with $P_a(s)$, by dividing $P_c(s)$ by $(s^2 - m_1 s + n_1)$. Assuming that the remainder of this division is

$$d_1 s + d_o$$

we get

$$P_a'(s_1) = j\,2b_1\,(d_1 s_1 + d_o) + c_1$$

After replacing s_1 by $a_1 + j\,b_1$ on the right-hand side of this equation, the final result is:

$$P_a'(s_1) = c_1 - 2d_1 b_1^2 + j2b_1\,(d_o + d_1 a_1) \qquad \ldots . (14.20)$$

Introducing in Eq. (14.14) the numerical values of $P_a(s_1)$ and $P_a'(s_1)$ obtained with the help of the expressions of Eqs. (14.18) and (14.20), respectively, gives the corrections of a_1 and b_1 from which, in turn, the corrections of m_1 and n_1 can be calculated.

By means of the above procedure a computation with complex numbers is only partly avoided. It can, however, be dispensed with entirely when a direct, general relationship is derived between the coefficients c_o, c_1, d_o and d_1 of the remainder polynomials and the corresponding corrections of m_1 and n_1 on the basis of Newton's method. The results of such a derivation are Bairstow's formulae:

$$m_2 = m_1 + \frac{c_o d_1 - c_1 d_o}{d_o(d_o + d_1 m_1) + d_1^2 n_1} \qquad \ldots . (14.21)$$

$$n_2 = n_1 + \frac{c_o(d_o + d_1 m_1) + c_1 d_1 n_1}{d_o(d_o + d_1 m_1) + d_1^2 n_1}$$

TABLE V

p_n	p_{n-1} $s_1 p_{n-1}'$	p_{n-2} $s_1 p_{n-2}'$	. . . .	p_3 $s_1 p_3'$	p_2 $s_1 p_2'$	p_1 $s_1 p_1'$	p_o $s_1 p_o'$
$p_{n-1}' = p_n$	p_{n-2}' $s_1 p_{n-2}''$	p_{n-3}' $s_1 p_{n-3}''$	. . . .	p_2' $s_1 p_2''$	p_1' $s_1 p_1''$	p_o' $s_1 p_o''$	r_a
$p_{n-2}'' = p_n$	p_{n-3}''	p_{n-4}''	. . . . . .	p_1''	p_o''	r_b	

In these formulae n_1 is always positive, whereas m_1 is positive (negative) when the corresponding conjugate complex pair of points is situated in the right (left) half of the s-plane.

After an adequate number of iterations the coefficients c_0 and c_1 of the first remainder polynomial become zero within the accuracy of the polynomial coefficients of $P_a(s)$.

The process of polynomial division by the quadratic divisor $(s^2 - m_1 s + n_1)$ can be expedited by using the scheme shown in Table VI which is subject to the following relationships:

$$p'_{\nu-2} = p_\nu - n_1 p'_\nu + m_1 p'_{\nu-1}$$

$$p''_{\nu-2} = p'_\nu - n_1 p''_\nu + m_1 p''_{\nu-1}$$

where p_ν are the coefficients of the original polynomial whose roots are to be determined, and p'_ν and p''_ν are the coefficients of the first and second quotient polynomial, respectively.

ACKNOWLEDGMENT

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TABLE VI

p_n	p_{n-1} $m_1p'_{n-2}$	p_{n-2} $-n_1p'_{n-2}$ $m_1p'_{n-3}$	p_{n-3} $-n_1p'_{n-3}$ $m_1p'_{n-4}$	. . . .	p_4 $-n_1p'_4$ $m_1p'_3$	p_3 $-n_1p'_3$ $m_1p'_2$	p_2 $-n_1p'_2$ $m_1p'_1$	p_1 $-n_1p'_1$ $m_1p'_0$	p_0 $-n_1p'_0$
p'_{n-2} $= p_n$	p'_{n-3} $m_1p''_{n-4}$	p'_{n-4} $-n_1p''_{n-4}$ $m_1p''_{n-5}$	p'_{n-5} $-n_1p''_{n-5}$ $m_1p''_{n-6}$	. . . .	p'_2 $-n_1p''_2$ $m_1p''_1$	p'_1 $-n_1p''_1$ $m_1p''_0$	p'_0 $-n_1p''_0$	c_1	c_0
p''_{n-4} $= p_n$	p''_{n-5}	p''_{n-6}	p''_{n-7}	. . . . . .	p''_0	d_1	d_0		

BOOK REVIEW

OPEN WIRE CARRIER TELEPHONE TRANSMISSION
C. F. Boyce, 1962.
Macdonald and Evans Ltd., pp. 307.
Australian price, £4/10/9.
Our copy direct from publisher.

Chapter Headings: Economics of Open Wire Carrier Transmission — Open Wire Crosstalk and Transposition Systems — Design of Open Wire Carrier Routes — Survey and Construction of Carrier Routes — Trunk Entrance Cables and Lead-in Arrangements — Open Wire Carrier Equipment — Power Plant — Interference Between Power Systems and Open Wire Carrier Systems — Damage and Interference Caused by Lightning — Planning and Application of Open Wire Carrier Systems — Installation Practice — Maintenance of Open Wire Transmission Systems — Transmission Characteristics of Non-loaded Cable and Open Wire Pairs.

Review: This book is the first dealing exclusively with carrier transmission that has been published in the English language. The author, who is Assistant Chief Engineer of the South African Post Office, has had many years of experience on the design of open wire carrier networks and is a recognized world authority on a number of problems in this field. The book is intended for use by engineers concerned with the planning, installation and maintenance of open wire carrier routes and systems, by students of communication engineering, and by design engineers in industry. It should prove to be very useful for all these purposes and should become a standard reference work in the field covered.

Approximately half the book is devoted to the design and construction of line plant, including transposition design, lightning and power interference. The balance is divided almost equally between general system design, and equipment design, installation and maintenance. The subject matter is presented clearly, a good index is provided and the publication is generally of a high standard. There is an adequate balance between principles and practice, and the information included is drawn from all countries which have had experience with open wire networks. Despite the concise presentation, it has not been possible to cover many of the individual topics in detail due to the wide scope and limited size of the book. Selected references to published papers have therefore been included at the end of each chapter, and it is pleasing to see that many of these are to articles which have appeared in this Journal.

The practices covered are mainly those used in South Africa, and most of these differ in varying degrees from those in Australia. Others such as the planning of rural carrier systems are applicable directly to this country. While many of the problems dealt with have been encountered in most countries using open wire systems, the solutions have been different due to such factors as costs, materials available, climate and past history. Nevertheless this adds to the interest of the book and will undoubtedly stimulate thought regarding the correctness of certain practices. In general, the book is an excellent one and can be recommended to any Australian engineer concerned with design and construction of open wire routes or with any aspect of carrier systems.

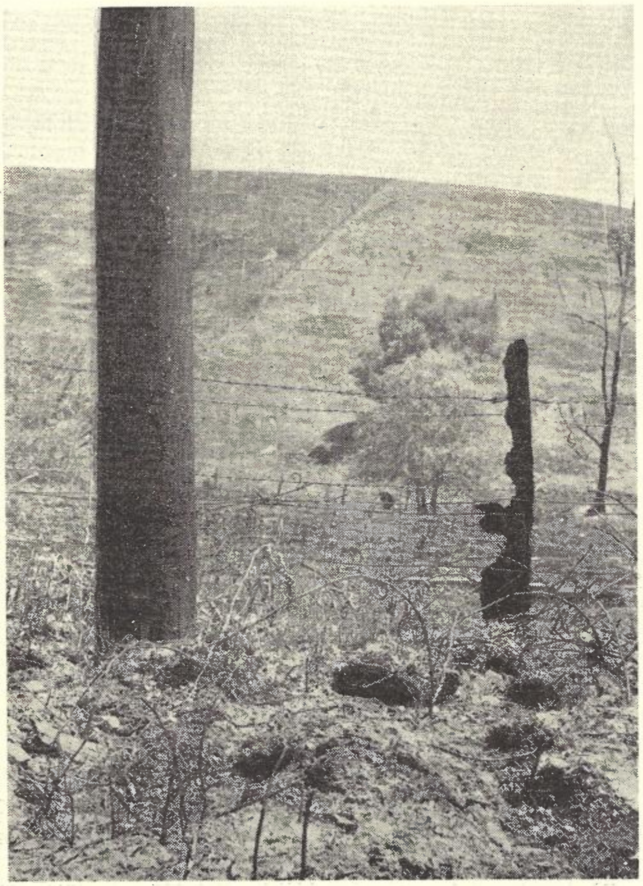
N.M.M.

TECHNICAL NEWS ITEM

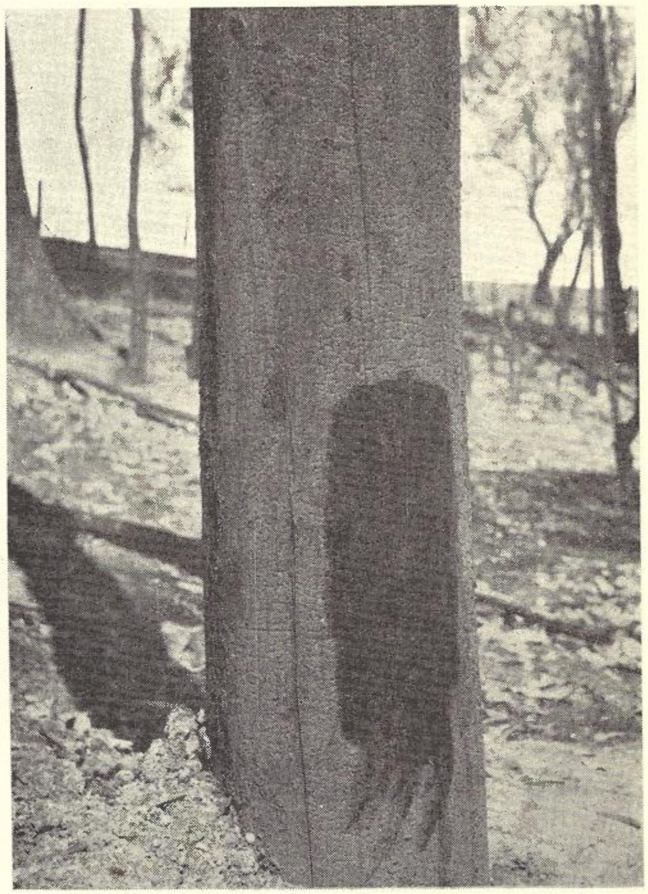
BEHAVIOUR OF CREOSOTED PRESSURE TREATED WOOD POLES IN BUSHFIRES

Following the Victorian bushfires of January 1962, a study was made of the performance of creosoted pressure treated wooden telephone poles in the fire areas. The hills area around Melbourne, where the fires occurred, is thickly timbered and for scenic reasons strenuous efforts have been made in the past by local authorities to retain as much of the natural vegetation as possible. As a result clearing along pole routes was kept to a minimum, a fact that seriously increased the fire hazard to departmental plant. Although a rural area, its pleasing situation has attracted a comparatively large population, so that there is an intensive network of telephone services. The majority of the aerial routes concerned have been in existence for some time and in recent years pole replacements, which have been numerous, were with pressure treated poles. This then enabled a direct comparison to be made of the behaviour of treated and untreated poles in the fires.

Over 200 poles were destroyed but not one pressure treated pole was lost or even severley damaged, although it is estimated that an equivalent number was subjected to the same fire intensity. Similar experiences have been reported on several occasions from overseas countries; in particular U.S.A., Germany and South Africa. The explanation put forward is that on exposure to fire the creosote in the outer layers of the pole volatilises and ignites at a temperature lower than that necessary to cause damage to the timber, and that the thick smoke created shuts off the oxygen supply and the flames are soon extinguished. The deposit of free carbon formed on the pole serves as an insulator against further damage. In these fires it was noticed that a thin outer layer of charred wood was formed on the pole which supports the above theory. The firm outer surface of the treated poles compared with the untreated poles, many of which would have had loose and partly decayed sapwood, also assisted materially in preventing their loss. It was noted that many of the poles had been treated less than 12 months previously.



Treated pole alongside burnt out fence. Note blackberry canes which show that pole was surrounded by growth.



Photograph illustrating the depth of charring on treated poles.

A TELEGRAPH DISTORTION ANALYSER

*J. G. BARTLETT, A.M.I.E.Aust.**
*L. L. BIRCH, B.E.**

INTRODUCTION

In recent years, there has been a rapid expansion of the telegraph service in this country. The use of machine working to replace manual morse operation, the introduction of telegraph switching systems such as TRESS and TELEX, and the need to connect several circuits in tandem to provide leased teletype services have all placed exacting requirements on the performance of telegraph channels, particularly those derived on V.F. telegraph systems. These requirements are likely to become even more stringent in future through the use of telegraph channels for the transmission of data to electronic computers.

An accurate measure of the performance of V.F. telegraph channels is essential if the optimum performance is to be obtained from these channels. Methods which have been used to evaluate channel performances have included:—

(a) analysis of fault statistics;
(b) measurement of distortion using a Telegraph Distortion Measuring Set;
(c) examination of oscilloscope traces of received signals;
(d) recording of interruptions to continuous mark or space signals.

The information which can be obtained by these methods is limited and for this reason the Telegraph Distortion Analyser has been developed.

TELEGRAPH TRANSMISSION

Telegraph channels handle information in binary digital form. The binary digits 0 and 1 may appear in various forms at different parts of the telegraph network. Typical forms are shown in Table I.

Telegraph machines used in Australia transmit and receive information by a five unit code at the rate of 50 bits (binary digits) per second. In telegraph terminology a bit per second is known as a baud. Each character is represented by 5 mark or space elements identifying the character, preceded by a spacing start element and followed by a marking stop element. Each signal element and the start element is normally of 20 milliseconds duration while the stop element signal is of 28 milliseconds duration. A typical character is shown in Fig. 1.

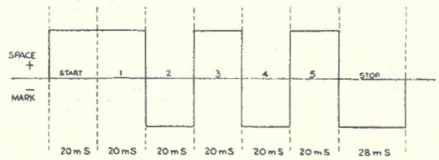


Fig. 1.—Letter R.

TELEGRAPH DISTORTION

Any difference in duration of a signal element from the nominal value will contribute towards failure of the system. This variation in length of the signal elements is known as distortion. Although the C.C.I.T.T. distinguishes several sorts of distortion, distortion is most simply expressed as a percentage (D) which for a signal of nominal 20 milliseconds duration is defined as $D=[(n-20)/20]\times 100$, where n is the actual duration of the signal in milliseconds. Distortion may be marking or spacing depending on whether the mark element is greater or smaller than the nominal value, and is generally classified into three types:

Table I

Binary Digit	Telegraph Term.	Single Current Working	Double Current Working	A.M. V.F.T.	F.M. V.F.T.	Teletype Printer Magnet	Reperforator Tape
0	Space	No Current	Positive Current	tone off	$fo+\Delta f$	unenergised	not punched
1	Mark	Current	Negative Current	tone on	$fo-\Delta f$	energised	punched

The fundamental requirement of a telegraph transmission system is that when supplied with information representing the digit 0 or 1 it shall reproduce this information at the receiving end of the circuit. Failure of the system will be indicated by the reception of a 1 (mark) when an 0 (space) is transmitted or by the reception of a space when a mark is transmitted.

In any telegraph system or network there will be a probability "a priori" of failure occuring. The telegraph distortion analyser provides information which allows this probability to be estimated and allows the design of the network to be soundly based.

Bias Distortion: Where a telegraph channel or machine has a definite tendency to vary the length of all signal elements by a fixed amount either by increasing the duration of marking elements and shortening spacing elements, or vice versa, this is known as bias distortion. A typical cause is an incorrectly adjusted relay which requires a greater number of ampere-turns to move it to the mark contact than is required to move it to the space contact. Bias distortion is independent of the duration of signal elements.

Characteristic Distortion: Characteristic distortion is a form of distortion which occurs when signal transitions occur before a steady state value has been reached on the preceding element. It is dependent on the electrical characteristics of the telegraph channel or the electrical or mechanical characteristics of the telegraph machine. Characteristic distortion varies with the duration of signal elements and mark and space elements are equally affected.

Fortuitous Distortion: Fortuitous distortion is produced by crossfire, noise, power induction, momentary power surges and other occurrences of a random nature.

Cumulative Effect of Distortion

A normal telegraph connection will comprise a transmitting machine, one or more telegraph channels, a receiving machine, and possibly an intermediate machine such as a reperforator transmitter. Each machine and channel will introduce some distortion which will be cumulative in its effect on the overall connection. It is generally accepted that for small values of distortion at least, bias distortion is algebraically additive, characteristic distortion is directly additive and fortuitous distortion quadratically additive.

MEASUREMENT OF DISTORTION

Telegraph distortion can be measured by various types of Telegraph Distortion Measuring Sets all of which indicate the average value of distortion present during the measuring period. The average value of distortion however, gives only a limited amount of information about the channel being tested as it is quite common for two circuits which have the same average distortion to have very different performance. For example, there may be two channels with an average distortion of 5%, one of which will produce 20% distortion on 5% of characters while the other may produce this distortion on only 0.1% of characters. An experienced operator of a T.D.M.S. will be able to discern this difference but will not be able to assess it quantitatively.

Where the standard of service on a particular telegraph circuit or connection is to be assessed, we must know the probability of any particular value of distortion occurring or, on the complete connection, the probability of some limiting value of distortion being exceeded. The Telegraph Distortion Analyser provides this information by sampling a number of telegraph characters, measuring the distortion of each and recording the number of times that the distortion falls within each of eleven ranges extending from 50% space to 50% mark. Generally, a sample of 2,000 distortion measurements is sufficient to assess the performance of a channel.

THE TELEGRAPH DISTORTION ANALYSER

General Description

The Telegraph Distortion Analyser consists of a very accurate digital timer (1) (the Beckman 7160H EPUT Meter) which samples at random the received telegraph character elements and

* See page 349.

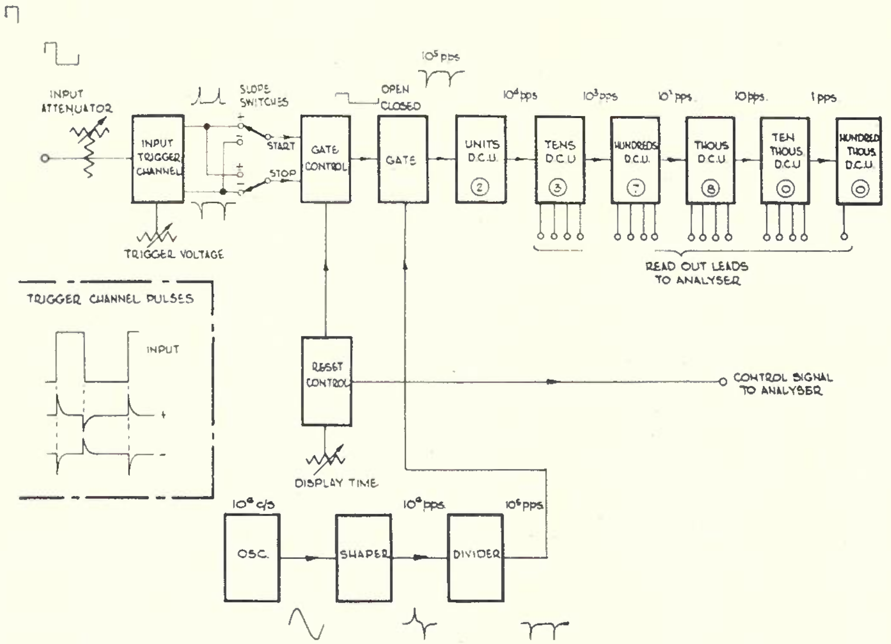


Fig. 2.—Beckman 7160 EPUT Meter—Period Operation.

measures their duration. The duration of the sampled elements in milliseconds appears at the output of the EPUT meter as a sixteen line binary code. These sixteen code leads are taken to the analyser where they control the operation of a chain of relays. These relays in turn control the operation of a group of subscribers' registers which record the distortion (in steps of 5%) of the sampled character elements. Operation of a key can replace any two meters, covering a range of 10% distortion in 5% steps, by ten meters recording the same range of distortion in ten one percent steps.

Measurement of Signal Duration

As mentioned already, the duration of signal elements is measured on the Beckman 7160H EPUT Meter (2). A simplified schematic of the EPUT Meter, set up in the condition in which it is used in the analyser, is shown in Fig. 2. In this condition, the function switch (not shown) is set to "Period" so that the time between two voltage transitions is measured. The instrument functions by counting on tandem connected decimal counting units (D.C.U.'s), pulses derived from a very stable 1 Mc/s oscillator. These pulses are fed through a gate which is opened and closed by the input signal.

Referring to Fig. 2, the 1 Mc/s oscillator is fed to a shaper which steepens the slope of the original sinusoidal oscillation. From the shaper it is taken to a 10 to 1 frequency divider and the output of the divider, consisting of 10^6 pulses per second, is fed via the gate to the cascaded D.C.U.'s. The input signal which consists of a square wave train having a peak amplitude of ± 50 volts is first attenuated so that the peak voltage is less than 1 volt and then fed to the input trigger channel which consists of a difference amplifier and voltage discriminator. Each time the input voltage exceeds an internally generated reference voltage, a positive pulse will be produced on one output lead and a negative pulse will be produced on the other output lead while, when the input voltage falls below the reference voltage, a negative pulse will be produced on the first lead and a positive pulse will be produced on the second. The reference voltage can be adjusted with the trigger voltage control and is normally set to about zero volts.

The two output leads are taken via the start slope and stop slope switches to the gate control circuit. With the start slope switch set to positive and the stop slope switch set to negative, the gate will open on the arrival of a positive going transition and stop on the arrival of a negative going transition. This means that spacing elements will be measured. Marking elements can be measured by reversing the operated position of the two switches. After the gate has closed it will remain closed for a time determined by the setting of the display time control in the reset control circuit. This control is set so that there is ample time for the relays and registers in the analyser to operate. At the end of the display time, the circuit will reset and will reoperate on the arrival of the next voltage transition which is either positive or negative going depending on the setting of the start slope switch.

During the time that the gate is open, 10^5 p.p.s. will be fed into the D.C.U's. which each consist of four binary counters. The D.C.U's. will therefore indicate the duration of the signal element being measured to the nearest 1/100th of a millisecond. The duration is indicated in two ways, firstly as a digital display on lighted lucite panels on the face of the instrument (a display of 87.3 milliseconds being shown in Fig. 2) and secondly, as a four-line binary code from each D.C.U. These four code lines appear on the digital recorder socket at the rear of the instrument. The analyser is actuated by the binary code appearing on the pins of this socket.

The four-line binary code used is shown in Table 2. In this code, 0 represents a voltage, 15 or more volts negative to ground, and 1 represents a voltage at ground or positive to ground. Both the visual display and the four-line code will be static for a time determined by the display time control.

Signal Duration and Distortion

Telegraph signal elements will be approximate multiples of 20 milliseconds and the amount each reading differs from an exact multiple of 20 milliseconds represents the amount of distortion present. If the space elements of the signal shown in Fig. 1 were measured, a reading of 40 milliseconds (start + 1st element) or 20 milliseconds (3rd or 5th elements) would be obtained. This would indicate zero distortion. If, however, a reading of 37 or 17 milliseconds was obtained, this would indicate 3/20 x 100 = 15% marking distortion. Similarly, readings of 43 or 23 milliseconds would indicate 15% spacing distortion. Marking elements can be measured similarly but as the 28 millisecond stop element would appear as 40% distortion, it is necessary to omit the stop element from the test signal.

Table 2

Decimal Digit Registered	Four line binary code: 1st binary stage	2nd binary stage	3rd binary stage	4th binary stage
0	0	0	0	0
1	1	0	0	0
2	0	1	0	0
3	1	1	0	0
4	0	1	1	0
5	1	1	1	0
6	0	0	1	1
7	1	0	1	1
8	0	1	1	1
9	1	1	1	1

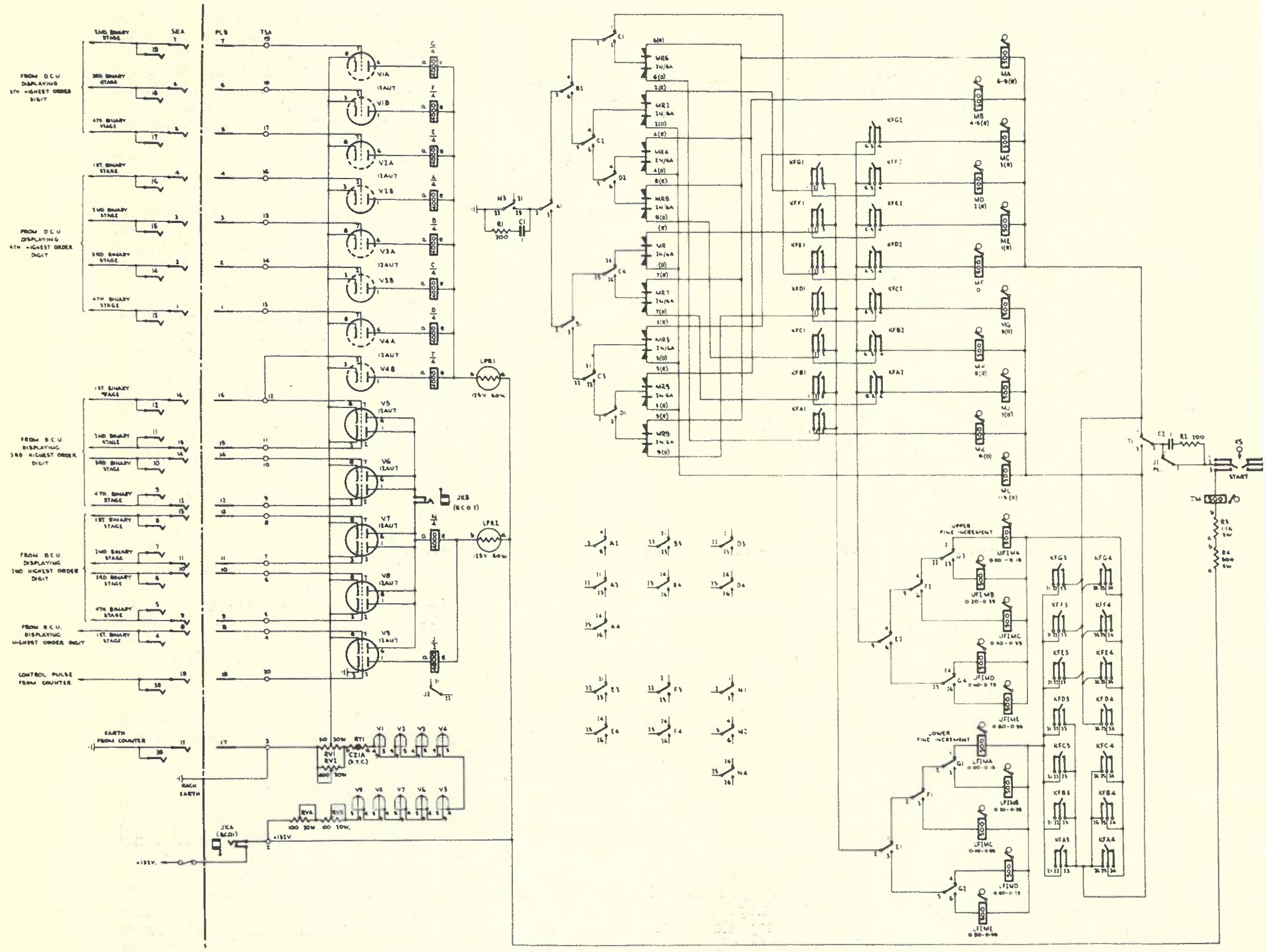


Fig. 3.—Analyser Schematic.

The stop element can be omitted by operation of a switch on the Teletype Corporation DXD4 Test Set used to generate the test message.

Analyser Circuit

The manner in which the information on signal duration is transferred from the EPUT meter to a permanent record on subscriber's registers is as follows:

The EPUT meter will normally be operated with the time switch set to 10^{-5} seconds, that is the D.C.U. displaying the sixth highest order digit will count in units of .01 milliseconds, The D.C.U. displaying the fifth highest order digit will count in units of 0.1 milliseconds, and so on.

In the ensuing description, the several D.C.U's. involved will be referred to by the units of time which they are counting. e.g. 1/10 milliseconds D.C.U. It will be realised, of course, that such designations are true only while the time switch is set to 10^{-5} seconds.

Referring to Fig. 3 the four read-out leads from binary stages 1 to 4 of the one millisecond D.C.U. are connected to the control grids of V2B, V3A, V3B and V4A respectively. If the voltage on any of the grids is positive the tube will conduct and operate the relay (A, B, C or D) in its plate circuit. Depending on the digit displayed on the EPUT meter, a positive or negative voltage will appear on each of the four read-out leads and cause the operation of the appropriate A, B, C or D relays so that the earth on contact A1 is transferred via the relay contact tree to one and only one of the ten leads, (0) to (9), at the output of the tree.

If the digit 3 is displayed, the code for this from Table 2 is 1, 1, 0, 0. Remembering that 0 represents a negative voltage sufficient to bias V2B etc. to cut off and "1" represents ground or a positive voltage, then tubes V2B and V3A will conduct and operate A and B relays. This extends the earth on A1 to lead 3.

Assuming KS2-3, N3 and J1 contacts made, T1 normal and Fine Increment Keys KFA — KFG unoperated, the earth on lead 3 completes the circuit from +132 volt battery via R4, R3, meter TM, KS2-3, J1, T1, meter MC and MR3 and operates the meters, TM, which records the total count, and MC (designated "+3"), which indicates that a signal element 3 milliseconds in excess of the nominal multiple of 20 milliseconds has been measured.

Referring again to Table 2, it will be seen that the binary code voltage from the first binary stage of each D.C.U. is "0" for zero and each even digit and "1" for each odd digit. This fact is used to differentiate between signal elements which are shorter than the nominal period (20MS or multiple thereof) and those which are longer. The first read-out lead from the ten milliseconds D.C.U. (pin 12 of the EPUT meter or TSA/12 of the analyser) is connected to the grid of V4B. Any count which is longer than the nominal period of 50 baud signal elements (e.g. 23, 41, 62 . . . . 125 etc.) will give rise to a negative voltage on the grid of V4B which will bias this tube to cut off. The T relay in the anode circuit of V4B will not operate and the register in the "evens" group MA-MF corresponding to the figure displayed by the one millisecond D.C.U. will operate. Any count shorter than the nominal period (e.g. 19, 37, 55 . . . 117 etc.) will cause V4B to conduct and operate the T relay. This connects the appropriate meter MG-ML in the "odds" group. The meters MA-MF are designated "0", "+1", "+2", "+3", "+4 to +5", "+6 to +9" respectively and the meters MG to ML are designated "–1", "–2", "–3", "–4" and "–5 to –9" respectively, the the former indicating durations in milliseconds longer than the nominal and the latter, durations shorter than the nominal. Note that the leads representing extreme values of distortion have been commoned to share a limited number of registers, e.g. "+4 to +5". As only a very small number of high distortion values are recorded in a typical count, a separate register for every one millisecond increment up to ± 9 milliseconds from the nominal period is not necessary.

The N relay is included to prevent any very short counts due to contact bounce from being recorded. If the tongue of a receive relay in a channel under test moved to the positive (space) contact then bounced off after 2 milliseconds, the voltage on the tongue will drop to zero until the tongue returned to the space contact. This negative going voltage change is sufficient to act as a stop pulse and the EPUT meter would record a count of 2 milliseconds. This would be incorrectly interpreted by the analyser as a reading of +2 or 10% distortion.

It will be seen from Table 2 that the binary code for all digits other than zero has at least one "1" (ground or positive voltage) in it. Hence if each read-out lead from the 10 millisecond and 100 millisecond D.C.U's. is connected to a control grid of the four twin triodes V5—V8, a display other than zero on either the 10 millisecond or 100 millisecond D.C.U. will cause at least one triode to conduct. All anodes of V5—V8 are commoned and taken to +132V via the N relay. Thus the N relay operates only when a count of 10 milliseconds or more is displayed. The N2 contacts in the register circuit prevent recording of counts less than 10.

It is necessary to ensure that the circuit for the register is not completed before all relays involved in the contact tree and also the T relay have assumed their final position in accordance with the display on the EPUT meter. For instance, during counting, the potentials on all read-out leads vary between positive and negative values as each binary stage is triggered. This could cause false operation of the registers. The J relay has been included to ensure that this does not happen.

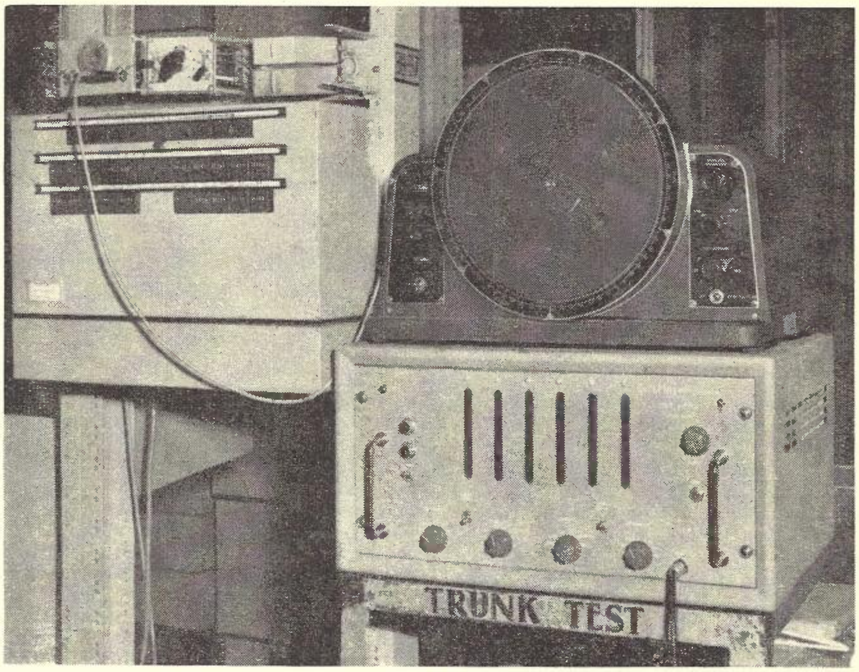


Fig. 4A.—Distortion Analyser with Associated Test Equipment.

This relay is in one anode circuit of V9, the grid of which is connected to pin 39 of the digital recorder socket at the rear of the instrument. This pin carries a control signal from the counter which is negative during the display period and positive from reset until the end of the next counting period. Thus the J relay is unoperated during display and operated for the remaining period of the cycle and is adjusted to ensure that it will release shortly after all other energised relays have operated.

As mentioned earlier, the analyser is capable of recording increments of distortion values as low as one percent (or 0.2 milliseconds). Experience with an earlier model analyser whose incremental steps were one millisecond had shown that insufficient points were obtained to plot a reliable curve

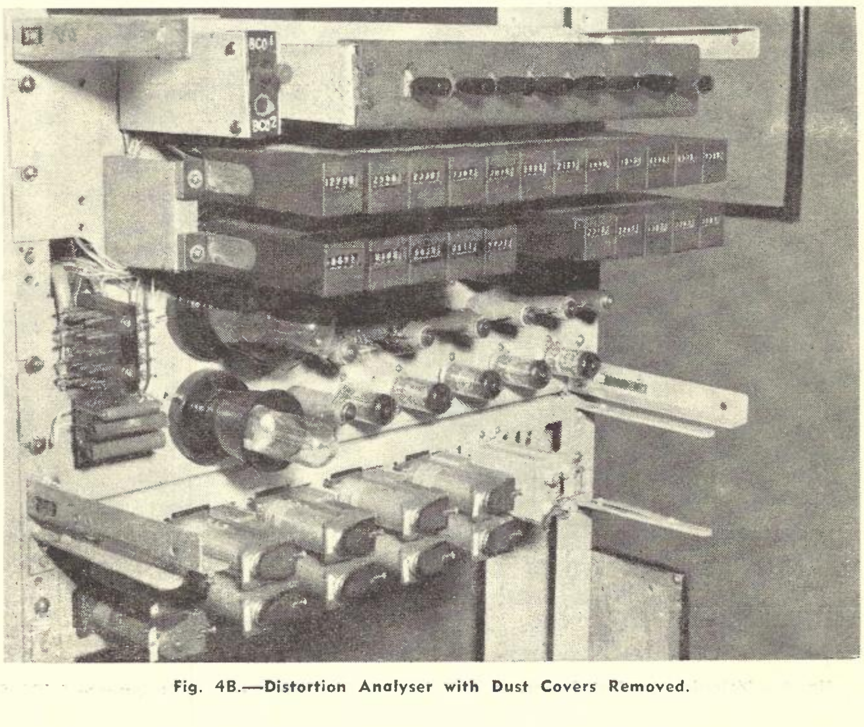


Fig. 4B.—Distortion Analyser with Dust Covers Removed.

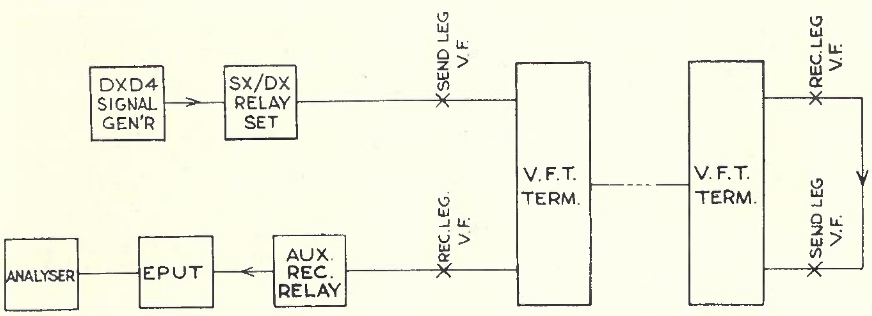


Fig 5.—Test Set-up.

representing frequency of occurrence versus distortion values. The standard deviation obtained in most cases was less than 1 millisecond which meant that nearly all of the distortion samples were recorded on two registers.

The facility built into the present analyser enables the operator to note on the EPUT meter the duration of signal element being displayed most frequently on the one millisecond D.C.U. and then throw the appropriate Fine Increment Key. If "9's" and "0's" were predominant, key KFD ("–1 to 0") would be operated. This removes the one millisecond increment meters MG and MF from circuit and replaces them by the ten fine increment (0.2 milliseconds) meters, UFI MA–E and LFI MA–E. The operation of the fine increment contact trees (relays E, F and G) is similar to the one millisecond increment tree except that only the last three read-out leads are used from the 1/10th millisecond D.C.U. These appear on pins 17, 18 and 19 and are connected to the grids of V2A, V1B and V1A respectively. Relays E, F and G are in the anode circuits of these tubes. Supposing a count of 19.8 milliseconds is displayed on the EPUT meter. The code for 9 is 1, 1, 1, 1 and therefore operates A, B, C and D relays and extends the earth from the N2 contact to lead nine and thence via key KFD1 (operated) to contact E1 in the lower fine increment contact tree. The code for 8 is 0, 1, 1, 1 and as only the last three lines of the four line code are used, relays G, F and E are all operated and extend the earth to meter LFI ME (0.80 to 0.99 milliseconds). Note that the code for 9 is 1, 1, 1, 1. As the first unit of the four line code is ineffective, the same three relays are operated by a "9" displayed on the 1/10 millisecond D.C.U. as by an "8". Examination of Table 2 will show that as far as the last three lines are concerned, the code for 6 is the same as that for 7, likewise 4 and 5, 2 and 3, 0 and 1.

Meter LFI ME is connected via KFD3 (operated) T1 (3), J1, KS2–3, TM, R3 and R4 to +132V battery. If the next signal element measured has a duration of 20.5 milliseconds the "0" displayed on the one millisecond D.C.U. will cause the earth on N2 contact to be extended via A1, B2, C1, KFD2 (operated) to E2 contact in the upper fine increment contact tree. The "5" displayed in the 1/10th millisecond D.C.U. code (1, 1, 1, 0) will cause the operation of G and F relays and extend the earth on E2 to meter UFI ME (0.40 — 0.59). (A "4" displayed on the latter D.C.U. would have had the same result).

Meter UFI ME is connected, in common with the four other meters in the upper fine increment group, via KFD4 operated to T1/1 then via T1/2, J1, KS, TM, R3 and R4 to +132V battery.

Change of Range

When, from an inspection of successive displays on the EPUT meter, it is obvious that values of distortion exceeding 5% will be unlikely to occur, all increments of distortion mentioned in the preceding description can be divided by ten by setting the time switch to 10^{-6} instead of 10^{-5} seconds. This feeds the output of the 1 megacycle oscillator to the first D.C.U. and 10^6 p.p.s. are counted instead of 10^5 p.p.s. as described previously. This feature is used when measuring the distortion of the test equipment. In such cases, the duration of any signal element is, without exception, 20 milliseconds (or multiple thereof) ±0.9 milliseconds. The D.C.U. recording milliseconds (3rd highest order D.C.U. when time switch is set to 10^6 seconds) will record "9's" and "0's", the former operating the T relay and the latter not, according to whether the measured duration was above or below the mean of 20 milliseconds. The 4th highest order D.C.U. will now be counting 1/10th milliseconds and operate the A, B, C and D relay contact tree to record an analysis in increments of 1/10th milliseconds or 0.5% distortion. The Fine Increment Keys can still

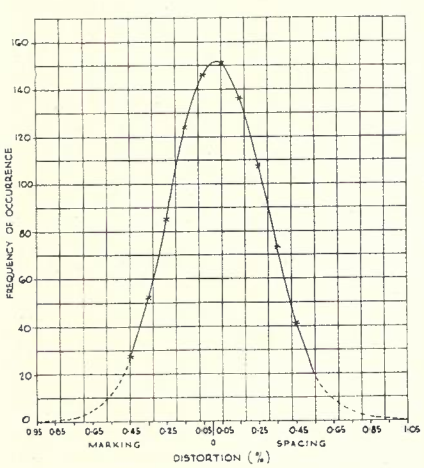


Fig. 6.—Distortion on Test Equipment.

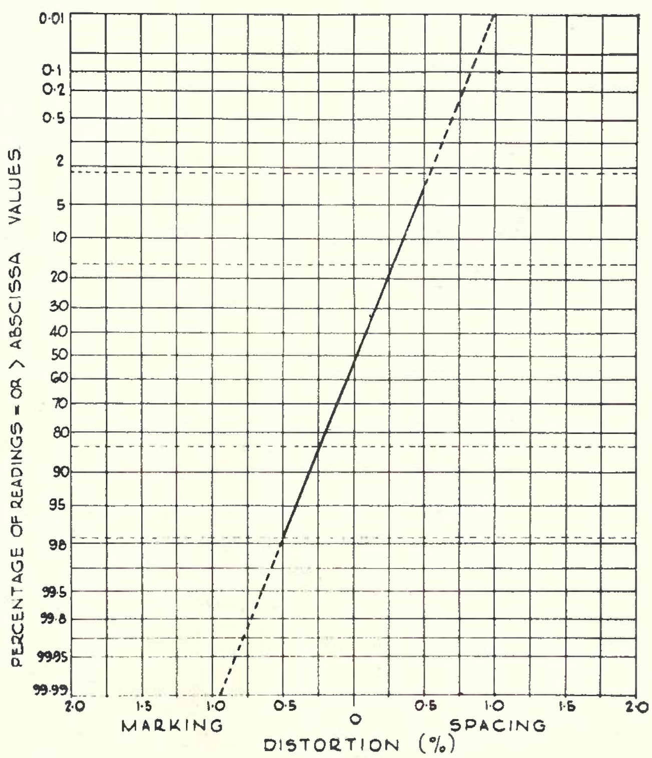


Fig. 7.—Test Equipment—7,000 Samples. Test Message at 50 Bauds.

be used to replace any two adjoining .5% meters with 10 meters recording in 0.1% increments.

Test Set-Up

The analyser is used in conjunction with a DXD4 teletype signal generator or similar equipment which will generate a standard test message in 5 unit start/stop code, a simplex to duplex relay set where it is necessary to change from single current to double current signals, and usually it is desirable to interpose a good quality relay such as the Carpenter 3E1 between the receiver leg of the channel and the EPUT meter. This reduces the recording time on channels prone to contact bounce. The display time control of the EPUT meter is set so that four or five elements are sampled per second thus making it possible to obtain a 2,000 sample in about 8 minutes. A photograph of the analyser and associated test equipment is shown in Fig. 4A. Fig. 4B is a close-up of the analyser itself with the dust covers removed, while a schematic of a typical set-up is shown in Fig. 5.

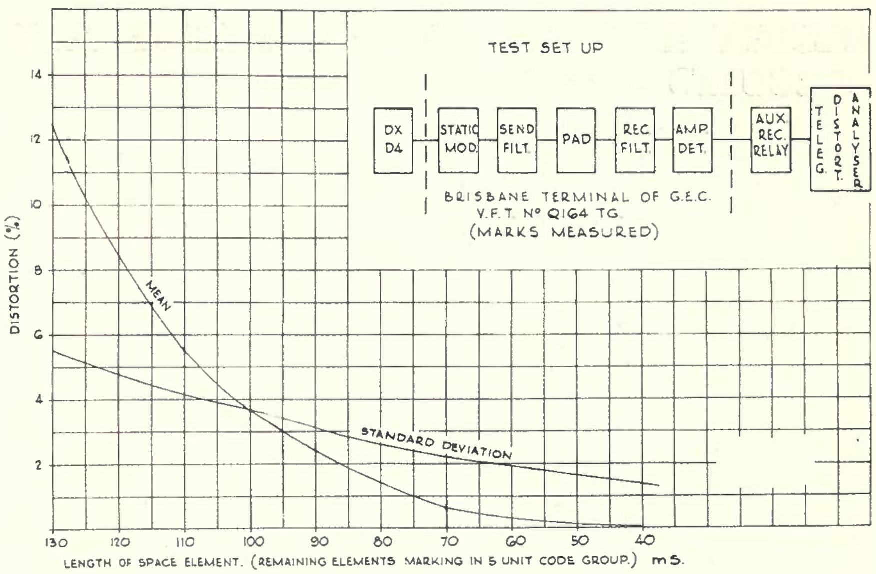


Fig. 9.—Typical Distortion Values versus Length of Spacing Element.

Analysis of Results

At least 2,000 readings are taken and plotted on arithmetical probability paper. The result of a typical set of readings is shown in Figs. 6 and 7. In the former, the readings are plotted on linear graph paper and it is seen that the points are distributed equally about the mean on the typical bell shaped Gaussian distribution curve. In the latter, probabilities (or cumulative frequency percent) are plotted on arithmetical probability paper. If the distribution is normal, the curve on this paper should be a straight line and it can be seen that the bulk of the points lie on such a line. From the latter graph it is simple matter to read off the mean and standard deviation of the distortion values, and the probability that extreme values of distortion will occur can be seen at a glance.

Some typical results obtained are shown in Figs. 8 and 9. Fig. 8 shows the curves obtained on typical V.F. telegraph channels, while Fig. 9 graphs the average and standard deviation of distortion values on a V.F. telegraph channel as a function of the duration of the spacing element. This graph shows clearly the effect of the A.G.C. circuit in the conventional amplifier detector.

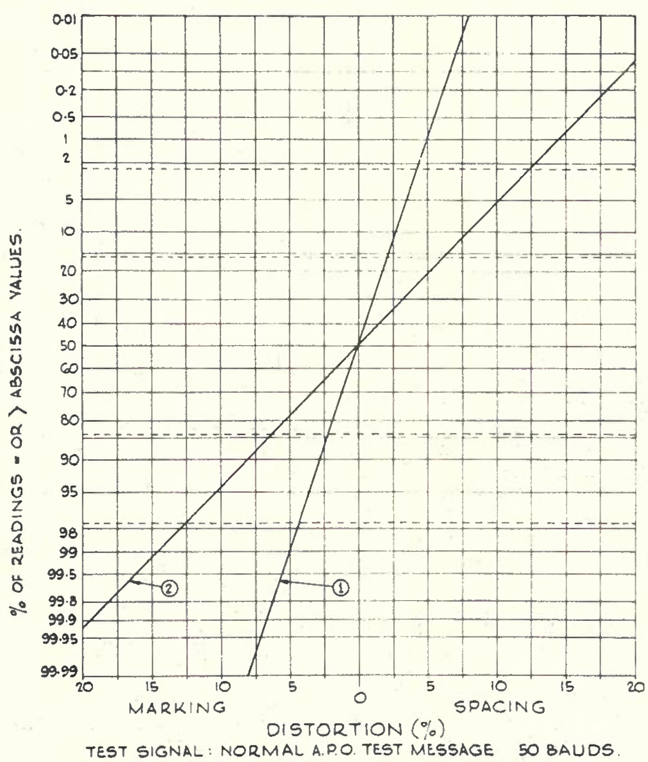


Fig. 8.—Typical Distortion Values—
1. Best Channels of Latest Systems.
2. Worst Channels of Oldest Systems.

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DESIGN ASPECTS OF TRANSISTOR AND DIODE SWITCHING CIRCUITS — PART 1

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1. INTRODUCTION

This is the first of several articles whose purpose is to outline the fundamental principles of design of two-state switching circuits, in particular those using transistors and semiconductor diodes. Two-state switching circuits are composed of basic elements which can have, at any one instant, only one of two possible stable states (e.g. a "make" springset pair is either made or open and nothing else). The design of these circuits is greatly facilitated by the use of Boolean algebra, which has alternative names such as the "algebra of logic". This arises from the possible representation of syllogistic arguments in terms of this algebra. These facets of Boolean Algebra have given an alternative name of "logic circuits" to switching circuits, and the design of the block schematic for such circuits is often referred to as their logic design. The knowledge of the required state of the output of such a circuit for all possible combinations of the states of the inputs provides the starting point for the design of a switching circuit and enables its switching function to be determined and then realised.

The design of a switching circuit can be broken into two steps. The first step is to arrive at a satisfactory logic design for the circuit. This results in a block schematic diagram of basic circuit modules which have known switching functions, and are consistent with practical circuit design. The second step is the design of elements of the block diagram. This generally amounts to the actual circuit design of several basic modules to perform given switching functions, and the investigation of and provision for suitable loading, operating speeds, etc., between these "standard" modules. This is especially the case in large systems such as digital computers where production of standardised modules becomes important, but it also applies in smaller systems.

The logic design of switching circuits is systematised and facilitated by the use of Boolean Algebra, and this first article thus outlines the basic principles of this algebra as the first tool in the design of switching circuits—be they composed of relays, vacuum tubes, gas tubes, transistors, diodes, magnetic materials, etc. Subsequent articles will consider transistor and semiconductor diode switching circuit elements, describing their two-state behaviour and illustrating their design as circuit elements. Other circuit modules such as memories, delays, binary counters, etc., associated with such switching elements will also be described and their uses discussed.

2. BASICS OF BOOLEAN ALGEBRA

Boolean algebra is a complete branch of mathematics in itself, and is basically divorced from ordinary algebra. The fundamental definitions and theorems of Boolean algebra are few, and the algebra is simple to apply.

* See page 350.

A	B	F(A,B)
1	1	1
0	1	1
1	0	1
0	0	0

FIG. 1A: F(A,B) = A + B
i.e. OR FUNCTION-CONVENTION I
OR AND FUNCTION-CONVENTION II

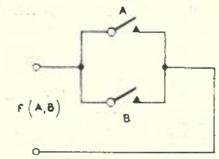

FIG. 1B: OR FUNCTION CONFIGURATION OF RELAY SPRINGSETS

A	B	F(A,B)
1	1	1
0	1	0
1	0	0
0	0	0

FIG. 1C: F(A,B) = A.B
i.e. AND FUNCTION-CONVENTION I
OR OR FUNCTION-CONVENTION II

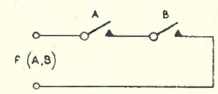

FIG. 1D: AND FUNCTION CONFIGURATION OF RELAY SPRINGSETS

Fig. 1.—Illustration of Fundamental Functions of Variables.

2.1 The Variables of Boolean Algebra

In ordinary algebra, a variable "x" can have an infinite number of values. Variables in Boolean algebra can have only two states. These two states (not values) are often written as "1" or "0", or as "true" and "false". These two states are completely complementary, both making up the universe of states in which a variable can exist. If a variable has not the state "1", it must have the state "0", and vice versa. The symbols "1" and "0" have no relation to the figures 1 and 0. The symbol "1" may be chosen to represent the operated state of a relay and, due to the complementary nature of the states, the symbol "0" must represent the unoperated state of the relay. Alternatively, the "1" and "0" symbols could be interchanged in the above statement. Since only two states can be assigned to a variable x, a complementary variable x' (sometimes written $\bar{x}$) can be defined as that which has the state "1" when x has the state "0", and which has the state "0" when x has the state "1". An example of complementary variables is provided by the two outputs of a bistable circuit, or, more simply, by a make springset and a break springset on the same relay.

2.2 Functions of Variables

There are only two fundamental functions of variables in Boolean algebra. These are the AND function and the OR function. Using these fundamental functions more complex functions of variables can be built up. These fundamental functions are defined below for the two possible conventions which could be adopted in assigning meanings to the states "1" and "0".

2.2.1 Convention I in which

1 = operated relay or presence of a switching signal.

0 = unoperated relay or absence of a switching signal.

(i) **OR Function**

f(A,B,C, ...) = A + B + C + ... is an OR function of the variables A, B, C, . . . and, by definition, has the state 1 when one or more of the variables A, B, C, . . . has the state 1.

A means of tabulating the states of f(A, B) for the possible combinations of the states of the variables A and B is shown in Fig. 1 (a). The tabulation is called a Truth Table and each row of the table shows a particular combination of the states of A and B and the resultant state of f(A,B). The relay contacts of Fig. 1 (b) can be seen to perform an OR function in that a circuit path is completed when either relay A or relay B or both are operated. In this and in subsequent sketches, relay contacts are shown in the "unoperated" condition.

(ii) **AND Function**

f(A,B,C . . .) = A.B.C. . . . . is an AND function of the variables A, B, C, ... and, by definition, has the state 1 only when all of A, B, C, ... have the state 1.

The truth table for f(A, B) = A. B is shown in Fig. 1 (c). The relay contacts of Fig. 1 (d) can be seen to perform an AND function since a circuit path is completed only when both relays A and B are operated.

2.2.2 Convention II is the dual of Convention I and, for this convention,

0 = operated relay or presence of a switching signal.

1 = unoperated relay or absence of a switching signal.

(i) **OR Function**

f(A, B, C, ...) = A.B.C . . . . is an OR function of the variables, A, B, C, . . . and has the state 0 when any one or more of A, B, C . . . . have the state 0.

This definition can be seen to be the complementary statement to that of the AND function in Convention I, and the same truth table of Fig 1 (c) applies to both definitions. However, Fig. 1 (b) depicts relay contacts performing an OR function whatever the chosen convention.

(ii) **AND Function**

$f(A, B, C, \ldots) = A + B + C + \ldots$ is an AND function of the variables A, B, C . . . . and has the state 0 only when all of A, B, C, ... have the state 0.

This is the complementary statement to that for the OR function in Convention I and the same truth table of Fig. 1 (a) applies. Fig. 1 (d) shows the physical realisation by means of relay springsets of an AND function whatever the chosen convention.

From the above definitions, it can be seen that a duality exists between the two conventions from the aspect of their representation in terms of Boolean Algebra. However, the physical circuits perform the same switching function no matter what convention is used. Hence, in design, one or other convention should be adhered to, the choice of a convention being made at the outset of a design. The manipulations of the Boolean Algebra are the same for both conventions because of the property of duality between them. Thus, the same physical realisation of the design will result no matter what convention is adopted. Different text books use one or other of these conventions and it is wise to ascertain which particular convention is being used in a text being studied. For the remainder of these articles, Convention I will be adopted as the basis of designating meanings to the states 1 and 0.

In many instances, the dot operator as in A.B is not written, this becoming more simply AB. The dot is then retained in positions where clarification might be necessary. The plus symbol is always retained.

2.3 Axioms

For want of a better word, the following equalities are called axioms. They would perhaps be better called fundamental theorems, or merely statements of the above definitions in terms of symbols, some of the symbols having particular states and others variable states. The proofs of these equalities lies in the definitions. Further consideration of these equalities can be found in References 1 and 2. The equalities are:—

$$\begin{array}{lll} 0 + 0 = 0 & 0.0 = 0 & \\ 0 + 1 = 1 & 0.1 = 0 & \\ 1 + 1 = 1 & 1.1 = 1 & A + A' = 1 \\ A + 0 = A & A.0 = 0 & A.A' = 0 \\ A + 1 = 1 & A.1 = A & (A')' = A \\ A + A = A & A.A = A & \end{array}$$

Other fundamental properties of Boolean functions are:—

(i) Both OR and AND functions are commutative and associative; that is:—

$A+B=B+A$

$A \, . \, B=B \, . \, A$

$A+(B+C)=(A+B)+C=B+(C+A)$
$=A+B+C$

$A.(B.C)=(A.B).C=B.(C.A)=ABC$

The use of brackets is seen to follow the same laws as in ordinary algebra.

(ii) Each function is distributive with respect to the other; that is:—

$A.B+A.C=A.(B+C)$

$(A+B).(A+C)=A.(A+C)+B.(A+C)$
or $=A.(A+B)+C.(A+B)$
$(=A+BC$ on simplification)

2.4 Theorems

The axioms above form the basis of Boolean algebra. From these axioms stem some useful theorems which can be used to simplify complicated functions. The theorems can be simply proved by means of truth tables. All possible combinations of the states of the variables in a particular theorem are first tabulated. Then the states of the various terms of each side of the expression are listed for each of these combinations. These are successively combined to obtain the states of the whole of each side of the expression, and the resulting columns for each side of the expression in the truth table should be identical for equality. The more useful theorems are:

$A+A.B=A$ . . . . . 1(a)

$A.(A+B)=A$ . . . . . 1(b)

$(A+B+C+\ldots\ldots)'=A'.B'.C'\ldots\ldots$ . . . . . 2(a)

$(A.B.C.\ \ldots\ldots)'=A'+B'+C'\ldots\ldots$ . . . . . 2(b)

$A.(A'+B)=A.B.$ . . . . . 3(a)

$A+A'.B=A+B$ . . . . . 3(b)

$(A+B).(B+C).(A'+C)$
$=(A+B).(A'+C)$ . . 4(a)

$A.B+B.C+A'.C=A.B+A'.C$
. . . . . 4(b)

$A.B.+A'.B'=(A'.B+A.B')'$ . . . . . 5(a)

$(A+B)\ (A'+B')$
$=\{(A'+B).(A+B')\}'$
. . . . . 5(b)

In the above theorems, a duality is apparent, the equations 1(a), 2(a), 3(a) etc., being the duals of 1(b), 2(b), 3(b) etc., respectively. The dual expression is obtained by replacing . with + and + with . in an expression, with due regard for brackets. However, a dual expression is not equal to the original expression.

A useful method of changing the aspect of an expression uses theorems 2(a) and 2(b). The two results shown below are useful in altering the aspect of an expression to fit in with the switching functions of transistor NOR gates. The behaviour of this type of gate will be discussed later, the results being presented here for completeness. These results are:—

(i)

$AB+CD=(A'+B')'+(C'+D')'$
$=[(A'+B').(C'+D')]'$
$=[(AB)'.(CD)']$
. 6

(ii)

$(A+B).(C+D)=(A'B')'.(C'D')'$
$=(A'B'+C'D')'$
$=[(A+B')+(C+D)']'$
. 7

2.5 Invalid Simplification

Generally, in switching circuit design, Boolean expressions are to be simplified. However, equations are sometimes met. Division and subtraction operations do not exist in Boolean algebra. Hence, when dealing with equations, it is inconsistent with Boolean algebra to subtract a common term from both sides of an equation or to divide both sides by an apparently common factor. For example,

(i) $A + AB = A$ is correct

but we cannot subtract A from both sides to obtain the obviously invalid result $AB = 0$

(ii) The equation below is correct

$(AB' + BC' + CA') \, . \, (A'B' + B'C' + C'A') = (A + B + C) \, . \, (A'B' + B'C' + C'A')$ But invalid division of both sides by $(A'B' + B'C' + C'A')$ yields the false result: $AB' + BC' + CA' = A + B + C$

The error of this equation is shown in the lack of identity of the last two columns of the truth table of Fig. 2. Each column represents one side of the equation, all combinations of states of A, B and C being considered. The validity of the original equation can be checked by the same truth table tabulation method.

2.6 The Truth Table

The truth table is a convenient means of tabulation of the combinations of the states of the variables and of the resulting functions of variables. It can be used, as already indicated, to prove the validity of Boolean equations. However, it is also of use in the systematic appraisal of a switching circuit and is the usual method of attaining the first step in the logic design of a switching circuit. A few remarks concerning this aspect of a truth table will now be made.

From the definition of the AND function for f(A,B) using Convention I, we can say that the truth tables of

A	B	C	A'	B'	C'	AB'	BC'	CA'	AB' + BC' + CA'	A + B + C
1	1	1	0	0	0	0	0	0	0	1
0	1	1	1	0	0	0	0	1	1	1
1	0	1	0	1	0	1	0	0	1	1
0	0	1	1	1	0	0	0	1	1	1
1	1	0	0	0	1	0	1	0	1	1
0	1	0	1	0	1	0	1	0	1	1
1	0	0	0	1	1	1	0	0	1	1
0	0	0	1	1	1	0	0	0	0	0

Fig. 2.—Truth Table Showing that $AB' + BC' + CA' \neq A+B+C$.

A	B	F(A,B)
1	1	1
0	1	0
1	0	0
0	0	0

FIG. 3A: $f_1(A,B) = AB$

A	B	F(A,B)
1	1	0
0	1	1
1	0	0
0	0	0

FIG. 3B: $f_2(A,B) = A'B$

A	B	F(A,B)
1	1	0
0	1	0
1	0	0
0	0	1

FIG. 3C: $f_3(A,B) = A'B'$

A	B	F(A,B)
1	1	1
0	1	1
1	0	0
0	0	1

FIG. 3D: $f_4(A,B) = AB + A'B + A'B'$

Fig. 3.—Truth Tables for the Functions Specified.

Fig. 3(a), 3(b) and 3(c) represent respectively:—

$$f_1(A, B) = A . B$$
$$f_2(A, B) = A' . B$$
$$f_3(A, B) = A' . B'$$

The definitions of the complementary variables A' and B' should be borne in mind.

If we now superimpose these three truth tables, we perform an OR function, and the resultant truth table of Fig. 3(d), tabulates the function f(A,B) where:—

$$f(A,B) = f_1(A,B) + f_2(A,B) + f_3(A,B) = A.B + A'.B + A'.B'$$

In the design of a switching circuit, the steps above are retraced in reverse. Generally, the tabulation in the form of the truth table is drawn up with each row AND combination of states of the variables considered in turn. The required state of the output function is then inserted for each row in turn. From the truth table so derived it is necessary to obtain the Boolean expression representing the required switching function.

If, for instance, the truth table of Fig. 3(d) was the result of considerations of the required circuit functions, the expression $f(A,B) = AB + A'B + A'B'$ can be written from the table by writing down the fundamental AND functions of the variables A and B (and of course A' and B') which give a '1' state to f(A,B), and by then combining these for an OR function. The use of the complementary variables is necessary since an AND combination of variables, by definition, produces an output "1" state only when all input variables have the "1" state. By this means, the required Boolean switching function can be derived from the truth table. This method extends to any number of variables.

An alternative method is to use the complement of f(A,B). In this case, writing the complement as f'(A,B) and using the same method as above for f'(A,B), which necessarily follows from f(A,B), it can be seen that $f'(A,B) = AB'$ By negating (or complementing) f'(A,B), we obtain an alternative (but equivalent) function for f(A,B), as below:—

$$f(A,B) = [f'(A,B)]' = (AB')'$$

It can be readily checked that

$$f(A,B) + f'(A,B) = AB + A'B + A'B' + AB' = 1$$

as required by the definition of complementary variables and stated as an "axiom".

3. APPLICATION OF BOOLEAN ALGEBRA TO LOGIC CIRCUIT DESIGN

The foregoing presents the theory of Boolean Algebra. The use of this theory is sufficient for the design of two-state switching circuit logic. As previously indicated, the first step in the design is to tabulate the possible combinations of states of the input variables and the required output state for each combination. This is achieved by the truth table tabulation method. Next, from the truth table, the Boolean expression for the required output function is written as indicated in the previous section. The theory of Boolean algebra is now used to simplify this expression and to group the terms of the simplified expression in a form best suited to the circuitry to be used. This will become more evident when the basic functions of various transistor gate circuits are considered. When AND and OR functions only are performed by the circuitry, as in the case of relay circuits, the simplification of the expression is quite sufficient. But as mentioned earlier, the use of transistor NOR gates requires some changes in the grouping of terms of the expression.

Other methods of simplification of a Boolean expression have been devised. One in particular, the Karnaugh Map method, is purely mechanical and can reduce the labour involved if the number of variables is small. Details of this method can be found in References 2 and 3.

4. THE LOGICAL DESIGN OF RELAY CIRCUITS

4.1 Typical Method of Design

As a typical example of the method of the Boolean Algebra approach to switching circuit design, a simple example is now considered. Relays are used as the basic circuit element. The design of more complicated circuits follows exactly the same lines. The statement of the design specification could be:—

"It is required that three relays A, B and C should provide a circuit path for cases when any two of the three operate and the third is not operated, and also when A alone operates. In other cases, no path is to be provided."

A	B	C	F(A,B,C)
1	1	1	0
0	1	1	1
1	0	1	1
0	0	1	0
1	1	0	1
0	1	0	0
1	0	0	1
0	0	0	0

Fig. 4.—Truth Table for Illustrative Example.

The truth table of Fig. 4 summarises this specification. From this table, the required switching function f(A,B,C) can be written:

$$f(A,B,C) = A'BC + AB'C + ABC' + AB'C'$$

This is now simplified using the theory and theorems of the previous sections:

$$f(A,B,C) = A'BC + AB'C + AC'(B+B')$$
$$= A'BC + AB'C + AC' \qquad \because B + B' = 1$$
$$= A'BC + A(C' + B'C)$$
$$= A'BC + A(C' + B') \qquad \because C' + B'C = C' + B'$$

This yields the relay springset configuration shown in Fig. 5(a). Boolean Algebra does not cater for change-over springsets. However, these are easily inserted for pairs of make and break springsets where possible, by inspection, and this step gives the circuit of Fig. 5(b).

4.2 The Use of Complements in the Design of Relay Circuits

In the design of relay circuits, the use of complements is sometimes advantageous, especially if a relay is to be controlled by the logic circuit. Three alternative ways of controlling relay R

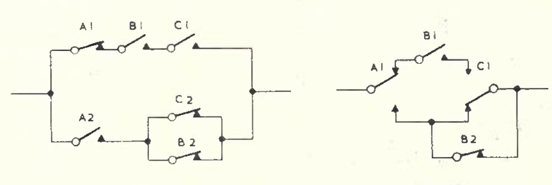

Fig. 5.—Relay Circuit—Illustrative Example.

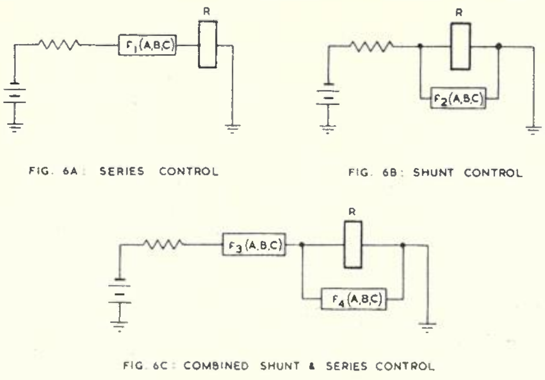

Fig. 6.—Methods of Controlling Relay R.

are shown in Fig. 6—the first is series control, the second is shunt control, and the third uses a combination of both methods.

In the case of series control of the relay, the switching circuit function $f_1(A,B,C)$ is determined in the usual manner. In the shunt controlled case, the switching circuit function $f_2(A,B,C)$ must be the complement of that of the series controlled case, a make springset in series with the relay having the same effect as a break springset shunted across the relay. Hence we can write:—

$$f_2(A,B,C) = f'_1\ (A,B,C.)$$

In the case of combination series and shunt control, it can be seen that the relay can operate when $f_3(A,B,C)$ has the '1' state and $f_4(A,B,C)$ has the "0" state, i.e. when $f'_4(A,B,C)$ has the "1" state. Thus, we can write:—

$$f_1(A,B,C) = f_3(A,B,C) \,.\, f'_4(A,B,C).$$

The expression for $f_2(A,B,C)$ can be formulated by complementing that for $f_1(A,B,C)$, or by returning to the truth table and writing it as the OR combination of the fundamental row AND combinations of the variables which produce a "0" state in $f_1(A,B,C)$. The expressions for $f_3(A,B,C)$ and $f_4(A,B,C)$ are best obtained by splitting $f_1(A,B,C)$ into two parts after reducing it to an AND combination of two partial expressions.

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ARTICLES BY P.M.G. DEPARTMENT STAFF APPEARING IN OTHER JOURNALS

"Aluminium Sheathing for Underground Cable"* by D. P. Bradley, B.Sc. B.Com., A.M.I.E.Aust.

A comparison is made of the relative properties of aluminium and lead in relation to the requirements of cable sheathing. Installation, maintenance and economic aspects of aluminium sheathing are discussed. Some details are given of manufacturing processes and of the extent to which aluminium sheathing has been accepted by cable-using authorities. The paper is written primarily from the point of view of a telephone cable user.

Aspects discussed include the problem of shielding cable circuits from electrical interference due to electromagnetic coupling with power transmission circuits, properties required in the sheathing to allow safe and economical handling and installation of cable including problems associated with installation of long lengths of cable in conduits, and precautions necessary to protect aluminium sheathing from corrosion.

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*This is an abstract of an article which appeared in the January, 1962 Journal of the Institution of Engineers, Australia.

AN OUTLINE OF OPERATIONS RESEARCH

E. B. HANDS, B.E.

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Editor's Note: This article on "Operations Research" is reprinted as it is an excellent and practical introduction to this subject. It is interesting to note that "Operations Research" is an old established technique in the telephone field and was in use long before the term was coined. For example a trunking study in an automatic telephone exchange is a typical "Operations Research" project. Operations Research has also drawn heavily on telephone traffic theory for its techniques.

INTRODUCTION

Operations research, an activity of great importance to industrial management, was born during World War II as an aid to military planning. The philosophy of the subject has been readily accepted by managers since the war in most countries of the world, in particular Britain and America. Development in Australia is currently taking place. An understanding of the broad concepts, definitions and limitations of the subject is required for its wise application in any company.

DEFINITION OF OPERATIONS RESEARCH

Many attempts have been made to define Operations Research, but to date no definition or specification has been proposed that is entirely satisfactory and acceptable to Operations Research practitioners. It is clear that it is concerned with certain aspects of decision making and is generally concerned with determining optimum solutions to managerial problems.

Before a definition is given, it will be as well to indicate what Operations Research is **not.**

(1) O.R. cannot and will not replace management decision-making. It is intimately concerned with management type problems, and the investigator must look at any particular problem from the same overall point of view as management. His task is only to assess the possible courses of action open to management in a situation and to compute the resulting outcome of pursuing certain decisions. Management must ultimately make the decision to follow a particular course of action. O.R. then deals with the quantitative aspects of management decisions.

(2) The O.R. department is not an efficiency group concerned with making people work harder. It is vitally interested in the effective use of all resources and usually bases computation on well-established plant data.

(3) O.R. is not work study or industrial engineering. Industrial engineering uses scientific methods for determining facts and it is true that O.R. uses these same methods and arrives at the same facts. However, the way the facts are handled by the two philosophies differs somewhat. Industrial engineering generally investigates the details of operations, and in the main, bases new methods on intuitive or obvious improvements in individual operations. O.R. generally considers the broad complex of operations and fits the operation of a system together as an integrated whole.

It is very difficult to draw the line between the two functions, but it would seem obvious that they should be co-ordinated in some way. O.R. generally uses more sophisticated techniques than industrial engineering in analysing problems and should therefore be concentrated on a different type of problem.

(4) When a study is made of the literature of O.R. a great deal of mathematics, statistics and probability theory will be encountered. Such a finding may lead one to feel that O.R. is only another form of applied mathematics, but this is not so. Certainly these methods are used and predominate in the techniques of the subject, but they do not correctly define the subject.

Having said something about what O.R. is not, a definition given by Professor Kendall in his presidential address to the Operational Research Society, 1958, will now have some background for its clarification. He said: "Operational research may be regarded as a branch of philosophy, as an attitude of mind towards the relation of man and environment, and as a body of methods for the solution of problems which arise in that relationship."

This definition is not very restrictive, nor are any definitions of the subject. Stafford Beer[1] has pointed out that O.R. is not "a" science; it is "science". From this view, it is not restricted to the study of any specific problem, but it can investigate all problems. The really fundamental technique is scientific method, a philosophy applicable to any branch of science.

Scientific method is a pattern of investigation for problems of any kind. Six steps are usually involved as follows:—

(1) Formulation of the problem.
(2) Construction of a model (usually mathematical) to represent the system under study.
(3) Deriving a solution from the model.
(4) Testing the model and the solution derived from it.
(5) Establishing controls over the solution.
(6) Putting the solution to work.

Each of these steps is obvious in an O.R. investigation.

The industrial application of O.R. has been mainly in the field of management decision-making, not because poor decisions are made at this level by any means, but because most decisions are either very far-reaching or can be department wide or company wide or are based on probabilistic occurrences or pay-offs. All of these reasons generally imply that a quantitative assessment of the optimum solution will be of real value in yielding:

(1) Reduced operating costs.
(2) Greater output, either from a unit or the plant.
(3) Higher productivity.

To achieve these ends, scientific method is used. In the formation of models, however, it has been found that certain standard methods occur frequently enough to warrant special mention. It is most important to realise that a specific technique cannot be selected by a cursory classification of a problem, but can only be adequately formulated after a thorough preliminary investigation.

STATISTICAL METHODS

Most problems involve statistics or probability theory to a considerable extent. It is essential therefore that all practitioners of the subject have at least a practical working knowledge of statistics.

Statistical methods are most useful in the second stage of the scientific approach, i.e., during model construction. These methods allow relationships between the relevant variables to be determined, as well as giving indication of the most important variables.

INTRODUCTION TO THE MODELS OF O.R.

Because of the recurrence of several problems of similar type in the field that has been investigated by O.R. since 1945, certain mathematical techniques have been developed that are nowadays quite standard approaches. These are:

(1) Linear programming.
(2) Queueing theory.
(3) Inventory theory.
(4) Monte Carlo methods.
(5) Game and decision theory.

Each of these techniques will be dealt with in turn below.

LINEAR PROGRAMMING

This technique of operations research has certainly received the greatest attention of any of the O.R. techniques, so much so that it has often been taken as synonymous with O.R. itself. I would like to quote a leading British industrialist's introduction of Mr. Stafford Beer when he was about to present a paper on linear programming, "Mr. Beer will give a lecture on linear programming, or, as it is sometimes called, operations research." It is not difficult to appreciate how such a conception was born, but it must be realised that linear programming is purely a technique, a very useful one nevertheless, of operations research.

Linear programming has achieved some quite outstanding increases in profit or level of manufacture or has yielded equally significant reductions in manufacturing or operating costs. A figure of 25% may be expected in most situations.

Three basic linear programming models have been established.

(1) Activity analysis.
(2) Transportation.
(3) Diet.

Each of these models has a slightly different form for the mathematical expressions established while the transportation model, because of the uniqueness of the equation form, may be solved by a comparatively simple procedure.

The aim in all linear programming problems is to determine the optimum or best way of allocating fixed and limited facilities and resources to a given demand pattern in such a way that some given objective is maximised or minimised as the case may be.

To explain this statement a little more clearly a simple example will be given.

A company selling to the automobile spare parts trade manufactures two standard components. The production schedule for the next three months has to be prepared and the following information has been provided.

The standard operation times (hours) per component are shown in Table I.

The aim then is to determine the optimum manufacturing schedule for the next three months with the manufacturing capacities as indicated as well as to determine which of the four operations would be the most profitable to increase in capacity.

A two dimensional graphical solution may be used in this particular problem because there are only two elements, P_1 and P_2 under study (in the general case, there are n elements requiring an n dimensional space representation).

Fig. 1 presents the graphical solution, details of which follow. The ordinate represents the number of units of P_1 that can be manufactured while the abscissa represents the number of units of P_2. The restriction lines are placed in the following manner.

If the turning capacity is completely used up in producing component P_1 then $1540/0.1 = 15{,}400$ units of P_1 will be produced, i.e., point "a" is at 15,400. If P_2 is manufactured only, then $1540/0.04 = 38{,}500$ units will be made, i.e., point "b" is at 38,500. The co-ordinates of any point on the line *a-b* will indicate the numbers of P_1 and P_2, that together will use the turning capacity completely. Then any point lying in the area bounded by the axes and the turning restriction will give combinations of P_1 and P_2 that will either take part or all of the turning capacity available.

In a similar way, the lines *c-d*, *e-f*, *g-h* may be constructed as the grinding restriction, assembly restriction and inspection restriction lines respectively.

TABLE I

STANDARD OPERATION TIMES

Hours

Component	Operation			
	Turning	Grinding	Assembly	Inspection & Testing
P_1	0.10	0.03	0.30	0.08
P_2	0.04	0.01	0.20	0.08

The hours available in each section are:

Turning	1,540
Grinding	420
Assembly	2,960
Inspection	1,120

The contributions to profit and overhead of these two components are fivepence and fourpence respectively, and it is expected that all the components manufactured by the plant will be sold yielding these contributions to profit and overhead.

It will be seen that the area *ohse* will contain all the possible combinations of P_1 and P_2 that may be manufactured without overloading any of the facilities.

The optimum solution must be determined as the next step. This may be done by plotting the iso-revenue line, the line of equal profit return, *m-n*, and moving this line away from the origin so that all lines are parallel until the limit of the area of the feasible solution has been reached. The slope may be determined in the following way. If a profit of 40,000d. was to be made by all P_1 items then 8,000 would have to be sold. If the same profit had to be made by selling all P_2 items, then 10,000 would have to be sold. In this way the points m and n may be determined respectively. Moving the iso-revenue line away from the origin, it is found that the point *s* yields the optimum combination, i.e., 1,600 units of item P_1 and 12,400 units of item P_2.

The total profit would be $1{,}600 \times 5 + 12{,}400 \times 4 = 57{,}600$d. This is the maximum profit that can be made under the given operating conditions.

The inspection restriction would be the most profitable to increase because the slope of that restriction line is nearest to the slope of the iso-revenue line.

It will be noted that existing manufacturing times, costs, etc., are accepted as a basis for these computations. It would be possible by a detailed study of all operating times to bring about further economies. Once the detailed study has been completed, the linear programming model will allow the overall system to be studied and optimised.

Two major steel works problems that could be studied by this method are:

(1) The allocation of sales orders to rolling mills considering mill capacities, operating costs and the shipment of the finished product.

(2) A balancing of all operating unit capacities in an integrated iron and steel works.

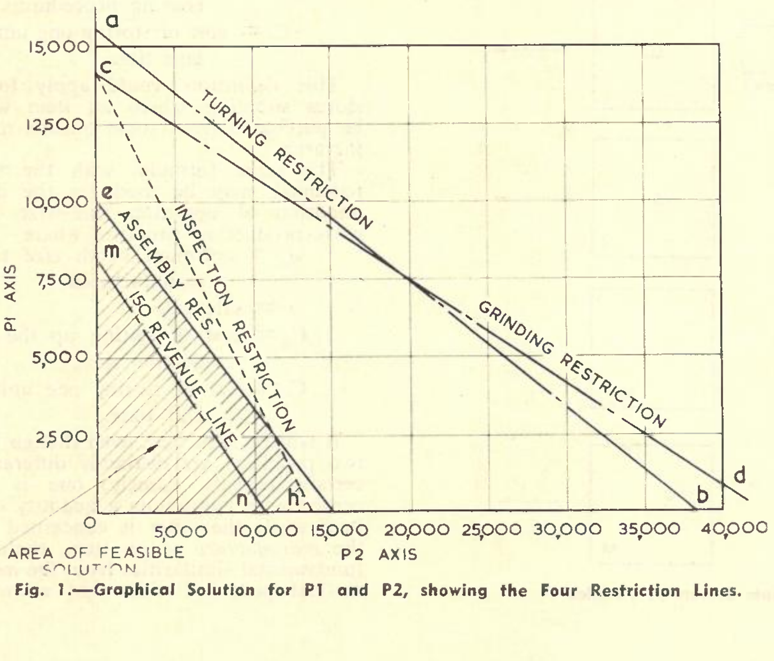

Fig. 1.—Graphical Solution for P1 and P2, showing the Four Restriction Lines.

QUEUEING THEORY

Queueing Theory, as the name implies, deals with situations in which queues are formed. Simple every-day illustrations come readily to mind, e.g., queueing for buses, at counters in shops, at a telephone booth.

On the steel plant there are many problems of a similar nature, e.g., ingots in a soaking pit before the bloom mill, lorries going over a weighbridge, siding capacities to hold all incoming rail vehicles till plant conditions allow their unloading, charging of open hearth furnaces, collecting materials from store, etc.

In most queueing problems either of two situations exist. In the simple case where there is one server and one queue, then the server may be serving or not, or alternatively, there may be a queue of some finite length or none. There are costs associated with all these conditions and these costs have to be bal-

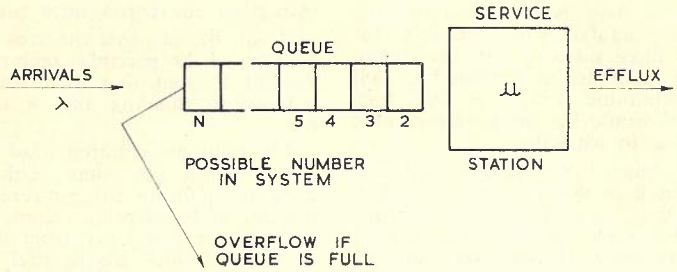

Fig. 2.—Single Service Station with Finite Queue.

anced to secure the best operating conditions; that is, in the general case, it is not economical to have the server working 100% of the time with a queue of some finite length always existing while on the other hand excessive idle time of the server has a cost associated with it also. The determination of the probabilities associated with server loading and queue length is dealt with by the mathematics of queue theory. Costing of the various alternatives is a standard procedure and in general the final computation is not difficult. The problem of costing lies in the determination of idle time and working costs.

Fig. 2 illustrates a queue of finite length before a single service station.

Practical queueing problems are generally complex because there may be several servers working in parallel (Fig. 3) (e.g., soaking pits feeding the bloom mill), several units operating in series (e.g., bloom mill, rail mill, continuous mill), priority queueing (e.g., heats being moved out of their chronological sequence while waiting to be stripped and charged to the soaking pits), or a combination of all these factors in any given situation. Generally, the expressions for the probability of finding a unit of the system in a given state (working, not working or delayed) can be established, forming a large set of simultaneous equations that generally require the services of an electronic computer for solution.

Thus, any situation where congestion may arise due to converging service lines (e.g., a road bridge like the Sydney Harbour Bridge) or sequential type operation is performed in which production flow will depend on some operations performed in some units, followed by transport and temporary delay before the succeeding operation, can be analysed using queueing theory. The elements of the operation that have most effect on congestion can be determined in this way and steps taken to achieve a better balance of performance. Economic levels of performance may also be determined.

Certain types of maintenance programmes may be analysed in exactly the same manner. For example, when a bank of similar machines, say a fleet of locomotives, has to be maintained, the decision about the number of maintenance men to carry out this service task is generally based on past experience and some tentative assessment of delays that may be incurred if all maintenance men are occupied at the time of another breakdown. The usual criterion in such situations is that the machinery requiring service should not be delayed at all because high costs are usually involved. However, a cost analysis will always indicate that some balance between expected delays to machinery and expected idle time of maintenance men may be achieved.

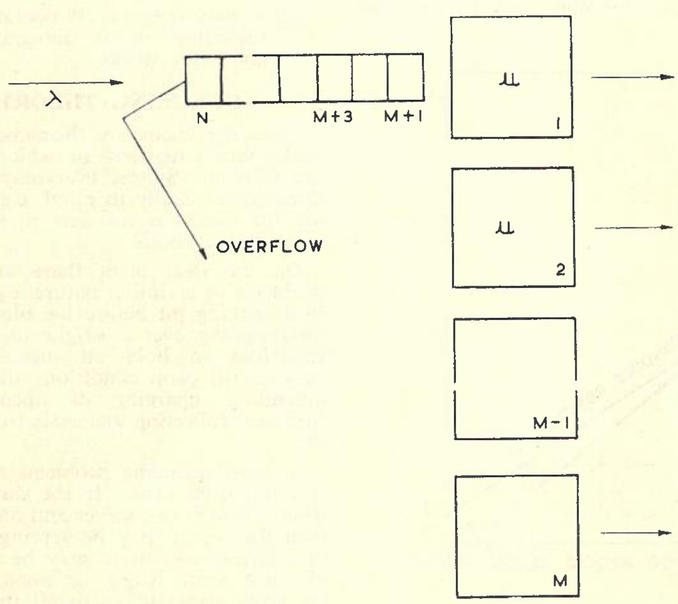

Fig. 3.—Service Station with Multiple Servers in Parallel.

INVENTORY

The control of stocks of all kinds is a major economic problem for all companies. The money involved in the purchase of stock materials, in holding these stocks in warehouses for long periods and all the other costs incurred in the stock problem, has caused some companies to go out of business, while others have faced grave economic difficulties for long periods.

For a plant such as the Newcastle Steel Works the stock problem may be subdivided into several well-defined groups:

(1) Stores Stock — those items purchased from outside suppliers that can be used in a general way for maintenance and construction.

(2) Spares — those items, either supplied by outside manufacturers or from the Company's own service departments, for specific machine replacements.

(3) Raw Material or Between Process Stock — that material required to be fed into a process for the manufacture of some desirable finished product.

(4) Finished Goods Stocks — those items produced by the Company as saleable product.

The mathematical models of inventory theory can be used in any of the above situations where the necessary conditions apply by a redefinition of certain terms in the expression.

For example, the simplest mathematical model that can be formulated is that for determining the optimum re-order quantity, q_o, namely:

$$q_o = \sqrt{\frac{2r\,C_s}{C_1}}$$

where q_o = optimum re-order quantity
r = rate of use
C_s = cost of initiating the purchasing procedure
C_1 = cost of storing one unit for unit time.

This definition would apply to the stores situation where an item would be purchased from some outside manufacturer.

The same formula, with the terms redefined, may be used for the determination of optimum run—size in a mass production situation where
q_o = optimum batch size to be manufactured
r = sale rate
C_s = cost of setting up the production run
C_1 = cost of storing one unit for unit time.

It will be seen that, even though these two problems are distinctly different in certain regards, namely, one is concerned with *purchasing* a quantity of an item while the other is concerned with the *manufacture* of an item, there are fundamental similarities from the mathematical point of view that allow the analytical structure of the problem to be understood readily.

The inventory situation to which the above equation applies may be represented diagrammatically by Fig. 4.

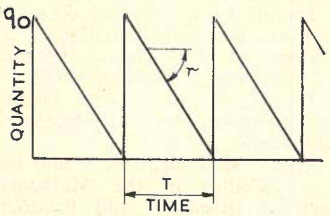

Fig. 4.—Simple Inventory Situation.

Once the optimum re-order quantity has been determined, the time period between orders may be determined readily as:

$$T = \frac{q_o}{r}$$

It is assumed that the rate of consumption is uniform over the period and from period to period. It is also assumed that immediately the stock has been depleted an order is placed and a delivery is effected. These assumptions apply in only a few practical inventory problems.

Because of the practical problems that may be faced in the industrial situation, e.g., a lead time for orders in which a random variation occurs, variations in the demand rate even though the average demand over a long time may remain unchanged, seasonal trends in demand, price variations and changes in interests or depreciation policy, etc., various models have been developed ranging widely in complexity. These will not be set out in this paper, but can be found in several standard texts (Churchman, Ackoff and Arnoff[2], Morse[3], Whitin[4], Arrow, Karlin and Scarf[5], Sasieni, Yaspan and Friedman[6]).

It is interesting to note, however, the way in which random variations in demand and lead time can be taken into account by safety allowances (ref. Fig. 5).

The safety allowance is determined by computing the probability of running out of stock together with the cost involved in being out. A balance will be determined which will give some chance of being out of stock. Whitin[4] has demonstrated clearly in an example how total annual inventory costs are directly affected by the chances of being out of stock. The graph of this situation is shown in Fig. 6.

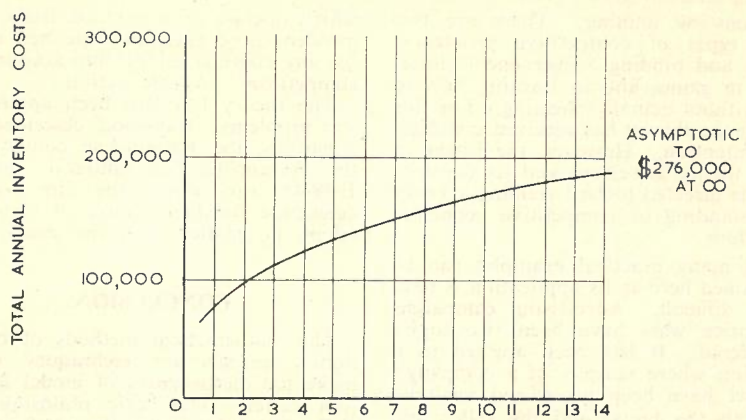

Fig. 6.—Total Annual Inventory Costs versus Chances of being Out of Stock.

In an inventory situation such as the one that has been discussed above, the optimum re-order quantity may be determined by use of the simple formula

$$q_o = \sqrt{2r \frac{C_s}{C_1}}$$ mentioned earlier,

taking r as the average consumption rate, and the safety allowance may be determined by studying the probabilities of being out of stock by either of the two causes, variations in demand or variations in lead time.

In examples quoted in the literature, savings in annual inventory costs have been approximately 25%, and it is hoped that similar savings will be made when the Company's stores inventory has been investigated.

MONTE CARLO METHODS

It is sometimes useful to simulate a complex situation that presents difficulties in the construction of mathematical models. Monte Carlo methods provide a good opportunity for the investigation of such systems.

The first step in carrying out a Monte Carlo study is to determine the logic of the system, all the operating rules associated with handling and flow and the basic data, usually in the form of frequency distributions.

This first step in the analysis is the most important as all the succeeding experimentation depends on the information determined at this stage. Once all the information has been gathered and thoroughly checked, experimentation may commence.

The experiment, or more correctly, series of experiments, will be carried out either manually (very time-consuming and generally inaccurate in most large systems) or by automatic computers.

Generally, the first experiment is designed to check the logic, operating rules and data and should yield results that are comparable with the physical system under study. The next step is generally to modify operating rules, or to change data, (such changes as may be made by the introduction of new equipment) and re-work the Monte Carlo model under new conditions for a period long enough to demonstrate the results of the change. Re-working of the model must be carried out as each group of changes is considered. This method has been used to investigate the consequences of adding new equipment to melting shops and of changing operating rules for the shops. The method has been used at the Newcastle Works to study the operation of the narrow gauge ingot system transferring ingots between the open hearth and the soaking pits and also to investigate the operations of ship unloading, ore screening, sinter plant operation, blast furnace operation and dumping station operations.

The real advantage of the method is that, in a complex system, the consequences of changes in operating rules can be investigated before the rule is put into effect in the plant situation. The effect on the overall system performance can be studied in detail on paper and any side effects may be modified accordingly.

GAME THEORY

All the models or techniques which have been discussed so far have neglected features which arise from competition. Competition manifests itself in problems where the effectiveness of decisions by one party is dependent on

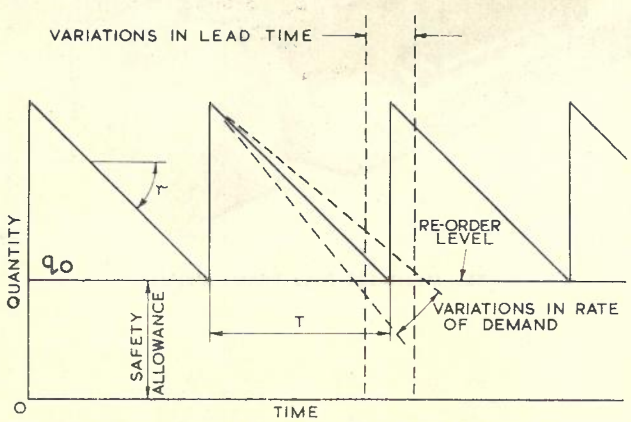

Fig. 5.—Inventory Situation with Safety Allowances.

decisions by another. There are two main types of competitive problem—games and bidding. Everyone is interested in games and in learning how to win without actually cheating. For this reason the theory has received considerable attention. However, the intent of game theory is serious and its development is directed toward yielding a better understanding of competitive economic behaviour.

Not many practical examples can be mentioned here as its application is relatively difficult. Advertising campaigns and price wars have been two topics considered. It has been applied to a situation where samples of a company's product have been taken and analysed by both the buyer and the seller and as a result of the analyses, the price was determined. Bidding models have been applied to situations where there are only a few firms in an industry, all of which operate on a contract basis. The problem is to determine the best quote for any contract taking into account the competitors' possible action.

The theory has also been applied to war problems. Haywood[7] described two situations, the Rabaul-Lae convoy and the Avranches Gap situation of the 1939-45 war, where the aim was to determine the best course of action to adopt, no matter what the enemy did.

CONCLUSION

The mathematical methods of operations research are techniques which make the mathematics of model formation easier. The basic philosophy of O.R. presented here is the most important feature of the science and has yielded, and will continue to yield valuable information to assist management decision-making.

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TECHNICAL NEWS ITEM

DEVELOPMENT OF THE TELEPRINTER EXCHANGE NETWORK

The Australian teleprinter exchange service (telex) has expanded rapidly in recent years. At 30th June, 1961, 989 subscribers were connected, an increase of 44% over the previous year. During the same period, traffic handled through the service increased by 42%.

A new model page teleprinter machine was chosen by the Australian Post Office in 1959 to cater for the increasing popularity of the telex service. World-wide tenders were sought and after a complete study of the tenders received, and after confirmatory tests had been performed, the Model 100 page teleprinter of European manufacture was chosen. The basis of this selection took account of the good operational facilities and pleasing, modern appearance of the machine, and its good economy arising from a reasonable capital cost, reliable performance, and low maintenance requirements.

The technical staff were trained in the functioning and maintenance of the new machines and installation proceeded as supplies became available. By the end of December 1961, 731 of the new type machines were in operation on telex services, and the Department plans to convert the remaining telex subscribers services to this machine by the end of 1962, in addition to providing it on all new services. At first the new machines were fully imported but assembly is now carried out in a Melbourne factory established especially for this purpose.

The Model 100 Page Printer Machine

800 LINE CORDLESS P.A.B.X.

T. CHAMPION*

INTRODUCTION

This article is a description of an 800 line P.A.B.X. equipped with double cordless manual positions with key senders, and providing full recall availability from incoming junctions. The first installation of this type, equipped to 600 lines, has been installed at the G.P.O., Perth. Conventional automatic switching equipment is used and comprises—

(a) Local and incoming group selectors.
(b) Composite racks of final selectors and uniselectors.

Three digit dialling is used on extension to extension calls whilst calls 'in dialled' onto incoming 4th selectors have the last three digits dialled on P.A.B.X. equipment. Hence levels 1–8 are common to the local and incoming selectors and trunk to the final selector stages as shown in Fig. 1. Level '9' from local selectors is the information level to the switchboard, and level '0' provides access to outgoing relay sets. From the incoming group selectors, level '0' connects to the manual position line-finder start and marking equipment.

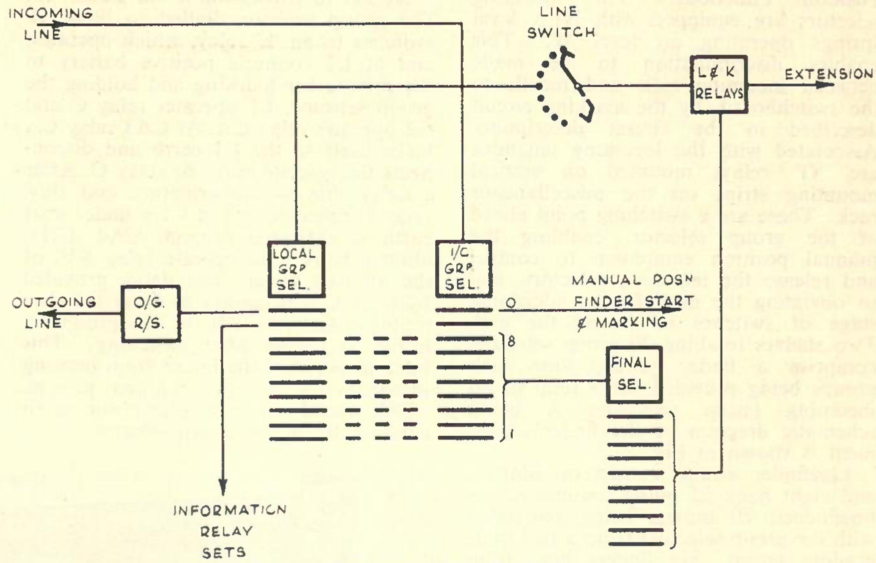


Fig. 1.—P.A.B.X. Trunking.

MANUAL POSITIONS

General. The system used is basically a linefinder, using allotters with uni-selector linefinders to search for the incoming junctions at a relay switching stage prior to the incoming group selector. The selector, after providing the linefinder start and mark on level '0' is released for re-use by the telephonist, so obviating the need for an additional switching stage.

Facilities: The facilities provided include the interception of incoming calls, and of recalls from extensions, at the incoming selector stage by manual position finder equipment. Automatic release of the group selector from level '0' and telephonist release of the group selector on recalls, permit their re-use to establish the call. The equipment used in an established call is individual to each junction, and common equipment used in finding and setting up the connection is released with a minimum holding time. The calls established through the telephonist revert to the same condition as a directly 'in dialled' call. The number of calls that can be routed through the manual position is governed only by the speed of answering and the number of junctions available.

Calls and recalls appear on their respective lamps with a flashing signal, changing to a steady glow for supervision when the telephonist answers. The supervision signal is extinguished and the finder equipment released when the called extension answers. The calls are allotted to alternate manual positions to provide a balanced call rate to each position. For maximum speed of answering and minimum holding time of the finder equipment, the linefinders are released when the called extension answers, a recall being necessary if the call has to be re-directed. However, to meet the condition where all phones are not equipped with recall facilities, the telephonist can be made to control the release.

Recalls are available for any incoming call terminating on an extension phone equipped with an earthing button, irrespective of whether the call was initiated through the telephonist or dialled directly.

The manual positions are provided with 'position busy' facilities to enable single board operation in light traffic or for maintenance purposes.

A key sender is provided which enables the called number to be quickly marked and sent, without a dial key or 'call for sender' key operation. Sending commences after the release of the key on the hundreds digit, three digits only being necessary to establish the call. The sender will wait for the telephonist to complete the called number if it overtakes the marking sequence, and when sending is completed, clears itself from the dialling circuit. Alternative manual dialling with a dial key operation is also available.

An information service is available

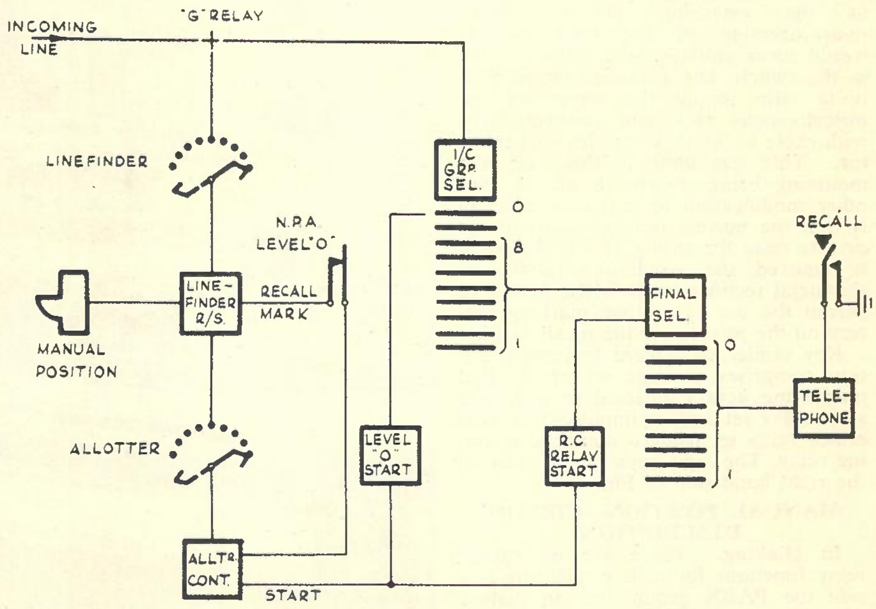


Fig. 2.—Finder Equipment Block Schematic.

* See page 350.

from level '9' on the local group selectors.

Equipment Associated with Manual Position Functions. The incoming selectors are equipped with NPA level springs operating on level '0'. This enables discrimination to be made between incoming calls and recalls to the switchboard, by the marking circuit described in the circuit description. Associated with the incoming junctions are 'G' relays mounted on vertical mounting strips on the miscellaneous rack. These are a switching point ahead of the group selector, enabling the manual position equipment to control and release the incoming selectors, and so obviating the need for an additional stage of switches to extend the call. Two shelves totalling 20 group selectors comprise a finder group, four such groups being provided for a total of 80 incoming group selectors. A block schematic diagram of the finder equipment is shown in Fig. 2.

Linefinder groups consist of allotters and eight bank 25 outlet uniselectors as linefinders, 20 outlets being associated with the group selectors from a two shelf grading group. Six finders per group are shared between two manual positions, calls being allotted alternately to finders from each position. Linefinder start and marking from each group is from 'L' relays trunking from outlets off level '0' on each pair of shelves. Five outlets per group are provided for an additional call holding store if all linefinders are busy, the calls being held on the 'L' relays and the group selector on level '0' until a finder becomes free to find and release them.

The final selectors are equipped with a differentially wound relay of 15 ohms + 15 ohms in series with the 'D' relay supplying battery to the extension phone. This relay provides the recall facility by operating to an unbalanced line condition caused by earthing one wire with an earthing type recall button at the extension phone. Some re-arrangement of the final selector would accommodate the additional relay in the switch, but a convenient method is to strip mount the relays on the miscellaneous rack and connect them with cable to 'U' jacks on the final selector. This was done in this case, the mounting being shown on Fig. 3. Another modification to the final selectors is that the normal holding earth to the private from the spring J4 (SE50 switch) is removed, the switch now relying on the metal rectifier earth, MRI. This is to permit the use of positive marking battery on the private for the recall facility.

Key sender equipment for each position comprises a single set of 10 digit numbering keys connected to a 3 digit store relay set and an impulse-train generator relay set using a magnetic counting relay. The digit keys can be seen on the right hand side of Fig. 4.

MANUAL POSITION—CIRCUIT DESCRIPTION

In Dialling. There are no special relay functions for calls originating outside the PABX group and 'in dialled' directly to extensions. The call progresses through G2 and G4 released to the incoming selector and through to the final selector in the normal manner as shown in Fig. 5.

Access to Switchboard via Level 'O'. The group selector dialled to level 'O' switches to an 'L' relay, which operates, and at L2 connects positive battery to the private for marking and holding the group selector. L1 operates relay C and C2 operates relay CA. At CA3 relay CA locks itself to the L1 earth and disconnects the operate earth to relay C. After a delay due to the armature end slug, relay C releases, and at C1 a finder start earth is extended through CA4, CH3, allotter bank 4 to operate relay S.F. of the allotted finder. The delay provided by relay C is necessary to cover the time required for relay 'B' in the group selector to release after switching. This interval prevents the finder from hunting unnecessarily for the marked private, which would not be available due to an earth at B3 in the group selector.

Earth is extended from E1, Key KCA2, bank 2 of either allotter No. 1 or No. 2 depending on position of KCA, B2 normal, SF4, interrupter contacts, linefinder uniselector to battery, so starting the drive. SF2 and SF3 have no function at this stage and SF5 applies earth to 'a' of relay 'B', but B cannot operate because of the earth from E1 via allotter bank 2 which is at 'e' of relay B. The testing circuit is from earth, MR1, 'E' relay, Key KCA3, Allotter bank 3, SF1 operated, linefinder bank 3 to positive battery of the marked group selector. Relay E operates to the positive battery and at E1 cuts the drive to the uniselector, and extends earth to the U jack 14 shelf common. The latter condition has no effect at this stage as level spring NPA has operated and opened the circuit.

Removal of earth from 'e' of relay B, permits this relay to operate from the SF5 earth to the uniselector battery. B1

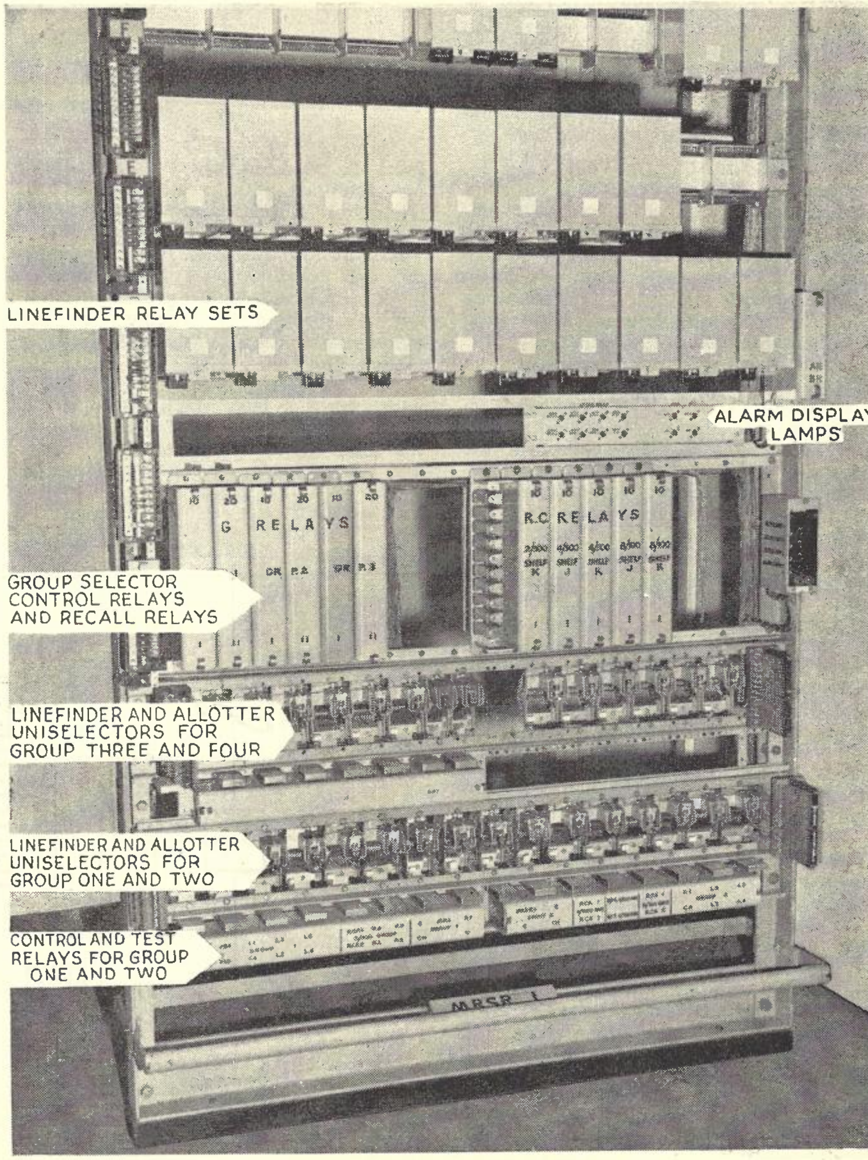


Fig. 3.—Miscellaneous Relay Set Rack.

prepares an alternative holding circuit for relay B upon the subsequent release of SF. B2 prepares the allotter step on and finder busy condition upon the release of E. B3 operates relay G from earth at RC1 through linefinder bank 4. Relay G locks itself via G1, linefinder bank 3, B4 operated to earth via BA4, which will be operated from B6. G2 and G4 switch the line into the group selector to an open circuit at D1 and D3, releasing the 'L' relay and subsequently releasing the group selector which is left ready for re-use by the telephonist.

B5 has no function at this stage. B7 connects flicker earth via DA5, RC3 to the call lamp and battery at the manual position. B8 removes a holding earth from the CH relay which, when all finders are busy, will release bringing up the call waiting lamp on the next incoming call, and connecting ring tone onto the 'L' relays to provide a call store until finders became free. At CH1 the allotter step on circuit is opened to prevent allotter drive during this period.

Relay BA has operated and at BA1 and BA3 switches the incoming call onto the A relay which operates to the calling loop. A1 connects ring tone. A3 operates the test jack lamp. A5 operates the night alarm. A2 operates relay AA, this being a relief relay which will hold when relay A flicks upon a reversal being applied at D2 and D4, so preventing a false release of the linefinder relay set. AA1 provides an alternative earth to hold relay 'B' operated when relay SF releases. AA2 prepares an operate circuit for relay DA.

With the release of relay E, earth is extended via B2 to the allotter drive stepping the allotter onto the next vacant linefinder. The start earth is disconnected when the 'L' relay releases releasing CA, unless another level 'O' call is waiting, in which case CA will be held, and the start earth will be applied to the new finder, operating the SF relay for another search.

The telephonist answers after operating key KA. KA1 and KA4 connect the telephonist across the line via relay contacts TRI and TR3. KA2 provides speech battery for the telephonist. KA5 operates DA from earth via TR2, AA2 to 'a' of DA, and DA locks itself at DA1. DA2 disconnects the ring tone. DA3 disconnects the night alarm. DA4 operates relay D. DA5 changes the call flicker earth to supervision steady earth for the changed condition of the call lamp. D2 and D4 operating provide a reversal for supervision and metering. D1 and D3 switch the dialling loop to the group selector in preparation for sending.

After speaking to the calling party, the telephonist keys the first digit to be dialled on the key sender (Fig. 6) (WD2011, Sheet 7). An AX, BX, CX or DX relay operating connects earth from CO6 to KA3, which is operated, and on to operate the DR relay of the linefinder in use. Relay DR locks itself via DR1 to COB3 earth. DR2 and DR4 transfer the group selector to the sender dialling common, and the selector receives the first digit impulses from PA2 upon the release of the first digit key. The second and third digits are likewise sent, and when relay COB operates at the completion of the third digit, relay DR is released due to the original operating earth at CO6 and the holding earth at COB3 being disconnected. The calling circuit reverts back to the telephonist's holding loop through the 'E' and 'F' relays, and tone and speech for the initial connection pass through the linefinder relay set via condensers C1 and C2. Relay F operates on reversal from the final selector when the called subscriber answers, and at F2 releases the 'B' relay so releasing the linefinder relay set. Relay 'G' is released at B4 and the call reverts to the 'in dialled' condition. By suitable strapping on the keyshelf, the telephonist may be made to control the release by operation of the release key KXR in lieu of the 'F' relay release.

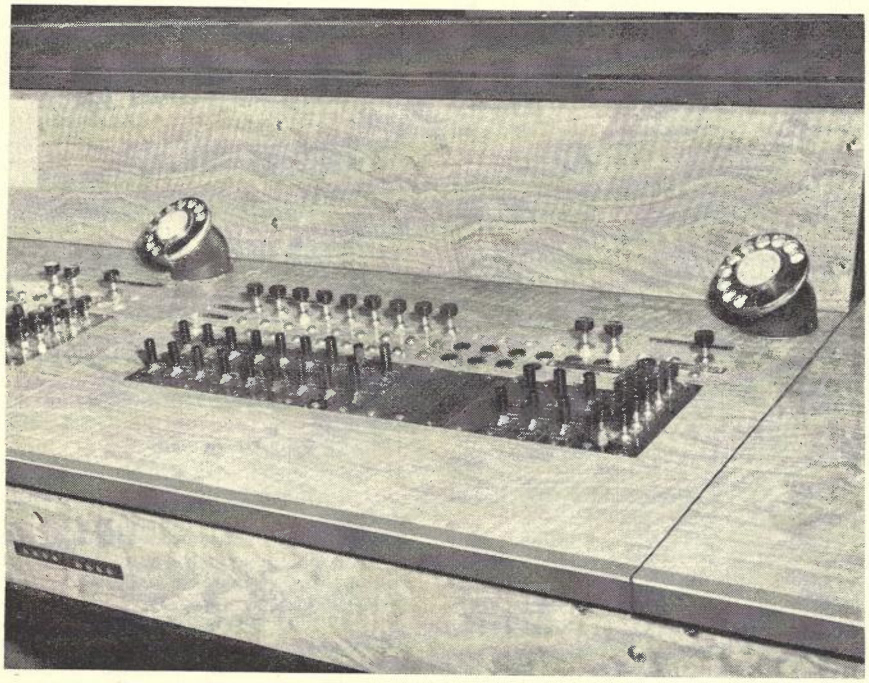


Fig. 4.—Manual Position. Speak, release, dial keys and associated call and recall lamps at left hand side of position. Sender keys and other miscellaneous keys at right hand side of position.

Access to Switchboard on Recall. An incoming call established to a telephone equipped with an earthing button for recall, can be switched as a recall to the switchboard for re-routing. The RC relay associated with the final selector is differentially wound and with a normal loop will not operate, but an earth applied at the telephone unbalances the windings allowing relay RC to operate. (Fig. 5) RC1 applies positive battery via relay RCA to the private wire of the final selector where the original holding earth is through a metal rectifier. The rectifier has a blocking resistance to the positive battery allowing it to become the testing battery for the line finder at bank 3. Contact RC2 in the final selector recall starts all finder groups from earth at RC2, RCA4, MR (1, 2, 3 and 4), CH3 allotter bank 4 to relay SF of the line finders. Linefinder start, relay E testing, and finder switching operate as described above, excepting at the point of relay E operating to the testing battery. E1 extends the earth to U jack 14 common of the group selector shelf and NPA being normal, as the selector is on a level one to eight, applies the earth to G3, linefinder bank 2, SF3 operated, RC2 to 'a' of relays RC and D. These operate and are locked up to the B5 earth by RC2.

RC1 disconnects the earth from the operate circuit of relay 'G'.

RC3 changes the flicker earth to the recall lamp.

D2 and D4 provide the correct line polarity to parallel the finder 'A' relay to the final selector 'A' relay which is on reversal. The finder 'A' relay operates to the calling loop and provides similar functions, as for the previous description of the incoming call.

D1 and D3 have no function at this stage as relay 'G' has not operated.

Earth applied from BA4, B4, linefinder bank 3, G1 normal, B3 of the group selector, private wire to the final selector, contact RC1, to 'a' of relay RCA, operates this relay which at RCA4 disconnects the start from all groups. Release of relay RC will release RCA and any further operation of the racall button will operate RCA preventing further starts being applied from the found recall. Additional RCA springsets provide a nine second delay alarm to indicate a recall permanent earth from an extension with a fault condition, while a final selector is on that number.

The telephonist answers after operating KA. Operation is similar to previous description, excepting that relay D is already operated by the recall condition. Telephonist speaks to both parties via linefinder banks 7 and 8, finds out the new number required and operates extension release key KR. Earth from KR2 is extended to RC1 operated, B3 operated, linefinder bank 4 to operate relay G. G2 and G4 switch the final selector circuit through linefinder banks 5 and 6 to an open circuit at KR1 which releases the selectors. Release of KR restores the dialling circuit to a similar condition as for the incoming call and subsequent linefinder release is also similar.

Function of TR Relay (Call Trapping). Clearing of the finder equipment also takes place if the calling party hangs up, as relays A and AA in releasing open the relay B holding circuit at AA1. Subsequent follow on calls could then be found by the released finder, and relay TR is provided to prevent the call being instantly switched to an answered condition if the answer key is still operated from the previous call. When relay SF operates to the new start, relay TR operates from the operated answer key KA5 locking itself up and preventing relay DA from operating to the new call. The flicker lamp calling indication is retained and at TR1 and TR3 the telephonist's speaking circuit is opened preventing the telephonist speaking to the new call until the answer key is released and reoperated so releasing relay TR.

Call Fail Alarm. Associated with relay CA are three contacts CA1, CA2, and CA5 which provide a nine second delay to the exchange alarm. This alarm indicates 'a failure to find under normal working conditions' as finding time should not exceed one or two seconds. However, in the case of all finders being busy, a call held on an 'L' relay will also register the alarm condition, and a visual check of linefinders is necessary to determine whether the alarm is due to a fault or to a busy condition.

KEY SENDER CIRCUIT DESCRIPTION

Marking of Three Digits from Telephonists Key Position. Four relays are used to provide the combinations for ten digits used for dialling. The digit code, showing the relays operated is—

Digit	*Relays*
1	C
2	A, B
3	A
4	A, C
5	A, D
6	B, D
7	C, D
8	D
9	B, C
0	B

Three groups of these code relays are provided for storing the three digits. They are designated X, Y and Z respectively, i.e. the AX, BX, CX, DX group being used for the first digit.

Earth from COB6 is extended via the operated digit key, the respective code wires a, b, c or d, E changeover contacts to operate the 'X' code relays. The operating earth is applied via the AX1, BX1, etc., contact to 'e' of the E relay, but with COB6 earth on the 'a' side, this relay does not operate until the digit key is released so removing the earth from 'e' and allowing the code relays to hold up in series with the E relay. E2, E3, E4 and E5 contacts switch the code wires through to the 'Y' group code relays ready for the next key operation. The new code is stored and upon the release of the digit key the F relay operates as before, switching the code wires through to the 'Z' group code relays. The third digit is stored on this group and with the digit key release, 'G' relay operates.

The digits stored are extended to DCR contacts in the impulse-train generator relay set where the marking earth from COA2 is applied to each group in turn via CO3 and COA2 changeover contacts. The DCR relay mentioned here is a magnetic counting relay with ten springsets, which are operated consecutively by impulses through the operating winding. As each contact operates and makes, the previously operated contact is opened, so that the equivalent operation may be comparable to a single bank 10 outlet uniselector. A release winding is provided to release all operated contacts at the completion of the counting or operating cycle.

Line Finder Selection and Dialling Loop. The answer key on the line finder circuit is operated and KA3 prepares the operate circuit for relay DR in the linefinder relay set. When the first digit key is operated, an AX, BX, CX or DX relay or combination of them is operated and the DR relay operate circuit is completed through a contact of these relays, to CO6 earth. Relay DR operates and locks itself to earth at COB3, and at DR2 and DR4, the group selector dialling circuit is switched to the impulsing common on contact PA2, which loops the selector in preparation for sending.

Impulsing, Counting and Digit Changeover. A start is applied to the impulse relay P from earth at E1 (operated when first digit key is released), CO5, TJ1 and 2, MA6, M4, P2 to 'd' of the P relay. After a delay due to C3 charging, relay P operates and breaks the operating earth at P2. C3 discharges through the ba and ed windings holding P operated for approximately 66 milliseconds. When P releases, the operating circuit is remade at P2 which charges C3 again, the time taken for charging being 33 milliseconds after which relay P operates as before. This, it will be seen, enables an impulsing cycle of 66 2/3% operated to 33 1/3% released to be obtained. The value of C mainly governs the speed of the impulsing, while varying 'R3' changes the 'weight' ratio of the impulses by approximately 5%.

P1 operates PA whose PA2 contact, capacitor C2 and resistance R4 provide the impulsing circuit for the selectors via the dial common and operated DR relay.

PA3 operates the counting relay DCR which at DCR contacts 1 to 10 extends relay M to COA2 earth via the marked digit code relays. Relay M operates on the marked digit and at M4 disconnects the starting earth from the P relay which ceases impulsing. M1 locks Relay M through MA3, and M2 releases DCR through the release winding ba. M3 operates Relay MA after a delay and MA6 further opens the impulsing circuit of the P relay. At MA3 the holding circuit of relay M is opened and as the DCR operating contact has been released, relay M commences to release. MA4 provides the initial operation of the 'sender taken' lamp. MA2 operates relay CO which locks from CO4, COB2 to earth.

CO3 changes over from the first digit marked on 'X' relays to the second digit marked on 'Y' relays. CO2 provides an alternative circuit for the 'sender taken' lamp. CO5 opens the E1 start earth and CO1 prepares the operate circuit for relay B. M relay releasing releases relay MA and the start earth is re-applied from F1, COA4, TJ, MA6, M4, P2 to the impulsing relay P. The impulse relay sequence is repeated and the delay between the relays M and MA operating and M and MA releasing provides the interdigit pause of the dialling circuit. This is adjusted to be between 450 and 550 milliseconds.

The first operation of relay P for the second digit, operates relay 'B' from the P2 earth, Relay B being locked up at B2. After the required number of impulses, the DCR contacts extend the COA2 earth via Y code relays contacts to operate relay M as before.

M3 operates MA and at MA5 earth is extended from B1 to operate COA which locks itself via COA3, COB5 to earth. COA2 changes the marking earth from the second digit 'Y' code relays to the third digit 'Z' code relays. COA4 disconnects the F1 start earth and COA1 prepares the operating circuit of relay BA. With the release of M and MA the start earth is re-applied from G1 to operate relay P for the third digit. P2 operates relay PA as before and PA1 operates relay BA which will hold operated during impulsing. Relays M and MA operate on the marked contact as before and an earth from MA1, BA1 operates relay COB which at COB1 locks itself to the MA1 earth.

COB2 and COB5 release the relays CO and COA respectively. COB6 releases the X, Y and Z code relays and COB3 releases the DR relay in the linefinder relay set, restoring the dialled circuit back to the telephonist. With the release of M and MA, COB relay is released at MA1 and the sender is restored to the normal ready condition. Relay COB can also be operated from the 'clear sender' key through the ab winding, and COB4 extends the key earth through M2, 750 ohm R1 to the release winding ba of the DCR relay when clearing the sender.

CONCLUSION

The equipment described is for an extension group of up to 800 lines. Smaller units of the order of 200 to 400 lines would be equally suitable for the equipment. Increase beyond the installed capacity may be made readily up to the maximum of 800 lines provided that provision for the total number of manual positions is made in the initial installation. The relevant circuits for this equipment are recorded on WD2011 Sheets 1 to 7.

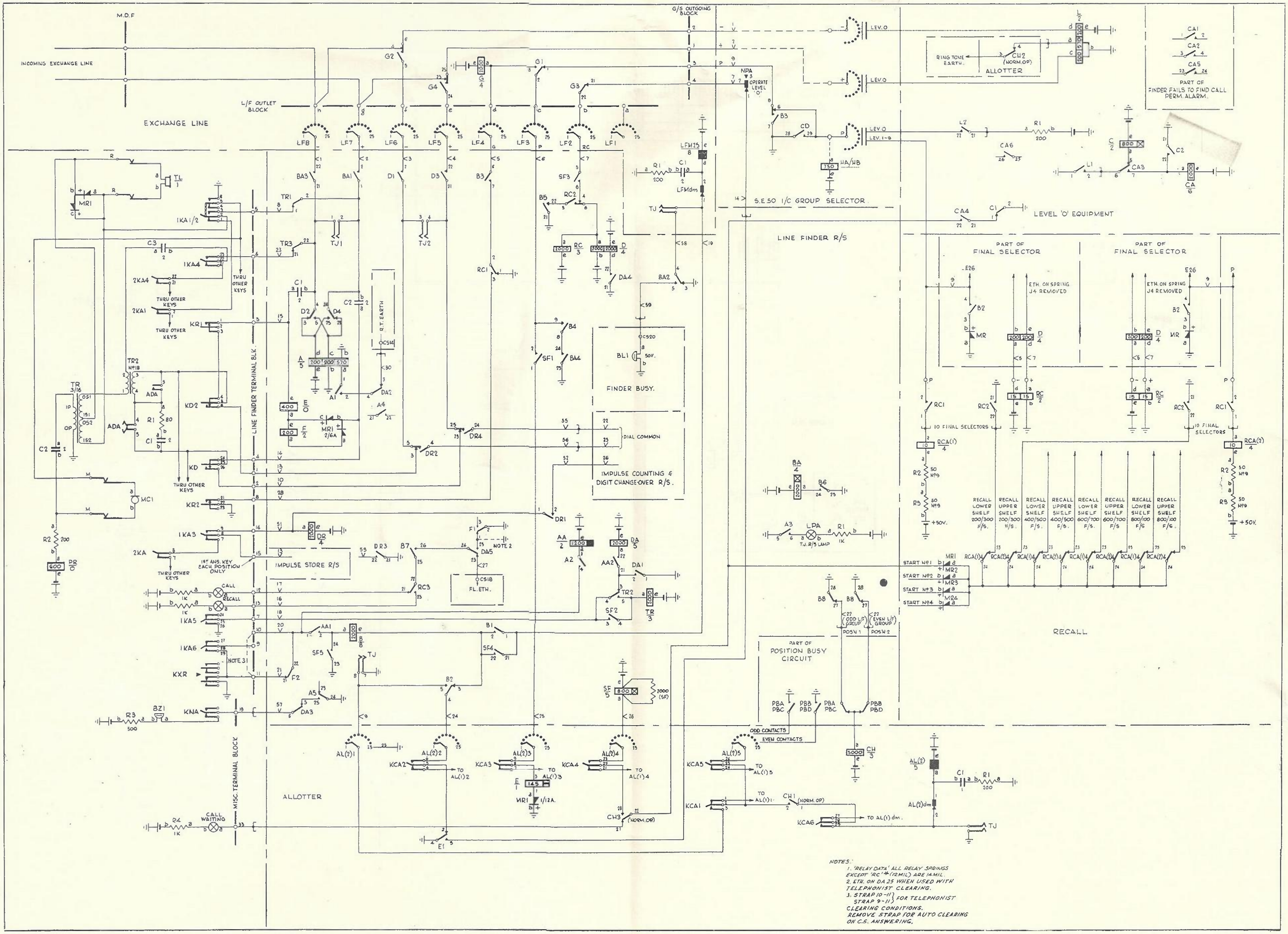
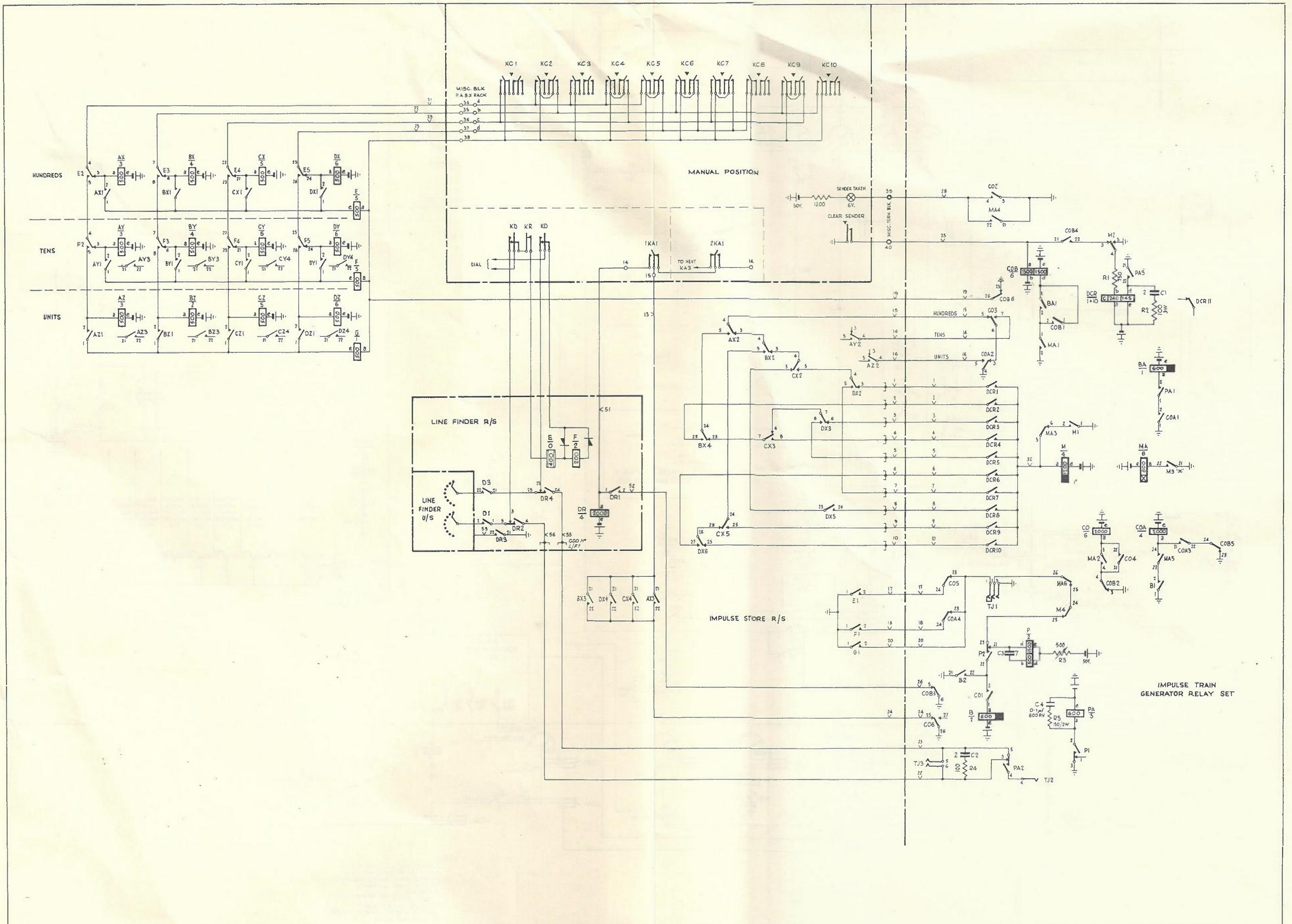


Fig. 5.—Schematic Circuit of P.A.B.X.



FORM C.D. 150.9

D

Fig. 6.—Circuit of 3 Digit Key Sender.

DIELDRIN DUSTING FOR THE PROTECTION OF CABLE AGAINST TERMITE ATTACK

*M. LEVERIDGE, B.Sc.(Eng.), A.M.I.E.E., A.M.I.E.Aust.**

Editor's Note. The method described here has been used successfully in the Perth area but has not been officially endorsed for general use by the Postmaster-General's Department, because of the toxic hazards involved. As the article describes, great care was taken to safeguard the health of the operators but these types of materials are not suitable for general use. Their efficacy has also to be proved over a long term. Nevertheless, the method has a number of interesting features and the article is published for this reason.

INTRODUCTION

It is well known to telephone engineers that lead sheathed cable is subject to deterioration from many causes. Lead is very durable when used under favourable conditions, but in many cases conditions are very unfavourable, and in these cases the lead sheath is subject to all the slings and arrows that outrageous fortune can offer.

There are many reasons why lead cable deteriorates, and some of these are:—

(a) Faults in manufacture.

(b) Mechanical damage including damage caused during installation.

(c) Damage caused by animals and insects, for example, rats and "ants".

(d) Failure of sheath due to fatigue when cables are permanently exposed to alternating stresses. This occurs on bridges or when cables are attached to unstable objects.

(e) Corrosion. By this term is understood the deterioration of the lead sheath due to unwanted chemical or electrochemical attacks beginning on the surface. This aspect is admirably covered in the Postmaster-General's Department Research Laboratory Report No. 3243 entitled "Deterioration of lead cable sheaths" (1).

The particular concern of this article is the depradation of the "white ant" against lead sheathed cables in ducts. These are usually large sized cables and cause considerable dislocation of service if the sheath is penetrated and moisture enters the paper insulation. "White ants" is the common but erroneous name for termites. Actually they are more nearly related to cockroaches than to ants, but their general appearance and subterranean habits have given strong support to the popular designation. They may be divided into two major groups, viz., wood dwelling and earth dwelling termites. The wood dwelling termites enter wood directly from the air, whilst earth dwelling termites build their nests underground, and build tubes or covered runways from the ground to the object of their attack.

LIFE HISTORY OF TERMITES (2)

Like ants and bees, the termites are social insects with specially developed types or castes. Again, as in the case of ants and bees, the vast majority of individuals are **workers** which have the duty of food getting, construction and care of the young. A small percentage of individuals have their jaws greatly enlarged, not for gnawing wood, but to serve as weapons, and these large headed, strong jawed members of the community are termed **soldiers.**

When a gallery wall is breached by an enemy, it is the soldiers' duty to protect the colony until the damage has been repaired by the workers. In some of the higher groups of termites a different type of soldier is encountered. The jaws are very poorly developed, but the forepart of the head is produced into a prominence or rostrum, and a corrosive milky fluid is exuded from a pore at the apex. This fluid serves as a very effective weapon of defence, and being acid in nature is responsible for the etching of metals traversed by termites. This particular type of soldier is known as a nasute soldier.

The Royal Pair are solely interested in perpetuating the species and although when first starting a colony they have a multitude of duties to attend to, after the first brood of young has developed, the Queen assumes massive proportions and becomes little more than an animated egg laying machine. When swarming takes place, usually in warm humid weather, the winged males and females emerge and prepare for a short flight to form new colonies. The wings are then shed, pairing takes place, and the couple burrow into the soil near a log or stump to commence the task of founding a new colony.

Termites react negatively to light and will only work in the dark. They are also very sensitive to dessication and thrive best in a humid atmosphere. These facts are important in considering control measures. Departmental 4 inch ducts appear to be ideal nesting spots for termites, and it is thought that the eating away of the cable sheath is quite purposeless and purely incidental to the other activities of the termite. The termites which were found to be attacking West Australian lead cables have

* See page 349.

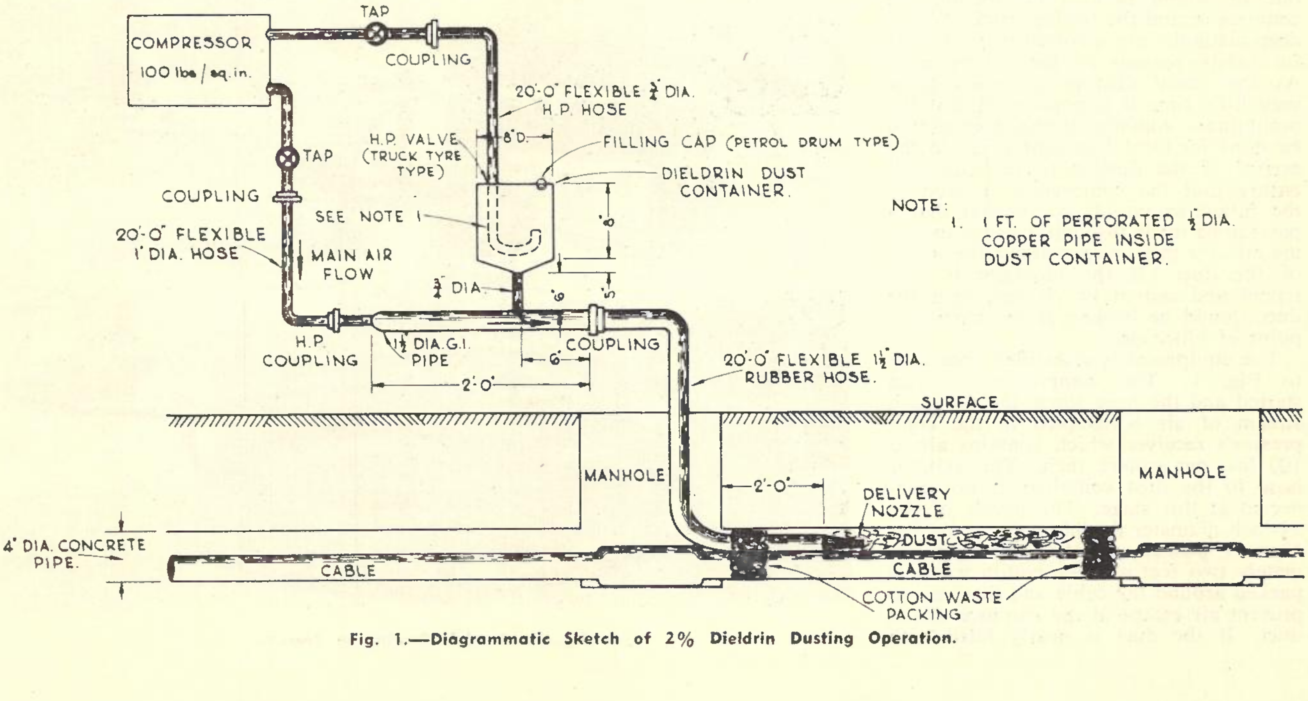


Fig. 1.—Diagrammatic Sketch of 2% Dieldrin Dusting Operation.

been identified as "Coptotermes raffrayi", and these have been found also attacking cables in the Eastern States.

TERMITE CONTROL OF EXISTING INSTALLATIONS

In the Metropolitan area of Perth, it was decided to approach the problem of termite attack in 4 inch ducts by a chemical method. It was considered that a powder be used and not a liquid solution as the liquid would possibly increase humidity and also cause clogging of the termite galleries. Investigation revealed that a 2% dieldrin dust would be adequate to treat termite infested 4 inch. ducts. This dust would be lethal to termites, would not be easily leached by water, and given suitable protective equipment would be safe for men to handle. The dust would also tend to adhere to the cable hauling compound surrounding the cable.

TREATMENT METHOD

The treatment is carried out, briefly, by blowing under pressure a mixture of air and the 2% dieldrin powder into the ducts. The equipment used is as follows:

(1) Broomwade Portable Rotary Air Compressor Plant which supplies 120 cubic feet/minute at 100 lbs. per square inch at 1,800 r.p.m.
(2) Injector unit — See Fig. 1.
(3) Dust bins to carry dieldrin powder to prevent moisture ingress.
(4) High pressure rubber hose —
  (a) 20 feet of 1 inch diameter hose.
  (b) 20 feet of 1½ inch diameter flexible rubber hose.
  (c) 20 feet of ¾ inch diameter high pressure hose similar to that used at garages for the pumping of car tyres.
(5) 500 feet of continuous flexible rod.
(6) Cotton waste for packing.

Sites of reported white ant activity are visited by the dusting crew. The dusting crew consists of at least two men, one of whom is able to operate the compressor and the towing truck. Where deep manholes are involved it is essential for safety reasons to have three men. As the actual dusting operation takes very little time it is considered that the preliminary rodding of the duct should be done by local line staff prior to the arrival of the dusting team. This will ensure that the compressor is used to the fullest extent. It is essential that a passage be made through the nest so that the air/dust mixture penetrates the whole of the duct. If the blockage is persistent and cannot be cleared, then the duct should be broken at the particular point of blockage.

The equipment is assembled according to Fig. 1. The compressor is then started and the hose supplying the main stream of air is coupled to the compressor's receiver which contains air at 100 lbs. per square inch. The agitator hose to the dust container is not connected at this stage. The nozzle of the 1½ inch diameter flexible delivery rubber hose is pushed up the duct approximately two feet and the cotton waste is packed around the cable and the hose to prevent air escape at the entrance of the duct. If the duct is nearly filled with cable, a smaller diameter hose must be used.

A man is stationed at the far end of the duct. The valve on the compressor is opened and air at pressure flows along the delivery hose up the duct and, provided the duct is cleared, the flow of air will be detected by the man at the far end of the duct who signals accordingly. If no such evidence is seen, then further rodding must take place.

Having obtained the all-clear signal from the man at the far manhole, then protective clothing is donned and the compressor operator opens the valve to the hose connected to the top of the can containing the powder. Thus the dust is agitated and blown out of the can. The dust mixes with the main air flow and the mixture of air and dieldrin dust passes along the delivery hose into the duct. When the dust penetrates to the far end of the duct, as evidenced by the appearance of the dieldrin dust cloud, the delivery taps at the compressor are turned off long enough for the far end of the duct to be packed with cotton waste. When both ends are sealed, the compressor operator turns on both taps at the compressor, and the requisite amount of dieldrin dust is blown into the duct. Fig. 2 is a typical street scene showing the items of plant, equipment and protective clothing in use. Generally, all ducts in the manhole are treated. It is considered that 9 lbs. of 2% dieldrin dust per 500 feet of duct is adequate to contaminate the termites. The action of the termites themselves by running backwards and forwards over the dust will also be a factor in ensuring its wide distribution. Death is caused by the termites grooming and cleaning themselves and one another and so swallowing some of the poison. Dieldrin dusting of ducts is limited, however, to known or suspected termite infestations. This is due to the magnitude of work involved if all ducts are dusted, and also the desirability of reducing the dusting to a minimum as the dieldrin dust is somewhat toxic.

RESULTS

Some miles of ducts have now been dusted in the Metropolitan area of Perth in the past two years and in no instances have termite infestations reappeared in any of the previously infested ducts. It is considered that the dieldrin will be effective for at least ten years. It is of course not easy to obtain conclusive proof as this would require the breaking open of ducts. However, all evidence to hand points to an effective measure of control. A full record of ducts treated is maintained in the Divisional Engineer's office and the efficacy of the system is thereby under observation. Dieldrin dusting of the ducts is generally confined to the cool weather due to the nature of the protective clothing which must be worn. (See Fig. 2.)

PRECAUTIONS WHEN USING DIELDRIN (3)

Dieldrin is a chemical which is toxic to termites, and if simple precautions are not carried out, the dieldrin may be absorbed into the human system in three ways:

(i) through the pores of the skin,
(ii) by breathing, and
(iii) by eating food with hands contaminated with dieldrin.

The use of dieldrin is unlikely to have any ill effects upon the health of the staff if the following precautions are faithfully carried out.

All dieldrin dust must be kept in labelled containers, and all warnings and instructions on the containers holding dieldrin must be read before opening. Dieldrin should be stored where it will

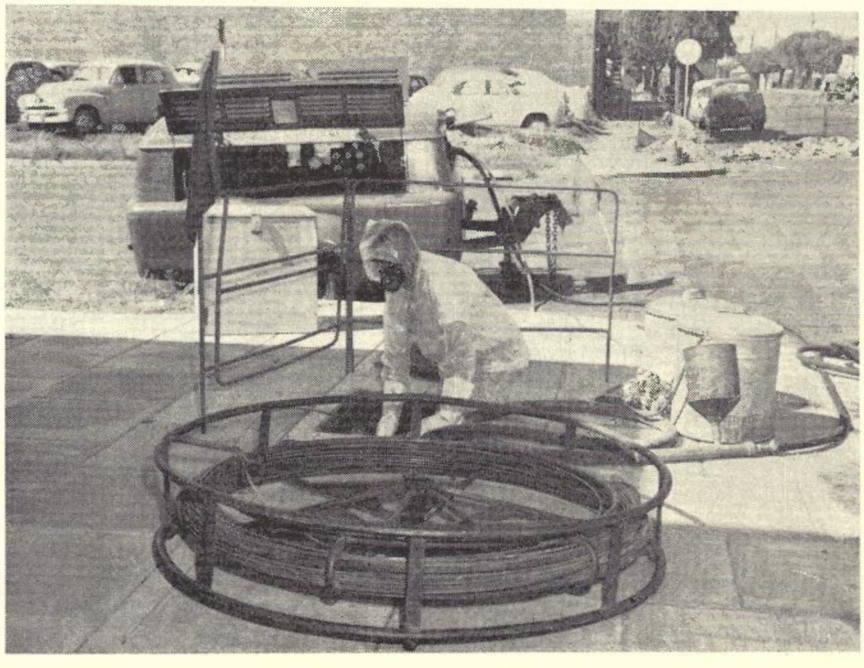


Fig. 2.—Dieldrin Dusting in Process.

not contaminate food, water, or cooking utensils.

When using compressor dusting equipment the equipment must be checked frequently for leaks. The staff must be provided with goggles, mask, suitable head gear, a long plastic coat and plastic gloves. Plastic clothing offers the best protection as it is easily freed of dieldrin by washing or brushing. Cloth type protective clothing may absorb, and subsequently release by movement of the wearer, quantities of dieldrin. Before protective clothing is removed any dieldrin on the outside of the clothing should be brushed off. For maximum protection, the mask and goggles should be the last items of protective clothing to be removed by the wearer. Any heavy concentration of dieldrin on protective clothing or skin must then be washed off immediately. Normal hygienic precautions should also be observed as mentioned below. Barrier creams should not be used, as they increase the risk of dieldrin absorption through the skin, and plastic gloves should never be worn over dieldrin contaminated hands. In order to avoid sustained contact with dieldrin dust, an individual officer must not be used on this work for more than two days in any one week, and staff should be rotated to effect this rule. The protective clothing should be kept in a plastic bag. This and the clothing must be thoroughly washed in soap and water, inside and out, and well rinsed after each day's use.

When recovering any cable from ducts, as there is now a possibility in Western Australia that the ducts may have been dusted with dieldrin, the staff have been instructed that plastic gloves should always be worn during the recovery operations, and that the normal hygienic precautions be carried out.

If dieldrin is accidentally swallowed, vomiting should be induced and medical attention should be sought immediately. If dieldrin is spilled on the skin, it should be thoroughly washed with soap and water. Contaminated clothing should be changed immediately. If dieldrin is splashed into the eye, it should be flushed with clean water for at least ten minutes and medical attention sought.

CONCLUSIONS

Dieldrin dusting of ducts provides a ready and practical method of termite eradication in departmental conduits. Given the strict safety precautions as outlined and constant supervision of practices, there is no need to expect ill effect on the operators due to the toxicity of the dieldrin.

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BACK COPIES

OUR CONTRIBUTORS

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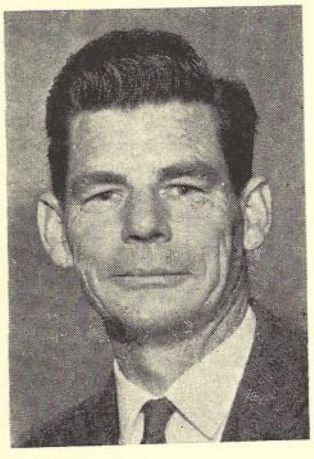
I. McMILLAN

R. E. KNIGHTLEY, author of the article "COMPAC", is Sectional Engineer (Planning) in the Overseas Telecommunications Commission (Australia). After serving as Cadet Engineer in the Postmaster-General's Department, he was transferred in 1945 as Engineer, Lines Planning, in Sydney. Resigning in 1948, he then worked on hydro-electric and other projects with the Public Works Department, New Zealand.

Returning to Australia in 1951, Mr. Knightley joined the Weapons Research Establishment as Engineer Grade 3 (Temporary), developing communications and other equipment associated with guided missiles. In 1954, he left W.R.E. to open a South Australian branch of British Automatic Telephone and Electric Pty. Ltd. In 1956, he joined O.T.C.(A.) and in 1960 was transferred to London as the Australian representative in the joint Development Group responsible for planning COMPAC. He returned to O.T.C.(A.) in November 1961. Mr. Knightly is an Associate Member of the Institution of Engineers, Australia.



H. L. C. READ

J. C. WHYBOURNE, author of the article "Emergency Telephone Service, Civic Exchange, Canberra" is a Divisional Engineer in the Internal Planning Section of the New South Wales Engineering Division. He joined the Postmaster-General's Department as a Technician-in-Training in 1940 and interrupted his course to serve in the R.A.A.F. Radar Section in the South-west Pacific area for 3½ years. He qualified as Engineer in 1949 and was appointed Group Engineer in the Country Installation Section in Sydney. Mr. Whybourne transferred to the Planning Branch in 1951 and, was promoted to Divisional Engineer in 1954. In this position he has been responsible for planning of exchange works for the greater part of New South Wales, including internal equipment planning aspects of the Sydney-Melbourne Cable Project. He has also been closely associated with the A.N.S.O. (Australian National Switching Objectives) Committee, and played a large part in bringing the National Numbering and Group Charging plans to finality and in developing the concept of Regional Planning. Mr. Whybourne is an Associate Member of the Institute of Engineers, Australia.

H. L. C. READ, author of the article "Vibration Testing" joined the Postmaster-General's Department in Sydney as a Telegraph Messenger in 1934. After service in the Second A.I.F., he transferred to the Engineering Division in 1946 and qualified as a Technician in 1952 and Senior Technician in 1956. He has been stationed at City South Automatic Exchange and City North Carrier Terminal in Sydney, and at Muswellbrook. Since 1959 he has been attached to the New South Wales Trunk Service & Telegraphs Section. Mr. Read is at present acting Supervising Technician and is engaged mainly on vibration testing of carrier equipment throughout New South Wales.

R. K. EDWARDS, co-author of the article "The Melbourne-Morwell Coaxial Cable System", joined the Department in 1952 as a Cadet Engineer, completing the Degree of B.E.E. at the University of Melbourne in 1955. After the final year of his cadetship, he travelled to Great Britain on a Federation of British Industries overseas scholarship, spending 1957 and 1958 with Standard Telephones and Cables Ltd. in London, engaged in studies of broadband coaxial and microwave systems practice. On his return in 1959, Mr. Edwards spent four months with the Radio Telephone Installation Division, Victoria, assisting with the Melbourne-Bendigo 4,000 Mc/s radio system installation, after which he joined the Long Line and Country Installation Section at the commencement of the Morwell coaxial cable project.

I. McMILLAN, co-author of the article "The Melbourne-Morwell Coaxial Cable System", assisted in the installation and line-up of this system. He joined the Department in 1950 as a Technician-in-Training and was promoted as Technician in 1955. He qualified as Senior Technician in 1956 and was appointed Supervising Technician Grade 1 in 1961. Since completing the Technician-in-Training course he has been employed in the Long Line and Country Installation Section, Country Branch, Victoria. Mr. McMillan gained valuable experience on German type carrier equipment when he assisted with the installation of the Melbourne (City West) terminals of the first and subsequent Z12N cable carrier systems supplied by Siemens and Halske. At present he occupies the position of Supervising Technician, Grade 2 (acting) on inspection and acceptance duties associated with the Sydney-Melbourne coaxial cable project.

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J. E. SANDER, author of the article "Earth Fault Location Test Set" joined the Postmaster-General's Department in 1942 as a temporary telegraph messenger in Perth, Western Australia. He was later appointed as a Technician-in-Training and after completing his training, was transferred to the Long Line Equipment Installation Section where he spent 3 years as acting Senior Technician installing miscellaneous open wire carrier equipments. Whilst he was with the Long Line Equipment Section Mr. Sander completed two years part-time study at the University of Western Australia towards the degree of Bachelor of Science. In 1951 he was appointed as a Cadet Engineer and in 1956 graduated Bachelor of Engineering with First Class Honours in Electrical Engineering, sharing with another student the Cable Makers' Association Prize in Electrical Engineering. After appointment as Engineer he transferred to the Telephone Equipment Circuit Laboratory at Headquarters where he spent 2½ years on miscellaneous circuit design work. In 1960 he was transferred to the position of acting Divisional Engineer, Suggestions, in which position he was responsible for the investigation of suggestions relating to telephone equipment matters submitted to the Improvements Board. Later Mr. Sander moved to the Exchange Equipment Design Subsection where he is at present responsible for various aspects of crossbar and trunk equipment plant.

J. G. BARTLETT, co-author of the article "A Telegraph Distortion Analyser" is Divisional Engineer, Trunk Service, Brisbane. He entered the Department in Adelaide in 1942 and qualified as an engineer in 1947. After experience in South Australia and the Long Line Equipment Section, Central Office, he transferred in 1952 to Queensland where he has been engaged mainly on the installation and maintenance of long line equipment. Mr. Bartlett is an Associate Member of the Institution of Engineers, Australia.

ROGER SMITH, author of the article "An Automatic Traffic Recorder", joined the Department in 1952 as a Cadet Engineer, subsequently obtaining the degrees of Bachelor of Engineering and Master of Engineering at the University of Adelaide. The latter degree was awarded for work on the bandwidth compression of speech signals.

Mr. Smith joined the Research Laboratories in 1957 and was employed in the Multichannel T & T Division until June 1961 where he was engaged on the design and development of carrier type telephone systems, and associated equipment. He then transferred to the Voice Frequency Transmission, Switching and Signalling Division and has since been involved in the development of equipment using electronic switching techniques, including assistance in the development of a small electronic telephone exchange.

He is a Graduate Member of the Institution of Electrical Engineers, London, and an Associate Member of the Institution of Radio Engineers of Australia.

J. G. BARTLETT

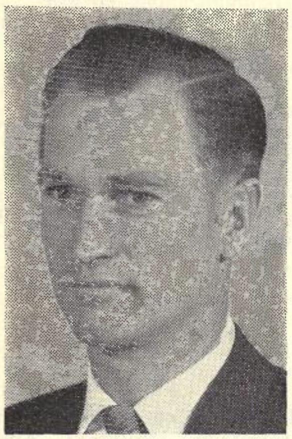
M. LEVERIDGE, author of the article "Dieldrin Dusting for the Protection of Cable against Termite Attack" was born at Leeds, England, in 1923. He was educated at the City of Leeds School, and the University of Leeds. He received his B.Sc. degree in Electrical Engineering in 1945. His first experience in communications was with Ferranti Ltd, Manchester, and after a short period joined the overseas staff of the Anglo-Iranian Oil Company in Iran. He served with this company for three years as an area communications engineer, gaining experience with a variety of communications equipment. He joined the Postmaster-General's Department in 1949 and has since been employed in External Plant Division. He is now Divisional Engineer, District Works No. 1 Division, Perth.

Mr. Leveridge is an Associate Member of the Institution of Electrical Engineers (England) and an Associate Member of the Institution of Engineers, Australia.

L. L. BIRCH, co-author of the article "A Telegraph Distortion Analyser" joined the Department in 1949 as Engineer, after completing a Degree Course in Electrical Engineering at the University of Queensland. His first post was in the Long Line Equipment Installation Division and in 1952 he transferred to the Transmission Planning Division as Group Engineer. In 1955 he transferred to Trunk Service Division and acted as Divisional Engineer for three years while the permanent occupant was absent on other duties. Since then he has been occupied mainly as Group Engineer, Trunk Service, and was engaged in an investigation of Voice Frequency Telegraph system operation prior to the introduction of T.R.E.S.S. in Queensland. Recently he has been acting in the positions of Divisional Engineer, Radio Service, Divisional Engineer, Trunk Service and Divisional Engineer, Automotive Plant.

F. W. ARTER

F. W. ARTER, author of the article "Design Aspects of Transistor-Diode Switching Circuits", joined the Research Laboratories in 1958 after completing a Departmental Cadetship, during which he obtained the degrees of Bachelor of Electrical Engineering and Master of Engineering Science at the University of Melbourne. He spent three years in the Voice Frequency Transmission Division of the Laboratories where he gained experience in the application of transistors and semiconductor diodes in switching circuits. At present he is Group Engineer in the Multi-channel Telephone and Telegraph Division of the Laboratories.



T. F. CHAMPION

T. F. CHAMPION, author of the article "800 Line Cordless P.A.B.X.," commenced as a Telegraph Messenger in Perth in 1944. He was transferred as a Technician-in-Training in 1946 and was advanced as a Technician (Telegraphs) in 1951. In 1952 he passed the Senior Technician (Telegraphs) examination and took up duty in Telegraph Maintenance until 1957 when he passed the Senior Technician (Telephones) examination and was transferred to Exchange Maintenance. In 1958 he was transferred to the Exchange and Subscribers Installation Division and was promoted Supervising Technician Grade 1 in that year. For the past two years Mr. Champion has been in charge of installation in the Perth Main Trunk Exchange.

ANSWERS TO EXAMINATIONS

Examination No. 4958 — Senior Technician (Telecommunications), Radio — July, 1961

SECTION A

QUESTION 1.

(a) *Define or briefly explain the following:—*

(i) Amplitude modulation.
(ii) Phase modulation.
(iii) Frequency modulation.

(b) *Assuming that a carrier is amplitude modulated by a sinusoidal (pure tone) signal what percentage of the total power is contained in —*

(i) the carrier, and
(ii) the side bands?

when modulation is applied at 50 per cent. and 100 per cent.

ANSWER 1.

(a) (i) **Amplitude modulation.** The carrier frequency remains constant but its amplitude is varied in accordance with the level of the applied audio frequency and at a rate equal to the latter frequency.

(ii) **Phase modulation.** The carrier amplitude remains constant but the phase angle varies at a rate equal to the applied audio frequency, the degree of variation depending on the magnitude of the applied audio frequency.

(iii) **Frequency modulation.** The carrier amplitude remains constant but the frequency is varied about the unmodulated value at a rate equal to the applied audio frequency, the deviation from normal frequency depending on the magnitude of the applied audio frequency.

(b)

	50 per cent Mod.	100 per cent Mod.
(i)	89	66.6
(ii)	11	33.3

QUESTION 2.

(a) *What is meant by neutralization as applied to a radio frequency amplifier?*

(b) *With the aid of diagrams describe a method of neutralizing a push-pull radio frequency amplifier.*

ANSWER 2.

(a) When the grid circuit of a radio frequency amplifier is capacitatively coupled to the plate circuit, energy is fed back from the plate circuit in the correct phase to sustain oscillation. The measures which may be used to prevent this oscillation include:—

(i) the use of pentode or tetrode valves in lieu of triode valves to reduce the valve grid to plate capacity to a minimum;

(ii) careful layout and shielding of the grid circuit and or plate circuit components to reduce coupling between these circuits to a minimum;

(iii) the use of special circuit arrangements which, even in the presence of grid plate capacitative coupling, prevent oscillation within the amplifier. Such circuit arrangements are termed neutralization and they depend for their operation upon the fact that the oscillation due to grid to plate capacitative coupling may be suppressed if an equal amount of energy to that transferred from plate to grid through the capacitative coupling is also fed back to the grid circuit in phase opposition to the undesired feedback.

Typical neutralization circuits are shown in Figs. 1a and 1b.

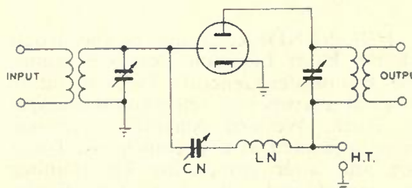


Fig. 1a.

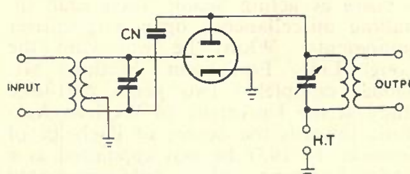


Fig. 1b.

(b) In the case of a push-pull radio frequency amplifier neutralization may be achieved by the circuit arrangement shown in Fig. 2. In this circuit

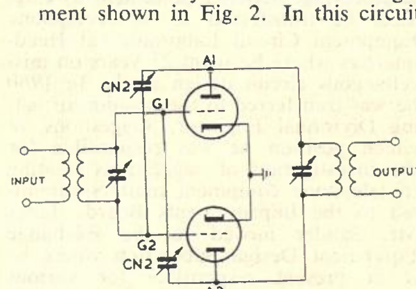


Fig. 2.

two capacitances CN_1 and CN_2 are connected from the plate terminals of each of the push-pull valves to the grid terminals of the opposite valves.

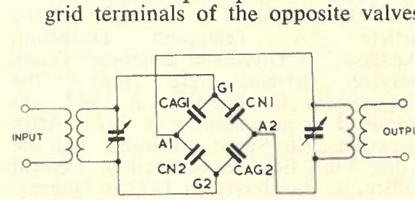


Fig. 3.

The equivalent circuit of this arrangement is shown in Fig. 3 from which it may be seen that the circuit has the form of a bridge and hence when bridge balance is achieved none of the energy in the output circuit (i.e., the voltage appearing across A_1, A_2) will be fed back to the input circuit (zero volts across G_1 G_2).

At balance $C_{AG1}/CN_1 = CN_2/C_{AG2}$

but $C_{AG1} = C_{AG2}$

$\therefore CN_1 = CN_2 = C_{AG1} = C_{AG2}$

For pure reactance conditions, i.e., when the effects of wiring inductance and valve internal inductances (grid and plate connections) may be neglected, the bridge neutralizing circuit for push-pull valves is independent of frequency. In practical circuit arrangements balance is maintained over a wide range of frequencies.

SECTION B

QUESTION 4.

The signal-to-noise ratio on a high-frequency radiotelephone link is 10 db when dipole aerials are used at the transmitter and receiver and a double sideband transmitter of 250 watts peak-power output is employed.

If each dipole aerial is replaced by a rhombic aerial, with a gain of 14 db relative to a dipole, and the double sideband is replaced by a single-sideband system, using a transmitter of 2 kilowatts peak-power output,

(a) what is the signal-to-noise ratio?

(b) what other advantages are likely to be gained by such a change?

COMMENTS 4.

(a) To obtain an exact figure for the new signal-to-noise ratio, it is necessary to assume that the noise level at the receiver input remains at its original value when the new system is employed. This is, of course, the simplest and most general case.

(b) A list is required of the advantages, other than improved signal-to-noise ratio, which the new system would have over the old. Any four of the points from the model answer should have earned good marks.

ANSWER 4.

(a) With dipole aerials and double-sideband transmission the signal-to-noise ratio is 10 db.

The improvement due to rhombic aerials replacing the dipoles is 2 x 14 db = 28 db.

Since a single-sideband system is to be used, a gain of 6 db is achieved through suppression of the transmitted carrier compared with double-sideband operation.

The single-sideband receiver will have half the bandwidth of the double-sideband receiver, thereby effecting a further 3 db signal-to-noise improvement.

The power increasing from 250 watts to 2 kilowatts, that is 8 times, gives an improvement of 9 db.

Therefore the total improvement in signal-to-noise ratio is equal to:—

28 db by using rhombic aerials.
6 db by using single-side-band tranmission.
3 db by using single-side-band reception.
9 db by increasing the radiated power.

A total of 46 db

So that the new signal-to-noise ratio is —

46 + 10 db = 56 db.

(b) 1. The increased power, the increased directivity of the rhombics and the decreased bandwidth, all provide additional protection of the system against interference from other signals incoming at the receiver, while the increased directivity may result in less interference to others.

2. The increased signal level will provide a valuable margin of protection to the system against the effects of fading and equipment deterioration.

3. Single-sideband reception gives some protection against the effects of selective fading.

4. Single-sideband transmission gives increased privacy to the system by decreasing the likelihood of casual interception.

5. Single-sideband transmission permits closer frequency spacing, thereby increasing the number of circuits which may be accommodated in the overcrowded high-frequency band.

6. As rhombic aerials can be designed to provide useful gain over a 2:1 frequency range, their use provides flexibility in the choice of operating frequencies to avoid propagation variations and interference.

QUESTION 8.

(a) Magnetic tape recording machines are used in large numbers throughout the National Broadcasting Service and tape recorded programmes are interchanged between the various studio centres throughout the Service.

(i) In what basic characteristics is it essential that the various types of recorder in use should have similar performance and explain why this is necessary?

(ii) In general there are four basic types of machine in use. What are these types and for what purposes are they used?

(b) A particular form of distortion, commonly called "Wow and Flutter", is experienced in mechanical recording systems.

(i) What characteristic of the system does this distortion affect?

(ii) Explain briefly the basic principle of the test equipment used to measure this form of distortion and also the method of reading the meters fitted in the test equipment.

ANSWER 8.

(a) (i) Tape recorders of all types employed in the National Broadcasting Service should have similar performance as regards speed, record-replay characteristics and use of standard tapes and spools. This permits free interchange of recorded tapes between the various types of machine without degradation of technicial quality.

(ii) Four basic types of machine are employed in the National Broadcasting Service:—

Studio Console. Used at fixed locations such as Broadcast studios for recording and replay of highest quality programme material.

Transportable Recorder. Mainly used for outside recording work where high quality performance is required, e.g., musical programmes. This machine is also adapted for rack-mounting at fixed locations.

Portable Recorder. Used for outside recording work involving speeches, interviews, etc.

Miniature Recorder. Battery-operated unit used for speech recording purposes at locations where a commercial power supply is not available.

(b) (i) "Wow and Flutter" distortion is evidenced as a change in pitch of a recorded signal and occurs in both disc and tape recording systems. It is caused solely by variations in speed of the disc or tape driving mechanism.

(ii) The "Wow and Flutter" meter measures the frequency deviation of a signal at 3,000 cycles per second impressed on disc or tape. The frequency deviation is proportional to the speed variations of the disc or tape driving mechanism. Hence the meter can be calibrated to read percentage speed variation (Wow and Flutter).

The meter comprises an amplifier tuned to 3,000 cycles per second which also limits the amplitude of the input waveform, thus ensuring that the instrument responds only to frequency variations. This is followed by a frequency discriminator, the output of which is coupled directly to a "Peak Wow" meter. The output of the discriminator is also fed to an amplifier, incorporating a 200 cycles per second low-pass filter, which in turn drives two other amplifiers—one having a 20 cycles per second low-pass characteristic and the other having a 20 cycles per second high-pass characteristic. The outputs of the last two amplifiers are simultaneously displayed on two meters designated R.M.S. Wow (0-20 cycles per second) and R.M.S. Flutter (20-200 cycles per second). By switching, the total R.M.S. Wow and Flutter can be shown on the "Wow" meter. The reading of each meter is obtained by observing the deflections of the pointer over a period of 20 to 30 seconds and noting the mean deflection.

SECTION C

QUESTION 7.

(a) *A special meter is used for reading the programme level in the audio circuits of radio and television broadcasting systems.*
What is the name of this meter, and in what main characteristic is it different from the various types of meter used for other purposes in these systems?

(b) *What is the approximate range, in decibels, of the acoustic sound output of a full symphony orchestra and in what respect does this range have to be taken into account in the design of the first audio amplifier in the studio chain?*

(c) *In the design of audio amplifiers for broadcasting and television the peak power handling capability is many times larger than the average power of the programme energy being amplified.*
What is the approximate ratio, in decibels, which the designer allows, and what relationship has this ratio to the main characteristic of the meter mentioned in part (a)?

ANSWER 7.

(a) This meter is called the "vu" meter, and the main characteristic in which it differs from the other meters in use in broadcasting and television systems is in the response time of its movement and pointer to audio frequency energy.
The specification for the meter includes the following condition —
"If a 1,000 c/s voltage of such amplitude as to give a steady reading of 100 on the voltage scale is suddenly applied, the pointer shall reach 99 in 0.3 seconds ± 10% and shall overswing the 100 mark by at least 1.0 and not more than 1.5%".

(b) The approximate range is 70 decibels. Depending on the type of microphone(s) used for the broadcast, the equivalent electrical output of the microphone(s) could vary from say −100 dbm to −30 dbm, i.e., ± 35 decibels about an average microphone level of −65 dbm. The first audio amplifier should therefore be designed to handle these extremes of electrical input signal.
As the lowest level mentioned above (−100 dbm) is only 38 db above the theoretical noise level (−138 dbm) in a perfect noise-free amplifier with a source of 50 ohm (microphone) impedance, the practical amplifier must obviously be designed to introduce as little noise as possible. The best quality amplifiers have an equivalent noise input level of approximately −125 dbm.
At the other extreme of input level, i.e., −30 dbm, the input voltage swing stepped up by the input transformer to the grid of the first valve, would be of the order of 1 volt. The design of the amplifier should take this into account, and by suitable choice of valve, feed-back, etc., avoid amplitude distortion caused by non-linearity of the valve characteristic.

(c) The approximate ratio is a minimum of 8 decibels but modern designs are allowing for 10 decibels and in special circumstances even higher ratios.
The minimum ratio of 8 decibels is the same ratio by which the "vu" meter, by reason of its 0.3 second response time, fails to respond fully to peaks in programme waveforms having a much shorter response time than the meter.

QUESTION 9.

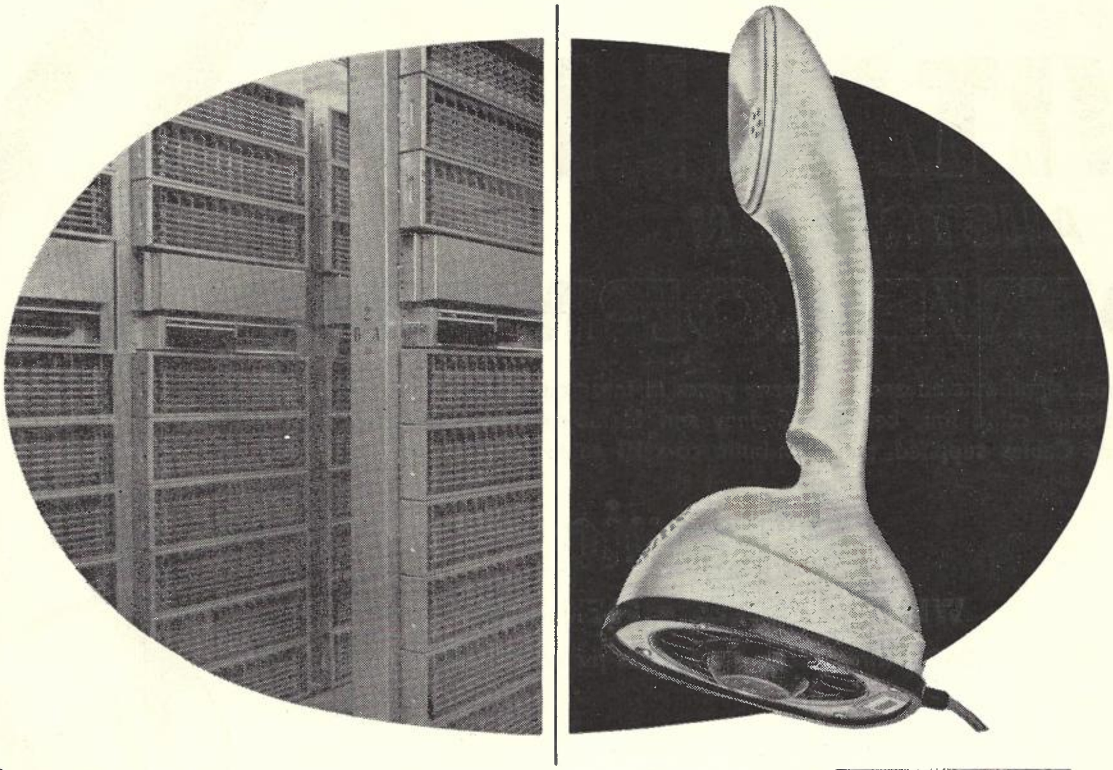
(a) *In radio broadcasting studios various sources of programme are used, e.g., microphone pick-up, gramophone records, tape recordings, interstate and intrastate programme lines, etc.*
   (i) *Show in a schematic diagram how these various sources in a composite programme from a single studio are amplified and controlled in level up to the point where the programme leaves the studio for the studio programme switchroom.*
   (ii) *Mark on the schematic diagram the programme levels which would normally be experienced at the various points in the system.*

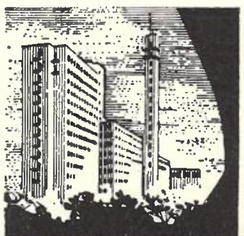
(b) *In the main studio switchroom programmes are switched to their various destinations, e.g., local and regional transmitting stations, interstate programme lines, etc. In order to achieve continuity of programmes this switching has to be organized to avoid breaks between successive programmes.*
   (i) *What is the time interval generally allowed for this switching to take place, and*
   (ii) *What are the various indications given to the switching operator which tell him exactly when to switch?*

ANSWER 9.

(a) See Departmental Drawing CF.254, Sheet 2.

(b) (i) The A.B.C. allows a fifteen second interval for the switching of programmes.
   (ii) The Technical Operations Sheet (TOS) indicates the scheduled time for each switching operation and the cue. The cue may be any of the following —
      gongs,
      time signals,
      a musical theme,
      spoken words.



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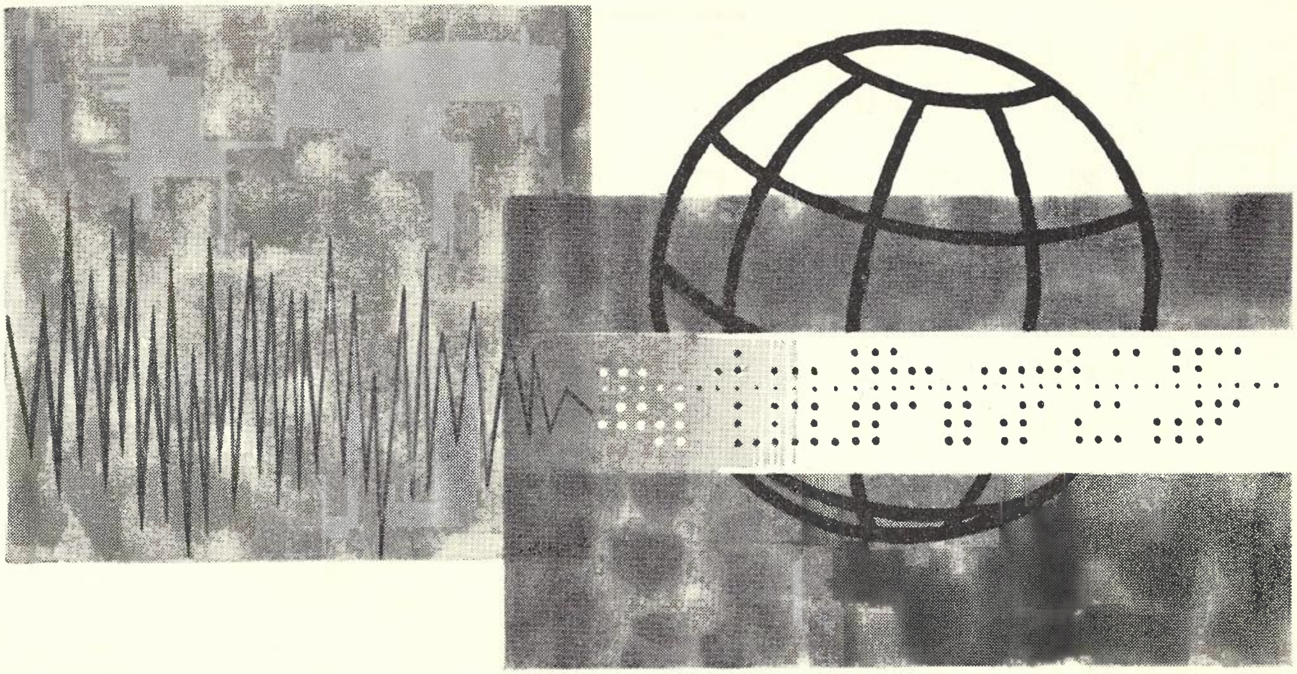

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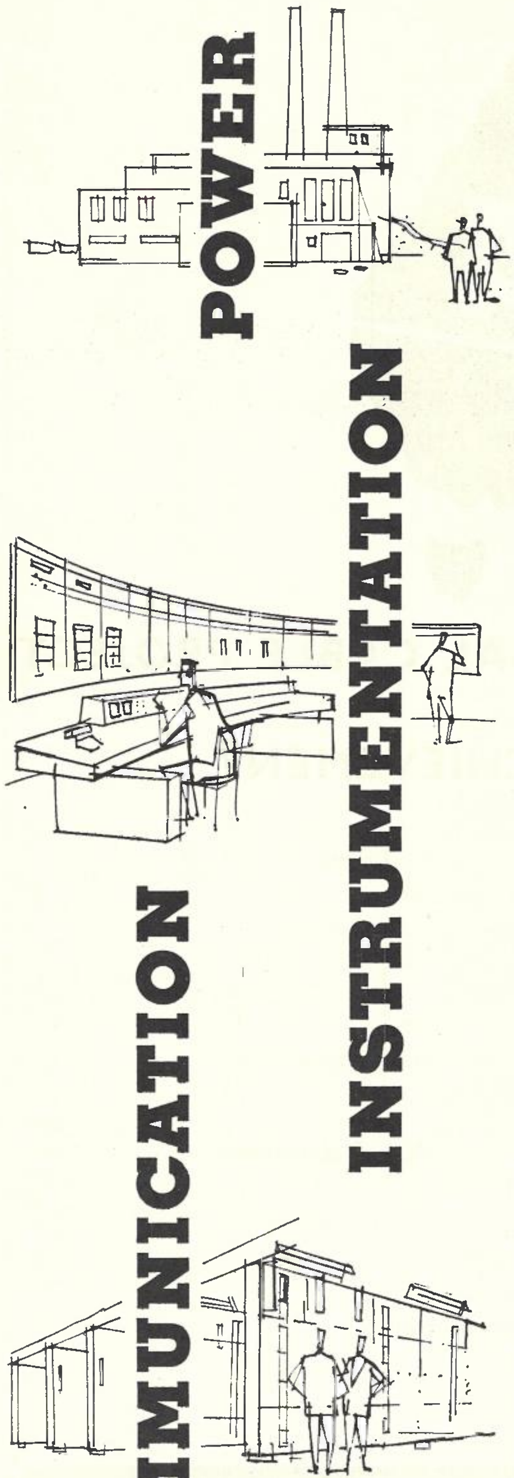

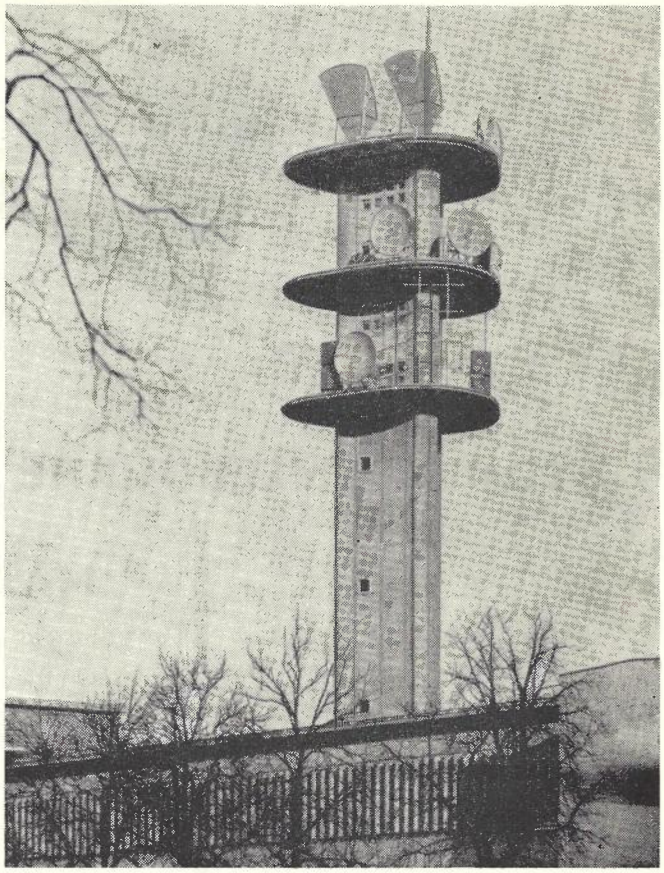

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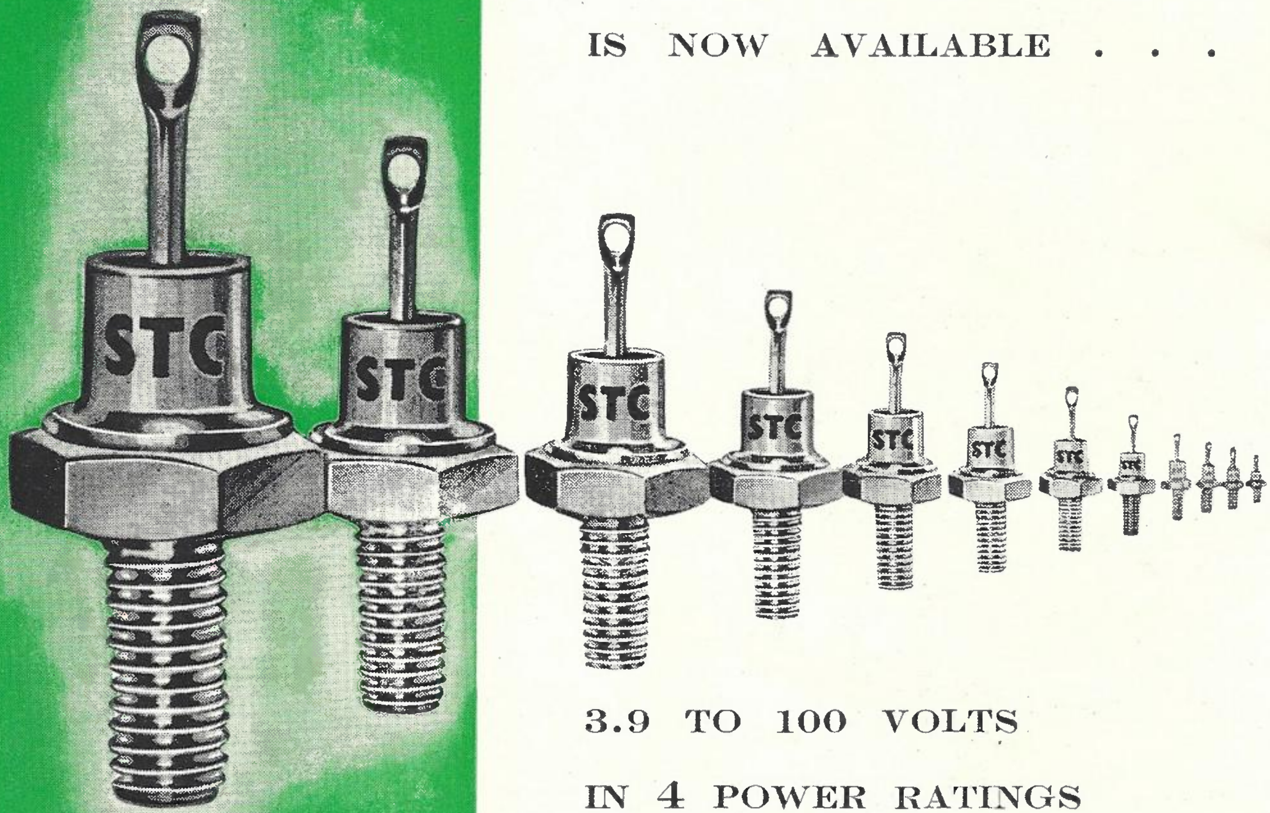

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