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BROADCAST PROGRAMME SWITCHING—ADELAIDE TRUNK EXCHANGE

F. P. O'Grady

Historical.—In recent years, the use of trunk lines and carrier systems for the transmission of broadcasting programmes between various points in the Commonwealth has expanded very rapidly. The first use of such facilities was on the occasion of the opening of the Houses of Parliament at Canberra by the Duke of York in 1927. On that occasion a broadcasting circuit was set up simply by patching a special one-way amplifier in place of the ordinary two-way voice frequency repeaters at intermediate repeater stations. At Adelaide, for example, the line was terminated in a 4012A transformer and connected through to the broadcasting studio. A pair of high resistance head receivers comprised the sole means of monitoring and supervising the circuit. It sometimes seems a long way back to that occasion, although in point of fact it is not so very long ago. Judged by the present state of the art of switching programmes, however, it is a long way back indeed.

Development.—Nowadays, all the resources of the communication art are pressed into service to make possible the efficient setting up, monitoring and disconnecting of broadcasting programme networks. It is commonly the case for several simultaneous broadcasting networks to be in use through the one office, therefore some special means is necessary to ensure satisfactory service. The process began originally by making use of the plug and cord method, the setting up of the actual connections being established on the existing toll test boards where these were installed and, in some cases, even on ordinary switchboards. While the cord and plug method has some points in its favour, it is definitely not the best method for use in a large centre where frequent changes in the network set up are required.

Adelaide Equipment

In Adelaide, as elsewhere, rapid development has taken place in the number and complexity of broadcasting network arrangements, and recently equipment has been installed which is designed to make the task of the officer setting up the connections as simple and safe as possible.

Method of Switching.—Consideration was given to all the usual methods of switching lines together and it was decided that, having regard to the number of lines to be handled, the nature of the circuits concerned and the particular conditions obtaining at Adelaide, that a method using uniselectors offered the best general solution.

Location of Equipment.—The broadcast programme switching equipment at Adelaide is installed in a separate room alongside the trunk equipment room. In the trunk equipment room are installed the toll test boards for ordinary

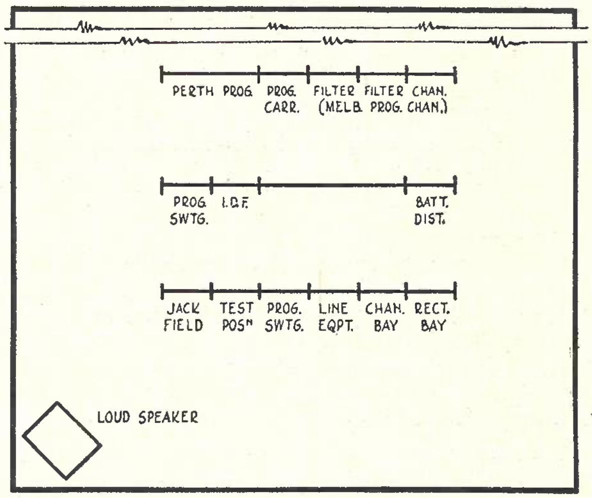


Fig. 1.—Floor Plan, Programme Room, Adelaide.

lines and general long line plant. In the programme switching room are installed separate toll test boards for broadcasting lines, switching equipment, amplifiers with associated equalizers, etc., channel amplifiers and also carrier programme terminals. The layout of the equipment is shown in Fig. 1. The decision to use a separate room for the programme equipment was made because of the urgent need to improve the conditions for both the programme staff and the staff engaged on ordinary trunk and carrier maintenance. Before the separate room was used, a very difficult position existed in regard to monitoring of programmes. If the programme officer used his loud speaker at normal volume, no one else in the room could work effectively. If he did not use the loud speaker at the proper volume level, he could not hear line noise, interruptions, etc., nor could he judge quality accurately. As this programme officer is the one on whom the responsibility for line conditions rests, it is clear that he should hear line noise, etc., before the studio operator complains. This was quite impossible under the conditions which existed when the programme switching work was carried out among the ordinary toll test boards. When the work of the ordinary toll test boards was increased by storm conditions, etc., involving the use of a large number of patch cords, the intrusion of a complicated programme switching job did not improve matters, either for the programme staff or the testing officer.

Facilities.—In planning the facilities for the Adelaide programme room it was considered that in the first place all permanent broadcasting lines between pick-up points and the studios both for national and commercial stations should be routed through 6-jack circuits on the toll test board in the programme room. This feature has proved of very considerable benefit in maintaining satisfactory service on permanent pick-up lines. Provision is made also on this toll test board for the various temporary lines (which are set up

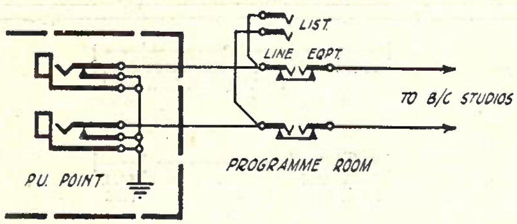


Fig. 2.—Pickup Lines Schematic.

as required) to be routed also through 6-jack circuits. On the same test board, there are terminated the permanent direct lines from the various studios which are used for handling programmes from interstate and country centres both in and out of the studios. The usual arrangement is to have at least one circuit to a studio for programmes being fed **into** that studio and a second pair for taking programmes **from** that studio for transmission to other points. In some cases, there are more than two pairs required, particularly in the case of the national studios. The permanent programme lines between the studios and the transmitters are also taken through 6-jack circuits on the test board. The effect of the foregoing is that the officer in the programme room has direct access to all lines and can monitor conveniently at any point desired. The feature enables also, for example, programmes coming from interstate to be fed direct to a transmitter in the event of complete failure of the studio plant.

Pickup Lines.—The pickup lines in Adelaide are terminated at the pickup point in a jack box, comprising a pair of 3630 carrier type jacks, with the inner springs strapped to one another, to the sleeves and to earth, giving a normal split earth on the line. After installation, the loop resistance is measured accurately and recorded in the programme room. A quick check can thus be made of the condition of the circuit. A routine test at Adelaide is to check the condition of every pickup line one hour before the

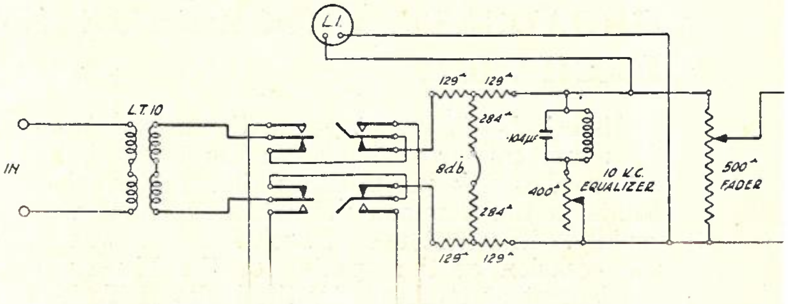


Fig. 3.—Line Equipment Panel Schematic.

advertised time of using the line. This test is made for all stations, national and commercial. Similar jack boxes are used for temporary lines as well as permanent lines. The circuit is shown in Fig. 2. The split earth and loop are disconnected when the pickup operator plugs in. The sleeves of the jacks provide a convenient earth for amplifiers, etc.

Line Equipment Panels. — Provision was included in the planning to enable any incoming line to be terminated in a line transformer to reduce longitudinal effects, to be equalized over the frequency spectrum involved and to have the level adjusted. Provision was made initially for four separate incoming programmes, but the rack space was designed for six. The equipment for the above purpose was mounted on suitable panels known as line equipment panels. The schematic of this is shown in Fig. 3.

Line Amplifiers.—The next item included in the planning was the provision of a number of line amplifiers which would raise the level of the incoming programme to any desired point.

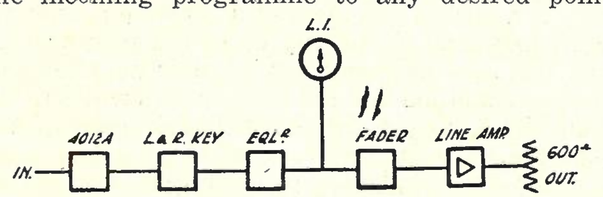


Fig. 4.—Line Equipment and Line Amplifier Unit Block Schematic.

These were provided on a basis of one line amplifier for each line equipment unit, the corresponding items being wired together as shown in Fig. 4.

Channel Amplifiers.—The next item was the provision of channel or splitting amplifiers which would enable any programme to be split into any desired number of separate outlets. It was decided to provide initially for twelve channel amplifiers, with space for eighteen ultimately.

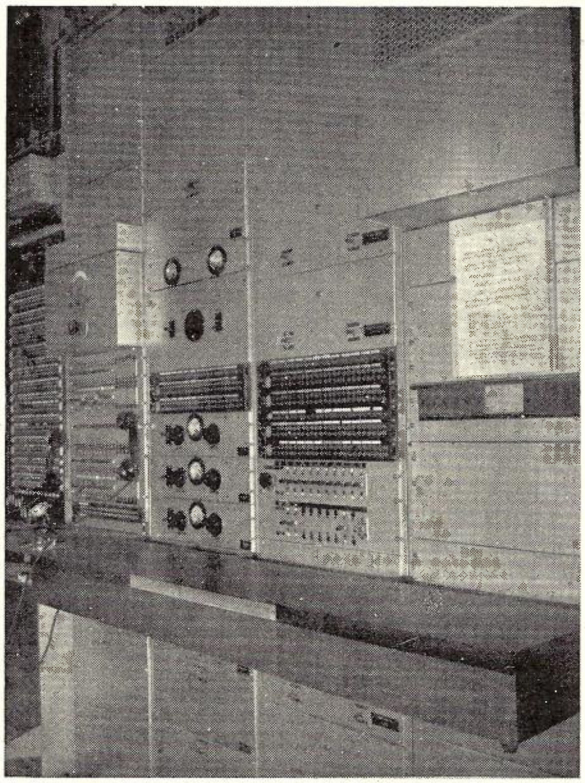


Fig. 5.—General View: Testing, Control and Amplifier Bays.

Fig. 5 shows a general view of the testing, control and amplifier bays.

Switching Details.—Having provided the testing facilities (which enabled any line to be intercepted in the conventional manner), the line equipment and line amplifier unit and the splitting amplifiers, the next problem was the actual means of switching the various components together to provide a particular network set up. It was decided that provision should be made to enable the input to any line equipment panel to be switched to any one of twelve lines initially with provision for extension up to twenty-four in the future. Also, that provision should be made for the output of any line amplifier to be switched to any one of twelve channel amplifiers either on a basis of all channel amplifiers being connected to the one line amplifier or in any combination totalling twelve, i.e., each of the four line amplifiers could feed three channel amplifiers, and so on. Each channel amplifier output was connected to a particular line, such as a line to a studio or a permanent programme circuit for interstate use.

To effect the actual switching twenty-five outlet four level uniselectors were used because this had the effect of minimizing the number of relays required, and particularly because it reduced the number of relay contacts involved in the transmission path. This was an important point, considering the nature of the problem. The use of the uniselector banks lent itself admirably to the use of wiring methods which minimize crosstalk between circuits. The contact pressures which could be employed on the banks and wipers was such that no fault from this source need be expected, bearing in mind that the amount of travel of the switches is exceedingly small compared with the normal use of the switch in automatic exchanges. The wiper contact pressure was increased somewhat over the figure normally employed.

To control the movement of the uniselector it was decided to use rows of standard keys arranged somewhat after the general fashion of the cordless switchboard. For example, an incoming programme could be thought of as coming along the horizontal bus bars of a row of keys and would be split into the appropriate

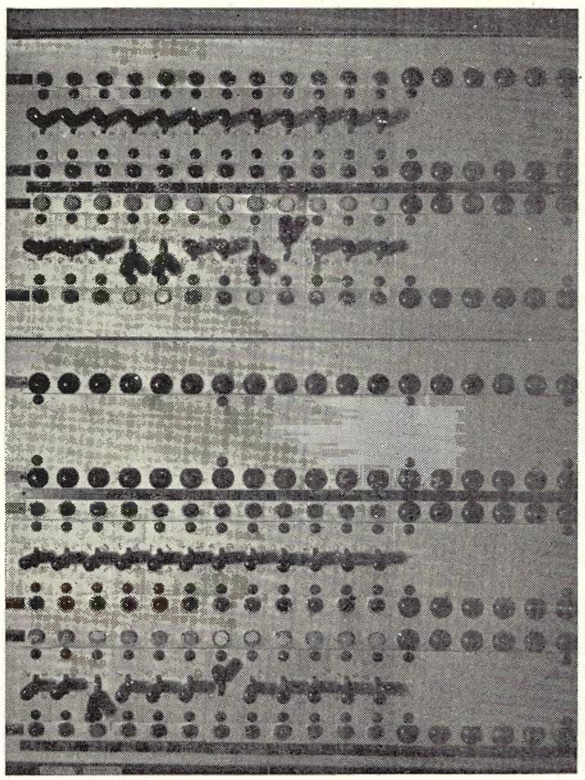


Fig. 6.—Input and Output Control Groups.

outlets as indicated by the particular keys being thrown up in this row. This method had the advantage of presenting a pictorial diagram to the officer effecting the switching in that he could see at a glance the actual routing of each programme. Consideration was given to the necessity for presetting of the network switching as is done by similar keys and uniselectors in the Adelaide studios, but after investigation it was agreed that presetting was not required, the circumstances being somewhat different in this case. Actually, as will be seen later, presetting to a certain extent is automatically provided by the arrangement adopted. Fig. 6 shows a view of the control keys and lamps.

The keys and associated lamps are arranged in two groups which are quite distinct. The first group contains the keys for switching any line to the input of any line amplifier. The circuit arrangement is such that only one line can be connected at a time to any line amplifier, irrespective of the number of keys which might be

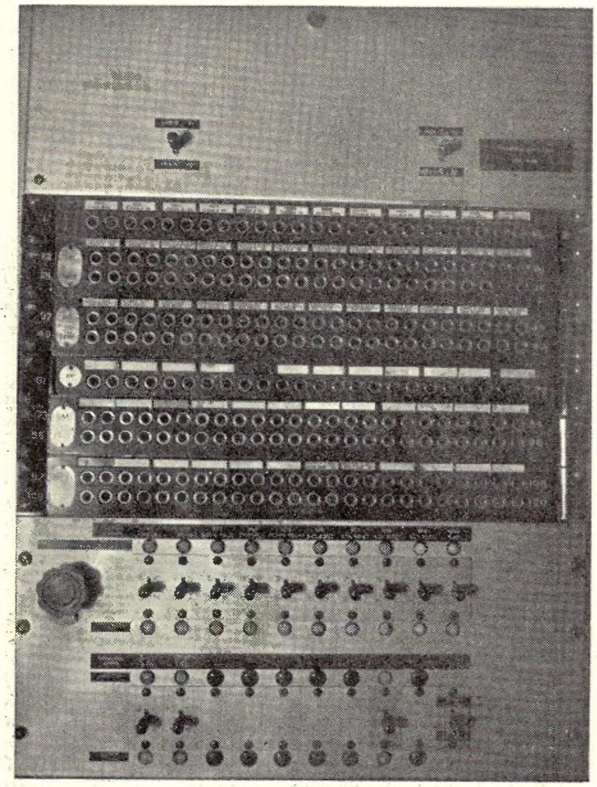


Fig. 7.—Monitoring Control Keys.

thrown. The arrangement is that the first key in the row from left to right determines the setting of the switch. If a second key further to the right of this row is thrown either deliberately or in error, it has no effect. If a second key is left thrown and at an appropriate moment the first key is restored, a practically instantaneous change will occur in the selection of the incoming line. This gives practically the same features as the usual presetting scheme used in studios, but is found in practice to be more suitable for use in the programme room than the studio scheme would have been.

The second group of keys and lamps controls the switching of the outlets, and, here, the horizontal busbars of the row of keys may be taken to correspond to the outlet of a particular line amplifier. In this case any number of keys can be thrown up and the programme will be split via the channel amplifiers into as many outlets as indicated by the keys. For example, if all twelve keys are thrown down in the first row, then the output of number 1 line amplifier will be fed simultaneously to all twelve outgoing lines. To economize in keys, the three-position lever type is used, the normal position being off, the lower position corresponding to line amplifier number 1 output and the upper position to line amplifier number 2 output, and so on. The second row of keys provides for number 3 and number 4 line amplifiers. If the key for line amplifier number 1 output and the key for line amplifier number 3 are both thrown, the general rule applies that the first key thrown controls, so that, assuming number 1 is thrown first, the output from number 1 line amplifier in this case would be connected to the particular channel concerned. As soon as this key is released, the switch will drive to the output of number 3 line amplifier, and so on, so that here again a simple type of presetting is available.

The keys are left thrown during the connection and thus indicate themselves the routing of the programmes. There is a theoretical objection due to the danger of a key being accidentally released, but it has been found in practice that this is a very rare occurrence, being much less frequent than was the accidental insertion or withdrawal of patching cords.

Monitoring Facilities.—Another group of uniselectors is used to steer the level indicator to any desired point and another group to steer the monitoring amplifier of the loudspeaker to any desired point. In this case non-locking keys are used, the key simply being depressed until the switch drives to the appropriate position. A lamp glows to indicate the position on which the switch is resting. Provision is made for switching the level indicator and loudspeaker to any one of the twelve positions initially, with expansion up to twenty-four later. Fig. 7 shows the loudspeaker and level indicator key group, while Fig. 8 shows the schematic circuit details.

Results.—The operation of the keys has proved to be extremely simple in practice and is a vast improvement over the array of patching cords which was previously employed. On practically all occasions the face of the toll test board and adjoining bays are completely devoid of patching cords, the whole network being set up, as it were, out of sight via the rotary line switches. It should be emphasized that the programme itself is not routed via the key springs, so that the well-known defects of series multiple arrangements of keys and relays in low level circuits are avoided in this installation. An examination of the circuit arrangement shows that the programme itself traverses the minimum of equipment consistent with the need for flexibility. Jacks are provided at appropriate points so that in the event of the most unlikely occurrence of a switch failing to operate correctly the patching cord method can be reverted to, to maintain service. So far, with experience extending over several months, no such occasion has arisen.

Mounting of Switches. — The switches are mounted as shown in Fig. 9 on a standard carrier type bay. The twenty switches shown in the top group are output switches, enabling up to twenty lines to be switched across any one of four line amplifier output circuits. Actually only eighteen can be used because the control keys are limited to eighteen in a row. The four lower switches are input switches, each associated with the input to a line equipment panel. (The bay on the left of the photograph is the Adelaide-Perth Programme Carrier Terminal.)

Instantaneous Switching. — The uniselectors drive at 60 steps per sec. and the switching from one circuit to another is practically instantaneous. The programme room in a trunk exchange is not normally called on to make instantaneous changeovers, but the feature exists if required and on a few occasions it has been found very useful in setting up special circuits.

Lines Connected. — The lines which are normally connected to the programme switching circuits are those which are in regular use for broadcasting; for example, the permanent lines between the programme room and each of the studios, both national and commercial, i.e., A.B.C., 5AD, 5KA, 5DN, as well as the programme carrier system to Melbourne and to Perth. There are twelve such permanent circuits in use at Adelaide, and as mentioned above this can be expanded to twenty-four as required. The circuits can be used on a one-way basis if desired. For example, certain lines can be set aside to take programmes **into** the A.B.C. studios while a separate group is used to take programmes **from** the A.B.C. studios. In these cases, the particular lines would be wired only to the input switches or to the output switches as required. In other cases, for example, the Adelaide-Melbourne programme carrier channel, a reversible arrangement is in use, the programme being used in either direction between Adelaide and Melbourne as required. In this case the carrier programme system audio circuit

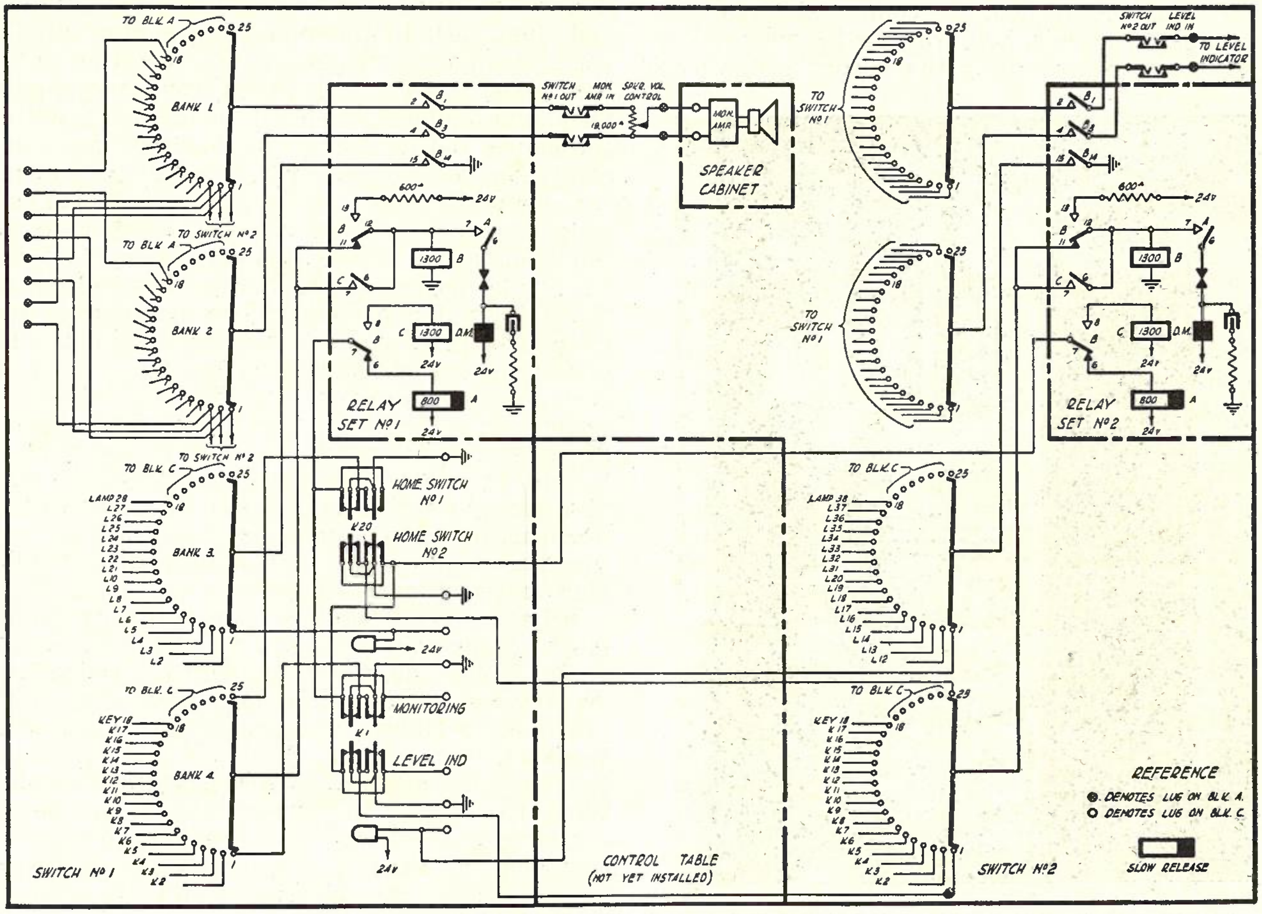


Fig. 8.—Monitoring Facilities.

is connected both to the input and to the output switches. The circuit arrangement is such that coupling cannot occur between the output of a channel amplifier and the corresponding input to the line amplifier.

Instantaneous Reversals.—It is possible to provide for instantaneous reversal of transmission in a very simple manner. For example, a carrier programme circuit can be connected to a particular input circuit, by throwing the proper key. A key can be thrown in the output group, connecting a particular channel amplifier to feed a programme into the same carrier programme system. The latter key, i.e., the output key, will control the relay contacts, breaking away the input circuit and feeding the programme to Melbourne. The release of the output key will cause an instantaneous change-over, the programme coming from Melbourne now passing into the line amplifier determined by the key which has been left thrown. Here, again, the presetting feature is evident. At present this is a hypothetical case, because the carrier programme system cannot be reversed instantaneously on account of the need for repeater stations to be reversed and other changes to be made. So far as the switching equipment is concerned, the feature of instantaneous reversal is available.

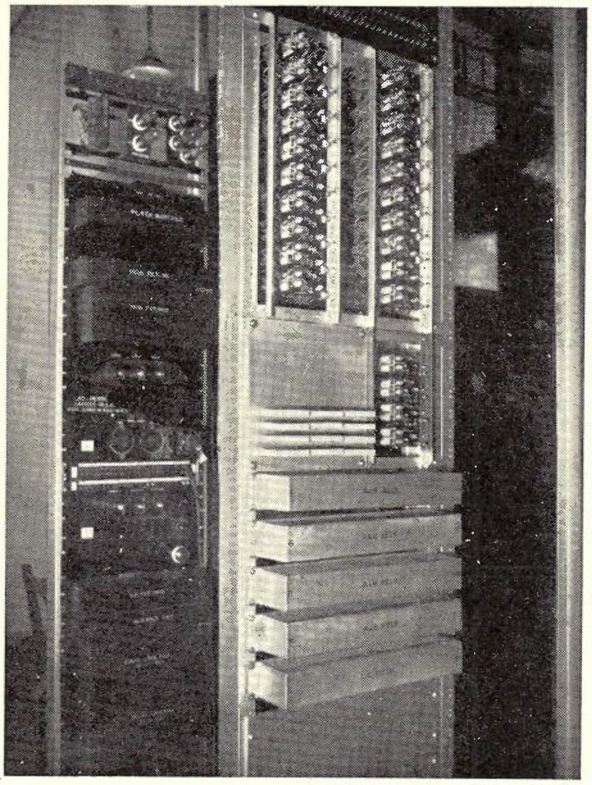


Fig. 9.—Mounting of Rotary Switches and Relays.

Use of Telephone Trunks.—Certain other lines, for example, Adelaide-Melbourne No. 1 and No. 2, which are physical trunk circuits normally and which are used frequently for broadcasting, are wired through the programme switching equipment permanently. The arrangement is that a particular line comes in via the ordinary low and high pass programme filter sets, through composite telegraph sets and phantom transformer groups and then goes into the programme room through relay contacts which are normally made and then back to the remaining equipment, i.e., voice frequency ringers, etc., to the trunk switchboard. The circuit is thus normal for telephone traffic. When a broadcast is required, the depression of a single key on the programme equipment will operate relays which will switch the composite sets out of circuit and will connect the drop side of the transformer to the input of a particular line amplifier. Alternatively, the depression of another key will switch the output of a particular line amplifier to feed a programme into this physical circuit. The operation of the relays also apply a tone to the sleeve of the trunk multiple jack to indicate to telephonists that this particular circuit is out of service. The relays also terminate the V.F. terminal repeaters to prevent singing. The use of these physical trunks for both telephone and broadcasting in the manner described has been found to possess many advantages over the older plug and cord method.

Prior to the adoption of the present equipment, it was not uncommon for composite sets to be left accidentally in circuit during a broadcast, or they were left out for long periods after the broadcast. It was also common for telephone trunks to be kept out of service through forgetfulness long after the broadcast had finished. With the present arrangement where the depressing or restoring of a single key is the only operation required, the circuits are restored to telephone and telegraph traffic with the minimum amount of interruption. Only those officers who have actually carried out extensive setting up of networks and disconnecting of them will appreciate how easy it is to plug into the wrong jack or to pull out the wrong cord under the conditions of strain which frequently accompany important broadcasts. The present equipment in the Adelaide programme room is strangely quiet and silent and simple in appearance compared with the somewhat hectic conditions which were previously associated with the toll test board during periods of heavy broadcast traffic. Figs. 10 and 11 illustrate the general circuit arrangements.

Power Supplies. — The equipment is designed for operation from the 24-volt battery for relays, lamps and uniselectors, the drive magnets of the latter being arranged as two coils in parallel, instead of in series. The remaining equipment, i.e., line amplifiers and channel amplifiers and monitoring amplifiers are operated direct from the commercial supply mains through filament transformers and anode rectifiers. The emergency power supply for the other long line equipment in the exchange guards against power failures. Provision is made also so that an incoming programme from Melbourne, for example, can be patched through direct to the studios, clear of all equipment in the event of unexpected failure of both the normal and emergency power supplies.

Line Amplifiers.—The amplifiers are divided into line amplifiers, which are also known as B or driver amplifiers, channel amplifiers and monitoring amplifier. The line amplifiers are shown in Fig. 12. These comprise two push-pull stages in cascade, using 606 or equivalent tubes as triodes, resistance coupled and with inverse feedback. These are arranged for a 600 ohm input and output. Keys are provided for measuring the plate current of the tubes. These amplifiers are operated on a fixed gain of 40 db. The frequency response curve is shown in Fig. 13.

Channel Amplifiers.—The channel amplifiers or splitting amplifiers as they are frequently called, comprise two tubes type 42 as triodes in push-pull. The input is 20,000 ohms, resistance coupled as shown, and in use the input circuit is switched across a 600 ohm resistance which terminates the output of the line amplifier. Any number of channel amplifiers up to twelve can be switched across the output of the one line amplifier without degrading the frequency response curve. The circuit is shown in Fig. 14.

Monitoring Amplifier.—The monitoring amplifier is mounted in the loudspeaker cabinet, which is of the standard high quality type as used in all A.B.C. studios and shown in drawing CA1007. The monitoring amplifier circuit is shown in Fig. 15.

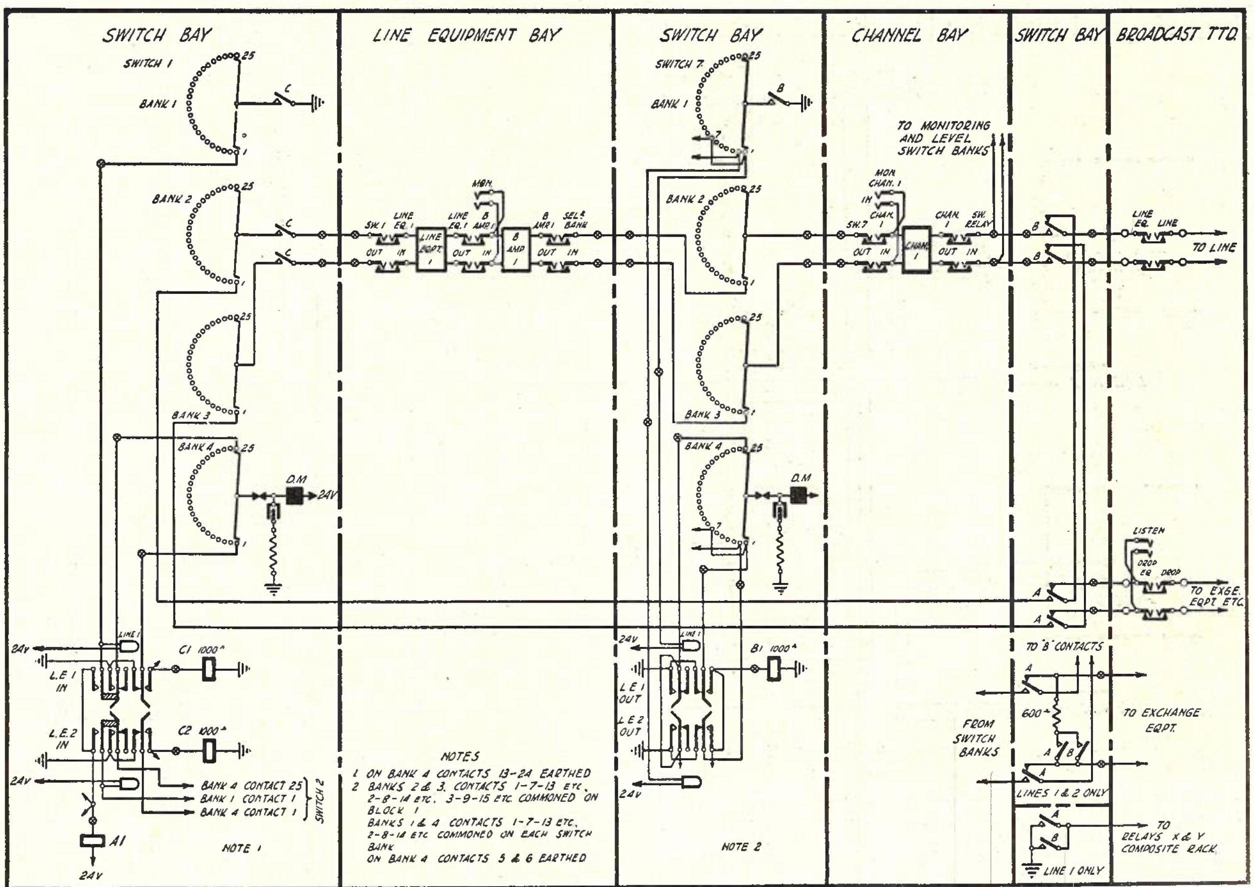


Fig. 10.—Programme Switching Equipment General Schematic.

Fading in Programmes.—For use on certain occasions a fader is provided to give a smooth transition from one programme source to another instead of a direct change-over. The fader is the dual type constant impedance General Radio type 553 F.C. This is patched in when needed.

Line Equipment Panels.—The line equipment panel contains a listening and ringing key, an equalizer, a level indicator and a fader used as a volume control. The listening and ringing key is useful in those circumstances where a pick-up from a country town is being carried out and where communication with the country town is required over the one pair of wires before and after the broadcast. The equalizer is a simple variable equalizer, intended to cater for open wire trunk circuits or short cable circuits. It is not relied on in connection with, say, the carrier programme channel from Melbourne to Adelaide, as equalizers are normally embodied in the particular circuit concerned in such cases. The level indicator is a simple high impedance voltmeter of the metal rectifier type and its principal function is to indicate by its movements that a programme is actually going through. It is not used in lining up the channels, as a precision type level indicator of the S.T.C. type 76LU is used for this purpose. As mentioned earlier, the high grade level indicator is switched across any the trunk test room. The schematic diagram of the monitoring facilities is shown in Fig. 8 and a general schematic for the programme switching showing one line only is shown in Fig. 10. The detailed circuit description is given in the appendix.

APPENDIX

Programme Switching — Circuit Operation. — This description covers the circuit operation of the switching circuits illustrated in Fig. 10.

To connect any one of the twelve lines to the input of a line equipment circuit, the respective control key in the "input" group is operated to the line equipment circuit to be used.

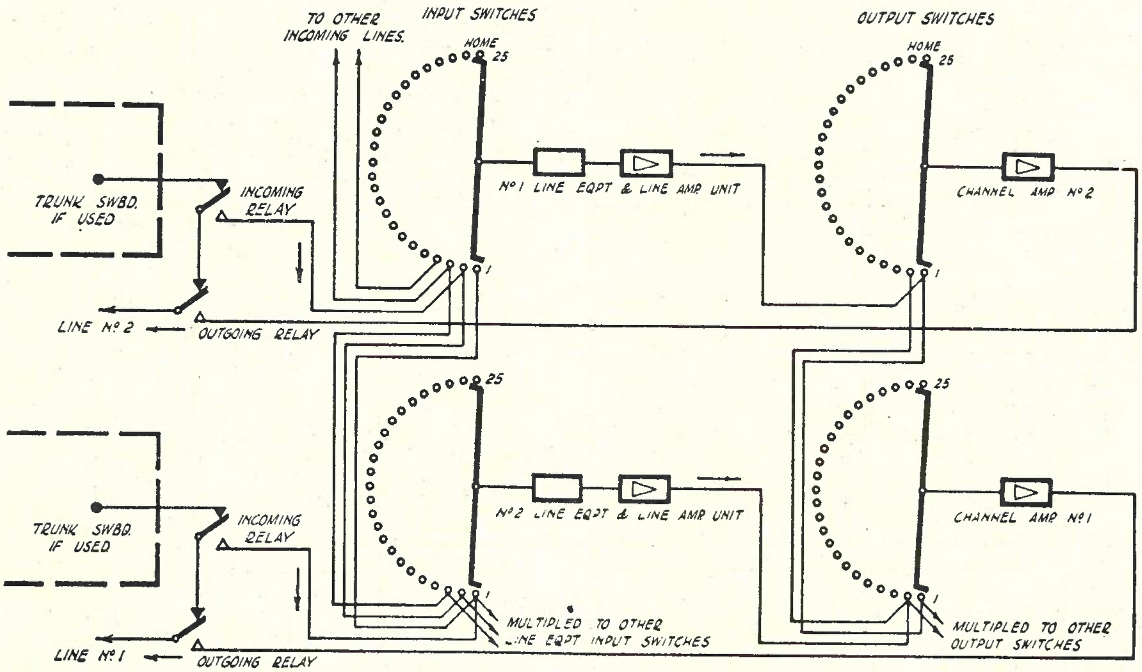


Fig. 11.—Programme Switching: Block Schematic Showing Typical Switching.

desired point by means of a rotary line switch controlled by a row of keys. The fader which is used for level control is set during the line-up and is normally not touched during the broadcast, any small variations in level being taken care of in the studio concerned. Fig. 16 shows the line equipment panels.

Temporary Lines.—As experience shows that more circuits are required for frequent broadcast use, they are wired into the programme room as described for the Adelaide-Melbourne physical circuits. To deal with the lines which are used only occasionally, such as those to country towns, tie lines are provided from the broadcast toll test board to the ordinary toll test boards in the adjacent room and any trunk or junction circuit can thus be patched through. In the programme room the tie line is wired permanently on to input and output circuits provided for the purpose. Thus any patching cords required on rare occasions are confined to the toll test board in

The switching circuit then performs the following:—

(a) Disconnects the line from its traffic or normal termination.

(b) Connects the line to the input of the line equipment circuit as follows:

Assume that a line is to be connected as an input to line equipment No. 1. The control key of this line is thrown to line equipment No. 1. Earth on the No. 1 private bank contact via the control key is replaced with earth through relay C, also via the control key. At the same time the homing private contact is earthed, completing the drive magnet circuit and the switch drives to contact 1.

The 1000 ohm earth through C relay prevents further driving, but C operates in series with the drive magnet.

The line wipers (2 and 3) which were disconnected during driving are now connected to the line equipment circuit via "C" contacts.

Earth is also fed via "C" contacts over bank 1 to the indicating lamp opposite the control key, the lamp now lights. This earth also operates relay A via the outer contacts of the control key.

To route any of the lines concerned as outlets from a given programme the following operations take place:—

The control key of the line concerned in the "Output" Group is thrown to the line equipment circuit concerned.

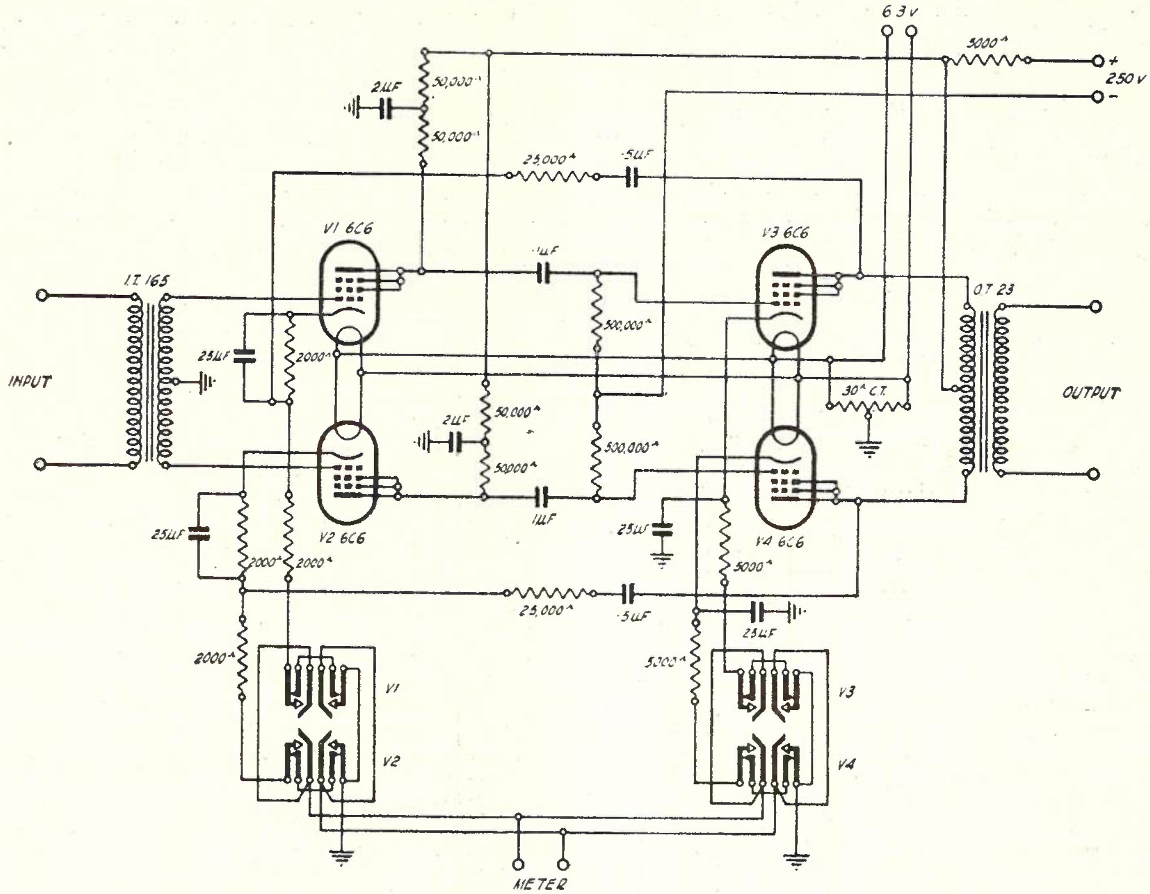


Fig. 12.—Line Amplifier Schematic.

The operation of A relay disconnects the line from its traffic termination and reconnects it to the input of line equipment 1 via the uniselector. Any test tone or programme incoming from this line will now be routed through the line equipment circuit and driver amplifier to the multipled banks of the output uniselectors as described in the general description.

The switching circuit then performs the following:—

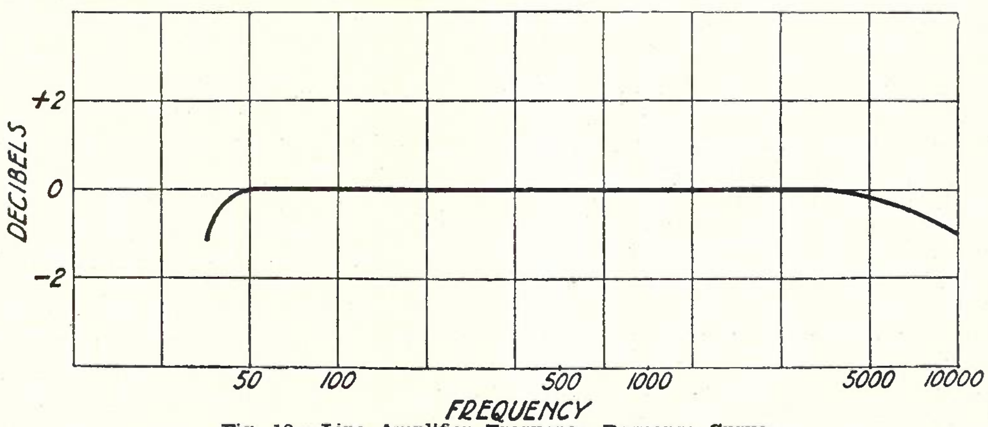


Fig. 13.—Line Amplifier Frequency Response Curve.

(a) Disconnects the line from its normal traffic termination.

(b) Connects the line to the "output" of the line equipment as follows:

Assume that the line is to be connected as an outlet from line equipment 1. Earth on the No. 1 private bank contact of the output switch via the control key is replaced with earth through relay "B," also via the control key. At the same time the homing private is earthed, completing the drive magnet circuit and the switch drives to contact 1.

The 1000 ohm earth through B relay prevents further driving, but B operates in series with the drive magnet.

"B" contacts connect earth to the lamp opposite the control key, which now lights, indicating that the circuit is in use.

The drive magnet drives the switch to the home position, which is now free of earth.

The drive magnet circuit is now incomplete and the switch comes to rest on the home position.

Monitoring Equipment—Circuit Description.— Fig. 8. The Monitoring loudspeaker and/or the volume indicator may be connected across the output of each channel amplifier with uniselectors operated by two-way non-locking keys in the monitoring group on the channel Amplifier Bay.

The output of each channel Amplifier is wired via patching jacks to a terminal strip at the top of the bay. From this point a cable connects

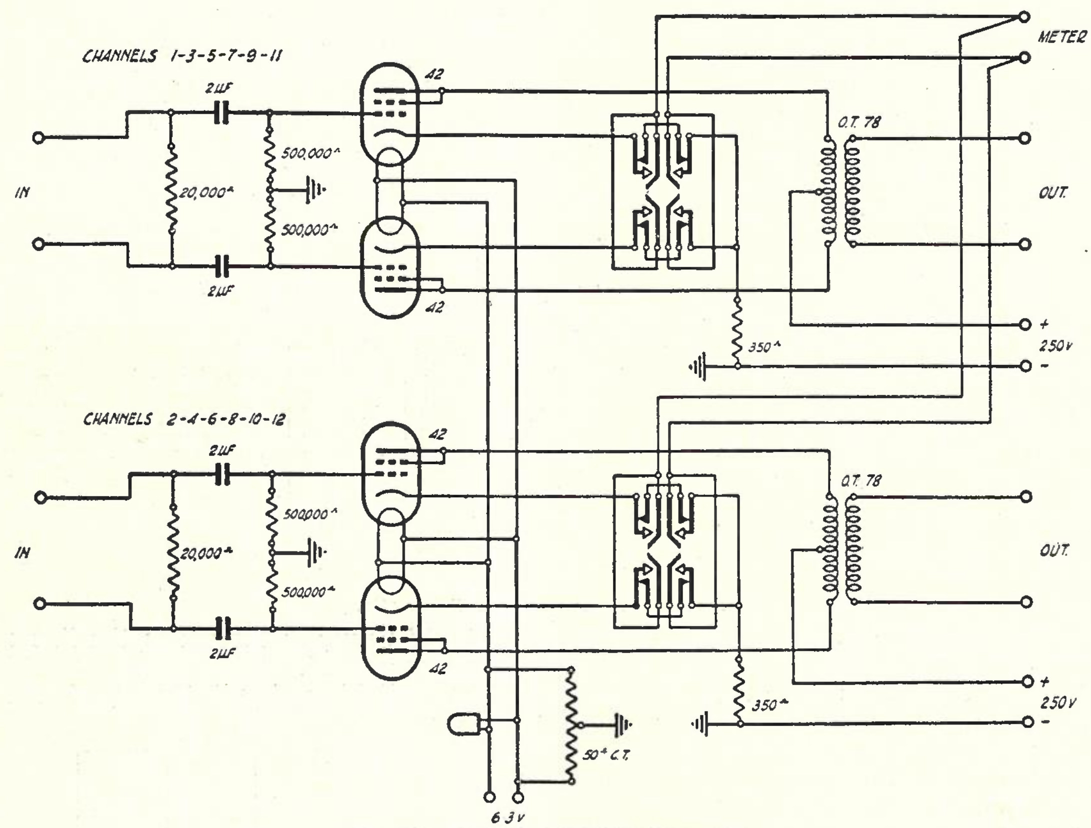


Fig. 14.—Channel Amplifier Schematic.

B relay in operating also disconnects the line from its traffic termination and reconnects it to the output of its channel amplifier, the input of which has now been connected to the output of driver amplifier 1, the programme from this source is now fed via the channel amplifier to the line.

Release:—To release the switches the control key is restored to normal, earth via the control key is then restored to the private bank contact in use, closing the drive magnet circuit.

"B" relay in output switch or "A" and "C" relays in input switches release and extinguish lamps.

The lines are also restored to traffic via the "B" and "A" relay contacts.

the outlets to banks 1 and 2 of the two monitoring uniselectors.

One non-locking switching key is provided for each of the twelve channel amplifiers. The monitoring loudspeaker and/or the level indicator may be connected to the channel amplifier output by operating the non-locking key in the up or down positions and holding it there until the uniselector has driven on to the required bank contact, a lamp opposite the key will indicate this condition. A homing key at the end of the row restores the switch to normal when monitoring has been concluded.

Assume that the monitoring uniselector is in the home position and that it is necessary to monitor across Channel Amplifier 6. The con-

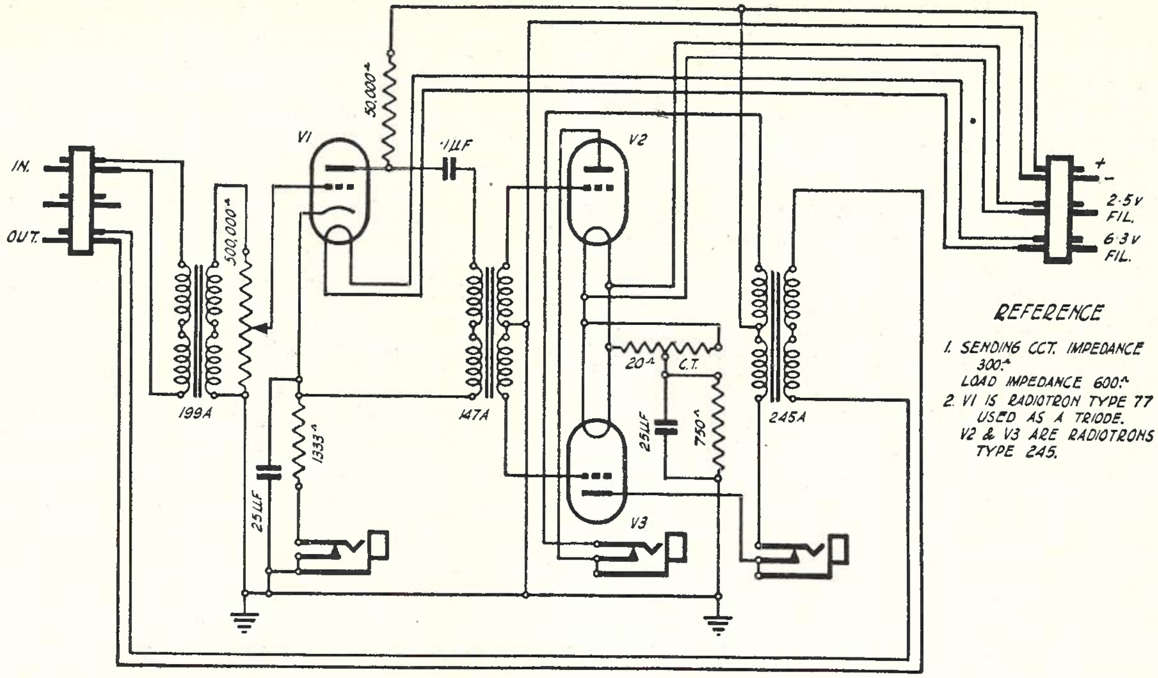


Fig. 15.—Monitoring Amplifier Schematic.

trol key for this channel in the normal position connects earth through its inner contacts to No. 6 contact in number 4 bank (private) of the uniselector. The control key should now be operated upwards, the earth is then removed from the bank contact thereby marking the bank and at the same time the earth is connected to A relay in the uniselector relay group which operates.

A 6 and 7 now close the circuit of the driving magnet, and the switch moves to the first bank contact, where the private wiper finds earth which prevents "B" from operating and keeps the driving magnet circuit closed.

The uniselector, therefore, drives to the sixth bank contact the private bank contact of which has been marked by the removal of the earth. When the private wiper reaches this contact the B relay operates in series with the drive magnet, which now stops driving owing to the absence of a direct earth on the private contact.

"B" relay now locks itself via B11 and 12 to 24-volts while "A" relay is released, opening the drive magnet circuit at A6 and 7.

"B" relay contacts now connect the line wipers (1 and 2) (which were disconnected while driving) through to the monitoring amplifier.

"C" relays operates through B7 and 8 to earth at the monitoring key, but at present performs no function.

The third wiper connects earth via B14 and 15 to the indicating lamp opposite the control key, which then lights, indicating the circuit being monitored.

The whole of the foregoing operations have taken place while the non-locking control key was held operated. Immediately the switch stops on the desired contact and the lamp lights the key may be released.

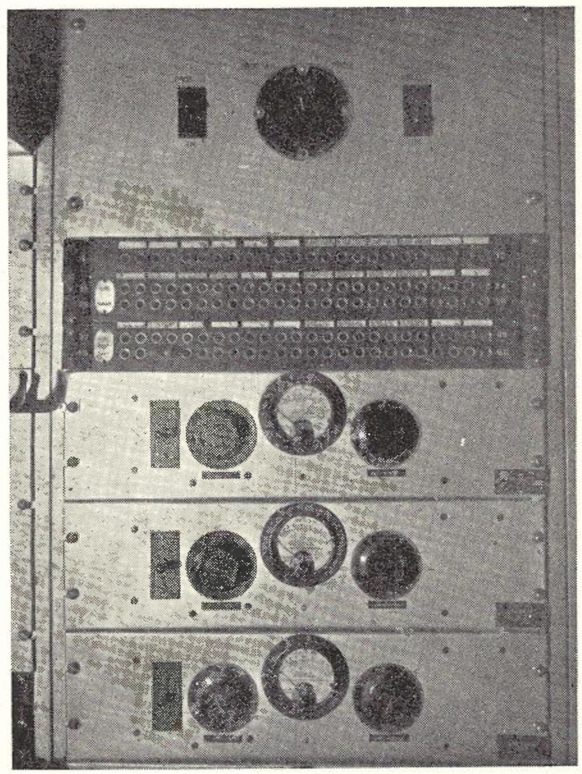


Fig. 16.—Line Equipment Panels.

The "C" relay which had operated without performing any function now releases, but its circuit is prepared via B7 and 8 to operate immediately another control key is thrown.

Monitoring of Channel Amplifier may now take place, the desired speaker level being adjusted with the volume control mounted adjacent to the Monitoring Control Keys.

On the release of the control key earth was re-connected to the private bank contact number 6, preparing the drive magnet circuit for subsequent operation.

If it is now necessary to monitor another channel the monitoring control key of that channel should be operated, the earth is thereby removed from the private bank contact concerned, at the same time earth is fed via B7 and 8 to relay C which operates.

Earth from the private now shunts relay B through C7 and 8, B releases and is then shunted via B11 and 12 and remains unoperated. C relay releases.

Relay A now operates from Earth from the control key via B7 and 6.

The drive magnet circuit is now complete from earth on the private via B11 and 12, A7 and 6 and now drives to the desired contact as previously described above.

The switch may be driven to the home position from any contact, the functions being similar to those described above, with the exception that the common homing key is used in lieu of a monitoring control key.

The level indicator may be connected to any channel Amplifier in the same manner as the Monitoring Amplifier.

A Review of the Development of Long Line Equipment in Victoria

E. A. Welsh

Long line equipment is the general term covering all types of apparatus necessary to provide and maintain efficient speech and signalling channels between remote centres. It may be divided into two groups:—

(a) That used to give increased facilities.

(b) That used to improve existing facilities.

A pair of wires, or even a single wire connecting two remote points may be considered as the basis of a long distance equipment installation. The wire provides the link, but, of course, suffers from the disadvantage that it only gives a single circuit, which has a limited range. By the addition of long line equipment, this circuit can be further exploited commercially, and considerably improved from the transmission viewpoint.

Composite Sets.—Take as an example the 600 lb. copper pair which was the first circuit between Melbourne and Sydney. This line provided only one communication channel but, with the introduction of composite sets, two additional morse circuits were provided in addition to the telephone channel. Although the composite set was introduced primarily for morse it is used to-day, as much, if not more, for direct dialling circuits from country centres. When V.F. dialling facilities are fully established the C.X. circuits will be displaced to a large extent and the wires will then be available for other purposes of signalling or control, e.g., remote switching for broadcast relays.

Lecture delivered before The Postal Electrical Society of Victoria on 10/6/1940.

The early composite sets consisted of two 5A.A reactances mounted on a baseboard with the necessary condensers mounted between them.

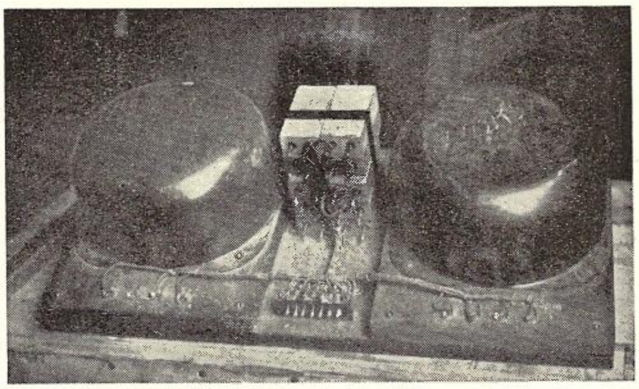


Fig. 1.—Early Type of Composite Set.

This type was bulky and intended for shelf mounting. With the introduction of the standard rack these sets were converted to the panel type, being mounted on a 19 in. x 12¼ in. steel plate with a shelf to hold the condensers. Experiments were conducted and it was found that the 5 A.A. coil in the telephone side could be replaced by two 4012A transformers using only the 4.3.8.7. or line winding of each coil. This made a considerable reduction in the price of each set as well as considerably reducing the weight and size.

When this type was later installed on lines carrying three channel carrier systems and where no carrier repeaters were installed, considerable attenuation was found on the high frequency channels. This was due to the internal capacity of the transformers bridged across the carrier

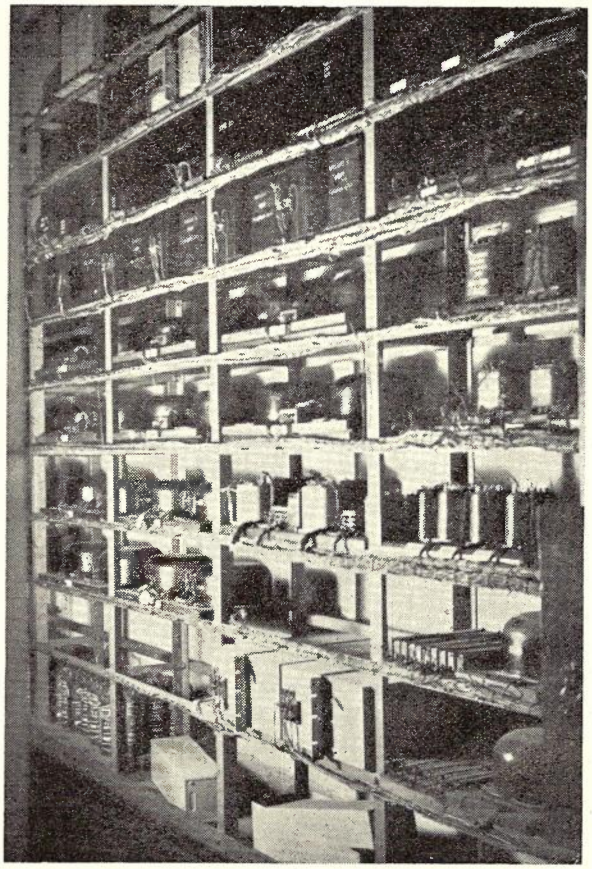


Fig. 2.—Old Type of Shelf Mounting.

portion of the circuit and was overcome by connecting half the primary and half the secondary in each coil. It might be wondered why the composite set was placed in front of the filter after this weakness became evident but it was done to give added protection to the filter in case of lightning discharges, the composite set being much cheaper and easier to replace than the filter. With the latest type of 5 A.A. reactances available it has been possible to reduce the size of the sets to 19 in. x 7 in. and make them individual units instead of mounting two on one plate. The new type composites are mounted on both sides of the rack with the wiring in the channel support. (See Fig. 3.)

Where the necessary physical wires are available, a large number of low-speed telegraphy requirements are satisfactorily met, at little cost, by using composite sets. Further morse circuits may be provided by the use of the type "B" Telegraph Carrier or the V.F. telegraph system.

Composite sets correspond to low pass filters with a cut off frequency of about 80 cycles. Their use therefore prevents the use of normal 17 cycle ringing current on the line for this frequency would be by-passed by the composite sets. The composite or 135 cycle ringer is used to overcome this difficulty. Following early design, these were originally of a shelf mounting type. This type was susceptible to vibration which led to a number of false signals being received. The relays used were not the most suitable type and would often fail to operate. With the development of better class relays, these ringers were designed for rack mounting and the sensitive relays mounted on sponge rubber to offset the effects of vibration.

Voice Frequency Repeaters.—Until the invention of the thermionic valve and the consequent development of the voice frequency repeater, the most serious hindrance to the extension of trunk lines was the excessive attenuation introduced. This could only be partially overcome by the costly expedient of using very heavy copper

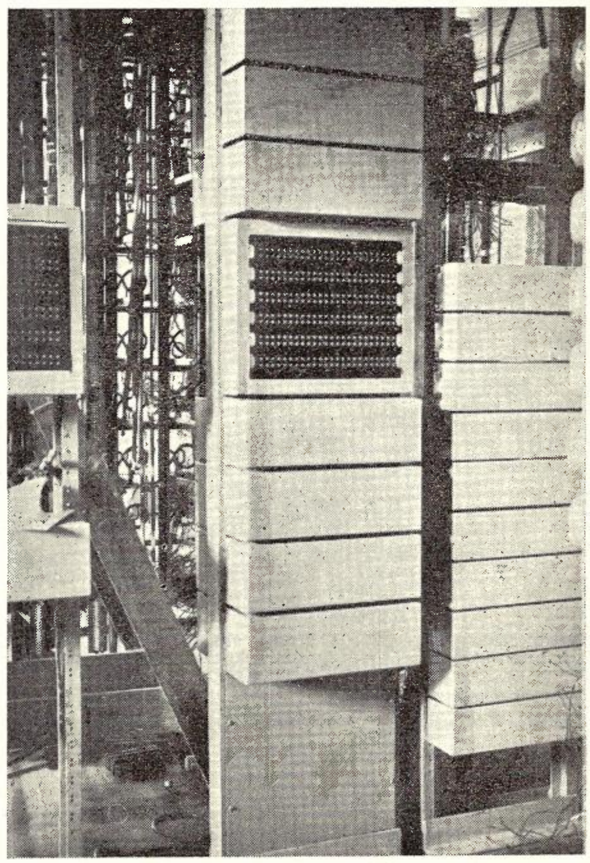


Fig. 3.—New Type of Composite Set Rack Mounted.

wires as for example the 600 lb. line to Sydney.

With the introduction of the repeater, this limitation has been eliminated and it is now possible, by installing sufficient repeaters, to extend trunk lines for any distance without excessive attenuation. On some lines as many as three and sometimes four are used. The first repeater used in Victoria was that installed at Cann River. This was of the "21" type, which utilized only one hybrid coil and one amplifying valve. The disadvantage of this type was that the hybrid coil had to be balanced on both sides so that the repeater had to be placed in the exact electrical centre of the line and both halves had to possess the same characteristics in order to balance each other and prevent "singing." This type was soon abandoned in favour of the "22" type (2 way 2 wire) which used a hybrid coil and an amplifying valve in each direction. This type may be installed at any point in the line, or even at the ends at which points they are known as terminal amplifiers.

The first 22 type repeaters used were manufactured by the Western Electric Coy., of U.S.A., and were mounted on steel panels 19 in. x 12¼ in. Repeaters were later reduced in size to 7 in. and mounted on a standard rack wired to take eight such repeaters with jacking facilities and a fuse and lamp panel at the top of the bay to distribute the power.

A measuring set was provided whereby a tone was fed through a variable attenuator in series with the repeater. The attenuator was adjusted to neutralize the repeater gain and the tone thus obtained compared with direct tone by means of a receiver until the tone with and without the repeater were equal. The gain of the repeater was then read on the calibrated scale of the attenuator. The tone for this measurement was obtained from a "tone box" which consisted of a vibrating reed tuned to 1000 cycles and operated by battery and earth. The output of this was very low and the set could be used only for gain measurements.

With the latest repeaters a considerable amount of floor space is saved since they are constructed to mount on both sides of the bay, and instead of the original eight repeaters and one gain measuring set, nineteen repeaters and a much improved gain measuring set are provided. The new measuring set removes the human element as a meter calibrated in db is provided, so that the gain or loss is read with much more accuracy. The tone for this set is supplied from a valve oscillator capable of delivering one milli-watt so that, with this type, loss measurements may be made.

With the introduction of repeaters 135 cycle signalling could not be used, for the lowest frequency which could be efficiently transmitted by a repeater was 200 cycles. A higher frequency was desirable and consequently 1000 cycles was chosen. Ringers have developed together with repeaters and we now have one which can readily be converted to a V.F. dialling receiver. The earlier type of ringer required a frequency of 1000 cycles interrupted at 17 cycle periods for its operation, but this latest ringer will operate on either straight or interrupted tone with equal immunity from false operation. Care must be exercised in lining-up channels equipped with this type of ringer since its operation on straight 1000 cycle tone would feed the 17 cycle ring to the testing instrument with consequent damage. A frequency of 800 cycles is now generally used for lining up measurements and if this is adhered to no trouble should be experienced from false ringer operation.

To prevent false operation due to voice currents, two circuits are connected across the line through an amplifier. One circuit will accept only a frequency of 1000 cycles and the other will pass all frequencies; their outputs are connected to full wave copper-oxide rectifiers, the D.C. sides of which are connected to relay circuits. When any frequency other than 1000 cycles is present in the circuit the rectified current from this source operates a relay which prevents the operation of the signalling relay.

Single channel carrier systems incorporate a signalling device which depends on the shifting of the carrier frequency by 500 cycles, for its operation. This method prevents the system being connected in tandem with another system by the four wire method, and means that a double conversion of frequencies must take place at the intermediate station.

With the T.M.C. repeaters now in use, the lower cut-off frequency of the repeater is sufficiently low to permit the use of 135 cycle signalling. This is an advantage for, in country offices it is necessary only to provide a 24V. dry cell battery, since no valves are used in the 135 cycle ringer. On repeatered lines which are not composited, a system of relays known as a ring-round device is used. A permanent source of 17 cycle current must be provided at the repeater station of this arrangement.

Carrier Systems. — Where additional speech channels are required without involving new wires they are provided by superimposing a carrier system over the existing physical line. The first multi-channel system in use in Victoria was the type "B" telephone system between Melbourne and Sydney. This system provided for three additional channels and, like all other new equipment, has its advantages and disadvantages. However, the disadvantages from the plant viewpoint were outweighed at the time by the traffic advantages. In this system, both sidebands were transmitted and the carrier frequency was transmitted to line continuously. Due to the amount of power transmitted and the absence of frequency staggering, cross-talk difficulties would be encountered with more than one system on the same route. The signalling on this system was comparatively simple. When the 17 cycle current from the switchboard was received on the carrier panel a relay was operated which stopped the carrier current on the particular channel. This released relays at the distant end which repeated the signal to the switchboard by means of the local 17 cycle supply. This had the advantage that in the event of a line failure, it was immediately indicated by a permanent signal.

In the subsequent development of carrier systems the suppressed carrier type was produced. In these systems, only one sideband is transmitted and this results in a saving in band width so that the transmitted band can be extended to provide better quality circuits. At the same time it is possible to "stagger" the frequencies of two systems with respect to each other and thus improve cross-talk conditions. The carrier frequency does not go to line and modulated carrier is only transmitted when speech is actually taking place.

When they were introduced, the power for these systems was supplied through a remote fuse panel which meant that fifty pairs of wires had to be run between the fuse panel and the battery supply bay serving two systems. By removing certain unwanted equipment sufficient space was made available on the battery supply bay to fit the necessary fuse and lamp panels to run the two systems. This made the systems self contained, as it was then only necessary to run three D.C. power leads namely 24V., 130V. and earth.

Single channel systems provide a means of increasing trunk line facilities where three channels are not justified for the present requirements. As traffic increases the single channel systems can be replaced by multi-channel systems. A type of system produced by the Telephone Manufacturing Coy., on one rack or bay can be expanded to a maximum of three channels by the addition of one bay per channel as required. The common filters are mounted on the first bay.

The earlier S.T.C. single channel systems (C.2F) were mounted on two bays with an inter-bay cable between them. These systems have since been re-built locally to mount all the equipment on one 10 ft. 6 in. rack provided with fuse and lamp panels. This results in a saving in floor space whilst the inter-bay cable is dispensed with. The later types are built on one bay and provision is made to run them direct from A.C. mains by means of rectifiers, space and wiring being provided for the power unit. In centres where the commercial mains are D.C., small rotary converters are provided to supply A.C.

The latest "Type J" multi-channel system described in the Telecommunication Journal, Vol. 3, No. 1, provides for twelve channels and exploits the frequency range up to 140 K.C. With present-day long distance equipment, one pair of wires may be made to do the work of seventeen pairs by installing one J system, one 3 channel system, and one composite set; and by installing a V.F. telegraph system its capacity can be extended even further.

Equipment Layout.—With the improvement of communication facilities, maintenance facilities have also improved. At Melbourne Central Exchange and major country offices where testing equipment is provided, instruments such as wheatstone bridges and voltmeters are fitted on each patching panel. Previously, testing gear was not associated with the board and in most cases the only testing instrument was a detector No. 2. In the smaller country offices, a strip of jacks is provided on the M.D.F. and wired to terminal strips. Where justifiable these are being replaced by standard test boards.

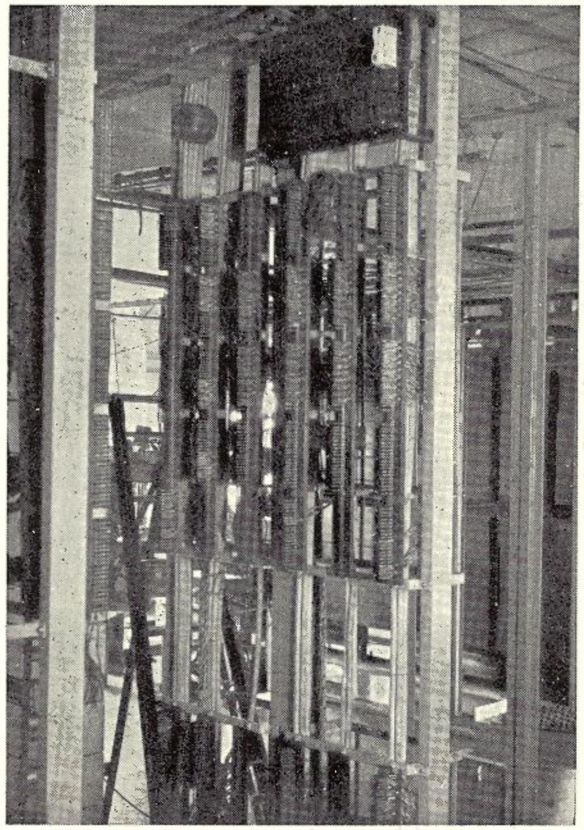


Fig. 4.—Front View of Link Frame.

At the same time, offices at which long distance equipment is installed are being rearranged to group all apparatus of the various types together and to rack mount equipment which is not at present of this type. This rearrangement requires the use of a different type of I.D.F.

With the shelf mounting arrangement of equipment, all types of apparatus are mixed together in the rack and wired rigidly together. When locating faults wires have to be disconnected by means of a soldering iron and later reconnected. Changes and rearrangement of apparatus in lines means the running and dismantling of wires which eventually makes the rack in an untidy state.

When the new trunk equipment floor at City West was designed, it was decided to lay out the equipment with the various types grouped together, and to facilitate this, the "link frame" was proposed. The link frame differs from an I.D.F. in that only one or perhaps two types of local bay equipment are terminated on it, whereas, on an I.D.F. all types are terminated and have to be cabled to it.

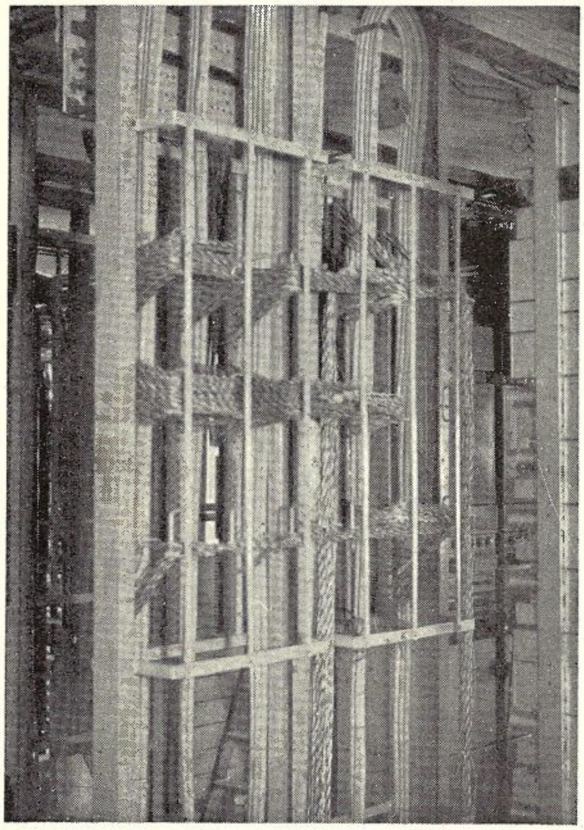


Fig. 5.—Rear View of Link Frame.

Both schemes provide a point where apparatus is linked into the circuit but in a big installation the link frame makes great reductions in series cable lengths.

Wangaratta was chosen to try out the link frame method, and to do this, a complete rearrangement of the office was necessary. Equipment, such as transformers, filters and composite sets which could be duplicated was mounted on standard racks with jack fields. These were erected on a new base board and cabled to the link frame. Apparatus which could not be readily duplicated such as V.F. repeaters and carrier repeaters was connected with "slavey" cables to enable them to be moved to new baseboards in their correct positions whilst in use. The broadcast carrier equipment which could not be worked on during the day was shifted at night.

During the re-arrangement, it was found that the link system as originally designed would not be quite satisfactory since apparatus of each type was provided for in each trunk line and was bridged in or out of the line by means of short bare copper links connected either vertically or horizontally. If any piece of apparatus was not required in a line its position remained vacant. This involved provision of considerable unused rack space.

The system was then modified to use short lengths of jumper wire instead of the links, thus every piece of apparatus was made available for any line and this facilitated trunk line rearrangements. No positions need remain vacant. On the basis of this experiment, the link frame now in use at City West was developed.

The City West layout was designed so that the Long Line Equipment is placed in the same order as it would appear in a trunk line circuit, i.e., composite sets nearest the M.D.F. followed by filters, transformers, amplifiers, ringers and finally carrier systems. The link frame is the first rack in each row and all local equipment in the row is cabled to terminal blocks on the frame. Cables are run from the M.D.F. to

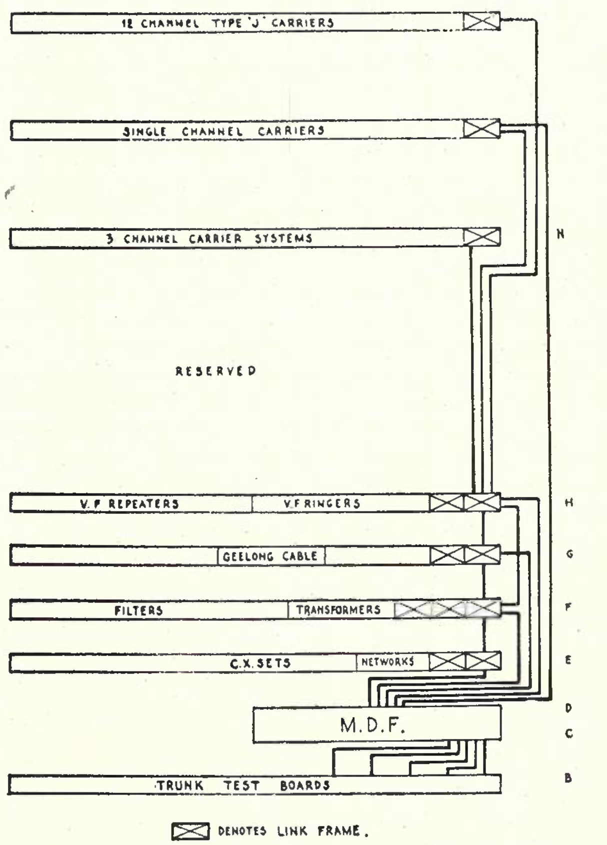


Fig. 6.—Layout of Long Line Equipment Racks at Melbourne Trunk Exchange.

blocks on each link frame and for flexibility, cabling is provided between individual link frames. The external line is jumpered on the

M.D.F. to the Trunk Test Board and then to the link frame corresponding to the first type of apparatus required in the particular line. The required apparatus is then jumpered in and the circuit extended by means of inter-link-frame cables to the next type of apparatus required and finally back to the M.D.F. and T.T.B. This makes the system flexible, reduces cabling and eliminates waste rack space. The carrier systems have been laid out so that all lines on the same route are grouped together. The general arrangement is shown schematically in Fig. 6.

The power supply is run along the sides of the link frames with copper bus bar and power panels with main distributing fuses for the various voltages are provided at the top of each link frame. Each link frame will be provided with an alarm lamp so that when an audible alarm is received it will be obvious in which row of equipment the fault lies. Each row bears a letter and each rack a number.

From a card which is prepared for each trunk line, it is possible to trace a circuit through the various pieces of equipment. The card shows the row, bay in row, and number of the piece of apparatus and the cable pairs used.

Conclusion.—Due to the increased knowledge of high frequency operation and the improved technique in manufacture, equipment for improving or increasing the capacity of communication channels is finding wider and ever-increasing use. Batteries and battery charging generators have in many cases been replaced by compact rectifier units and instead of the expedients which were adopted in the early days, we now have transmission apparatus which is designed and specified to the requirements of the particular job. Furthermore, with the growth of Long line equipment work, it has been possible to steadily improve and standardise equipment details and methods of installation. Jobs can now be planned to cater for requirements many years ahead with reasonable safety. Besides the improvements in "stock" types of apparatus there are many special developments such as the equipment for the Mainland-Tasmania and Melbourne-Geelong cables, which have been covered by previous articles and therefore have not been dealt with in this summary.

MEASURING INSTRUMENTS

A. A. Lorimer, M.E.E., A.M.I.E.(Aust.)

(Continued from Volume 3, No. 3.)

RECTIFIER INSTRUMENT

(a) **Principle and Description.**—This instrument utilises an ordinary D.C. moving coil current meter to indicate the unidirectional impulses obtained through a rectifier. Although not essential, the most usual form is for A.C. to be fed into two diagonal corners of a bridge type rectifier, the D.C. meter being connected across the opposite corners. In the bridge rectifier units specially developed for instrument work, the active elements are made small and compact to reduce capacitance effects and so improve the frequency characteristics, also to operate the rectifier itself under the optimum working conditions. Apart from these features the rectifiers are the same in principle and general operation as the larger pattern used for heavier current work. The type most commonly used here in many makes of instrument is the Westinghouse copper-oxide type (made in ranges of 1.0, 5.0 and 10.0 milliamp), although some instrument makers incorporate other types of their own manufacture.

(b) **Characteristics.**—Again, as in the thermocouple instrument the rectifier type, through incorporating a D.C. meter as the indicating element, possesses many characteristics common with those of the moving coil instrument. Some characteristics may be modified, or others included due to the rectifier itself. To avoid confusion, remarks will refer to the circuit with the bridge type rectifier, although these remarks will apply with very little modification to other cases where half wave rectification or some different circuit is used.

(i) **Suitability for D.C. and A.C.** The complete instrument is intended for use on A.C., although it will operate on D.C., under which condition the rectifier elements act simply as series resistors. The D.C. response differs from the A.C. by about 11% (assuming the A.C. to be a sine wave with form factor 1.11) because the meter pointer takes up a position corresponding to the average value of the unidirectional rectified impulses while the scale is marked in terms of the R.M.S. value of the A.C.

(ii) **Frequency Range.** The design of the rectifier units has been constantly improved during recent years with the result that the frequency range has been increased tremendously. A few years ago instruments were claimed as suitable to 4000 or 5000 cycles; now the Westinghouse instrument types are guaranteed to have a good performance to over 100 kilocycles. Smaller units still are used to carry measurements into radiofrequencies of several megacycles. The lower limit is set by the frequency—usually from 15 to 20 cycles—below which the instrument coil and pointer follow the fluctuations of the unsmoothed rectified impulses with an appreciable oscillation, resulting in an unsteady pointer indication.

(iii) **Variation of Resistance with Current.** The rectifier unit possesses the characteristic of a resistance which increases with decrease of current. In the region of the maximum allowable current through it the rate of resistance rise is slow, but when the current is reduced to a small part of this value—say, 10% or less—the rate of increase becomes very rapid. This means that the resistance of the complete instrument is not constant, but becomes very high at the lower scale values of current.

(iv) **Linearity of Scale.** Within limits it can be taken that the D.C. deflecting torque from the series of rectified current impulses is proportional to the A.C. input alternating current value. At very low current values where the forward resistance of the two conducting rectifier elements is very high, this proportionately is modified by the A.C. current leakage through the reverse resistance of the two blocking elements and the meter deflection is reduced in proportion. Down to at least as far as the linear scale of a D.C. meter is normally read, however, this effect is inappreciable and the scale can be taken as linear and similar in appearance to that of a moving coil meter.

(v) **Sensitivity and Range.** The three ranges in which the commonly used Westinghouse instrument units are made are 1.0, 5.0 and 10.0 milliamp. The smaller "Westector" units can be used for currents below this with meters down to at least 100 microamp full scale. For ranges higher than these, heavy current type rectifiers could be used, but the larger self-capacitances would by-pass more of the current and the frequency range would become more restricted. It is usual to etxend the current range by means of current transformers.

(vi) **Accuracy.** The rectifier units being subject to a number of variations which introduce errors, the accuracy and stability are not high unless used under well-regulated conditions. For general purposes, where moderate ambient temperature changes are met, the total inaccuracy, including that of the D.C. meter, may be of the order of 2% to 3% of full scale value.

(vii) **Temperature Coefficient.** An increase of temperature causes a decrease in both the forward and the reverse resistance of the rectifier elements. The nett result is found to be an increase in the proportion of the leakage which is shunted past the indicating meter, through the reverse resistance of the elements, thus causing a reduction in the D.C. indication for a given A.C. The rectifier meter, therefore, tends to be less sensitive as the temperature rises.

(viii) **Sources of Error.** In addition to those errors common to the moving coil instrument, it has additional possible errors due to the rectifier. These include **wave form error** if used on A.C. in which harmonics have altered the wave form factor from that at which the meter was calibrated, **temperature** error due to the change of rectifier resistance (mostly in the reverse direction) resulting in decreased sensitivity with rise of temperature, **frequency errors** due to the increasing capacitance leakage currents at the higher frequencies, and finally **ageing** and **instability** errors in the rectifier material.

(ix) **Methods of Adjustment.** The rectifier can be shunted to alter the sensitivity, but this will detract from the linearity of the scale and may necessitate the marking of a non-linear scale. Any change of this shunt, thereafter, will tend to make the response depart from this initial scale shape. The usual method of adjustment is by the adjustment of the sensitivity in the D.C. meter.

INDUCTION INSTRUMENT

(a) **Principle.**—A brief general description only need be given for this type, which is not encountered much in general measurements, but is used in switchboard work where clear indication and only moderate accuracy are necessary. It operates on the principle of the flux from A.C. through an electromagnet inducing eddy currents in a pivotted disc, the interaction between the flux and the secondary flux due to these currents producing a deflecting torque and causing the disc to rotate till equilibrium is established by the restoring torque in the control springs.

(b) **Characteristics.**—The instrument is rugged, compact, with strong torque and long, almost circular scale. It is designed for commercial frequency of a restricted range and even in this range the frequency has some effect on the response. It also is affected by temperature changes and by wave form changes.

POTENTIAL MEASURING INSTRUMENTS

General.—(a) Description. — All the types of instrument already described for the measurement of current can also be used for the measurement of potential differences or "potential" by the simple expedient of building up sufficient resistance in series to limit the current to the value applicable to the meter, when put across the potential circuit. As one of the first requirements of a voltmeter is that it should not take any more power than necessary from the circuit it follows that the meter selected is not a heavy current range of some amps, but is kept to one of the smallest milliamp ranges, or, in some cases, is the most sensitive microamp range available. A compromise has to be made between an ultra-sensitive delicate and more expensive instrument on the one hand, and a cheaper, rugged one taking a heavier current drain from the circuit. The selection must be decided, principally by the nature of the measurement; if the instrument is needed to measure the potential of a power supply then a current of even 100 milliamp for the voltmeter is negligible; if it is to measure the drop across a high resistance bias supply or the potential of a dry cell then even one milliamp may put too much load on the circuit and affect the quantity to be measured.

(b) **Characteristics Common to Most Types.** The measurements of all the types covered in the previous paragraphs will, as potential meters, possess the same general characteristics as the corresponding current meters and hence the previous description will obviate the necessity of a full discussion on each. For the more important types it will be necessary, therefore, to refer only to such new features as have been added or existing ones which have been modified by the addition of the resistor multiplier and the marking of the scale in units of potential across the circuit rather than in units of current through it.

(i) **Method of Adjustment.** One feature common to all these "current operated" voltmeters is the alternative method available for adjusting the sensitivity. Either the current in the meter may be left unaltered and the multiplier resistance adjusted or vice versa. The latter is the preferable method, for it is often useful in order to assist in rapid calculations of circuit resistance or power loss, etc., to have the resistance fixed at some definite simple value, such as a direct power of ten. The usual adjustment, therefore, is to operate on the current sensitivity by any of the available methods outlined for the current meters, although no hard and fast rule can be established.

(ii) **Range Extension and Limitation.** The voltmeter ranges can be extended "indefinitely" by the addition of extra series resistors. The design is simple as each new section carries the same current as the rest—determined by the full scale current of the meter. A practical limit is eventually reached due to the combined effect of many factors. As multipliers extend into the extra high potential ranges their size becomes bulky and, moreover, the spacing and mounting become both large and expensive to prevent breakdown between various sections. Also, as the voltmeter has the same current rating irrespective of potential range the power consumed is proportional to the potential and in the lower resistance heavier current type of instrument may become sufficiently great in the limit to introduce ventilation and cooling problems in the design or to affect the potential of the supply measured because many high potential sources may not have the power capacity in them to supply any appreciable current. On the other hand, where a very sensitive milliammeter or micro-ammeter is used as the indicator, the resistance per volt required is correspondingly high and the actual resistance value of the multiplier sufficient to take the drop across a high voltage supply becomes tremendous. In this multiplier, although of large resistance value, the current capacity required is so low that, probably, a small and compact unit can be made. One source of error which occurs in this case is that under varying atmospheric conditions the insulation leakage inside the instrument may become sufficiently low to form an appreciable shunt across the higher multiplier ranges and so affect the accuracy of those potential ranges.

(iii) **Reduction of Temperature Coefficient.** Another important common feature is that where the resistance of the milliammeter may vary by a considerable percentage due to temperature changes or other causes the series multiplier being invariably composed of a low temperature coefficient alloy such as manganin, constantan or eureka, etc., will tend to swamp this out. If the total resistance of the voltmeter is 100 times that of the current element then the temperature coefficient of the instrument as a voltmeter will be only 1% the temperature coefficient of resistance of the milliammeter section. It follows from this that low range voltmeters and millivoltmeters have larger temperature coefficients than the higher ranges because a greater portion of their resistance consists of the high coefficient section.

(iv) **Frequency Effect.** Resistance multipliers especially when compactly wound may, in an A.C. voltmeter, impose a frequency limitation not present in the current meter used, due to the inductance and self-capacitance of the windings having an appreciable effect as the frequency increases and making the "impedance" of the multiplier differ from the resistance or from the low frequency impedance.

Some characteristics, not necessarily common to all the types, are as follow:—

MOVING COIL VOLTMETER

The stability and accuracy of the multipliers are so good that, subject to the limitations already described for the very high ranges, the accuracy of the voltmeter can be considered to be the same as that of the milliammeter incorporated in it. The sensitivity of range has a practical limitation because of the fact that the milliammeter alone may need a potential drop of from 10 to 20 millivolts across its terminals, even without extra series resistance, to give full scale current. The need for including a substantial extra drop in a multiplier so as to reduce the error due to temperature coefficient brings the limiting range up to, say, 50 millivolt except in the case of specially designed low range instruments.

DYNAMOMETER AND MOVING IRON VOLTMETERS

In both of these types the means for current sensitivity adjustment are not as convenient as in the moving coil type and consequently in the voltmeters it may be preferable to leave the current untouched and make the adjustment on the resistance of the multiplier.

In both also, the current unit imposes the frequency limitation; the multiplier can be regarded as a non-reactive resistor over a frequency range far beyond that for which the current indication is reliable. In the current coils, also, the impedance varies with frequency due to the inductance and capacitance so that the series multiplier serves to reduce the overall change of impedance due to frequency in the same way that it reduces the overall resistance change due to the temperature coefficient of the copper section. This additional error increases the necessity for maintaining the multiplier resistance considerably greater than the resistance of the current meter used, and means that these types are not eminently suitable for low voltage ranges.

THERMOCOUPLE VOLTMETER

Naturally, in order to produce a voltmeter with high resistance, and low current consumption, the resistance multiplier is placed in series with a low current thermocouple—say, from 2 to 10 milliamp rating. A 10 milliamp couple may have a resistance of 40 to 50 ohms and, due to its temperature rise, a variation of up to 1% in resistance between zero and full rated current; the 2 milliamp couple may be 500 to 600 ohm resistance and may vary by over 10% under load conditions. For the more sensitive voltmeter, therefore, a multiplier of up to 100 times the couple resistance will be necessary before the resistance can be regarded as appreciably constant. For a considerably lower range the resistance variation may amount to several per cent., but this does not actually cause the same degree of error in calibration since the scale, being non-linear, is calibrated to the individual characteristics of the particular couple and associated resistor and the effect due to the resistance variation is included. An error is introduced, though, if an extra resistor is placed in series to extend the range of the instrument, for in that case the percentage change of resistance is not uniform and the voltmeter deflection will not follow exactly the same law for which the scale of the previous range was marked.

The thermocouple itself as a current device is suitable to the higher radio frequencies. As a voltmeter, therefore, the frequency limitation is imposed by the multiplier. If wound resistors are used the limit will probably be met at lower frequencies of a few megacycles. If, on the other hand, the frequency characteristics are improved by using the carbon or composition type of resistor it will be found that the large temperature coefficient and the natural instability of these types detract from the accuracy of the instrument.

For adjustment it is usually the best method to leave the resistance at some convenient fixed value and to adjust the sensitivity by the D.C. meter used across the output of the thermojunction.

RECTIFIER VOLTMETER

Because of the varying resistance characteristics of the rectifier elements the resistance, between zero and full scale potential, will not be constant. In low voltage ranges—up to 3 or 4 volts using the 1.0 milliamp rectifier unit—the resistance variation is sufficient to necessitate a non-linear scale individual to each separate range. At higher ranges the overall resistance variation is negligible, down to the lower working limit of the scale, and the scale can be taken as linear. The low potential ranges also have considerable coefficients due to the big changes in the rectified resistance with the temperature change. As in the case of the thermocouple meter, the use of a moving coil instrument as an indicator provides the most simple method of adjusting the sensitivity where an adjustment common to all potential ranges is necessary.

Two other types of potential meter — the electrostatic and the electronic—have not been covered under the current meters. These two alone, as distinct from all the others, depend for their operation on the difference of potential across some part of the circuit. They can be used to measure current by placing them across a known resistance R in the current circuit and applying Ohm's law $I = E/R$.

ELECTROSTATIC VOLTMETER

(a) **Principle and Description.** — The electrostatic voltmeter depends for its operation on the electrostatic attraction between two bodies maintained at a difference of potential. The force of attraction is proportional to the area of the exposed surface, to the square of the potential difference, and inversely to the distance between the bodies and is dependent on the medium separating them. In the lower potential ranges where, on account of the extra low attractive force, a greater surface area is necessary to compensate for this, the design takes a form similar to the familiar variable air condenser constructed on a considerably smaller scale. In this case the bank of moving plates or vanes is mounted on a pivotted spindle between jewel bearings and the attractive force draws them in between the fixed vanes until equilibrium is restored by the building up of the restoring torque in the control springs. In the high potential ranges the same design may exist with possibly one moving vane in between two fixed vanes and with a corresponding increase in clearance between them depending on the potential to be measured. An alternative design for the high potential type is to have two parallel metal plates, one fixed and the other hinged and free to move slightly towards the fixed plate before being halted by a stop. The slight movement caused by the mutual attraction resulting from the applied potential is magnified by one of a number of different multiplying mechanisms and finally transferred to the movement of a pointer across a scale. At high potentials, corona discharge effects are very important and intense fields build up at any sharp edges on the meter parts on which the potential is impressed. The main attracting discs or plates and other parts likely to be influenced are well finished with rounded edges and corners and are usually plated to maintain a good smooth, untarnished surface. One of the biggest dangers, naturally, in a voltmeter of this type is the possibility of a flashover between electrodes and various methods are used to protect against this, i.e., a spark gap set to breakdown at a lower value, a fuse, or a series resistor or capacitor to limit the discharge. For the lower potential ranges, the series resistor is usually the protection adopted, if any.

(b) **Characteristics.**

(i) **Suitability for D.C. and A.C.** The attraction due to the potential varies as the square of the potential, hence the torque is identical for "D.C." potentials and the equivalent R.M.S. "A.C." potentials.

(ii) **Frequency Range.** The instrument can be designed to be suitable for use at radio frequency, although under this condition the capacitance of the unit may lead to capacitive currents which may be not only excessive for the supply being measured, but may result in heating troubles in the instrument. Where a series resistor has been inserted as a protection against the effects of breakdown this must be removed for measurements at radio frequencies, otherwise the drop across it due to the capacitance current will lead to inaccuracy.

(iii) **Scale Shape.** The scale shape cannot be predicted in general terms except to state that it is non-linear and, in most cases, individual to the particular instrument. The attractive torque increases as the square of the potential, leading to a square law scale, but this is modified by the contour and the lining up of the vanes, by the characteristics of the mechanism for multiplying the small displacement (where this feature is used) and by the nature of the controlling forces, i.e., whether control springs with uniform torque or gravity control with a non-uniform response. In general, the scale is very contracted at the lower end, the first graduation possible to read with any accuracy being often one-quarter to one-third the full scale value. The scale may continue to open up to full scale or may open towards the centre and again contract towards full scale, depending on the above factors.

(iv) **Accuracy.** Due to the very non-uniform scale divisions and to changes in the instrument characteristics the accuracy is only moderate. Probably, inaccuracies of from 2% to 5% of full scale might occur in the various grades of instrument.

(v) **Range.** Because of the rapid decrease of torque at low potential values the instrument is not generally suitable for sensitive ranges (say, below the order of 100 volts). The upper limit runs to hundreds of kilovolts, in which case the instrument reaches gigantic proportions with dimensions possibly exceeding even ten feet in height or length. The range is often extended by the use of a potential divider—a number of capacitor units in series across the potential to be measured—with the voltmeter placed in parallel with one unit—the one nearest to earth potential. In this case the capacitance of the voltmeter must be small compared with that of the shunting capacitor, otherwise, due to the change in capacitance as the voltmeter vanes change their position, the shunting ratio will not be constant and the total potential will not be a constant multiple of the voltmeter indication.

(vi) **Load.** On D.C. the electrostatic meter imposes practically no load as, once the initial small surge of charging current is over, the only load is due to the slight leakage from the finite insulation resistance value. At low A.C. frequencies the load can also be taken as negligible, but as the frequency is increased notice has to be taken of the corresponding increase in capacitance current.

(vii) **Sources of Error.** The instrument is, from the nature of the design, rather fragile, and rough handling or rough usage is liable to result in slight displacements in the vanes or other delicate parts, leading to a change in characteristics, and hence a change in accuracy. Electrical sparking across the vanes also pits them or burns away the edges and so alters the contour and the response. Errors due to control springs and pivot friction are, of course, common to this as to other types.

(viii) **Methods of Adjustment.** This can be done preferably by adjusting the control springs or, alternatively, by altering slightly the lining up of the moving vane system. It is difficult, however, in most cases, to alter the position of any vane or set of vanes and still retain the same "scale shape." It has been found from experience that where such adjustments become necessary it is usually simpler to calibrate a new scale completely to conform to the changed characteristic of the instrument.

ELECTRON TUBE VOLTMETER

(a) **Principle and Description.** — This instrument will be described in general terms only, not because it is of little interest or importance, for on the contrary it has rapidly become, in A.C., as important as the moving coil instrument in D.C., but because the great variety of designs prohibit any attempt to enter into detail about each type. Fundamentally the operation of all the different models or types depends on the fact that a change of potential on the grid of an electron tube causes a change in the anode current, which change can be read either directly, or after successive stages of amplification, in the response of a moving coil milliammeter.

(b) **Characteristics.**

(i) Theoretically at least, the electron tube voltmeter, like the electrostatic voltmeter, takes no current. It operates simply on the applied potential. Actually, however, there is a very small but, nevertheless, finite load imposed by the resistance and capacitance measured at the instrument terminals, but this may be equivalent to possibly more than 10 megohms resistance in parallel with a few micro-micro-farads capacitance and so is usually negligible except for measurements across very high values of resistance or at radio frequencies. Not all the instruments have high inputs such as this, for some have resistors of high value purposely across the input terminals, while others use transformer input connections.

(ii) **Accuracy.** This is usually only moderate as, in addition to the normal inaccuracy of the D.C. meter used as the indicator, there are the extra inaccuracies and instability in the amplifier circuits and these may vary over wide limits, depending on the design.

(iii) **Range.** The electron tube type is particularly suitable for the construction of sensitive ranges, hitherto beyond the practical limit of measurement. The limitation is, in general, caused by considerations involved in the amplifier since the difficulty in retaining stability and constancy increases when extra amplification is introduced to extend the measuring range still lower. For direct reading the upper range limit is not high, but, naturally, the range can be extended almost indefinitely by putting a known resistor or capacitor potential divider across the potential and measuring with the voltmeter the drop across one small portion.

(iv) **Frequency Range.** This depends wholly on the design. Where required, the electron tube meter can be designed for satisfactory use on A.C. up to radio frequencies of well over 100 megacycles. Most models are suitable for A.C. only as the amplifier stages will not respond with only a D.C. change on the input. Some are suitable for both D.C. and A.C., though separate calibrations may be necessary on the two supplies.

(v) **Scale Shape.** This will also depend on the design. Some instruments possess reasonably accurate linear scales, but in others the general law may be either expanding or contracting. The presence of the amplifier and the ability to introduce networks and to select the conditions of operation so as to vary the response to some desired manner in relation to the input make it possible to obtain on the indicating D.C. meter a response to suit almost any particular requirement (such as, for instance, a logarithmic response to enable a moderately linear decibel scale to be drawn).

CONCLUSION

The above paragraphs, though far from a complete description, give some indication of the characteristics and uses of the principal instruments for the measurement of current and potential, instruments which depend for their operation on different principles and each of which has its own particular sphere of usefulness. Around these have grown up an innumerable number of other measuring instruments and measuring circuits, both simple and complex, all dependent in the final analysis on the indication given by a current or potential meter once the quantity to be measured has been converted into electrical units. Thus, measurement of the intensity of light is made possible by the use of a photo-electric cell whose current output varies with the intensity of the light; sound is measured by converting the sound energy into electric energy through a microphone and thence through an amplifier; small mechanical displacements are indicated by the change of capacitance of a small air condenser, one electrode of which moves with the body displaced, and causes a change in an electrical circuit incorporating that condenser; the temperature of a furnace is measured by the output from a thermo junction; speed is indicated by transforming into electrical impulses a series of mechanical impulses proportional to that speed.

Other instruments operate without using any of the indicating movements already described. Thus high potentials are measured by the mechanical adjustment of a spark gap; other quantities are measured by the settings of calibrated resistors in bridges or potentiometers; potential is also measured by the striking potential of a gas discharge tube with calibrated controlled grid circuit. In each of these a current or potential meter, though not used in the measurement, is still essential at some stage for the calibration of the instrument.

And so the list grows indefinitely—always increasing—extending the range here, improving the accuracy somewhere else, or adding to the formidable array of measurements still one more quantity which has not been measured before by direct means.

A description of these, with their own individual characteristics and points of interest, could readily fill a separate chapter for each. The one main feature common to all is that the foundation of each measurement rests on the ability to read accurately and reliably some simple electrical quantity of current or potential. Therefore, a thorough understanding of these two measurements and of the possibilities and limitations of the instruments by which they are usually made goes a long way towards a proper appreciation and estimation of the reliance that can be attached to the results from general measuring circuits.

THE NEW MELBOURNE TRUNK EXCHANGE

L. Paddock

(*Continued from Vol. 2, No. 6*)

Delay Supervisor's Desk

The function of the Delay Supervisor's desk is to provide an immediate indication of any overload conditions which arise. It is particularly necessary that the Supervisor be acquainted with any condition which may warrant changes in operating procedure.

The desk is shown in Fig. 6. Provision is made for two Supervisors to perform keyshelf operating work, whilst blank keyshelf space is available for two other officers to carry out duties such as traffic load recording and analysis.

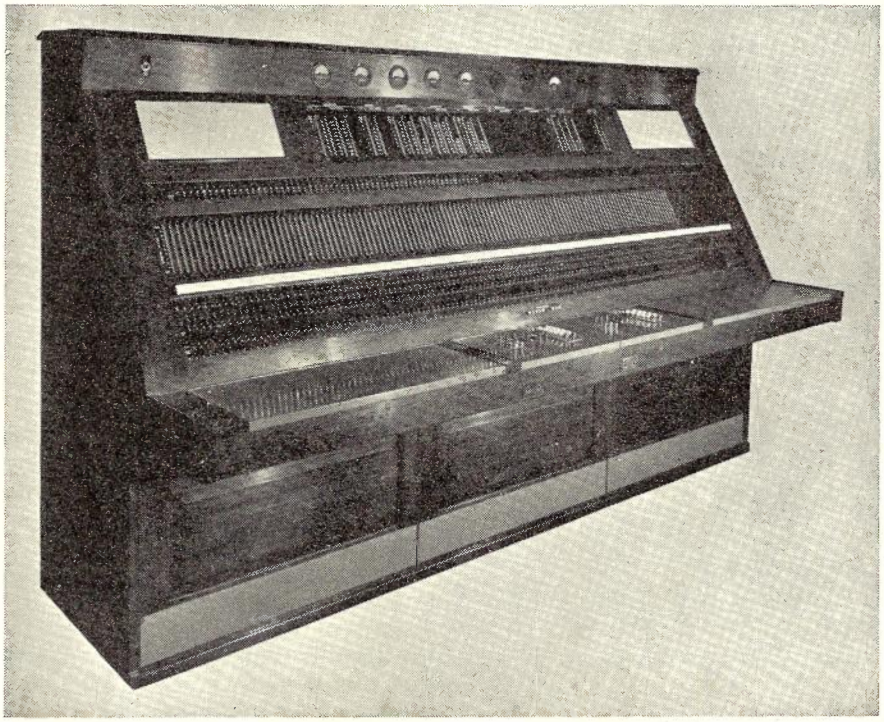


Fig. 6.—Delay Supervisor's Desk.

The following is a summary of the supervisory and control facilities provided on the desk:—

(a) Indication of incoming traffic load conditions.

(b) Indication of suite staffing arrangements, for co-ordination with (a).

(c) Indications of switching of link positions amongst the demand positions and their associated load display fields.

(d) On main and minor trunk line groups:—
- Indication of number of calls stored.
- Indication of group congestion.
- Indication of delay working.
- Control of alternative routing.
- Control of establishment of delay working conditions.
- Setting of anticipated delay periods.

(e) Setting of anticipated delay periods on interstate trunk line groups.

(f) Marking of demand positions for delay working.

In addition to the foregoing, the Delay Supervisor can:—

(a) Receive calls from any main suite telephonist in the Melbourne Trunk Exchange and also direct from any Victorian country telephonist.

(b) Originate calls to all places to which Demand, Through and Suspense telephonists have access.

(c) Obtain access, by order wire to the routing and P.D. Positions.

The desk accommodates a calling lamp display associated with the Interstate, Through and Trunk Inquiry Suites, together with one of each of the Load Display Fields in the Demand suite. A maximum of ten waiting calls can be indicated by each Calling Lamp Display. Waiting calls in excess of this quantity up to 10 more are indicated on meters calibrated in calls and mounted near the top of the desk. The lamp at the top of each display strip flickers when No. 1 waiting call has been unanswered for more than a certain period. This period can be varied within certain limits by adjustment of apparatus. A representative delay setting is 15 seconds.

Associated with each Lamp Display are similar lamp strips designated with position numbers. Glowing lamps denote positions staffed, that is, positions in which plugs are inserted into telephone jacks. These lamps are normally out and they function only when relevant "Positions staffed" buttons are pressed.

The foregoing facility enables the Supervisor, by observing the staffed positions in relation to the loads on various suites as indicated by the Load Display Field, to take any necessary corrective action to assist an overloaded field by transferring a telephonist from a less heavily loaded display field. Other factors to be considered by the Supervisor before making a change relate to the incidence of assistance being rendered by the link positions, each of which, as stated in a previous article (see Vol. 2, No. 5, p. 304), is automatically switchable between two load display fields, and as first choice, will switch to the display containing the call which has been waiting longest for an answer, providing the waiting period exceeds 20 seconds, and secondly it will assist the Load Display which has the greatest load at the time.

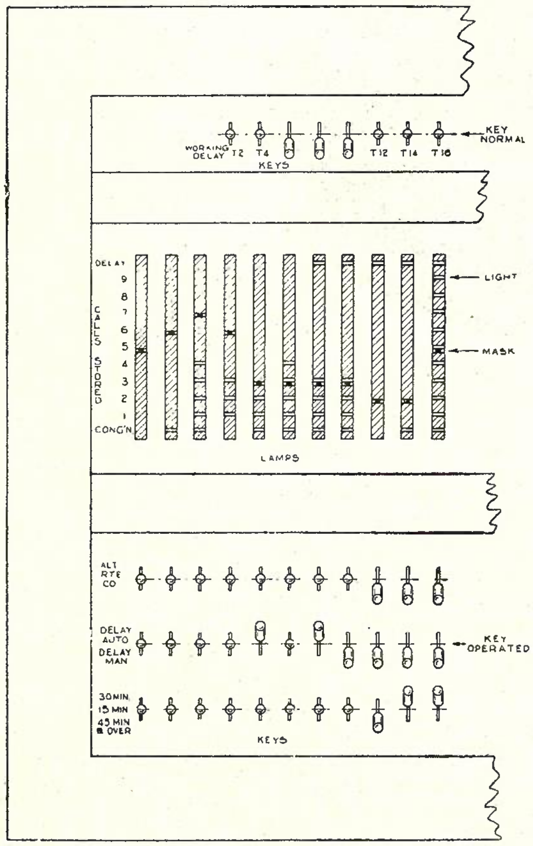


Fig. 7.

The behaviour of the link positions, as regards the particular field they are serving at any moment, is indicated on a lamp strip mounted on the Delay Supervisor's desk and must be given due consideration in relation to any staff rearrangement proposed by the Delay Supervisor.

Trunk Line Supervision and Control.—A section of the lamp display of the desk is shown in Fig. 7. This is the portion relating to the groups of trunks to country centres, each centre being represented by a strip of lamps and a set of control keys in vertical line beneath them. The bank of vertically mounted lamp strips together with related keys mounted beneath, provides for supervision and control of trunk line groups both main and minor. The apparatus per group is as follows:—

(a) **Lamp Display Strip.**

This contains 11 lamps, the lowermost lighting to indicate group congestion. The uppermost lights to indicate when delay working conditions are in force, flickering if the group has automatically gone into delay and steadily glowing if placed in delay manually or transferred from automatic to manual delay, these latter functions being performed by the Delay Supervisor. The nine intervening lamps indicate the number of calls in storage. An adjustable detail indicates the storage quantity stage at which it is decided, under normal traffic conditions, that delay working should be introduced for the group under consideration.

(b) **Alternative Route Cut Off Key.**

If the group is an alternative route for another group, the throwing of the key downwards disables the facility and confines its outgoing traffic to its own keystrip code.

(c) **Delay Auto. and Delay Manual Key.**

When this key is at normal, demand working remains in force irrespective of the number of stored calls. When thrown to "Auto," delay working is automatically introduced as soon as the number of stored calls equals the number previously determined as that at which delay working should be instituted.

As previously mentioned, the Delay Lamp flickers to attract the attention of the Supervisor, who acknowledges the condition by throwing the key to "Manual," which changes the lamp to a steady glow. The throwing of the key to Manual at any time immediately introduces delay working.

(d) **Delay Time Setting Key.**

This key controls the lamp signal which a telephonist receives when she keys up a group in delay, informing her whether 15, 30 or 45 (or more) minutes' delay is anticipated, this being indicated to the telephonist in the form of a lamp signal which will give a flicker, flash or steady glow to indicate the anticipated delay. The anticipated delay periods for interstate groups of trunks are set up on a group of keys at the right of the panel. The keys control lamps in panels situated so that one is visible from any point in the switchroom and the delay is indicated by coloured illumination behind a stencil; the colours white, green and red indicate delays of 15, 30 and 45 minutes respectively, and the stencil indicates the route.

The first eleven columns of apparatus in Fig. 7 show examples of different trunk group conditions which can arise. Their explanation is as follows:—

Column 1.—Delay datum point, 4/5 stored calls. Demand working in progress. Group not congested.

Column 2.—Delay datum point, 5/6 stored calls. Demand working in progress. Group congested but no calls in storage.

Column 3.—Delay datum point 6/7 stored calls. Demand working in progress. Group congested and 4 calls in storage.

Column 4.—Delay datum point, 5/6 stored calls. Demand working in progress. Three calls in storage, but the group at that moment is not congested. By recording the total period for which the congestion lamp is out whilst calls are in storage, and then dividing by the number of occasions observed, the average delay in releasing calls from storage for free trunks is obtainable.

Column 5.—Delay datum point 2/3 stored calls. Demand working in progress. Group congested. Two calls in storage. Delay Auto. key thrown, so that one more stored call will automatically introduce delay working conditions.

Column 6.—Delay datum point 2/3 stored calls. Demand working in progress. Group congested. Four calls in storage, two being beyond the datum point. Delay working has not come into force because the Delay key is at normal. The Supervisor may have deliberately permitted this condition to arise owing to having been informed by the distant end that, for example, a race meeting is in progress and that the current traffic represents only intermittent rushes of short-duration calls.

Column 7.—This shows what happens in the Column 5 case on the arrival of another stored call. The Delay lamp actually is flickering.

Column 8.—The Supervisor, having noted the flickering in the previous case, throws the Delay key to Manual, which causes the Delay lamp to glow steadily. Having done so, it is immediately necessary for her to:—

(a) Nominate a Delay position for handling this group's tickets.

(b) Advise the Pneumatic Distribution Position about (a).

(c) Determine the anticipated period of delay to be signalled to telephonists.

(d) Prevent the group from being used as an alternative route, should such normally be the case.

(e) Advise the Monitor relative to the position in (a) of the state of affairs.

Regarding (a), a position already working delay for another group (or groups) might be nominated, or another Demand position might have to be taken into use. In the former case, a straightforward notification as per (b), followed by (e) only is necessary. In the latter case, preliminary action is necessary as regards finding a position, the transfer of which to delay working will not adversely affect incoming demand loading conditions. The line of action adopted by the Supervisor will, in this case, be governed by an inspection of the lamp displays relating to the traffic loads and staffed positions in the various groups. As previously explained, the traffic load displays are permanently indicated and the "staffed positions" in the various groups may be ascertained by pressing appropriate group button.

Regarding (b), the Supervisor does this by means of an order wire button on the keyshelf.

Regarding (c), in a case such as being described, delay working will at least commence with the shortest period (15 minutes), so that the Delay Period key will be set at normal. The setting of a longer delay might become necessary later on, which action might arise, for example, from the Monitor concerned reporting an increasing accumulation of tickets, or the delay telephonist might report the matter direct by making a call to the Delay Supervisor.

Regarding (d), this is done by throwing the Alternative Route Cut Off key downwards.

Regarding (e), the Supervisor takes her Connecting Circuit into use and keys up the code of the Monitor concerned.

Column 9.—The Supervisor might learn, for example, that a route which hitherto has been working smoothly, without stored calls and even without congestion, has suddenly broken down completely, and further, that no information can be given as to when the fault will be rectified, beyond a statement that it might be some appreciable time. This column illustrates the action to be taken. The Delay key is thrown at once to Manual, the delay period set at 45 minutes, and the alternative routing facility exercised by the group is cut off. The Delay lamp glows steadily. The Supervisor would, of course, have to take action as described for the previous case.

Column 10.—The lamp strip in this case shows the conditions which should be displayed when delay working is satisfactorily in progress. That is, all trunks in the group are permanently taken up by the Delay telephonist (causing the Congestion lamp to glow), all stored calls which had arisen under demand working condition have been worked off, and the Delay lamp is glowing steadily. A setting of 30 minutes anticipated delay is illustrated.

Column 11. — Cases can arise, temporarily, wherein all lamps in the display strip are glowing, and the condition might arise as follows:—

The delay datum point is shown at 4/5 stored calls but the Supervisor has learned that only short-duration calls are in progress. She there, fore decides, for the time being, not to allow delay working to come into force. The stored calls continue to increase and, noting that they persistently remain at nine, she at last decides to switch over to delay. The nine storage lamps will not go out until all stored calls have been worked off (or, alternatively, until all outstanding demand tickets for the group have been collected, and the "demand" set-up of each such call abandoned).

Marking of Demand Positions for Delay Working.—When demand telephonists key up codes of trunk groups in delay, they receive the delay signal and the anticipated period of delay, but they are prevented from obtaining access to the group. When a demand position is working delay, access must not be barred; therefore entry is permitted by the delay supervisor operating the relative position key which permits the operator to over-ride delay signals.

Incoming Calls. — Two incoming calls can simultaneously be routed to the desk. A "left side" call lights a pilot lamp behind the left bulletin frame and lights the Answer lamp in the left keyshelf, while a "right side" call lights corresponding lamps on the right side of the desk.

The answering circuit key throws in two directions, forward to speak and backward to force the call off the desk should the distant end be dilatory in clearing down.

Outgoing Calls.—Facilities are provided for one outgoing call to be set up from each position, the keyshelf apparatus concerned being as follows:—

Connecting Circuit comprising an Engaged lamp, a Call Supervisory lamp and a combined Speak and Release key.

Digit keystrip and associated set of three supervisory lamps.

Tone cut-off and Sender change-over lever keys.

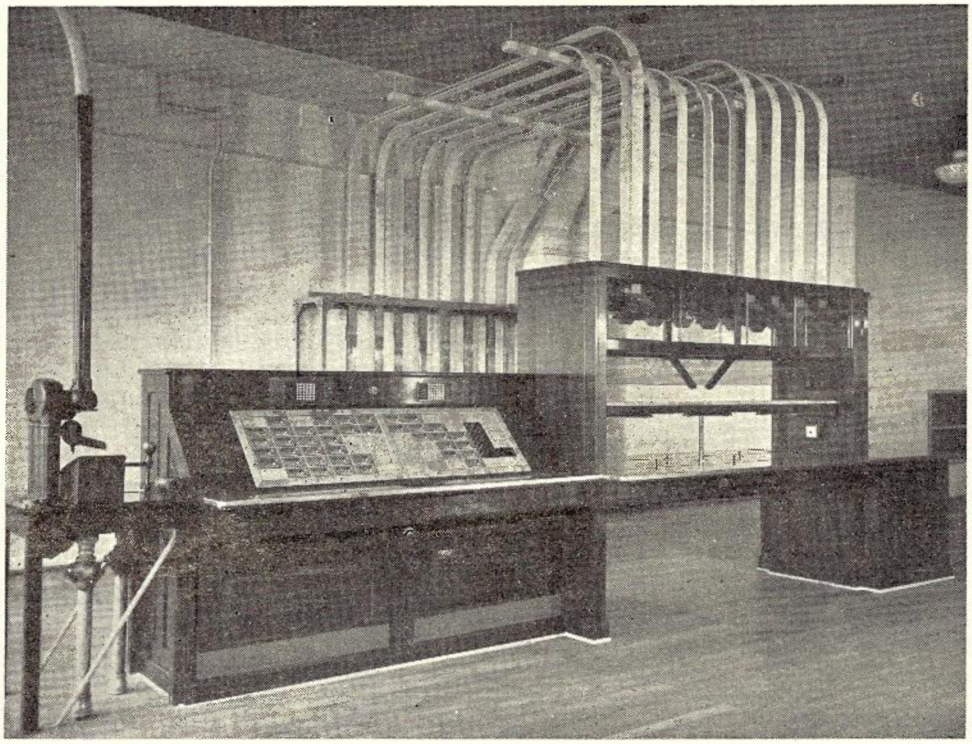


Fig. 8.—Pneumatic Tube Distribution Desk.

Ring and Primary Routing press-buttons.

The circuit terminates in a 1st Selector which trunks to 1st local selectors to obtain access to the metropolitan network, and to Second Trunk selectors which cannot connect to Intrastate trunk lines.

The operating procedure in respect to outgoing calls is thus similar to that obtaining on main suite positions.

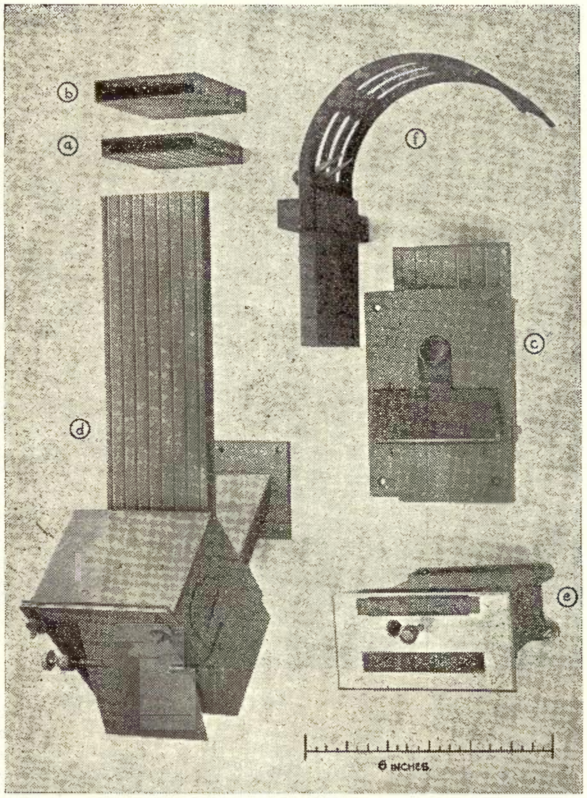
It is possible for an incoming and an outgoing connection to be set up simultaneously on each position, but it is arranged that the Supervisor can talk on them only one at a time. If both Speak keys are thrown, that of the outgoing call takes preference.

Pneumatic Distribution Position

Docket Distribution.—Details relating to trunk line calls are entered on dockets which provide a record of service required during the progress of the call, and on completion the expired time is entered and the docket routed to a telephonist who prices the call. The docket is then forwarded to the Accountant, who extracts the charge to the relative subscriber's account.

Dockets are circulated by means of pneumatic ticket tubes, through which they are individually passed without being placed in a carrier or container. The tubes are of extruded brass, rectangular in shape, the bore being 2¾ in. x ⅜ in. and the wall thickness 20 s.w.g. The internal surfaces are slightly ribbed longitudinally to reduce friction.

Dockets 5¼ in. long by 2⅝ in. wide are cut from paper about 6 mils. in thickness. One end of the docket is bent upwards to form a sail, and, by



(a) Tubing. (b) Jointing Sleeve. (c) Despatch Valve—Collecting Tube. (d) Receiving Valve — Collecting Tube. (e) Despatch Valve—Distributing Tube. (f) Delivery Head—Distributing Tube.

Fig. 9.—Details of Tubing and Valves.

virtue of the air movement, the dockets are propelled through the tubes and discharged automatically at the terminal destination. The "sail," 8 millimeters high, is formed by machine before the dockets are distributed to the Positions.

The Pneumatic Distribution position which is shown in Fig. 8, forms a combined pricing and distribution suite. Outlet pressure valves are arranged in two groups at the left of the suite, each group having an ultimate capacity of 36 outlets, one outlet being provided for each 2 operating positions. The left hand end of the suite forms a desk at which are positions for 6 pricing telephonists, three on either side. About 18 in. above the desk and extending over its length is a glass tray on which are ejected dockets being collected by vacuum tube from the operating positions. Each of the 6 pricing positions is equipped with a line on which enquiries concerning prices may be extended from the trunk inquiry positions.

Conveyor belts are set below the face of the desk so that dockets may be despatched to the distribution operator, if necessary, or to the sorting telephonist, if completed.

Installation of Tubes.—Tubes pass from the P.D.P. to the operating positions via chases in the switchroom floor. These are 6 in. deep and were provided by using 6 in. floor joists over the concrete construction and fitting a jarrah decking thereon.

As special plant is necessary to shape bends or sets in the tubing, these were prepared in the factory and were delivered to the job in marked groups or "nests." Suitable straight lengths were selected to complete the runs with the minimum amount of cutting and to provide inspection points as required. Inspection points take the form of a port in the edge of the tube. They facilitate the location and removal of obstructions in the tube, should such occur, but are normally sealed by a cover plate retained by spring clip.

The tubes were placed on edge wherever possible, but to form some bends it was necessary to place them on the flat. Sleeve joints were used and rendered airtight by a sealing compound. The joint must be carefully butted, truly square, and all edges which face the direction of travel must be internally chamferred to an angle of 30 deg. and smoothed.

Despatch Tubes.—The provision of despatch tubes is at the rate of one per two positions, and only one docket may occupy the tube at a time. Despatch valves are mounted on a reservoir tank, the outlet tube to the position, passing through the tank but without access to it. An aperture from the tank to the valve is normally held closed, but when required, air is passed through the valve to the tube. This valve and another are actuated when required, i.e., after placing a docket in the valve orifice, by the depression of a plunger key which operates a solenoid armature to control a flapper valve which uncovers the pressure inlet and covers the docket inlet so that pressure is applied to propel the docket through the tube. On being operated the solenoid locks through a local contact to an earthed contact at the outlet valve, which is tripped by the docket on arrival. The solenoid thereupon releases, shuts off pressure and prepares the tube for further use.

Collecting Tubes.—Each collecting tube serves 9 or 10 positions, a despatch valve being fitted in the keyshelf of each position. The tube operates on suction and, in contrast to pressure tubes, a number of dockets may be travelling in the tube simultaneously.

The despatch valve on collecting tubes is a simple contrivance having a hinged flap which is opened to permit the insertion of a docket, but normally remains closed.

The discharge valve for collecting tubes is probably the only portion of the system which calls for accurate adjustment, for, while other valves will operate satisfactorily over wide margins, the McGregor discharge terminal requires very careful adjustment as the door must be in Dynamic and Static balance. The discharge of the ticket through the terminal depends on the balancing of the two halves of the door as regards vacuum, atmospheric pressure, gravity, and the inrush of air when the door opens, as against the downward movement of the column of air in the tube. A valve of each type and a piece of tubing is depicted in Fig. 9.

Air Supply.—The air supply for the system is obtained from blowers (see Fig. 10) which are installed in duplicate. Each blower is equipped with an 8 H.P. motor, the shaft of which is extended at each end to mount a 2 stage blower. The standard vacuum or pressure developed by these blowers is 24-26 inches water gauge (about 1 lb. pressure per square inch).

The pressure air duct is connected to the outlet side of one blower while the vacuum duct is connected to the inlet side of the blower at the opposite end of the shaft.

Silencers have been fitted to reduce noise. These are 9 ft. sections of timber duct inserted in the main run and treated internally with sound absorbing material. This absorbs noises due to motors and to ripple produced at the impeller blades. As the speed of the blower unit is 2900 r.p.m., it will be realized that much noise could be transmitted to the operating room if suitable precautions were not taken.

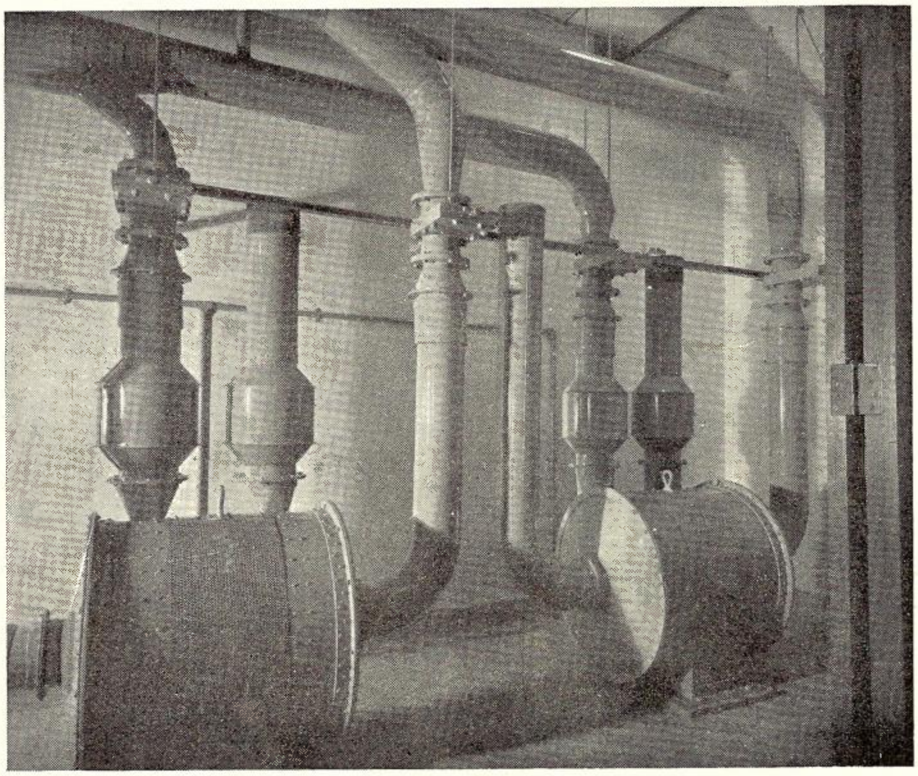


Fig. 10.—Blowers for P.D.P. System.

Owing to the load on the pressure blower varying from maximum to zero, it is necessary to provide a by-pass to atmosphere on the delivery side to permit a small discharge of air at all times. This is to prevent the generation of excessive heat due to churning of the air under the condition of no load and so prevents the machine motor and bearings becoming unduly heated.

Alarm System.—An alarm is provided on collecting tubes and is controlled primarily by a pneumatic relay which is fitted at the extreme open end of a tube and closes a pair of contacts when the vacuum fails, as it would do in the event of machine failure, or despatch or receiving valves remaining open or a docket blockage occurring in the tube.

Consequent on the operation of the pneumatic relay, a group of electro magnetic relays produce an alarm after a delay of approximately 10 seconds. A tube pilot lamp lights on the panel of each position served by the tube concerned to advise the operators: (a) to refrain from posting further dockets in the tube; and (b) to check that failure is not due to despatch valve being open. An out of order key, per vacuum tube, is provided to operate alarm lamps relating to that tube, and in addition one common shut down key is fitted:—

(i) To prevent the lighting of tube alarm lamps when blowers are not running;

(ii) As a check that machine has been shut down if this is intended;

(iii) As a warning to remove the alarm cancellation on the re-application of vacuum, as at commencement of day's work.

Speed of Dockets.—The tubes are designed to work on speeds as follows:—

Length up to 150 feet.—30 feet per second.

Length from 150 feet to 200 feet.—25 feet per second.

Length from 200 feet upwards.—20 feet per second.

These speeds have been attained easily in the case of pressure tubes, but with vacuum collecting tubes, speed has been to some extent sacrificed to ensure satisfactory ejection at the receiving heads, and the average speed is about 18 feet per second.

Tubes Connected.—Approximately 5600 feet of tubing was required for the installation, which comprises 47 pressure tubes and 14 vacuum tubes. The pneumatic tube distribution system was supplied by Messrs. Standard Telephones & Cables Pty. Ltd.

TRAFFIC FORECASTING IN THE MELBOURNE NETWORK

A. R. Hutchinson, B.Sc.

The capital and maintenance costs involved in the provision of underground junction cable and its associated equipment are very heavy, therefore, it is important that the methods of forecasting future developments of traffic on main junction routes should be as accurate as possible. The junction and switch provision is based upon the forecast traffic and either unnecessarily lavish or too sparing provision is inefficient.

As the forecasting of traffic development is a phase upon which no definite instructions are laid down, this article is intended to describe the methods evolved for forecasting the traffic in the Melbourne network as based upon the practice of the British Post Office and modified to suit local requirements.

The problems of forecasting in this country are more restricted than in Great Britain where, in 1929, estimates were required for periods up to 25 years ahead of the traffic for the whole London area covering some 30,000 junction routes. Beside this, the problems of the Melbourne network seem modest but nevertheless there are at present 144 junction routes between main exchanges, 112 routes between mains and branches, and also a great number of minor routes and prospective routes which require forecasting, although not yet passing traffic.

In the search for some laws governing the growth of traffic along any route it is clear that the traffic will depend in some way upon the sizes of the exchange areas at which the traffic originates and terminates, and also very largely upon the community of interest between the areas. It is reasonable to expect very different traffic conditions, for example, between two exchanges serving industrial areas as against two exchanges serving residential areas. It would be unsound to base traffic development upon the subscribers' development figures at either the originating or terminating areas alone, although it certainly will depend in some way upon both, for even if we assume that no growth takes place in subscribers in the one area while those in the other double, a considerable increase in traffic will occur. Thus, if we have two exchange areas of sizes A and B, the traffic between them will in some manner be proportional to their product.

From the curves obtained by plotting the exchange lines against the traffic for successive years over a number of routes, it has been found that the following relation exists:—

$$\text{Traffic Units (T.U.)} = M(AB)^x$$

Where—

M = a constant

B = subs. lines at originating exchange area.

A = subs. lines at distant exchange area.

x = An index which depends on the trend in calling rates.

The constant M which determines the steepness of the curve represents the community of interest between A and B, and for this reason has been termed the "Acquaintance Factor." The exchange lines are expressed in thousands in order to avoid unwieldy products as M would otherwise be an inconvenient decimal number. The value of the index x depends upon the trend of calling rates on the routes under consideration. In the London network during the period 1921 to 1927 the calling rates were found to be declining and the equation most representative of the general traffic tendency was:—

$$TU = M(AB)^{0 \cdot 37}.$$

Where the calling rate for the areas concerned is steady, an index of 0.50 would best apply to exchanges having the average development of the whole area, while where the calling rates are increasing rapidly as in most exchanges in the Melbourne network, a higher index is applicable.

In order to give an equation which can be readily calculated as a routine in all cases an index of 0.50 has been adopted for the Melbourne network, as the basic equation $TU = M\sqrt{AB}$ can then be readily calculated on a slide rule. However, as the square root applies only where calling rates are stationary, a correction must be made to take account of the fact that the calling rates on individual routes will depart from these conditions very considerably, the square root being a first approximation only.

If it were necessary to calculate a value of the true index for each route in order to make the correction, the method would tend to be rather cumbersome but a simplified method has been evolved for use in the Melbourne network embodying this correction automatically and without special calculation. This method is to plot from past traffic studies a graph for each junction route between main exchanges, against a time base, of the quantity:—

$$\frac{TU}{\sqrt{AB}} = \frac{\text{Traffic units observed at date of traffic study.}}{\text{Square root of the product of the originating and terminating area subscribers.}}$$

This quantity really amounts to the junction traffic units per root mean of the subscribers in the originating and terminating areas. When this quantity has been plotted over a number of traffic studies the trend in the calling rate for that route is easily seen. If the calling rates are stationary, the resultant graph will approximate a straight line parallel to the time base, while with a rising or falling trend in the calling rate the curve will show a rise or fall. In order to make a forecast of traffic it is only necessary to project the curve to the date for which the forecast is required and read off the value of the ordinate, then to multiply this value by the root mean of the subscribers at the forecast date, thus:

Forecast Traffic—

$$= \text{projected value on graph} \times \sqrt{A_1 B_1}$$

where

A_1 = forecast subscribers at originating exchange area.

B_1 = forecast subscribers at terminating exchange area.

In applying this formula it should be noted that the exchange lines concerned are not those on the main exchanges alone, but include all of the branches and satellites trunking through those mains.

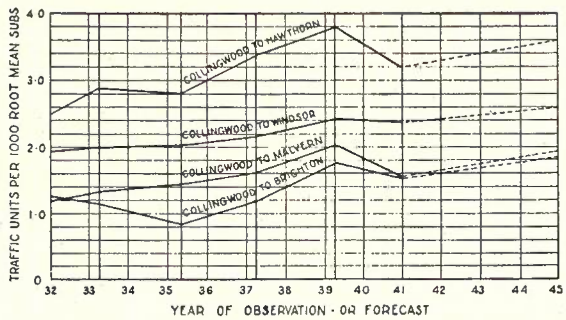


Fig. 1.

An example is given in Fig. 1 showing the method applied to four main routes from the Collingwood Exchange. It will be noticed that on all of these routes the figures for the last traffic study show a decline over the previous, and this is attributed to the war. A similar decline has been seen at a number of exchanges, but it is interesting to note that at Windsor and Hawthorn, where a decline was observed at checks made soon after the commencement of war, more recent checks have shown heavy increases.

TABLE I.

Route (1)	Traffic Units Dec., '40 (2)	Originating Subs. (Thousands) Dec., '45 (A_1) (3)	Terminating Subs. (Thousands) Dec., '45 (B_1) (4)	$\sqrt{A_1 B_1}$ (5)	Forecast Traffic per 1000 from graph (6)	Forecast 1 Traffic (TU) Dec., '45 (5) x (6)
Collingwood to Windsor	38.5	15.4	23.1	18.8	2.60	49.0
,, ,, Malvern	19.5	15.4	16.8	16.0	1.90	30.4
,, ,, Hawthorn	46.6	15.4	26.3	20.1	3.45	69.5
,, ,, Brighton	15.9	15.4	13.5	14.4	1.90	27.4

The graphical method has advantages not merely in removing the necessity for computations of acquaintance factors and indices required in forecasting, but in reducing the possibilities of error in the making of these computations. With the visual record, any abnormal departure from the previous trends shows out more readily, leading to investigation as to its cause. The accuracy of the method is limited only by the accuracy to which the trend on the graph can be forecast, and by the accuracy of the subscribers' development as estimated by the Survey Officer. These factors are subject to changes which cannot be foreseen, such as effects arising from national emergencies, but these will not be serious for short range forecasting as traffic studies are made at two year cycles and changes can be readily picked up, while extreme accuracy is not required or attainable for long range forecasting.

In Table I. is set out in detail the computation of the forecast traffic for a five-year period on the four routes shown in Fig. 1. A comparison is shown in Table II. of the traffic which would have been obtained by each of three methods with the observed traffic at the date of the last pre-war traffic study in each case.

(a) Basing traffic directly upon the subscribers' development figures at the originating exchange alone;

(b) the acquaintance factor method uncorrected to adjust for the trend in the calling rate; and

(c) the corrected method based upon the trend shown in Fig. 1 prior to the December, 1938, traffic study.

From the table it will be seen that the uncorrected acquaintance factor method used in this case would give slightly worse results than a straight-out subscribers' development forecast, but this is fortuitous and is not generally the case. Both methods are seen to be far from the actual observed traffic so that the necessity for calling rate correction will be evident. In the case of the four routes listed the actual increases in traffic were 56%, 220%, 200%, and 100%, respectively, greater than would be given by basing upon the originating subscribers' development alone. On the other hand, very much greater agreement with observed results is given by the graphical method described and applied to the trends shown in Fig. 1 on each of the four routes.

In dealing with the junction routes between the branch and main exchanges the same method is applied, but in this case the terminating traffic is spread over the whole of the network, there-

TABLE II.

Route	Traffic Observed Sept., '31	Forecast Traffic based on Colld. Subs. development Dec., '38	Forecast Traffic based on Uncorrected Acquaintance Factor Dec., '38	Forecast Traffic based on correction for trend from Fig. 1 Dec., '38	Actual Observed Traffic Dec., '38
Collingwood to Windsor	16.6A	25.0	23.5	29.0	30.5
,, ,, Malvern	8.9	13.4	13.1	20.5	23.0
,, ,, Hawthorn	19.5	29.5	31.5	50.4	49.8
,, ,, Brighton	7.6	11.5	11.1	14.1	16.0

TABLE III.

Exchange	Subscribers on Exchange Feb., 1941	Originating TU per line at last study	Percentage increase in TU per line over last 5 years
Ascot	4655	0.039	22
Box Hill	2155	0.038	52
Brighton	5026	0.050	21
Brunswick	4645	0.041	— 2 (Decline)
Canterbury	7054	0.036	24
Carlton	5575	0.098	36
Caulfield	4145	0.029	26 (3 years)
Collingwood	4539	0.064	8
Elsternwick	6972	0.036	12
Malvern	7832	0.046	24
Northcote	3755	0.031	— 5 (Decline)
Oakleigh	1921	0.034	17 (4 years)
Sandringham	2185	0.032	— 8 (Decline)
South Melbourne	4252	0.077	17

fore, the subscribers' development figure used is that for the network as a whole. Thus the multiplier is the square root of the product of the branch exchange subscribers and the network subscribers (in thousands). This method is very satisfactory where the number of subscribers on the branch exchange is considerable, but may be inaccurate where branches are started with two or three hundred lines. In such small installations it is often more satisfactory to use a straight-out subscribers' development figure for the branch exchange.

In development of traffic from primary line units and upon final selectors it is important to take account of the trend in originating and terminating traffic units per line for the exchange as a whole. This has varied over wide limits with exchanges in the Melbourne network as shown in Table III. covering the last five years for which observations are available, but in general it is seen that the increases have been very substantial. The values are plotted on graphs and, with most exchanges, there has been a tendency to ease off in the rate of increase, showing that saturation is being approached.

The above table does not include all exchanges in the Melbourne network. For those omitted the records are not complete over a long enough period. It does not necessarily follow that in the cases where a decline in the originating TU per line is shown there has been any real decline in telephone usage, on the contrary this may be an attendant of very rapid development. The Brunswick exchange is an example of such an area, previously highly industrialised, where a large increase in residential subscribers occurred, and as these have a low originating TU per line the net result has been a lowering of the average for the whole exchange. Collingwood is an interesting case in that for many years it showed a continuous decline in originating TU, tending to confirm the general impression that the area was losing its place as an important business centre. A traffic check made recently shows a considerable increase in TU per line, which is no doubt due to the stimulus given to industrial development brought about by the war.

INFORMATION SECTION

Readers are invited to submit questions on either theoretical or practical aspects of Telecommunication Engineering. Answers will be published in this section.

ENAMELLED SILK AND WOOL-COVERED STAR QUAD CABLE—COLOUR CODE

Recent purchases of switchboard cable have been in accordance with B.P.O. Specification 516D, which specifies a star quad arrangement of the conductors instead of the usual twin arrangement.

For the benefit of those who will be using this cable, the following table shows the colour scheme specified:

Position of quad in layer	Colour of Wire Markings		Colour of Quad Whippings	
	Pair A B	Pair C D	Centre & even layers	Odd layers
1st (Marker)	Red	Green	White with orange strands	Black with orange strands
Intermediate, 2nd & 4th, etc.	Blue	White	White	Black
3rd, 5th, etc.	Red	Green	White	Black
Last (reference)	Blue	White	White with orange strands	Black with orange strands

At present there is no standard colour code for multiple twin switchboard cable.—R.M.O.

THE RELATIVE ADVANTAGES OF CAIHLO AND COMPOSITE CIRCUITS FOR TELEGRAPH SIGNALLING

The caihlo circuit has many advantages over the composite circuit for the transmission of telegraph signals. The caihlo consists of a circuit superimposed on a telephone pair by the addition of repeating coils at the terminals and at intermediate points where telephone access is necessary. These repeating coils are connected differentially for telegraph currents and result only in increased ohmic resistance. The conductor resistance is low, as both telephone wires are used in parallel.

The caihlo is comparable with a single wire physical morse channel of low conductor resistance, but, as it is derived on a pair of wires, it is subject to heavier leakage in wet or foggy weather. In practice it is frequently necessary to limit the value of line currents on caihlo due to unbalances in repeating coils and line wires. These unbalances result in audible "thump" in the telephone channel on which the caihlo is derived. The "thump" is reduced by reducing telegraph current values or by the introduction of filters in the caihlo circuit. These filters pass the frequencies necessary for satisfactory telegraph work, but eliminate from the line the higher frequency components which cause disturbance in the telephone circuits.

Two composite telegraph circuits can be derived from one telephone pair by the introduction of filters which pass only frequencies which are inaudible in standard telephone instruments. The form of filter used is effective only when the telegraph currents are relatively small, and for this reason it is necessary to reduce the telegraph currents to values which approach the minimum for satisfactory signalling. The combination of the restricted current value and the restricted pass frequency range make the circuits useful only at low signalling speeds. Under certain conditions teleprinter signalling is possible over comparatively short distances, but the composite cannot be regarded as a first-class circuit for this purpose. The composite circuit being derived on one conductor is less subject to leakage than the caihlo.

To summarise, the caihlo circuit is capable of carrying high-speed telegraph signals and is equal to a physical morse conductor, the comparatively low conductor resistance compensating for the higher leakage value. One caihlo can be derived on a telephone pair.

The composite circuit is capable of carrying low or hand-speed signals, but two such circuits can be obtained on one telephone pair.—E.D.C.

SINGAPORE ANTS

Everyone is familiar with the damage to buildings and plant caused by termites—commonly called white ants—but cases of destruction of insulation on wires or of cable sheathing by "true" ants are so rare that it is felt that readers will be interested in the following account of a type of "true ant" at Mt. Magnet, West Australia, and of the methods employed to combat it.

Each summer a plague of small ants—known locally as "Singapore Ants"—infest the township, but it was not until February, 1940, that any damage to plant was caused by them. On this occasion they attacked the insulation of the wiring of a filter circuit which was nibbled and torn by the ants apparently in an attempt to establish their nests amongst the wiring. It was then the belief that they would not cause damage of that kind under any other circumstances.

Local attempts to reduce their numbers were unavailing and the matter was referred to the Division of Economic Entomology, C.S.I.R., for advice. The ants were identified as true Singapore Ants—Monomorium Destructor—and the use of a dilute arsenic bait to exterminate them was advised. This bait, which can be used for exterminating most species of ants, is made up and used as follows:—

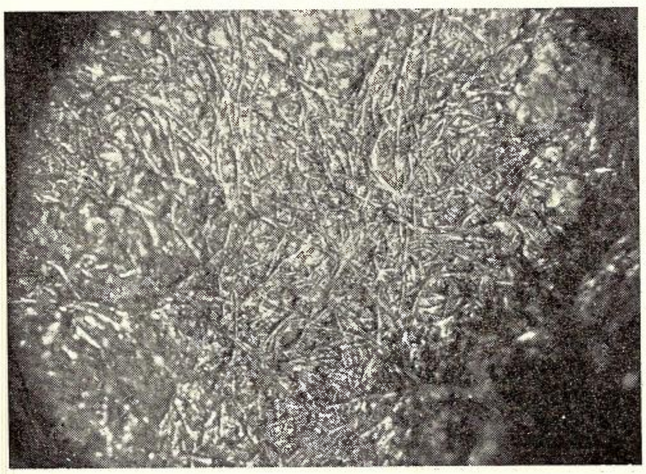


Fig. 1.—Photo. Micrograph of Section of Sheathing showing Marks made by the Mandibles of the Ant. Magnification 70.

A 0.2% aqueous solution of sodium arsenite is prepared and in every quart of this solution is dissolved 1½ lb. of sugar. The most satisfactory container consists of a small, thoroughly cleaned tobacco tin—or other similar tin provided with a lid. The top portions of the sides of the tin should be crushed inwards so that when the lid is replaced in position there is plenty of room for the ants to get into the tin through the depressions so made. In the bottom of this tin is placed a crushed mass of torn-up clean rag or a piece of clean sponge or other absorbent material (cotton wool is not very good, because the ants tend to become entangled in the hairs). The poison bait is poured into the tin until the absorbent material is fully saturated and there is a small portion of the bait lying free in the bottom of the tin. The lid is replaced and if there is any danger of its being handled by children the lid should be soldered into position. The bait should be placed in the shade where the ants are seen to make their runways, several tins being used even though the infestation is comparatively small. The poison is very dilute and is consequently slow in its action. The ants may be seen feeding on it with avidity for several days, apparently without ill-effects. The worker ants visit the tins, carry the poison back to the nests and feed all the larvae and the queens with the substance; after two or three days the ants will die, but probably all that will be noted is the fact that the ants have disappeared. Where there is a heavy infestation, careful observation may show large numbers of dead and dying ants on the ground. It is well to stress the fact that the effectiveness of the bait is largely dependent upon the extreme dilution of the poison, which causes the whole colony to be killed instead of merely the few workers which happen to visit the bait.

By the time this solution was available at Mt. Magnet cold weather had reduced the activities of the ants, which had practically disappeared, but at the commencement of the hot weather later in the year they once more infested the township, and the following letter from the local Postmaster gives a graphic account of the plague and its elimination:—

> "The ants made their usual appearance at the beginning of the hot weather, about the end of October. They first attacked the Postmaster's quarters, where they had been particularly numerous and destructive every summer. I carried out the C.S.I.R. Entomologist's instructions carefully, thoroughly cleansing the tins first, and the results were just as he predicted. After a few days of feeding on the mixture the ants disappeared from that particular section. Others attacked in different portions of the house, including the pantry, kitchen and bathroom, but my wife kept a careful watch and immediately they commenced streaming along in mass formation (as is their habit), she would place a fresh bait directly on their path, and although they would not take the bait immediately they soon got a taste, and then commenced carrying it away to the colony underground somewhere, completely disappearing in three or four days.
>
> "We used a pint and half of the mixture in the quarters before any ants attacked the office portion of the building. One hot day I noticed a stream about ten abreast from the end of the counter to the wet sponge and ink-pot on the counter. I placed a tin with the bait at the point they appeared from between the counter-end and the wall and sprinkled insectibane from there to the sponges and ink-pots, killing all in that section. After an hour or so the ants commenced to stream in and out of the bait tin and for some four weeks, since they have disappeared for days at a time, when another lot would arrive. I found the tin eaten dry and shining clean recently, and refilled it. There are still a few coming and

going to it, but although I have watched carefully, there is no sign of them in any other part of the office.

"Previous summers we used dozens of tins of insectibane and insect sprays and spent hours fighting the pests all over the house and the office. They were very bad in the parcels rack and some parcels became infested with them, in spite of continuous action. Also new canvas verandah blinds in the quarters were covered with dead ants, which we used to sweep off, only to find millions more streaming from all directions. They made a distinct thinning of the canvas like a pathway and numerous small holes. This year, through the action taken by yourself and the careful observance of Dr. Nicholson's instructions, we have been able to keep them off the blinds altogether, and out of the whole building."

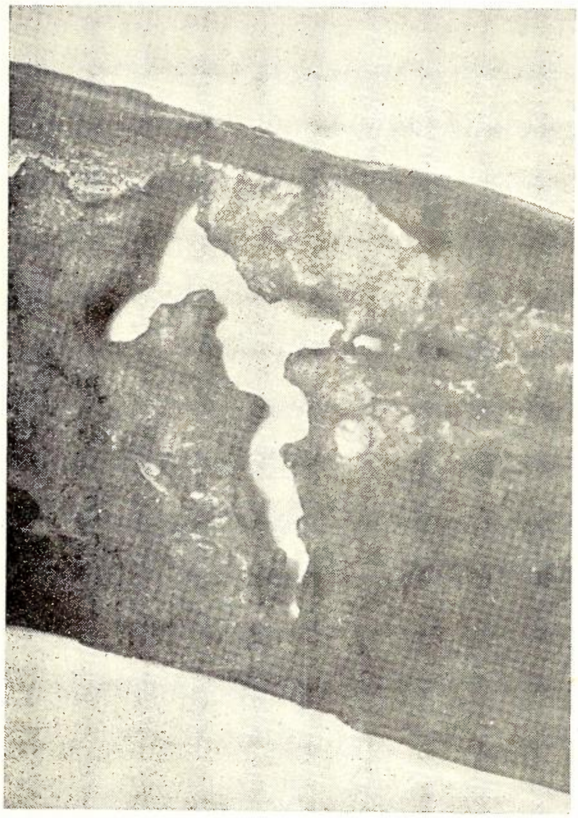


Fig. 2.—Photograph of Damaged Cable Sheathing showing Hole made by Singapore Ants. Magnification 4.5.

A month after this letter was written the most interesting case of damage occurred. A faulty 50-pair P.I.L.C. cable at Mt. Magnet was found to have a hole gnawed through the sheathing and the insulation eaten off several conductors. It was also noted that there were numerous Singapore Ants in the iron pipe containing the cable. When the damaged sheathing (see Figs. 1 and 2) was examined in the Research Laboratories, it was found that the sheathing was unevenly attacked over a length of 1½ inches and over a width of 1 inch. The lead had been cleanly gnawed away and there was no sign of the muddy nest material which termites usually plaster on damaged cable. The marks made by the mandibles of the insects were much smaller than those usually seen on cables damaged by termites, one small hole penetrating the sheathing being only about 1/50th of an inch by 1/100th of an inch, indicating that it was produced by a very small insect. In comparison with this, holes produced by termites are generally 1/16th of an inch or more in diameter. The grooves produced by the insects were exceedingly small, being approximately 1/100th of an inch long and somewhat less than 1/1000th of an inch wide, thus proving that the damage was caused by the Singapore Ant.

Particular interest is attached to the case since there is no previous record of this species of ant causing this type of damage and, in fact, it is only on rare occasions that any damage is attributed to "true" ants as distinct from termites.

With regard to the ant itself, it is a small, very shiny insect, generally less than one-twelfth of an inch in length. Its colour is light honey yellow with the last three segments of the abdomen black or blackish brown. The original home of the insect is supposed to be India, but it has been transported to all the warmer parts of the globe and is becoming a common pest in the coastal towns of Queensland and West Australia, feeding on almost all sorts of animal foods, vegetable foods and sweet stuffs.

A somewhat similar ant—the Pharaos Ant (Monomorium Pharaonis)—is frequently confused with the Singapore Ant. It is the same size, but it is entirely yellow in colour and has not the same shiny appearance. However, it is just as destructive. The poison used to exterminate the Singapore Ant is as mentioned above, equally effective against nearly all true ants. Another similar and very effective poison can be made up as follows:—

> Mix 31 grains of sodium arsenite in two pints of water and stir in two pounds of honey.

This is set out in the same manner as the poison described above. Sometimes it will be found that the ants are not attracted to the sweet bait, in which case a meat extract should be used instead of honey.—C.A.K.

C.B. CORD TYPE P.B.X. WITH THROUGH DIALLING FACILITIES

C. J. Prosser

Some years ago, the introduction of the A.X. relay enabled the supervisory circuit of the C.B. Cord Type P.B.X. to be improved so that a single calling supervisory signal indicated an extended but unanswered call, but two supervisory signals, both answering and calling, indicated a call on which the conversation had been completed and the extension had replaced the receiver on the switch-hook.

With the growth of automatic networks throughout the Commonwealth, the need has arisen for circuit modification to this type of switchboard to permit direct dialling from extension to exchange over the cord circuit. It was realized that such a circuit would have the added advantage that automatic exchange equipment would not be held unnecessarily by the failure of the telephonist to clear the connection promptly on completion of the call.

With these ends in view, the circuits have been revised in the Telephone Equipment Laboratory. The operation is as follows:—

Extension to Extension Call:—When the answering plug of the cord circuit (see Fig. 1) is lifted from its normal position, the operation of the plug seat switch causes both answering and calling supervisory indicators to display. The telephonist inserts an answering plug into the jack of the calling extension line (see Fig. 2), thus feeding battery from the plug seat switch via the answering 120 ohm/120 ohm battery feed retard to the calling extension. The current path includes the AS relay which operates. Contact ASI opens the circuit of the answering supervisory indicator which ceases to display.

By operating the speak key SK, the telephonist connects to the calling extension, ascertains the extension required, inserts the calling plug of the cord circuit into the jack of that extension line and rings on the line by operating the ringing and listening key to the non-locking position shown in the circuit as the RK springs. The calling supervisory indicator continues to display until the called extension answers. When this occurs, the loop provided when the called party lifts the receiver from the switch-hook, allows current to flow from battery at the plug seat switch around the called extension's loop via the calling 120 ohm/120 ohm retard and calling supervisory relay C.S. This relay operates and contact CS1 opens the circuit of the calling supervisory indicator, which now ceases to display.

Thus one supervisory indicator displaying in a cord circuit indicates an uncompleted call.

When the conversation is finished and both extensions replace their receivers, the loop on each side of the cord circuit is opened, and each supervisory relay is de-energised and releases. Contacts AS1 and CS1 then complete the circuit

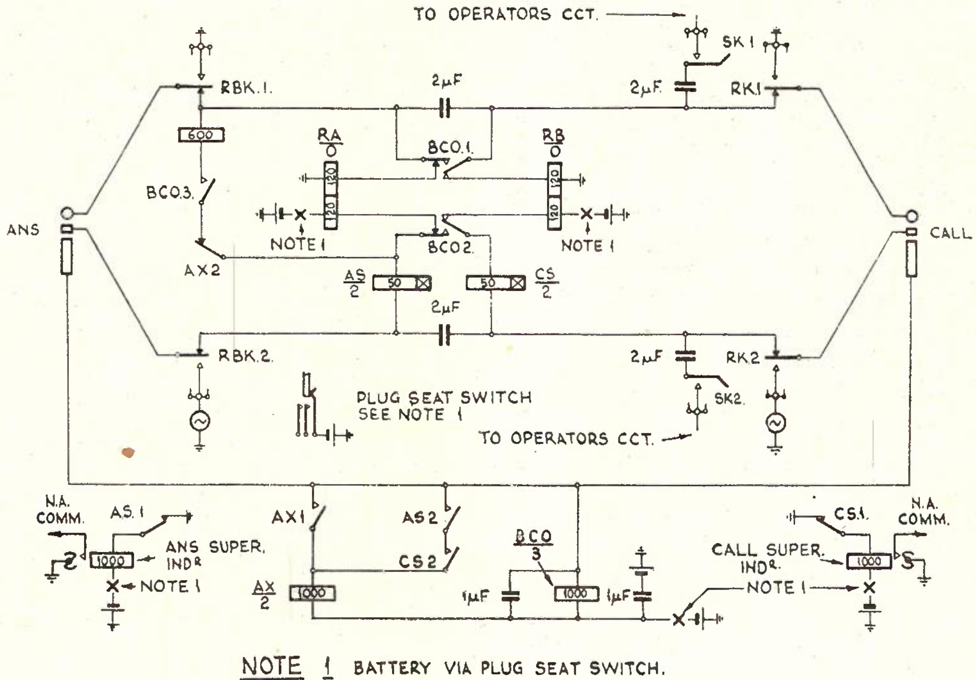


Fig. 1.—Cord Circuit.

of the answering and calling supervisory indicators respectively and both display, indicating a completed call.

Exchange to Extension.—When the telephonist answers a calling exchange line, circuit is provided from earth at the sleeve of the line jack (Fig. 3) via the BCO relay to battery at the

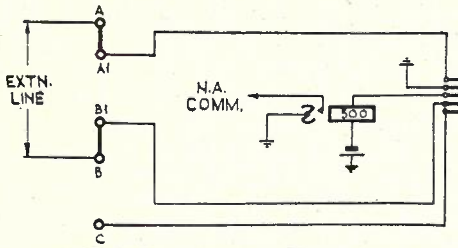


Fig. 2.—Extension Line Circuit.

plug seat switch (Fig. 1), and the BCO relay operates. Contacts BCO1 and BCO2 clear the P.B.X. battery from the cord circuit and extend the calling exchange line via the tip and ring of the cord circuit. Then, by throwing the speaking key, the telephonist can speak to the calling party. Contact BCO3 connects the hold coil in series with relay AS across the cord circuit to trip the ring and hold the connection and current from the exchange then flows over the loop circuit formed by the hold coil and relay AS bridging the cord circuit. Relay AS is thus operated, and contact AS1 opens the circuit of the answering supervisory indicator to prevent

jack of that line and rings. The calling supervisory indicator continues to display.

When the called party answers, the direct current loop established when the receiver is lifted from the telephone allows current to flow from the exchange via the CS relay and called extension party's loop, and relay CS operates. Contact CS1 opens the circuit of the calling supervisory indicator which now ceases to display. Contact CS2 completes the circuit of relay AX which now operates from earthed battery at the plug seat switch via relay AX, contacts AS2 and CS2 to earth. Contact AX1 completes a locking circuit for relay AX to earth at the sleeve of the exchange line jack. Contact AX2 disconnects the hold coil from across the connection as it is no longer necessary, the extension loop now serving to hold the exchange connection.

When the conversation is finished and the called extension replaces the receiver the circuit for direct current from the exchange is opened. Relays AS and CS are de-energised and release. Contacts AS1 and CS1 complete the circuit of the answering and calling supervisory indicators respectively, and as the two supervisory indicators displaying, indicate a finished conversation, the telephonist may then clear the cord circuit. Contacts CS2 and AS2 releasing, open the operating circuit of relay AX which, however, is still held over the locking circuit previously mentioned. When the telephonist re-

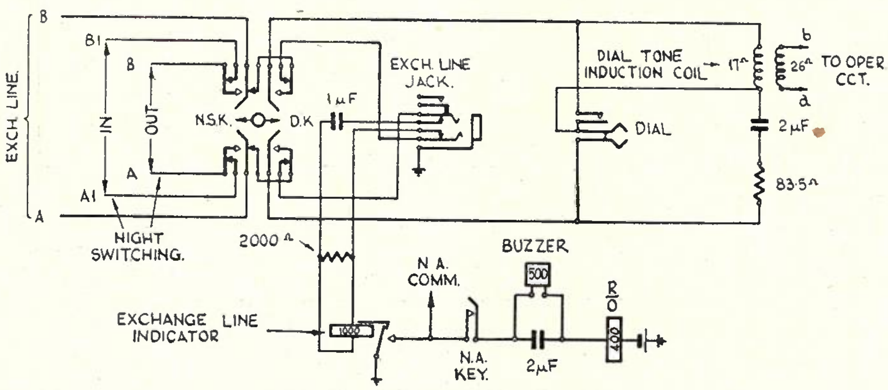


Fig. 3.—Exchange Line Circuit.

that indicator displaying. Contact AS2 prepares the operating circuit of relay AX. The telephonist's set include 2 mF. condensers and thus is open circuit to direct current. Relay CS is therefore unoperated at this stage, and the calling supervisory indicator displays from the time the answering plug is lifted from the plug seat switch.

Thus again, one supervisory indicator only displays during the set up of the desired connection.

The telephonist, having ascertained the desired extension, now inserts the calling plug in the

moves the answering plug from the exchange line jack, and earth is disconnected from the sleeve circuit, relays AX and BCO release to restore the circuit to normal.

Extension to Exchange.—The calling extension is answered just as described for an extension to extension call, the calling supervisory indicator only displaying after the telephonist inserts the answering plug.

Having ascertained that the calling extension desires an exchange call, the telephonist inserts the calling plug into the jack of an exchange line and the extension can proceed to dial, after first listening for dial tone in those areas where that tone is in use. The insertion of the calling plug, connects earth from the sleeve of the exchange line jack to the sleeve circuit, and the BCO relay operates as previously described for an exchange to extension call. The operation of relay AS, when the calling extension was answered, commenced the preparation of the operating circuit of AX. Now the operation of the BCO relay has

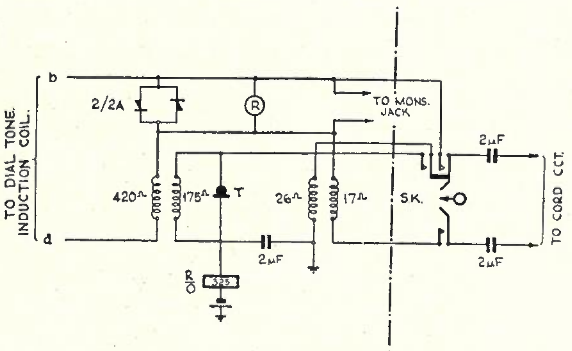


Fig. 4.—Telephonist's Circuit.

extended the loop to the automatic exchange and thus relay CS is operated on current from the exchange, while the same current holds relay AS operated. The operation of CS disconnects earth from the circuit of the calling supervisory indicator which now ceases to display, and contact CS2 completes the circuit of AX which operates and locks as previously described. The operation of the BCO relay connected the hold coil across the cord circuit and this must be disconnected to permit the extension to dial. Contact AX2 achieves this.

When the extension replaces the receiver, the loop for direct current is broken and the exchange line is cleared. The clearing supervision and subsequent restoration of the cord circuit to normal is as previously described for an exchange to extension call.

General Comment.—The following special features are of interest:—

(i) The two 2 mF. condensers in the cord circuit (Fig. 1) associated with the listening key are provided to prevent electrical coupling between cord circuits when two or more keys are thrown together. A 1 mF. condenser across each BCO relay is provided to absorb the inductive kick from the relay when a connection is being taken down, and to prevent shocks being received from the sleeve of the plug. The contacts of the plug seat switches are protected by a 1 mF. condenser in each cord circuit.

(ii) Referring to Fig. 3, the purpose of the 2000 ohm N.I.R. across the exchange line indicator, is to prevent the indicator flicking down on the withdrawal of a plug from the line jack. A dialling key is provided per exchange line to enable the telephonist to make exchange calls. The telephonist can supervise the call during the progress of dialling by means of the 17 + 26 ohm induction coil which is coupled to the telephonist's circuit, the 17 ohm winding being short circuited during impulsing. For each exchange line, a night switching key is provided.

(iii) The connections of the induction coil in the telephonist's circuit (Fig. 4) have been transposed so that the 26 ohm winding is used as the primary coil. This alteration has been made to improve transmission. No transformer cut-out key is provided, as telephonist's telephones and handsets used with these P.B.X.'s are equipped with No. 10 or No. 13 insets and

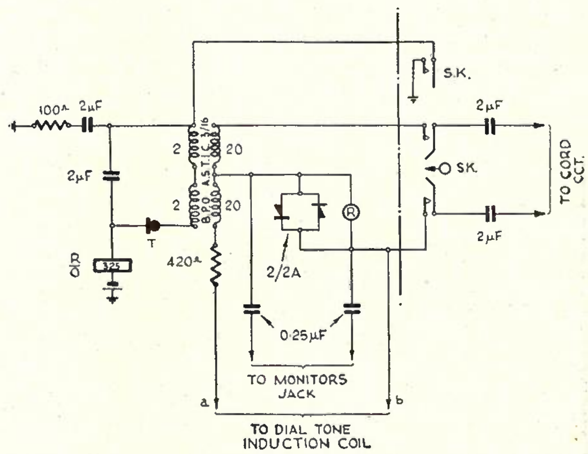


Fig. 5.—Alternative Telephonist's Circuit.

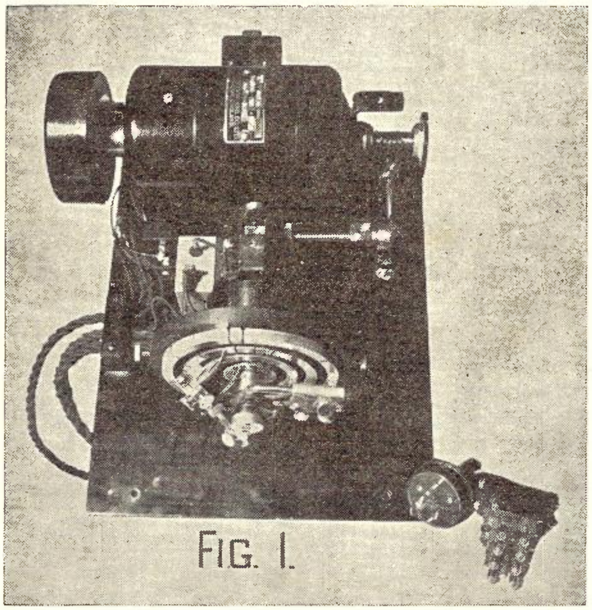
the anti-sidetone transformer is required to be permanently in circuit. A metal rectifier 2/2A has been included in the telephonist's circuit as a shock absorber to eliminate clicks when the dial restores to normal after each digit. An alternative telephonist's circuit using the B.P.O. telephonist's induction coil 3/16 is shown in Fig. 5.

A Teleprinter System With Tape Transmission

E. J. G. Bowden, V.D.

The phenomenal growth of Darwin and the increasing importance of the Northern Territory in recent months has made it imperative to make the greatest possible use of the two telegraph circuits between Adelaide and Darwin. Each line consists of a single conductor approximately 2,000 miles in length, Line No. 40 being of 265 lb. copper, and Line No. 2 of 400 lb. G.I. A duplex teleprinter circuit has been operated for some considerable time over the copper line, while the iron line is worked as a hand speed duplex morse circuit. As the copper line is required for considerable periods each day for Cable Company's traffic, and there is very heavy departmental traffic between Adelaide and Darwin, the need for making full use of the line will be apparent.

As a teleprinter transmits to the distant end, signals which are set up by the operator on a manual keyboard similar to that of a typewriter, the speed of transmission depends on the skill of the operator. It is limited mechanically only by the maximum speed of the apparatus, which is normally 400 characters (66 words) per minute.



The speed of transmission may, therefore, be anything between zero and 66 words per minute. Obviously no operator, however skilful, can manipulate the keyboard to transmit the full 400 characters each and every minute, and, in practice, speeds much less than this are the rule. The speed of transmission is further reduced by such factors as badly written telegrams, and the necessity for the operator to handle, initial, and time the messages.

On the suggestion of a Senior Traffic Inspector means were sought by the Engineering Branch, a few weeks prior to Christmas, 1940, to adapt the Adelaide-Darwin Teleprinter system for "Tape" transmission. In such a system the messages are punched up by one or more operators by keyboard perforators on a tape which is then fed through a tape transmitter at the maximum speed of the teleprinter system (normally 400 characters per minute). Thus while the tapes may be punched up in comparative leisure,

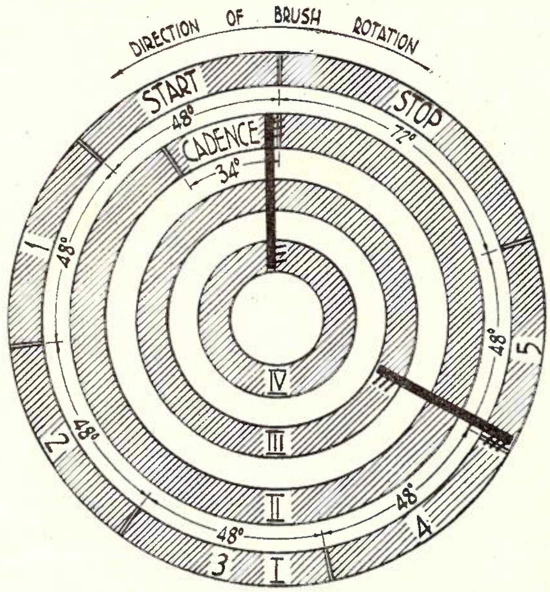


Fig. 2.

the transmission from one end of the circuit to the other is effected at the maximum speed of the apparatus with consequent saving in line time. There are no pauses except when changing from one spool of tape to another.

The primary consideration was the design of a "Plateau" using standard Murray Multiplex brush arms and brushes revolving at approximately 400 r.p.m. The device eventually adopted, and affectionately (or otherwise) known to the staff as "the Whizzer," is shown in Fig. 1. It is operated by a standard teleprinter motor, and the brush arms are driven through standard teleprinter gearing, thus ensuring that spare parts for the mechanism are available. Fig. 2 indicates the arrangement and layout of the plateau as adopted after experiment. Ring 1 simulates the normal signals sent out by a teleprinter, and is arranged so that it can be rotated or "oriented" with respect to the remainder of the plateau. The thumb screws for locking this ring in position can be seen in Fig. 1. Ring 1 is linked by one of the brush arms with ring 3, while ring 2 is for the sole purpose of operating the tape transmitter cadence magnet, and is linked by the brushes with ring 4. Fig. 1 shows the "stop" segment on ring 1 divided into two parts, and there are several extra segments on ring 2 close to the "cadence" segment. These are not shown in the drawings, and were provided on the plateau only in case it became necessary to vary the length of the "stop," "start" or "cadence" segments respectively during trials. The plateau "North Australia Telegraph Services," by H. Hawke, in Vol. 2, No. 4, page 251.

The operation of Switch "B" (Fig. 3) permits either tape transmission or manual operation of the teleprinters. In either method the "Home Record," i.e., the record of the message transmitted, is available, if desired, on the sending teleprinter. When the "Home Record" is not required, switch "C" is operated, and this applies a holding battery which precludes any possibility of chattering or "chaff cutting" in the "Home Record" mechanism.

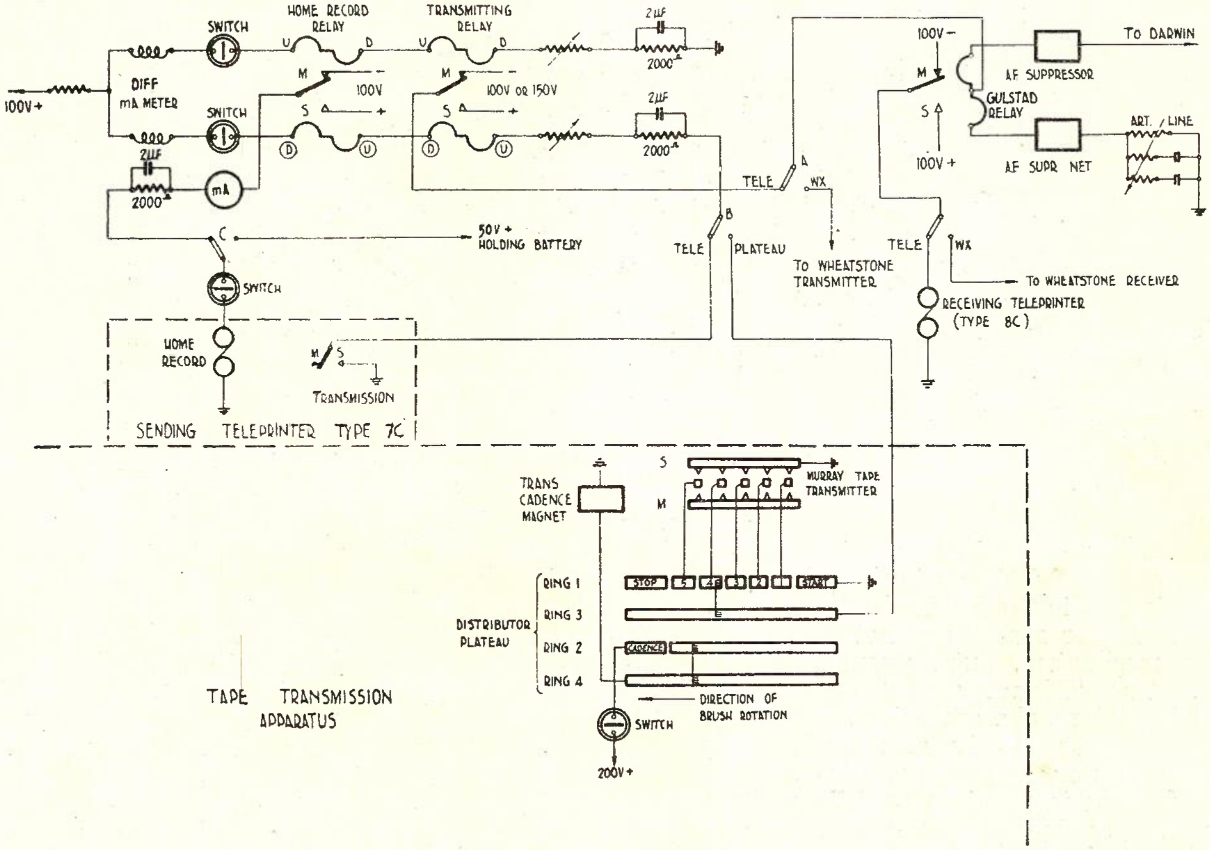


Fig. 3.

arrangement shown in Fig. 2 has, however, proved entirely satisfactory on the difficult Adelaide-Darwin circuit, and should therefore meet the requirements of any other circuit.

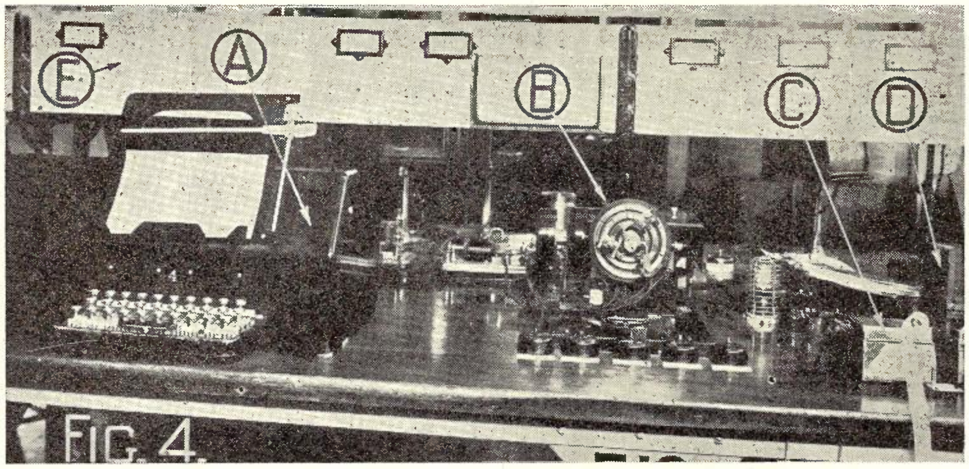
Fig. 2 also indicates the relative position or "orientation" found most suitable for ring 1 with respect to the "Cadence" impulse. This impulse steps forward the tape in the transmitter, and operates the transmitter contacts in accordance with the perforations in the tape, and must be timed very carefully.

Fig. 3 shows the schematic circuit in use at the Adelaide end. Details of the Wheatstone and other apparatus not relevant to teleprinter operation have been omitted. The arrangement at Darwin is similar in principle. Further details of the Adelaide-Darwin circuits, and the normal apparatus thereon are contained in an article,

Referring again to Fig. 1, which shows the apparatus with the protective cover removed from the gearing, the brush on ring 2 is shown resting on the "cadence" segment. The condenser at the rear of the plateau is portion of the spark quench circuit. As the motor is driven from the commercial power supply a 3-pin power plug is provided. The 8-point instrument plug shown provides for all other external connections.

Fig. 4 shows the complete sending end of the circuit at Adelaide, and the following items can be distinguished:—(A) The 7C sending teleprinter; (B) the plateau unit, with controlling switches in front; (C) the Murray tape transmitter; (D) (partly seen only) the Murray perforator; and (E) the message conveyor belt housing, which passes down the centre of each table. The 8C receiving teleprinter, the normal line apparatus are mounted on adjacent positions.

Fig. 5 indicates the alterations necessary to the keyboard of the standard Murray perforators to operate with this system. These changes are necessary owing to differences in the signals transmitted to effect the various mechanical functions on Murray and teleprinter systems respectively. It is indeed fortunate that Murray perforators could be adapted for use in this system with no other alteration than the changing of certain key signs.



Apart from the key marking changes indicated, the chief difficulty in punching for the new device is that in the Murray system the operation of the "Letter space" key not only operates the letter mechanism, but transmits a "space" as well. The "Figure space" operates similarly. On teleprinters, the operation of the "Letter" or "Figure" keys merely sets the mechanism to print letters or figures as required.

If a space is required to follow, the "Space" key must be depressed. Operators with a little practice find no difficulty in punching suitable tape on the altered perforators.

With this system it has been found desirable to dispense with any automatic stopping device such as the tape automatic start-stop lever on the Murray transmitter. Instead, the operator simultaneously operates by hand the tape lever on the transmitter as well as switch "B" (Fig. 3) to control the starting and stopping of transmission. As the brushes are revolving continuously, the "Start" impulse is sent out each revolution from ring 3 unless cut off at switch "B." An automatic device operated by the tape lever on the transmitter could be provided to effect this cut-off. This would involve setting aside from the Murray Multiplex circuits special transmitters for the tape operated teleprinter circuit, and the lack of spares available makes this impracticable.

Some notes regarding the lining up and maintenance of this apparatus may be of interest. In the first place, correct speed is vital to satisfactory operation. The main difficulty in this regard was overcome by the use of standard teleprinter motors and governors. The standard speed for teleprinter motors is 3000 r.p.m. and all motors of teleprinters, including those used on the system under discussion, are adjusted to this speed. To ensure satisfactory operation with such teleprinters, it has been found necessary to adjust the plateau motor (Fig. 1) to 2730 r.p.m. This gives a brush arm speed of 390 r.p.m. and

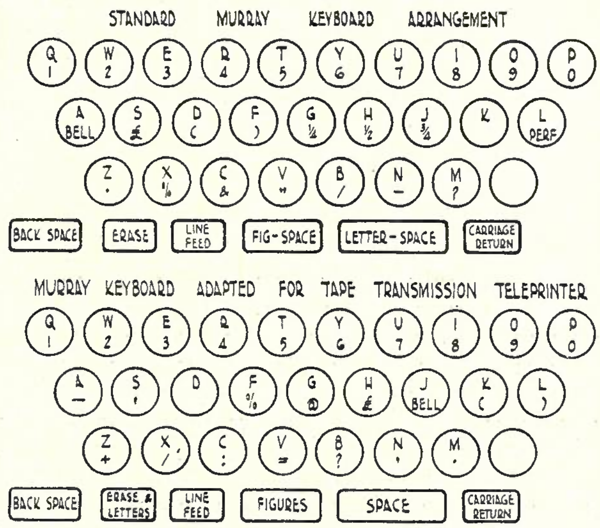


Fig. 5.

the transmission speed of the system is, therefore, 390 characters (65 words) per minute.

A check of the speed is instantly available at any time by observing the "Home Record." A further check is provided by opening the line and observing the transmission on the "Home Record" and on the receiving 8C teleprinter simultaneously.

After the Adelaide-Darwin circuit has been lined up each morning in the usual way, and Wheatstone and Manual teleprinter operation proved out, trial tapes are exchanged between Adelaide and Darwin. All facilities are then available as required.

The apparatus has now been in use for several months and has so far given no trouble, in spite of the fact that the tape transmitters are operating at 390 letters per minute instead of at the normal Murray Multiplex speed of 270 letters per minute, and the teleprinters at much higher average speeds than when manually operated. Special care has been given to the maintenance of the transmitters and teleprinters. Any extra wear on the receiving teleprinters, due to increased speed, is more than offset by the fact that the sending teleprinter is scarcely used, even a "Home Record" being rarely required.

The system would appear to be extremely useful on any heavily worked teleprinter circuit where multiplex apparatus would not be justified, or could not for other reasons be provided.

As a tribute to the telegraph mechanical staff it may not be out of place to mention that the first model of the device described above was working on the test bench within 24 hours of the decision to make the experiment. The earlier models which were driven by ordinary D.C. motors, without governors, were unsatisfactory, due to speed variations. The use of a standard teleprinter motor with its centrifugal governor has completely overcome the speed trouble, and the apparatus now requires only normal attention after it is run-in each morning. It has solved a serious problem on a difficult and extremely busy circuit.

AERIAL LINE CONSTRUCTION—PART II.

A. S. Bundle

This part deals with:—
- (a) Strength of Poles.
- (b) Steel Poles.
- (c) Economics of Pole Provision.
- (d) Erection of Poles.

STRENGTH OF POLES

Types of Loading.—To study the strength of poles, it is necessary first to consider the loads to which they may be subjected. Broadly, these may be set out as:

(1) Wire loading due to the horizontal pull of wires at terminations and angles.

In practice it is usual to counteract these loads with stays, so that ordinarily they may be omitted from calculation of pole strength.

(2) Wind pressure on wires and pole.

This loading is greatest when the wind is blowing across the line of the route, and is counteracted principally by the poles themselves. Stays are sometimes provided for additional support on important routes. Their provision results from the adoption of a standard type of pole and a standard depth of pole setting: under severe conditions the additional support of stays is necessary.

(3) Downward Loads due to:
- (a) Weight of wires and fittings;
- (b) downward force of line wires on poles higher than those adjacent;
- (c) vertical component of the force applied to the pole by a ground stay when counteracting horizontal loads.

If as a result of a heavy downward load a pole bows in the middle it is said to buckle, and if the load continues to be applied the pole will collapse.

It is necessary to consider this buckling effect only where the length of the pole is great in proportion to the thickness. As poles usually have adequate section in order to resist the applied bending moment, troubles due to buckling are not frequent. They occur mainly in cases of light steel poles fitted with ground stays; the tendency of such a pole to buckle because of its lightness is aggravated by the downward thrust exerted by the stay when counteracting a horizontal force.

(4) Miscellaneous Loads such as:
- (a) Swaying action of wind.
- (b) Minor collisions with animals, vehicles, etc.
- (c) Movement of and weight of workmen up pole.
- (d) Pressure of ladder against pole.

These factors are difficult to calculate in association with the loads set out under the previous headings and are usually covered by a factor of safety.

Factor of Safety.—Factor of safety is the factor by which the calculated loading is multiplied in order to determine the actual loading which a pole (or other fitting or structure) is to be designed to withstand. Thus, a pole designed with a factor of safety of 4 will be 4 times as strong as is necessary to withstand the calculated loading.

Poles should always have a factor of safety in excess of 3, as this is the factor of safety of the line wires and it is important to ensure that the poles are stronger than the wires.

For timber, a minimum factor of safety of 5 is usually recommended because of the irregularity in fibre strength and the possible presence of splits, cracks, gum veins and decay pockets.

The resistance of the timber will depend on the nature of the loading. For occasional momentary loads, such as wind gusts, the fibre strength is 3 times that under long-continued loads of the order of 10 years' duration.

With mild steel it is necessary to consider the elastic limit, which practically coincides with the stage where permanent set occurs. As it is desirable to avoid loading to this stage, a factor of safety of 2 on the elastic limit is desirable and as the elastic limit is approximately half the ultimate strength, the usually accepted factor of safety for structural work is 4 when based on the ultimate strength.

Resultant Force.—The effect of the forces acting at the head of a pole due to the combined effects of wind pressure and wire tension on all the wires may be represented by a single force F_r (termed the resultant force) acting at a point about midway between the top and bottom arms, its magnitude being equal to the algebraic sum of the forces.

For accuracy, the height (H_r) of the resultant point above ground level, may be calculated from:

$$H_r = (F_{a1}.H_{a1} + F_{a2}.H_{a2} + F_{a3}.H_{a3} + \ldots + F_{an}.H_{an} \div (F_{a1} + F_{a2} + F_{a3} + \ldots + F_{an} \quad (1)$$

Where: F_{a1}, F_{a2}, F_{a3} and H_{a1}, H_{a2}, H_{a3}, etc., are respectively the forces acting at arm 1, arm 2, etc., and heights above ground level of the various arms.

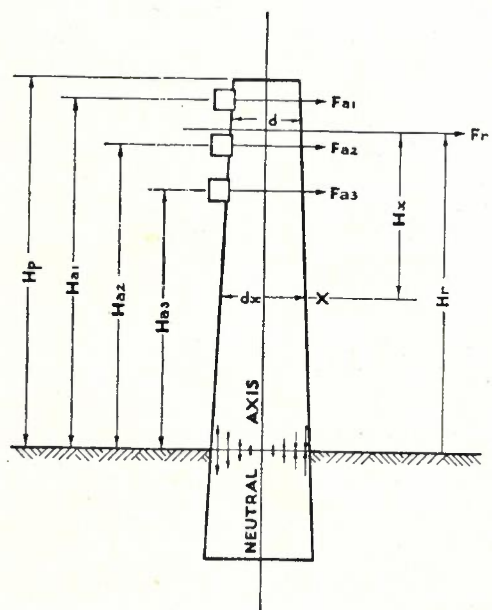


Fig. 11.

Pull of Wires.—The pull of wires on a terminal pole comprises the total tension of all the wires.

For strength calculations it is necessary to allow for the maximum wire tension to be expected; this will occur at low temperatures. It is also necessary to have regard for development and to allow for the maximum number and weight of wires and fittings to be carried.

The pull of wires on an angle is given by:

$$P_a = 2\ T \cos \theta/2 \quad (2)$$

where P_a = pull of wires, in lbs.
T = maximum aggregate tension (in lbs.) of all the wires being considered.
θ = angle subtended by the wires.

If the "Angle Depth" (D_a) is measured as shown in Fig. 12 then:

$$P_a = T\ D_a \div 50 \quad (3)$$

Vertical wire loading caused by vertical angles in the wires, mentioned in para. (3) (b) above, may be calculated in a similar manner.

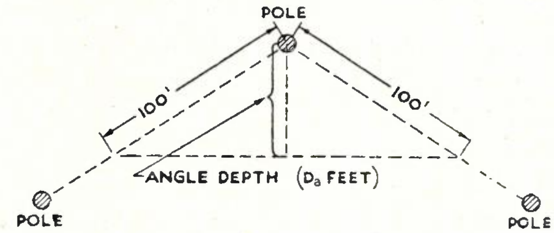


Fig. 12.

Wind Pressure.—The pressure of the wind on a cylindrical body is calculated from the formula:

$$P_w = K\ V^2\ A \quad (4)$$

when P_w = wind pressure, in lbs. per sq. ft.
K = a coefficient determined by experiment
V = velocity of wind in miles per hour
A = projected area of surface exposed to the wind, in square feet.

For wires and thin poles up to 3" diam., the value of K may be taken as 0.003 for practical purposes. For poles of larger diameter its value varies appreciably as shown by the graph in Fig. 13. As the pressure is only important at the higher wind velocities, a figure of 0.001 for K should be accurate enough for practical purposes.

It is necessary to allow for the maximum wind velocities likely to be experienced: in normal conditions, 70 m.p.h. is a reasonable figure and 80 m.p.h. for exposed localities. In sheltered localities, the figure could be reduced to 60 m.p.h.

(It is worthy of note that the wind velocity varies appreciably with height above ground: at 32' it is roughly twice that at 2' on open grass land.)

The load on a pole due to wind pressure on the wires may, for practical purposes, be calculated as a horizontal force of magnitude KV^2A_w (where A_w is the projected area for 1 span of all the wires to be carried), acting through the resultant point of the pull of the wires, i.e., at a height H_r.

The load due to wind pressure on a pole may, for practical purposes, be calculated as a horizontal force of magnitude KV^2A_p (where

A_p is the projected area of the pole), acting through a point midway between the ground level and the top of the pole. Thus its moment

$$M_w = KV^2 A_p \times \tfrac{1}{2}H_p \quad \ldots\ldots \quad (5)$$

where H_p = the height of the pole above ground level.
This may be written $\tfrac{1}{2}KV^2 A_p \times H_p$ ...... (6)
Or, in other words, the wind load is equivalent

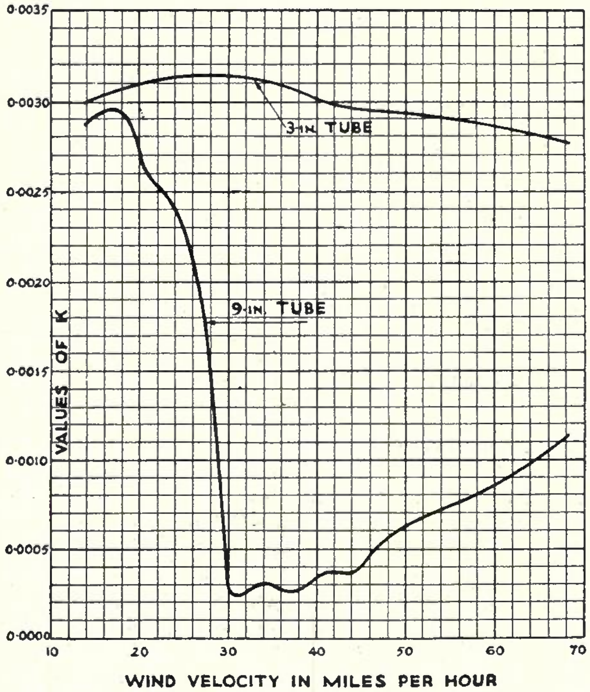


Fig. 13.—Resistance of Tubes in Wind.

to a force equal to half the wind pressure on the pole, acting at the top of the pole.

As demonstrated in an example given later on wood poles, this moment is usually much less than that due to wind pressure on the wires and it is usually accurate enough to regard it as acting through the resultant point. The wind loading (F_w) is then calculated as:

$$F_w = K\ V^2\ (A_w + \frac{A_p}{2}) \quad \ldots\ldots \quad (7)$$

Horizontal and Vertical Loading.—The various loads on a pole may, for most practical purposes, be calculated and grouped under two headings:

(a) Horizontal loads acting at or near the pole top;

(b) vertical loads along the pole.

Horizontal loads exert a bending moment (B.M.) on the pole which acts as a cantilever.

Vertical loads have a buckling effect, and may also influence slightly the resistance to bending where the material of which the pole is constructed has lower compressive strength than tensile strength (e.g., wood). That this effect is not serious is shown in an example on wood poles given later.

Cantilever Formula. — The combined stresses exert a bending moment which is greatest at or near the ground level. The actual point depends on the nature of the foundation; if the pole is set in a rigid foundation, such as concrete, the maximum B.M. will be at ground level, but if in light soil it will be rather lower. For practical calculation ground level may be assumed as the point of maximum B.M.

The resistance of the pole against this B.M. depends upon—

(a) The shape and area of the pole section, and

(b) the strength of the material in the pole.

On a pole with a symmetrical section there will be no stress on a plane (termed the neutral axis) passing through the centre. There will, however, be a tensile stress on one side of the neutral axis and a compressive stress on the other side, and these stresses increase from zero at the neutral axis to a maximum at the edge. This effect is indicated in Fig. 11. The strength of the pole will depend upon the ability of the material in the pole to withstand the stresses where they are greatest, i.e., at the extreme edge.

This is expressed more precisely by the equation:

$$F \times H = f \times Z \quad \ldots\ldots \quad (8)$$

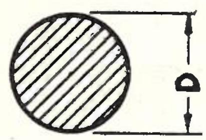
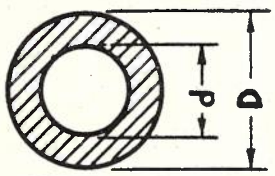
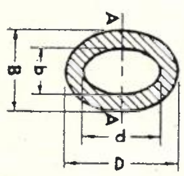
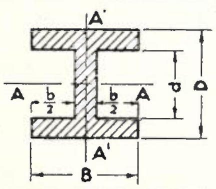
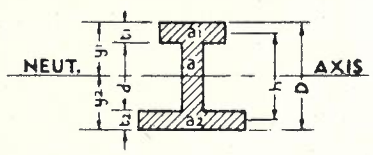
where F = the force applied.
H = the distance from the point of application of F to the point at which the stress is considered.
Z = the Section Modulus, i.e., an expression which takes account of the shape and area of the section—see Table 2.
f = the Modulus of Rupture, i.e., the breaking stress of the fibres—obtained by testing samples to destruction—see Table 3.

It will be noted from examination of the section moduli in Table 2 how important is the overall width of the pole, e.g., in the case of the circular section the strength will vary as the cube of the diameter.

Tapered Poles.—The B.M. is greatest at the ground line and decreases to zero near the pole top; and it follows, therefore, that the most efficient form of pole is one that is stronger at the ground line and tapers steadily to a minimum at the top arm.

If a pole were of uniform diameter throughout, the stress (i.e., force per unit area) would be greatest where the B.M. is greatest, i.e., at ground level. However, in a tapered pole, the area is less above ground level and so the stress may be greater and the pole break above the ground. Thus, it is advisable to ascertain what

TABLE II.—SECTION DATA FOR VARIOUS POLE SECTIONS

Shape of Section	Area of Section (A)	Moment of Inertia of Section (I)	Modulus of Section (Z)
	$\frac{\pi}{4} D^2$ $= 0.7854 D^2$	$\frac{\pi}{64} D^4$ $= 0.0491 D^4$	$\frac{\pi}{32} D^3 = 0.0982 D^3$
	$\frac{\pi}{4} (D^2 - d^2)$	$\frac{\pi}{64} (D^4 - d^4)$	$\frac{\pi}{32} \left(\frac{D^4 - d^4}{D}\right)$
	$\frac{\pi}{4} (BD - bd)$ (See Note 1.)	$\frac{\pi}{64} (BD^3 - bd^3)$ (See Note 1.)	$\frac{\pi}{32} \left(\frac{BD^3 - bd^3}{D}\right)$ (See Note 1.)
	DB — db	$\frac{1}{12} (BD^3 - bd^3)$	About A — A: $= \frac{BD^3 - bd^3}{6D}$ About A^1 — A^1: $= \frac{(D - d)\,B^3 + d\,(B - b)^3}{6B}$ (See Note 2.)
 a_1 = Area of top flange a_2 = ,, ,, bottom flange a = ,, ,, web $y_1 = \frac{a_2(2D - t_2) + a_1t_1 + a(d + 2t_1)}{2A}$ $y_2 = \frac{a_1(2D - t_1) + a_2t_2 + a(d + 2t_2)}{2A}$	$a + a_1 + a_2$	$\frac{a_1t_1^2 + a_2t_2^2 + ad^2}{12} +$ $\frac{a_1a_2(D + d)^2 + a_1a(t_1 + d)^2}{4A}$ $+ \frac{a_2a(t_2 + d)^2}{4A}$	$Z_1 = \frac{I}{y_1}$ $Z_2 = \frac{I}{y_2}$ (See Note 3.)

Note 1.

These apply to bending about the axis A — A.

Note 2.

Section Moduli for the sections of commonly used R.S.J.'s are as follows:—

About A — A:

6″ × 5″ = 15.054	4″ × 3″ = 3.893	7″ × 3½″ = 10.258
6″ × 3″ = 6.996	8″ × 6″ = 28.764	12″ × 5″ = 34.488

About A^1 — A^1:

6″ × 5″ = 3.951	4″ × 3″ = 0.884	7″ × 3½″ = 1.376
6″ × 3″ = 0.974	8″ × 6″ = 6.513	12″ × 5″ = 3.508

Note 3.

The exact calculation of the Section Modulus is very tedious. A rough approximation is to take the least Section Modulus as h x a_1 (or a_2, whichever is least).

For convenience, the least Section Moduli for forces along the web on Australian Standard Single-headed rails are given (in inch-cube units):—

Rail	Z	Rail	Z
110 lbs.	17.89	60 lbs.	7.16
107 ,,	16.57	45 ,,	4.21
100 ,,	16.3	30 ,,	2.25
90 ,,	13.04	20 ,,	1.35
80 ,,	11.21		

are the limits to the taper; a circular section is taken to demonstrate the procedure.

From equation (8) it follows that the stress at any point X along a pole of uniform circular cross-section due to a force F is given by the expression:

$$f = \frac{384F}{\pi d_x^3} \times H_x \quad \ldots \ldots \quad (9)$$

Where: H_x = the distance from the point X to the point of application of F in feet

d_x = the diameter of the pole at X in inches (It is usual to measure the height of a pole in feet and the diameter in inches).

If d = the diameter of the pole (in inches) at the point of application of F,

and t = the taper of the pole in inches per foot of pole.

$$\text{then } d_x - d = H_x . t \text{ or } H_x = \frac{(d_x - d)}{t} \quad \ldots \ldots \quad (10)$$

substituting for H_x in (9) we get—

$$f = \frac{384F}{\pi d_x^3} \times \frac{d_x - d}{t.} \quad \ldots \ldots \quad (11)$$

Differentiating this expression and equating to zero to find the maximum value, we find f is a maximum where $d_x = 3d/2$. That is to say, the greatest stress on a tapered pole of circular cross-section is at the point where the diameter is $1\frac{1}{2}$ times that at the point of application of the load.

Hence, the design of such a pole should ensure that it has adequate strength at the ground line and the taper such that the diameter at the

TABLE 3—STRENGTH OF MATERIAL USED IN POLES

Material	Ultimate Tensile Stress		Ultimate Compressive Stress		Shear Stress		Modulus of Elasticity	
	lbs. per square in.		lbs. per square in.		lbs. per square in.		lbs. per square in.	
Cast Iron	20,000		90,000		3,000		17,000,000	
Wrought Iron	55,000		55,000		11,000		29,000,000	
Mild Steel	70,000		70,000		14,000		30,000,000	
Cast Steel, Forged Steel	80,000		80,000		66,000			
Timber—	**Green**	**Seasoned**	**Green**	**Seasoned**	**Green**	**Seasoned**	**Green**	**Seasoned**
Grey Gum, Grey Box, Ironbark (Grey or Red), Wandoo	15,000	24,000	7,500	12,000	2,000	2,500	2,400,000	3,000,000
Silvertop Ash, Blackbutt, Bloodwood, Brush Box, Yellow Box, Red Box, Forest Red Gum, Blue Gum, Yellow Gum, Karri, Mahogany (Red or White), Stringybark (Red, Brown, White, Yellow), Tallowood, Turpentine	12,000	20,000	6,000	10,000	1,500	1,900	2,100,000	2,600,000
Mountain Ash, Jarrah, Messmate	10,000	16,000	5,000	8,000	1,200	1,600	1,700,000	2,200,000
Oregon, River Red Gum, Pine	7,000	12,000	3,500	6,000	800	1,100	1,500,000	1,900,000

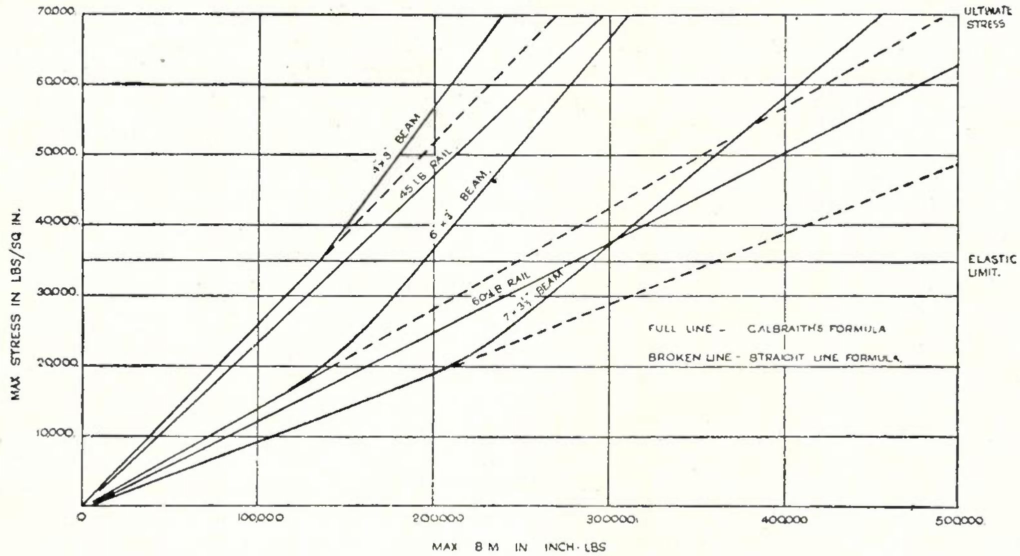
point of application of the load is not less than 2/3 the diameter at the ground line.

Poles with Unequal Axes.—The load on a telephone pole is usually greater across the line of the route than it is along the route, both because the effect of wind pressure on the wires is greatest at right angles to the route, and because the line wires usually support the pole along the line of the route. At angles, the resultant effect of wire tension and wind pressure is along the line bisecting the angle. Thus, for efficiency, most telephone poles should be stronger across the line of the route than along it.

Formula (8) is applicable to the resistance of the pole to loads across the line of the route, but there are two factors which limit the strength of the pole along the line of the route: these are buckling and twisting.

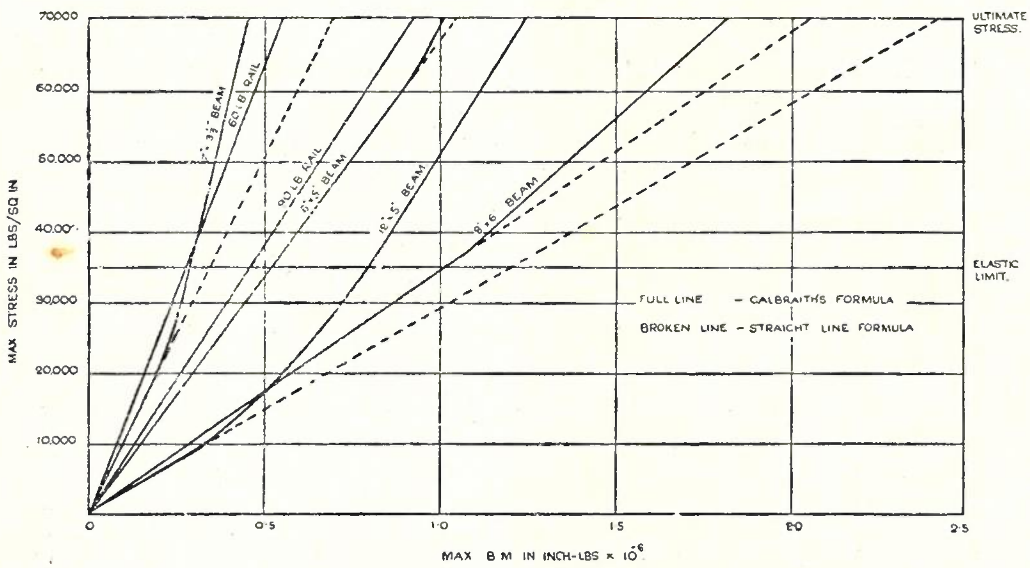
Buckling is emphasised frequently by the fact that in most poles the arm is attached to the side of the pole, or at least, in such a manner that the weight is not applied through the centre of the pole (i.e., to say the load is eccentric).

If the section axes are unequal and a load is applied along the greater axis, there is a tendency for the pole to twist round and bend along the minor axis. With the conditions existing on a pole route, it has been calculated that in the case of beams the resistance along the major



CHARACTERISTIC CURVES OF R S J's & RAILS WHEN USED AS POLES (NORMAL ECCENTRICITY)

Fig. 14.



CHARACTERISTIC CURVES OF R S J's & RAILS WHEN USED AS POLES (NORMAL ECCENTRICITY)

Fig. 15.

axis is not appreciably affected unless the section modulus along the minor axis is less than 1/4 of the section modulus along the major axis. By reference to Table 2, it will be seen that a 6″ x 5″ "I" beam is not affected, but with a 7″ x 3½″ "I" beam this effect has to be taken into account.

This effect was studied by the late L. Galbraith, of Melbourne University, who evolved a formula which made allowance for the twisting effect under the normal conditions by which a pole is loaded, and at the same time is partially supported against twisting, by the line wires. The calculated stress on commonly used sections of rolled steel joists and rails compared with the ordinary cantilever formula (9) is shown on Figs. 14-15. These figures have been fairly closely supported by experimental tests in the case of the beams, but appear rather low for rails. It is possible that the elastic limit of the steel in the rails tested was higher than that of the beams.

Load of Ground Stay. — The downward load (W_d) on a stayed pole due to the combined horizontal force and the tension in the stay wire:

$$= F \times H_s \div S_s$$

where F = the horizontal force

S_s = the spread of the stay (i.e., the horizontal distance from the centre of the pole to the point where the stay enters the ground)

H_s = the height of the stay (i.e., the vertical distance between the point of attachment of the stay and the point where the stay enters the ground).

Calculation of Buckling.—The downward load (W_b) which, when applied centrally, will buckle a pole, may be found from the expression:

$$W_b = 2.\ \pi^2\ E.I. \div H_r^2 \quad \ldots\ldots \quad (12)$$

Where: E = modulus of elasticity of the material in the pole (see Table 3)

I = least moment of inertia of the pole section (see Table 2)

H_r = length of pole in inches from ground level to the point of application of the load.

The safe central loading of the pole (W_s) is given by:

$$W_s = W_b \div S \quad \ldots\ldots \quad (13)$$

Where: S = factor of safety.

The buckling tendency is emphasised if, as is usual, the arm is mounted toward the outside of the pole: in other words, if the load is eccentric. In such a case, the equivalent central load can be found from the expression:

$$W_c = W\left(1 + \frac{e\,A}{Z}\right) \quad \ldots\ldots \quad (14)$$

Where:

W_c = the equivalent central load, in lbs.

W = the eccentric load, in lbs.

e = the eccentricity (i.e., distance in inches between centre of pole and centre of arm).

A = area of section, in square inches.

Z = section modulus along the axis in which the eccentric load tends to bend the pole.

In the case of a pole fitted with a ground stay, it may, for practical purposes, be assumed that the resultant downward force from the stay (W_d) is applied centrally. Thus the total loading on the pole is $W_c + W_d$ and this must not exceed W_s.

Consider the case of a 7″ x 3½″ beam pole 30′ long to carry 24/200 lbs. H.D.C. wires at an angle in the route which measures 160°; a ground stay is attached at an angle of 45°.

E = 30,000,000
I = 2.4
A = 4.4 sq. inches
Z = 1.376
H_r = 30′ — 5′ — 1.5′ (about)=23.5 feet=282 inches.
S = 4
W = 420 lbs.
W_d = 2800 lbs. under maximum conditions of wire tension and wind loading.
e = 1.75″ + 1.5″ = 3.25″

First find the safe central loading from (12) and (13) and then the total equivalent central loading applied.

From (12) and (13)—

$$W_s = 2\ \pi^2 E.I \div H_r^2\ S \text{ lbs.}$$
$$= 2 \times 9.86 \times 30{,}000{,}000 \times 2.4 \div (282^2 \times 4) \text{ lbs.}$$
$$= 4465 \text{ lbs. (approximately).}$$

From (14)—

$$W_c = 420 \times \left(1 + \frac{3.25 \times 4.4}{1.376}\right) \text{ lbs.}$$
$$= 420 \times 11.4 \text{ lbs.}$$
$$= 4788 \text{ lbs.}$$

As W_d is given as 2800 lbs. it follows that the total equivalent central loading ($W_c + W_d$) = 4788 + 2800 = 7588 lbs.

This exceeds the safe central load (W_s) and hence the pole under severe conditions would be overloaded and liable to buckle.

Example on the Strength of Wood Poles.—It is interesting to study a typical wooden pole. As explained in Part 1 of these notes, decay at the ground line is the commonest cause of failure and so the problem is to provide a pole, and if necessary treat it, so that there will be sufficient undecayed wood at the ground line to give it adequate strength after a reasonable period of years.

A useful example is to ascertain the minimum effective diameter of sound wood required for safety in a 24′ Ironbark pole 4′ in the ground, the resultant point for the wire loading being 2′ from the top; the pole is carrying, say, six 200 lbs. H.D.C. wires and sixteen 40 lbs. cadmium copper wires in a locality where the maximum wind velocity recorded is 70 m.p.h. (A standard pole would be 11″ at the ground line and 8″ at the top.)

The pole is required to support the wind pressure on the wires for half a span on each side of it. From equation (4) it follows that the B.M. at ground level due to this pressure:

$$= H_r \times K.V^2A_w$$
$$= 18 \times .003 \times 70 \times 70 \times 165 \times \frac{(6 \times .119 + 16 \times .05)}{12}$$
$$= 5508 \text{ ft. lbs.}$$

From equation (5) the B.M. at ground level due to wind pressure on the pole:

$$= H_p/2 \times K.V^2A_p$$
$$= \frac{20}{2} \times .001 \times 70 \times 70 \times 20 \times \frac{1}{2}\left(\frac{8}{12} + \frac{11}{12}\right) \text{ lbs.}$$
$$= 776 \text{ ft. lbs. (nearly).}$$

Hence the total B.M. at ground level—

$$= 6284 \text{ ft. lbs.}$$
$$= 75408 \text{ inch lbs.}$$

This is the maximum calculated moment, but a factor of safety of 5 is desirable. That is, the pole should, for safety, be strong enough to withstand 5 times this B.M. In other words, it should have a resisting moment of 377,040 inch lbs.

From equation (8) and Table 2 it follows that:

$$M = f. \times .0982\ d^3$$
$$\text{and hence } d = \sqrt[3]{\frac{M}{f \times .0982}}$$
$$= \sqrt[3]{\frac{377040}{12000 \times .0982}} \text{ inches}$$

(12,000 is the ultimate compressive stress of an Ironbark pole: is lower than the tensile stress.)

$$= 6.84 \text{ inches.}$$

That is, the pole which was originally 11" diam. at the ground line will be safe until the decay at this point is such as to reduce its effective diameter of sound wood to 6.84 inches. (It should be emphasised that this term "effective diameter" relates to the effective area of sound wood in the pole at this point: any decayed wood, cracks, etc., must be allowed for.)

The American Telephone and Telegraph Co. has issued detailed instructions for the inspection of poles in this manner, giving tables of minimum effective ground line diameters for all classes of poles under various degrees of loading and including information of allowances to be made for hollow hearts and enclosed and exposed pockets.

Buckling never occurs with wooden poles because of their relatively great width in proportion to their length, but it is interesting to consider in the above case the effect of vertical loading on the Resisting Moment. The total vertical load on the pole at ground line is approximately 250 lbs. This would be spread over an area of about 37 sq. inches when the diameter is 6.84", and the resulting compressive stress = 250/37 = about 7 lbs. per sq. inch, which is negligible compared with the compressive strength of wood, which is 12,000 lbs. per sq. inch.

Imagine that the wires have been removed and a 16-stone workman is standing on a ladder set 12' out from the pole at the foot and 16' up the pole. The bending moment applied to the pole by the top of the ladder $= \frac{W_m \times S_l}{H_l} \times H_l$.

Where: W_m = weight of man, in lbs.
S_l = spread of ladder, in feet
H_l = height of ladder, in feet

H_l cancels out and B.M. $= 16 \times 14 \times 12 \times 12$ inch lbs.
$= 32,260$ inch lbs.

As this is well below the safe loading, there would be no chance of the pole falling and injuring the workman.

STEEL POLES

Types of Steel Poles.—From the foregoing it will be seen that the use of iron or steel for the manufacture of telephone poles appears promising, both because of the greater durability of these materials and the possibility of working them to the most efficient shape.

For efficiency, a pole should be tapered and should also be stronger in one direction than the other. Certain special poles have been made to fit in with one or other or both of these requirements and are worthy of mention.

Oppenheimer Pole.—This is a type of galvanised tubular iron pole with elliptical section. A taper effect has been obtained by building the pole in three or four sections, each of which has a different diameter, the heaviest, of course, being at the bottom and reducing to the lightest at the top. These poles are galvanised to prevent rusting. They are the nearest approach to the ideal design of pole that is used in Australia. They are designed to take short iron arms which clamp about the pole and thus provide the condition of central loading. To obtain sufficient support in the ground, two specially shaped steel plates are attached by means of a type of U-bolt.

Siemens' Pole.—This is a round tubular galvanised pole. Taper is provided in two ways. One type consists of a single length of specially rolled tapering section which fits into a cast-iron base that is provided with fins to obtain a firmer anchorage in the ground. In the second type, the taper is obtained by using several sections of different diameters as in the case of the Oppenheimer pole.

Stewarts & Lloyds' Pole.—An extensive range of round tubular poles was made by this firm. They, too, obtained a taper by the use of lengths of tubes of different diameters.

The special tubular iron poles already mentioned are to be seen on telephone and telegraph routes in many parts of the Commonwealth. Despite the fact that they closely approach the ideal pole for economy in material, the cost of manufacture outweighs any advantage thus gained. The poles now in use were purchased by the State authorities in pre-Federation days. So far as the writer has been able to ascertain, none of these poles have been purchased since the Commonwealth Government has been in control of telephone and telegraph communication.

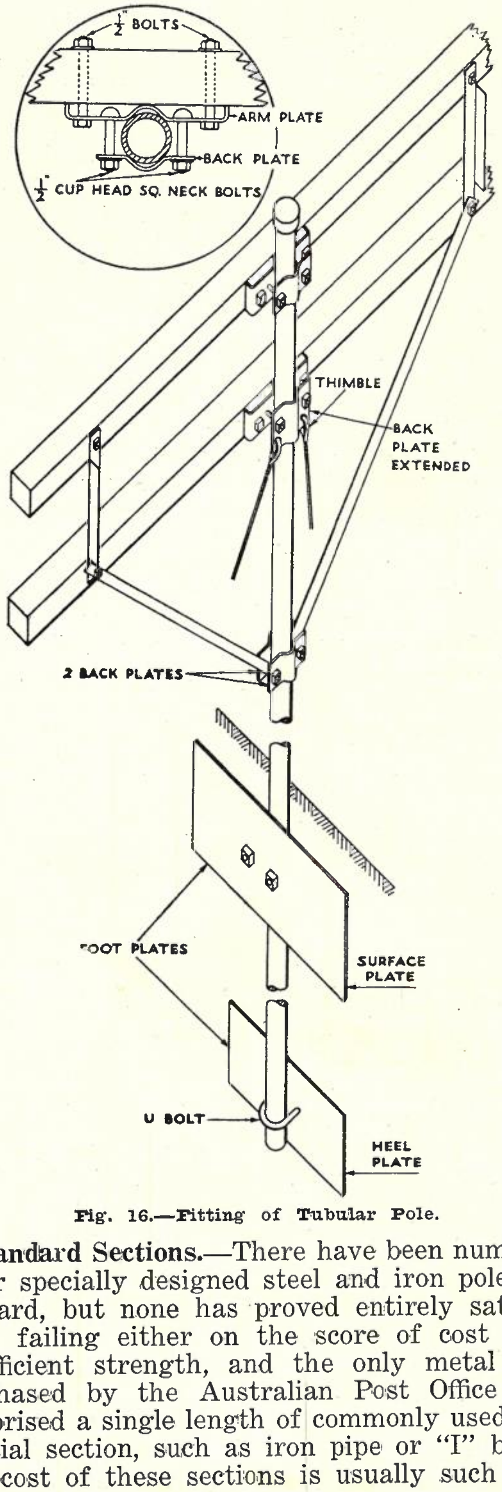


Fig. 16.—Fitting of Tubular Pole.

Standard Sections.—There have been numerous other specially designed steel and iron poles put forward, but none has proved entirely satisfactory, failing either on the score of cost or of insufficient strength, and the only metal poles purchased by the Australian Post Office have comprised a single length of commonly used commercial section, such as iron pipe or "I" beams. The cost of these sections is usually such as to justify their use only in localities where durable wood poles are not readily obtainable.

On an economy basis, secondhand steel rails form the most satisfactory type of metal pole. These rails are obtainable from abandoned railways to mines and the like or from renewals of existing railway tracks, at rates which justify their use after boring and providing the necessary fittings.

Fitting of Rails and Beams.—To enable arms to be fitted to rails and beams, 11/16" holes are drilled, or burnt by oxy-flame, at appropriate distances along the web, and the arms are bolted with a single 5/8" bolt as in the case of a wooden pole. On single-headed rails, the flange is wider than the beam and, in order to hold the arm square on the pole, it is necessary either to provide a special hardwood packing piece between the arm and the head, or to cut a piece out of the flange. Where there are large numbers of rails to be dealt with and suitable facilities are available to keep handling costs low, this latter method, using an oxy-flame is the better.

Because of their smaller cross-section it is necessary to provide additional area at the foot of steel poles to ensure that they are firmly supported against overturning in the ground. This is done by attaching footplates with U-bolts. These footplates are fitted so that their maximum area is in the line of maximum load which, as explained previously, is practically always across the line of the route. Similarly, rail and beam poles are erected with the web across the line of the route as the beam is stronger in this direction.

Except in very firm ground, a plate or block is fitted under the foot of a steel pole to prevent it sinking. This is specially important in cases where a ground stay is attached to the pole and is also advisable where the soil is light or soft and where there is an additional downward thrust on the pole due to a vertical angle in the line wires.

Fitting Tubular Poles.—On light routes, use is often made of any available iron arms such as were provided for use with Oppenheimer or Siemens' G.I. poles. However, the number of such arms is limited and their purchase is seldom economically justified, while they also influence lightning discharges, so that it is now common practice to fit wooden arms. Several fittings have been used in the past, including U-bolts, back-caps from old Siemens' poles, and a double plate fitting involving the use of a special double-ended bolt. Three fittings which have recently been standardised, in association with standard commercial bolts, meet all requirements for the attachment of arms, staywire and braces. These fittings and their use are illustrated in Fig. 16.

As in the case of rail and beam poles, footplates are attached with U-bolts and a base-plate or block is required except in certain circumstances.

Tested Strength of Tubular Poles.—Below are some recorded tests of tubular G.I. poles which are furnished to show the actual resisting moment of such poles:—

Type of Pole	Loading	Resisting Moment
24′ Oppenheimer pole (2 poles tested).	Horizontal pull 16′ above ground along the major axis; elastic limit reached at 245 lbs.	47,000 inch lbs.
22′ Tapered Siemens' pole (single tapered length $3\frac{3}{4}'$ diam. at ground level).	Horizontal pull 16′ 6″ above ground; elastic limit reached at 500 lbs.	99,000 „ „
26′ Siemens' Pole in 4 sections.	Horizontal pull 22′ above ground; elastic limit reached at 360 lbs.	95,000 „ „
22′ G.I. Pipe pole (3″ G.I. water piping), 2 poles tested.	Horizontal pull 17′ above ground; elastic limit reached at 350 lbs.	71,400 „ „

ECONOMICS OF POLE PROVISION

The question of whether steel or wooden poles shall be used and if the latter, what preservative treatment shall be applied, should be considered in all cases; the decision will depend firstly upon the economics and, secondly, upon such factors as the availability of steel poles or preservative plant, and, possibly, funds limitation.

Such an economic study usually consists of a comparison of the higher initial cost and any associated periodical charges for the more durable poles against the lower initial cost and associated periodical charges and earlier renewals of the less durable poles. It will be realised that some of these costs are initial only and others are recurring: in making the comparison they are usually all brought to the basis of present values. That is, the cost of each scheme is taken as being the initial provision cost plus that sum which, if banked at the time of erection of the pole, would, at ordinary bank interest rates, be sufficient to cover the subsequent charges for maintenance and renewals.

TABLE 4.

Sinking Fund Allowance for Various Average Lives.

(INTEREST RATE 5%)

Allowance is given as a percentage of the Capital Cost.

Life	1	2	3	4	5	6	7	8	9	10
Allowance	100	48.8	31.7	23.2	18.1	14.7	12.3	10.4	9.1	8.0
Life	11	12	13	14	15	16	17	18	19	20
Allowance	7.0	6.3	5.6	5.1	4.6	4.2	3.9	3.6	3.3	3.0
Life	25	30	35	40	45	50				
Allowance	2.1	1.5	1.1	0.8	0.6	0.5				

Note.—If the item has a residual value at the end of its life, the allowance should be multiplied by a factor equal to — (1 — Ratio of Residual Value to Original Value).

To provide for replacement of the poles, arms, etc., as they are condemned, an annual charge is calculated and is called a Sinking Fund Allowance (S.F.A.). This is taken as a percentage of the capital cost; the percentage depends upon the average life and can be ascertained from Table 4.

The calculation is usually based on a single typical pole fitted with arms and erected. Any factors (e.g., wire and insulator costs) which do not affect the issue are excluded.

Unless it is expected that the pole route will be dispensed with within a definite time, it is assumed that the route will be retained for ever.

Interest rates of 5% are usually assumed, and on this basis the present value of an annual charge commencing immediately and continuing for ever is found by multiplying the annual charge by 20.

If, for example, it is desired to ascertain whether it is cheaper to provide steel poles with an estimated life of 44 years or wooden poles with a 3-yearly brush treatment of the butt to give an estimated life of 22 years, the comparison shown in Table 5 is made, approximate typical figures being given.

The most economical scheme will be that which shows the lowest total in Table 5.

In the case of initial preservative treatment such as the hot-cold tank method previously described, this cost must be added to the initial cost of the poles. The estimated pole life must be extended and the annual Sinking Fund allowance reduced accordingly.

ERECTION OF POLES

The method used for erecting a pole will depend upon the size and type of the pole, the erecting gear available, the number of men available and the local conditions. The writer proposes to outline some methods commonly used and to place emphasis on several features considered worthy of attention. Matters covered are:—

(i) Safety precautions.
(ii) Pole holes.
(iii) Erection by hand with use of pikes.
(iv) Erection by hand with assistance from a motor vehicle.
(v) Erection with assistance of pole lifting jack.
(vi) Erection with derrick or crane.
(vii) Erection with assistance from specially equipped motor vehicles.
(viii) Erection of long poles.
(ix) Erection of steel poles.

Some motor vehicles are now being equipped with special fittings designed to assist in the erection of poles, and where such vehicles are available they should be used, as they will almost invariably reduce both the cost and accident hazards. There are, however, few of these trucks available at present and hence the majority of poles are erected by hand.

Safety Precautions.—Very few accidents result from pole erection work because of attention to proper precautions by the Foremen, but it is well to review the precautions necessary because of the serious damage that can occur should a pole fall while being erected. These are as follows:—

(1) Once lifting commences there must be no idle talk and every man must give his full attention to the task.

(2) The party leader must give all orders, the only other speakers being the men with pikes required to take the weight of the pole at the end of a lift as indicated later.

(3) All gear required must be laid out in readiness where it will be handy, but will not interfere with the operations.

(4) The ground in the vicinity must be cleared except for the lifting gear mentioned above.

(5) Both prongs of the pike should enter the pole.

(6) The butt of the pike must be kept on the ground during lifting, and during the supporting stages the arch of the rear foot should be kept over the butt of the pike to prevent it from slipping.

(7) All lifting gear should be in good condition and of sufficient strength to handle the load: pike prongs should be sharp and secure and the shaft sound: ropes should be overhauled before use: knots and lashings should only be made by an experienced operator.

With regard to (5) above, some practice is required in getting both prongs to enter the pole, but it will be found simple if the pike is

TABLE 5—Economic Comparison

Cost of Schemes			Explanatory Remarks
Scheme 1. To provide steel poles.			
Initial cost of pole, fitted with arms and erected		= £6.5	
Annual Charges:			
(a) S.F.A. for replacement of arms costing £2 every 22 years .... =	1/-		From Table 4 it will be seen that the Sinking Fund allowance for a life of 22 years is 2.5% of cost, i.e., 2.5% of £2 = 1/-.
(b) S.F.A. for renewal of pole, £5.5 every 44 years .... =	.66/-		Renewal cost is higher than initial cost, generally. From Table 4, S.F.A. for 44 years is 0.6% of cost, i.e., 0.6% of £5.5 = .66/-.
Total Annual Charge .... =	1.66/-		
Present Value of Annual Charge .... =		£1.66	P.V. of 1.66/- per year for ever = 1.66/- × 20 = £1.66.
Total cost of Scheme 1		£8.16	
Scheme 2. To provide wood poles, inspect them annually, and treat them triennially.			
Initial cost of pole, fitted with arms and erected		= £4	
Annual Charges:			
(a) Annual inspection .... =	1/-		
(b) S.F.A. for triennial brush treatment costing 3/- .... =	1/-		Dealt with as a S.F.A. for treatment having a life of 3 years. From Table 4, S.F.A. for 3 years life = 31.7% of cost, say ⅓ of 3/- = 1/-.
(c) S.F.A. for renewal of pole and arms costing £5 every 22 years .... =	2.5/-		It is assumed here that the arms will last the life of the pole and be renewed at the same time as the pole. If this is not likely, separate S.F.A.'s must be provided for poles and arms. From Table 4, S.F.A. for 22 years = 2.5% of cost = 2.5% of £5 = 2.5/-.
Total Annual Charge .... =	4.5/-		
Present Value of Annual Charge .... =		£4.5	
Total cost of Scheme 2		£8.5	

held with one hand comfortably above and one slightly below the centre of balance, the prongs rested against the pole so that both are touching it, the pike withdrawn a distance of about 18" to 2', and then moved forward firmly until the prongs enter the wood.

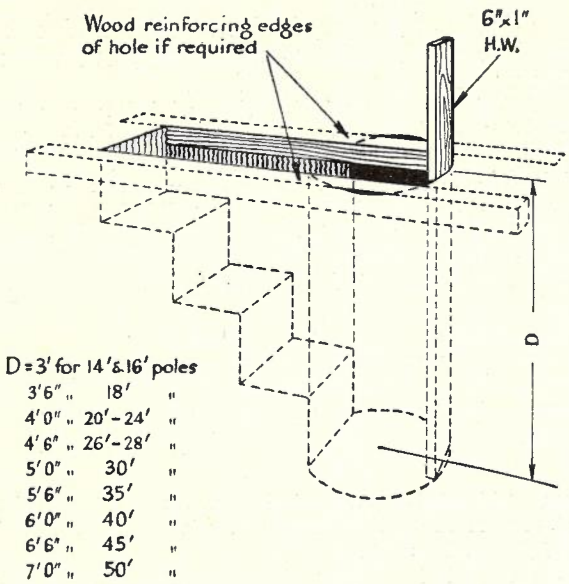


Fig. 17.—Stepped Hole for Pole.

Pole Holes.—Usually a stepped hole is dug for the pole (Fig. 17), although the shape of the hole is not important where a crane or derrick is used which can support the whole weight of the pole at or above the centre of gravity. The steps provide convenient room for the operator during excavation and simplify the work of erection by reducing the lifting effort and limiting the sideward movement. The sides of the hole where it is stepped limit the sideward movement of the pole and hence it is important to ensure that the width of the hole in this section be only slightly (say, 1 or 2 inches) greater than that of the pole itself. The accuracy of work in making this hole is specially important in cases where the pole is erected by hand or with the assistance of a pole lifting jack. In crumbly or sandy soil, blocks should be fitted along the sides of the hole as indicated in Fig. 17 to provide additional support. The width of the hole at the deepest end should be sufficient to take the butt of the pole and provide clearance for a narrow rammer. Any greater excavation only makes more work and reduces the support given to the pole both during and after erection.

Undisturbed ground is much firmer than filled ground, even if the latter is carefully rammed, hence the hole should be dug so that it is across the line where the principal support is required, provided, of course, that the direction so chosen is suitable for pole erection. In normal circumstances this means that the hole is dug along the line of the route.

Erection by Hand with Assistance of Pikes.—In lifting a pole by hand, the pole is laid with the butt over the hole and the head raised by hand or with a jack or pikes so that during the early stages the lower end rests on the top step and the butt enters the hole. If one is available, a pole cart (Fig. 18-I.) is used to set the pole over the hole and take the weight in the early stages. Failing this, the initial lift is taken by utilizing the top arm (Fig. 18-II.). In the latter case, the pole is laid slightly out of the line of the hole so that it will line up with the hole when it has been turned and raised to rest on the end of the arm.

The remaining stages of the lifting are illustrated in Figs. 18-III. to VIII. A short pike (6') or a dead-man is used to take the weight of the central portion of the pole, while two pairs of pikes (10' and 14') assist in lifting and supporting the upper end of the pole and prevent it from moving sidewards. Pairs of pikes are so organized that at the end of each lift one pair takes the weight while the others, reaching their limit of length, are withdrawn and entered lower down. Before each lift is taken, it is arranged that one pair of pikes will take the weight and all workmen should clearly understand which pair will do so before the lift is started. At the end of the lift, each man keeps his pressure on the pike until those whose pikes are to take the weight signify by calling out "right" that they have a proper grip.

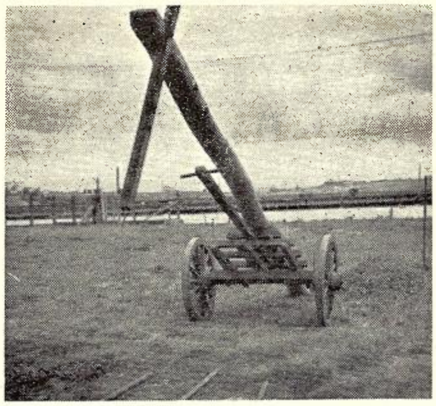
The number of men required varies with the size of the pole and the equipment available. Usually five are required for poles between 24' and 30'; for shorter poles fewer men and pikes are needed, whilst for longer poles more men and a 16' pike are required.

When the pole has reached the vertical position, it is twisted so that the arm is square to the line of the wires. This is done by means of a turning rope or a cant hook (Fig. 19-IX.).

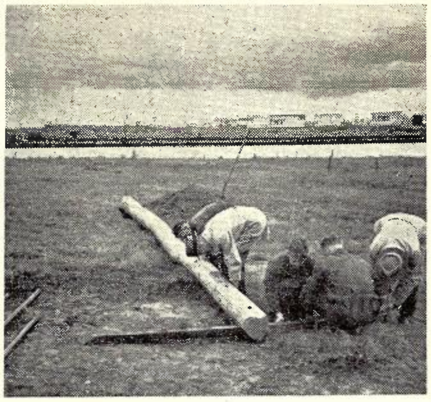
The position of the butt of the pole is checked for correct alignment; if necessary, it is kicked into position. This is usually done by inserting a sinking bar alongside the butt of the pole near ground level and forcing the head of the pole over so that the butt is levered into position.

When this has been done, the alignment of the arm is again checked and the pole plumbed. To plumb the pole, four pikes are spaced 90° apart around the pole, two being in line with the wires and two in line with the crossarms (Fig. 18-IX.). The pole is then lined up by an operator stationed some distance from the pole with the plumb line in front of him. If the pole is to be moved over in a particular direction, one man on the pikes releases the butt of his pike and allows the pole to move backwards slightly whilst the man opposite him pushes the pole over in the required direction. When the pole has been lined up from this angle, the process is repeated by the opera-

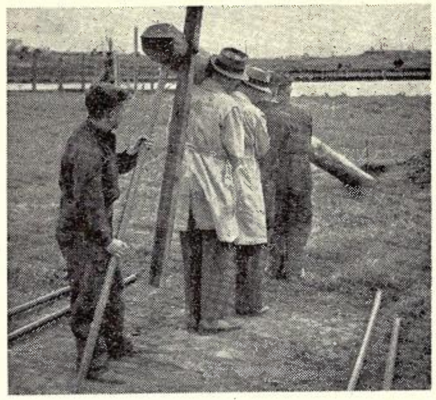
(Continued on p. 243)



I. Pole cart if available used for initial lift.

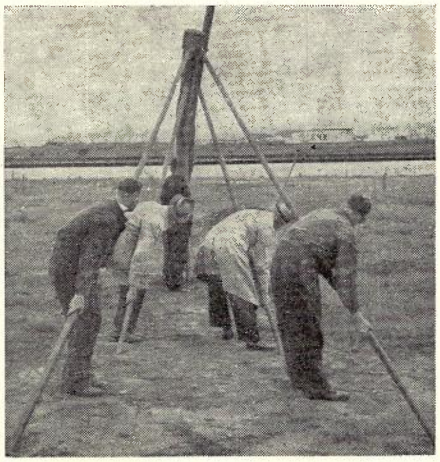


II. Hand lift on to end of crossarm: Pikes laid out ready for later use.

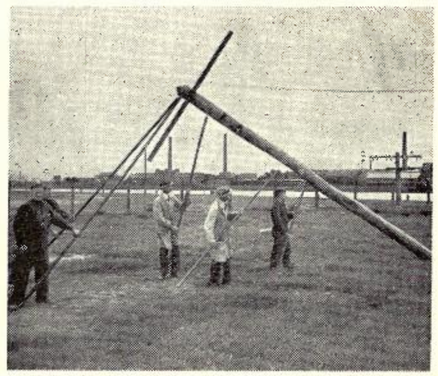


III. Lift on shoulders: Hand pike takes weight as others move down for further lift.

IV. Longer hand pikes take weight and aid lifting.



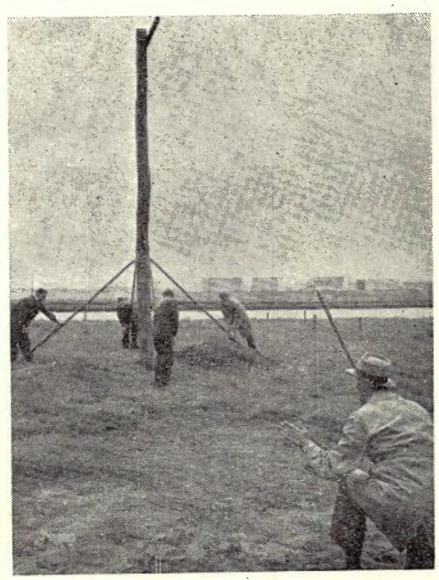
V. Pole Higher: Pikes used for lifting. (Note V spread to keep pole straight.)



VI. Alternately long and short pairs of pikes take weight while others change to lower position.

VII. Longer pikes changing to lower Position. (Termed "fleeting the pikes.")

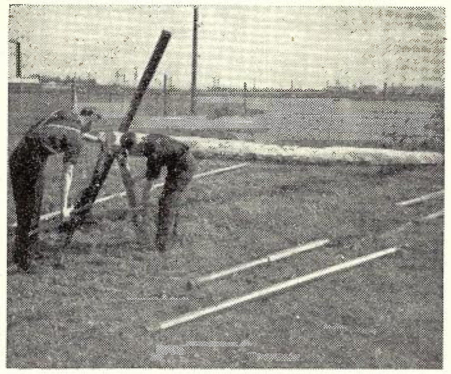
VIII. Lifting in later stage.



IX. Four pikes support pole while foreman "sights" with plumb-line.

Fig. 18.—Erection of Pole by Hand, Using Pikes.

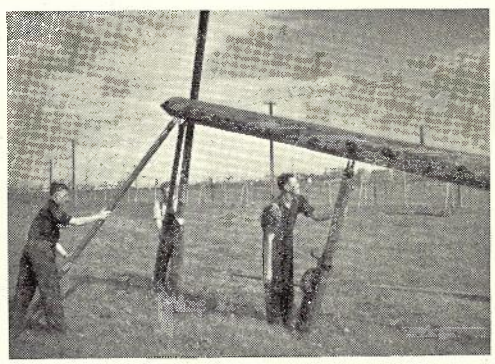
I. Close-up of Pole Lifting Jack.



II. Pole is first jacked on to end of crossarm.

III. Short pikes support pole: Jack does the lifting.

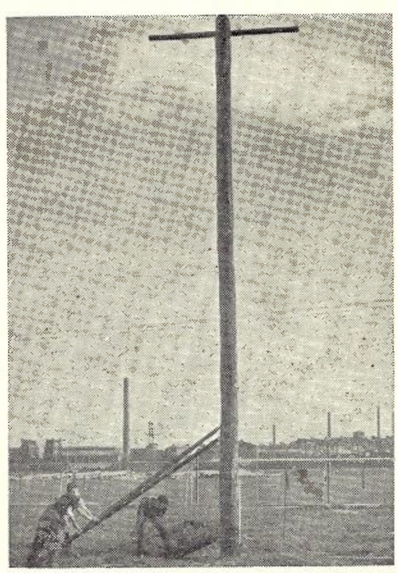
IV. A buoy is fitted in loops on jack to increase effective length.



V. As height increases longer pikes are used. (Note their spread to prevent sideward movement.)

VI. A longer buoy is fitted to jack: Pikes support pole while jack is shifted.

VII. Jack and pikes move down pole in stages.



VIII. Final lift: Jack operated in top step of hole.

IX. Turning pole with turning rope and sinking bar.

Fig. 19.—Erection of 38 ft. Heavy Pole with Assistance of Pole Lifting Jack. (Erected by 3 men in 15 minutes.)

tor moving to a point 90° from where he first lined up. Following the plumbing, the butt is again checked to ensure correct alignment.

With the pole held securely by the four pikes, the ground is filled in and thoroughly rammed. Ramming is very important, particularly for the soil near the butt of the pole. Usually, two men are employed with rammers, whilst one uses the shovel for filling. In the early stages, the earth is shovelled in gradually and fully rammed.

Erection with Pole Lifting Jack.—An alternative method to the direct hand lifting, as described above, consists of using a pole lifting jack, which does most of the actual lifting, while two pikes are used to prevent sideward movement and to take the weight when the jack is being shifted to another position down the pole. In the early stages, the jack alone is used, but as the pole gets higher a short buoy can be attached to the jack through special loops provided for this purpose. The lift of the jack is much steadier than that from hand lifting and consequently the operator has excellent control. If proper attention is given to the width of the hole the operator with the jack can control the pole single-handed, and it is only necessary for two more operators to follow up with pikes and take the weight when the jack operator reaches the end of the lift and has to release and change to a lower position.

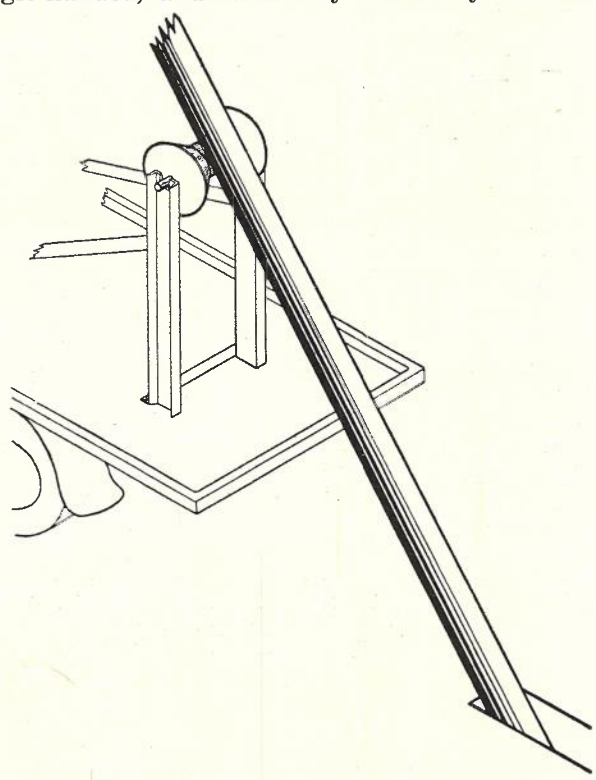


Fig. 20.—Utilising Truck Energy for Lifting.

This method, whilst not so quick for short poles, is particularly suitable for heavy ones and reduces the effort required from workmen. It is very useful where the man-power available is limited and in difficult country where properly equipped motor vehicles cannot be economically taken to the spot. In the writer's opinion, this device is not used at present as extensively as it should be.

Fig. 19 illustrates stages in the erection of a heavy 38′ pole by three recently recruited linemen-in-training with no previous experience of pole erection. With very little practice it was possible to erect the pole in 15-20 minutes with perfect safety. The presence of a fourth man, whilst not essential, is of assistance.

Assistance from Motor Truck.—Fig. 20 illustrates a simple device which has been used in America to enable the energy available in the form of a motor truck to assist in the erection of a pole during the stage that requires most energy. The combination of this device with a pole lifting jack presents possibilities for quick erection where fully equipped pole lifting trucks are not available.

Specially Equipped Motor Vehicles. — Where there is sufficient pole erection (and removal) work to keep a motor truck occupied for a reasonable percentage of its time, there is economic justification for the provision of a derrick attachment and power-take-off. The derrick must be capable of quick erection and its height slightly more than half that of the longest pole usually erected: the power-take-off provides the lifting energy. The pole is seized at or slightly above the centre of gravity, lifted to slightly more than half its height, guided to an erect position with ropes attached to the butt, and then lowered into the hole. Fig. 21 illustrates the method, but with hand-erected derrick and man-power used for lifting.

As the stepped feature of the hole is not used in this case, the hole could be made with an earth auger or similar device. In U.S.A. pole-erection trucks are sometimes provided with power-operated hole borers, but this style of fitting has not yet been adopted here.

Erection of Long Poles. — For specially long poles, two methods are available:—

(1) The erection of a jury mast and tackle as shown in Fig. 21; or

(2) the use of the stepped hole method using a derrick and/or pole jack for initial stages and a derrick directly behind the butt for the later lifting.

For long poles it is advisable to attach four long ropes to the top to guide the head of the pole, assist in the final lifting and plumbing, and act as temporary stays until the foundation is completed and the pole securely held.

Erection of Steel Poles.—These sometimes present difficulties in erection when their weight is excessive. To enable pole pikes to be used a stout rope should be wound spirally around the pole—about one turn per foot of pole length. One prong of the pole pike can then be inserted under the rope. Except with short poles it is desirable to use a derrick or jury mast.

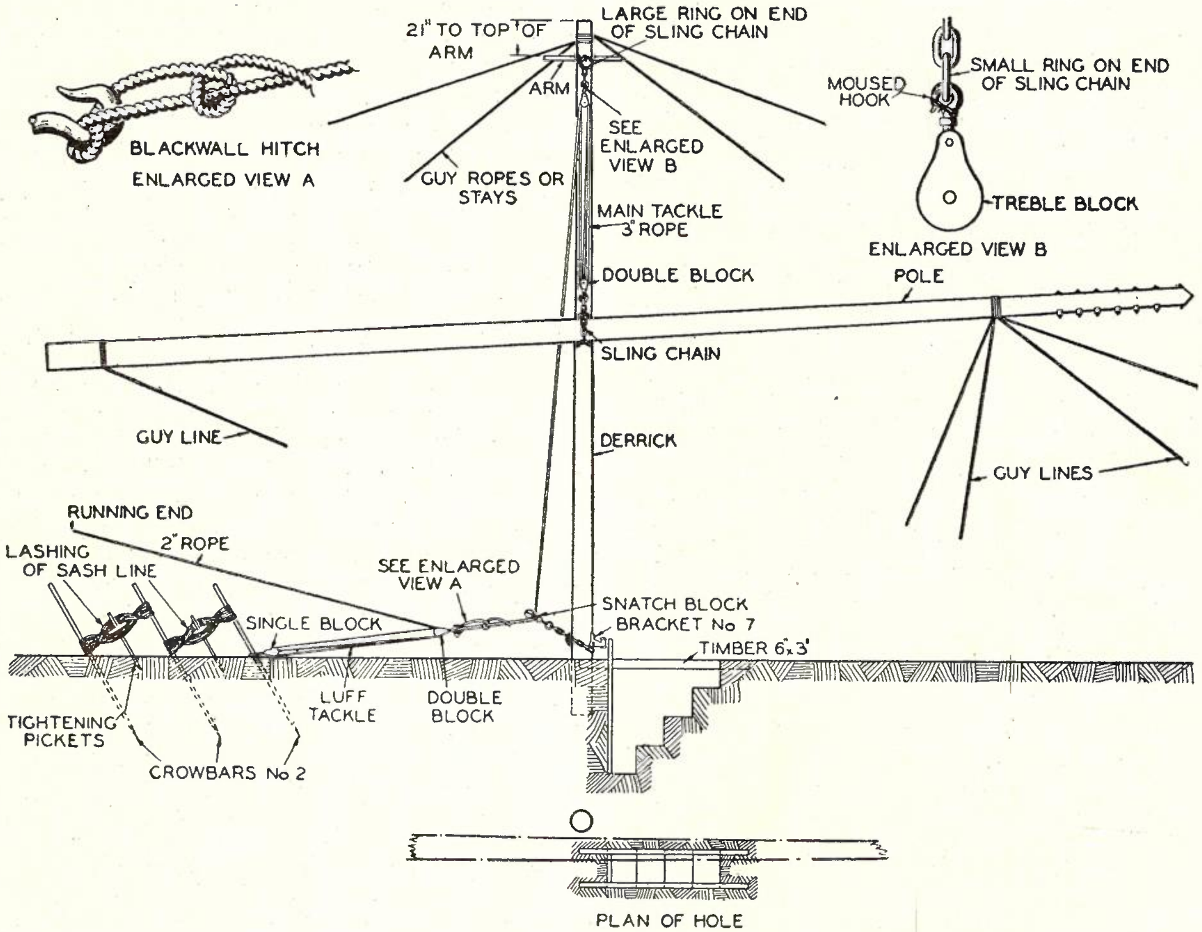


Fig. 21.—Erection of Poles with Derrick.

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ANSWERS TO EXAMINATION PAPERS

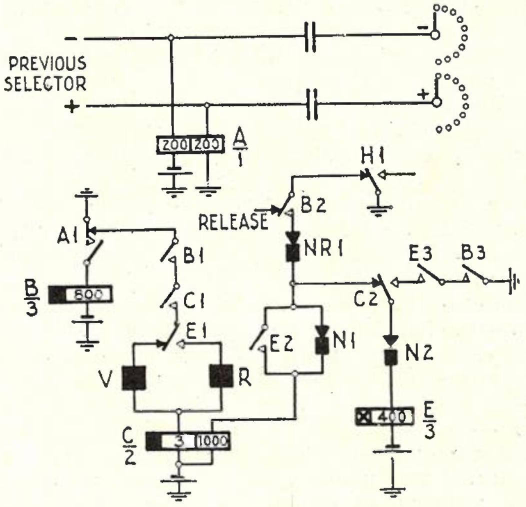
The answers to examination papers are not claimed to be thoroughly exhaustive and complete. They are, however, accurate so far as they go and as such might be given by any student capable of securing high marks.

EXAMINATION NO. 2323.—MECHANIC, GRADE 2 TELEPHONE INSTALLATION AND MAINTENANCE

O. C. RYAN

Q. 1.—Draw a diagram showing the connections of the relays and magnets that control the movement of the wipers of an ordinary final selector. If the last two digits of a called subscriber's number were 95, how would the required movements of the wipers be effected? (The release circuit is not required.)

A.—The arrangement of relays and magnets is indicated in Fig. 1. Relay A operates from the subscriber's loop and at A1 operates relay B. Contact B1 prepares the impulsing circuit to the vertical magnet via the 3 ohm winding of relay C. B2 completes the circuit



Q. 1, Fig. 1.

of the 1000 ohm winding of relay C, which operates. At the break of the 1st impulse, relay A restores and earth is applied to the V.M. via B1, C1 operated, E1 normal, V.M., 3 ohm winding of relay C to battery. The selector steps to the 1st level. When the dial impulse springs remake, relay A reoperates, recloses the circuit of the slow releasing relay B and releases the vertical magnet. This process is repeated for each impulse. If the second last digit is 9, the wipers will step to the ninth level, relay A remaining operated during the pause between digits. When the switch stepped off normal, the N1 springs were opened and the 1000 winding of relay C was disconnected from earth at H1. Relay C, however, holds on the 3 ohm winding during the impulse train. At the end of the second last digit impulse train, relay C restores and completes a circuit for relay E via H1 normal, B2 operated, NR1 springs, C2 normal, N2 operated, E relay coil to battery. E1 changes over the impulsing circuit to the rotary magnet and the next train of impulses operates the rotary magnet and steps the switch to the 5th contact. Relay C reoperates via E2 and holds on its 3 ohm winding as before, during impulsing. Relay E is held from earth via B3, E3, C2 and N2, all operated. After the completion of the second train of impulses, relay C restores and the E relay circuit is opened at NR1, E relay restores.

Q. 2.—(a) Explain the functions of the Main Distributing Frame and the Intermediate Distributing Frame at a C.B. exchange.

(b) Give a diagram showing the connections of a subscriber's line circuit at each frame.

A.—(a) The main distributing frame at a C.B. exchange is provided for the following purposes:—

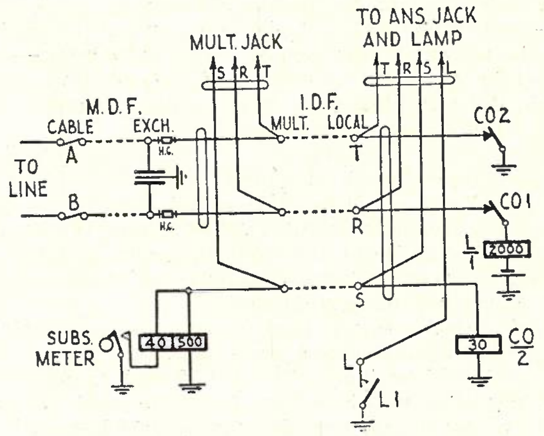
(i) To provide a ready means of terminating and cross-connecting the external cables which are arranged on one side of the frame in order of cable pairs, to the internal switchboard cables which are arranged on the other side of the frame in numerical order of subscribers' numbers, so that by means of jumper wires any cable pair may be cross-connected to any subscriber's number.

(ii) To provide protection of the internal plant from contacts with power supply and from lightning.

(iii) To provide a point of access for the testing of lines and of exchange equipment.

The intermediate distributing frame has the following function:—

(i) To provide a cross-connecting point for connecting any subscriber's multiple number with a suitable answering circuit. By this means the traffic can be evenly distributed on the "A" positions, so that the telephonists are evenly loaded. Changes in traffic may necessitate changes in the location of the answering equipment, and without the I.D.F. it would be necessary to change either a subscriber's number or to effect extensive changes to the permanent cabling.



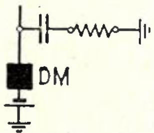
Q. 2, Fig. 1.

(b) A diagram showing the connections of a subscriber's line circuit at each frame is indicated in Fig. 1.

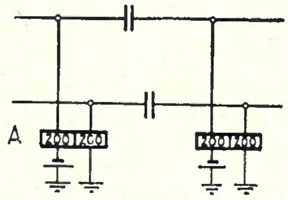
Q. 3.—Give two different examples with simple circuit diagrams of the use of condensers in telephone exchange circuits and explain the function of the condensers in each case.

A.—Two examples of the use of condensers in telephone exchange circuits are indicated in Figs. 1 and 2.

Fig. 1 indicates a condenser in series with a timing resistance used as a spark quench associated with the drive magnet circuit of a uniselector. The condenser



Q 3 FIG 1



Q 3 FIG 2

is used to absorb the current due to the inductive voltage on opening the D.M. circuit, and the timing resistance is designed to dissipate and regulate the current discharged from the condenser on closing the interrupter circuit, so that the heat generated will not be sufficient to weld the interrupter spring contacts together.

Fig. 2 indicates two condensers connected in the negative and positive leads of a final selector. The function of these condensers is to isolate the battery feeds of the calling subscriber's loop from those controlled by the called subscriber's loop, and at the same time permit speech currents to be transmitted through the circuit without appreciable loss. The condensers act as barriers to the D.C. signals, but have a low impedance to A.C. of speech frequency.

Q. 4.—(a) Describe briefly the testing facilities provided on a Test Desk in an automatic exchange.

(b) What facilities are provided for connecting a subscriber's line to the testing circuit?

A.—(a) The testing facilities provided on a Test Desk in an automatic exchange are as follows:—

(i) A voltmeter and keys are provided which enable the following tests to be applied to lines:

(a) Condenser Discharge.
(b) Loop Resistance.
(c) Insulation Resistance.
(d) Earth on either side of the line.
(e) Foreign battery on either side of the line.
(f) Speed, Ratio and Counting tests of dials.

(ii) A mechanically operated dial speed tester is also provided on certain desks.

(b) The facilities provided for connecting subscribers' lines to the testing circuit are:—

(i) Test Distributor Trunks: These enable a line to be picked up via a test distributor and test final selector which are provided for each 100 subscribers' lines. The banks of the test final selectors are in full multiple with the banks of the final selectors in the group concerned and by means of the dial on the desk any subscriber's line may be selected and connected via the keys to the testing circuit.

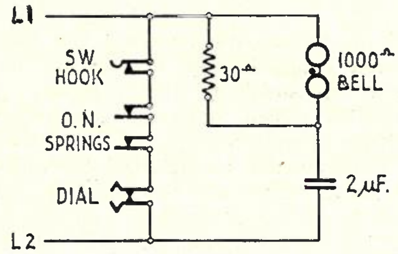
(ii) Test plugs on the line and protector side of the M.D.F. are provided and connected to the testing circuit via keys on the test desk.

(iii) Inspectors' Trunks (09 lines) are provided on the test desk to enable substation faultmen, etc., to call the test desk direct. By the operation of keys on the desk, these circuits may also be connected to the testing circuit.

Q. 5.—(a) Explain with the aid of a diagram the circuit conditions in an automatic telephone when dialling is taking place.

(b) What standards are adopted as regards impulse speed and ratio, and why is it necessary to maintain them?

A.—(a) Referring to Fig. 1, the impulsing circuit is from L1 through the switchhook and dial off normal springs in series, and the dial impulse springs to L2. During impulsing, the 2mF condenser in series with the



Q. 5, Fig. 1.

30 ohm non-inductive resistance of the induction coil and 1000 ohm bell in parallel is connected across the impulse springs to reduce high voltage surges and to correct impulse distortion.

(b) The standards adopted are as follows:—

(i) Speed: 10 impulses per second.

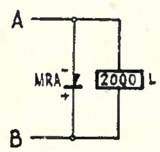
(ii) Impulse Ratio: 33-1/3% make, 66-2/3% break.

It is necessary to maintain the standards because the impulsing circuits of the various switches, controlled by the dial, in an automatic exchange are designed to work satisfactorily at these standards, and routine tests are applied to keep the switches within specified limits.

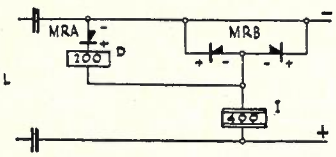
Q. 6.—Explain briefly the principle of a Metal Rectifier as used in telephone exchange circuits, and give two examples of its application.

A.—The principle of a Metal Rectifier is briefly as follows:—

When cuprous oxide is formed on copper at a high temperature, the junction between the two materials has the property of conducting in one direction only and offering a very high resistance to a current flowing



Q 6 FIG. 1



Q 6 FIG. 2

in the opposite direction. The resistance through the combination is relatively low from oxide to copper and very high from copper to oxide. Two examples of the application of metal rectifiers to telephone exchange circuits are indicated in Figs. 1 and 2.

Fig. 1 indicates a method of using a rectifier with an ordinary relay to enable it to be operated from alternating current and renders the use of a specially constructed A.C. relay unnecessary.

In Fig. 2, Relay D in series with the rectifier MRA replaces the shunt field relay controlling the reversal of current and metering in an auto-auto repeater and obviates the necessity for a specially constructed relay.

With current flowing in the normal direction, Relay I operates in series with MRB, Relay D does not operate due to the rectifier, MRA, connected in series with it, but when the line current is reversed Relays D and I operate in series with the rectifier MRA and MRB is non-conducting.

(To be continued.)

EXAMINATION NO. 2295—ENGINEER—NATURAL SCIENCE

E. H. PALFREYMAN, B.Sc., B.E.

Q. 1.—Find by differentiation the values of x which give turning values to the curve—

$$y = 2x^3 + 3x^2 - 36x + 15.$$

Of these values so obtained, indicate, also by differentiation, which is a maximum and which is a minimum. Determine the point of inflexion of this curve.

A. 1.—Here $dy/dx = 6x^2 + 6x - 36$
$= 6(x - 2)(x + 3)$

and the turning values are given when $dy/dx = 0$.

i.e., when $x = +2$ or $x = -3$ .... (1.1)

Further $d^2y/dx^2 = 12x + 6$

and substituting the above values of x we have—

when $x = +2$

$d^2y/dx^2 = +30$ giving a minimum (1.2a)

and when $x = -3$

$d^2y/dx^2 = -30$ giving a maximum (1.2b)

Finally the point of inflexion occurs when $d^2y/dx^2 = 0$, i.e., when $12x + 6 = 0$, giving $x = -1/2$ .... (1.3)

Q. 2.—A picket of 6 men has to be formed out of 10 men. Determine—

(a) How many selections can be made;

(b) In how many of these selections will one particular man be included;

(c) How many selections can be made so as not to contain one particular man.

A. 2.—(a) The number $= 10C_6 = 10C_4$

$$= \frac{10.9.8.7}{1.2.3.4} = 210 \quad .... \quad (2a)$$

(b) Choose the one man and select 5 others from the remaining 9 men,

then number $= 9C_5 = 9C_4$

$$= \frac{9.8.7.6}{1.2.3.4} = 126 \quad .... \quad (2b)$$

(c) Leave out the one man and select the required 6 from the remaining 9 men,

then number $= 9C_6 = 9C_3$

$$= \frac{9.8.7}{1.2.3} = 84 \quad .... \quad (2c)$$

Q. 3.—Given that—

$$\cos\theta + j\sin\theta = \varepsilon^{j\theta}$$
$$\text{and } \cos\theta - j\sin\theta = \varepsilon^{-j\theta}$$

derive the value of cos θ and of sin θ as a series of terms of powers of θ.

A. 3.—By adding

$2\cos\theta = \varepsilon^{j\theta} + \varepsilon^{-j\theta}$

and by subtracting

$2j\sin\theta = \varepsilon^{j\theta} - \varepsilon^{-j\theta}$

but $\varepsilon^{j\theta} = 1 + (j\theta)/1! + (j\theta)^2/2! + (j\theta)^3/3! + (j\theta)^4/4! .....$
$= 1 + j\theta - \theta^2/2! - j\theta^3/3! + \theta^4/4! .....$

and similarly

$\varepsilon^{-j\theta} = 1 - j\theta - \theta^2/2! + j\theta^3/3! + \theta^4/4!$

Hence

$2\cos\theta = 2(1 - \theta^2/2! + \theta^4/4!)$

i.e., $\cos\theta = 1 - \theta^2/2! + \theta^4/4! .....$ .... (3.1)

and

$2j\sin\theta = 2(j\theta - j\theta^3/3! + j\theta^5/5!)$

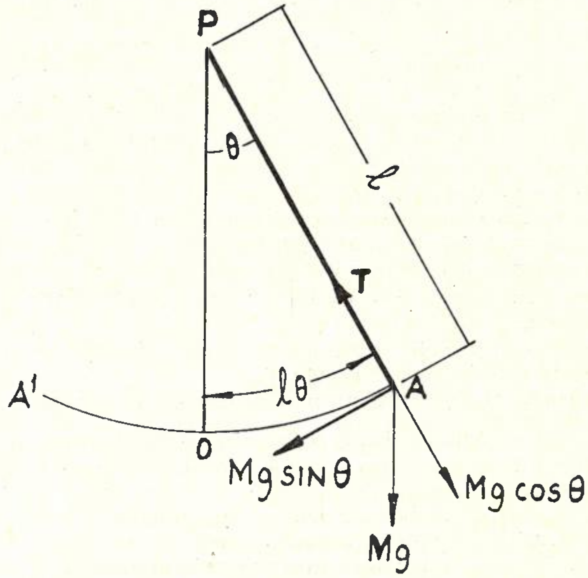
i.e., $\sin\theta = \theta - \theta^3/3! + \theta^5/5! .....$ .... (3.2)

Q. 4.—In a simple pendulum it can be proved that for small displacements a relationship exists between the force of restitution and the displacement such that the pendulum executes Simple Harmonic Motion.

State and prove the relationship for a pendulum with bob of mass "m" and length "l," illustrating your answer with a diagram.

A. 4.—

A body moving in a straight line executes S.H.M. if the restoring force F towards a fixed point in the line



Q. 4, Fig. 1.

is proportional to its displacement x from that point, i.e., if F/x = a const.

In the case of the simple pendulum shown in Fig. 1:

(a) The path is an arc which approximates to a straight line when the displacement is small.

(b) The restoring force is $F = mg. \sin\theta$ which is the revolved part along the arc of the force mg vertically downwards.

(c) The displacement is $x = l\theta$.

Thus $F/x = Mg \sin\theta / l\theta$.
$= Mg/l\theta$ (when θ is small)
$= Mg/l$ = a const. .... (4)

Q. 5.—(a) Define the unit "Henry" as applied to the measurement of self-inductance.

(b) Two coils of 2 Henries and 8 Henries self-inductance respectively are so placed that their coupling factor of mutual inductance is 0.5. Calculate the energy stored in the magnetic field for a D.C. current of 10 amperes flowing through the coils when connected—

(i) Series aiding;

(ii) Series opposing.

A. 5.—(a) A Henry is defined as the inductance in which a current whose time rate of change is 1 ampere per second produces an e.m.f. of 1 volt.

(b)

$L_1 = 2H.$ and $L_2 = 8$ H.

Hence $M = K\sqrt{L_1 L_2}$
$= 0.5 \times \sqrt{2 \times 8}$
$= 2$ H.

Now $L_{sa} = L_1 + L_2 + 2M$
$= 14H.$

and $L_{so} = L_1 + L_2 - 2M$
$= 6H.$

Hence $E_{sa} = \frac{1}{2} L_{sa} I^2$
$= \frac{1}{2}.14.100$
$= 700$ joules .... (5.1)
and $E_{so} = \frac{1}{2} L_{so} I^2$
$= \frac{1}{2}.6.100$
$= 300$ joules .... (5.2)

Q.6.—A sinusoidal carrier having a maximum voltage amplitude "V" is modulated by a sinusoidal tone having a maximum amplitude "v." Deduce a formula to give the resulting instantaneous values of the voltages of the carrier, of the upper and of the lower sidebands.

A. 6.—Let the instantaneous voltage values of carrier and modulating tone be
$v_c = V \sin Ct$
and $v_m = v \sin Mt$ respectively.
Then the amplitude of the resulting modulated voltage will be
$V + v_m = V + v \sin Mt$
and the instantaneous value will be given by
$v_r = (V + v \sin Mt) \sin Ct$
$= V \sin Ct + v \sin Mt \sin Ct$
$= V \sin Ct + \frac{1}{2} v (\cos \overline{C-M}t - \cos \overline{C+M}t)$
$= V \sin Ct + \frac{1}{2} v \cos (C-M)t - \frac{1}{2} v \cos (C+M)t$
The three terms in this last expression are the instantaneous voltage values of (1) the carrier, (2) the lower sideband, and (3) the upper sideband respectively.

Q. 7.—Calculate the field strength in microvolts per metre of a long wave radio transmitter given the following data:—

Aerial current = 50 amperes
Effective height of aerial = 100 metres
Wave length = 6,000 metres
Distance = 200 kilometres
Formula constant = 3.77×10^5

The attenuation due to the finite conductivity of the soil should be neglected.

Assuming a receiving aerial of effective height = 40 metres and resistance 30 ohms, erected at the point concerned, calculate the current in the aerial circuit.

A. 7.—(a)
$F = K\,hI/\lambda\,d$ in microvolts per metre
$$= \frac{3.77 \times 10^5 \times 100 \times 50}{6000 \times 200}$$
$= 1571\ \mu V/$ metre .... (7a)
(b) $I = FH/R$
$$= \frac{1571 \times 40}{30}$$
$= 2095 \mu A$ .... (7b)

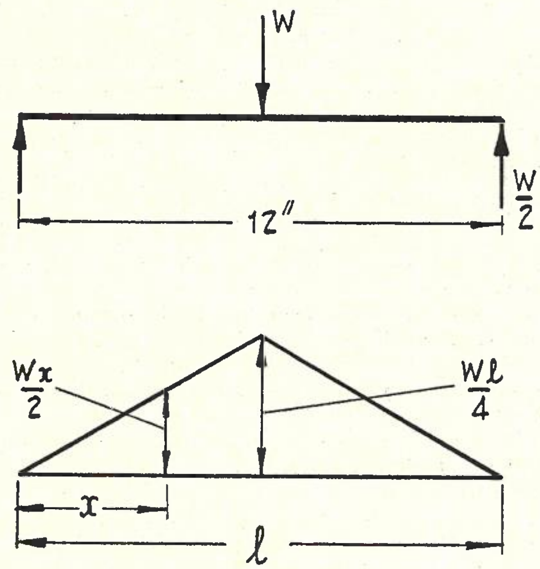
Q. 8.—The bending strength of a certain timber is 5,400lb./sq. inch determined by centrally loading to fracture, a beam simply supported on 12 in. centres:—
(a) Draw the bending moment diagram;
(b) Calculate the breaking load required having been given the following:—

$$\textbf{Bending strength} = \frac{\textbf{Bending moment}}{bd^2/6}$$

where "b" = breadth of test beam = 2 ins.
"d" = depth of test beam = 2 ins.

A. 8.—(a) The reaction at each support is W/2 lbs., the bending moment at a distance x from either end is Wx/2 lbs. inches and thus the maximum B.M. will be at the centre, where $x = l/2$ and equal to $Wl/4$ lbs. inches.

(b) The formulae is
$$S = \frac{M}{bd^2/6}$$
$$= \frac{Wl/4}{bd^2/6}$$
since $M = Wl/4$ the maximum bending moment.
$$\text{Thus } W = \frac{S.bd^2/6}{l/4}$$
$$= \frac{S.bd^2\ 4}{6l}$$
$$= \frac{5400 \times 2 \times 4 \times 4}{6 \times 12}$$
$= 2400$ lbs. .... (8b)
The value of $Wl/4$ in part (a) is thus
$2400 \times 12/4 = 7200$ lbs. inches.



Q. 8, Fig. 1.

(To be continued.)

EXAMINATION NO. 2295.—ENGINEER.—LINE CONSTRUCTION

W. H. WALKER

Q. 1.—Indicate briefly the considerations which would justify, in your opinion, the replacement of trunk line aerial wires with trunk type underground cable where a long and important main trunk line route enters a city area and what factors would determine—
(a) The length of trunk cable to be provided;
(b) the route to be adopted;
(c) whether lead-covered cable in ducts or armoured cable is used;
(d) the number of pairs in the cable to be used and whether the conductors should be contained in a single cable or divided into two separate cables.
If the trunk cable requires to be loaded, partly for carrier working up to 30 kilocycles and partly for voice frequency working up to 10 kilocycles, what value of inductance would be selected for the loading coils in each case and at what approximate spacings would they be located in the cable run?

A.—The considerations which would justify the replacement of trunk line aerial wires with trunk type

U.G. cable where a long and important trunk line route enters a city area are:—

1. The condition of the pole route: A high proportion of the poles and fittings may require renewal; there may be long spans, wires of mixed gauge and class, and the route may be loaded to the limit of the pole capacity.

2. The grade of service may be poor on account of mechanical weaknesses or electrical interference. Such conditions may be due to—

(i) The existence of long spans and irregular wire tensions and angles in the pole line which are difficult to stay adequately;

(ii) The presence of trees overhanging or close to the route;

(iii) The proximity of old wooden buildings with a high fire risk;

(iv) The existence of power parallels;

(v) A large number of electric power crossings may exist or neon signs be erected close to the trunk wires.

3. To meet further development the circuits must be suitable for the operation of carrier systems and their electrical characteristics require to be modified for that purpose. These characteristics include impedance, attenuation and crosstalk, the most important in the case of loops into carrier repeater stations being Near End Crosstalk.

4. Economic comparison of costs.

5. Apart from factors 1 to 4, other considerations which may influence such action include:—

(i) Aesthetical considerations;

(ii) When the operations of other public authorities will necessitate considerable alterations to the trunk route.

(a) The factors which would determine the length of cable to be provided include:—

(1) Whether the existing aerial route is a loop at a repeater station, in which case the cable would be laid for at least the full length of the loop.

(2) The length of cable should ensure that the terminal pole or poles are so located that the cable will carry the lines clear of the principal hazards to aerial construction associated with the trunk lead into the city.

(3) The cable should be laid to a suitable point to locate the terminal pole or poles and as far as or beyond any branching point so that the aerial routes beyond the terminals will not be heavily loaded and any extensions of the cable will be unlikely for many years, as such extensions will involve high costs in modifying the adjacent transposition sections.

(4) In conjunction with the above factors the length of the cable will be influenced, to some extent, by the transposition section layout of the main aerial trunk route. For example, it might be desirable to extend the cable for a short distance beyond a point otherwise considered suitable in order to obviate the inclusion of a short transposition section or to save the pole respacing work required to reduce the irregularities in the spacing of transposition poles which may exist in the first one or two transposition sections.

(5) Consideration of the establishment of a carrier repeater station on the outskirts of the city associated with the eventual complete replacement of the aerial route by a carrier cable and the suitability of the present proposed station (and terminations of the cable) in the full cable scheme.

(b) The route to be adopted would be the shortest from the exchange to the trunk terminal pole subject to the following considerations:—

(1) Location and availability of existing conduit routes.

(2) Laying costs of new conduit routes.

(3) Likelihood of interference from—

(i) Mechanical damage;

(ii) Electrolytic corrosion;

(iii) Chemical corrosion;

(iv) Insect attack.

(4) Location of loading points to ensure satisfactory spacing of loading coils for the various frequencies for which the cable will be loaded.

(c) The factors which would determine whether lead-covered cable in ducts or buried armoured cable would be used include:—

(1) Economic considerations:

When considering the provision of ducts for the trunk cable in city areas, due allowance must be made for the development of subscribers' services along the route and, therefore, it is likely to be economical to provide conduits, if not already existing, and use unarmoured trunk cable in one of the ducts.

(2) Liability to mechanical damage:

Cables in ducts are less liable to mechanical damage than buried cables, but they may be more subject to damage from electrolysis, chemical corrosion and insect attack.

(3) Flexibility:

Armoured cables buried under paved footways and roadways in city and suburban streets are much less accessible for repairs or additions than unarmoured cables in a duct. For reasons of flexibility and accessibility, therefore, trunk cables are usually laid in ducts in city or inner suburban areas, while the use of buried armoured cable is usually confined to outlying localities.

(d) (1) The size of the cable would be determined by—

(i) Rate of development;

(ii) Availability of ducts laid.

In general, the size of the cable will be sufficient to provide for the 20-year development of the route, but if this requires a large cable in ducts it may be more economical to provide two cables—one now and the other in 10 years' time—to meet the development over the two ten-yearly periods.

(2) The provision of one or two cables would be determined primarily by—

(i) Whether the route is a loop to a carrier repeater station:

Where a loop is under consideration, two separate cables will normally be provided for "in" and "out" pairs to the repeater station, as the screen provided by the lead sheaths eliminates the serious Near End Crosstalk problem which exists where "in" and "out" pairs are in the one cable and the power levels transmitted in these directions differ greatly. In such circumstances the small increased cost of two cables compared with one cable is more than compensated for by the advantages in improved electrical characteristics.

(ii) The eventual development plan for the route:

Even when a loop to a carrier station is not being considered and a single cable might be otherwise satisfactory, consideration of future requirements may show that ultimately the main route will be replaced by two carrier cables provided on the "go" and "return" system so that it may be found desirable to install two such cables at the outset over the section at present being dealt with.

Loading of Trunk Cables.—Circuits in trunk entrance cables operating up to 30 kC/sec. require to be loaded with 3.5 mH inductance coils spaced at approximately 705 feet for star quad cables and 750 feet for multiple twin cables.

Circuits operating up to 10 kC/sec. require to be loaded with 14.0 mH inductance coils spaced at approximately 3000 feet.

The remainder of the circuits would be loaded for V.F. operation up to 3 kC/sec. To match the impedance of the cable portion of these circuits with the open wire portion they would be loaded with 28.0 mH coils spaced at approximately 6000 feet.

Q. 2.—(a) Discuss the general principles upon which economic comparisons between alternative methods of undertaking engineering works are based.

(b) Consider the following problem of dealing with an aerial trunk line route between two towns 20 miles apart which already carries six crossarms full of wires. An average of two additional physical circuits will be required each year, and the route is capable of carrying additional wires to meet requirements up to a maximum period of seven years hence, but extensive pole replacements and other alterations are now necessary in order to meet up-to-date requirements.

Describe in detail the procedure you would follow in making an economic comparison between the following methods of dealing with the problem:—

(1) Retain the aerial route, carry out the repairs and alterations required, adding the additional circuits each year until the seventh year, after which, by the eighth year, the route must be replaced by an armoured underground trunk cable.

(2) Replace the route now with an armoured trunk underground cable of sufficient size to meet the estimated 20-year requirements.

(3) Lay an underground pipe line now, replace the aerial route with an underground trunk cable that will meet requirements for ten years and at the end of that period provide a second cable to meet requirements for a further ten years by drawing it into the same pipe.

To illustrate the procedure suitable amounts to represent the estimated capital costs likely to be involved in the various methods, together with suitable percentage rates covering interest, maintenance and depreciation charges, may be assumed.

A.—(a) When investigating the economics of two or more schemes for the provision of telephone plant to meet expected development it is necessary to bring the varying charges concerned to a common basis. The common basis used is known as the "Present Value," and is the amount which, if immediately invested at the prevailing rate of interest, would provide the money necessary to meet all the capital and annual charges incurred during the period over which the comparison is being made.

The period being considered must be the same for all the proposals being compared, and unless it is known that the plant will be abandoned at the end of a definite period, all economic comparisons assume that the plant will be kept in service for ever. The calculations on this basis are known as "Perpetuity Calculations."

In general, Perpetuity Calculations involve consideration of:

(i) Capital costs both initially and those required later for the extension of the plant.

(ii) Maintenance and renewal costs, both for the plant provided at the beginning and any subsequent extensions.

All these costs are then reduced to a Present Value basis and the total Present Value of the capital costs is the amount of money which must be invested now at the ruling rate of interest to provide the initial outlay and the cost of extending the plant as required, to meet development.

The Present Value of the maintenance and renewal costs, usually referred to as the annual charges, is the sum of money which, invested now at the ruling rate of interest, will provide an annuity equal to the amount of these charges as they become due. In Perpetuity calculations this annuity will enable the plant to be maintained and renewed so that it will provide service for ever.

The Present Value of the scheme in perpetuity is then the sum of all these Present Values and by calculating this value for all the proposals being considered a comparison of the economics of each scheme can be made.

Where it is known that the existing or proposed plant will only be retained for a definite period, the Present Value of the annual charges will be that amount which will provide an annuity equal to the maintenance and renewal charges only over the period being considered. The Total Present Value charges to the end of that period will be credited with the Present Value of the Recoverable Value of the dismantled plant and debited with the Present Value of the Capital Cost and Annual Charges of the plant by which it is replaced.

(b) The following calculations relate to the making of economic comparisons between the schemes proposed in (1), (2) and (3) in connection with the replacement of an aerial trunk route between two towns 20 miles apart with U.G. cable, and are based on an Interest Rate at 5 per cent.

(1) Retain aerial route and add two additional physical circuits until its full capacity is reached at the end of the 7th year, when it must be replaced by an armoured U.G. trunk cable.

(i) **Aerial Wire Costs.**

Capital.		
Value of existing pole route, 960 wire miles @ £20 per wire mile	£19,200	
20 miles of pole line @ £240 mile	4,800	
	————	£24,000
Value of two physical pairs of wires, including arming costs: 80 wire miles @ £25 per wire mile	2,000	
Cost of repairs to route required immediately, including pole replacements, etc.	3,000	
Maintenance.		
Annual maintenance charges for pole route @ 45/- per mile	45	
Annual maintenance charges for existing 960 miles of wires @ 11/- per wire mile	528	
Annual maintenance charge for additional circuits = 80 wire miles @ 11/-	44	

Sinking Fund.

Sinking fund for pole route = 3.6% of capital cost.

Sinking fund for wires = 1.9% of capital cost.

Residual Value.

Residual value of pole route in 7 years' time 2,500

(ii) **Cable Costs.**

Size of cable required:—Cable required to meet 20-year development figures. Assume 2 physical pairs represents 3 channels per annum and no carrier systems are operated on this route.

Existing channels	=	36
3 channels per annum for 20 years	=	60
		96 channels

Lay 104 pr. 20 lb. S.T.Q. armoured cable with loading.

Capital.

Cost of laying 20 miles of 104 pr. 20 lb. S.T.Q. armoured cable @ £1,100 per mile	£22,000
Cost of loading 96 pairs @ £2/10/- per pair mile	4,800
	£26,800

Maintenance.

Annual maintenance charge for cable @ 1/- per wire mile £208

Sinking Fund.

Sinking Fund for cable = 1.4% of capital cost.

(iii) **Perpetuity Calculations.**

Capital Expenditure.

Amount	Date	Factor	P.V.	Details
3000	Immediately	1.0	3000	Repairs and renewals to aerial route.
2000	1st year	.952	1904	Cost of additional physical circuits per annum.
2000	3rd ,,	.907	1814	
2000	4th ,,	.864	1728	
2000	5th ,,	.823	1646	
2000	6th ,,	.783	1566	
2000	7th ,,	.746	1492	
26,800	8th ,,	.711	19,055	Cost of armoured cable and loading.
Total P.V. of Capital Ex.			32,205	
Less P.V. of residual value of asset replaced. 2500 × .711			1,778	
Nett P.V. of Capital Expenditure			30,427	

Annual Charges

Amount	Commencing	Factor	P.V.	Details
573	Immediately	5.87	3364	Existing route. Maint. £573 required to end of 7th year. No S.F. as route then to be replaced by cable.
44	2nd	4.83	213	Additional physical circuits required to end of 7th year.
44	3rd	3.92	172	
44	4th	3.07	135	
44	5th	2.24	99	
44	6th	1.46	64	
44	7th	.711	31	
583	8th	14.2	8279	Maint. £208, S.F. £375 for armoured cable.
Total P.V. of Annual Charges			12,357	
Total P.V. of all charges			42,784	.... (1)

(2) Replace aerial route now with an armoured trunk cable to meet 20-year requirements. The data under (1) will also apply in this case, except that the residual value will be reduced to £2,000 as the 7-year value included 14 additional pairs of copper wires.

(i) **Perpetuity Calculations.**
Capital Expenditure.

Amount	Date	Factor	P.V.	Details
26,800	Immediately	1.0	26,800	Cost of armoured cable and loading.
Less P.V. of residual value of asset replaced			2000	
Nett P.V. of Capital Expenditure			24,800	

Annual Charges.

Amount	Commencing	Factor	P.V.	Details
583	Immediately	20.0	11,660	Maint. £208, S.F. £375 for armoured cable.
Total P.V. of Annual Charges			11,660	
Total P.V. of all charges			36,460	(2)

(3) Lay conduit now and replace aerial route with underground trunk cable to meet requirements for 10 years and then provide a second cable to meet requirements for a further ten years, by drawing it into the same pipe.

(i) **Sizes of cable required.**

Existing circuits	36
First 10 years' development @ 3 circuits per annum	30
	66
Second 10 years' development @ 3 circuits per annum	30
	96

Therefore, provide 74 pr. 20 lb. S.Q.T. cable initially and 28 pr. 20 lb. S.Q.T. cable in 10 years' time with loading.

(ii) **Capital.**

Value of 20 miles of conduit @ £700 per mile	£14,000
Value of 20 miles of 74 pr. 20 lb. S.Q.T. cable @ £700 per mile	£14,000
Value of 20 miles of 28 pr. 20 lb. S.Q.T. cable @ £400 per mile	8,000
Residual value of pole route	2,500
Cost of loading 74 pairs @ £2/10/- per pair mile	3,700
Cost of loading 22 pairs @ £2/10/- per pair mile	1,100

Maintenance.

Annual maintenance charges for conduit @ 23/- per duct mile	23
Annual maintenance charges for 74 pr. cable @ 1/- per pair mile	148
Annual maintenance charges for 28 pr. cable @ 1/- per pair mile	56

(iii) **Sinking Fund.**

Sinking fund for conduit—.5% of capital cost.
Sinking fund for Trunk cable—1.4% of capital cost.

(iv) **Perpetuity Calculations.**
Capital Expenditure.

Amount	Date	Factor	P.V.	Details
31,700	Immediately	1.0	31,700	Conduit, £14,000. Cable, £17,700.
9,100	10th year	.645	5,870	Cable, £17,700
Total P.V. of Capital Expenditure			37,570	
Less P.V. of residual value of asset replaced			2000	
			35,570	

Annual Charges.

Amount	Commencing	Factor	P.V.	Details
497	Immediately	20	9940	**Conduit.**—Maint. £23. S.F. £70. **Cable.**—Maint. £156. S.F. £248.
183	10th	12.9	2361	**Cable.**—Maint. £56. S.F. £127.
Total P.V. of Annual Charges			12,301	
Total P.V. of all charges			47,871	(3)

(4) The total P.V. for each of the schemes is, therefore:

(1) £42,784;
(2) £36,460;
(3) £47,371;

and it would, therefore, be most economical to replace the aerial route with armoured trunk cable immediately.

(To be Continued.)

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COMMUNICATIONS:

All communications should be addressed to:—

A. R. GOURLEY,
Hon. Secretary, Postal Electrical Society of Victoria,
G.P.O. Box 4050, Melbourne.

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