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The

Telecommunication Journal of Australia

Vol. 7, No. 4 *June, 1949*

REVIEW OF OVERSEAS DEVELOPMENTS IN TELEPHONE AND ASSOCIATED EQUIPMENT

J. S. Silvester, A.M.I.E.(Aust.)

The author was sent overseas in 1948 to investigate latest developments in switching systems. Leaving Australia in September, 1948, and returning in February, 1949, visits were made during this period to Great Britain, France, Switzerland, Holland, Belgium and Sweden. Many aspects of switching systems and related telecommunication problems were observed and investigated during the visit, and it would be impracticable to deal at any length with the whole of the field covered. The objective of the following summary has been to set down briefly salient items which were felt to be symptomatic of current developments overseas.

New Developments in Telephone Equipment

Siemens No. 17 System: This system uses the motor uniselector for switching. Considerable attention has been devoted to cabling, commoning of banks, etc., also to the covering and protection of the apparatus by means of metal covers at the front and rear of the bays. The system is a marking system, the marking being carried out by minor switches which receive the impulses from the dial. The selectors have one control set per five selectors (the minor switches form part of the control circuit); the final selectors have one per group of 9. Incoming selectors have an individual control set each. By the use of two marking switches per control set, one rank of selectors can be dispensed with.

The Universal System: This system has been developed by the Bell Company, and an exchange of this type is at present being installed at Havana, Cuba. A model is at present in Paris at the L.M.T. factory, where the inspection was made. The switch used in the system is a flat type and moves across bare wires forming the multiple. The system works at present with a vertical shaft driven by a common motor per vertical. Development of the switch is still progressing. Trials are at present being made of a small 4-watt 2-phase motor to drive each switch individually. The method of driving the wiper mechanism across the bank is also receiving attention, as 5 or 6 different methods of doing this were being tried out.

The 7E System—Bell Company, Antwerp: Of the systems examined, this is the most up-to-date in regard to electronic control. The identification of the subscriber's line calling is made by the change of potential on the private wire brought about by looping the line. The subscribers' lines have no "line" or "cut off" relays. The different

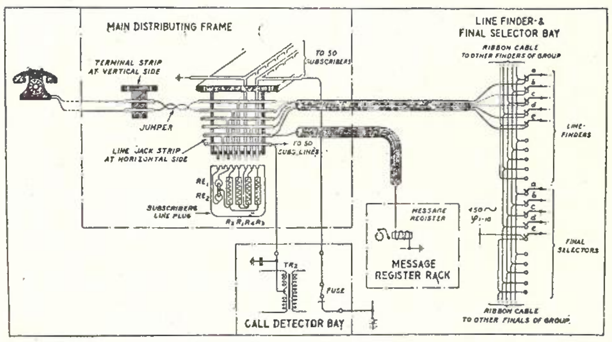


Fig. 1.—7E System. Main Distributing Frame—Schematic.

types of lines, such as the first and last in a P.B.X. group, etc., are marked by different potentials. The levels of the finders, selectors, etc., are marked by phase differences of the 450 cycle A.C. tone current; phase difference of 30 degrees is used for this purpose. In the detector circuit of the line finders, one cold cathode tube per 50 lines only is required. The system works at present with rotary machine driven equipment, but there is no reason why switches of a different type could not be used with this system effectively. The system has many other interesting features including 4-figure V.F. code sending between offices in lieu of impulsing (600 and 900 cycle currents being used for this purpose). The use of V.F. current permits the transmission of the numerical information directly from the originating register to any other register, even in distant areas, without requiring any impulse-repetition or regeneration of impulses at tandem exchanges. The Company has an 800 number P.A.B.X. of the 7E system installed and working at its factory. Figs. 1, 2 and 3 show details of this equipment.

The Crossbar System—Ericsson Company, Sweden: A 40 line R.A.X. has been received by the B.P.O. and is being tested out in their Circuit Laboratory. This unit was supplied by the Ericsson Company of Sweden. Crossbar manufacture at both the Ericsson and Swedish Post Office factories was inspected.

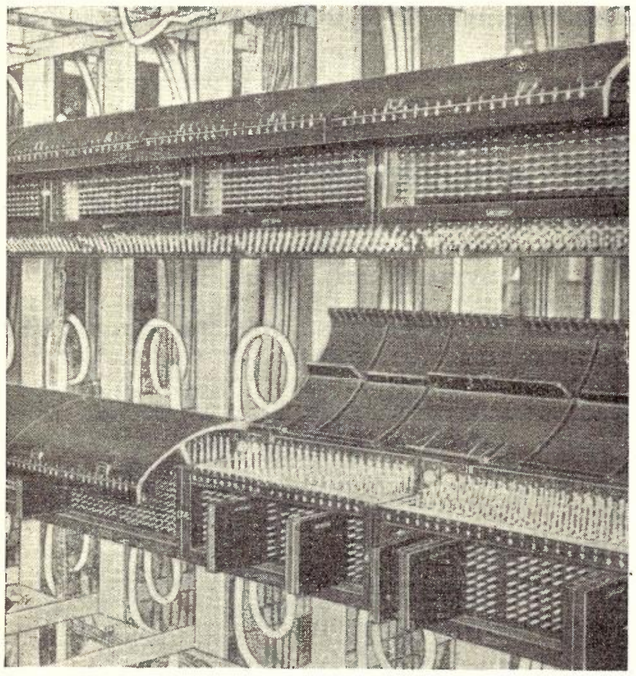


Fig. 2.—7E System. Subscriber's line plug containing resistors and rectifiers.

There has been a lot of work carried out on the development of this switch and the system. Front and rear views of the switch are given in Figs. 4 and 5. The crossbar switch is used in both "step by step" and marking systems in Sweden. Crossbar switches are also used for registers in connection with the 500 pt selector developed and manufactured by Ericsson's Ltd. The crossbar switch is one of the simplest components so far designed for use in registers. I inspected an exchange of 16,000 lines equipped with crossbar registers and the 500 pt switch throughout, at Upsala.

The crossbar switch in conjunction with electronic marking and detection (as used in the 7E system) would be an interesting step in the direction of complete electronic switching.

The crossbar in Sweden has been investigated by the B.P.O. Engineers and a paper on this subject was read in 1948 by J. A. Lawrence before the I.P.O.E.E.

This switch gives very reliable service in Sweden in both large main exchanges and small R.A.X.'s requiring very little maintenance effort.

The 41 System, Sweden: The standard system in use at present is called the "41 Crossbar System." The principal features of the system are as follow:—

(a) All the switching operations which normally require mechanically operated switches are effected with crossbar switches (see Figs. 6 and 7).

(b) A crossbar switch is used where a bi-motional selector would be used in a conventional "step by step" system, the crossbar switch carrying only one call per switch. In the place of uniselectors in the "step by step" system, a crossbar switch is used with the individual bridges each representing a uniselector.

(c) Where bi-motional selector operation is required the selecting magnets of the crossbar switch are arranged as a relay type impulse counting circuit, which is able to respond directly to impulses derived from the subscriber's dial. Where group selector hunting is required, the bridge magnets are arranged as a self-drive relay chain.

(d) The exchange voltage is 36 and the crossbar switch magnet windings require currents of the order of 50 m.a. so that contact wear on impulsing relays is somewhat less than that experienced with the more usual power magnets of conventional bi-motional selectors.

(e) The circuit elements used in the Standard 41 system are arranged so that wherever the facilities required are the same, a similar element is used. In general, the system is a four-wire system, i.e., two line, private and meter wires. The 41 system is designed for exchanges up to 2000 lines, larger exchanges becoming uneconomical.

The "Link System," Sweden: To cater for the larger exchanges, a new system on the semi-marker principle has been designed with the group selector units divided into common control groups of four switches. The four switches in, for example, the first group selector are so inter-connected that ten incoming trunks can be connected to any one of ten groups of twenty out-going

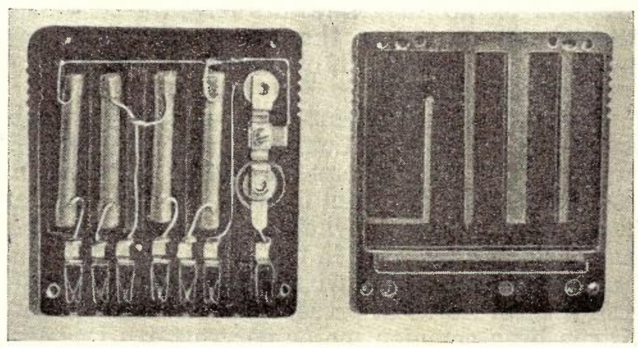


Fig. 3.—7E System. Main Distributing Frame showing Line Plugs which take the place of L and K relays.

trunks. The line finder and final selector consists of a group of 8 crossbar switches serving 100 lines. There are four primary and four secondary switches, the secondary switches giving access to

20 trunks to first selectors and 20 trunks from penultimate selectors. The economy of this "link" system will be quite considerable when compared with the present "41" system.

The 2000 Switch, "Step by Step" System: B.P.O. 2000 type equipment is the present standard system of the British Post Office and of the Australian Post Office.

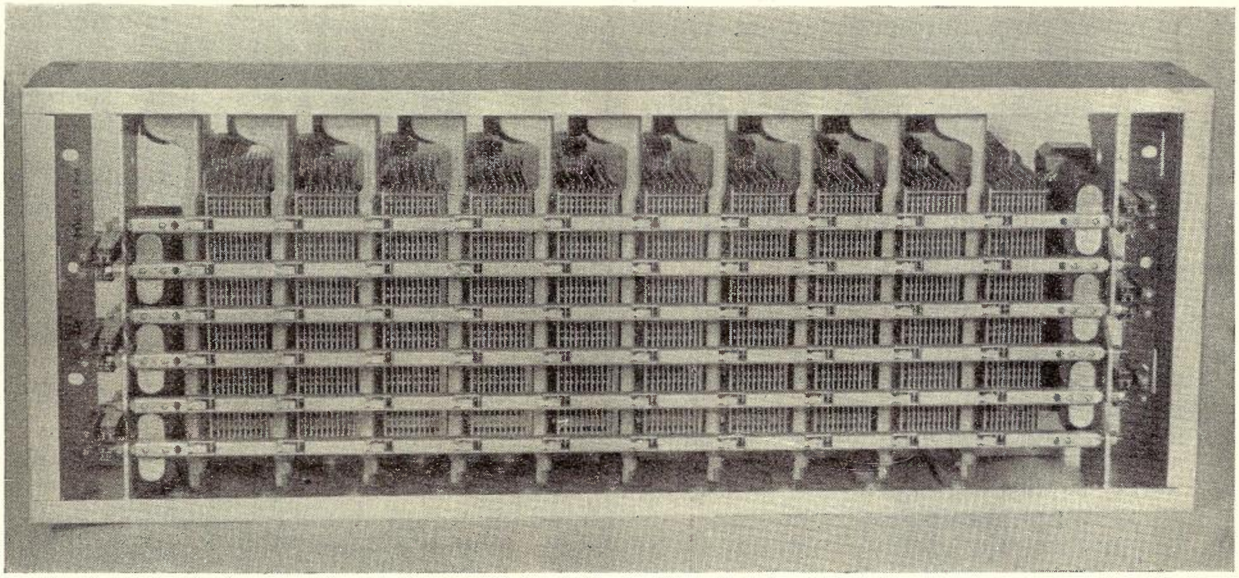


Fig. 4.—Crossbar Switch manufactured by Ericsson Co., Sweden—Front view.

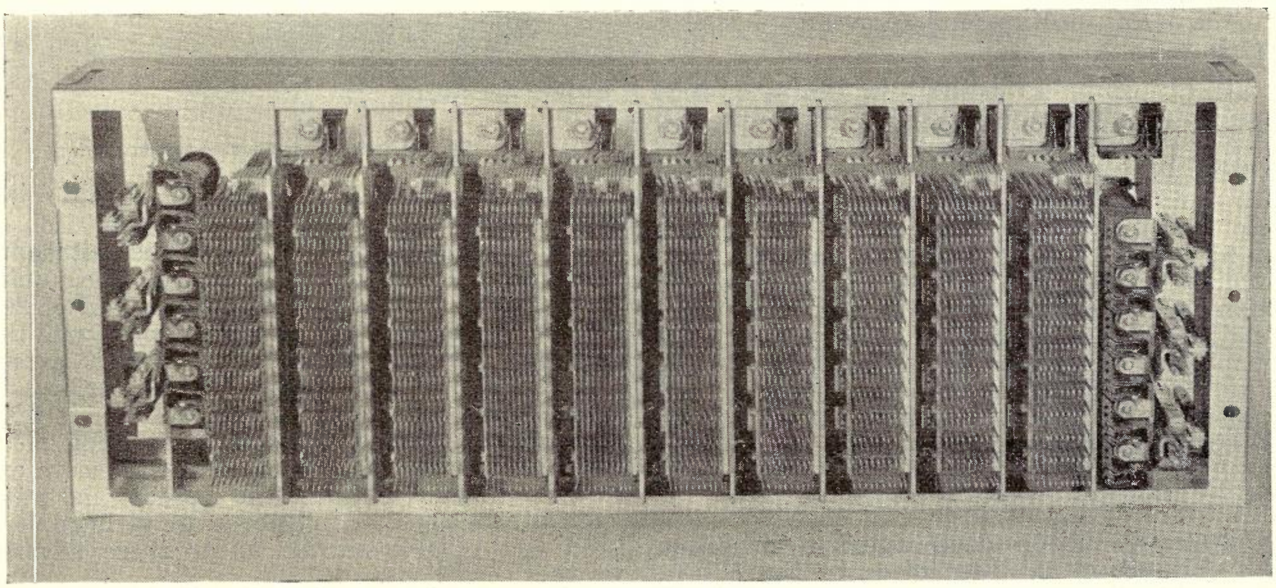


Fig. 5.—Crossbar Switch manufactured by Ericsson Co., Sweden—Rear view.

Electronic Systems: The development of electronic switching is being investigated by all the companies in Sweden, Holland, Belgium and England. Dollis Hill Research Laboratories has a section set aside for this work for the B.P.O.

From time to time, experience of the operation of 2000 type switching equipment, as with other systems, has shown that modifications could be introduced to improve manufacturing techniques or performance in service. Various changes have, therefore, been adopted by the manufacturers and the purchasing authorities. The more recent developments are listed hereunder:—

(i) The wiper assembly bracket has been redesigned to prevent distortion of wiper carriage with excessive pressure. The bracket is now reversible.
(ii) The shape of wiper tips has been modified to reduce wear. Further investigations are in progress tending towards the replacement of the collar type wiper assembly with a complete new design of wiper assembly.
(iii) The rotary off-normal springset operating roller is replaced by a fixed operating plate to reduce wear.
(iv) The rotary detent is case hardened at the latching lug to reduce wear and manufactured from thicker material.
(v) The rotary disc is offset to improve security of latching in the normal position.
(vi) "Tobin" bronze magnet fixing screws are used to avoid loss of flux via switch covers in position.
(vii) An anti-bounce plate is fitted to the underside of the bridge plate to act as a counterweight against carriage bounce, which may cause wipers to catch during release.
(viii) The mechanically operated springsets have been replaced by 600 type relay springset assemblies and the operating levers redesigned to replace the present rollers.
(ix) The interrupter assemblies have been redesigned.

Investigations are proceeding by all companies and the B.P.O. on further improvements to this switch.

G.E. Company. Proposed New Design of 2000 Type Switch: The proposed switch can be used on existing racks in line with the present standard switch and the same shelves and banks, as the release action is self-contained. The design is under consideration by the B.P.O. The switch has a return release in lieu of the square release action of the standard 2000 switch. This release action has advantages for D.S.R. use. The pillars are diecast and more robust than the present steel stampings. The rotary drive is located at the top of the shaft close to the upper bearing and coupled by means of a spline. Most of the adjustments can be made from the front of the switch. A number of parts is still the subject of further attention from the design aspect.

Uniselectors: A new development in connection with uniselectors has been made by the A.T.E., Liverpool. The spark suppressor unit, consisting of the small condenser and resistance, has been replaced by a small atmite (silicon carbide) disc mounted on top of the magnet spring interrupter springs.

The heavy and light duty uniselectors of B.G.E. manufacture are under test by the B.P.O.; both types have been fitted with adjustable wipers. The adaptation is simple and provides for very easy adjustment of the wipers to the bank when required.

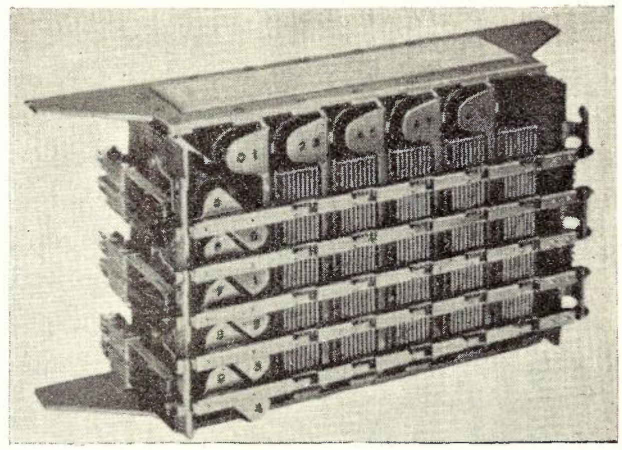


Fig. 6.—Crossbar Switch manufactured by Board of Telegraphs, Sweden.

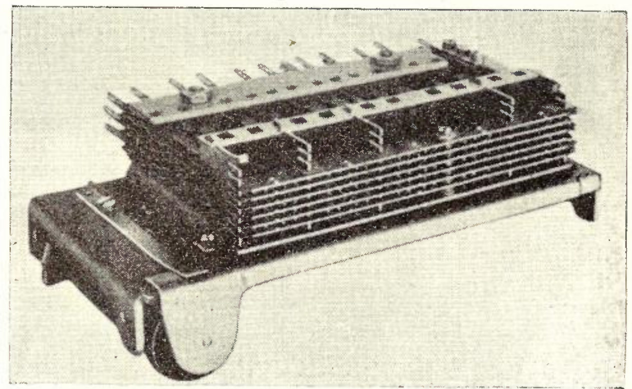


Fig. 7.—Bridge from Crossbar Switch.

Rural Automatic Exchanges: The R.A.X. problem is met by the B.P.O. by the installation of U.A.X. equipment similar to the 50 line unit manufactured by the A.T. & E., England. These units are extended in 50-line steps until a total of 200 lines is reached. The first unit is equipped with the necessary common apparatus to permit extension to 200 lines. In Sweden, the subscribers in rural districts are more isolated and remote than they are in England, the conditions being more like Australian rural districts, but with more extreme weather conditions. The crossbar and relay installations inspected in Sweden are giving a very good and reliable service under these adverse weather conditions.

A 40 line crossbar R.A.X. installed in a wooden hut at the side of the road amongst very heavy timber was inspected at Kruser Berg (see Fig. 8). The hut had double walls, no windows and two doors, with a space between them forming a small lobby. The electricity supply meters and switches were installed in this lobby, to which the Electric Light Co.'s representative had access. These huts cost approximately £150 sterling each; the whole

R.A.X., £2000. The log book showed that the technician had visited the exchange six times in four years to top up the battery. No other faults had been in evidence. The R.A.X. operated on one battery on the float system.

The next R.A.X. visited was an 800 line installation, all of crossbar switches. The charging in this case was on "charge float" at the cheaper "off load" rate. The log book showed very few visits for faults at this exchange. The calls from these R.A.X.'s are metered, and also included in the Time Zone Metering Scheme, the meters responding to repeated impulses when required. The third R.A.X. was a 10 line installation installed in a farm house in the loft. It operated from the parent exchange with a battery supplied over the exchange lines, all ringing, tones and speaking battery being supplied in the same manner. The total cost of these 10 number R.A.X.'s is approximately £130.

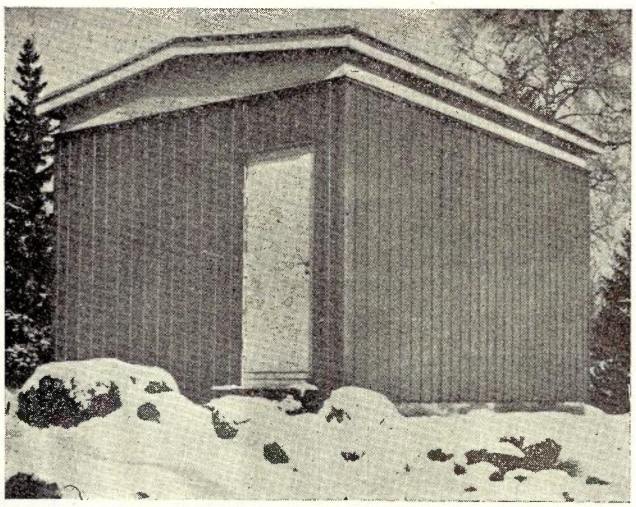


Fig. 8.—R.A.X. at Kruser Berg, Sweden.

Trunk and Manual Switchboards

The switchboards for trunk line operation in England are similar to the sleeve control type of switchboard in use in Australia. The B.P.O. circuits differ slightly from the Australian, but remain the same in principle. Switchboard sections were recently developed by A.T.E. Co., Liverpool, at the request of the B.P.O. for a lighter framework construction and other modifications.

In Sweden, an interesting development is the practice of tilting the front of the switchboards towards the operator to prevent interference by reflections from the room lighting. The face of the switchboard is constructed about 10° to 15° from the vertical.

Automatic Ticketing: This is not favoured by the B.P.O., mainly on account of the cost of equipping each automatic subscriber's line in the network, with the necessary apparatus for identification in addition to the special equipment for the printing of tickets, etc. It would also be necessary, to be fully effective, that a demand service should be given on all trunks; switch hook supervision on all services would also be essential. The B.P.O. is planning to control all trunk traffic with one operator, with an improved method of handling the dockets. This is being tried out at Canterbury, Kent. A "Powers-Samas" system with punched tickets has been installed. This system has been described in two articles in the P.O.E.E. Journal issued in January and April, 1949, under the heading, "Mechanical Trunk Fee Accounting."

The basic principle of the system is as follows:

Timed telephone traffic details are recorded on a ticket which, subsequently, is used as a punched card. The controlling telephonist inserts the called and calling subscribers' numbers, date, time and duration of the call, together with any special information such as "personal," "fixed time call," etc. Tickets from each exchange are sent at daily intervals to the Telephone Manager's office. Here they are passed to operators, who, equipped with Powers-Samas Automatic Key Punches, read off the essential data, and by means of key operations translate this into holes punched into the cards in specific positions in accordance with a code. Each card is passed via two punching machines. The second operator adds data purposely ignored at the first operation, and also checks the punching of the original data punched into the card at the first operation.

The punched cards are then passed, via an automatic verifier machine, which checks that the two punching operations have produced identical holes in the card. Thereafter, the cards are passed to a machine which extracts from each the data on which the call charge is based, and transmits this information to an electrical calculator. This equipment, built from Siemens motor uniselectors, P.O. uniselectors and 3000 type relays, accepts the information, computes the charge, and passes the information as to charge back to the machine, where it is punched into the card. Each calculated amount is also marked in an accumulator, this circuit giving a running total of revenue which can be read on a display panel. The calculator prices accumulated charges for cards at the rate of 100 per minute. At the end of specified periods of the accounting cycle, cards are passed to a Powers-Samas tabulator. Each group of cards refers to trunk calls made by a particular subscriber, and the cards are in date sequence and preceded by a "guide" card which carries punched information in respect of calling subscriber's exchange and number. The tabulator extracts information from each card and prints the details on a trunk statement, and accumulates the total for the cards which is printed at the bottom of the card. For short haul trunk traffic, they favour timed multiple metering. A system of ticketing that could be controlled from the position by the telephonist may be a satisfactory method of handling the docket system.

Automatic Ticketing, Belgium: The Telephone Administration at Belgium is changing over completely to ticketing, and dispensing with the timed multi-metering scheme in use on short haul calls. They consider the cost of ticketing is so expensive that full use should be made of the apparatus.

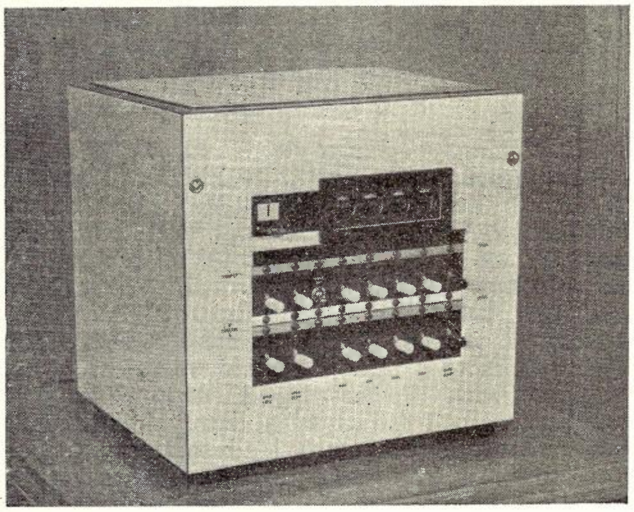


Fig. 9.—Key Type P.B.X. manufactured by Ericsson Co., England—Front view.

The ticketing with the Bell system starts to function as soon as "O" is dialled; consequently, a lot of tickets have to be discarded due to ineffective calls. These are sorted out before they reach the Traffic Branch, via the docket chutes.

The system used in the same network on exchanges installed by the A.T.E.A. Company differs in operation insofar as the docket is not printed until the call is completed. The ineffective call information is printed on a roll by another printer in parallel with the main printer. The printer on this system consists of a standard typewriter with a solenoid super structure.

Line Identification in connection with trunk line working for identifying the subscriber making the demand for a trunk call is not favoured by the B.P.O. The reason given is the same as in the case of automatic ticketing, i.e., that the cost of equipping all existing lines with the necessary apparatus would be high, and would not be justified on account of the small loss that occurs due to incorrect information by subscribers.

In connection with the apparatus for giving this service, the A.T.E., Liverpool, has developed an electronic device using a cathode ray tube and screen. The number is written by the travelling spot, and the whole number is retained on the screen for a period long enough for the telephonist to note the number. The screen is on the face of the switchboard. The S.T.C. Company has a system also, operating with small, cold cathode tubes.

Subscribers' Line Identification is also used on the trunk positions at Ghent, Belgium, the figures being displayed in revolving drums similar to the subscribers' meters. Ghent Exchange has Bell Company's machine rotary system installed. The manual trunk line positions are equipped with a timing clock for cord circuits. The outward junctions operate with free line lamps which only glow when the telephonist presses a non-locking key on her position.

Size of Manual Local and Trunk Exchanges: It is proposed by the B.P.O. to restrict future trunk exchanges to a maximum of 150 positions. The economics indicate in favour of large exchanges, but the psychological factors arising from the congregation of large staffs in one building oppose the use of large exchanges. This has been published in the I.P.O.E.E. paper of 4th October, 1948, under Staff Management, by W. S. Proctor.

Miscellaneous Telephone Equipment

Electronic Ringing and Tone Machines: Two static machines using valves to generate the different frequencies have been developed by the A.T.E. Company and mounted on standard panels. The outputs are 2.5 and 5 watts, giving all impulses such as S and Z impulses, metering impulses 1 to 6, NU tone, Busy Line, Ringing Tone, and Dial Tone, as well as ringing current of 75V. The valves operate on 50 volts at 100 mas. These would meet the requirements of R.A.X.'s and P.A.B.X. installations.

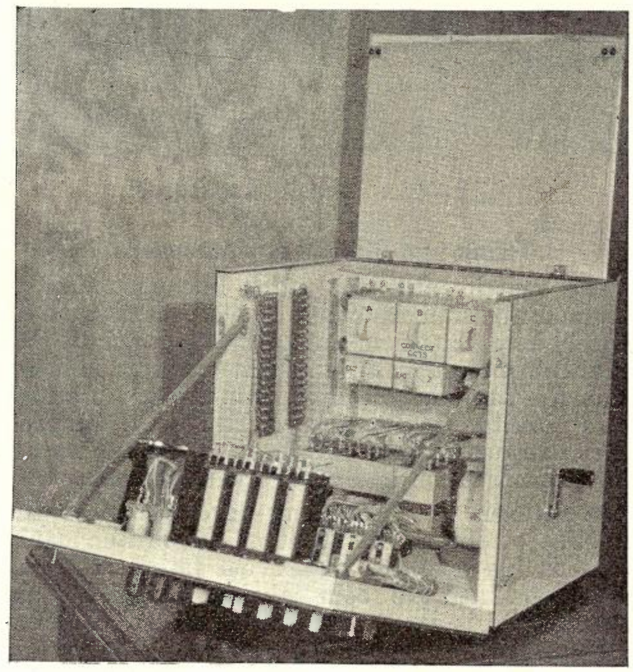


Fig. 10.—Key Type P.B.X. manufactured by Ericsson Co., England—Rear view.

Silicon Carbide Discs: These are used very extensively in Sweden as suppressors in lieu of non-inductive resistances and condensers. The type used in Sweden is approximately ⅜" diameter, with pigtails for connecting. They are also used by the A.T.E., Liverpool, as spark suppressors on uniselector magnets.

Substation Apparatus: The "trigger" dial developed by the G.E. Co., England, is undergoing life and field tests by the B.P.O. Satisfactory results have been achieved to date in these tests.

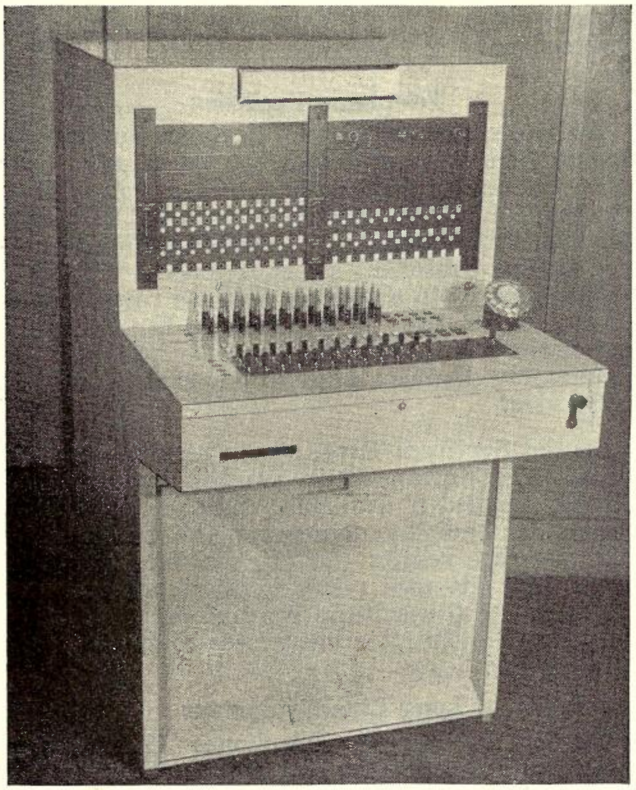


Fig. 11.—Cord Type P.B.X. manufactured by Ericsson Co., England—Front view.

The 332 Type Telephone has a few minor improvements made to it. Rollers are fitted to the platform operating the switch springs to prevent the plungers binding where they make contact. The insulating studs operating the springs are turned at right angles to the plate.

Cordless Switchboards: Ericssons Ltd., England, manufacture a cordless switchboard of plastic faced laminated wood, with the apparatus sliding out instead of being mounted on a hinged front. The wiring is of plastic covered P.V.C. wire, with an outer cover of "Cotopa" or "Fortisan" coated with cellulose acetate lacquer. (The lacquer contains a fungicide.) (See Figs. 9 and 10.)

Relay Spool: A plastic moulded relay spool for 3000 type relays has been developed by Ericssons. This does away with the wrapping of insulating paper when commencing winding.

P.B.X. Switchboard, Cord Type: The Australian type P.B.X. is being manufactured in England. A development of interest is the use of bakelite plyboard instead of a steel fabricated frame with movable panels (see Figs. 11 and 12). Any timber could be photographed and the grain and colour reproduced. It is pleasing in appearance and gives improved insulating qualities. A new cord terminal has also been developed dispensing with the usual screw terminals which hold the tag ends of the cords. This terminal block enables cords to be changed without the use of a screwdriver. A shortening clip is also used to take up the slack in the cords.

Hand Generators: A new generator of the Australian 4C type has been developed by the T.M.C. Company, England. It has a rotating Alnico magnet and single coil. It has neither brushes nor collector rings. The output is 3 watts and the generator is approximately of the same dimensions as the Alnico 4C generator. It should be satisfactory in service in P.B.X. and extension switches.

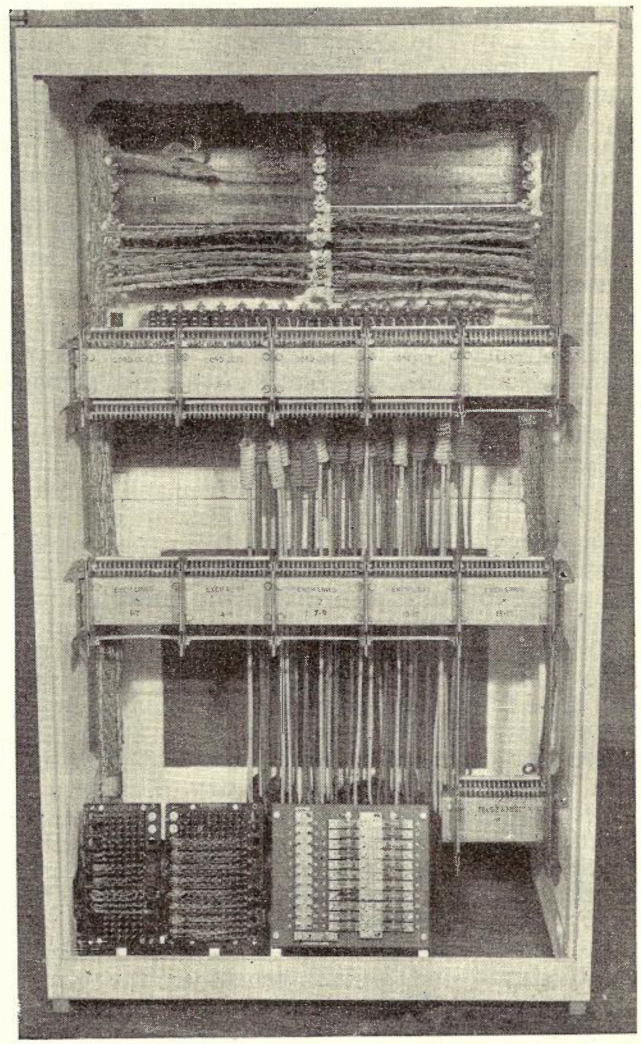


Fig. 12.—Cord Type P.B.X. manufactured by Ericsson Co., England—Rear view.

Wiring of Substation Apparatus: Investigations in Australia led to the purchase of P.V.C. covered wire for the cabling of subscribers' premises. This supersedes the lead covered cable formerly used for the purpose and it was noted that P.V.C. covered cable is also being used by the B.P.O. and other Administrations.

Installation of Subscribers' Equipment: In Switzerland, all substation equipment is installed by private contractors who are licensed to do this class of work.

Party Lines: The shared service in use in England differs from the Australian practice, in that service is not secret, although emergency service is guaranteed at all times. Our system is favoured by the B.P.O. and steps may be taken to vary the agreement with the subscriber to give a service similar to the Australian system. In the case of country party lines, every effort is made on conversion to automatic to induce multi-party subscribers to take 2-party line services. This lines up with the practice in Australia.

P.A.B.X.'s: The system developed by the Automatic Telephone and Electric Antwerp Company, comprises the following sizes—4, 5, 9, 10, 15, 21, 39, 50/5 and 50/10. The first three are all relay types; the others use uniselectors up to and including the 39 line type; over 39, bimotional switches are used. An attendant's cabinet is only used when there are over three exchange lines, as calls can be answered by any phone and transferred as required.

Ipsophone: This device for recording telephone conversations is manufactured by the Ipsophone Exploitations Co. Ltd., Zurich, where a demonstration of the equipment was witnessed. The coupling between the Ipsophone apparatus and the exchange line is via a transformer. The termination is made in the transformer and matches our line termination. No impulses or excessive voltage surges are sent to line from their equipment. The level of the transmission from the equipment to line is also within the limits we prescribe. The apparatus would cost approximately £600 sterling per unit. I interviewed one of the large department stores (Zelmoli Ltd.) in Zurich, who have four of these devices installed, giving a 24-hour service. They receive from 80 to 100 orders per day, which are transcribed from the wire records three times per day. The firm is pleased with the facility which is giving every satisfaction. The Telephone Department shows in the directory the pickup symbol "φ" after the firm's number, which has an explanatory note in the front pages explaining the facility.

The Ipsophone factory at Zurich, Switzerland, manufactures and installs machines for giving weather reports. The apparatus is similar to that used for the Ipsophone service and mounts on standard carrier panels. The information is recorded on wire and can be picked up by dialling the necessary number. It is used by sporting clubs and supplies information re the weather prospects at different times of the day.

Directory Holders: A very neat and novel telephone book holder and shelf is used in all public cabinets in Geneva. The books are held in a bakelite holder and rotate from a hanging position below the shelf to a position on top of the shelf to permit any of the three books being opened and laid flat on the shelf. These holders are manufactured by the "Terag" Telephone Reklance A.G., Switzerland.

Telephone Facilities

Radio Programme over Telephone Service: In Switzerland, 5 programmes can be selected over the telephone line, when the necessary connections are made for this service. A fee of 2.20 francs per month is charged for the facility. The connection at the subscriber's end is made to either a wireless set or to a speaker only, as required. An extension line relay is provided on the exchange end of the line to give the necessary access to the programme channels. This facility is also provided in Sweden.

Special Services: Race, sports results, etc., are obtained by dialling 11 in Sweden. The information is supplied if available, and the appropriate charge is made by depressing the reverse key once for race results (i.e., 10 centimes each). If more than one race result is given, an extra 10 centimes per 5 results is charged. Any information that the operator has access to is given but charged for.

Long Line Equipment

Carrier Equipment Telephone: Considerable attention has been given by all companies to the better grouping of the components of each panel so that more channels can be provided per bay. The apparatus is mounted in a drawer type of panel, and slides in on runners instead of being bolted to the face of the uprights as with present installations. This method of assembly, as well as folded steel sections for racks, has been adopted by all of the companies, i.e., S.T.C., A.T.E., G.E.C., and Phillips.

Phillips, Holland, have fully miniaturised the components. This has been attained by the use of the new magnetic material Ferrox-cube, which is used for cores in the filters, the volume of the coils being reduced by a factor of 5 by the use of this material. The system demonstrated was the latest 48 channel system using frequencies from 10 to 200 kc/s over cable pairs using go and return cables. The repeater spacing with this 48-channel system is 16 miles. The carrier spacing is 4 kc/s. Modulation is in 3 stages. In the first stage, the channels are modulated with a terminal carrier of 60 kc/s. In the second stage of modulation, groups of 12 basic channels are assembled by channel carriers of 192-196 to 236 kc/s to form a basic group in the frequency band 252 to 300 kc/s, which requires only simple filtering. By a third stage of modulation with four basic carriers 240, 360, 408 and 456 k/cs the four basic groups are brought into place in the super-group 12-204 kc/s. With the drawer type of panel the racks and panels are wired independently, and after being assembled connection is made between the two by means of 8 standard twin plugs which bridge the connections through. These jacks can also be used for patching and testing. In the Phillips 48-channel equipment, the components are made of uniform height and varied in width to give uniform height for interconnection by bare busbar wiring.

The G. E. Company has also developed a 48-channel system. The S.T.C., at their factory at Southgate, demonstrated a telephone carrier system, using a separate channel (Telegraph) equipped with cold cathode tubes to control all the supervisory signals in the group of 60 channels associated with it, a channel identification signal being sent backwards and forwards to connect the signals to the channels as required. The only signals sent over the speech channels themselves are the dialling impulses. The supervisory signals are transmitted in this system by a 4-figure code. The size of the relay sets per channel is reduced in this system to about 12 relays per channel. Provision is made for 2 electronic controls per system of 60 operating in groups of 30, but in one group of 60 should one channel control fail.

Coaxial Cable Systems: The average costs of providing trunk circuits over a period of 20 years by means of 20 lb. audio, 12 and 24 circuit, and coaxial cable systems has been assessed by the B.P.O. for various rates of growth and lengths of circuits. It was concluded that in the average practical case the coaxial system is cheaper than the 12 or 24 circuit carrier system, and that it is cheaper than 20 lb. audio cable systems for the provision over a period of 20 years of about 600 circuits on routes over 30 miles long, or about 200 circuits on routes over 50 miles long. The conclusions were based on the prices then current and the cost of maintenance. There is reason to expect that the cost of coaxial systems, compared with audio cable systems, will be substantially reduced in the future, and that it will become economical to use coaxial systems for smaller and shorter routes.

Radio Links: The provision of these links is governed by annual costs, as in the case of cables. The links are used at present in cases when the country is too rugged for cabling, or where a submarine cable would be required. The B.P.O. is installing both cable and aerial link between Birmingham and London with a view to studying the annual costs of both schemes.

Submarine Cable Repeaters are being manufactured at S.T.C. factory at Woolwich. The apparatus is housed in a metal case, 10 feet by 2 feet by 2 feet. This includes valves, transformers, etc. Power for operating the filaments and plates is supplied from each end of the cable. 6 volt 0.5 amp. valves are used with a plate current of approximately 5 to 6 mas. 600 to 1000 volts D.C. are supplied over a separate lead in the cable. Two types are contemplated, (a) deep, and (b) shallow water types.

Telegraph Equipment

Teleprinter Switching Scheme: A national automatic switching system is being installed by the B.P.O. for an Inland Public Telegraph service. The object of the scheme is to enable any teleprinter office to obtain connection with any other telegraph circuit by switching together the various intermediate telegraph links between the offices concerned. The layout of the switching network is based on 26 switching centres. These are divided into **Zone Switching Centres**, i.e., Birmingham, Bristol, Glasgow, Leeds, London North and London West. These centres will have direct teleprinter trunks to all other Zone Switching Centres, to all Area Switching Centres, Class 1, and to Area Switching Centres, Class 2, where justified by traffic.

Station line circuits connecting teleprinter offices to these centres may be either wholly physical lines having not more than 10% distortion, or V.F. channels.

Area Switching Centres, Class 1, will be Bangor, Belfast, Edinburgh, Exeter, Greensby, Hull, Liverpool, London Centre, Manchester, Newcastle, Nottingham, Southampton.

These centres will be directly connected by teleprinter trunks to all Zone Switching Centres and to such other switching centres as may be justified by the traffic.

Area Switching Centres, Class 2: Aberdeen, Bournemouth, Brighton, Cardiff, Dundee, Leicester, Sheffield, Swansea; each of these centres will be directly connected by trunks to at least one Zone Switching Centre and to other switching cables, where justified.

The trunk circuits interconnecting the switching centres will normally be V.F. channels.

Numbering Scheme: A direct dialling system with area numbering will be used; therefore, the number to be dialled to reach an office will depend on the area in which the originating office is situated. A common directory will be issued for the country as a whole, using a mixed figure and letter code, i.e., BM521, where the letters are the telegraph code of the parent switching centre, and the numerals represent the number allotted to the office concerned at this centre.

This scheme is to be carried out in 4 stages and the estimate is to complete the whole installation by autumn, 1952.

Dialling: A dialling unit is provided at each teleprinter. This unit is equipped with dial, three supervisory lamps and six keys. The impulses from the dial are relayed to the line as double current signals.

Switching Equipment: Step by step, using standard 2000 type equipment. This has been adopted to facilitate the provision of switching equipment, give economy on equipment costs, and amplify staff training and maintenance arrangements.

Racks and Frames: The general rack equipment will conform to standard telephone equipment practice, with slight modification for working with 80 volts for signalling purposes.

Signal Generators: Service signals will be produced by three motor-driven signal generators. These are returned to the caller if the call encounters that condition on the trunk.

"NC"—signifying "No circuits" should there be no outlets from the selectors, or trunks are engaged.

"OCC"—signifying "occupied" should all lines to the required office be engaged.

"DER.T"—denoting "Trunk line faulty."

"DER.S"—denoting "Station line faulty."

"MOM"—wait signal.

"WRU"—who are you?

Testing equipment and routine testers will also be provided as well as observation facilities.

Type of Teleprinter in use: Teleprinter No. 11B, which will replace the existing printer No. 3, as the changeover proceeds, is a new design of tape-printing teleprinter which conforms to the CCIT recommendations as regards speed (50 bauds) and code (international Alphabetic No. 2) and incorporates a 20 character answer-back unit. The notable features of the new design are:—

(a) Ribbon inking.
(b) External paper mounting, paper feed and printing mechanism.
(c) Paper failure alarm contacts integral with the machine.
(d) Receiving cam orientation device.
(e) Improved type head clutch.
(f) Positive operations of the keyboard combination bars by the key lever using "saw tooth" principle.
(g) "Run out" key for obtaining repetitions of any desired character.
(h) "Here is" key for tripping the "answer-back" unit locally.
(i) Improved type face.
(k) Reduced noise level.

Electronic Impulse regenerator for Teleprinters, and an electronic distributor with a magnetic operated head replacing the motor-driven type with brushes, are being developed at the A.T.E. Company's Research Laboratories at Taplow.

Facsimile System: Phillips' Laboratory, Holland, has developed a high-speed facsimile system transmitting a 10 x 8 inch page picture in 8 to 10 seconds in lieu of the previous development of 8 minutes.

Impulsograph: Hasler Company, at Berne, Switzerland. This instrument was developed and manufactured by the company for timing relays, measuring impulses, etc., instead of using oscillographs and other recording apparatus. The recordings in the case of this device are made on a paper strip $\frac{3}{8}$ inch wide covered with a thin layer of wax. The movement of the recording pin scratches this layer. An electro-motor moves the strip at consistent speed. It operates with and without amplifiers.

Tape Recorder: The E.M.I. Company has developed at His Master's Voice Studios a ferrous oxide-coated plastic Tape Recorder and Player. It gives a very pleasing and fine performance, the tape running for 20 minutes. Any position of the tape can be played independently by running the tape backwards or forwards as required. There was no background noise of any description at the demonstration. Another development is a slower moving disc type with special pick-up. This gives a longer playing time on each disc.

Stereophonic Recording: Phillips, Holland. A demonstration of stereophonic recording was given at Phillips' Laboratories, using two independent channels for recording and playing back. The recording was carried out by using independent crystal microphones mounted on a pedestal with a top shaped like a head, with the microphones taking the place of ears. The recording was done on separate tracks on the tape and played back through different channels to speakers placed on opposite sides of the auditorium. The effect produced gave a good impression of the placing of the different instruments in the orchestra.

B.P.O. Research and Circuit Laboratories

The Circuit Laboratories are situated adjacent to the staff headquarters, so that easy contact may be made with the staff in connection with tests being carried out on equipment, etc. The work carried out by the circuit laboratory relates not only to automatic telephone exchange equipment, but also to other apparatus which is either similar to, or is required to work in conjunction with, telephone switching equipment, such as, for example, subscribers' apparatus, trunk signalling, telegraph switching and miscellaneous circuits using telephonic type relays.

The nature of the work falls under the following headings:—

(1) Testing of circuits developed by the Post Office.
(2) Assembly of models of circuits for such tests.

(3) Testing of circuit models submitted by contractors.
(4) Brief testing of circuit elements as required for circuit design.
(5) Demonstrations of facilities, layout, accessibility, etc.
(6) Test and criticism of new developments from the "Practical" point of view.
(7) Measurement of time lags and similar operating characteristics.
(8) Tests of proposed maintenance adjustments of various apparatus.
(9) Investigations of special maintenance trouble in telephone exchanges.
(10) Assembly, tests or overhaul of special routine testers, acceptance testers, and other exchange testing equipment of a unique or novel character.
(11) Assembly or modification of experimental apparatus for field trial or other experiments outside the Circuit.

The tests are, therefore, mainly concerned with functions and performance, and they naturally include simple measurements of current, impedance, timing, etc., and also include the checking of physical dimensions when this affects performance or adjustment. Great stress is laid on the tests being of a practical nature in all cases, and this is reflected in the use of skilled workmen for the actual tests, and in the conditions under which tests are made. It also accounts for the absence of equipment for making chemical, metallurgical, acoustic, or other tests which are more proper to Research Laboratories and staff.

Equipment: An essential and much used item of equipment is electro-magnetic oscillograph (3 elements) manufactured by the Cambridge Instrument Company, equipped with both drum and continuous film cameras. The instrument has been adapted in several respects to meet the special requirements of the laboratory, and has an electrically controlled tuning fork, which gives a transverse line across the oscillogram every 10 m/s. There is also a cathode ray oscillograph (S.T.C.), the auxiliary equipment for which is made up in small portable units, making it particularly suitable for field work. Direct visual observation is assisted by a "Time Base" unit, which automatically holds stationary the wave forms of impulses at frequencies as low as 10 i.p.s., and a cathode ray tube having an "after glow" of several seconds is employed for direct observation of transient operations. For permanent records, a separate continuous film camera can be coupled up with the oscillograph in a few seconds, and with this camera has recently been adapted by the Circuit Laboratory for automatic exposure a series of oscillograms such as for the investigation of irregularities in time pulses, etc. A dark room equipped with the usual facilities is, of course, a necessity, and this is in one corner of the laboratory in order to be easily accessible. In addition to the oscillographs, there is a selection of testing instruments available for the common use of the Testing Staff, and this includes high grade measuring instruments, bridge networks, and a range of timing instruments such as millisecond meters, impulse ratio testers, and impulse frequency measuring devices. Three pulse machines, generating impulses of any frequency or ratio, and in trains of any number of digits, are mounted on trolleys. These are separate from the standard 10 i.p.s. impulses which are part of the common services fed to all racks.

Television

A general interest was taken in television and as many programmes as possible were viewed. A visit was made to the Marconi Works, at Chelmsford, where cameras for indoor and outdoor shots were seen in operation, and the manufacture and operation of the transmitting apparatus was inspected. Receiver manufacture was also shown. No tubes were being manufactured at these works.

A demonstration of screen projection by Cinema Television was attended. This was 405 lines and projected on to a screen approximately 10 feet x 12 feet. The magnification brought out the effect of the lines too prominently, but demonstrated the possibility of this class of service.

E.M.I., England, gave a demonstration at His Master's Voice Gramophone Company's Studios, of the meeting of the Empire Parliamentary Delegates at No. 10 Downing Street. This meeting was televised in very dull, wet weather, but was reproduced in the three receivers very clearly.

An inspection of Alexander Palace, London, was made to see the procedure for putting plays over the television directly, as well as by film. The operation of the whole of the transmitting apparatus was also shown. This is also 405 line definition.

Phillips, Holland, and L.R.I., France, were also visited, and an inspection made of the development in those countries. The receiver manufactured by Phillips, using a Schmidt optical reflector and small 3 inch diam. tube with the picture reflected on to a 12 inch square ground glass screen, gave more pleasing performance with less glare than the 15 inch direct tube. The small 9 inch tube is too small to be comfortable for viewing a long programme. The small tube manufactured and mass produced by Phillips permits the receiver being assembled in smaller cabinets. The normal 15 inch tube requires a very deep cabinet to house the extra length of the tube.

At La Radio Industries, France, a demonstration was given against a standard picture, of line frequencies varying between 400 and 1000. There is a very marked difference between the reception with 405 lines and that of 625, but above that the difference is hard to detect.

In conclusion, the author wishes to place on record his sincere appreciation of the hospitality, courtesy and assistance extended to him by the staff of the B.P.O. and representatives of the various Companies and Administrations in the countries visited by him whilst carrying out his investigations.

MACHINERY IN MODERN UNDERGROUND LINE CONSTRUCTION

R. J. Mathew

Introduction: In keeping with the trend towards greater use of machinery in modern civil engineering, the use of mechanical aids, both specially constructed and adapted from standard items, has progressed so rapidly in line construction work in Australia that a description of several of the major items of this type of plant in use, together with some data regarding different makes, may be useful to telecommunication engineers. The greatest advance has been in the use of earth moving machinery, such as tractors (equipped as required for any specific job), trenching machines, and air compressors with associated pneumatic tools.

There is a range of tractors made by firms such as Caterpillar, Allis Chalmers, International Harvesters and Tractors, and Cleveland Tractor Co., covering machines from 20 h.p. to 163 h.p. drawbar pull, each of which can be fitted with scoops or dozing blades capable of various settings and either cable or hydraulic controlled. These tractors can be used for items such as felling and stacking trees for clearing purposes, moving and levelling ground, filling tipping trucks, and drawing other tools such as rooters, rippers, cable-laying ploughs, cable drum trailers, etc.

Trenching machines, capable of digging trenches in other than shale or rock, are of various makes, such as Barber Greene, Aveling Barford, Allen and Buckeye, and possess varying characteristics and applications.

Air compressors of such well-known brands as Ingersoll Rand, Broomwade, Consolidated Pneumatic, Le Roi, Sullivan, Holman, are used in the operation of various pneumatic tools for excavation and similar purposes.

Tractors

General: Until a few years ago, little use was made of tractors in the Engineering Branch of the Department, the first two units being supplied to New South Wales for the Sydney-Maitland trunk cable project in 1939. Since that time, expansion has been such that to-day in New South Wales there are 16 Departmentally owned tractors of various sizes and makes in service, and in the Commonwealth approximately 40.

Tractors used for clearing and earth moving are usually of the crawler type, or those fitted with steel tracks equipped with grouser fins to increase gripping power in difficult terrain. Practically all such tractors can be fitted with steel shoes or rubber pads for use on roads where traction is easy and grousers would damage road surfaces. Early tractors used petrol or kerosene as fuel, but most later designs are fitted with diesel engines usually equipped with a small petrol motor for starting.

All popular American tractors, with the exception of Cletrac, are designated by an alphabetical and numerical code. The letter "D" in all nomenclatures signifies diesel engine, and the numerical code is, in some cases, related to either the weight of the machine in tons or grading in horsepower.

Practically all tractors in use are fitted with either single or double drum power control units, logging winches, or combined single drum power control units and logging winches which are the most modern fitting and most suitable for this Department's use. These fittings are generally mounted at the rear of the tractor operator's seat and driven from the power take-off incorporated in the tractor, though, in isolated cases, power control units are front-end fitted for use with cable-controlled dozing blades.

Single drum power control units permit of cable control of only one item of equipment, such as a cable-controlled blade, a cable-controlled rooter, a logging arch, or a scoop, whereas, with a double drum power control unit, two items of equipment can be controlled simultaneously. Power control units are of light construction and not designed to carry heavy loads, but merely to lift a blade or rooter quickly through a series of pulley-blocks. The winding speed of a medium-size power control unit—one fitted to a Caterpillar D6 tractor—is 440 feet per minute and the maximum load is 5000 lbs. with a bare drum and 3100 lbs. with a full drum. Power control units must never be used to assist in hauling a tractor from a bog or they will be seriously damaged.

Logging winches for various tractors are designed to wind a steel rope which has a safe working stress greater than the weight of the tractor to which such equipment is fitted and, as the name implies, they were originally fitted to enable a tractor to stand in a convenient position and haul a fallen log from an inaccessible position to one in which normal motor transport could handle the log. Logging winches are similarly used to pull down trees either singly or in groups, or to make a large clearing with the use of two parallel tractors fitted with logging winches, the ropes from which are connected round a belt of timber to be cleared.

The combined logging winch and single drum power control unit can be used either for clearing, winching a tractor out of difficult terrain where the tractor's own power is insufficient, and for operating a cable-controlled dozing blade, cable-controlled rooter, or similar equipment.

When a tractor is equipped with a hydraulic controlled blade and a combined logging winch and power control unit it can perform practically any function required of these machines, though in special cases equipment such as quadruple drum power control units are necessary to operate up to four control cables from the tractor.

Tractors have up to 8 forward and 8 reverse speeds and are so geared that, while their ground movement in lowest gear is very slow, speeds can be varied in accordance with the load to be moved. Forward speeds range from approximately 1.5 to 7.9 m.p.h., while reverse speed is of the order of 1.5 to 7.3 m.p.h.

There are main and track drives on all tractors through heavy duty disc clutches, the main drive

Make	Type	Draw-bar H.P.	Max. Drawbar Pull (Lb.)		Speeds (M.P.H.)				Engine		Type or Gauge	Overall Dimensions			
					Forward		Reverse								
			Ob-served	Calcu-lated	Min.	Max.	Min.	Max.	Cyl.	RPM.		Length	Height	Width	Weight—Bare (Lb)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Caterpillar	D2	25·8	5903	6480	1·7	5·1	2·1	2·1	4	1525	in. 50 40	ft. in. 8 11	ft. in. 4 $9\frac{3}{4}$	ft. in. 5 $5\frac{3}{4}$ 4 $7\frac{3}{4}$	6730 6880
	D4	35·68	7852	8637	1·7	5·4	1·9	1·9	4	1400	60 44	10 $1\frac{1}{2}$	5 $0\frac{5}{8}$	6 6 5 2	10050 9810
	D6 (Old)	44·75	9692	10753	1·7	4·6	1·9	1·9	3	850	Wide Stand.	10 $8\frac{3}{8}$	6 $2\frac{1}{4}$	7 9 6 3	16180 15530
	D6 (New)	65	15500	16350	1·4	5·8	1·8	5·4	6	1400	74 60	12 $5\frac{1}{4}$	6 $0\frac{1}{2}$	7 $10\frac{1}{4}$ 6 $8\frac{1}{4}$	17330 16695
	D6 (Impvd.)	55	14300	15850	1·4	5·8	1·8	5·4	6	1400	74 60	12 $5\frac{1}{4}$	6 $0\frac{1}{2}$	7 $10\frac{1}{4}$ 6 $8\frac{1}{4}$	17160 16630
	D7	80·44	21351	22750	1·4	6·0	1·6	5·4	4	1000		13 $6\frac{1}{4}$	6 8	8 2	23910
	D8	130	26208	28800	1·6	4·9	1·6	2·6	6	950		15 3	7 6	8 $7\frac{3}{4}$	34175
Allis Chalmers	HD7	60·10	12171		1·84	5·82	2·19	2·19	3	1500	63 52	10 8	5 $9\frac{1}{8}$	6 9 5 10	13600 13260
	HD10	86·63	19002		1·69	6·03	1·86	4·17	4	1600	74 62	12 6	6 $5\frac{3}{4}$	7 $10\frac{1}{4}$ 6 $10\frac{1}{4}$	21050 20380
	HD14	132	28000		1·72	7	2	3·20	6	1500		13 9	6 8	7 8	29000
	HD19	163	36000			7		5·5	6	1750		15 $10\frac{3}{4}$	7 4	9 $1\frac{1}{4}$	40000
International	TD6	30	7160		1·5	5·4	1·7	1·7	4	1450	narrow wide	8 8	6 $0\frac{1}{4}$	4 5 5 3	6800 7000
	TD9	38	9000		1·5	5·3	1·7	1·7	4	1400	narrow wide	9 6	6 $5\frac{7}{8}$	4 $10\frac{7}{8}$ 6 $2\frac{7}{8}$	9500 9850
	TD14	53·5	13500		1·5	5·8	1·5	3·4	4	1300	narrow wide	11 2	6 $11\frac{1}{4}$	6 2 7 8	15000 15500
	TD18	74·25	18973		1·5	5·7	1·5	3·3	6	1200	narrow wide	13 $2\frac{1}{4}$	7 $5\frac{7}{8}$	6 10 7 10	21500 22000
	TD24	140	24000		1·6	7·9	1·5	7·3	6	1300		15 $2\frac{1}{4}$	7 4	8 6	36275
Oliver Cletrac	AD	30·5	6020		1·78	3·74	1·36	1.36	4	1530		9 $1\frac{1}{2}$	4 6	4 $9\frac{1}{4}$	7600
	BD	38·05	8012		1·8	5·41	1·8	3·14	6	1400		9 9	4 $9\frac{9}{16}$	5 $0\frac{1}{8}$	9400
	DD	61·19	11816		1·70	4·88	2·02	3·64	6	1200		10 5	5 5	5 $7\frac{3}{4}$	13700
	F-DE	120·5	28600		1·61	5	1·58	2·82	6	1300		15 0	7 4	8 4	29760
	HG	18·00	3060		2·02	5·25	2·35	2·35	4	1700	HG. 42 HG. 68	7 7	4 2	4 $4\frac{1}{4}$ 6 $6\frac{1}{4}$	3270

Table No. 1.—Principal characteristics of tractors.

clutch engaging the engine while the track drive clutches and brakes permit either track to be rotated or stopped for steering purposes. On some tractors a reverse action is incorporated in individual tracks to permit of quick turning, thus to turn to the right in forward motion the right hand track can either be stopped or reversed, while the left hand track moves the tractor forward.

Tractor diesel engines are now generally of 3 to 6 cylinders, according to horsepower required.

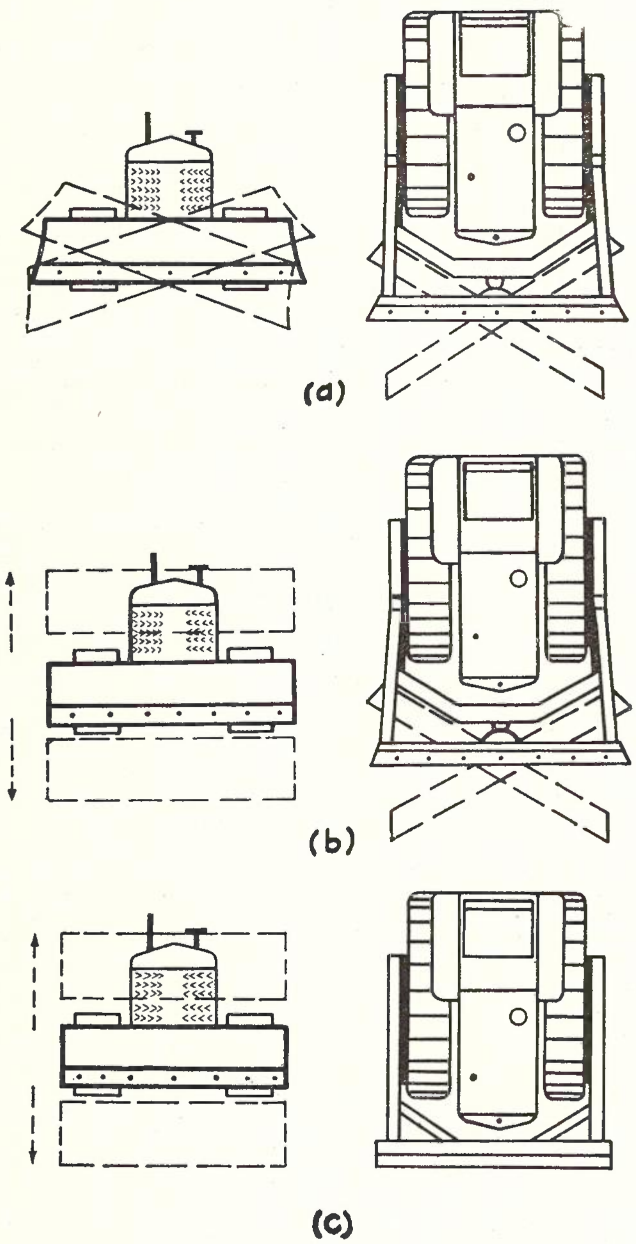


Fig. 1.—Types of Dozer.

	Vertical Lift	Horizontal Angling	Vertical Tilt
(a) Trail Builder	Yes	Yes	Yes
(b) Angle-Dozer	Yes	Yes	No
(c) Bulldozer	Yes	No	No

Table No. 1 gives a resume of the main details of popular makes of tractors in Departmental use.

Tractor Equipment: Bull-dozers. One of the most useful fittings used on tractors is the dozing blade, which may either be cable-controlled through a supporting harness from a power control unit, or hydraulically controlled by means of two rams, one on either side of the machine, the oil being fed to the rams through control valves from a pump generally front-end fitted as an extension to the crankshaft of the tractor.

Both systems are widely used, firms such as "Le Tourneau" favouring cable control, while well known hydraulic controls are "La Plante Choate," "Baker" and "Heil," the last-named also supplying a cable control. While hydraulic control of a blade has the advantage of holding the blade in any selected position, cable control is more positive and possibly more trouble free, although it has the disadvantage that the blade will rise in certain circumstances when this is undesirable.

Dozing blades are of the straight or bulldozer type, angle and combined angle and tilt type, or trail builder type, as shown in Fig. 1.

The original "bulldozing blade" was one fitted square across the front of a tractor and capable of only vertical motion. This blade is now almost universally superseded by the trail builder type, which is fitted in the same position but pivoted on a centre point, permitting either end of the blade to be raised or lowered as required and set in the desired position. It may also be easily angled in relation to the body of the tractor. With this type of blade one point can be set forward and down, enabling it to be used as a gouge in severing tree roots for clearing purposes. The chief use of dozing blades on Departmental work is for timber clearing as shown in Fig. 2, or for making and grading access roads and levelling tracks prior to use of a mole plough for cable laying.

Specific details of clearing estimates are not available, but it can be assumed that clearing of normal timber with a tractor will reduce labour to, at the most, 20% of that required by hand labour. The type of tractor normally used is the 60 h.p. (D6) for trees up to 12 in. diameter and 80 h.p. (D7) for most other heavier clearing, the largest tractors of 130 h.p. (D8) being required only for extremely heavy clearing.

Building of access roads and levelling for mole plough work does not generally entail extensive cut and fill work, and equipment such as 8 and 12 cubic yard scoops is not necessary, but a tractor of the 80 h.p. type, fitted with a dozing blade which is approximately 10′ 6″ long, does a satisfactory job. In a recent work, ¼ mile of such track 16 ft. wide, involving two fills of 18 ft. height, was built with a tractor and two men in two weeks.

In normal conduit construction a dozer is often used for the backfilling of trenches, two methods applicable being shown in Fig. 3. The use of an angle blade with the tractor traversing the trench

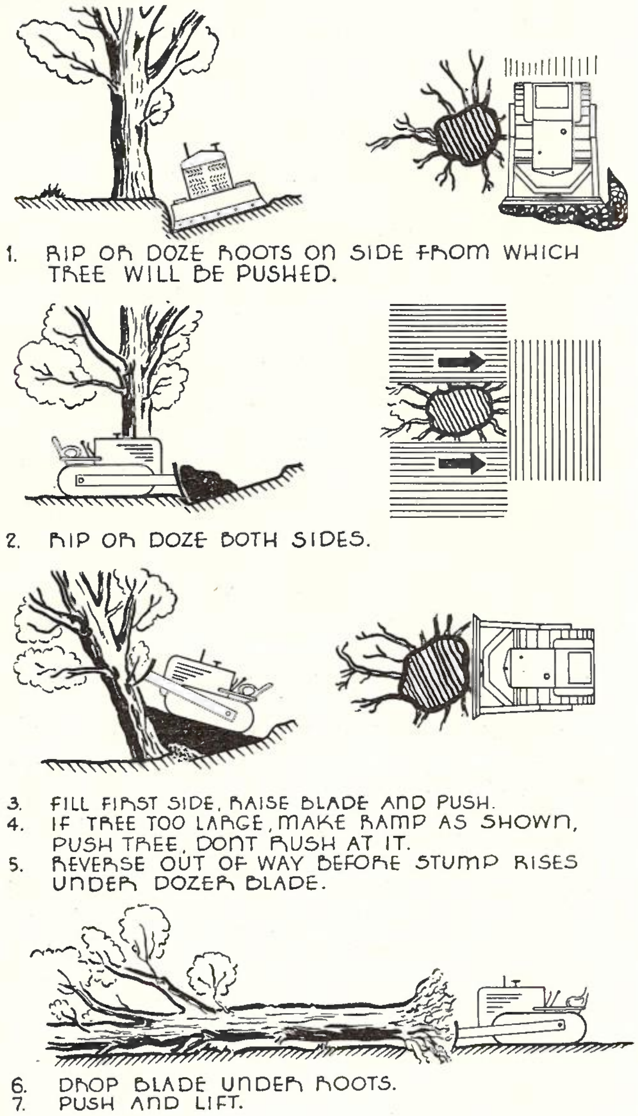


Fig. 2(a).—Use of dozer for clearing large areas.

Fig. 2(b).—Use of dozer for stacking trees or mill yard logs.

is only satisfactory in good running soil such as sand or fine loam, the side fill method being the one generally used.

For estimating purposes, the dirt moved by a dozer per hour can be calculated from the formula:—

Output = $C \times S \times E \times 60/T$ cubic yards.
Where C = Loose volume moved per trip in cubic yards
S = Co-efficient of slump. Typical values are:— Top-soil 0.87, earth 0.80, light clay 0.70, heavy clay 0.67, rock 0.50
E = Efficiency of operation. Use 70%, that is a "42 minute hour" for safety under average conditions.
T = Cycle time in minutes.

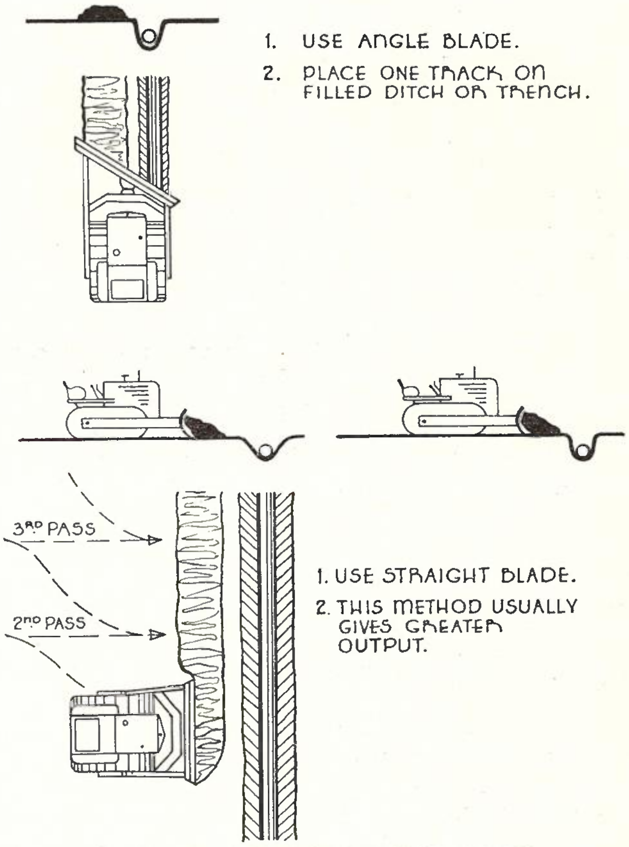


Fig. 3.—Use of dozer for back-filling trenches.

The co-efficient of slump for various types of soils is the fraction (solid soil/excavated soil) and in estimating, the solid soil content is the amount generally calculated. Assuming straight "Out and Back" or shuttle dozing, and a distance of 100 ft., the cycle time is calculated as follows:

	Minutes
Time out, low gear at 1.7 m.p.h. (149 feet per min.) = 100/149 =	.67
Add gear shift =	.15
Time back, high reverse gear at 3.64 m.p.h. (320 feet per min.) = 100/320 =	.31
Add gear shift =	.15
Total cycle time "T" =	1.28

For back filling, such as dozing back into a trench from one side, cycle time "T" is usually taken as 0.65 to 0.80 minutes in open country and up to 1 minute in suburban streets. Fig. 4 shows a bulldozer back-filling a trench in a suburban street.

The average blade full of loose earth for various types of tractors is:—

Horse power of Tractor	Length of Blade	Capacity of Blade—c. yds.
25-30	8′	2
35-40	8′ 6″ — 9′	2½ — 3.
60-65	10′ — 10′ 6″	5 — 5½
100-130	12′	6

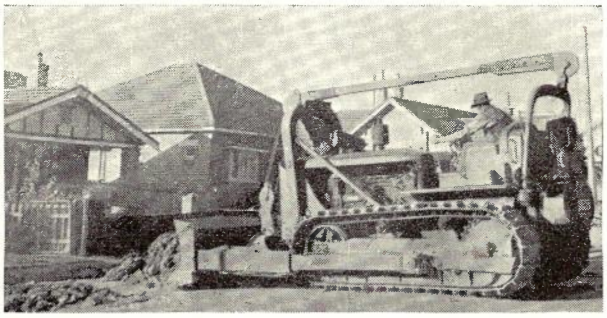


Fig. 4.—Bulldozer in action back-filling a trench.

Because of the numerous variables in C, S & E in the "output" formula, it is better to work on actual performance charts based on studies of jobs over long periods. One such chart for level dozing is shown in Table No. 2, and it is considered that the loose dirt output of 50 cubic yards per hour for a 25-30 h.p. tractor over a 50 ft. haul is safe estimating for backfilling of Departmental trenches with a dozer. With a good operator only one man is necessary for this work, but if the operator is inexperienced a second man is advisable in suburban streets to guide the operator over kerbs, etc.

End Loaders: For the removal of spoil from excavation work, a tractor equipped with a front-end loader is a useful piece of equipment (see Fig. 5). This item is a scoop, generally of ¾ cubic yard capacity, fitted in the front of a tractor of approx. 60 h.p. and capable of being lifted by hydraulic control, from ground level to a height at which the scoop can be tripped by the operator, using a hand rope, and the contents emptied into a tipping truck. Under average conditions, a 4 cubic yard tipping truck can be filled with a front-end loader in 15 minutes. Modern front-end loaders have specially designed tracks to minimise damage to bituminous surface roads.

Fig. 5.—End loader.

Rooter and Cable-Laying Ploughs

With the recent expansion in the use of buried cable, for both trunk and subscribers' purposes, the use of rooters, normally designed for breaking up hard ground and soft rock, is being extended in Departmental activities. Rooters are of the 3 or 5 tyne variety, weighing between 2 and 6 tons and penetrating the ground to depths ranging from 20 in. to 30 in. They are tractor drawn and the tynes can be raised or lowered to any desired position within their range by either hydraulic

Length of Haul (feet)	Tractor Draw-bar H.P.							
	25–30		35–40		60–65		100–120	
	Dirt Moved		Dirt Moved		Dirt Moved		Dirt Moved	
	Firm	Loose	Firm	Loose	Firm	Loose	Firm	Loose
1	2	3	4	5	6	7	8	9
50	28	50	35	60	85	125	115	180
100	22	30	24	35	50	80	70	115
150	15	22	17	25	35	60	50	85
200			13	21	30	45	40	65
250					23	35	33	50
300					15	25	25	36
350							20	30
400							15	25

Table No. 2.—Approximate average volume of dirt moved per hour by a bulldozer (in cubic yards).

or cable control from the tractor, the latter method being via a rear mounted power control unit. Lighter tools, such as rippers, do not usually penetrate the earth so deeply. When used for preparing access roads, levelling sites, etc., the full number of tynes can be used, but for preparatory work in laying buried cable usually the centre tyne only is used. Before attempting to use a cable laying plough for laying cable direct in the ground, it is essential that the cable track be cleared of all possible obstructions such as rock floaters or boulders, which may weigh up to 3 or 4 tons, and tree roots. In this operation, it is desirable to root to a depth greater than that at which the plough will be laying a cable and thereby assist in prevention of damage to the cable. Where intermittent solid rock is met with at varying depths, the rooter will rise as the tyne hits the rock surface, enabling its location to be plotted by a workman employed for that purpose, after which it is necessary to excavate the rock by other means prior to laying of the cable.

The following table gives the tractive effort normally required for various sizes of rooter ploughs:—

Rooter weight (unballasted) lbs.	Tractor drawbar h.p.
3000 (ripper)	50-60
6000	70-90
Above 6000	100-130

The two chief manufacturers of rooters in Australia are the British Standard Machinery Co. Ltd. and Le Tourneau Ltd., the former supplying both hydraulic and cable-controlled rooters, while the latter, as in dozers, rely solely on cable control. Table No. 3 shows relative dimensions, etc., of cable controlled models of rooters.

The tynes, or teeth, which are fitted with replaceable shoes of heat-treated die steel, are detachable in all models, and in the larger models are 10″ x 3″ section up to 67″ long, and weigh as much as 500 lbs. each. Fig. 6 shows the method of setting the depth of the tynes, the control of a cable controlled rooter and the applications.

A combined rooter and mole plough, capable of penetration to a depth of 42″ as a rooter and laying 4 cables concurrently as a cable-laying plough, has recently been constructed in New South Wales, the design being based upon an A.T. & T. Co. cable-laying plough. This equipment is of a different design to the ploughs already described, the rooting and/or cable-laying tyne being housed in a mast framework 12 feet high, the tyne being raised or lowered to the required depth by cable control and locked in position. Fig. 7 shows the plough laying the Katoomba-Lithgow section of the Sydney-Orange trunk cable. Pending completion of this plough for use on large trunk cable projects, a three-tube plough blade was fitted behind a model R39C rooter fitted with a special tyne giving an overall length of 23′ for the rooter and plough, and a cable-laying depth of 30″.

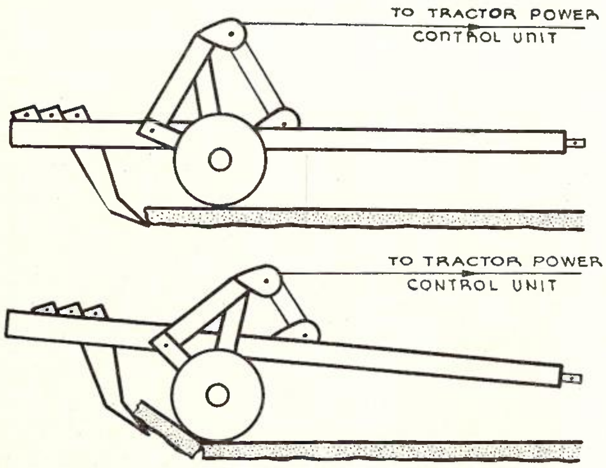
Ploughs for laying one or two cables up to approx. 1.8″ diameter are of the skid or wheel types, the former being fitted under a cable trailer. This type has not been found satisfactory and has been replaced by the wheel type, in which cable guide tubes are fitted behind a rooting tyne whose depth can be set as desired. For this work, pneumatic tyres are preferred to the steel tyres used in commercial rooters, as they tend to cushion the effect of uneven ground and allow the cables to be laid with less prospect of damage. In the standard Commonwealth design of cable-laying plough, the wheels are integral with the chassis and form a fulcrum between the hauling tractor and the rooting tyne and cable guide tubes, which are located at the rear of the wheels and set at required depth by means of a regulated bellcrank. In all cable-laying ploughs the cable trailers are towed behind the ploughs with suitable adjustable cable feeding pulleys fitted as required.

For handling cable drums and other heavy items in locations inaccessible to normal motor transport, either side, front, or rear-end jibs can be fitted to tractors, operation of the lifting cable

Machine	Model	Weight	Number of tynes	Approx. depth	Overall length	Overall width	Height in towing	Teeth clearance above ground
1	2	3	4	5	6	7	8	9
		lb.		inches	ft. in.	ft. in.	ft. in.	inches
Britstand	R39C	8200	3	28	18	8 7	6 9	12
	R510C	9000	5	28	18	8 7	6 9	12
	R313C	14000	3	31	18 3	8 7	7 3	9
Le Tourneau	S	4400	3	20	13 6	6 6	4 7	11
	H	7500	3	29	17	8 4	5 6	14
	K30	12300	3	30	20 5	8 3	6 10	6

Table No. 3.—Rooter dimensions.

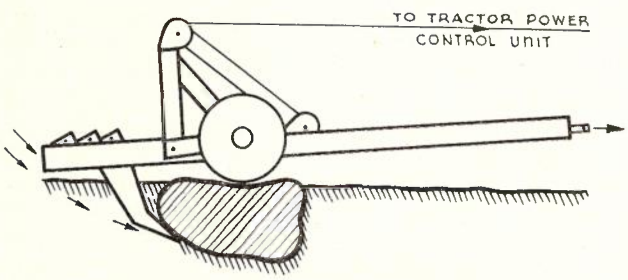
being by means of a power control unit or logging winch. For front or rear mounted jibs, a counter weight is often necessary, and in the case of a rear-mounted jib this can be provided by a dozing blade.



(a) "Lift" and "pull" rooting.

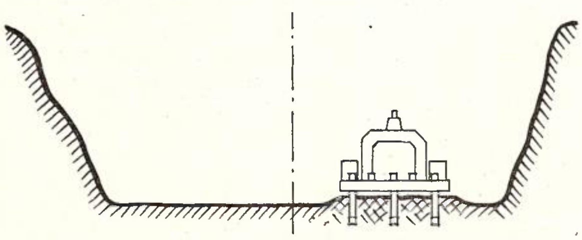
This method is used for the heavy rooting of slab concrete, shale, etc. Where material is not quite so tough the "lift" and "pull" operations can be done at the one time.

1. Bring rooter tooth up and under the slab, but DO NOT try to pull forward with tractor.
2. Lift rooter tooth by engaging power control unit.
3. Pull forward with tractor as slab breaks.



(b) Boulder removal.

1. Sink tooth right under boulder.
2. Use only one tooth.
3. Lift and pull forward at the one time.



(c) Normal rooting.

1. Plan job so that rooters do not interfere with scrapers.
2. Particularly in cuttings, root half width for full length, letting scrapers travel on firm ground, and assuring one-way traffic.
3. If the material is very hard, reduce number of teeth rather than the ripping depth.

Fig. 6.—Rooter Plough Applications.

Trenching Machines

In underground conduit construction, the use of mechanical trench diggers is rapidly expanding. Normal Departmental trench work does not warrant the use of very heavy excavating machinery, such as mechanical shovels or dragline excavators, which are used in work such as road and rail cuttings, but, instead, can usually be handled satisfactorily with the bucket type of trenching machines or ditchers. These types of machines employ an endless bucket line moving round a boom, which can be regulated to the depth of trench desired.

In some trenching machines the digging end of the boom is lowered into the ground, using the upper end of the boom as a pivot, thus making a cut at an oblique angle to the ground surface, but in others the whole boom moves up or down as required, and the face of the completed trench is almost vertical. In congested localities, such as suburban streets, where gas and water services may be encountered at regular intervals of between 20′ and 50′, the use of the latter type of boom is a decided advantage as it enables much more excavation to be done by machine than when the sloping boom type is used. Most modern trenching machines of the bucket-line type are self-propelling on crawler type tracks, the one engine, which is either petrol or diesel, performing the two functions of revolving the bucket line and propelling the machine.

In all machines there is automatic bucket clearing on to a conveyor which deposits the spoil at the side of the excavated trench, a follow-up scraper for cleaning the trench, and an overload release which prevents engine damage. The trenching machine most commonly used in excavation for multi-duct conduit works is the Barber Greene Ditcher Model 44C (see Fig. 8). This machine has a digging range to 8′ 3″ depth and, by settings of teeth in the bucket line, trench widths of 18″, 21″ and 24″ are obtainable. There are three forward and one reverse travelling speeds enabling the machine to be travelled at a maximum speed of 2.2 m.p.h. when not digging. For digging purposes, only first and second forward speeds are used, the bucket line revolving at speeds of 146 and 187 feet per minute respectively, and by means of further gearing through five gears and two sets of sprockets, digging speed can be regulated between 10″ and 92″ per minute, according to the type of soil; so that under the most favourable conditions this machine is capable of excavating a trench 24″ wide, 8′ 3″ deep and nearly ¾ mile long in an 8-hour day. For open country work, a safe estimation in loamy soil is ½ mile of trench per day. For suburban work, excavation distances can be estimated at 200 yards per day in closely settled areas, and 440 yards per day in outer suburban areas. The digging boom of the Barber Greene machine is centred between the tracks, and as the width of the machine is approximately 8′ the minimum centre distance of a trench from a fence alignment is 4′. In metropolitan areas, where other utility bodies have observed their allotted positions in footways, it is generally practicable to use this type of trenching machine for Departmental operations, but where centre digging is not practicable side-digging ditchers can be used.

Trench depth regulation of most bucket line excavators is by means of a vane located at a set vertical distance from the bottom of the bucket line, trailing a guide line erected above ground at such a height that the height of the guide line above ground, plus the depth of trench, equals the vertical distance of the vane to the bottom of the bucket line. If the guide line is stretched taut and graded parallel to the required trench bottom, a graded trench can be cut irrespective of ground contour.

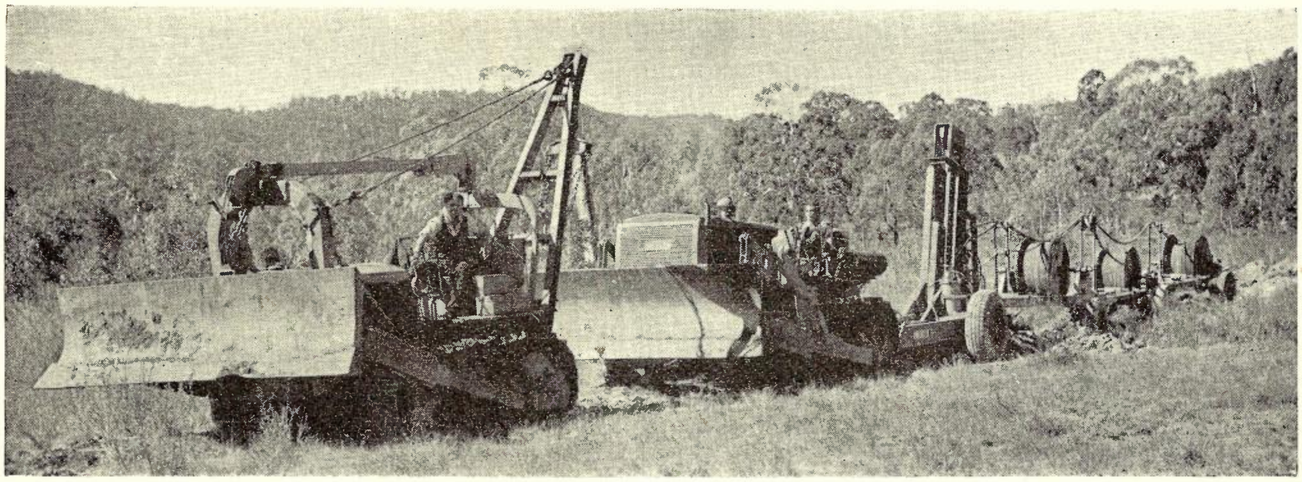


Fig. 7.—Cable-laying train laying three cables simultaneously.

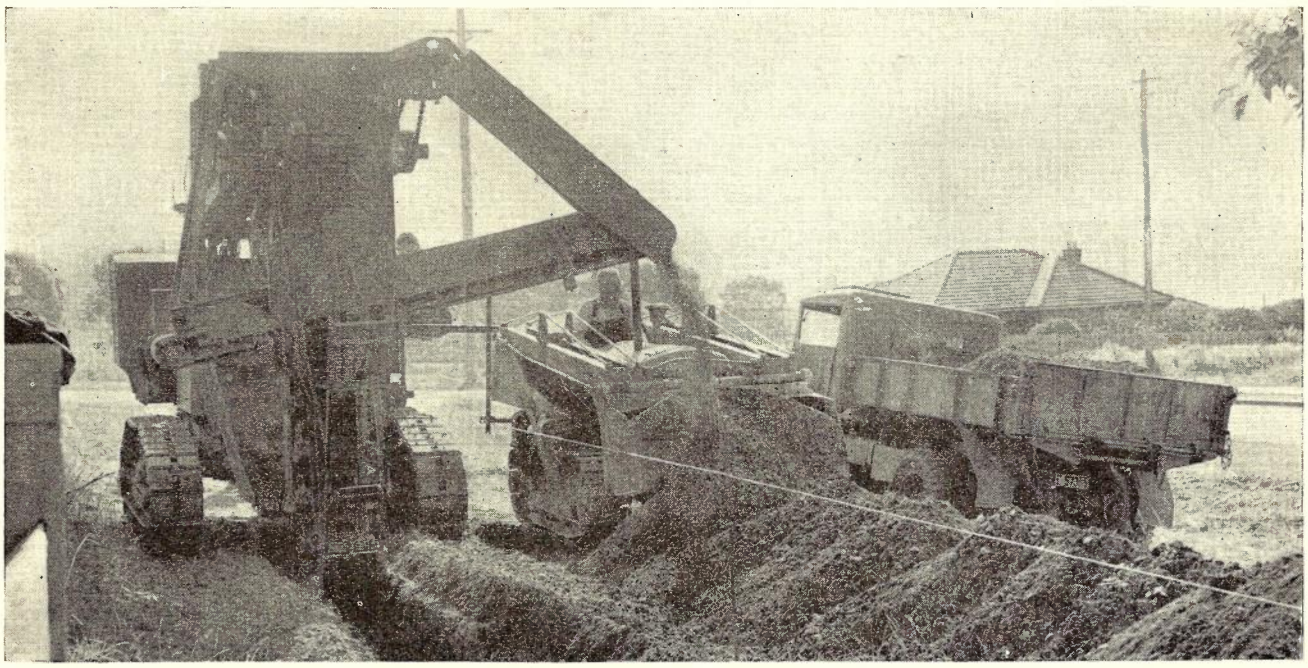


Fig. 8.—Trenching machine, front end loader and tipping truck as a complete excavation and spoil removal unit.

The English-made Aveling Barford trenching machine (shown in Fig. 9) is much lighter and smaller than the Barber Greene Ditcher weighing 3 tons and digging a trench 11″ or 18″ wide to a maximum depth of 3′ 6″. Propulsion of the machine is by a steel cable which is attached to a suitable gad or stake set in the ground along the centre line of trench up to 300 feet ahead of the machine, which automatically winds the cable on a drum as the trench is cut and draws the machine forward. The travelling speed of this machine whilst digging varies from 25 feet to 175 feet per hour.

The machine is very useful for single pipe work

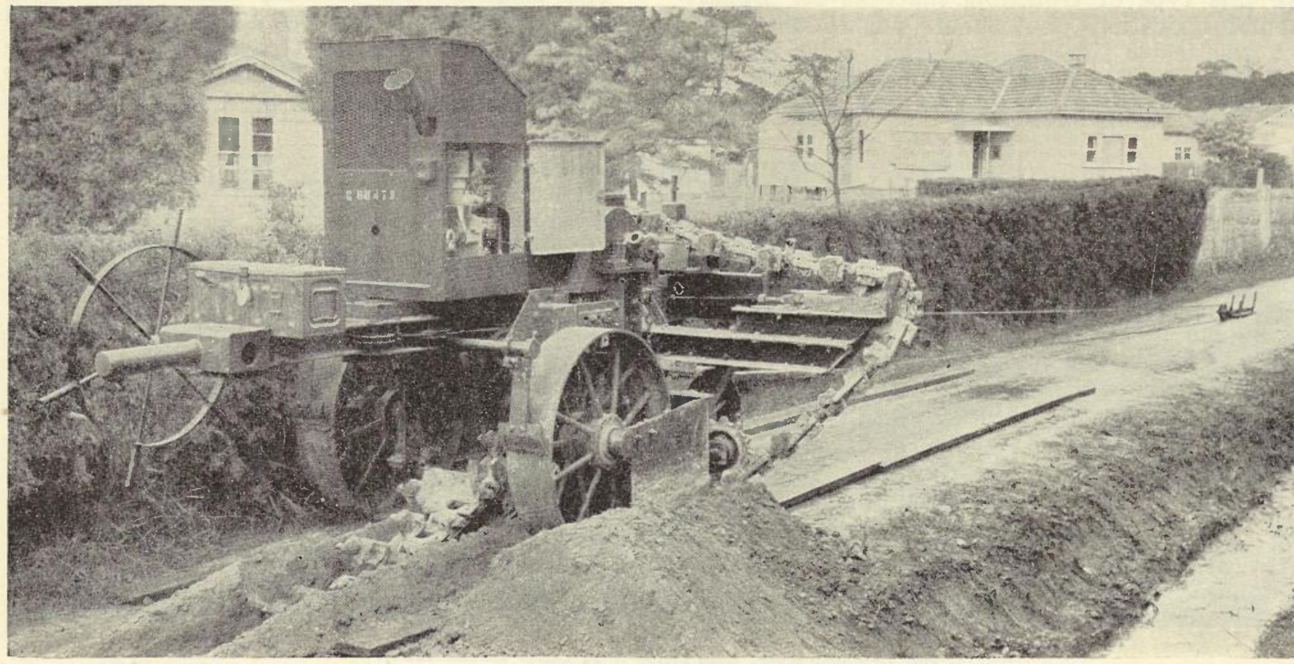


Fig. 9.—Aveling-Barford trench-cutting machine.

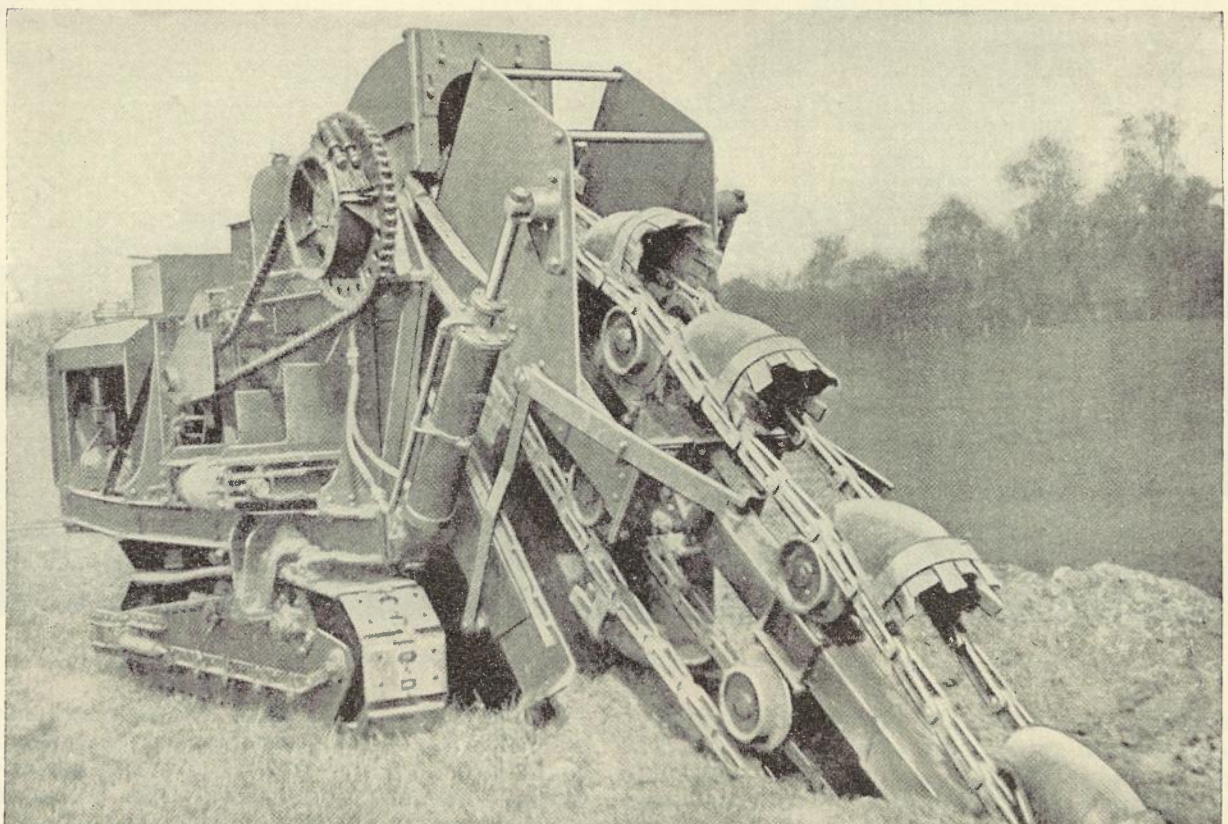


Fig. 10.—"Allen" 12-18 trench excavator.

such as 4″ earthenware pipes in open country, but in densely populated suburban areas its use is not generally economical owing to the angle of the face of the trench and the consequent excessive handwork involved in excavating bulkheads where the machine cannot operate at water and gas service crossings. The most recent Departmental purchase of bucket line excavators is model 12-18 Allen trenchers, which are capable of digging a trench 19″ wide and 6′ deep at a rate varying from 150 to 450 feet per hour (see Fig. 10). The boom of this machine is of the angle type and the machine suffers from the disadvantage previously mentioned. The trencher is self-propelled, however, and is a good medium between the Aveling-Barford and Barber-Greene.

The boom is hydraulically controlled, pivoted at the top, and the machine when in travel trim measures 23′ 3″ overall length. The crawler tracks are 6′ 2″ long and 12″ wide, and exert a pressure of $8\frac{1}{2}$ lbs per sq. in. This equipment is capable of working in more confined spaces than the Barber-Greene type and, for this reason, is generally more useful than the latter on narrow footways, between or beside other public utility mains where there are not excessive cross service pipes. Table No. 4 gives a comparison of the three types of trenching machines described.

machine and is useful for small isolated works, as a machine capable of a 21″ wide cut weighs only $4\frac{1}{2}$ cwt. and is easily transported.

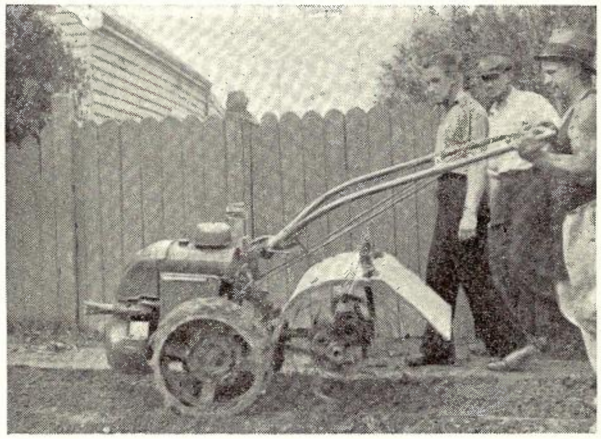


Fig. 11.—Roto-tiller.

Compressors and Pneumatic Tools

Machine rock excavation, where trenching machines are not suitable, is done with pneumatic compressor tools. Compressors used by the Department range from 80 cubic feet to 170 cubic

Machine	Trench Range		Overall dimensions in travel trim				Weight		Road Speed range (M.P.H.)	Digging Speed range (per min.)	Engine		Boom Control
	Width	Depth	Length	Width	Height	Track Width	Tons	Cwt.			Type	H.P.	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)		(9)	(10)	(11)	(12)	(13)
	inches	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.							
Barber Greene Model 44C (See note)	18–24	8 3	17 9	11	16	7 2	10	5	$\frac{1}{2}$–2	10″–7′ 8″	Petrol	57	Cable
Allen Model 12-18 ..	13–19	6	23 4	5 2	7 3	4 5	6	11	$2\frac{1}{2}$–4	2 6″–7′ 6″	Diesel	40	Hydraulic
Aveling-Barford ..	11–18	3 6	13 3	7 9	6 8	4 8	3	0	—	5″–2′ 11″	Petrol	8	Cable

NOTE.—The latest Barber Greene Model 44C is fitted with a 65 H.P. diesel engine.

Table No. 4.—Comparison of trenching machines.

The excavation of soil trenches which do not warrant transport of heavy machinery can be aided by the use of tilling machines of the rotary hoe type, one being tried with a certain amount of success being the "Rototiller," which has been used to assist in excavation of a trench up to 7 feet deep, to the writer's knowledge. This machine, which is made in several models, is powered with a single cylinder two-stroke engine and is self-propelling at the rate of approximately 1 m.p.h., the width of cut varying from 15″ to 36″. The machine, a general view of which is shown in Fig. 11, breaks up a surface to a depth of up to 6″ per cut, using rotating tynes, but the spoil has then to be shovelled from the trench by hand. It is essentially a light duty

feet of free air per minute capacity at 100 lbs. per square inch pressure. The prime movers are either petrol, semi-diesel, or full diesel, and the compressors generally are two-stage, with an inter-cooler. Table No. 5 gives details of models, capacities, etc., of Ingersoll Rand, Broomwade and Consolidated Pneumatic compressors in general use by the Department. Most models are either two or four-wheel trailer-mounted, but it has been found economical to truck-mount several machines to improve mobility.

The smaller models are used for isolated works such as pole holes or small quantities of rock excavation, while the larger machines are most economical where there is continuous rock or in localities which may necessitate extended iron

Make	Model	Capacity		Prime Mover		Stages of compression	Tool Capacity at full output		
		Cubic feet free air per min.	Pressure Lb./Sq.in.	Type	H.P.		Spades	or Pavement Breakers	or Drills
1	2	3	4	5	6	7	8	9	10
Broomwade	SVD1	110	100	Diesel	27	1	4	2	1–2
	SVD2	167	100	Diesel	38	1	6	4	1–3
Ingersoll-Rand . .	100	100	100	Petrol	25	2	2	1	7
	200	128	100	Petrol	43	2	4	2	2
Consolidated Pneumatic	CP90	90	100	Petrol	26	2	2	1	1
	CP160	160	100	Diesel	42	2	4	2	3

Table No. 5.—General details of air compressors.

pipe air lines with consequent friction losses, which, however, are not as great as in the case of rubber hose air line. Generally, such extended lines should not exceed 1000′ of 2″ G.I. pipe with a 170 cubic feet machine, the effective pressure at this limit being reduced by approximately 10%. The normal air line to tools is $\frac{3}{4}$″ internal diameter high pressure hose in average lengths of 60′.

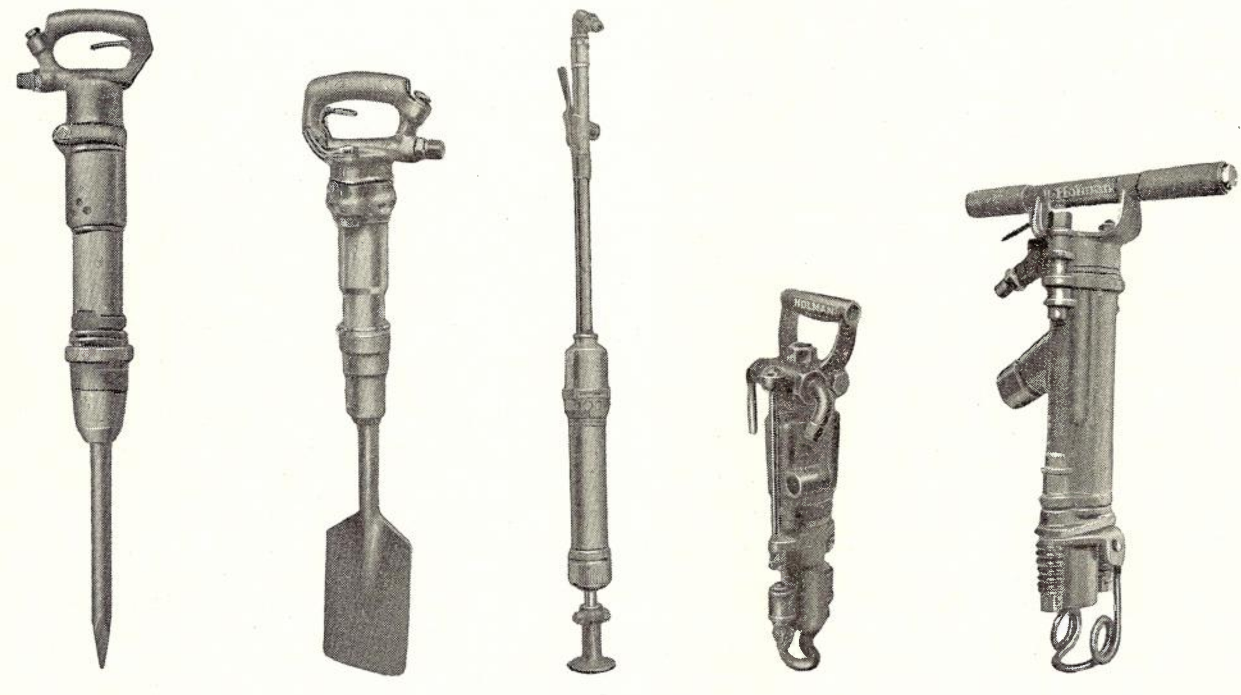


Fig. 12.—Pneumatic tools used for excavating.

The tools generally used in excavation work are:—

Spades: Light tools carrying spade-shaped bits for excavation of clay or tunnelling in cramped locations. Moil points are also used for work such as breaking walls of concrete manholes.

Pavement Breakers: These tools are of varying weights from 55 lbs. to 85 lbs. and can be fitted with a variety of bits or steels, such as moil points, chisels of various sizes, asphalt cutters and tamping pads. They are used generally for cutting trench edges in concrete and asphalt footpaths, breaking concrete and macadam road surfaces and excavation of trenches or pole holes in rock or shale formation, where blasting is impracticable, and for consolidating refilled trenches when fitted with a tamping pad. The type of pavement breaker depends on the class of work to be performed and the physical capacity of the operator; for instance, where a tool needs to be used horizontally, or where continuous lifting of the tool is necessary, a light tool causes less fatigue to the operator with consequent increased output. On the other hand, where very thick slabs of concrete require to be cut with moil points, the heaviest tool which the operator is capable of handling gives best results.

Rammers: These are tools of medium weight, approximately 50 lbs., with long handles and air control located in such a position that stooping by the operator is unnecessary in back-filling open cut trenches. Pads of various sizes and shapes are fitted as circumstances require. The hammer speed of rammers is much less than that of pavement breakers.

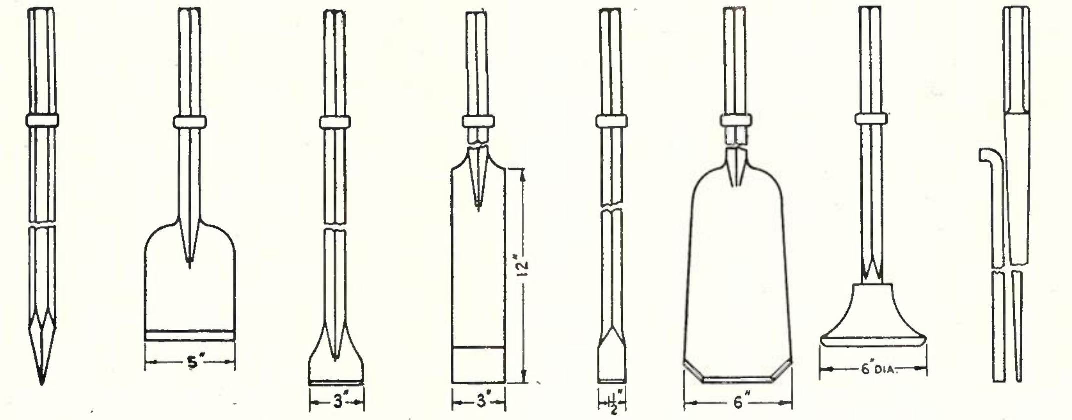


Fig. 13.—Accessory tools used with paving breakers.

Drills: These are tools which have both a hammer and rotary action, so that a star-shaped drill point is turned while hammer blows are being struck on the bit, resulting in a circular hole being drilled. Drills are of the "wet" or "dry" type, the former being used where water under pressure is available and so constructed to allow water to be fed through a hole in the centre of the drilling bit to the bottom of the hole being drilled. This type of drill prevents, to a large degree, rock dust from being carried into the air and swallowed by operators, thus reducing the possibility of Silicosis damage to the lungs. Dry drills allow air under pressure to be fed to the drilling surface to automatically clear the bit as required without removing the bit from the hole being drilled.

When using "dry"drills, it is necessary to feed water to the drilling surface to reduce drill wear as well as to lay dust. Originally, drill bits, which vary in length from 1′ 6″ to 8′ or longer if required, were fitted with specially tempered steel cutting edges which required sharpening regularly by an experienced tradesman, but in modern steels the cutting bits are detachable and taper-fitted to the steel shank. The cutting bits are discarded as they wear and can be replaced in a few seconds.

Sump Pumps: These are rotary type pumps operated by an air motor. They are submerged to the required depth, fitted with an air inlet from the compressor and an outlet hose of approximately 2″ diameter. The delivery capacity of sump pumps, which are made by practically all regular pneumatic tool manufacturers, varies between 100 and 200 gallons per minute, with a 10 feet head and 80 lbs./sq. inch air pressure. These

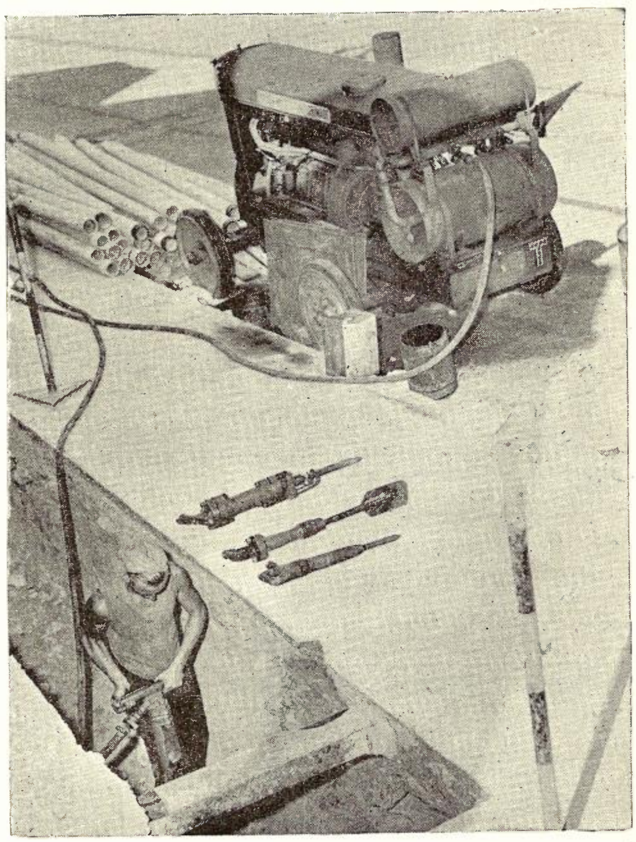


Fig. 14.—Pneumatic compressor and typical tools used on rock in a city street excavation.

units are particularly valuable in pumping flooded manholes and open conduit trenches.

Rotary Grinders: These tools are somewhat similar in construction to sump pumps, the pump vanes and body being replaced by an emery wheel suitably guarded. Some types of sump pumps can readily be converted to grinders as required and used for both purposes, although most manufacturers supply both types of tools as separate units. Grinders are useful in conduit construction to cut cast or wrought iron pipes in situ for manhole alterations, etc., to clean rough surfaces or edges of ironwork liable to damage

Type	Make	Model	Air Consumption (c. ft./min.)	Working Pressure (lb./sq. in.)	Weight without Steel (lb.)	Length exclusive of Steel (inches)	Handle S–Single D–Double	Blows/min.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Spade	Broomwade	CD.40	38	80	19½	32½	S	1800
		CD.4	25	80	15	27½	S or D	2200
	Ingersoll-Rand	73	34	80	19½	19¼	S	2000–2200 approx.
		173	34	80	24½	26¼	D	
		75	38	80	26¾	21¾	S	
		175	38	80				
	Consolidated	"Model 3"	30	80	19¾	19½	S	3050
	Holman	NSP101	35	80	17	17	S	2500
Rock Drill	Broomwade	BWD.230	50	80	29	17¼	S	2700
		BWD.250	60	80	37	17¾	D	2500
		BWD.600	65	80	46	18½	D	2200
		BWD.258	90	80	55	19¾	D	2200
	Ingersoll-Rand	JB.4	72	80	52	22¼	D	2000
	Consolidated	CP.22 or 235	65	80	28	19⅞	D	2000–2500 approx.
		CP.32	80	80	47	21	D	
		CP.42	84	80	56	24¼	D	
	Holman	HD.1	58	80	28½	16½	D	2000–2500 approx.
		SL.10	80	80	58	20¼	D	
		SL.100	80	80	65	21¼	D	
		Silver bullet	90	80	58	20½	D	
Pavement Breaker	Broomwade	RB.660	50	80	82	27	D	1450
		RB.110	40	80	55	25	D	1630
		RB.55	50	80	74	28	D	1350
	Ingersoll-Rand	CC.80	45–62	70–90	80	28	D	2000 approx.
		TB.8	45–65	70–90	82	28¾	D	
	Consolidated	BQ.46	65	80	50	21½	D	1500–2000 approx.
		CP.117	56	80	76	27¾	D	
	Holman	SS.44	36	80	43	21	D	1500–2000 approx.
		SS.33	48	80	60	22	D	
		SS.11	55	80	75	23	D	
Sump Pump	Broomwade	TP.3	65–70	75	68	29½		
	Ingersoll-Rand	25	80	80	56	23½		
		35	142	80	75	28		
	Consolidated	CP.2	50	80	64	23		
	Holman	615	80	90	62	23		
		620	90	90	71	23½		
Rammers	Broomwade	SR.10	34	80	50	51		350
		SR.5	22	80	19½	42		700
		BR.3	12	80	7½	23		1050
	Ingersoll-Rand	24	24	80	23	51		800
	Consolidated	No. 2 Simplate	26	80	26½	46⅝		850

Table No. 6.—Details of compressor tools.

cables, and cut flat and bar iron where tools such as bolt cutters or hack-saws cannot be used.

Various other types of tools, such as riveters, circular saws, wood drills, etc., can be used with pneumatic compressors, and the use of wood-working tools is now being exploited on aerial line construction work for slotting poles and drilling holes in poles or crossarms. Table No. 6 gives some details of the variety of spades, pavement breakers, drills and rammers which may be selected for excavation and refill work.

Figs. 12 and 13 show the more generally used tools, and Fig. 14 shows a typical application of a compressor in city street excavation work. Fig. 15 illustrates rock excavation in rough country carried out by compressor tools during the installation of the Sydney-Orange trunk cable.

Conclusion: While this article has been compiled with the idea of describing and tabulating some useful information in regard to machinery being used in modern line construction, it is not intended to be a complete treatise or reference on the subject, and has only referred to well established tools in use. Other labour-saving devices and tools, such as hydraulic controlled earth boring machines for laying pipes under roads without disturbance of the surface, are being developed and may tend to displace certain of the line construction machinery now in use or add to its present scope.

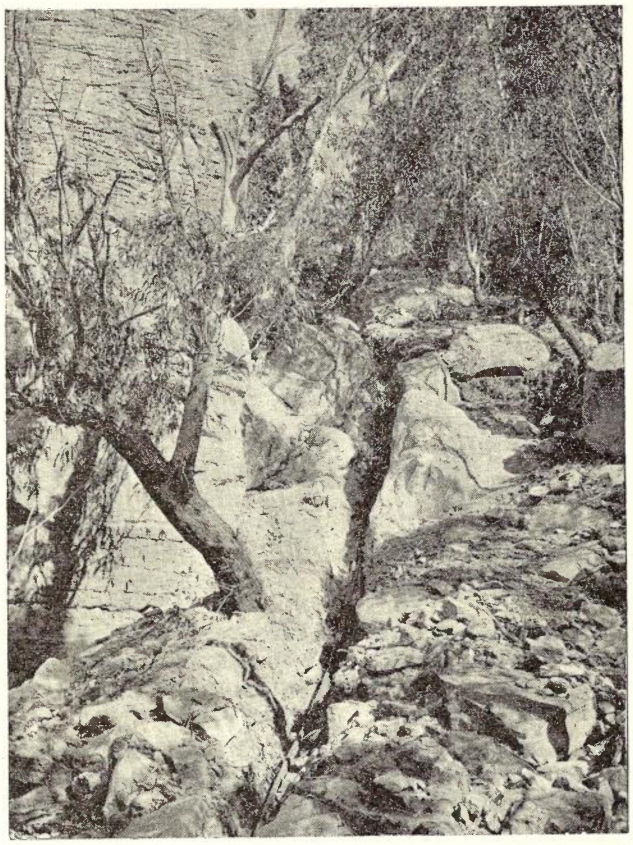


Fig. 15.—Rock excavation in rough country carried out by pneumatic compressor tools (Mount York, Blue Mountains, N.S.W.).

CABLE CARRIER SYSTEMS IN AUSTRALIA

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Introduction: In a previous article in this journal (1), a description was given of the Sydney-Newcastle-Maitland carrier cable, the first cable of its type installed in Australia. Similar cables consisting of two 24-pair 40 lb./mile star quad carrier type cables forming a "go" and "return" system have since been installed on different routes, and others will be completed shortly. It is the intention of this article to review generally the principles of multi-channel carrier operation on such cables, the different types of carrier systems being provided, and the application of such systems to existing voice frequency type cables. Later articles will give more detailed descriptions of the interesting features of the particular types of installation.

Historical: The development of feedback amplifiers and cable crosstalk neutralising technique at high frequencies in the early 1930's (2), (3), led directly to the introduction of the first commercial multi-channel cable carrier system in U.S.A. in 1936 (4). The equipment was designed for use with existing voice frequency cables, large networks of which had already been provided, and made possible the provision of greatly increased trunk line facilities at a relatively low cost. Each system provided 12 telephone channels, and used separate cables for each direction of transmission. The frequency range of 12-60 kc/s was selected to provide the most economical operation, having regard to the cable characteristics and the high cost of improving cable crosstalk, which would be necessary if higher frequencies were used. The equipment was also designed to be, as far as possible, identical with equipment being developed concurrently for multi-channel operation on open wire lines and coaxial cables, thus reducing design and manufacturing costs and simplifying equipment maintenance.

The successful operation of 12-channel systems in the U.S.A. led almost immediately to the introduction of similar systems in England (5), and in Europe. However, on most routes in these countries, cables suitable for the operation of 12-channel systems were not available, and special cables of types similar to the Sydney-Maitland cable were designed for use with the carrier systems. The first cables of this type after neutralizing the far end crosstalk by special condenser balancing networks at the receiving end, gave satisfactory crosstalk values up to about 75 kc/s, and in comparison with voice frequency cable systems carrier operation was economical for distances greater than approximately 80 miles.

It was at this stage of development that the Sydney-Maitland project was first considered, and in order to obtain the maximum cable traffic carrying capacity available at that time 17-channel cable carrier systems were ordered. The additional 5 channels were gained by locating 2 channels in the 4-12 kc/s range and 3 channels in the 60-72 kc/s range.

Later investigations showed that by adjusting the far end networks at higher frequency values it was possible to obtain satisfactory crosstalk between every pair of a carrier type cable up to frequencies in excess of 100 kc/s. This led to the development in England of 24-channel systems using cable frequencies of up to 108 kc/s. In Europe special types of cable were developed to permit the operation of 48- and 60-channel systems on short routes, using cable frequencies of up to 204 kc/s and 252 kc/s respectively.

In Australia, the chief application of cable carrier systems has been to routes where there are no existing cables, and new cables have been provided for 12-, 17- and 24-channel operation. Recently cable carrier equipment has also been applied to obtain additional channels from existing voice frequency type trunk cables which have reached the limit of their traffic carrying capacity.

General Principles of Cable Carrier Operation

General Economic Considerations: The cost of a cable carrier installation consists of the cable cost together with the equipment and associated building costs. The cable cost is dependent upon the number of channels to be carried by each cable pair, or, in other words, upon the maximum frequency to be transmitted by each cable pair. For frequencies up to about 100 kc/s, the cost of providing cables with the desired crosstalk characteristics rises only slightly as the maximum frequency increases, but beyond this value a disproportionate increase takes place.

The equipment costs may be sub-divided into terminal and repeater costs. Terminal costs are roughly proportional to the number of channels provided by the terminal and the cost of each repeater is small compared with the terminal cost. Building costs are chiefly those associated with the provision of new repeater stations, as space for the terminal equipment is usually available at towns of a size justifying the provision of a carrier cable terminal installation.

The design of any cable carrier scheme must be based on reducing the cost per channel to a minimum. From a consideration of cable and equipment costs, it will be seen that the cost per channel will decrease as the number of channels is increased. However, after the limit where the cable costs rise disproportionately is reached, it is found that the cost per channel begins to rise again. The cable carrier system should thus be designed to obtain the greatest number of channels possible per cable pair, having regard to the cable limitation.

In order to reduce repeater equipment and building costs to a minimum, repeater stations should be located as far apart as possible, having regard to the noise permitted on the telephone channels.

Consideration of the costs involved shows that in general the most economical type of operation of cable carrier systems is four-wire operation using the same frequencies for each direction of transmission. The use of a separate cable pair for each direction of transmission eliminates the use of directional filters at terminal and repeater stations. As a certain frequency band must be allowed in the region of the cut off frequencies of the directional filters to make the filter design practicable, the elimination of these filters enables additional channels to be operated in this region. In addition repeater equipment is reduced to a very simple form.

Channel Frequency Spacing: It is generally accepted that an effective bandwidth of 300-3400 c/s is required for the satisfactory transmission of speech on an individual trunk channel (6), particularly when it is necessary to switch a number of channels together to set up a long distance call, as with each additional link the channel bandwidth is reduced. To obtain the necessary bandwidth and allow frequency margins for the design of channel band filters, carrier frequencies are spaced at 4 kc/s intervals. In order to simplify the carrier supply equipment and reduce its cost, all carrier frequencies are now almost universally made multiples of 4 kc/s.

Noise Limitations: At the input to any amplifier there is a certain noise power, due chiefly to the thermal agitation of electrons in the input resistance (7). This thermal agitation noise cannot be reduced, and is proportional to the frequency bandwidth transmitted, but is independent of the input resistance value and the position in the frequency spectrum in which the band is located. For a 3,100 c/s channel bandwidth, the thermal agitation noise power is approximately 133 db below 1 milliwatt. Other noise sources may increase the total noise power slightly above the thermal agitation value, for example, cable noise when the amplifier input is connected to a cable pair.

In special carrier type cables, the cable noise is generally below the thermal agitation value, but in existing voice frequency type cables, especially ones with direct current dialling on some pairs, the general noise level may be considerably higher than the thermal agitation value.

The general effect of the noise power is to limit the amount to which speech levels are allowed to fall at the input to an amplifier, it being necessary to maintain a certain level difference to ensure that undue noise is not introduced into the speech channel. This is due to the fact that the speech

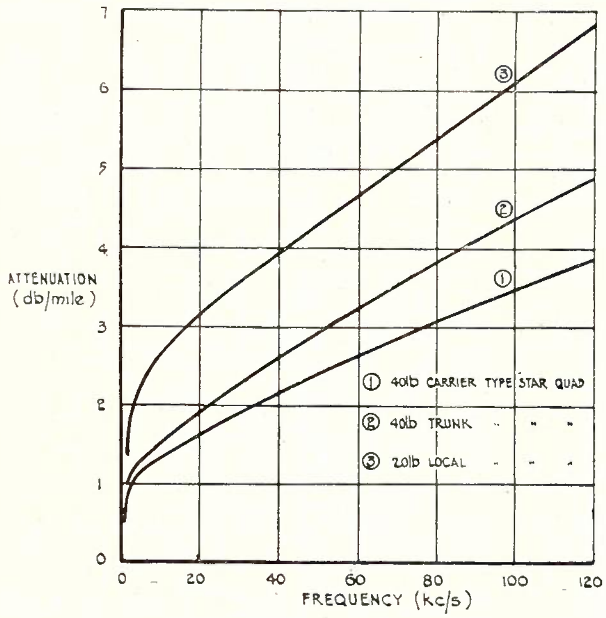


Fig. 1.—Cable attenuation V. frequency.

and the noise are amplified together by the amplifier. For a channel with a large number of amplification points, the minimum level to which the speech would be allowed to fall at the input to any amplifier would be less than if only a few amplification points were involved. This follows since the noise powers which are introduced at each amplifier input are directly additive so that for the same level margin above the noise value the channel noise would increase as the number of amplification points is increased.

For the greatest number of amplification points likely to be used in any cable carrier channel in this country, the minimum value to which it is desirable to allow the speech level to fall at an amplifier input is approximately 52 db below the level at the trunk switchboard. In certain exceptional cases the level may be decreased by a further 4 db at one or two points, provided that the other minimum levels are increased slightly. If the total noise level at the amplifier inputs is higher than the thermal agitation value, for example, due to cable noise, the minimum signal level must be increased accordingly.

Transmitting Levels: For the maximum plate voltage of 154 volts standardised for Long Line Equipment, it is generally uneconomical to design valves with a power handling capacity greater than 1 watt. The maximum speech channel level capable of being transmitted by a feedback type amplifier with this overload capacity, without causing interference between channels due to modulation in the amplifier, varies with the total number of channels carried by the amplifier (8). For amplifiers carrying 17 or 24 channels, the maximum transmitting level per channel permissible is +5 db relative to the level at the trunk switchboard, provided that each channel is equipped with a limiter to ensure that the effective power applied to the channel at the trunk switchboard does not exceed 6 milliwatts. For amplifiers carrying 12 channels only, the maximum transmitting level could be increased to +7 db per channel, but as most 12-channel amplifiers are designed to carry 24 channels at a later stage the level of +5 db is usually used for these systems also.

Cable Characteristics: The maximum distance allowable between repeater stations is dependent on the attenuation per mile of the cable used, since the maximum and minimum levels in a section, and, therefore, the total attenuation, are limited by amplifier and noise considerations. Typical attenuation versus frequency characteristics of cables used for carrier operation are shown in Figure 1.

The cable attenuation at any frequency is dependent on the temperature of the cable, due chiefly to the variation of resistance of the conductors with temperature. Figure 2 shows the variation in attenuation per degree Fahrenheit change of temperature for 1 mile of cable of the Sydney-Maitland type. It will be noted that, in the range 8-70 kc/s, the change in attenuation with temperature is approximately independent of fre-

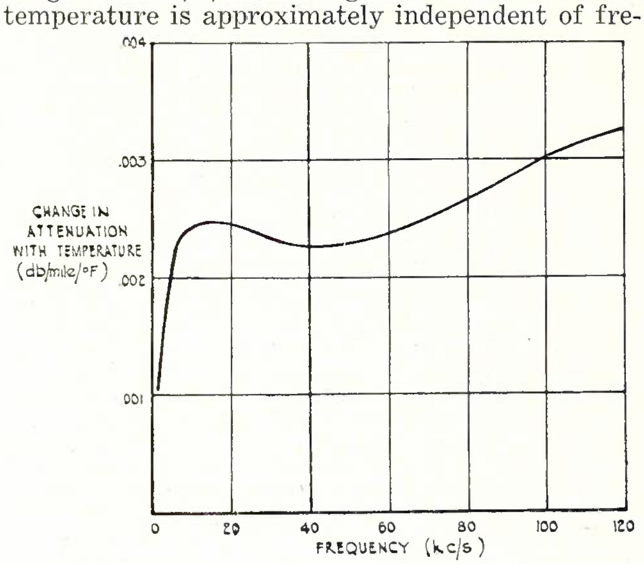


Fig. 2.—40 lb. carrier type star quad cable. Variation in attenuation with temperature.

quency. This is of importance in the design of equipment to compensate for the variation of cable attenuation. The necessity for some form of automatic regulating equipment in certain cases may be seen readily from the fact that a 2 degree change in temperature on a 1000 mile circuit would cause an overall attenuation variation of

5 db. Fortunately, for underground cables buried over 18 inches deep, the temperature variation is seasonal rather than daily or weekly, and on the shorter cable routes at present provided in Aus-

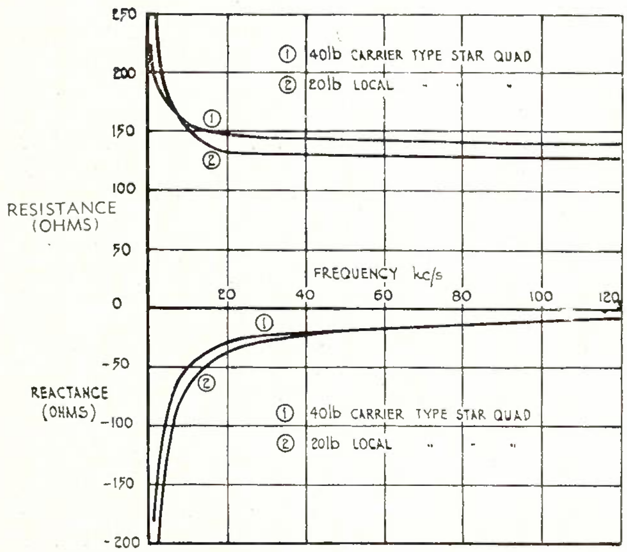


Fig. 3.—Cable impedance V. frequency.

tralia attenuation variations can usually be compensated for by a seasonal adjustment of amplifier settings. Special automatic gain control equipment is, therefore, necessary at only a few stations in Australia.

The impedance versus frequency characteristics of typical cables are shown in Figure 3. These characteristics are of importance in reducing cable crosstalk, as will be shown in the next section.

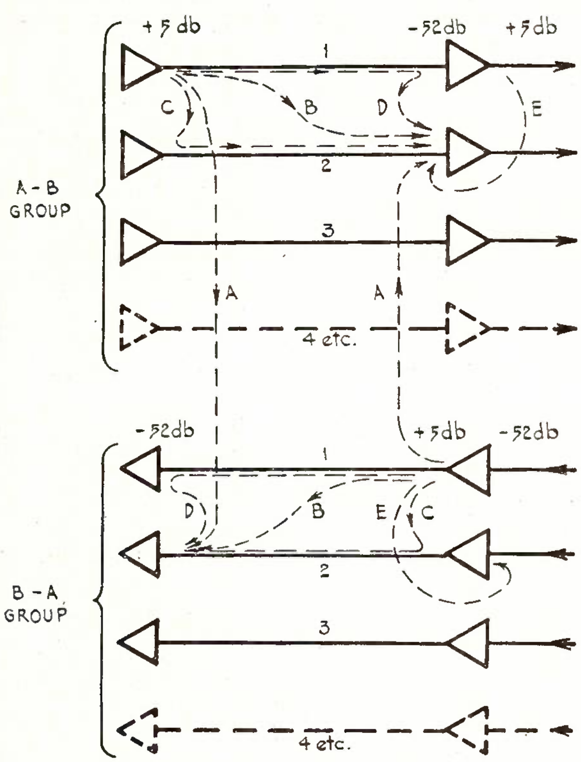


Fig. 4.—Crosstalk paths—carrier systems using same frequencies in each direction.

Crosstalk in Carrier Type Cables: For normal cable carrier system operation using the same frequencies for each direction of transmission, the types of crosstalk path possible in any repeater section are shown in Figure 4. These represent the paths by which a channel of carrier system No. 1 can interfere with the same channel of carrier system No. 2 in the repeater section. Similar paths exist between all combinations of cable pairs in every repeater section, and the

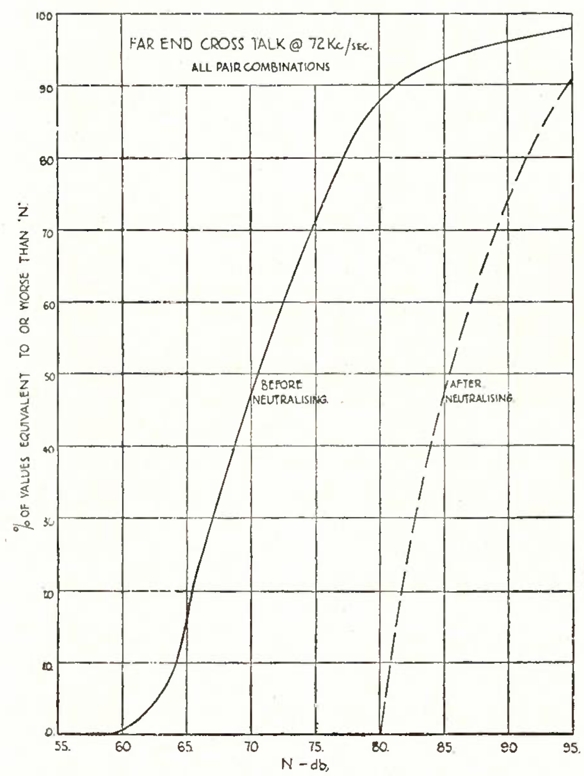


Fig. 5.—Carrier type cable—typical far-end crosstalk reduction by neutralising.

crosstalk powers induced in any channel from the corresponding channels of all other systems add to form a general noise known as "babble." This noise will obviously increase with the number of carrier systems operated on the same cables, and with the number of repeater sections.

Path A represents a near end crosstalk path between channels in opposite directional groups. As there may exist a maximum level difference of 57 db between the disturbing and disturbed channels, if an effective crosstalk of 80 db were required, an actual crosstalk of 80 + 57 = 137 db would be necessary. It is found that the near end crosstalk increases with frequency, as does the level difference between groups. In order to obtain satisfactory crosstalk for a maximum of 24-carrier systems on routes of the maximum length likely to be used in this country, it is necessary for near end crosstalk to be at least 135 db for 95% of the combinations and at least 125 db for all combinations in any section at the highest frequency to be transmitted. These values can be obtained only by specially screening the groups for different directions of transmission, or by using separate "go" and "return" cables. As the latter method is the most practicable from a cable manufacturing point of view, it is used in almost all countries, including Australia.

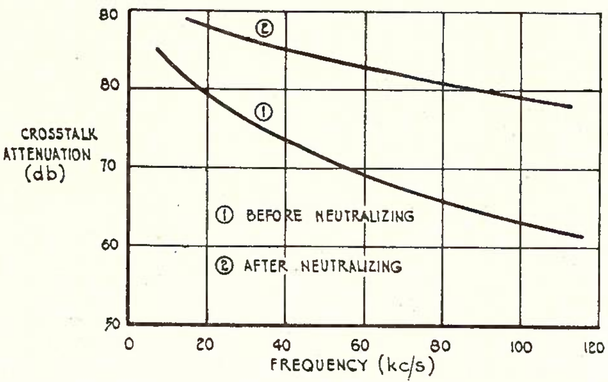


Fig. 6.—Carrier type cable—typical far-end crosstalk variation with frequency.

Path B represents a far end crosstalk path between channels in the same directional group. It is this type of crosstalk which is reduced by the crosstalk neutralising technique described fully in previous articles (1), (9). The requirements necessary for any repeater section are not worse than 75 db for 90% of the combinations and 70 db for all combinations over the whole frequency range. Typical values obtained before and after neutralising are shown in Figure 5. The variation of far end crosstalk with frequency between typical cable pairs is shown in Figure 6.

Paths C and D represent reflected near end crosstalk paths which result in far end crosstalk similar to that produced by path B. The near end crosstalk values of a carefully manufactured cable are usually slightly better than the far end values before neutralising. Neutralising networks, however, do not improve the near end crosstalk, but often degrade it slightly. In order that the reflected near end crosstalk should not be worse than the far end crosstalk after neutralising, and thus become controlling, it is necessary to ensure that the impedance of the equipment at the ends of each cable is as near as possible to the cable impedance. The equipment impedance is usually designed so that reflected powers are at least 20 db below the incident powers, or, in other words, the return loss is not less than 20 db over the whole frequency range.

Path E is very similar to path A, and the required minimum crosstalk values are the same. Provided that reasonable precautions are taken at repeater stations in the termination of cables and the wiring of equipment, no difficulties are experienced due to this type of crosstalk.

Carrier Operation on Voice Frequency Type Cables: (10), (11). Where two existing voice frequency type cables are available on a route, the method of operation of carrier systems is similar to that on the special carrier type cables. However, at repeater stations where voice frequency pairs in the same cables pass directly through, it is usually necessary to transpose carrier pairs from one cable to the other to avoid crosstalk troubles due to coupling via the voice frequency pairs. The type of crosstalk coupling and the effect of the transposition in reducing level differences is illustrated in Figure 7. In cases where the two cables follow different routes and it is not possible to overcome the crosstalk difficulty in this way, special crosstalk suppression coils are often necessary on the voice frequency pairs.

Where single cables only are available on a route, different frequencies must be used for each direction of transmission to eliminate near end crosstalk troubles. In order to avoid special directional filters at terminal and repeater stations separate cable pairs are used for each direction of transmission except in a few special cases. Some further crosstalk problems are introduced by this method, but they can be readily overcome by means of simple crosstalk suppression filters fitted on the carrier pairs. This method of operation and the problems involved will be fully discussed in a later article.

As existing voice frequency type cables were not designed for multi-channel carrier operation, the crosstalk characteristics are inferior to those

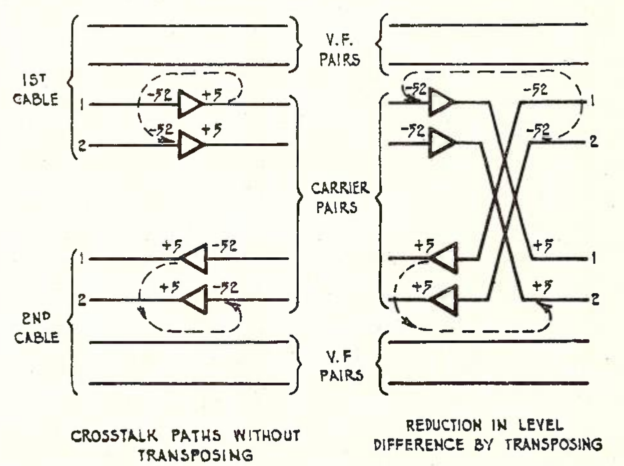


Fig. 7.—Carrier systems operating on two V.F. type cables—crosstalk reduction by transposing carrier pairs at repeaters.

of the carrier type cables, and it is necessary to select cable pairs suitable for carrier working. Crosstalk neutralising networks must then be provided to reduce far end crosstalk to the values required. The technique of selecting suitable cable pairs is similar to that used in the case of junction carrier systems and described in a previous article (12). In some cables, special measures are necessary to reduce excessive high frequency noise, for example, by the fitting of suppression filters on cable pairs connected to an open wire route at the branching point. Where voice frequency or 30 kc/s carrier loading is provided on the voice frequency type cables, it is, of course, necessary to deload the cable pairs required for multi-channel carrier operation.

Choice of Number of Channels: The number of channels provided by a cable carrier system is determined by the minimum and maximum frequencies that it is desirable to transmit on the cables. In most cases the minimum frequency used is 12 kc/s, as for frequencies below this the rise in cable impedance makes it more difficult to obtain the desired return loss value, and the change in cable attenuation with temperature complicates the design of automatic gain regulating equipment. In addition, the design of feed back amplifiers is simplified considerably if the ratio of the maximum to minimum frequencies transmitted is kept as low as possible. The maximum frequency usable is limited by the cable crosstalk in a repeater section, and the number of repeater sections required on any route.

With these limitations the more general types of cable carrier systems in use in various countries and their particular application are shown in Table I.

TABLE I.

No. of Channels	Frequency Range kc/s.	Application
12	12-60	Selected pairs of V.F. type cables All pairs of carrier type cables
17	4-72	Selected pairs of V.F. type cables All pairs of carrier type cables
24	12-108	Selected pairs of V.F. type cables All pairs of carrier type cables
48	12-204	All pairs of short carrier type cables Selected pairs of long carrier type cables
60	12-252	Most pairs of short carrier type cables

It will be seen that, with the exception of the 17-channel system, the numbers of channels provided by the various systems are multiples of 12. This enables the simplification of the terminal equipment, each terminal consisting of a number of identical 12-channel units followed by suitable frequency translating and combining equipment. This arrangement also permits the use of terminal equipment similar to that used on 12-channel open wire and coaxial cable carrier systems and simplifies the interconnection of systems of all types.

The 17-channel system was designed to operate in the frequency range of 4-72 kc/s in spite of the disadvantages involved in using the 4-12 kc/s range. The difficulties in impedance matching and amplifier design were overcome successfully, and as the maximum distance over which the systems are at present operating does not exceed 120 miles, there has been no necessity so far to provide automatic regulating equipment to compensate within close limits for attenuation variation with temperature.

Repeater Spacing: The maximum spacing allowable between repeater stations based on the maximum attenuation of 57 db is shown for the types of system in use in Australia in Table II.

TABLE II.

No. of Channels	Maximum Repeater Spacing (Miles)	
	40-lb. Carrier Star Quad.	20-lb. local type Star Quad.
12	21.8	12.25
17	20.0	11.2
24	15.8	8.9

Carrier Systems in Use in Australia

The routes on which cable carrier systems are at present in operation, or will be installed in the

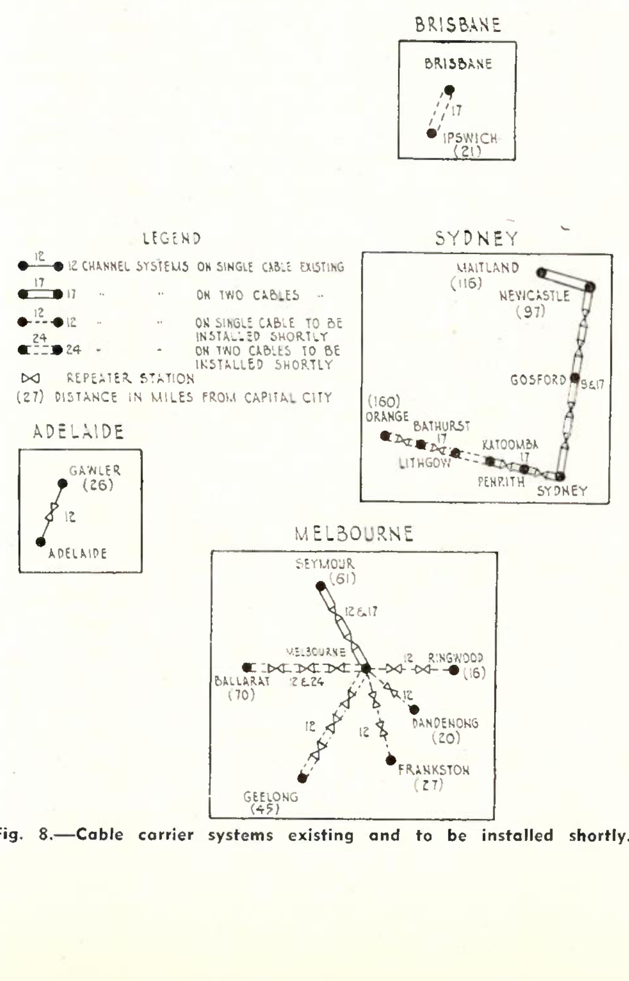
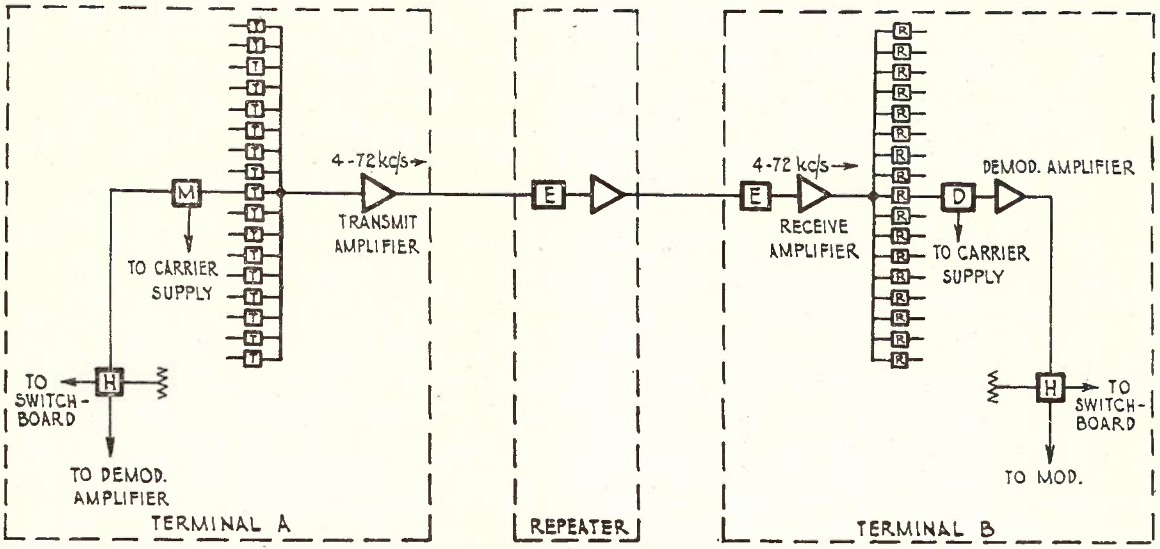


Fig. 8.—Cable carrier systems existing and to be installed shortly.

near future, and the types of system used, are shown in Figure 8. Details of each particular type of equipment will be given in future articles, but a brief review of their essential characteristics is included in this article to enable a comparison to be made.

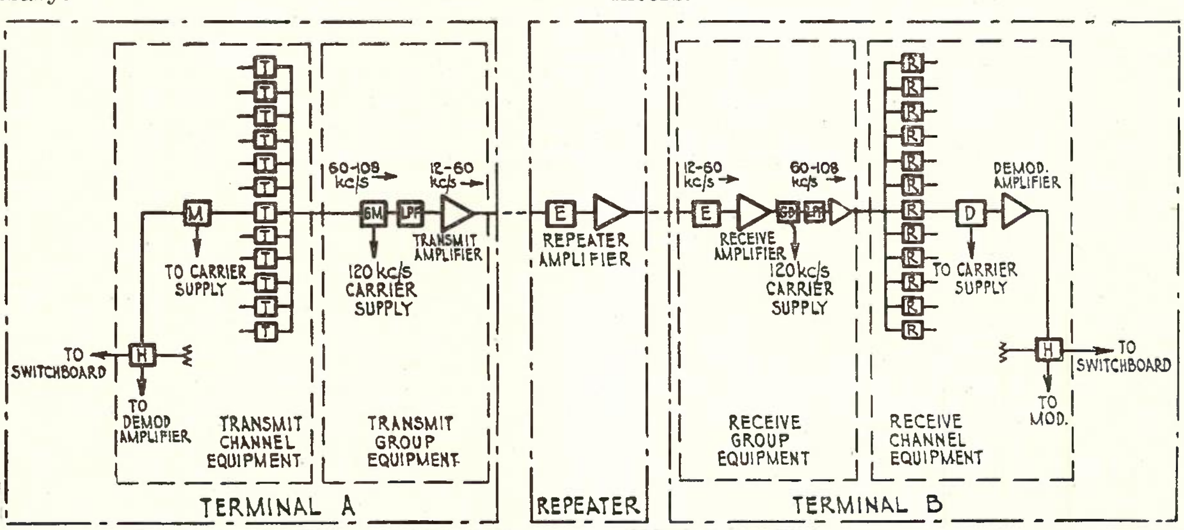


H—Hybrid Coil. E—Line Equaliser. M—Channel Modulator. D—Channel Demodulator. T—Transmit Channel Band Pass Filter. R—Receive Channel Band Pass Filter.

Fig. 9.—17-channel system—schematic showing one direction of transmission.

17-Channel System (13). A block schematic showing the equipment required for one direction of transmission of a 17-channel system is given in Figure 9. The equipment is relatively simple and follows generally the technique used in three channel open wire carrier systems. Coil and condenser type channel band filters are used throughout the system, and in order to obtain the required channel bandwidth at the higher frequencies very careful design and manufacture are necessary.

12-Channel System (4), (5), (14): Figure 10 is a block schematic of equipment required for one direction of transmission of a 12-channel system. It will be seen that the individual channels are first modulated and combined to produce a 12-channel group in the range 60-108 kc/s. This group is then modulated with a 120 kc/s carrier frequency and the lower sideband selected to obtain the 12-60 kc/s band for transmission over the cable. The chief reason for this method of generation of the cable frequencies is to permit the use of crystal type band filters, which are most economical for frequencies above 50 kc/s. Crystal band filters enable a very good channel frequency response to be obtained at a cost slightly less than that of coil and condenser type filters.

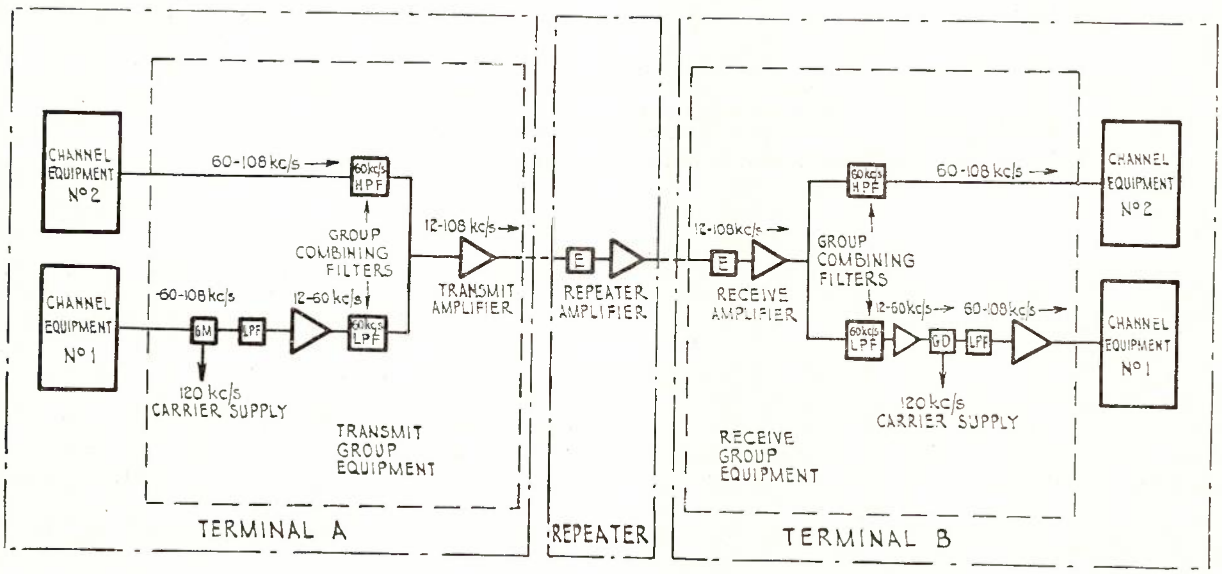


E—Line Equaliser. H—Hybrid Coil. M—Modulator. D—Demodulator. GM—Group Modulator. GD—Group Demodulator. LPF—Low Pass Filter. T—Transmit Channel Band Pass Filter. R—Receive Channel Band Pass Filter.

Fig. 10.—12-channel system—schematic showing one direction of transmission.

The channel equipment for the 12-channel cable carrier system up to the 60-108 kc/s point is identical with that used in the type "J" 12-channel open wire carrier system, which was described in a previous article (15). The channel equipment comprises the major portion of the terminal equipment, the group modulators and demodulators being comparatively inexpensive.

24-Channel System (16): In 24-channel cable carrier systems, the 12-60 kc/s frequencies of a 12-channel system are combined with a second 12-channel group in the 60-108 kc/s range to form a 12-108 kc/s band for transmission over the cable. A block schematic showing the equipment required for one direction of transmission is given in Figure 11. Each channel equipment is identical, an advantage from both the manufacturing and maintenance aspects. As in the case of the 12-channel system, the channel equipment comprises the major portion of the terminal equipment.



GM—Group Modulator. GD—Group Demodulator. E—Line Equaliser. LPF—Low Pass Filter. HPF—High Pass Filter.

Fi. 11.—24-channel system—schematic showing one direction of transmission.

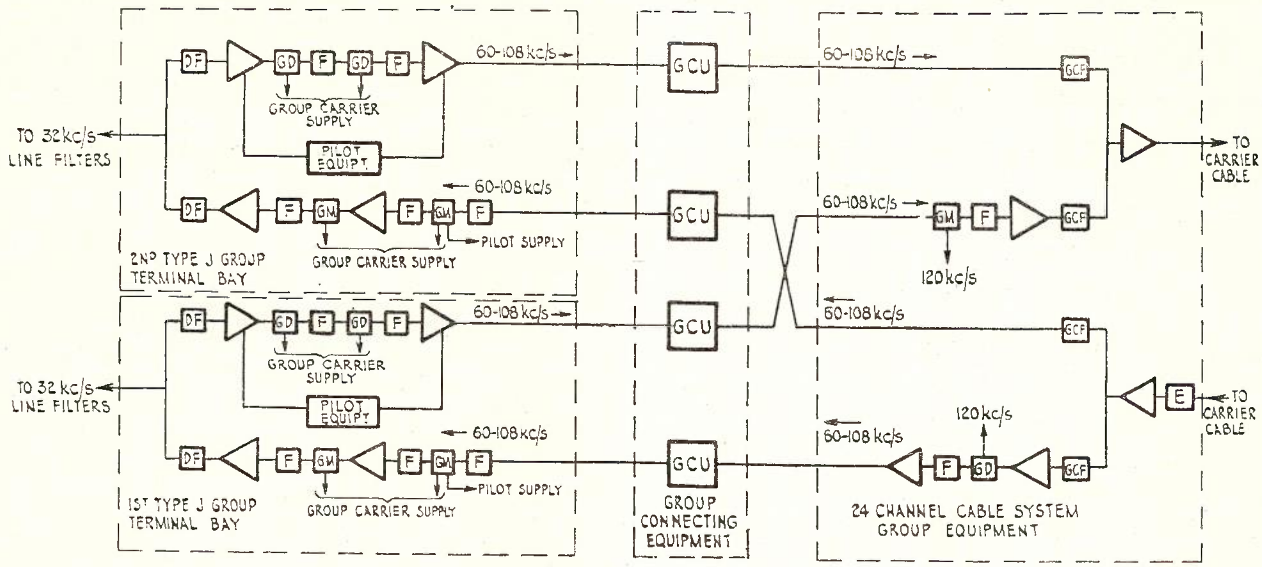
Group Connection of Carrier Systems

The standardisation of channel equipment in 12- and 24-channel cable, 12-channel open wire and coaxial cable carrier systems permits a very simple means of interconnecting systems of different types without demodulating all channels of the 1st system to voice frequencies and then modulating again to the line frequencies of the 2nd system. This effects a considerable saving in terminal equipment costs, the channel equipment in both connected terminals being unnecessary, and the frequency response of the overall channels is also improved, due to the reduction in the number of band filters in each channel. Figure 12 shows the means of connecting a 24-channel cable system to two 12-channel open wire carrier systems. It will be seen that the systems are connected at the 60-108 kc/s points by means of group connecting units. These consist chiefly of level adjustment pads and filters to prevent the transfer between systems of unwanted group modulation products, and pilot frequencies used for the control of automatic gain regulating equipment.

Economic Application of Cable Carrier Systems

When additional trunk line facilities are required on a route and the total number of channels involved and the route conditions are such as to warrant the provision of a trunk cable, the relative economics of a carrier type cable scheme and a voice frequency cable scheme, such as the Melbourne-Geelong type (17), must be considered. Except where a relatively small number of channels is involved, the cost of a new carrier type cable itself is less than that of a new voice frequency type cable giving the same channel capacity, due to the reduced number of cable pairs required in the carrier type cable. However, the equipment cost involved is much greater with a carrier type cable installation than with a voice frequency type cable, and it is found that the carrier type cable is economical only over a certain minimum distance, this distance depending on the number of channels to be provided and on other factors peculiar to the route under consideration.

Where a voice frequency cable installation has already been provided on a route and extended facilities are required, the minimum distance for which it is economical to operate carrier systems on the existing cable, rather than to provide an additional voice frequency type cable, is less than the case considered above, as the cost of providing the carrier type cables is not involved. In some of these cases, although the distances involved are in the range where voice frequency operation is economical, the availability of carrier equipment and the speed of installation is an important factor in providing urgent traffic relief and carrier working may be adopted for this reason. Examples of the operation of carrier systems on existing cables to provide urgent relief, even though the facilities could be provided more economically by voice frequency type cables, are the junction carrier installations of the type previously described in this journal (12).



E—Line Equaliser. GM—Group Modulator. GD—Group Demodulator. F—Filter. GCF—Group Combining Filter. GCU—Group Connecting Unit. DF—Directional Filter.

Fig. 12.—Connection of 24-channel cable and Type J 12-channel open wire carrier systems without demodulating channels to voice frequencies.

In cases where the channels provided on a cable route are to be extended on 12-channel open wire or other cable routes, group connection will effectively save a large part of the cable carrier terminal equipment cost. In this case the minimum distance for which cable carrier operation is economical, as compared with voice frequency cable operation, is further reduced.

The economics of the different types of cable carrier working in comparison with voice frequency cable operation will be dealt with in detail in a subsequent article.

Future Developments

Carrier type cables of the Sydney-Maitland type are at present being laid on several routes in Australia, and a large programme for the future provision of cables of this type has been planned. However, subsequent development for new routes must be limited by the introduction of coaxial cable carrier systems, which are at present used extensively in Great Britain and the U.S.A. These coaxial cable systems are capable of providing a larger number of channels than is provided by two 24-pair carrier type cables carrying 24-channel carrier systems, and the cost per channel is generally less than that of the cable carrier systems. After the introduction of coaxial systems in Australia, it is probable that further installations of cable carrier type equipment will be confined largely to existing carrier cable routes, and to trunk line relief on existing voice frequency type cables.

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THE INSTALLATION OF A GAS PRESSURE ALARM SYSTEM ON AERODROME CONTROL CABLES — DARWIN

S. J. Byrnes

Darwin is situated in the North of Australia and is the first landing place for overseas aeroplanes flying to Australia via Singapore and Java. Before the recent war the facilities at the Darwin aerodrome were limited, but during the war they were greatly expanded to cope with the needs of the Armed Forces. Developments in radio aids to navigation were made during the war, and many of these have been installed in the Darwin area.

One of the main aids is radio communication between the aircraft in flight and the control station at the aerodrome. At Darwin, the radio receiving station operated by the Department of Civil Aviation is situated at the aerodrome, while the transmitting station is located at a point approximately 7 miles away. The communication cables between these two points were installed during the war by various sections of the Defence Services, including the U.S. Army. As the need to provide service without delay was urgent, it was necessary to use the cable on hand, even although it was not the type that would normally be used for a work of such importance. Service was provided by sections of aerial cable, as well as unarmoured cable, single and double steel tape armoured cable and wire armoured cable laid underground.

Arrangements have been made for the installation by the P.M.G. Department of a new cable system in association with the provision of new receiving and transmitting stations for the Department of Civil Aviation, but, owing to the general shortage of material and manpower, it has not been possible to carry out this work immediately. In the meantime, it was essential that failures on the existing cable be reduced to a minimum on account of the importance of the circuits involved, and the serious disruption of air services likely to be associated with a failure. For this reason the P.M.G. Department was asked to instal a gas pressure alarm system on the control cables.

Although some misgivings were felt whether the scheme would be successful, on account of the number of incipient sheath failures likely to exist because of severe termite attack and intercrystalline fracture, it was decided to proceed with the work. The advantages of such a system are that existing faults in the cable sheath are located and remedied during the installation of the system. If further faults occur in the system later, an alarm is given at the control station when the pressure in the cable drops to a pre-determined figure. At the same time, the escape of the gas from the cable prevents moisture entering unless the hole in the sheath is very large. (See Telecommunication Journal of Australia, Vol. 5, No. 1, page 22, for details of the gas pressure alarm system.)

The installation was carried out by the author from the Cable Protection Staff, Melbourne, with the assistance of cable jointing staff from Adelaide and Darwin, who obtained experience during the installation which was of value during subsequent maintenance. As the impending wet season (November, 1948-March, 1949) was near at hand, the staff and all material necessary for the installation and the initial period of maintenance were transported by air to Darwin. Approximately 3000 cub. ft. of compressed air and 400 cubic feet of acetylene gas were used during the installation of the gas alarm system.

On the night of arrival in Darwin the town had its first fall of rain for seven months, resulting in the failure of the cables at many points. After surveying the layout and construction of the route, it was considered that some sections were likely to have fewer faults than others, due to the type of cable; and with this thought in mind, it was decided to commence the installation on the assumed good sections. The installation work was, therefore, grouped broadly into three cable sections, namely:

Section A—Aerial cable.
Section B—Underground cable between the aerodrome and Berrimah repeater station.
Section C—Underground cable between Berrimah repeater station and the radio transmitting station.

The general layout of the cable system and the disposition of the gas alarm equipment is shown in Fig. 1. Briefly, the procedure in dealing with each section of cable involved four main operations, the installation of compound filled seals to form gas-tight cable sections; the charging of the cable with dry compressed air; the location and repair of sheath failures, and the installation of gauges and alarm equipment.

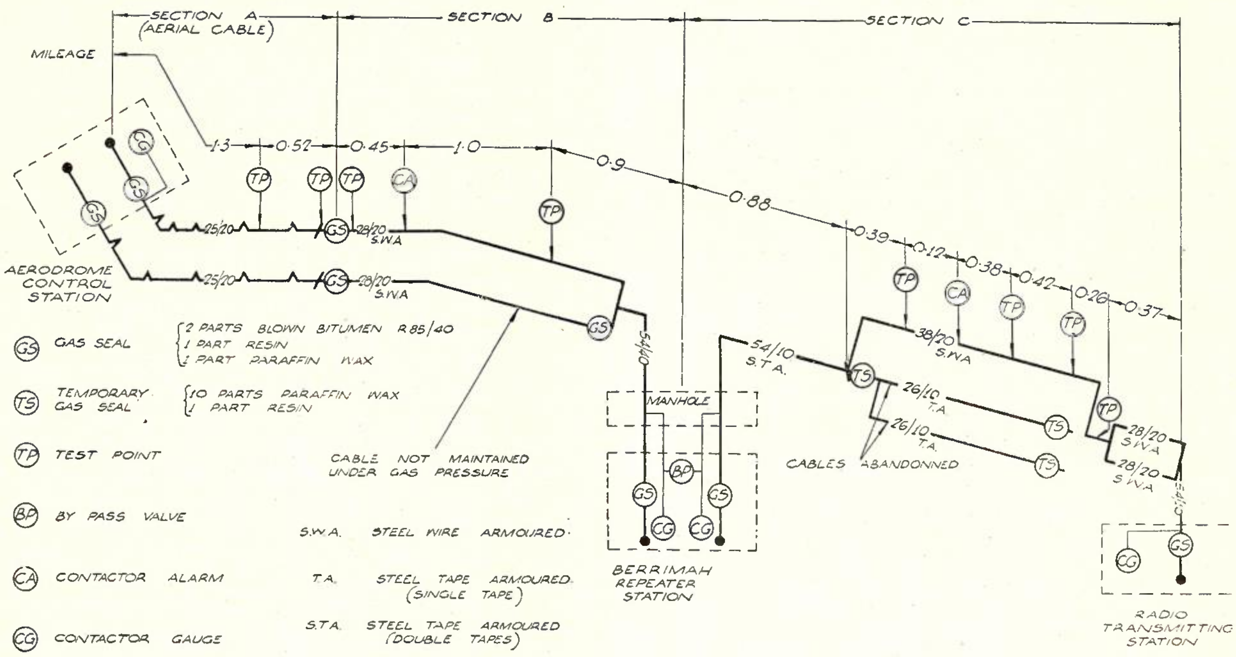

Fig. 1.—Layout of cables and gas pressure alarm system.

Gas-tight Seals

Normally, in a cable length of 7 miles, gas seals would be located at each end only, and alarm contactors provided at intermediate points. In the present case additional gas seals were required at the junction between aerial and underground cables, and also to seal off some sections which were too full of sheath fractures to warrant repair.

Due to the climatic conditions, considerable difficulty was experienced in sealing the cables with the normal cable sealing compound, which is used in the more temperate climate of Melbourne. A preliminary injection of seals was carried out on several short lengths of cable to determine the degree of solidification of the compound. These lengths were then housed in manholes and, in one case, a cylinder of air, set at a discharge rate of 10 lbs./sq. inch, was left connected to a valve located on the end of one length. Thermometers were suspended in the manholes and temperature readings were recorded at various intervals during the day and evening for two consecutive days. The lowest reading recorded was 92°F at 8 a.m. on the first day, and the highest reading was 110°F at 11.30 a.m. on the second day.

One seal broke down immediately a pressure of 5 lbs./sq. inch was applied, the second, five hours after a pressure of 10 lbs./sq. inch was applied; while the third, which had the cylinder connected to it, showed signs of holding until midday on the second day, when a slight leak was apparent. In the case of the first seal, the compound had forced its way up the threads on the injector flange and oozed out over the cable sheathing. When the injector flange screws were removed, the compound immediately beneath was found to be quite pliable in all cases.

Owing to the short time available it was not possible to experiment with compounds of other mixes. It was therefore decided to seal the cables indoors where possible, preferably where a draught of cool air was prevalent. In cases where the cables were sealed in the field, they were housed in locally constructed jointing pits, with the pit lids raised on sheets of corrugated asbestos cement, thus causing a draught through and over the pit. (See Fig. 2.) In addition to this, at the aerial cable head, electrolysis type insulating joints were installed on either side of the gas seals in an endeavour to keep the sheathing surrounding the gas seals reasonably cool, by preventing heat conduction along the cable sheath.

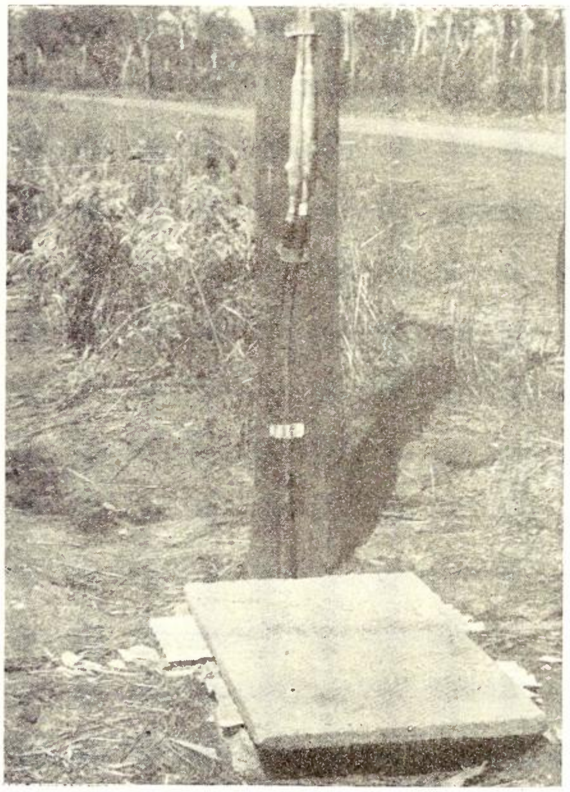

Fig. 2.—Junction between aerial and underground cables. Gas-tight seal in jointing pit with raised cover.

Section A—Aerial Cables

The aerial cables consisted of two 25 pair 20 lb. unarmoured cables, and the joints between these cables and the two 28 pair 20 lb. steel wire armoured underground cables were located on a pole six feet above ground level. As the atmospheric pressure in the aerial cables varied from dawn onwards, a problem which had to be overcome was the sealing of the cables without this increased pressure affecting the seal make-up, by creating a void during cooling operations. This was affected eventually by preparing the cables during the afternoon and pouring the seals during the early evening.

Having completed the seals between the aerial and underground cables, compressed air was forced into the aerial cables. One cable held pressure when charged, but the second one would not hold air long enough to enable the location of the leaks. As the time to carry out the complete installation was limited, and the condition of the underground cables was not known, no attempts to locate the leaks in the second aerial cable were made.

Section B—Underground Cable between the Aerodrome and Berrimah Repeater Station

Having sealed the cables terminating in the Berrimah repeater station, and also having placed a seal in an intermediate branch cable, and being hopeful that the seals at the aerial cable head would hold, the initial charging operations in the two lengths of underground cable from the aerial cable head to Berrimah were commenced. Cylinders of compressed air, containing 100 c. ft. were connected at a discharge rate of 10 lbs./sq. inch to the cables at strategic points en route. These were alternatively changed from position to position to assist in the rapid acceleration of the charging of the cables. Great care was taken at all times to conserve the compressed air, as supplies could not be obtained locally, and the nearest source was approximately 2000 miles away.

While the cables were being charged in this section, operations were commenced at the Berrimah repeater station upon the installation of contactor gauges, by-pass valves, test points, notice boards and numerous bearers to support the seals and the cables associated with the cables being put under pressure.

Leak location tests taken in the section after charging showed that bad housing of cables in pits was the cause of many fractures of the sheathing. It was also apparent that there was a fairly large leak in one of the 28 pair 20 lb. steel wire armoured cables approximately half a mile from the aerial cable head towards Berrimah. As the fault was near to one end of the section, and the air was escaping at a rapid rate, it was not

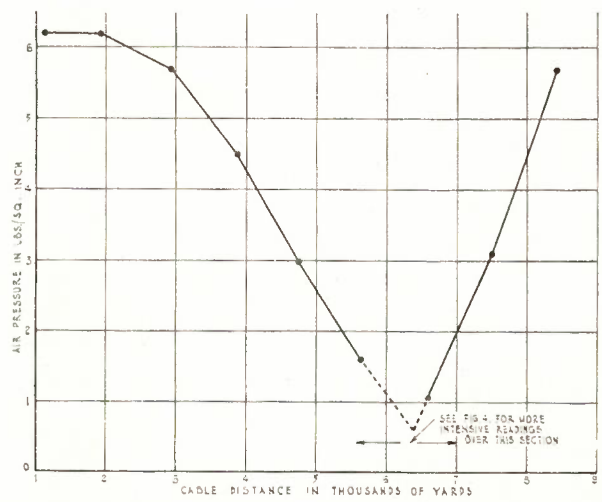

Fig. 3.—Fault location graph for 5 miles of cable on Section B.

possible to obtain an accurate location by plotting pressure readings against route distance. A longer section was obtained by looping together the two 28 pair cables at the aerial cable head by means of a rubber tube. This created a temporary five mile section with the fault approximately in the centre. Pressure readings were taken, and the resultant graph is shown in Fig. 3. The graph indicates that the fault is approximately 6400 yards from the beginning of the section.

While the section was being re-charged, additional test points were fitted in the half-mile sec-

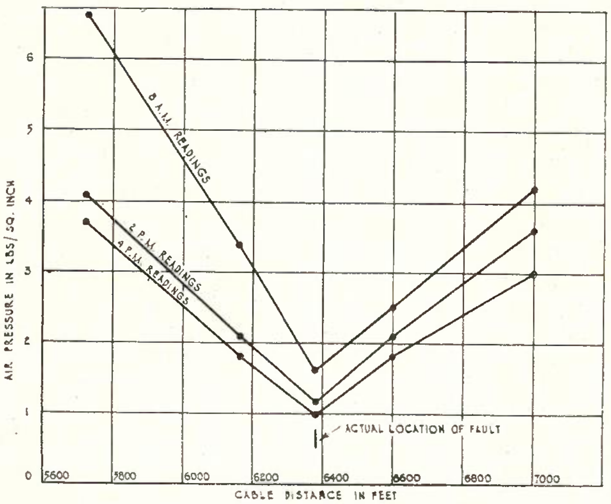

Fig. 4.—Fault location graphs for 1400 feet of the 5-mile section referred to in Fig. 3.

tion in the vicinity of the fault, dividing it into three equal sections. The position of the fault was gradually narrowed down, by fitting further test points and taking pressure readings. Tests finally showed that the leak was so close to one of the test points that there was not sufficient air in the immediate vicinity to register on a six inch 0-15 lbs. Bourdon pressure gauge. Compressed air was charged into the cable in the area of the fault for ten minutes and then disconnected. An effort was made to read the cable at ten minute intervals at test points on either side of the fault over a section of half a mile; but the flow was so great that the readings were of little use.

Two regulators were then checked for comparison of discharge and pressure creep, and two cylinders were connected to the cable half a mile apart on either side of the fault, in an endeavour to form a constant pressure gradient. Three series of pressure readings were taken during the day, and the resultant graphs, shown in Fig. 4, were similar in shape and gave an accurate location of the fault. After repairs to this fault had been effected and the cable re-charged, further tests indicated that there were still two more smaller leaks in the same half-mile section. All three faults were due to inter-crystalline fracture, which possibly may have been caused prior to installation when the cable was subjected to continual exposure to the sun over a long period before laying and to extensive vibration during transport.

In view of this experience, pot holes were sunk at various intervals over the half-mile section, and, as it appeared that the whole length was affected with intercrystalline fracture, it was decided, rather than replace the length, to seal the faulty cable adjacent to Berrimah and concentrate on one 28 pair 20 lb. cable which contained sufficient pairs for the important services. Moreover, one of the two aerial cables had already been abandoned for a similar reason. The second cable was soon made gas-tight, and thus a gas-tight cable from the aerodrome control room to Berrimah was obtained. A contactor alarm was installed in this section, the alarm being mounted on a pillar as shown in Fig. 5, and not in a manhole as is the usual practice.

Section C—Underground Cable between Berrimah Repeater Station and the Radio Transmitting Station

After completion of Section B, operations were commenced between Berrimah and the transmitting station. As most of the cable failures over the past 12 months had occurred in the two 26-pair 10 lb. single tape armoured cables in this section,

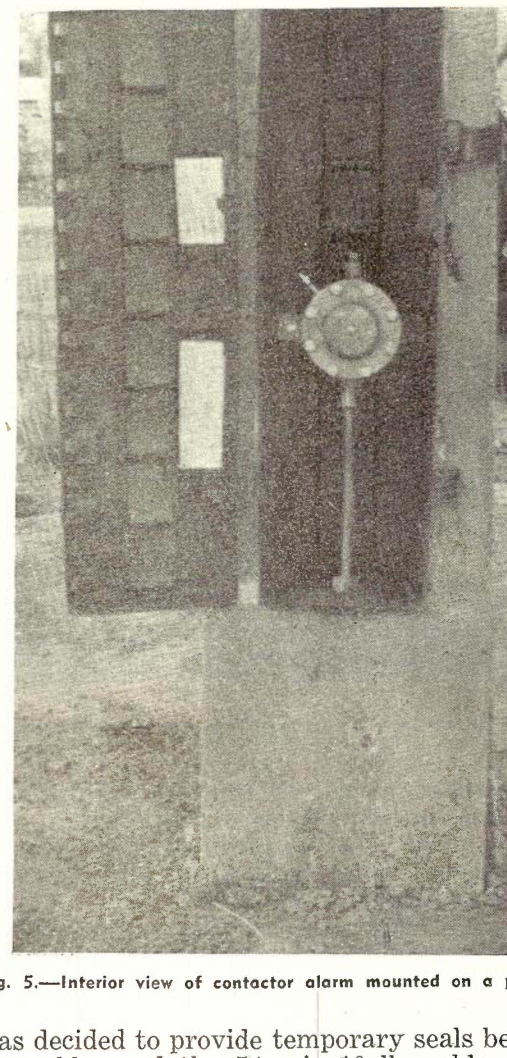

Fig. 5.—Interior view of contactor alarm mounted on a pillar.

it was decided to provide temporary seals between these cables and the 54-pair 10 lb. cable at one end, and between the same cables and the 28-pair 20 lb. steel wire armoured cables at the other, before commencing charging operations. By separating the sections in this manner for the initial charging, the fault location in each section was simplified.

The resulting temporarily sealed sections were charged, and whilst waiting for the pressure to stabilise the contactor alarm gauge was installed and mounted in the transmitter equipment room. A vertical gas-tight seal was injected into the 54-pair 10 lb. cable at the transmitters, the seal being placed on a wall adjacent to louvres, which are permanently kept open. (See Fig. 6.) Fault location in each of the three sections was then commenced. The faults located in the 54-pair 10 lb. steel tape armoured section from Berrimah to the junction with the two 26-pair 10 lb. cables, before it was gas-tight, were due to:—

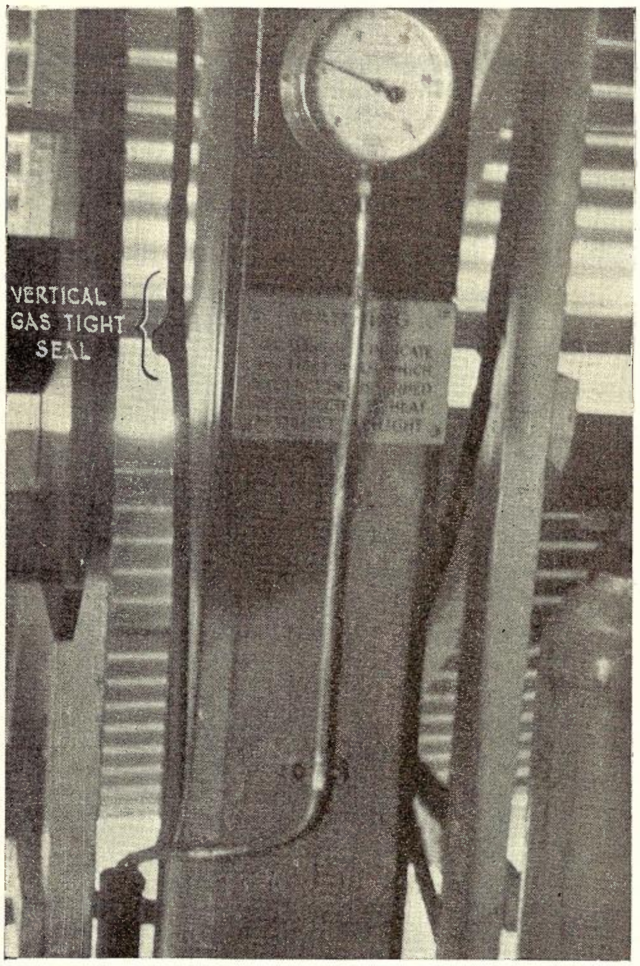

Fig. 6.—Contactor gauge and gas-tight seal in radio transmitting station.

(a) Armouring cutting the sheath during laying operations.
(b) Termites in ducts attacking the sheathing in numerous places.
(c) Damage to cable in ducts through rodding, and,
(d) Flaws in manufacture.

During the initial stages of fault location in this section, two cylinders of compressed air were again used, connecting them to the cable a quarter of a mile apart on either side of the suspected fault. They were checked and set at a discharge rate of 10 lbs./sq. inch for a period of fifteen minutes, and then disconnected simultaneously. After an interval of five minutes, three sets of readings were taken at five minute intervals by which time the pressure had dropped to practically zero. The readings obtained, when plotted and graphed, resulted in a fairly constant gradient and a reasonably accurate indication of the location of the fault, as shown in Fig. 7.

Several short lengths, totalling approximately 40 yards in each, had to be replaced in the 28-pair 20 lb. steel wire armoured cables between the junction with the 26-pair 10 lb. cables and the transmitters. There were many fractures in the sheathing of both cables, several being caused by a fire at one time passing over a H-girder on which the cables cross an open drain 30 feet in width. When these faults had been rectified, the cable was again charged with air, and this time there were no leaks.

An interesting feature at one stage of plotting in this section was that readings taken within half an hour of each other during one of the tests showed that, although the graphs differ appreciably, each gave a good approximation of the position of the fault. (See Fig. 8.)

Having re-charged the temporarily sealed sections of the 26-pair 10 lb. single tape armoured cables, attempts were made to locate some of the leaks. However, it was found that it was impracticable to charge either of these cables in any one part long enough to carry out leak location tests.

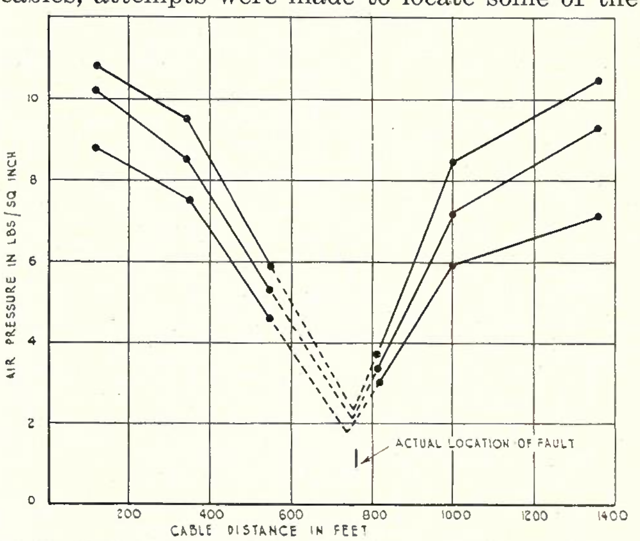

Fig. 7.—Fault location graphs for 54-pair cable on Section C taken at five-minute intervals.

One instance of this was at a point adjacent to the junction with the 28-pair 20 lb. cables. Both cables were looped together with a length of $^3/_{16}$" internal diameter rubber hose, and cylinders of compressed air, discharging at the same relative pressure, were connected one to each cable, 400 yards distant. Test points were fitted on both cables at spacings of 132 ft. between the cylinders and where the cables were looped, and it was found that at several of these points there was not sufficient air in the cable to register a reading on a 6-inch, 0-15 lb. pressure gauge. When the cylinders were turned off, there was not a sign of air at any of the points after an interval of five minutes. The cables are single tape armoured, and have been damaged by termites, which were able to enter through the $^3/_{16}$" gap existing between each turn of armouring and attack the sheathing.

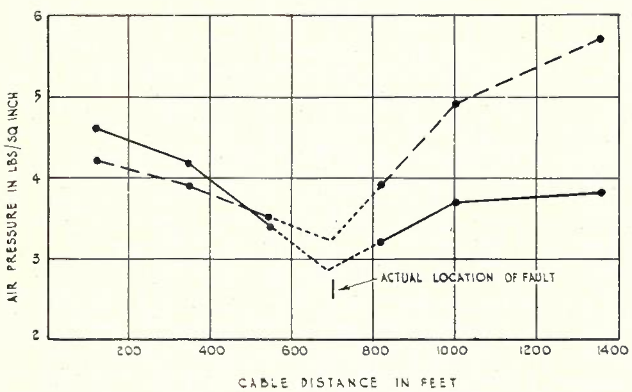

Fig. 8.—Fault location graphs for 28-pair cable on Section C.

As it was not possible to repair these cables, it was decided to replace both cables by one 38-pair 20 lb. steel wire armoured cable. The cable was pressure-tested before laying, and when laid and jointed to the 54 and the two 28-pair cables the whole section from Berrimah to the transmitting station was charged with gas, and after stabilising was found to be gas-tight. The temporary seals at the junctions of the 54-pair 10 lb. and 28-pair 20 lb. cables with the 26-pair 10 lb. cables, had been installed in such a way that they were cut away when the 26-pair cables were abandoned.

An external view of the mounting of the contactor alarm in this section is shown in Fig. 9.

During the installation all cables were charged to a pressure of 15 lbs./sq. inch. This was then reduced to 10 lb./sq. inch, which was the final pressure left in the cable, the contactors and contactor gauges being set to operate at a pressure of 5 lbs./sq. inch. The alarms from the aerodrome control room, the transmitting station and the field alarms were extended back to Berrimah via pairs in the respective cables.

In order to carry out the initial maintenance of the system sufficient plant and equipment was left at Darwin, and the staff instructed as fully as possible on the duties associated with the maintenance of the system.

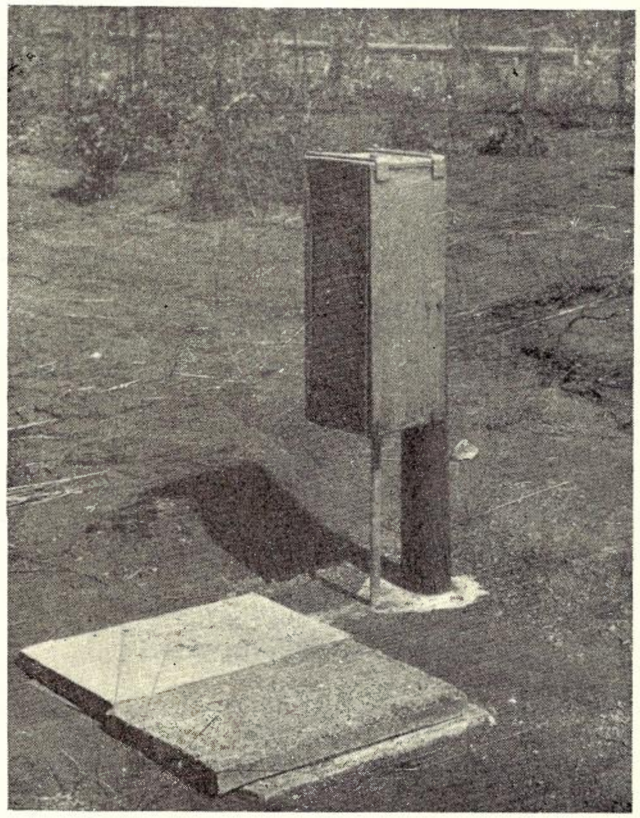

Fig. 9.—Exterior view of mounting for a contactor alarm.

The successful placing of the cable under gas pressure, despite a number of unusual difficulties, and at a distance of more than 2000 miles from the main source of material supplies, was a matter of considerable satisfaction to those engaged upon the work. The problems encountered in cable sealing, charging the cable with gas, and leak location, had a number of unique factors, the solving of which has contributed materially to gas pressure alarm experience generally. It is pleasing to record that since the system has been installed no breakdown of the cable has occurred over a period of eight months, including the "wet" season, despite several sheath breaks.

CONTROL TERMINAL EQUIPMENT FOR OVERSEAS RADIO TELEPHONE SERVICES

W. O. Gibberd, M.Sc., A.M.I.E.(Aust.)

Introduction: Long distance radio telephone circuits differ from the relatively stable long distance line telephone circuits in that they are subject to considerable variations which require special treatment to ensure that satisfactory conditions are obtained. In this paper a brief description is given of the principal features of a Western Electric, type C3, radio control terminal, four of which were installed recently in Sydney, on the London and San Francisco radio telephone circuits. These control terminals reduce, to some extent, the effects of the variations of the radio circuit.

Reasons for Using Control Terminals: In the normal four-wire telephone circuits which may be provided by trunk cables, carrier on cable, regulated open-wire carrier systems, etc., the transmission equivalent of the path in each direction does not vary with time. The general arrangement for such a circuit is shown in Fig. 1, and each four-wire/two-wire terminating set consists only of a hybrid coil and network, together with any pads which may be necessary to adjust levels. The main requirement of the terminating sets is that the total loss across the hybrids should exceed the total gain in the two four-wire paths by the maximum amount to prevent "singing" or "near singing" distortion.

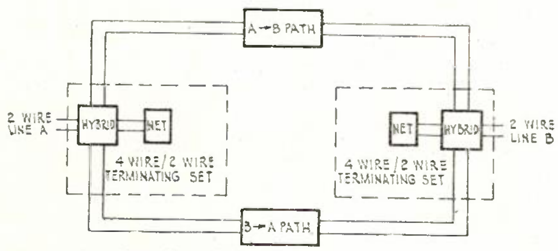

Fig. 1.—Normal four-wire telephone circuit.

In general, the circuits are adjusted to give a zero equivalent between two-wire terminals. If coil type hybrids are used, the total gain in the two paths will then be 12 db. The loss across each hybrid is governed by the balance obtained between the network and the line to which the terminal is connected. In practice a compromise network is selected, and the return loss obtained is sufficient to prevent "singing" and also to reduce echoes to a point where they are not objectionable. In addition, once the circuit is adjusted initially, the balance obtained is usually sufficient to prevent singing when the line attenuation changes slightly with weather conditions.

Short radio links, where the received signal is derived from the direct or ground wave, are similar to the normal four-wire telephone circuits, any variation in received signal being compensated for by the automatic volume control (A.V.C.) feature of the receiver, with the result that the gain of each transmission path is substantially constant. In long radio circuits, however, the circuit has not the desirable features of the line circuits and short radio links. The received signal varies in level, sometimes at a rapid rate, owing to fading. With the phenomenon known as "selective fading" the sideband frequencies may be attenuated by a different amount to the carrier, with the result that the A.V.C. feature is of no avail. Fades of 20 db occur commonly on the overseas radio telephone circuits between Sydney and London and Sydney and San Francisco. Therefore, the equivalent of the path in each direction is a variable factor.

The noise level on radio circuits is often higher than on land lines, and in order to reduce the effect and increase the signal to noise ratio it is necessary to ensure that the radio transmitter is fully modulated by speakers of all volumes. In order to do this a constant volume amplifier, known as a vogad (Voice Operated Gain Adjusting Device) is inserted before the input to the transmitter. The vogad is an amplifier whose gain is varied in accordance with the level of the received speech in such a way that a substantially constant output level is obtained for a large range of input levels.

At the receiver the effect of selective fading is compensated for to some extent by the installation of a "receive vogad" immediately following the output of the receiver. The function of this vogad is to restore the received speech with its variations due to fading to the constant volume form in which it left the transmitter. Thus there are three variable factors in each path, namely, the equivalent of the radio frequency path, the gain of the transmit vogad, and the gain of the receive vogad.

Due to these variations, it is impracticable to use normal four-wire/two-wire terminating sets to combine the sending and receiving paths, as an increase in gain in either transmission path after the initial adjustment could be large enough to cause the circuit to sing.

In order to convert the four-wire radio circuit to a two-wire circuit suitable for connection to the land line network, a control terminal is used at each end of the radio link. This terminal is almost always installed in a locality remote from the radio transmitter and receiver, as the radio stations must be situated where space is available for antenna arrays, and the radio receiver must also be situated in an area free from man-made electrical interference. The control terminal itself combines the sending and receiving paths, usually at a location close to a trunk exchange. Fig. 2 shows the arrangement usually adopted.

Control Terminal Equipment, Vodas Equipment: The term vodas is derived from the initial letters of the phrase, "Voice Operated Device Anti-Singing," and, as the title implies, its purpose is to combine the two radio paths while at the same time preventing the circuit from singing. The control terminal equipment is shown in a simplified form in Fig. 3, and in more detail in

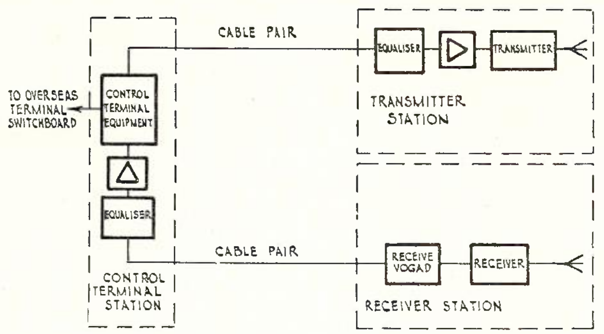

Fig. 2.—Connection of control terminal to radio transmitter and receiver.

Fig. 4. It will be seen that the circuit can be divided broadly into two portions, consisting of a send and receive path connecting the hybrid coil to the radio transmitter and receiver respectively. The circuit is so designed that only one of these paths transmits at any instant. The four relays, TVHO1, TVHO2, TEHO1 and TEHO2, form a relay chain which performs the switching operation. In the normal condition there is a low attenuation in the receive path, and a high attenuation is inserted in the send path. When the relay chain is operated the reverse is the case.

The privacy equipment when equipped consists essentially of metal rectifier type modulators, and use is made of the reversible feature of these modulators to save cost by employing the same equipment in each direction. The two directions of transmission are combined by means of hybrids. The respective paths in the control circuit are suppressed before and after the privacy equipment to guard against singing or echoes around the privacy hybrid coils. As the privacy equipment is separate and distinct from the control terminal, and its operation does not affect that of the control terminal, it will not be described further in this article.

The operation of the switching relay circuit is controlled by voice waves through the medium of amplifier detectors. When speech is received from the radio receiver, it passes through the privacy equipment and the noise reducer, and at this point enters the receive amplifier detector, which is bridged across the circuit. The speech is rectified, and as a result the RM relay is operated. This in turn operates the REHO (receive echo hold over) relay, which prevents the operation of the relay chain and "locks" the terminal in the receiving condition. At the conclusion of the received speech the RM relay is released and the circuit restored ready for transmitted speech. A short delay of 20 milliseconds is introduced by the REHO relay to guard against false operations of the chain by echoes received from the land line.

When speech is received from the land line it passes through the hybrid coil and transmit vogad, where it enters the transmit amplifier detector, which is bridged across the circuit at this point. Provided that no speech is being received from the distant terminal, the relay chain will operate and convert the terminal to the sending condition. The speech waves then travel via the privacy equipment to the radio transmitter.

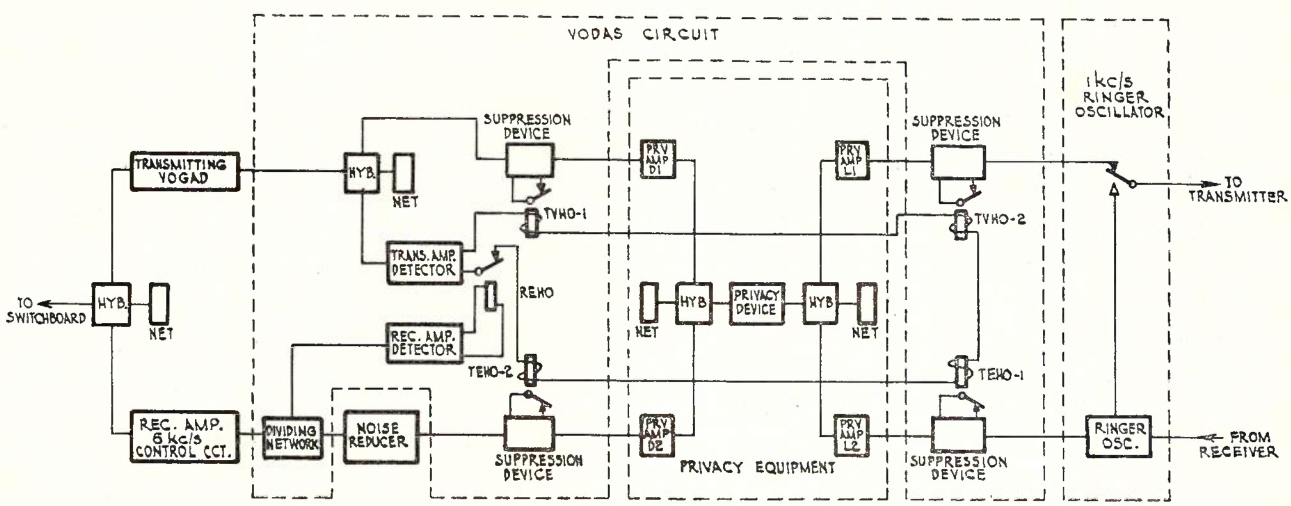

Fig. 3.—Control terminal, simplified block schematic.

Suppression is obtained in the send direction by a short circuit which is placed across a high impedance portion of the circuit by relays. In the receive path suppression is obtained by means of hybrid coils. In the normal condition the hybrids are unbalanced, allowing through transmission, but when the relay chain is operated the hybrids are balanced and an attenuation of approximately 100 db is inserted.

Vogad Equipment: The vogad is essentially a variable gain amplifier, whose gain is varied in such a manner that input volume levels in the range -41 Vu to +4 Vu produce an output volume which varies about a constant value of approx. +10 Vu. This value is an average value, and variations of 3db from it are allowed to occur in order that the inflections of speech may not be entirely lost, and thus the identity of the voice is maintained. The gain of the vogad assumes a value of 30 db in the idle condition, that is, with speech of values less than -41 Vu incoming, and it may vary between 6 db and 51 db in the normal operating condition.

The vogad gain is varied by a combination of a variable loss metal rectifier network and a pair of variable mu valves arranged in a push-pull circuit. A gain increaser circuit increases the gain as soon as speech frequencies are applied until the output volume is approximately +10 Vu, after which a gain decreaser circuit operates and prevents further increases in gain. A disabling feature is incorporated, so that the gain of the vogad does not change appreciably from its previous transmitting gain during the times when speech is being received from the distant end, thus preventing sudden changes in gain when speech is resumed from the transmitting end. The vogad is disabled by means of a relay (VD) which is operated by the RM relay in the receiving amplifier detector circuit, when speech is received from the distant terminal.

6 kc/s Control Equipment: In the case of a radio circuit equipped with control terminals, there is no danger of singing, as the terminal transmits in one direction only at any instant.

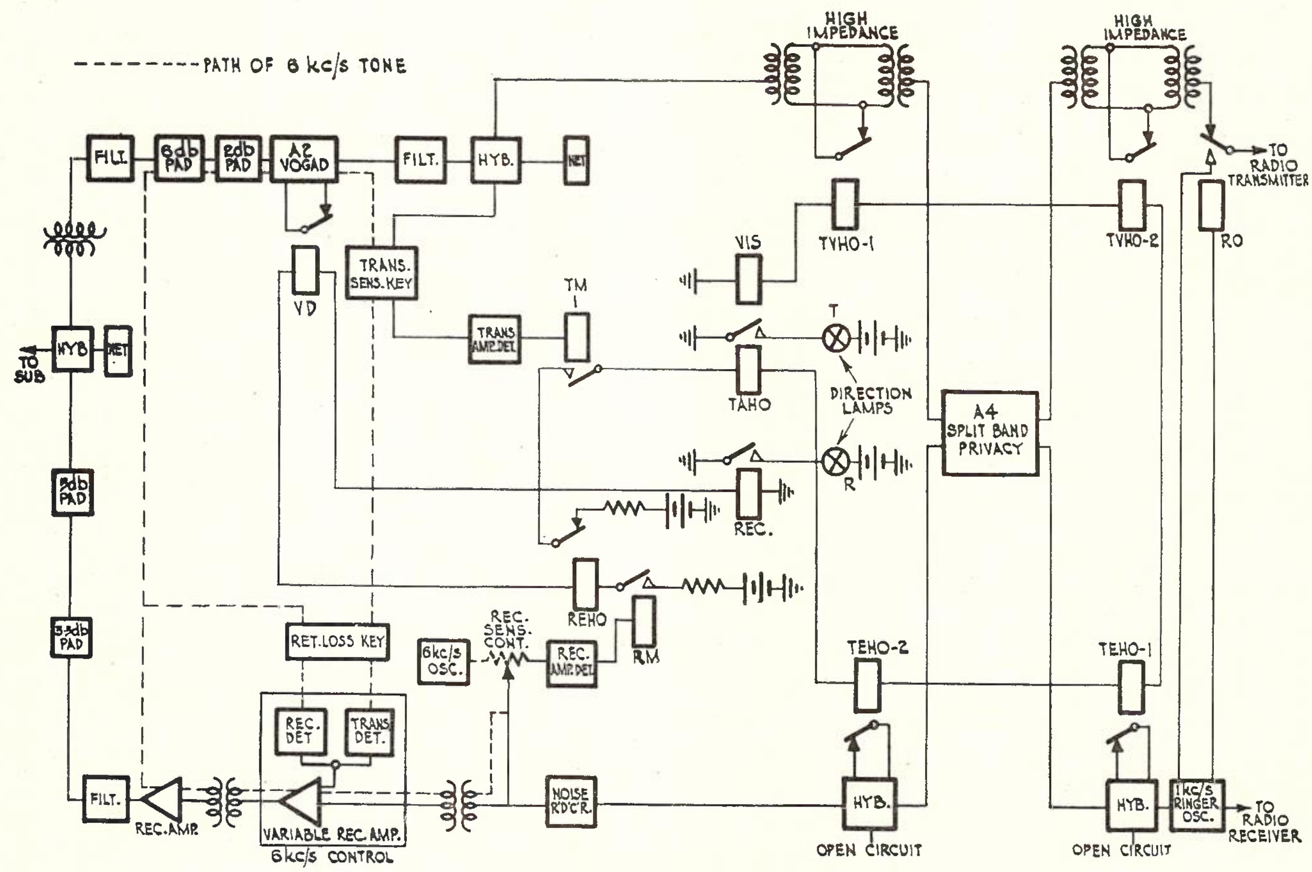

Fig. 4.—Control terminal, block schematic.

However, the return loss of the land line against the network across the hybrid coil is still important, as there is a danger that echoes of received speech, which are transmitted across the hybrid coil, may be amplified by the vogad and give false operation of the transmit amplifier detector.

If the received speech is sufficiently strong to operate the receive amplifier detector, then the operation of the transmit amplifier detector is prevented by relay REHO. The VD relay in the vogad is operated by the RM relay of the receive amplifier detector, and this relay when operated disables the vogad. Thus variation of the vogad gain, and false operations of the transmit amplifier detector, are prevented when the receive amplifier detector is operated.

It is possible, however, that echoes from received speech, which are too weak to operate the receive amplifier detector, may operate the transmit amplifier detector, and thus reverse the circuit. This must be avoided by ensuring that in this condition the effective sensitivity of the transmitting amplifier detector is kept sufficiently low relative to the sensitivity of the receive amplifier detector. The number of db by which this false operation is guarded against is known as the echo margin. Referring to Fig. 3, if

Sr is the sensitivity of receive amplifier detector,
St is the sensitivity of transmit amplifier detector,
Vg is the gain of vogad,
Rl is the loss across the hybrid,
E is the echo margin,
and Gr is the gain of the receive amplifier,
then E = (Sr – St) + Rl – Vg – Gr.

The transmit amplifier detector sensitivity St is set permanently at its optimum value, but the receive amplifier detector sensitivity Sr is adjusted from time to time by a Technical Operator to ensure that the RM relay will operate on speech levels just above the varying noise level on the radio circuit. The loss across the hybrid coil Rl varies with the line connected at the switchboard, but the minimum loss obtained is generally not less than 5 db. The gain of the vogad, Vg, varies with the level at its input as discussed previously.

In order to maintain a positive echo margin with the minimum loss of 5 db through the hybrid coil for all possible settings of Sr and for varying values of Vg, it is necessary that the receiving amplifier gain Gr should be automatically set so that Gr + Vg – Sr is constant.

In the Western Electric equipment, the 6 kc/s control circuit is used to vary the gain of the receive amplifier to achieve this. A 6 kc/s tone, which is generated by a stable oscillator, is passed through a differential potentiometer to the receive circuit in front of the variable receive amplifier, as shown in Figs. 4 and 5. The tone is restricted by low pass filters to the path shown by dotted lines in Fig. 4 and solid lines in Fig. 5. The differential potentiometer also adjusts the receive amplifier detector sensitivity, and is wired so that the level of the 6 kc/s tone is reduced when the sensitivity is increased, and vice versa. The level of this tone when introduced into the main receive circuit is thus K – Sr where K is constant. The tone passes via the receiving amplifiers and the vogad to the transmit detector input, where its level is K – Sr + Gr + Vg. The tone is rectified and used to bias a variable mu valve in the variable receive amplifier in such a manner that

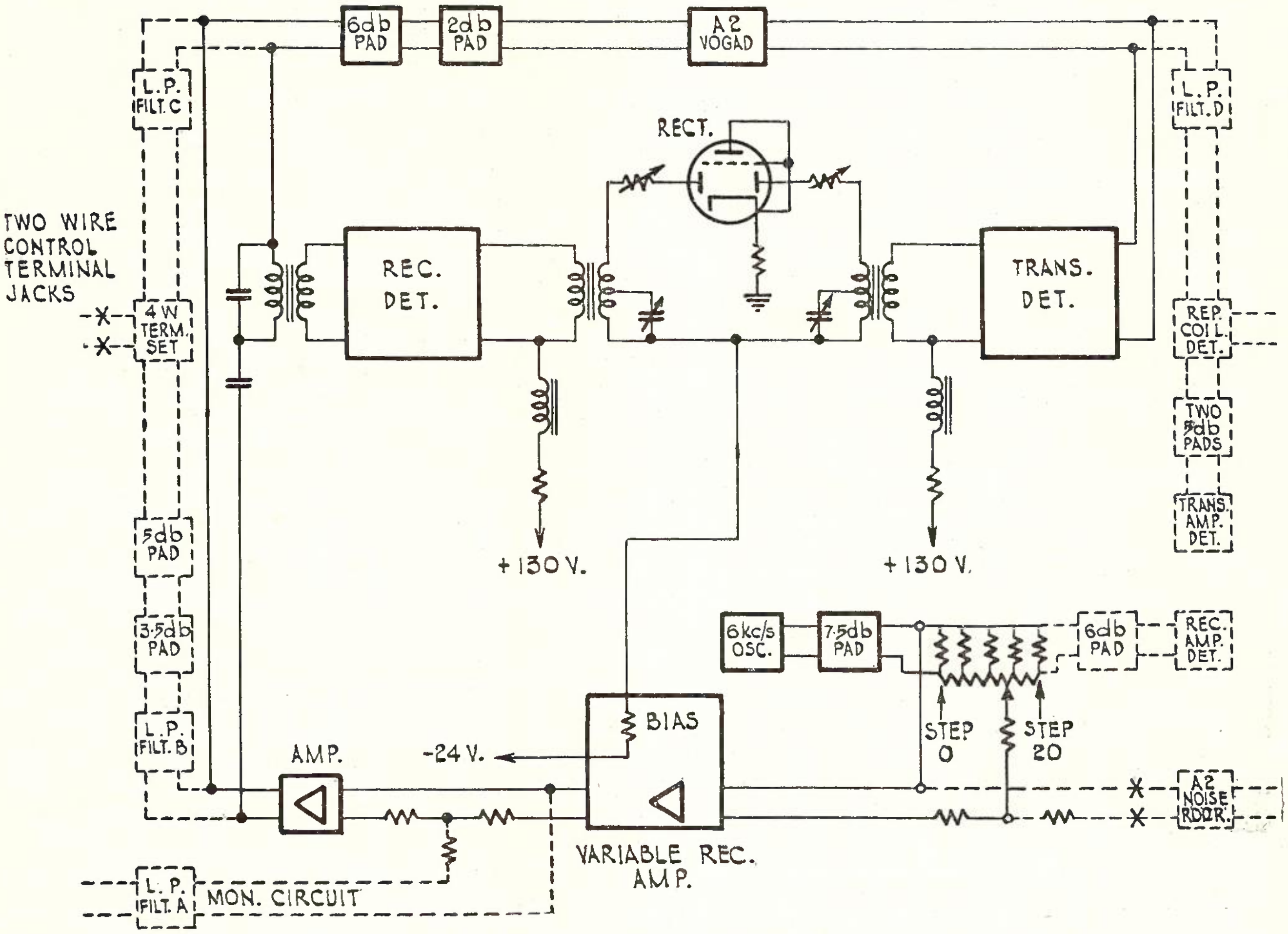

Fig. 5.—6 kc/s control circuit, schematic.

the input level at the transmit detector is kept constant. The gain of the receive amplifier is thus varied automatically to maintain the echo margin.

The receive detector is provided to protect the vogad from false echo operation, which could otherwise occur when the vogad is operating at low gain. In this condition echoes from received speech or noise which are too weak to operate the

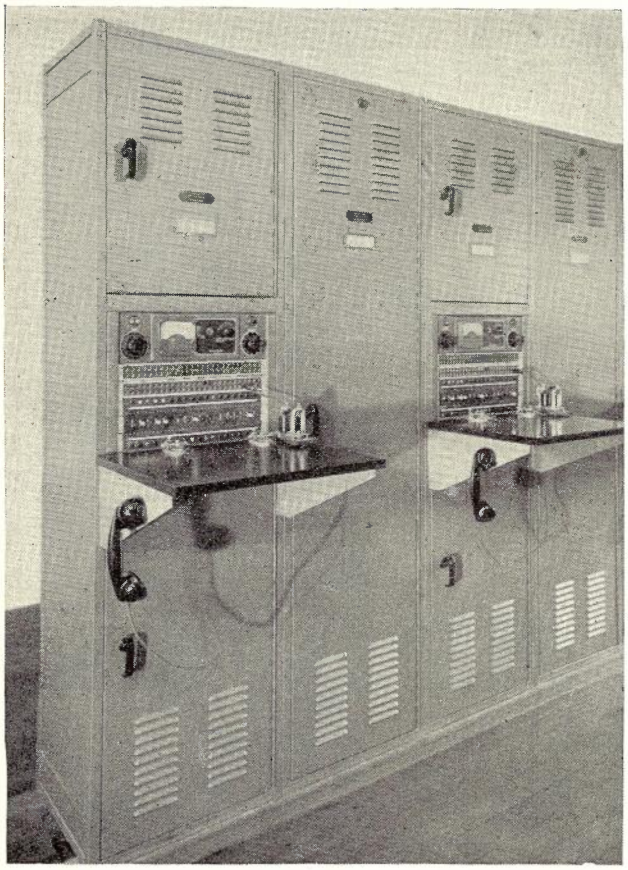

Fig. 6.—View of two control terminals.

receive amplifier detector in the vodas and disable the vogad, could cause undesirable changes in gain of the vogad. The receive detector overcomes this if necessary by further reducing the gain of the receive amplifier.

Both send and receive detectors consist essentially of amplifiers, tuned to 6 kc/s, which drive a common double diode, the total rectified current of which is used to bias the variable mu valve in the variable receive amplifier.

Noise Reducer: The noise reducer shown in Figs. 3 and 4 is used on volume regulated radio telephone circuits to produce a quieter circuit for the listener by reducing the annoying effects of radio noise when speech is not present. The noise reducer circuit consists of a metal rectifier type variable loss circuit, an amplifier ciruuit of fixed gain, and a gain increaser circuit. The characteristics are such that, when there is no received speech, the variable loss circuit introduces an additional loss of about 20 db into the receive path. The gain increaser circuit removes substantially all of this loss when incoming speech exceeds a certain threshold value. The operating point can be varied by means of a potentiometer, which may be adjusted by the Technical Operator during operation, according to the amount of noise on the circuit.

Owing to the nature of the circuit, a certain amount of clipping of speech syllables occurs, but as this takes place only when the speech level is law and masked by noise it is not important.

General: Because of the variations which may occur in the radio paths, the circuits are monitored continuously by the Technical Operator. The new equipment has improved visual monitoring facilities and alarms, which remove the need for continuous aural monitoring. A volume indicator is teed across either the send or receive path, depending upon the direction of transmission at any instant. It is switched from one path to the other by means of contacts of the VIS relay, which is in series with the vodas relay chain.

Fig. 6 is a view of two control terminals. Each terminal requires two cabinets—a "control cabinet" which mounts the writing shelf, key panel, etc., and an "auxiliary cabinet." Above the jack strip may be seen the volume indicator, with its associated scale switch. The dials on the left and right of the volume indicator control the noise reducer sensitivity and receive amplifier detector sensitivity respectively.

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TRANSMISSION TESTING IN AUTOMATIC EXCHANGE AREAS

J. L. Harwood

Introduction: Early in the history of telephone development it was evident that some standards of speech transmission would have to be established to ensure a satisfactory and uniform grade of intelligibility over telephone circuits. While considerations of setting up, signalling, supervision and clearing down of telephone connections via the medium of the exchange system are of primary importance, special regard must be paid to the transmission aspect, because with inferior speech transmission the most comprehensive and efficient switching system becomes valueless.

After the electro-magnetic receiver, the carbon transmitter and the induction coil had been combined into a workable telephone instrument, engineers were forced to pay close attention to the transmission characteristics of telephone lines. While exchange systems remained isolated and separate, high line losses could be tolerated, but, with the growth of inter-exchange traffic over junction and trunk lines, the study of speech transmission was intensified. The decibel notation was introduced as a means of assessing the overall equivalent of a circuit, and with the advances made in vacuum tube technique over recent years measurements can be made with ease and accuracy over a wide range of frequencies.

It was found that the intelligibility of transmission over a telephone channel depended largely on the portion of the frequency spectrum which it could transmit uniformly and without excessive attenuation. For many years a minimum range of approximately 200-2500 c/s was the objective, but the intelligibility is improved by transmitting higher frequencies. Many modern carrier systems have 3400 c/s as the upper limit. The low frequencies do not contribute appreciably to the intelligibility, but govern the naturalness of the speech. Frequencies below 200 c/s are not considered to be of appreciable value for telephone communication.

* **Standard Grade of Overall Transmission:** The Standard Grade of Overall Transmission (S.G.O.T.) is described as that value of transmission and reception realised when using the departmental handset telephone type 566 (now 162AT) on a 300-ohm non-reactive line connected to a 22-volt CB No. 1 exchange cord circuit (comprising a repeating coil and a 70/30-ohm supervisory relay) to which is connected, per medium of a 15 db non-reactive pad, another similar cord circuit, line and telephone instrument. To obviate the necessity for providing a large number of standard telephones, merely for testing purposes, and the carrying out of elaborate tests, a noise generator has been developed which, when used on a standard telephone instrument connected to a 300-ohm non-reactive line and a 22-volt CB No. 1 cord circuit, will deliver a power of –5 db (with reference to 1 milliwatt) into a 600-ohm non-inductive resistor. In automatic exchange areas the higher battery voltage permits a greater line resistance to be used, with consequent line plant economies, but the same standard applies, viz., the subscriber's telephone, when a standard noise generator is used against the transmitter, must deliver a power of –5 dbm into a 600-ohm volume indicator connected to the opposite side of a normal transmission bridge in the local exchange.

* Present standards based on "volume efficiency" are to be replaced shortly by limits determined by "transmission performance" standards.

As an example, the following table shows the maximum local line resistances which can be tolerated before the transmission characteristics of a straight line subscriber's service become inferior to the Standard Grade:—

Type of Telephone	Max. resistance allowable for exchange lines (allow 10 ohms for each protector) in ohms
(a) Trans. CB1 or equiv.	300
(b) Inset No. 10 or equiv.	440
(c) Local battery telephone	710

In automatic exchanges where barretters are installed an additional 100 ohms line resistance can be tolerated in the case of (a) and (b), and in many cases will render the use of local battery telephones unnecessary.

Complete information regarding the transmission requirements of subscribers' services may be obtained from the Telecommunication Journal, Volume 1, No. 5, "Transmission Improvements in Exchange and Subscribers' Equipment," by E. P. Wright.

Testing and Maintenance of Standard Transmission

The purpose of this article is to describe briefly the means adopted in the Adelaide Metropolitan Exchanges to test and maintain the standards of local line and junction line transmission.

Subscribers' Apparatus: Due to the relatively stable characteristics of the telephone receiver little attention is necessary beyond ordinary checking of reception by speaking through the 25 db pad from the test desk to each subscriber when the normal routine transmission test is performed. Receiver faults thus detected or reported by subscribers can generally be cleared by the maintenance staff without the necessity for quantitative measurements. It is possible, however, to use the ordinary noise generator to test a receiver, but care must be taken to ensure that the transmitter current is cut off at the test desk when making the test, otherwise the transmitter is active and the increased output from the telephone will overload the volume indicator. The results obtained by tests of receivers in this manner vary widely and no great use has been made of the facility except in special cases.

Subscribers' transmitters are tested for resistance and volume, and the intelligibility of speech is judged by the testing officer. If, in the opinion of this officer, a transmitter is doubtful, arrangements are made for the subscriber's premises to be visited by the maintenance staff, and use is made of the noise generator to prove the volume efficiency of the transmitter.

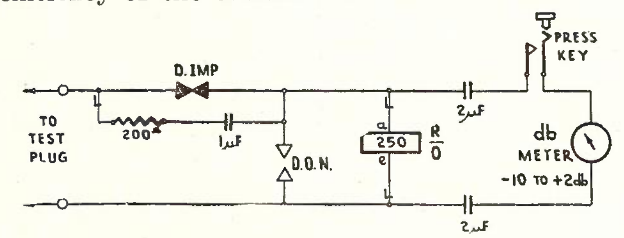

Fig. 1.—Portable transmission measuring set.

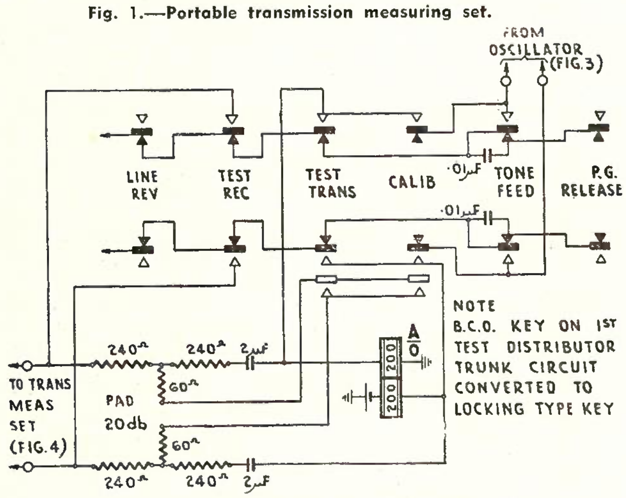

Fig. 2.—Test desk tone feed circuit.

Cases occur frequently in which the volume efficiency of a transmitter is satisfactory, but speech from it sounds "raspy" or "woolly" and intelligibility, particularly when the 25 db pad is used, is poor. In these instances the testing officer directs the technician at the subscriber's premises to change the transmitter, irrespective of its volume efficiency.

With the concentration of testing and maintenance control in the metropolitan area it is necessary for transmitters on subscribers' services in branch exchange areas to be tested from main exchanges some distance away. It is essential in these cases to ensure that the battery feed to the transmitter under test is fed from the local exchange concerned and that allowance is made for the attenuation of the junction between the main and branch exchanges.

Exchange Equipment: In order to test the transmission efficiency of automatic exchange switching equipment and junctions, constant output oscillators have been installed in all main exchanges and several of the larger branch exchanges, and portable volume indicators have been provided for each exchange staff. At exchanges where oscillators are installed, a tone feed circuit is provided on the test desk for the purpose of feeding the test tone to any final selector test number in the local exchange or adjacent branch exchange not so equipped.

To test final selectors for transmission efficiency it is necessary only to dial the test number of the group concerned, via the test distributor, operate the tone feed and B.C.O. keys on the test desk and then, with the portable volume indicator, to test each switch in turn by dialling the test number and observing the volume of the tone as indicated on the meter. Fig. 1 shows the circuit of the portable volume indicator and Fig. 2 shows the method of feeding tone via the test commons of the test desk to any required number in the exchange. Only one test distributor trunk circuit should be selected for use for these tests, as it is necessary to convert the B.C.O. key plunger to lock in the operated position, as, otherwise, the final selector test number multiple appearance will be busied by the test final selector. The ringing current from each final selector is tripped immediately by the use of a retard coil and rectifier (see Fig. 3) arranged to prevent the operation of the line circuit associated with the test number being used.

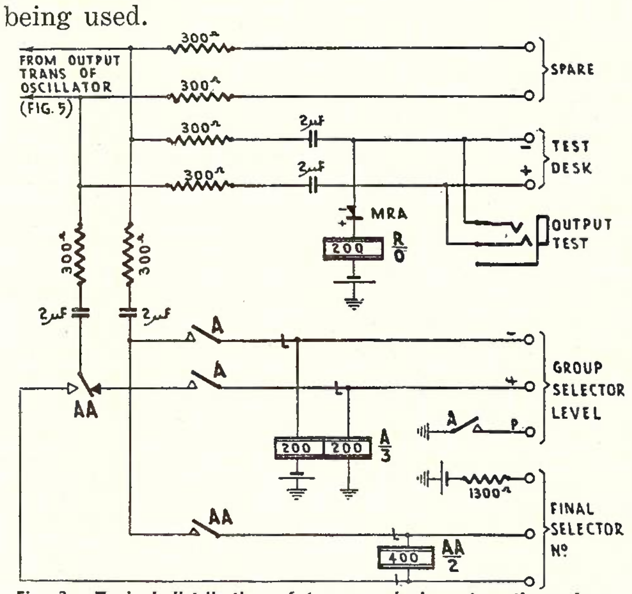

Fig. 3.—Typical distribution of tone supply in automatic exchange.

Each final selector is tested with the portable volume indicator and the results obtained should be consistent. If irregularities are encountered further investigation is necessary. The most common faults encountered are:—

(a) Open circuit condensers.
(b) Short circuit turns or layers in the relays bridged across the speaking path.
(c) High resistance contacts between wipers and banks.

It is not necessary to test group selectors for transmission efficiency other than for the purpose of detecting high resistance contacts between wipers and banks. This type of fault, however, should be detected by normal routine testing.

To test repeaters and discriminating selector repeaters the tone test number (selector level) in the distant exchange is dialled from the test jacks of each switch. The readings obtained on the portable volume indicator should be consistent and any irregularities followed up. In the case of tests on repeaters, the junction and incoming group selector at the distant exchange are also tested, but in the case of discriminating selector repeaters a separate series of tests is necessary to prove each junction.

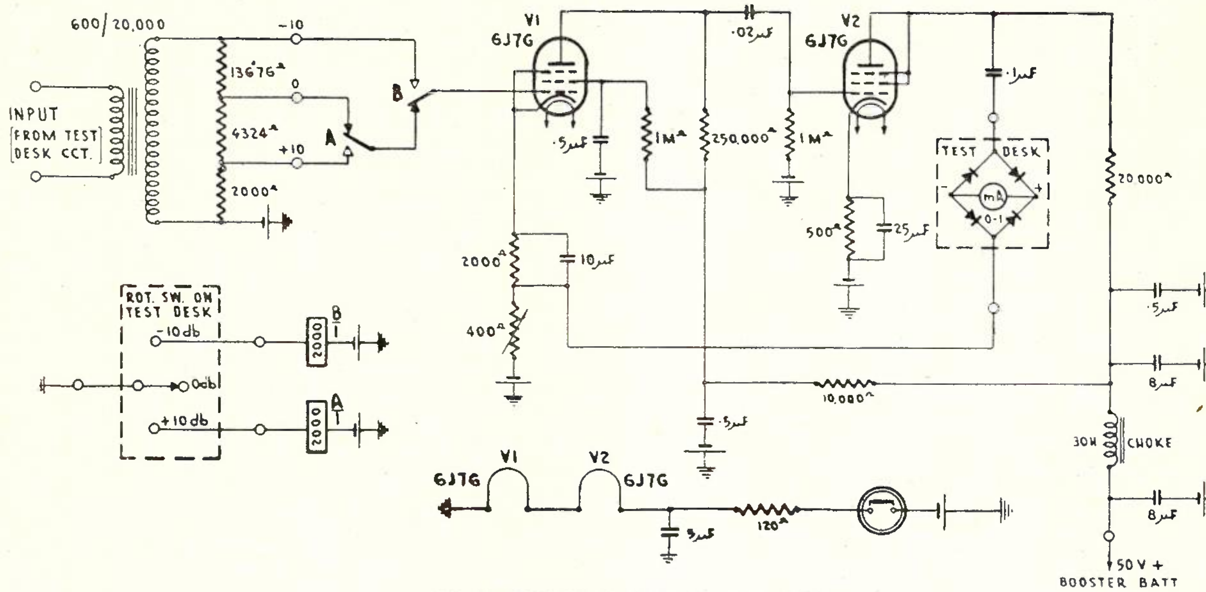

Fig. 4.—Test desk volume indicator circuit.

To test repeaters on junctions from main to small branch exchanges where no oscillator is provided, it is necessary for the tone to be fed from the test desk tone feed circuit in the main exchange to a selected test number in the distant branch exchange. All repeaters are then tested by dialling this number and observing the volume indicated on the meter. Final selectors in small branch exchanges are tested in a similar manner, a different test number being dialled for each group of final selectors.

Cord circuit transmission losses in manual exchanges are measured by using a portable volume indicator and a tone feed circuit permanently wired to suitable test jacks on the switchboard.

Testing Equipment

Mounting Arrangements: The oscillators and volume indicators are mounted on the special apparatus racks in the automatic exchanges and only the indicating meter and rotary switch controlling the volume range are mounted on the test desk. The portable volume indicators have been made up from the standard two-cell battery box fitted with dial, meter, press-button, carrying-handle, test-cord, etc., and have been calibrated to read from –10dbm to +2dbm.

Volume Indicator: The test desk volume indicator consists of an amplifier with negative feedback to ensure a high degree of stability during the life of the valves and under varying voltage conditions (see Fig. 4). The valve filaments are connected via a resistance to the 50-volts negative exchange battery, and the anode supply is obtained by the 100 volts potential difference between the 50 volts positive and 50 volts negative batteries available in each automatic exchange. The test desk circuit has a 20db pad included in the test commons when making transmitter volume tests, and the sensitivity of the instrument is diminished accordingly. The range of volumes which may be read is from –20db to +12db for transmitter tests and from –40db to –8db when the receiver test key is operated. On large test desks several meters are used from the one volume indicator amplifier circuit by connecting the moving coil of each instrument in series.

Oscillator: The oscillators used are of the constant output type adjusted to feed a tone of 1600 c/s at 1.54 volts to a number of parallel feed circuits, each of which has separate resistance networks to make up the 600-ohms internal impedance. The oscillators are stabilised by the use of a 240 volt 15 watt electric lamp connected to the output stage of the oscillator. Variations in output level increase or decrease the temperature of the filament, with corresponding variations in its resistance which, in turn, varies the gain of the oscillating valve and so counteracts the fluctuation of output level (see Fig. 5). An earth pulse is fed to a control relay on each oscillator to interrupt the tone for 0.5 seconds at intervals of 6 seconds, to prevent locking-up of voice frequency dialling circuits should tone numbers be inadvertently called from country exchanges.

A calibration key is provided on the test desk to connect the output of the oscillator to the volume indicator for the purpose of checking both circuits (see Fig. 2).

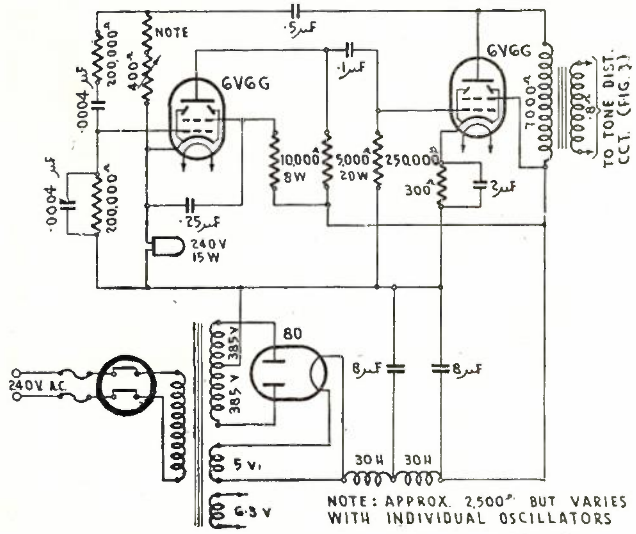

Fig. 5.—Constant output oscillator, 1600 c/s, 1.54 volts.

Tone Circuits: Single-tone feed circuits may be provided in branch exchanges not equipped with oscillators by utilizing the main exchange tone supply. The 1.54 volts output from the oscillator is stepped up to 4.62 volts by the use of a 4012A transformer connected as a 1 : 3 ratio step-up transformer. The tone at this relatively high voltage from a low impedance source is fed over a separate cable pair to the branch exchange where it is connected via another 4012A transformer (1 : 1 ratio) to a variable network, which is adjusted to give an output of 1 milliwatt in 600 ohms with an internal impedance also of 600 ohms. A start circuit from the branch to the main exchange is used to eliminate the feeding of tone at this relatively high level continuously through an underground cable circuit.

Conclusion

The necessity to maintain speech transmission paths in automatic exchange areas at the highest possible efficiency is of the utmost importance, and from the foregoing it will be seen that this can be achieved economically and reliably by the methods described.

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POSTAL ELECTRICAL SOCIETY OF VICTORIA

Annual Report for 1948-49

The usual bi-monthly lecture programme was arranged for the year and lectures were delivered by members of the Society on topical subjects. The Society was also fortunate in being able to arrange for a talk by Mr. E. F. Halkyard, of the State Electricity Commission, on the Kiewa Hydro-Electric project.

Appreciation for delivery of lectures during the year is expressed to the following gentlemen, Messrs. A. Camfield, C. T. Boston, A. Puttick, E. J. Stewart, A. H. Kaye and E. F. Halkyard.

The lectures were held in the Radio Theatre, Melbourne Technical College, by the courtesy of the Principal, Mr. F. Ellis, M.A., B.E., and Mr. R. R. Mackay, M.I.R.E., and we are indebted to them and Mr. Permewan for the material assistance they are rendering the Society.

The costs of publishing the Telecommunication Journal of Australia have further increased, and the Department again agreed to subsidise the Journal to an amount of £200 for this year.

The Committee is very pleased to report that Mr. R. W. Turnbull has joined the Board of Editors in place of Mr. J. A. Kline, who had resigned on promotion to another department.

At a meeting of the Society held in June, 1948, Rule 16 was amended to provide for the holding of the Annual Meeting in June instead of December each year, to correlate the financial year with the annual subscriptions to the Journal. To conform with this new arrangement, the period of service of the present Committee was extended to June, 1949.

The number of overseas subscribers to the Journal continues to increase, and with the addition of subscribers in other countries the distribution is becoming world-wide. During the present year subscriptions have been received from France, Switzerland, Germany, Poland, Rhodesia, Lebanon and Italy, countries which were not previously on our list.

The number of members and subscribers at 30/4/49 was 2523.

Appreciation is expressed to Miss I. Owens for the valuable services rendered as Distribution Manager during the current year. It is desired to express thanks to the authors of articles and members of the drafting staff who have given freely of their time in preparing articles and illustrations for the Journal, and also to those members who have so willingly assisted in collecting subscriptions.

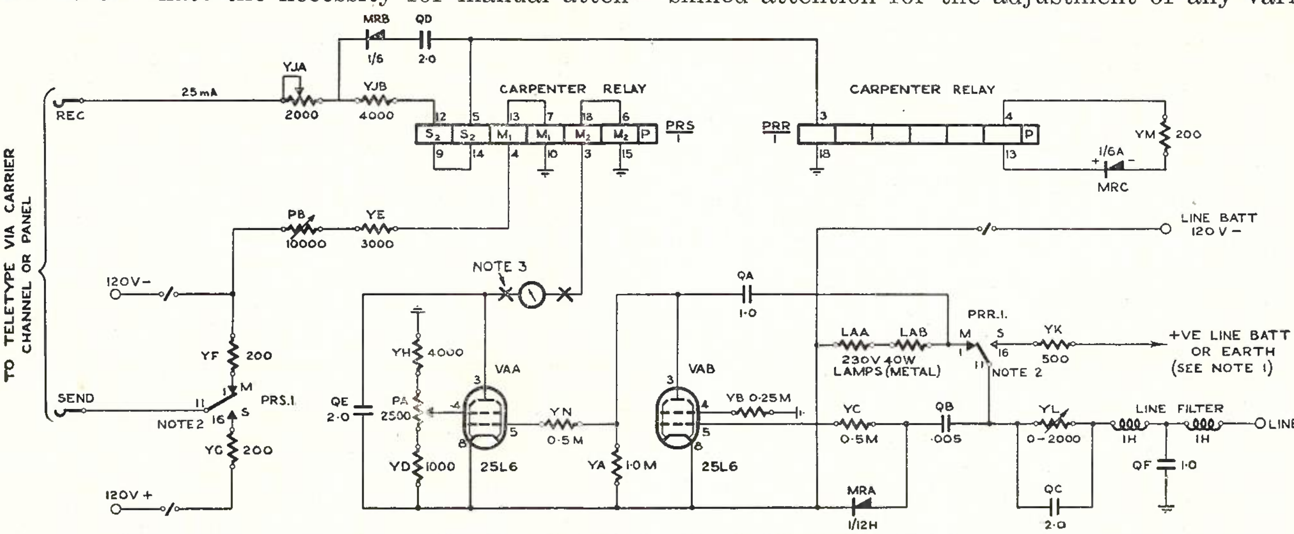
START-STOP MACHINE OPERATION OVER OPEN WIRE LINES SUBJECT TO VARYING LEAKAGE

E. D. Curtis

General

In the February, 1947, issue of the Journal (Vol. 6, No. 3) a method of receiving morse signals from lines subject to varying leakage was described in detail, and reference was made to trials which had been made with the same general circuit arrangement for start-stop systems. Since that time the design has been stabilised and the circuit now used is described in the following text and diagrams. The object of the arrangement is to provide two-way or point-to-point operation between start-stop machines working over lines subject to varying leakage, and to eliminate the necessity for manual attention for the adjustment of balances or variables. Any system which requires adjustment of balances or variables to meet varying leakage is subject to increased distortion of signals as the re-adjustment point is reached, and the fact that re-adjustment is necessary is indicated only by the appearance of errors in the copy. An arrangement which eliminates re-adjustment must be superior, provided that it functions equally reliably under normal conditions.

In some cases in Victoria, it is not possible or not economical to provide for continuous attention at all points on a circuit which may require alterations of variables, and in the absence of the repeater or terminal units to be described the circuit would be subject to frequent failure. An example to illustrate this point is a night news distribution service between Melbourne and Warrnambool. The link on which this service is carried consists of two caihlos over 45 miles of underground cable between Melbourne and Geelong, worked as double current send and receive lines, coupled to approximately 120 miles of open wire caihlo line, via a repeater in the Geelong office. The open wire line passes through the Western District of Victoria, and is subject to very heavy leakage during wet, dewy or foggy weather. The repeater at Geelong functions in the same way as a carrier to simplex repeater, and is unattended during the hours that the news service operates. At Warrnambool, the service terminates at the local newspaper office, where skilled attention for the adjustment of any variables is not available. The repeater is necessary at Geelong as the distortion introduced on the 45 miles of underground cable with single current signalling is beyond the allowable limit and it is necessary to use double current signalling over that portion.



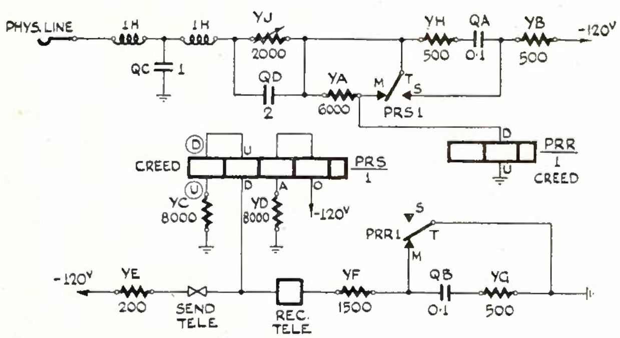
Notes: 1. Use +VE line batt. for polar reception at dist. terminal. Use earth when E.T. unit used at dist. terminal.
2. Usual spark shunts fitted.
3. Meter switching and spark shunts not shown.

Fig. 1.—Carrier to Simplex repeater for machine working (electron tube type), Model 2.

Figs. 1 to 6 give circuit details and explanatory diagrams, the repeater (Fig. 1) being used as the head station, either at a C.T.O. or at a V.F. carrier channel termination forming the repeater between the physical line and the 2-wire double current portion of the circuit. At the country end, a polarised relay unit (Fig. 2), or an electron tube type of unit (Fig. 3), may form the terminal. In all cases the transmission from the country terminal is of the battery and earth type, while the transmission from the repeater to the country terminal is battery and earth for the electron tube type of terminal, or double current for the polarised relay unit.

Circuit Descriptions

Carrier-Simplex Repeater for Machine Working (Fig. 1): (a) With the distant carrier terminal (or carrier panel) sending marking and the open wire physical line circuit marking, the passage of current to line through lamps LAA and LAB



Note: 120V supply from rectifier unit with +VE side earthed.

Fig. 2.—Teletype terminal panel, physical line type, double current reception, battery and earth sending.

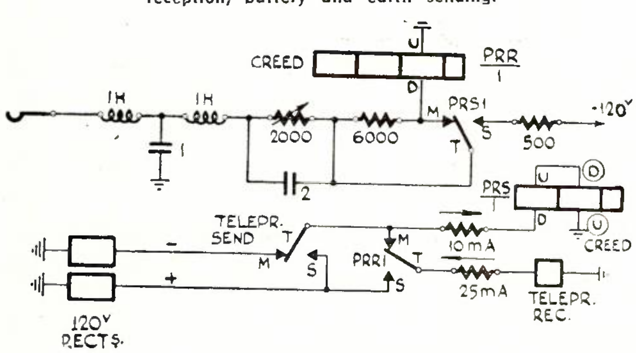


Fig. 2a.—Teleprinter unit.

causes the capacity QA to be charged to the potential drop across LAA and LAB, the charging circuit being completed via the tube VAB, in which the grid and cathode are at the same potential when the line current is steady. Tube VAB functions as a grid-controlled rectifier. Under conditions of no line leakage, the line current is approximately 30 m.A. With no signals passing, the grid and cathode of tube VAA are at the same potential and the anode current VAA is adjusted to a value of 25 m.A by the operation of potentiometer PA. This anode current passes through the windings of the polarised relay PRS (Physical Receive/Carrier Send) in a direction to give a marking effect. The magnetic effect in the coils concerned (Carpenter type No. 3 E.1) may be expressed as $(2 + 2) \times 25 = 100$ M.

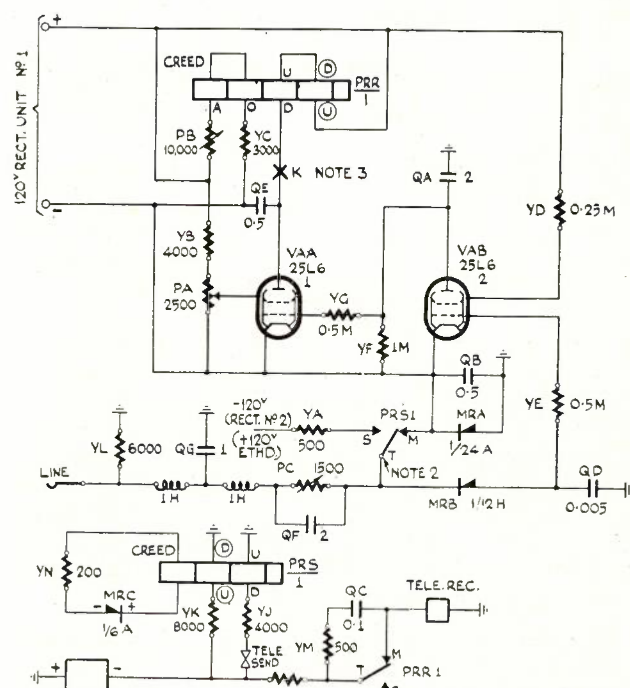
(b) 25 m.A's incoming on the carrier receive leg passes through YJA, which is variable for the accurate setting of the 25 m.A value, YJB (4000) windings of PRS and through one winding of PRR (Carrier Receive). PRR is held to marking but the direction of this current through PRS is that it tends to space. Magnetic effect $= (2 + 2) \times 25 = 100$ S.

(c) 120 volt negative battery is fed via the potentiometer PB (10,000), the limiting resistance YE (3000) and two windings of PRS, the direction being to mark. The magnetic effect of the coils 4/13 and 7/10 is only half that of the remaining coils of the relay, and with the current through these coils adjusted to the normal value of 25 m.A, the magnetic effect within the relay is $(1 + 1) \times 25 = 50$ M. The sum of the magnetic effects in PRS = 100 M + 50 M – 100 S = 50 M.

(d) When the physical line current is interrupted in a manner such as it would be with single current or battery and earth sending from a distant panel, the potential drop across LAA and LAB ceases, or is greatly reduced. QA discharges via YA, extending negative potential, equal in value to its previous charge, via YN to the grid of VAA causing the cutting off of the anode current of VAA and the loss of the magnetic effect of the 3/18 and 6/15 windings of PRS. PRS therefore spaces (100 S — 50 M = 50 S).

(e) Restoration of the line circuit, or with the marking condition from the distant end, results in the original voltage drop across LAA, LAB and grid and cathode of VAA and the restoration of the original magnetic conditions in PRS. During these operations, the tongue of PRS sends the relevant marking or spacing condition to the carrier (or panel) send leg.

(f) When line leakage occurs, the current sent to line increases beyond the normal 30 m.A, and when single current impulses are sent from the distant end the current fails to fall to zero when



Notes: 1. 2-120V rectifiers are used, No. 1 insulated from earth and No. 2 (line battery) with +VE side earthed.
2. Usual spark shunts connected.
3. Meter switching not shown.

Fig. 3.—Teletype terminal panel, physical line type, battery and earth sending and receiving (electron tube type), Model 3.

the open circuit condition is given. In general, the maximum change which can occur as a result of an open circuit from the distant end is 30 m.A, this value being reduced as the leakage occurs. Advantage is taken of the rising resistance/current curve of the metal filament lamps to increase the ohmic value of the sum of LAA and LAB when the current to line increases due to leakage,

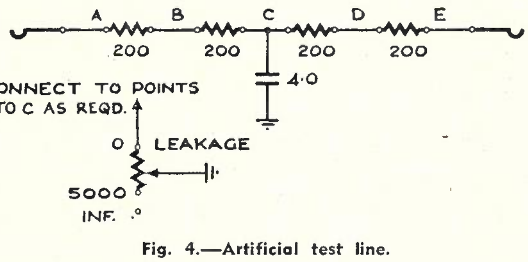


Fig. 4.—Artificial test line.

thus giving greater sensitivity of the unit when required to receive the smaller changes in line current resulting from the leakage. The values used in LAA and LAB may be varied to suit particular line conditions, those given being for the usual form of line used, i.e., caihlo on telephone trunks. The current/resistance curve of the 230 volt, 40 watt metal filament lamp is given in Fig. No. 5.

(g) The conditions with marking incoming from both carrier and physical line are given in (a), (b) and (c). Space incoming from the carrier side results in a reversal in the direction of current through the windings 12/9-14/5 of PRS and also through the 3/18 winding of PRR. PRR repeats the spacing condition to the physical line and, in addition, opens the circuit of LAA and LAB. Anode current is cut in VAA, but the altered conditions in PRS [i.e., $(2 + 2) \times 25$ M + $(1 + 1) \times 25$ M = 150 M] cause relay to remain in the marking position and avoid re-transmitting the spacing condition back over the carrier.

(h) After PRR has moved to the spacing side and restores to the marking condition, the surge to the line to charge the line capacity to the negative potential causes a value of potential across LAA and LAB in excess of that which is due to the normal line current. During the time that PRR 1 is to spacing, QB is charged to approximately the 120V-line potential via MRA, and this potential is available to control negatively the grid of the rectifier tube VAB for the period necessary for the potential across LAA and LAB to fall to its normal value. The conductance of VAB is controlled by resistance YB.

(i) The potentiometer PB controlling the bias current in PRS is varied in the "line up" on a particular type of physical line and is not variable in operation. QE is a "Mush" bypass capacity. Condenser QD and MRB give a phase displacement to the current change through PRS to prevent it lifting. Resistance YM and MRC minimise the spacing effect of the relay transit time on single current signals by slightly delaying the tongue movement in the mark to space direction. The line limiting resistance YL is provided to limit the line current to 30 m.A under no leakage conditions. In general, the value of YL at the main station should be adjusted to be approximately equal to that of PC at the distant station.

(j) When sending to an electron tube type terminal unit, the spacing contact of PRR is connected via YK to earth. When sending double current signals to a polar unit, the spacing contact of PRR is connected to 120V+ ve battery via YK. When sending double current signals, the circuit of YM should be opened.

Terminal Panel for Double Current Reception and Battery and Earth Sending—Using Polarised Relays (Figs. 2 and 2a): Improvements in the Carrier-Simplex repeater, mainly the introduction of the grid controlled rectifier and the elimination of C2 R2 network used in the earlier types, permits the sending of double current signals from the repeater to the terminal and the use of polarised relay reception. The circuit arrangement of the polarised relay unit is shown in Figs. 2 (Teletype) and 2A (Teleprinter). A single rectifier of the R.E.C.10 or R.A.87 type provides all the power required where teletypes are used and an additional unit of the same or smaller type is required for teleprinter work. In operation, the double current incoming signals operate PRR which repeats the signals to the teletype receiving magnet (Fig. 2), PRS being inoperative under these conditions. Operation of the teletype send

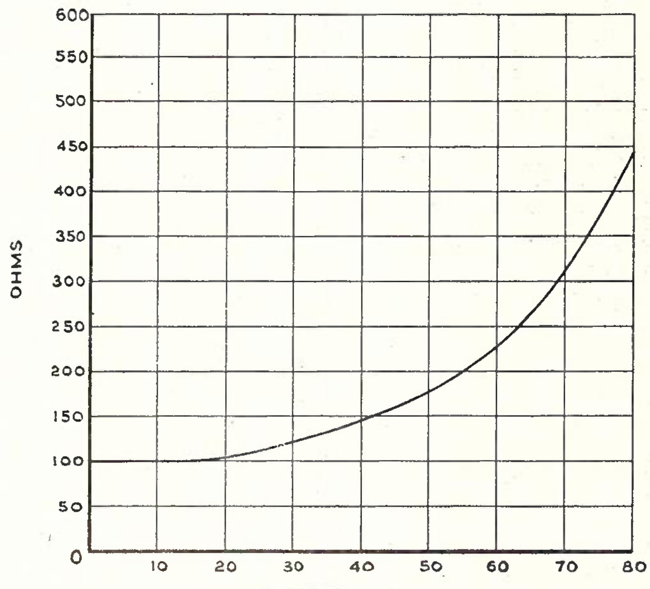


Fig. 5.—Current resistance curve for 230V 40W M.F. lamp.

side results in the operation of the receive magnet for home record and PRS operates to send the signals to line. When sending, PRR is held by the 6000 ohm leak circuit. For teleprinter operation, the reception is similar, but the tongue of PRR feeds double current signals to the teleprinter receive magnet. When sending, relay PRS and the teleprinter receive magnet operate in parallel from the teleprinter send contacts giving home record and sending to line. These units are the preferred arrangement for reception at the country terminal.

Terminal Panel, Battery and Earth Sending and Reception—Electron Tube (Fig. 3): The unit

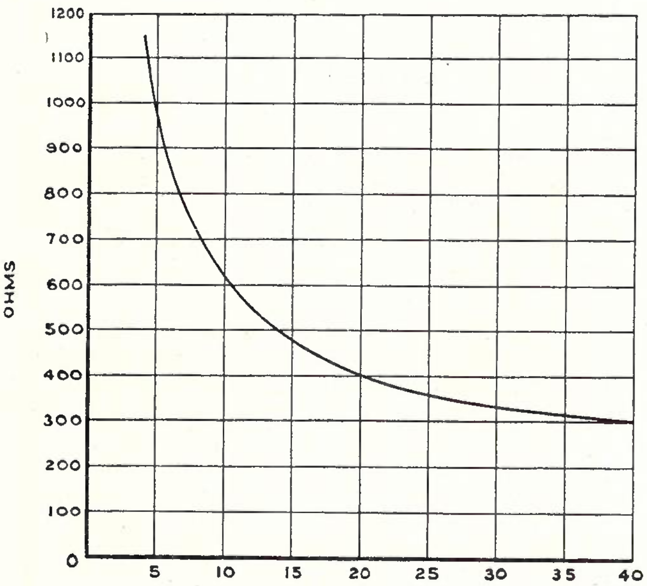


Fig. 6.—Current resistance curve for 1/24A rectifier (forward direction).

is generally similar to that previously used, and is designed for the reception of battery and earth impulses (a number of circuits exist of the older types, and their modification for double current working is not justified at present as the performance of each type is practically equal). In the later type, advantage is taken of the falling current/resistance characteristic of the copper oxide rectifier to increase the sensitivity of the unit as the incoming current is reduced as the result of line leakage. The condition is the reverse of that experienced at the head station, in that, while with no leakage the incoming current is 30 m.A, as leakage is introduced the current through MRA is reduced. As the current through MRA is reduced, its forward resistance increases and the potential drop across MRA falls at a much lesser rate than would be the case if MRA were replaced with a fixed ohmic value. The current/resistance curve of a typical rectifier of the 1/24A type is shown in Fig. 6.

Incoming negative line current from the head station through MRA causes QA to be charged via VAB to the potential drop across MRA. With steady incoming current, the grid and cathode of VAA are at the same potential (via YG and YF) and the anode current is adjusted to 25 m.A by the manipulation of the potentiometer PA. Relay PRR marks with the preponderance of magnetic effect in the D to (U) winding over the magnetic effect in the O-A windings. The potentiometer PB controlling the current in the holding circuit is operated to control the bias condition, and its function will be described in the paragraphs on "lining up." When the incoming line current ceases (spacing) the drop across MRA ceases and QA discharges through YF, extending a negative potential to the grid of VAA via YG and causing the cut-off of the anode current in VAA. Relay PRR spaces and extends a spacing condition to the teletype receive magnet. Restoration of the incoming marking signal restores the drop across MRA and anode current is restored in VAA, resulting in PRR again marking.

Operation of the teletype send contacts causes the operation of PRS. When PRS spaces, negative battery is sent to line in place of the earth via MRA. Home record is given when current through MRA falls during the spacing condition, QA and VAA functioning as in the case of incoming signals. When PRS is to spacing, QD is charged to the negative line potential via MRB, and, on the restoration to the marking condition, QD extends a negative "cut-off" potential to the grid of rectifier tube VAB for sufficient time to prevent QA being overcharged as a result of the high drop across MRA, due to the peak discharge of the line capacity. QB and QE are "mush" filters. YN and MRC serve to delay the commencement of movement of the PRR relay tongue from mark to space to minimise the effects of space bias resulting from battery and earth transmission. Resistance YL partially bypasses to ground the line capacity discharge when the far end send relay moves to spacing and acts to limit the value to which the resistance of MRA rises (YL is in parallel with MRA to ground). Modifi-

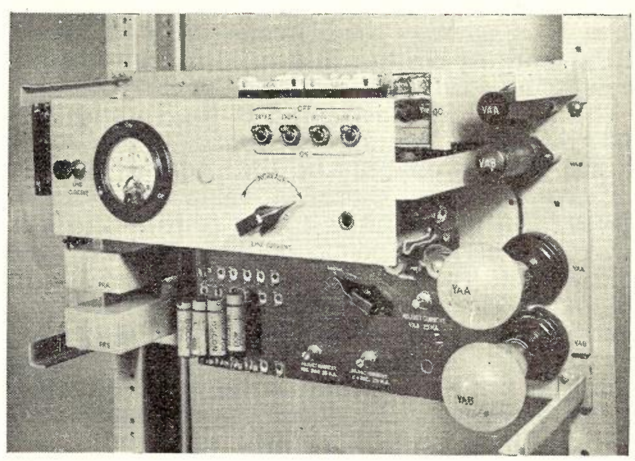


Fig. 7.—Panel for one repeater unit.

cations to permit the use of teleprinters are generally the same as in Figs. 2 and 2A and an additional 120V + ve supply is necessary.

Lining Up the Circuit and Maintenance Checking

The arrangement for lining up and checking during maintenance are comparatively simple, being as follow:—

Carrier-Simplex Repeater Unit (Fig. 1):

(a) The anode current in VAA is adjusted to a value of 25 m.A by the manipulation of potentiometer PA.

(b) Potentiometer YL is adjusted to give a line current of 30 m.A under no leakage conditions. The value of resistance in YL should be approximately equal to that in YJ (Polar Unit) or PC in electron tube terminal unit.

(c) Potentiometer PB is adjusted to give a current of 25 m.A in the holding circuit.

(d) Condition and adjustment of relays are checked.

Terminal Unit Polarised Relay Type (Figs. 2 and 2A):—

(a) Condition and adjustment of relays are checked.

(b) YJ is adjusted in conjunction with the adjustment of YL at repeater unit so that the values in each are approximately equal.

Terminal Unit Electron Tube Type (Fig. 3):—

(a) The anode current in tube VAA is adjusted to 25 m.A.

(b) The line current is adjusted (potentiometer PC) in conjunction with the repeater station so that the value in PC is approximately equal to that in YL.

(c) Potentiometer PB is adjusted to give a current of 30 m.A through the holding circuit.

Overall Tests for Lining Up:

(a) Using a standard signal generator type 100C, signals are sent from the country terminal to the repeater. Distortion is recorded on test set No. 161 A1 (W.E.) for "Units" and "Letters." Potentiometer PB is varied so that the amount of bias recorded on units is equal and opposite to the bias recorded for letters. The repeater should then operate to the fail point of the line without further adjustment.

(b) Using the signal generator at the repeater station (or at the main terminal) a signal is sent to the country terminal and the distortions recorded. With the polarised relay unit, no adjustment should be necessary if the relays are in good adjustment. With the electron tube type of terminal unit, the same tests and adjustments are made as in (a), varying potentiometer PB to arrange

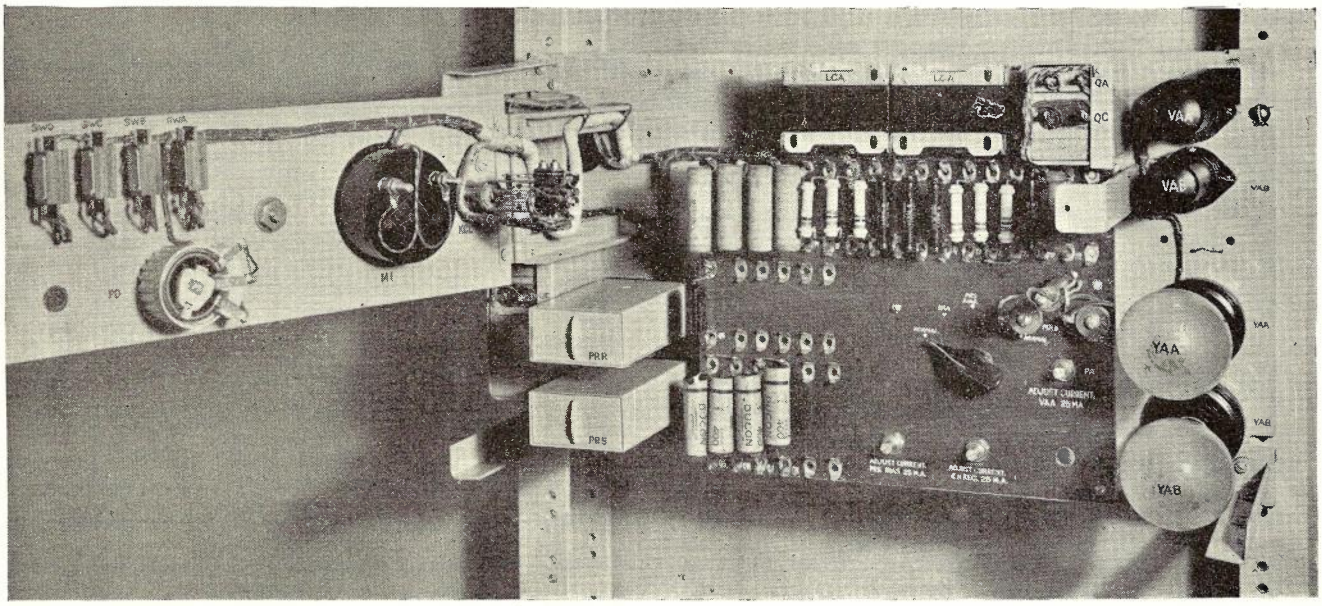


Fig. 8.—Electron tube type country end terminal.

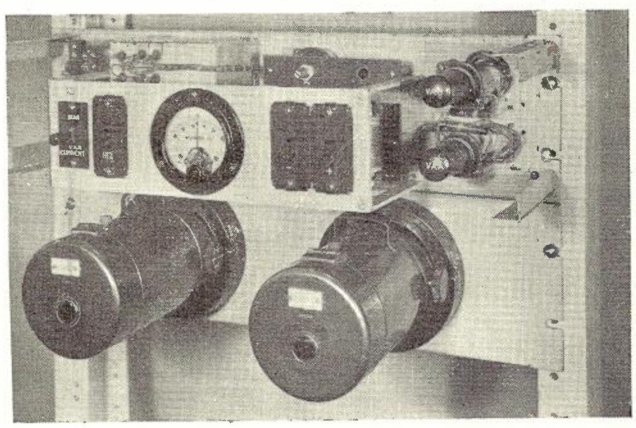


Fig. 9.—Panel for one repeater unit—sub-panel open.

the distortion swing equally about zero.

(c) If standard signal generators are not available, the adjustments should be made by running recurring letter S from each end in turn, varying PB at the country terminal and PB at the repeater unit to a point where maximum machine ranges are achieved.

Once the circuit is correctly lined up, the compensation for distortion introduced by line leakage is automatic and nothing is gained by further changes.

Tests Over Artificial Line

In order to form a basis for comparison with other circuit arrangements, tests were made with the terminal and repeater units using an artificial line as shown in Fig. 4. The signals were sent from a 100C signal generator and received on a No. 161 A1 (W.E.) set. Line current was adjusted to a value of 30 m.A with no leakage and leakage increased until the fail point was reached. The results of the tests are set out in tables Nos. 1, 2 and 3.

Mounting

The repeater unit is mounted on a standard $10\frac{1}{2}$ inch panel and arranged so that double-sided mounting on racks is possible. The whole of the equipment is protected from dust by a standard cover cut away to reveal the battery switches, a meter and key and variable control for the line current adjustment. Fig. 7 is a photograph of a Panel for one repeater unit with the cover removed to show the method of mounting the components. Fig. 9 shows the same unit with the subpanel opened to show the method of wiring and arrangement of components. Fig. 8 shows the electron tube type of country end terminal together with its relay panel. The cover of the repeater unit has been removed to show the components.

Table No. 1—Terminal Unit sending to Repeater Unit (Figures recorded at the Repeater End)

Leakage shunt ohms	Value of holding current (PB) mA	Distortion		Outgoing line current (space incoming) mA	Change in line current (space incoming) mA	Machine range
		units	letters			
Inf.	25	0	−5	30	23	25–100
5000	,,	0	−5	34	20	25–100
3000	,,	0	−5	36	18	25–100
2000	,,	0	−5	38	16	27–102
1000	,,	0	−4	41	12	27–100
750	,,	+1	−3	43	10	25–100
500	,,	+2	−1	45	8	24–100
400	,,	+3	0	46	7	26–96
300	,,	+7	+4	47	5	Small range

Tests indicate that the position at which the leakage is applied does not vary the recorded distortion values.

Table No. 2—Repeater sending to Terminal (Figures recorded at the Terminal)

Leakage shunt ohms	Value of holding current (PB) mA	Distortion		Incoming marking current mA	Machine range (incoming)	Machine range (home record)
		units	letters			
Inf.	30	+2	0	23	22–100	22–96
5000	,,	+1	−2	19	23–102	22–93
3000	,,	+1	−2	17	28–100	22–93
2000	,,	0	−3	15.5	27–100	20–93
1000	,,	−2	−4	10	27–100	18–94
750	,,	−3	−4	8	26–100	20–94
500	,,	−4	−4	6	24–98	20–94
300	,,	−5	−5	3.5	25–100	23–94
250	,,	−5	−5	2.5	25–100	Small range
100	,,	−10	−10	0.5	30–100	Fails

Table No. 3—Repeater sending to Polar Unit (Figures recorded at the Polar Unit)

Leakage shunt ohms	Distortion		Incoming marking current mA	Machine range (incoming)	Machine range (home record)
	units	letters			
Inf.	− 3	− 4	30	28–100	23–96
5000	− 3	− 4	26	28–100	23–96
3000	− 3	− 4	23	28–100	23–96
2000	− 3	− 5	20	27–98	22–95
1000	− 4	− 5	15	27–98	20–94
750	− 4	− 5	13	29–98	20–90
500	− 4	− 5	10	29–98	20–90
300	− 5	− 6	6.5	28–96	20–90
250	− 6	− 7	5	34–96	20–90
200	− 7	− 8	4.5	35–95	20–90
100	−20	−20	2	45–95	Fails

The distortion figures and fail point in the Polar-Repeater direction were the same as recorded in Table No. 1.

ERRATA

"Installation of Junction Carrier System (Newtown-Miranda)," Vol. 7, No. 2, October, 1948, Page 65.

In Fig. 17—Directional Filters—omit the series capacity and the shunt capacity and inductance at the "Low Pass" terminals.

ANSWERS TO EXAMINATION PAPERS

The following answers generally give more detail than would be expected in the time available under examination conditions. The additional information should be helpful to students.

EXAMINATION No. 2823—SENIOR TECHNICIAN—BROADCASTING
RADIO I.

N. S. Smith, A.M.I.R.E. (Aust.)

Q. 6.—What means are adopted for dissipating the heat from the anodes of large transmitting tubes in broadcasting stations of high power?. Describe in detail one system commonly used, indicating the precautions to be taken to ensure satisfactory operation of the tube.

A.—Two methods for dissipating heat from anodes of large transmitting tubes are:—

(1) Forced air cooling, in which fans are used to blow cool air on to the anodes which usually are of radial fin construction to provide a large cooling surface area.

(2) Water cooling. In this type the valve anodes are cooled by continuously circulating water.

Method (2) will be described briefly.

The water cooled valve has an external anode and is fitted in a specially designed socket through which distilled water is passed. The rate of flow of the water varies according to the heat to be dissipated and may range from 5 to 50 gallons a minute, and since the anode of the valve is at a high potential above earth (up to 15,000 volts), the use of distilled water is essential. An insulated section of pipe, usually in the form of helix of rubber hose or a porcelain spiral, connects the water jackets of the valves to the circulating system.

A typical system requires:—

(i) Water circulating pumps and motors.

(ii) Storage Tanks.

(iii) Water cooling unit (usually forced air draught cooling).

(iv) Valves, gauges, thermometers, alarms, piping, etc.

(v) Protective equipment. (See also later).

(vi) Water distillation plant.

A sketch of the elements of such a system is given in Fig. 3.

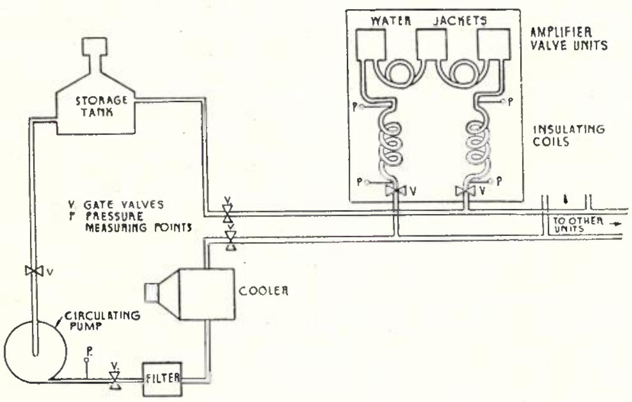


Fig. 3.

The main precautions to be taken are to guard against

(i) Incorrect rate of flow of water.

(ii) Incorrect temperature of water.

(iii) Application of anode and filament voltages before the water circuit is operating normally.

(iv) Excessive leakage current, which is in effect a measure of the water insulation.

The above are provided for by suitable alarm and interlocking circuits, utilizing, for example, a water flow meter, contact thermometers and an ammeter to measure leakage current. The circuits are so arranged that the power supplies are removed from the transmitter in the event of serious failures.

Another point of interest is the measure adopted to prevent electrolytic action eating away copper fittings. A lead or copper "target" is inserted in the fitting and projects into the water. Resultant electrolytic action eats away only the target which may be regularly renewed.

Q. 7.—A radio transmitter is commonly connected to its radiating system by means of an open wire transmission line. Why is this done and what factors affect the electrical characteristics of the line?

What is meant by standing wave ratio and how can it be measured?

What is the function of the coupling network at the aerial end of the line?

A.—The radiating system of a transmitter is usually erected remote from the transmitter building to avoid distortion of the radiated field which would occur due to the presence of the buildings. Other effects would also occur in the case of a high power transmitter.

The electrical characteristics of the line are dependent upon:—

(i) The gauge of wire, i.e., diameter.

(ii) The composition of the wire.

(iii) The height above ground.

(iv) The spacing between the wires and also the type of line—whether two-wire, four-wire, six-wire, etc.

(v) The quality of the insulators.

(vi) The weather and associated factors.

The important relationship of the above is their effect on the characteristic impedance of the line. The calculation of this varies with the type of line but may be illustrated by considering a two-wire line, the characteristic impedance, Zo, of which is given with sufficient accuracy by the expression:—

$$Z_o = 276 \log_{10} 2D/d$$

where D = centre to centre spacing, d = diameter of wire } in same units.

The "Standing wave ratio" of a line is the ratio of maximum to minimum current (or voltage) values occurring over the length of the line.

The origin may be briefly explained as follows:—

When a line is correctly terminated the current distribution over the line will be equal at all points (considering the usual lengths of these lines).

When the termination is incorrect, i.e., the line is not terminated in its characteristic impedance, reflection will occur at the point of mismatch. The reflected wave will have a phase difference with respect to the original wave, and will augment or diminish this wave depending on the phase relationship at a particular instant. The net result is that the current distribution instead of being uniform varies from point to point and will have a maximum and minimum value.

The numerical value of the S.W. Ratio is an indication of the degree of mismatch, e.g., a ratio of 1.5:1 indicates that one impedance is 1½ times greater than the other, (600 ohms and 400 ohms would meet this case).

The standing wave ratio is measured by traversing the line with a conveniently mounted R.F. ammeter loosely coupled at a constant distance from the line and noting the current readings at a number of points. An indication of the maximum and minimum points will be found and these locations explored for more accurate determination of the actual current values. Fig. 4 illustrates this method.

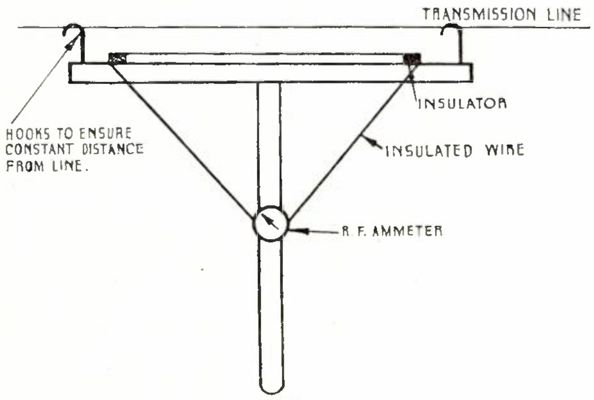


Fig. 4.

The coupling network at the aerial end of the line may serve the following purposes:—

(a) Match an unbalanced aerial to a balanced line or vice versa.

(b) Match a transmission line and aerial of different impedances.

(c) Enables the reactance component of the aerial impedance to be "tuned out."

Q. 8.—Define reactance and impedance. A coil of 200 microhenries inductance and a resistance of 200 ohms are connected in series. What is the impedance of the circuit at a frequency of 500 kilocycles? If an A.C. voltage of 1,000 volts R.M.S. at 500 kilocycles is connected across the circuit, what is the magnitude and phase angle of the current flowing? What capacity should be placed in series with the coil to reduce the phase angle to zero?

A.—(i) Reactance is the opposition offered by an inductance or capacitance to the flow of alternating current.

Numerically

Inductive reactance $= 2\pi fL$

Capacitive reactance $= 1/2\pi fC$

$L =$ inductance in henries.

$C =$ capacity in farads.

(ii) Impedance is the total opposition offered to the flow of alternating current in a circuit. It has a complex value depending on the inductance, capacitance and effective resistance of the circuit, and on the relationship between these elements (whether in series or parallel, or in a combination of both).

$L = 200\mu H \quad R = 200\Omega \quad f = 500$ kc/s

Impedance $= Z = \sqrt{R^2 + X^2}$

where $R =$ effective resistance of circuit

$X =$ reactance of inductance

From above definition:

Reactance $X = 2\pi fL$

Substituting

$$X = 2 \times 3.14 \times 500{,}000 \times 200 \times 10^{-6}$$
$$= 628 \text{ ohms.}$$
$$Z = \sqrt{200^2 + 628^2}$$
$$= 659 \text{ ohms approximately.}$$

Current $I = E/Z = 1000/659 = 1.52$ amps.

Let phase angle $= \theta$

$\tan\theta = X/R = 628/200 = 3.14$

from which $\theta = 72° \, 20'$

At resonance the capacitive and inductive reactances are equal.

i.e. $X_L = X_C$

$\therefore X_C = X_L = 628$ ohms.

Now $X_C = 1/2\pi fC$

or $C = 10^{12}/2\pi fX_C$ micro micro farads

$C = 10^{12}/(6.28 \times 5 \times 10^5 \times 628)$

$= 507.9 \ \mu\mu f$

Answers

$Z = 659$ ohms approx.

$I = 1.52$ amps.

Phase angle $= 72° \, 20'$

$C = 507.9 \ \mu\mu f$.

EXAMINATION No. 2817—ENGINEER—TELEPHONE EQUIPMENT

C. J. Prosser

GROUP I.

Q. 1. (a) Describe the practical differences between the release circuits in group selectors of the pre-2000 and the 2000 types.

(b) Explain with reference to a schematic diagram of the relative circuit elements the operation of the vertical and rotary stepping circuits of a 2,000 type group selector.

A.—(a) The release circuit in the pre-2000 type group selector consists of a release magnet, the circuit of which is prepared when the vertical off normal springs operate, and completed when the D relay falls back at the conclusion of the call. When the calling subscriber hangs up, the release of D causes the rotary magnet to operate and withdraw the double dog. The shaft then rotates under the control of the cup spring in an anti-clockwise direction out of the level and drops vertically to normal. A contact operated by the release magnet earths the incoming private wire while the switch is releasing and guards the switch from seizure by another caller before it has restored to normal.

In the 2,000 type selector, no release magnet is provided, as the release action is a continuation of the rotary motion in a clockwise direction off the level to the 12th step and then vertically downwards and back to the normal position under spring control. At the end of the call, the release of the Final Selector removes earth from the P wire, and the switching relay releases, causing the quick release of relay C. which has no copper slug or short-circuited winding at this stage. Relay B releases, and a circuit is closed for the rotary magnet via B and C normal contacts, rotary interrupter (toggle) springs and off-normal springs to Release Alarm Earth. The switch self-drives until the wipers are off the level, when the shaft drops and rotates back to normal, opening the circuit of the rotary magnet at the off-normal contact. During the release of the switch, earth remains connected to the incoming P wire over a normal contact of the C relay, off-normal springs, and a normal contact of the switching relay HB.

Owing to the different mechanical design, the 2000 type switch requires a longer period to release than the pre-2000 type, and the release guard is maintained for a longer period (approximately 300 ms. as against 100 ms.).

(b) The relative circuit elements concerned in the vertical and rotary stepping of the 200 outlet 2000 type group selector are shown in Fig. 1.

Vertical Stepping. When a digit is dialled, the A relay (not shown), bridged across the positive and negative lines, releases and re-operates. At each release, the vertical magnet receives a pulse via battery, vertical magnet, 5 ohm winding of relay C, C1 operated, NR4 normal, A1 normal, B1 operated, to earth, and the wipers make one vertical step.

The off-normal N springs operate, and energise relays HA and HB over their 550 ohm windings in parallel, contact B5, N1 operated, R normal, C2 operated, NR1

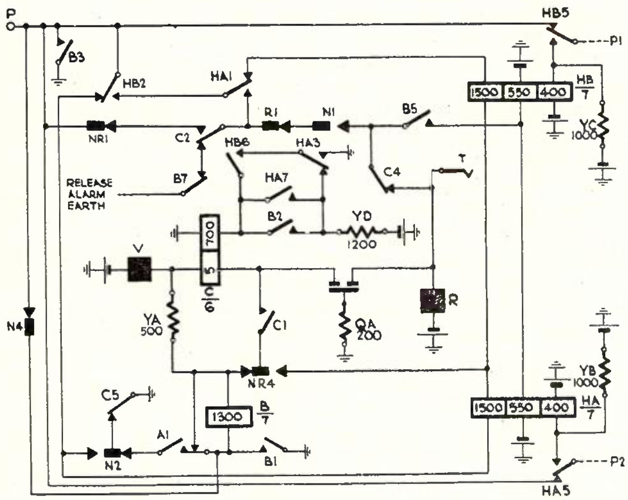


Fig. 1.—Vertical and rotary circuits group selector 200 outlet, 2000 type.

normal, B3, to earth. The 700 ohm winding of relay C is now short-circuited via earth, winding of C, HB6 operated, HA3, to earth, and being slow to release, remains operated during dialling by the pulses through its 5 ohm winding. After the last impulse has been received, relay C restores and completes the circuit for the Rotary Magnet.

Relay B is fast operating, having no copper slug, but is slow to release owing to the short circuit at A1 during the "break" period.

Rotary Stepping. The rotary magnet is energised via battery, rotary magnet, C4 normal, N1 operated, R normal, HA1 operated, HB2 operated, B3 to earth, and steps the wipers on to the first outlet. The rotary interrupter R springs operate, thus breaking the circuit of the rotary magnet and also the 550 ohm windings of relays HA and HB. If the contacts on which the wipers rest are both busy, relays HA and HB remain operated on their 400 ohm windings since the wipers encounter earths on the P contacts, and the rotary magnet re-operates and steps the wipers on to the second set of bank contacts. The cycle is repeated until a free outlet is found, when either HA or HB releases and breaks the circuit of the rotary magnet. If both outlets are free, then both HA and HB release, and break the circuit of the rotary magnet.

Relay C re-operates when HA or HB or both release, and disconnects the A relay to extend the connection to the next selector.

If all outlets are busy, the rotary drive continues to the 11th step when the S springs operate, HB releases and disconnects the rotary magnet.

Q. 2.—(a) Why are auto-auto relay sets required at main exchanges of the 2000 type as installed in metropolitan networks in Australia?

(b) Explain fully the reasons for associating junction hunters with auto-auto relay sets in pre-2000 type exchanges, but not in 2000 type exchanges.

A.—(a) Auto-auto relay sets are required at main exchanges of the 2000 type on junctions from first selector levels to other main exchanges, and from second selector levels to branch exchanges in the same group to obviate the necessity for three-wire junctions. If a selector level contact were trunked direct to a distant exchange, three wires would be required in order that the switching relay could be held operated on the private (or third) wire. The insertion of a relay set between the selector and the junction makes it possible to use a two-wire junction with consequent savings in line plant which more than offset the cost of the equipment.

The functions of the relay set are:—

(a) Returns guarding and holding earth to the preceding switches.

(b) Repeats impulses from the calling subscriber over the junction to the distant exchange.

(c) Provides a transmission bridge which feeds current to the calling subscriber.

(d) Gives the registering battery impulse when the junction current from the distant exchange reverses.

(e) On receipt of the reversal, reverses the battery feed to the calling line for supervisory and public telephone fee collecting purposes.

(b) Junction hunters are associated with auto-auto relay sets in pre-2000 type exchanges in order to secure the most efficient trunking arrangement between one rank of selectors and the following one when the latter is located at a distant exchange, thus economising in the number of junction pairs required.

For small groups of junctions, grading of the selector outlets provides an efficient arrangement, but, where the number of junctions on a particular route is large, say, over 30, the advantage attending selection of circuits in large groups has led to the use of 25 point junction hunters between the selector banks and the relay sets installed on outgoing junctions. Thus, whereas one selector has access to 10 trunks on any particular level, by connecting each trunk to a 25 point junction hunter and connecting these 25 outlets to the outgoing junctions, the number of outlets available to the selector may be increased up to $10 \times 25 = 250$.

Increasing the size of the group of junctions available from the selector level increases the efficiency of the group, and, as the availability to a source of traffic increases, the number of outlets required to carry the traffic decreases. Trunking into larger groups is therefore more efficient and economical than trunking into a number of small groups and justifies the use of 25 point junction hunters between 10 point selector levels and auto-auto relay sets on all but minor routes.

In the case of 2000 type exchanges, however, selector levels have a capacity of 20 outlets, and it is seldom economical to further group the outgoing junctions through junction hunters. Such a course would only be justified in the case of a large group of junctions carrying exceptionally heavy traffic.

Q. 3.—A 2000 type automatic exchange employs line finders of the bimotional type and is equipped for partial secondary working. Explain with reference to a schematic diagram of the relative circuit elements.

(a) How continuous service is provided to subscribers associated with a control set to which any abnormal condition may have developed.

(b) How calls are directed to another control set in the event of an associated line finder failing to operate from any cause.

A.—(a) If a fault develops on a control set and it fails to switch to a free line finder within 6 seconds of receiving a start signal, an alarm is given, the faulty control set is automatically taken out of service and the start signal is transferred to another control relay set. Referring to Fig. 2 as each call is initiated, ground on

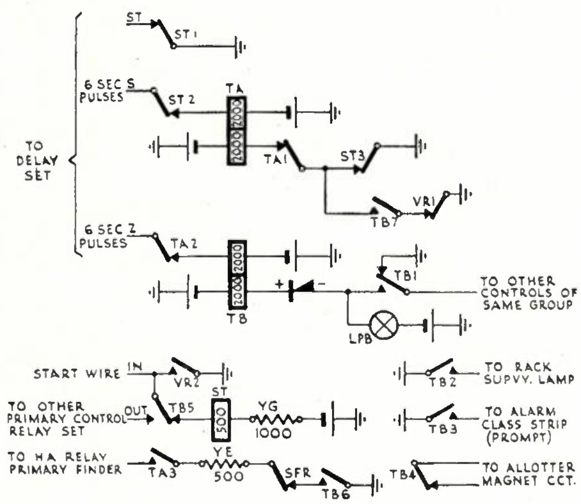


Fig. 2.

the start wire operates relay ST, and ST1 operated grounds the lead to start the delay set. Relay TA operates from ground on the "S" pulse via ST2 operated, and locks via TA1 and ST3 both operated, to ground. TA2 operated prepares a circuit for relay TB to the "Z" pulse, and TA3 operated disconnects the holding circuit to relay HA in the primary finder. If a fault, such as relays LK or VR not operating, exists in the control set, ground is extended from the "Z" pulse and relay TB operates 6 seconds after relay TA. TB1 operating closes holding circuit for relay TB to ground on common lead and lights lamp LPB.

TB2 lights rack supervisory lamp, TB3 starts subsection alarm, and TB4 operating breaks the allotter magnet circuit.

TB5 operating transfers the start wire to another control set and releases relay ST. Relay TA does not release as TB7 operating completes a holding circuit via VR1, and the alarm is given until fault is cleared. Service to the subscriber is not interrupted as the second control set takes over the call.

(b) If a line finder fails to function correctly within the 6 seconds delay period, it is busied out and the primary control relay set is automatically taken out of service on the operation of relay TB.

Referring to Fig. 2, when the circuit to relay ST is broken by TB5 operating, ST releases before relays LK and VR and thus ensures the release of relay TA. If the primary line finder has not moved off normal, (see Fig. 3.), relay HA is operated from ground via TB6

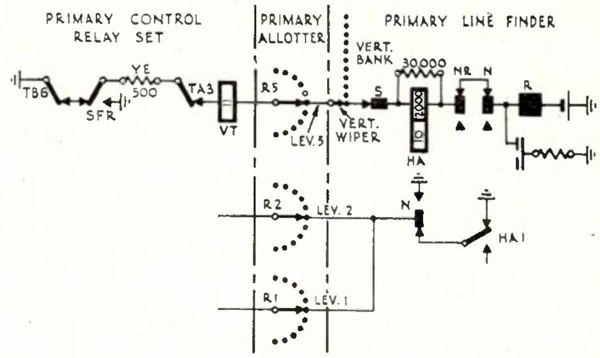


Fig. 3.

operated, SFR normal, YE 500Ω, TA3 normal, relay VT, primary allotter wiper and bank R5, vertical wiper on normal, contact S normal, relay HA, NR and N normal, rotary magnet R to battery.

HA1 operated extends ground via N normal to primary allotter R1 or R2 to busy the line finder. Relay TB contacts transfer the start wire to another control relay set and connect the alarms (see Fig. 2). The call is thus taken over by a second control set and line finder.

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HA1 operated extends ground via N normal to primary allotter R1 or R2 to busy the line finder. Relay TB contacts transfer the start wire to another control relay set and connect the alarms (see Fig. 2). The call is thus taken over by a second control set and line finder.

GROUP 2

Q. 4.—A single manual exchange operating on the magneto principle exists in a large metropolitan network. The network is 95 per cent. automatic, the equipment employed being of the Strowger step by step type. For calls incoming to the magneto exchange from automatic, what facilities do you consider necessary to provide on the incoming junctions and manual positions handling this class of telephone traffic in order to give ideal service conditions from the subscriber's point of view. Give your reasons for including each facility you consider is necessary.

A.—Incoming traffic at the magneto exchange from automatic exchanges should be handled by means of "call indicator" positions which provide similar service to automatic-automatic calls, the calling subscriber dialling a normal prefix followed by a train of digits and being unaware that the call is completed manually at the magneto end. The facilities are as follow:—

(a) Assuming that a 6-digit system is in use and the magneto exchange is allotted a two-digit prefix, dialling the first two digits routes the call to an available incoming junction operator's position at that exchange, and the further operation of the four remaining digits causes the required subscriber's last four digits to appear visually on a display panel in front of the operator.

(b) The operator, without speaking to the calling subscriber, tests the multiple jack of the called line and, if it is free, connects the circuit manually to the required subscriber's line, using any one of her cords and plugs for this purpose. The act of plugging into the subscriber's line jack brings into operation a finder circuit which connects the cord and plug to the calling junction, thus completing the call by means of a single cord and plug.

(c) Incoming junctions have access to any one of the suite of call indicator positions and calls are displayed in the order in which they are received at the position, thus minimising delay in answering and distributing the load over the positions.

(d) At the stage where the plug is inserted in the called line and the finder circuit locates the calling junction, ring tone is connected to the calling line and ringing current to the called line, thus providing standard ringing facilities. The displayed number disappears and is replaced by the next number to be dealt with.

(e) In the event of the called subscriber's line being engaged, the operator depresses a busy tone key and busy tone is returned to the caller from the relay set associated with the junction. This enables the whole of the cords on the position to be used only for effective calls, other than D.N.A. calls, of course.

(f) When the called subscriber answers, ringing current and ring tone are disconnected, and a reversal of current occurs over the junction in accordance with normal practice for registering the call. (Condensers must be fitted in all magneto telephone circuits in order to provide the necessary ringing circuit and loop on answering.)

(g) The supervisory lamp associated with the cord glows when the calling subscriber clears, to ensure prompt disconnection of the cord.

(h) The supervisory lamp flashes and a special tone is connected to the operator's receiver should the called subscriber require to make a call before the operator removes the plug.

Q. 5.—In a certain network an automatic exchange of the 2000 type is operated from a single battery of 432 ampere hour capacity. The cells of this battery are of the lead acid type with glass containers. Charging, etc., is done by rectifiers.

Assume you are the Engineer responsible for the oversight of the maintenance of the exchange. Outside ordinary office hours the Technician-in-Charge of the exchange telephones you at your home and advises that one of the glass jars of a cell in the exchange battery has broken and that the acid has all spilt out on the battery room floor.

- **(a) Would service at the exchange be interrupted?**
- **(b) Detail the action you would take up to the time the battery and battery room can be said to be restored fully to normal.**
- **(c) What instructions would you issue to the Technician immediately following his telephone advice of the battery mishap?**

A.—(a) Under normal floating procedure a rectifier would be connected to the battery at the time of the mishap, and the loss of the acid from one cell would soon result in a high resistance, provided the plates and separators were not seriously displaced, in effect leaving the rectifier connected directly to the exchange. Assuming that the traffic was normal and the rectifier switch in the automatic charge position, the rectifier would carry the load up to its rated output. A heavier load could be met by switching in a second rectifier; thus, service would not be interrupted. However, the disconnection of the battery would mean the loss of the main noise suppressor, and subscribers might hear some noise from the rectifier, although a choke coil usually forms part of the rectifier charging unit and would suppress most of the hum. Also, as the charge leads from the rectifier would be of lighter conductors than the discharge leads to the exchange, crosstalk might be heard. If the accumulator plates short-circuited, the fall of 2 volts would be compensated for by the self-regulation of the rectifier, or could be corrected by the manual control, and service would be maintained. If the load was in excess of the rectifier output, the exchange voltage would fall, and if it fell below 46 volts switch operation would be seriously affected, as the permissible voltage range for 2000 type equipment is 46 to 52 volts.

(b) The faulty cell connection should be unbolted, the plates and separators carefully removed, and a conductor of suitable capacity bridged securely between the adjoining cells. Emergency charging leads should be available and would be suitable. In arranging the bridging load, obstruction to subsequent replacement of the cell must be avoided. Adjust rectifier output to maintain exchange voltage between 46 and 52 volts, switching in the second rectifier if necessary. Place negative plates in spare jar of clean water, and separators in spare space in adjacent cells or in jar of acid. Positives may be allowed to dry on bench. Prompt action in these matters will save the plates and separators. Remove broken glass, absorb spilt acid with sawdust, or flush floor with hose into sump if facilities are available.

Other means of neutralising and disposing of the acid from floor and stillage are powdered chalk or whiting, ammonia, or carbonate of soda (washing soda), which should be available. Precautions against acid burns and damage to clothing should be taken.

At the earliest opportunity, the cell should be reassembled in position, in a new jar, replacing any damaged separators, and the acid replaced. The cell should then be charged separately through a suitable resistance during slack traffic hours, and then reconnected with, at most, a momentary open circuit to the main battery during removal of the temporary bridge which would not affect service with the rectifier in operation.

(c) The Technician should be instructed to bridge out the faulty cell, adjust the rectifier charging rate to maintain the correct voltage, switching in the second rectifier if necessary. Further instructions as in (b) should be given, but the Engineer should, if possible, visit the exchange to supervise the work, and arrange for such assistance as might be necessary.

EXAMINATION No. 2824—SENIOR TECHNICIAN—TELEPHONE
TELEPHONY I

J. Hardie

Q. 1.—(a) In a 2000 type exchange a release alarm operates:—

- **(i) How would you locate the group selector causing the alarm?**
- **(ii) Indicate three probable causes of release failure of a 2000 type group selector.**

A.—(i) The exchange alarm display system (lamps) will indicate the particular floor on which there is an alarm; the floor display indicates the section of the floor. The sub-section lamp (red) will be glowing. By observing all racks in the sub-section, the release lamp (green) will be seen. The rack shelf lamps will show in which shelf the fault lies. Remove the link from test jack springs 11 and 12 of each switch in turn, at the same time observing the rack lamp. When the link is removed from the faulty switch, the lamp will be extinguished and the alarm cleared.

In practice it is advisable to locate the faulty switch by observation, instead of removing the release link, for, after removing the link, it is often difficult to determine the nature of the fault.

(ii) (1) Wipers fail to cut in and strike bank.
(2) Wipers catching on the 11th step bank contact (caused by carriage bounce).
(3) Rotary detent fouling carriage (caused by carriage bounce).
(4) Rotary disc fouling comb plate.
(5) Switch not cutting in off vertical pawl or N.R. lever.
(6) Insufficient restore spring tension.
(7) Interrupter not opening.
(8) Mechanical bind which would prevent the switch from releasing.

Q. 1.—(b) In a certain primary line finder group it is observed that the finders step vertically to a certain level, but do not cut in on the level—

(i) What fault condition would prevent the finders cutting in on the level?

(ii) Why is this guarding feature necessary?

A.—(i) The failure of a "K" relay (in a subscriber's line circuit) to operate when the calling line has been found.

(ii) The guarding feature is necessary because, if K fails to operate, a number of finders would switch to the calling line and, due to the paralleling of certain circuits in the finders, damage would be caused by excessive current flow. This is prevented by the circuit arrangements as shown in Fig. 1.

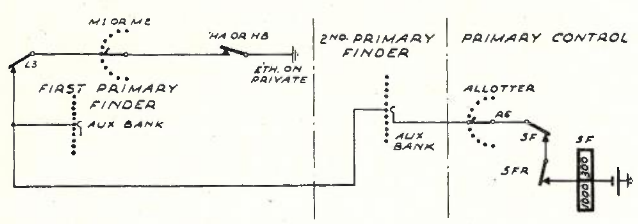


Fig. 1.

A finder finds the calling line, but, for some reason, the subscriber's K relay fails to operate, relay L remains operated. The start signal is therefore maintained, and, when the allotter has stepped, a second finder commences to search. At the same time, owing to L relay being operated, an earth is extended to the auxiliary bank contact from the private wire of the first group selector via HA1 or HB1, M1 or M2, as shown in Fig. 1. This earth appears on corresponding auxiliary bank contact of all finders in the group. When the second finder reaches this level, relay SF is held on its 1000 ohm winding. Since SF is held, the circuit for HA relay is maintained and the finder is prevented from entering the level. Since the finding action has not been completed in the case of the second finder, the primary control set is still held. With the arrival of the time pulse, the second finder is released and the control set locked out. The alarm operates and the start signal is transferred to a third control set, which causes a third finder to search for the calling line, but this is also held outside the level; the process continues until the fault is cleared. The alarm merely signifies a fault. It is then necessary to locate the particular finder resting on a rotary contact having the non-operated K relay.

A second important reason why this feature is necessary is that, when K relay in the line circuit fails to operate, the subscriber's dialling is seriously interferred with.

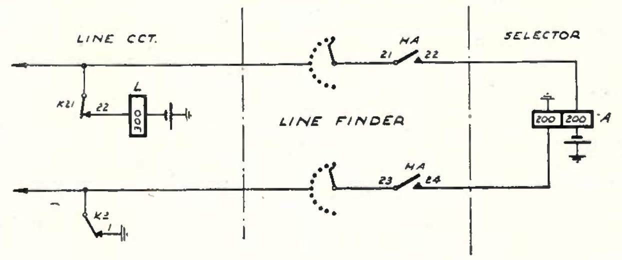


Fig. 2.

With the failure of K to operate, one half of the impulsing relay of the group selector is short-circuited from earth at K.1-2 line finder bank, HA.23-24, 200 ohm coil of A. The other coil is shunted from battery through L, K.21-22, line finder bank, HA.21-22 to A relay 200 ohm coil to negative battery. (Fig. 2.)

Q. 1.—(c) A subscriber's uniselector of the homing type fails to return to the home position when the calling loop is removed. What is the probable cause of the failure?

A.—(i) Faulty contact at interrupter springs.
(ii) Dirt collected under magnet and armature, thus reducing the stroke.
(iii) Faulty wiper contacts on the homing arc.
(iv) Open or high resistance wiring or relay contacts in the magnet drive circuit.
(v) Failure of the K relay to release, due to relatively high resistance ground on private. This fault frequently results in a number of subscribers' uniselectors camping on the same trunk, from which they will not release.

The homing drive circuit is from earth at homing arc US.1, homing plate, L.1-2, K.26-27, dm. 2-1, DM to battery. The self-interrupted drive takes place until the circuit is broken at the home position (Fig. 3).

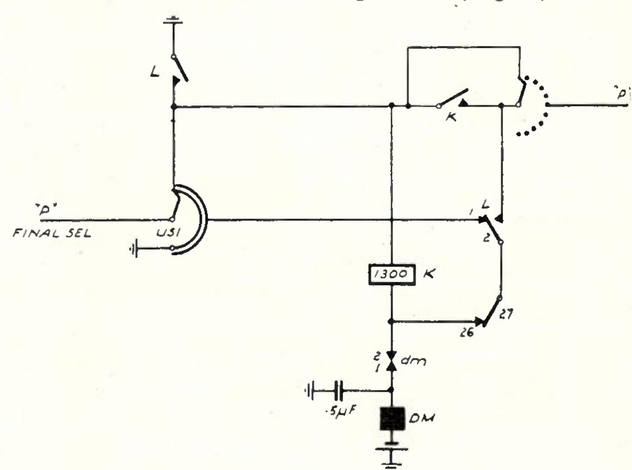


Fig. 3.

Q. 1.—(d) The wipers of a 2000 type group selector, when searching over a level, stop on a busy contact. What unstandard adjustments would be most likely to cause this trouble?

A.—Any reason which will cause the testing relay HA or HB to release whilst searching over busy bank contacts.

(i) Wiper gaps too wide.
(ii) Wipers retarded on the bank contacts.
(iii) Wipers advanced too far on the bank contacts.
(iv) Rotary back lash due to incorrect adjustment of rotary front stop.
(v) "Floating" contacts on mechanically operated spring sets.
(vi) "Floating" contacts on relay springs.
(vii) Interrupter gaps too wide. (This frequently causes S.O.B. troubles on 1st contact of a level.)
(viii) No rotary stroke.
(ix) Fast releasing HA or HB relays, due to incorrect stroke, tensions or residuals.
(x) High resistance connections on wiper cords, tags, or in any portion of the testing windings of HA and HB relays. (This is not strictly a mechanical adjustment, but is worthy of mention. It is the reason for many S.O.B. faults.)

Q. 2.—(a) There are three types of metering circuits in use in automatic exchanges. These are—

(i) Reverse Battery Metering.
(ii) Booster Battery Metering.
(iii) Positive Battery Metering.

Briefly describe each system and indicate the type of meter used with each system.

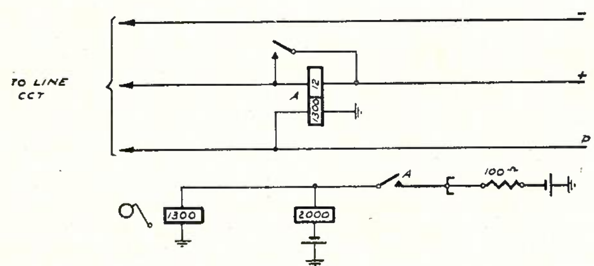


Fig. 4.

A.—(i) Reverse Battery Metering.—A polarised relay is connected in the line circuit of each trunk. When the called subscriber answers and reversal takes place, both windings of "A" assist and the relay operates. Relay "A" closes the circuit to the 1300 ohms. meter, which operates and remains so for the duration of the call.

The 12 ohms. winding of "A" is short circuited by its own contacts and is thus removed from circuit whilst the conversation is in progress. (Fig. 4.)

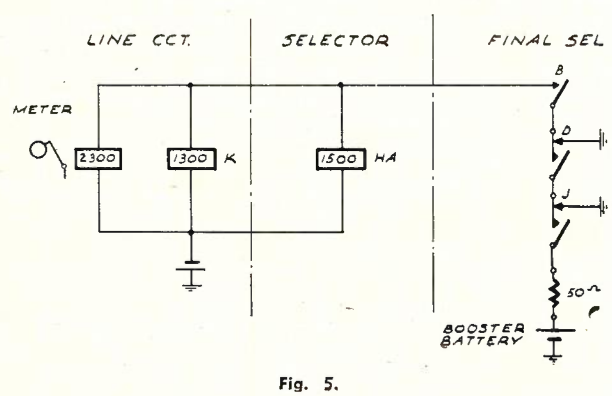


Fig. 5.

(ii) **Booster Battery Metering.**—When the called subscriber answers, "D" relay in the final selector operates and booster battery is applied to the private wire for the slow release period of relay "J." The meter, which is of 2300 ohms. resistance, is tensioned not to operate on 50 volts, but will operate when the additional 50 volts positive battery is applied to it. The meter is adjusted to hold on 50 volts and therefore remains operated for the duration of the call. (Fig. 5.)

(iii) **Positive Battery Metering** (Using 100A Type meter).—In this system a meter of 500 ohms. resistance is connected in series with a metal rectifier to the private wire. (There is one rectifier to each primary outlet.) When the called subscriber answers, a positive battery pulse is connected to the private wire for the slow release period of relay "J." This causes the meter to operate. When relay "J" restores (after its slow release period) and the positive battery is removed from the private wire, the meter (100A) restores and in doing so registers one call. The meter then remains in the non-operated position for the duration of the call. Multi-metering is possible with this system (Fig. 6).

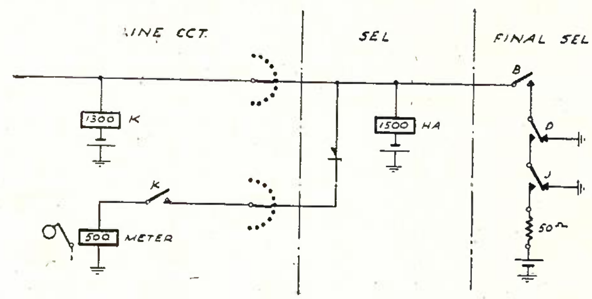


Fig. 6.

Q. 2.—(b) Dialling into a group selector takes place over the following circuits:—

(i) A high resistance subscriber's line.
(ii) A subscriber's line with low insulation.
(iii) A fast dial (12 impulses per second) in a subscriber's telephone over a normal resistance line.

Describe briefly for each condition the effect on the impulsing circuit of the group selector.

A.—(i) 1. Resistance decreases the rate of the building up of the flux in the relay core; therefore, the operating lag is increased.

2. Resistance decreases the final value of current flowing in the make period; the flux is, therefore, less and the release lag is decreased.

Since the make period of A is equal to the make period of the dial plus the difference between the releasing and operating lags, it is decreased by both of these effects.

Switch failure is likely to occur if the make period is less than 20% of the total impulse period; consequently the length of line through which switches may be correctly operated is limited by the amount of distortion experienced.

(ii) Low insulation will cause a small current to permanently flow through "A" relay; hence the relay will operate more rapidly and release more slowly. Since both effects increase the make period, a considerable amount of distortion is introduced. It is usual to specify that switches function correctly when insulation resistance is infinite and when it is 10,000 ohms.

(iii) High dial speeds do not affect the operate or release lags of impulsing relays, providing the relays have time to flux correctly. Very fast dials do not allow the relays to flux fully with their consequent failure. The normal dial has a ratio of $33\frac{1}{3}$ make to $66\frac{2}{3}$ break, and the correct dial speed is 10 I.P.S. Translated into time, this means that one impulse takes 100 milliseconds, of which $33\frac{1}{3}$ M.S. is make and $66\frac{2}{3}$ M.S. break. During the make period, A and B relays must operate correctly and during the break C relay and the vertical magnet must operate.

If the dial speed is increased to 12 I.P.S. the effect on the impulse is as follows:—

$$\frac{1000 \text{ Milliseconds}}{12 \text{ I.P.S.}} = 83\tfrac{1}{3} \text{ Milliseconds}$$

The ratio of make to break remains constant, so the make period is approximately 27.8 M.S. instead of $33\frac{1}{3}$ M.S. and the break ratio is 55.5 M.S. instead of the normal break of $66\frac{2}{3}$ M.S. It will be seen from Fig. 6 that the margin for the correct operation of A.B.C. relays and the vertical magnet is considerably reduced. The slugged relays B and C must hold during the make and break of the dial. (Fig. 7.)

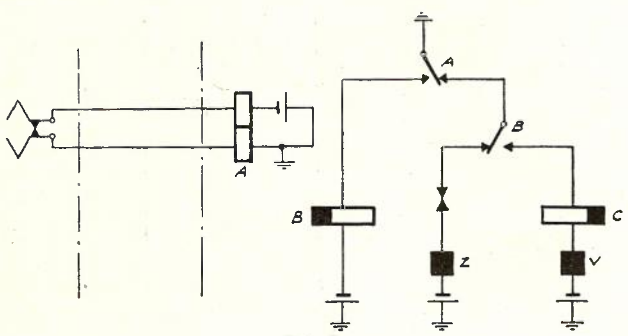


Fig. 7.

Q. 2.—(c) When impulsing through several repeaters (relay sets) (fitted with 3000 type impulsing relays and ballast resistors) in tandem, what condition, in your opinion, would limit the resistance of a junction between two repeaters, providing the transmission was satisfactory?

A.—The factors limiting the resistance of junctions between repeaters in tandem are:—

(i) "Initial pick up." This refers to the initial operation of the "A" relay in a group selector at the distant exchange upon seizure. It is caused by the introduction of the inductance of the F and E relays of the repeater into the selector A relay circuit and causes a preliminary impulse.

(ii) "Subsequent pick up." This occurs at the end of a train of impulses. When "C" relay restores and inductance of F and E relays is again introduced into the selector "A" relay circuit, the back E.M.F. from F and E causes the selector "A" to release and give an additional impulse.

(iii) "Pick up after reversal." This condition arises when reversal takes place. When "D" relay in the repeater reverses current over the calling line, the flux goes through a neutral period and the repeater "A" momentarily releases to re-operate immediately. This open period of "A" relay can cause the release of the connection. See article by Mr. W. King, Vol. 7, No. 2 Telecomm. Aust.

Q. 2.—(d) Impulsing relays of the 3000 type are provided with armatures of special shape and adjustable residual screws. Explain why these are necessary.

A.—Isthmus armatures are of two types—pear-shaped for repeaters and oblong slot for selectors and finals. The two shapes are made so that they can readily be identified. The pear-shape is designed to work in conjunction with 50/50 ohm "A" relays and barretters. The effect of the isthmus is as follows:—

(i) Becomes saturated at a much lower value of ampere turns. Thus the relays give a more uniform performance over a wide range of energisation, due to varying line conditions.

(ii) The moment of inertia of the armature is reduced.

(iii) The flux in the circuit for a given current is reduced in order to ensure prompt release.

Adjustable residual screws are necessary because:—

(i) "A" relay adjustments are critical (Red label) and so would not come within the tolerances of fixed residual studs. The fixed studs are
a 4 mils.
b 12 mils.
c 20 mils.

(ii) Due to the great amount of work an impulsing relay has to carry out, residuals have frequently to be altered to conform to standard adjustments. This would not be possible with fixed residuals.

EXAMINATION 2817—ENGINEER TRANSMISSION SECTION 1—LONG LINE EQUIPMENT

E. J. Wilkinson, A.M.I.R.E.

Q. 1.—Define (a) the Decibel; (b) the Neper.

A carrier frequency amplifier has a gain of 60 decibels. The input circuit is 600 ohms resistive impedance and the output circuit feeds into a 200 ohm resistive load. What is the current in the load when an A.C. potential of 1 volt is applied at the input?

A. 1.—(a) The decibel is a unit used in the comparison of two amounts of power, voltage or current. By expressing the ratio of two such amounts logarithmically calculations associated with gain and attenuation measurements are greatly simplified.

In practical definition the ratio of two amounts of power P2 and P1 is said to be "N" decibels (db) if

$$N = 10 \log_{10} P_2/P_1$$

Similarly $N = 20 \log_{10} E_2/E_1$ or $20 \log_{10} I_2/I_1$ where E and I are voltage and current values respectively. In these latter cases it is essential that the output and input impedances be equal.

(b) Like the Decibel, the Neper is a unit which expresses the ratio of electrical power logarithmically. The logarithm used, however, is the natural logarithm to the base "ε". In transmission line measurements, where the line is terminated at the received end by an impedance equal to the characteristic impedance of the line, and the send and receive currents are flowing in like impedances, the attenuation of the line is given as follows:—

$$\text{Attenuation (nepers)} = \log_\varepsilon I_s/I_r$$
where I_s = send current
I_r = receive current
$\varepsilon = 2.718$

(c)
$$60 = \log_{10} (\text{W output}/\text{W input})$$
$$W_0 = W_1 \text{ antilog}_{10} 6$$
$$= W_1 \times 10^6 = 10^6/100$$
$$I_0 = \sqrt{W_0/R}$$
$$= \sqrt{10^6/(600 \times 200)}$$
$$= 2.88 \text{ amps.}$$

Q. 2.—State some of the principal assumptions made in the development of the classical theory of electric wave propagation along two parallel conductors.

Develop the expression for the Attenuation Constant (β) and Wavelength Constant (α) in terms of the Primary Electrical Constants R, L, G and C of an ordinary transmission line, given that the Propagation Constant (γ) may be written:—

$$\beta + j\alpha = \sqrt{(R + j\omega L)(G + j\omega C)}$$

A.—The theoretical case of two parallel conductors is the nearest approach to the practical case of an ordinary transmission line. In order that a mathematical analysis may be made to derive equations useful in predicting and improving the efficiency of such a line, certain assumptions must be made:—

(a) Each conductor is considered to be identical and uniform, both geometrically and electrically.

(b) The mathematical analysis of complex speech currents involves the use of Fourier's series, or a similar method, all of which require that the complex wave may be resolved into a number of sine functions. If it is assumed that the voltage and current at the input end of the line are sine functions of time, and continue as such along the length of this line, the propagation of such currents may be studied by treating the case of their constituent sine waves.

(c) The electrical primary constants of the line R (resistance in ohms per unit length), L (inductance, in henries per unit length); G (leakance, in mhos per unit length), C (capacitance, in farads, per unit length) must be assumed to remain constant in value with changes in frequency and in current value.

(d) The electrical energy is transmitted by the surrounding medium and the conductors act as guides for the wave.

(e) The rates of propagation of flux in the case of the magnetic component of the wave, and of strain in the case of the electrostatic component are negligible.

(f) The effect of transient conditions are negligible. Currents and voltages reach steady state conditions very rapidly. What happens during the transient period, in which the steady state conditions are built up, is of minor importance.

(g) The line may be represented by a number of elements containing series and shunt circuit components as shown in Figure (1).

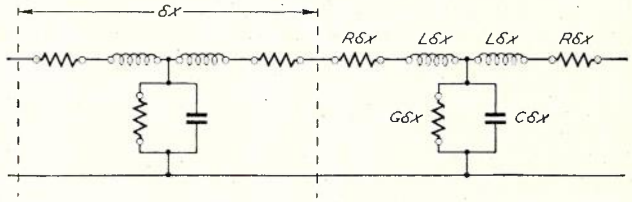


Fig. 1.

To develop expressions for Attenuation Constant (β) and Wavelength Constant (α) in terms of the Primary Electrical Constants, R, L, G and C of a line given that Propagation Constant

$$(\gamma) = \beta + j\alpha = \sqrt{(R + j\omega L)(G + j\omega C)}$$

Since the propagation constant γ is a vector,

$$\beta + j\alpha = \sqrt{(R + j\omega L)(G + j\omega C)} \quad \text{.... (1)}$$

Squaring both sides—

$$\beta^2 + 2j\alpha\beta - \alpha^2 = GR - \omega^2 LC + j(\omega LG + \omega CR) \quad \text{.... (2)}$$

Equating real and imaginary parts—

$$\beta^2 - \alpha^2 = GR - \omega^2 LC \quad \text{.... (3)}$$

$$2\alpha\beta = \omega(LG + CR) \quad \text{.... (4)}$$

Since $(\beta^2 - \alpha^2)^2 = (\beta^2 + \alpha^2)^2 - (2\alpha\beta)^2$

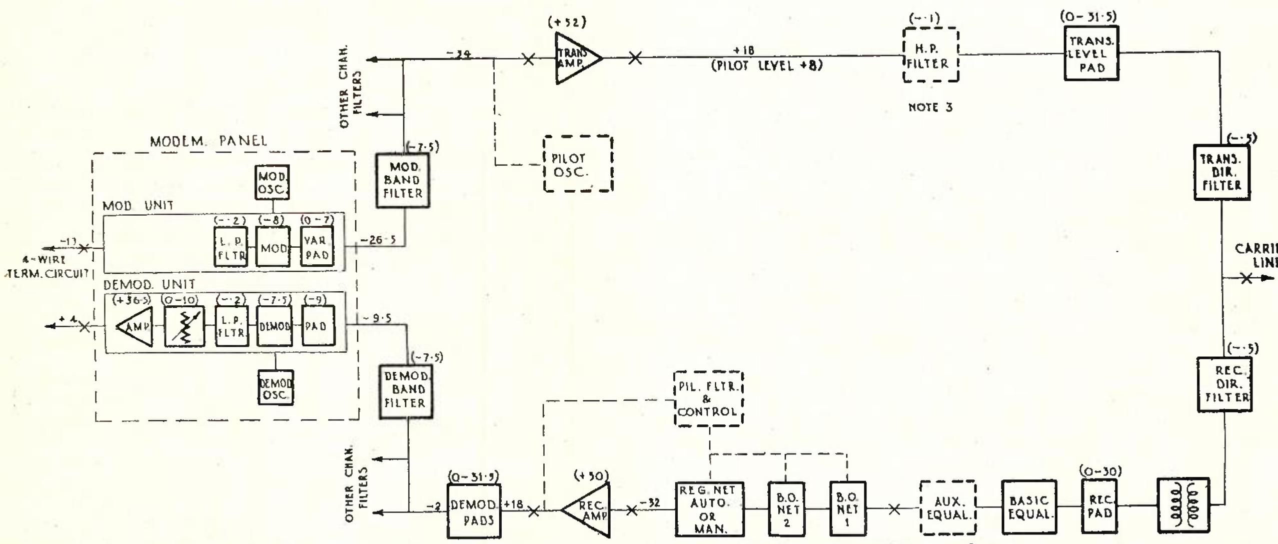
$$\therefore \beta^2 + \alpha^2 = \sqrt{(G^2 + \omega^2 C^2)(R^2 + \omega^2 L^2)} \quad \text{.... (5)}$$

Adding (3) and (5)—

$$\beta = \sqrt{\frac{\sqrt{(R^2 + \omega^2 L^2)(G^2 + \omega^2 C^2)} + (GR - \omega^2 LC)}{2}}$$

Subtracting (3) and (5)—

$$\alpha = \sqrt{\frac{\sqrt{(\beta^2 + \omega^2 L^2)(G^2 + \omega^2 C^2)} - (GR - \omega^2 LC)}{2}}$$



Notes: 1. Levels shown refer to SWBD (Odb).
2. Db gain or loss of equipment units given in parenthesis.
3. Installed at "A" terminals only.
4. Optional equipment shown ---------.
5. X denotes test jacks.

Fig. 2.—C5 terminal—schematic.

Q. 3.—Describe a modern 3 channel carrier telephone system using automatic gain regulating equipment suitable for use on open wire lines. Indicate the levels throughout the terminal at main points between the voice frequency input jacks and the directional filter out jacks.

A.—The first section of the above question is answered in Telecom. Journal, Vol. 7, No. 2, October, 1948. Exam. No. 2721, Sect. 1, Q. 3, by Mr. J. T. McLeod. A detailed description of the C5 type of equipment is supplied in the above reference and additional information is available in recently issued Transmission Engineering Instructions—Long Line Equipment CO 5300 (Type C Carrier Telephone Equipment), Long Line Equipment CO 1301 (C5 Three Channel Carrier Telephone Terminal). The levels throughout the terminal are shown in Fig. 2.

EXAMINATION No. 2823—SENIOR TECHNICIAN—BROADCASTING
RADIO II

N. S. Smith, A.M.I.R.E.

Q. 1.—What is meant by "negative feedback"?

Give one method of applying negative feedback to an audio frequency amplifier.

What are the advantages to be gained by employing negative feedback?

A.—Negative feedback is the process of feeding back a proportion of the amplifier output to the input in such a way as to oppose the input voltage.

Negative feedback may be obtained by two methods:

(a) "Voltage" feedback, in which the feedback voltage is proportional to the voltage across the output load.

(b) "Current" feedback in which the feedback voltage is proportional to the current through the load.

It can be shown that the gain of an amplifier with feedback is equal to

$A/(1—A\beta)$ where A = gain without feedback.
β = fraction of output voltage fed back.

Fig. 1 shows a two-stage transformer coupled amplifier with negative voltage feedback. A voltage proportional to the load is fed through the potentiometer R_1 R_2, the drop across R_2 being applied to the cathode of the first valve, in series with the input voltage.

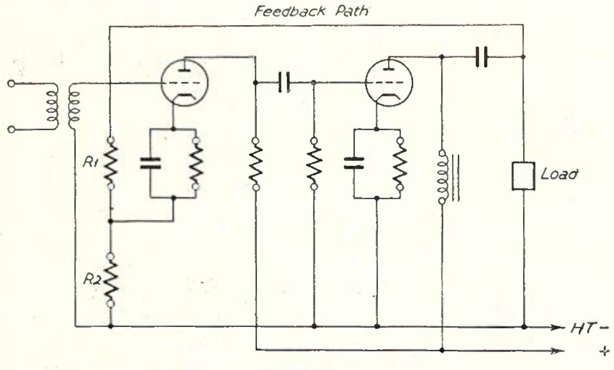


Fig. 1.

Some advantages derived from negative feedback are:

(i) Reduction in harmonic distortion.
(ii) Reduction in phase distortion.
(iii) Reduction in noise.
(iv) Improvement in frequency response.
(v) Amplification becomes substantially independent of electrode voltages and valve constants.

Other effects, sometimes advantageous, are:

(a) Reduction in gain.
(b) Modification of internal impedance of amplifier.

Q. 2.—What type of microphone would you select for the following applications:—

(a) A studio talk?

(b) An orchestral concert?

Give reason for your answer, and describe the principle of operation of the microphone given under (b).

A.—(a) Moving coil type. "Billiard ball" with baffle.

(b) Cardioid type.

(a) This type would be used since it is small and not too conspicuous. The baffle tends to give it a "semi-directional" characteristic which is sometimes an advantage in an announcing studio.

(b) The cardioid would be used because its good directional characteristics enable "audience noise" to be greatly reduced, it has a good frequency response and moderately good sensitivity.

Cardioid Microphone.

Basically a cardioid microphone consists of a pressure operated microphone and a velocity operated microphone in a common housing. (In practice switches are fitted to enable either one, or both to be selected.) The pressure operated unit may be a moving-coil type in which a diaphragm, actuated by the varying air pressure, causes a coil to move in a permanent-magnet field. This movement, by cutting the lines of force of the field, induces into the coil a current, which, in frequency and amplitude, is a faithful replica of the diaphragm movement. The pattern of this unit is essentially non-directional as in Figure 2b, although it varies somewhat with frequency.

The velocity operated unit is usually a "ribbon-microphone" in which a thin ribbon is suspended between the pole-pieces of a permanent magnet in such a way that the magnetic field cuts the edge of the ribbon. The ribbon is actuated by the velocity of air particles moving as a result of the varying pressure of the air caused by a sound wave. Again we have a conductor cutting lines of force and a voltage is induced in the ribbon proportional to the degree of movement of the ribbon. This microphone has a bi-directional pattern as shown in Fig. 2c. When these two microphone outputs are combined the "heart-shaped" or cardioid pattern results. This is essentially unidirectional as shown in Fig. 2a.

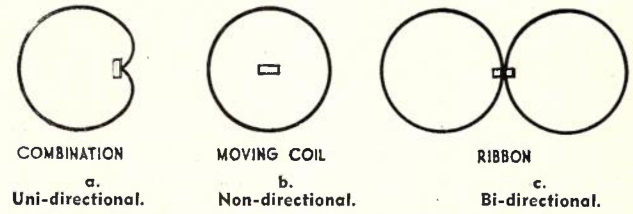


Fig. 2.—Three positions of cardioid microphone.

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