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THE POSTAL ELECTRICAL SOCIETY OF VICTORIA

The
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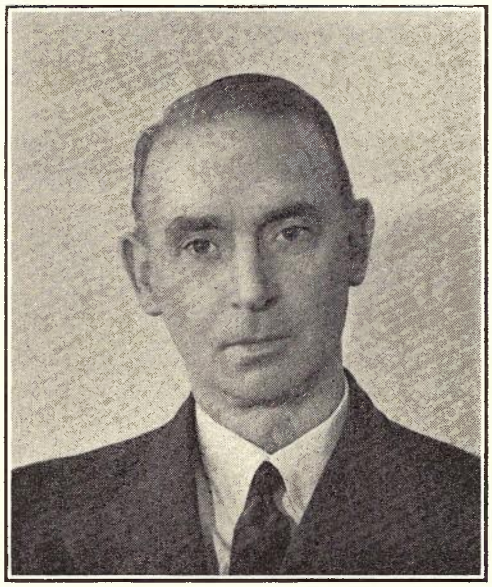
MR. R. V. McKAY, A.M.I.E.(Aust.)



The Society extends its congratulations to Mr. R. V. McKay, A.M.I.E.(Aust.), on his appointment as Chief Engineer of the Post Office. His ability, wide knowledge and drive have thus been officially rewarded, but to his associates his outstanding characteristic is that he is a man's man and this has won him the respect and regard of his colleagues. His ability in sport, the genuine enjoyment with which he joins in social games, his ready assistance to anyone in difficulties, are well known and form an enviable background for the arduous duties of Chief Engineer.

A wide experience in New South Wales has prepared him for his present position. His rapid rise at all stages of his official career indicates the confidence he has inspired in his superiors. Upon completing his schooling in Sydney he joined the Department as Cadet Engineer in 1908. After the prescribed four years of training he passed the examinations to become an engineer in 1913, but immediately acted in the grade equivalent to Divisional Engineer, to which he was appointed in 1914.

For some years he was in charge of the Dubbo engineering district and the valuable experience gained there in district work and the organization of engineering undertakings has been evident in his subsequent progress. In 1924, he was recalled from the country to take the position of Supervising Engineer, Telephone Equipment, in Sydney, and in this capacity he directed the development of the network of exchanges throughout New South Wales. By his appointment in 1934 as Supervising Engineer, Central Office, his controlling influence was extended to the telephone equipment of the whole of the Commonwealth. The classification of this position was twice raised while he occupied it, and when the Chief Engineer was away from the office Mr. McKay was empowered to take over certain of his duties.

Mr. McKay has supported the activities of the Society by attending meetings, offering advice or suggestions and contributing an article to the Journal, and in his new appointment he has our confidence and good wishes.

MR. R. LAWSON, O.B.E., M.I.E.(Aust.)

Our former Chief Engineer, Mr. Lawson, has accepted appointment with the Air Board as Director-General of Supply and Production and has also been made a member of the Aircraft Production Commission. The selection of Mr. Lawson for these positions causes no surprise to his colleagues in this Department. The successful promotion of our war effort will depend on the men who control these activities, and the organizing ability and energy of our former Chief are very necessary qualities in this connection.

The Society loses a very good friend in Mr. Lawson. He has given assistance in many directions and one of his last acts while he was Chief Engineer was to read a paper on "The Sydney-Newcastle-Maitland Telephone Cable" to a meeting of the Society.

The good wishes of the Society go with Mr. Lawson in his new sphere. It is unnecessary to inform our readers of his official career, which was given in the issue of December, 1936. Since that date, Mr. Lawson has been a member of Boards enquiring into the Civil Aviation organization and matters affecting the Works Department, indicating the confidence the Government had in his ability, which has now culminated in the appointments referred to above.

The Sydney-Melbourne Type J Carrier Telephone System

J. T. O'Leary (Bell Telephone Laboratories Inc., New York) J. B. Scott (Standard Telephones & Cables Pty Ltd., Aust.)
A. M. Thornton (Standard Telephones & Cables Ltd., London)

Introduction. — The open-wire route between Sydney and Melbourne has a history as old as the telephone art itself. Constructed first in the year 1858 as a telegraph route it has served as one of the main arteries in Australia's communication system. The first telephone channel was opened in 1907. Since then, by the continued application of modern developments, it has taken care of the ever expanding traffic between the two largest cities in the Continent.

The carrier current art has played a prominent part in the development of this route. The business growth that came after the close of the last war was largely met by the application, first of the type B and later the type C carrier telephone systems, each of which provided three additional telephone circuits on a particular pair. Later, a special carrier programme circuit was applied to serve as a connecting link between radio broadcasting stations.

Now that the route is again rapidly approaching the saturation point with respect to these types of systems, the latest open-wire carrier system has been called upon to provide the necessary circuits to meet the increase in the volume of traffic. This new system is known as the type J system and provides 12 channels on a single pair in addition to the three channels already derived from a type C system and the normal voice-frequency circuit. The total capacity of a pair thus equipped is 16 telephone channels.

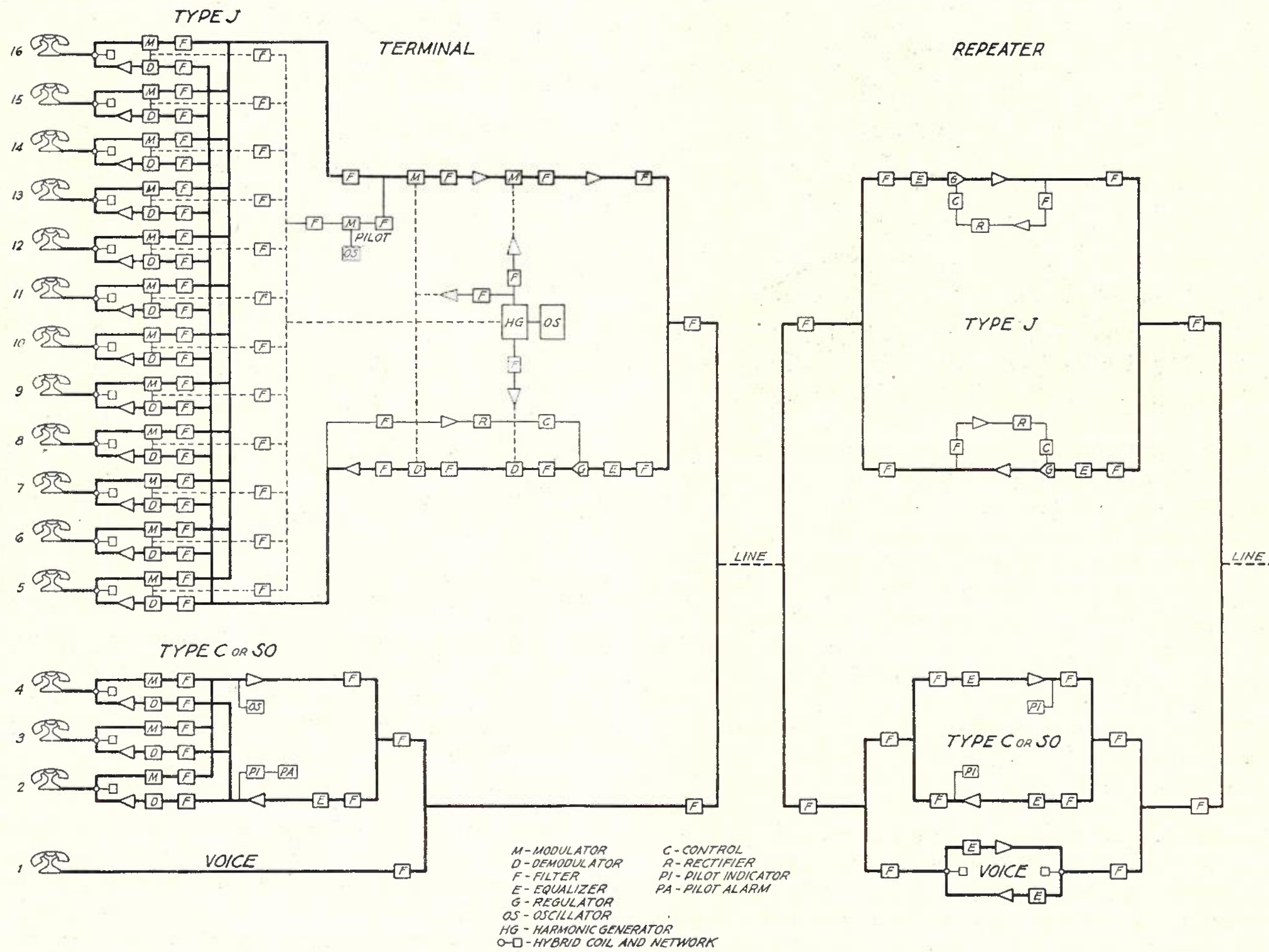


Fig. 1.—Terminal and Repeater Layout.

Five years ago, in order to operate successfully the large number of carrier systems between Sydney and Melbourne or intermediate points, the Postmaster-General's Department reconstructed the top crossarms on the line to give an insulator spacing of 9 ins., 18 ins., 9 ins. instead of 14 ins., 14 ins., 14 ins. and a vertical spacing of 28 ins. between the arms. At the same time additional transpositions were inserted, the frequency range covered being suitable for type C systems, i.e., up to 30 kc. This modification was applied to the top three arms between Sydney and Goulburn and the top two arms between Goulburn and Melbourne.

As the amount of traffic increased still further, the Department was faced with a major line reconstruction to accommodate still more type C systems or an alternate cable scheme. Either of these projects would involve a very large capital outlay, particularly as the great bulk of the traffic is between the two terminal cities and consequently new circuits are required over the whole distance. The development of the J System opened up the possibility of obtaining additional channels on the line without undue expense. The ultimate scheme could then be deferred or else proceeded with by instalments and the cost spread over a considerable period. Thus, for example, it would be practicable to commence laying a cable at the ends of the route where traffic density is highest and still obtain sufficient through circuits on the intermediate open-wire line by means of the C and J systems.

With these economic aspects in mind the Department initiated a series of measurements on the line to ascertain its capabilities. The results showed that at least one of the carrier transposed pairs had general transmission characteristics quite suitable for a J system, and that very little additional work on the line would be required except in the treatment of "in" and "out" loops at some of the repeater stations.

Consideration has also been given to the application of more than one J system to the route and this aspect is discussed in a later section of this article.

Brief Description of J System

A full description of the J system, which was developed by the Bell Telephone Laboratories, has been given in the Bell System Technical Journal[(1)] and it is not, therefore, proposed to give more than a brief outline of the system itself in this article, the main object of which is to describe its application in Australia.

Circuit Arrangements.—Fig. 1 shows the schematic arrangement of the terminal and repeater equipment of the 12-channel system and also the three-channel system associated with it on the same pair.

In principle the J system is similar to existing three-channel systems, inasmuch as different frequency groups are used in the two directions of transmission and hence equivalent four-wire operation is obtained over the open-wire pair. The four frequency allocations available are shown in Fig. 2, the one equipped between Sydney and Melbourne being of the NA type.

The inputs of the 12 channels pass from the four-wire terminating sets to the copper-oxide modulators and the band filters and then to a common transmitting group circuit. At this

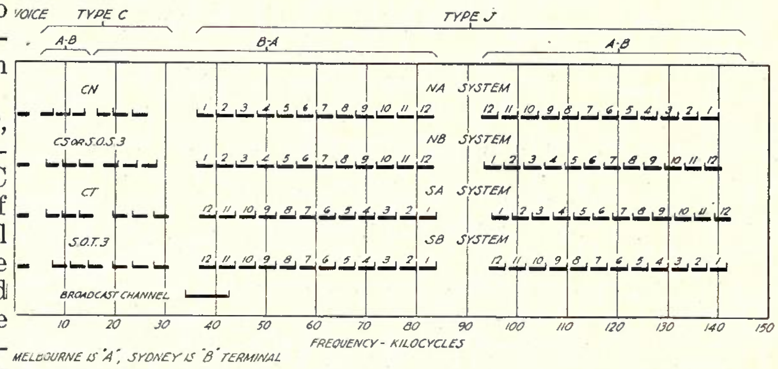


Fig. 2.—Frequency Allocation. (The present Melbourne-Sydney System is Type N.A.)

point a single frequency pilot current is introduced and is protected by a narrow band elimination filter which prevents interference in the pilot channel from the sideband of the adjacent channel.

The frequency range occupied by the channels at this stage is 60-108 kc, as shown in Fig. 3. This diagram also indicates the frequency translations and the carrier frequencies used in the subsequent stages of modulation and demodulation.

The channel and pilot currents are modulated in the first group modulator by a 340-kc carrier and the sideband occupying the range 400-448 kc is selected by the transmitting band filter and passed on to the intermediate amplifier and second group modulator. In this stage of modulation the carrier frequency employed depends on the direction of transmission; at the Sydney terminal it is 484 kc and at the Melbourne terminal it is 308 kc. The output currents then pass through a low-pass filter, having a cut-off of about 200 kc and the sidebands which now occupy the frequency range required on the line are amplified by the transmitting amplifier and proceed via the directional filters and line filters to the line.

The receiving portion of the terminal equipment operates in a similar but inverse way in order to produce from the received line frequencies the primary group of 60-108 kc for the final stage of demodulation to voice frequencies. The group receiving circuit also contains a regulating amplifier which automatically inserts or removes artificial line under the control of the incoming pilot current in order to maintain a constant output level to the receiving channel equipment despite changes in the line attenuation. This apparatus has already been described in the article (1) cited above.

The primary modulation stage to the 60-108 kc

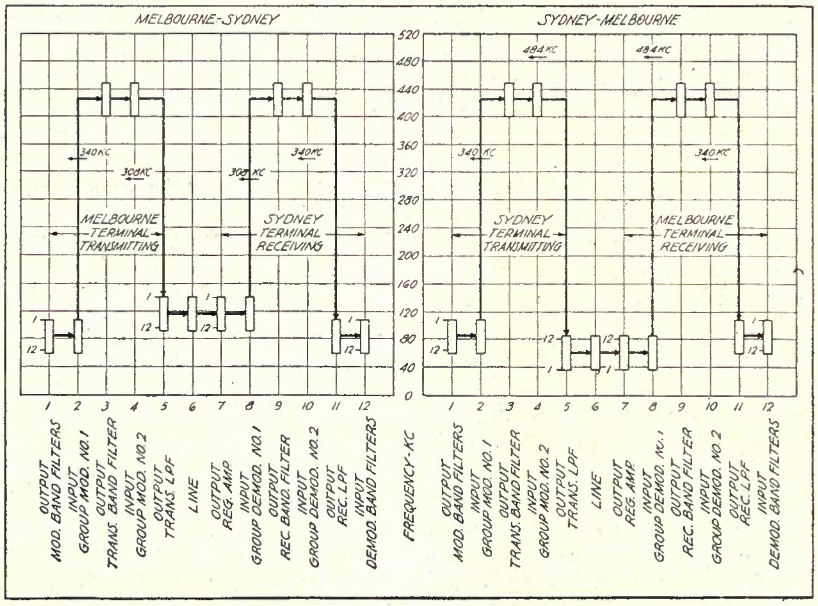


Fig. 3.—Frequency Translations of N.A. Systems.

range is common to the latest types of carrier systems, e.g., the 12-channel cable system, the open-wire J system and the coaxial system. This choice of frequency range enables crystal filters to be efficiently used as the channel band filters with consequent improvement in quality. In the case of the J system, some of the frequencies required on the line overlap those produced in this primary group and consequently two stages of group modulation are required to make the necessary frequency translation without interference.

The repeaters of the J system are similar to those of the C system in principle, but a regulating amplifier is used to insert or remove artificial line as at the terminal, while a fixed gain power amplifier actually supplies the gain and basic equalization required for the preceding repeater section.

The carrier supplies are primarily derived from a valve controlled by a tuning fork in an oscillatory circuit which feeds a fundamental frequency of 4000 cycles into a small coil. This coil, which has a permalloy core, is operated in a magnetically saturated condition and the output from the circuit is rich in odd harmonics of 4 kc. The even harmonics are obtained from an associated copper-oxide modulator.[2] From the harmonic generator circuit are obtained all the frequencies required for the channel modems and also for the group modulators and demodulators, although the group carriers require some degree of amplification in order to obtain the necessary power. The general arrangement of the carrier supply circuit is indicated in Fig. 1. Actually as many as ten systems can be supplied from one common set of apparatus, which is duplicated, the emergency supply automatically being brought into service in the event of failure in the regular supply.

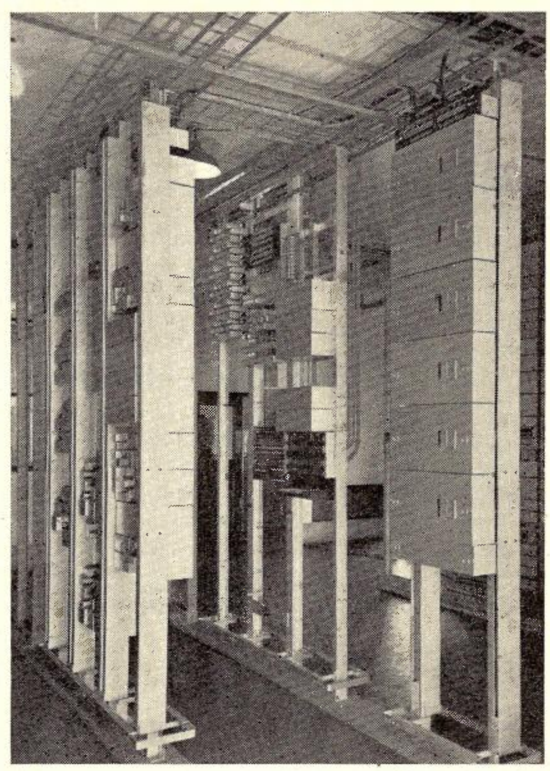


Fig. 4.—Terminal Equipment at Melbourne.

Equipment. — The accompanying photographs show that the apparatus itself follows modern practice in general, although certain changes have been made in the framework construction of some of the bays in order to provide suitable runways for the wiring. This is illustrated in Fig. 4, which shows the Melbourne terminal

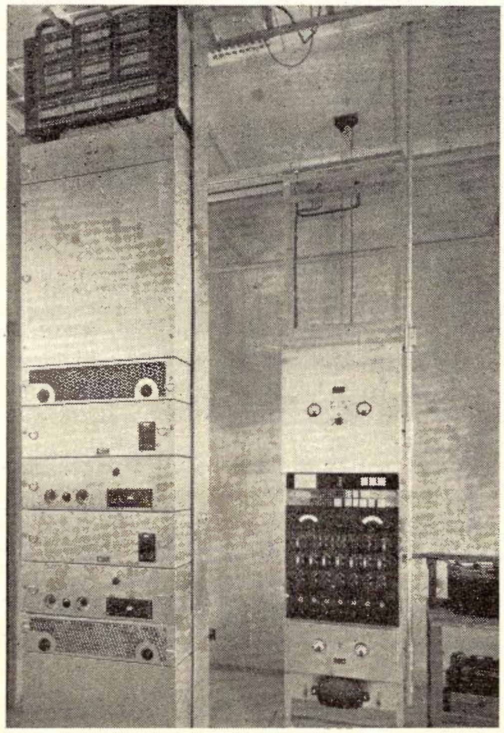


Fig. 5.—Repeater Bay and Power Bay—Euroa.

equipment. Three of the bays in the right-hand row are of the usual channel-iron construction, while the remaining bays employ the built-up frameworks which enables interpanel and interbay wiring to be connected directly into the panels and at the same time to be accessible from the front. Provision is also made in the side troughs for shielding and segregation of the wires. In the left-hand row are the channel and group carrier supply bays and group terminal bay. At the right-hand end of the other row is a channel bay while beyond this is a line bay mounting cable terminal, protectors, line filters and high frequency patching jacks. The miscellaneous bay and four-wire terminating bay complete the installation. A great deal of this apparatus is common to several systems and three more systems could be provided by the addition of six additional bays.

Figs. 5 and 6 show two views of Euroa unattended auxiliary station. Apparatus associated with the repeater proper mounts on the left-hand bay in Fig. 5. One such bay is required for each repeater. Fig. 6 shows the north and south line filter bays with space on either side for additional line filter bays or crosstalk suppression filter bays as required. A trench in the floor runs between the manholes which are located in the corners of the room and the disc cables are brought in at the bottom of the bay instead of at the top as is usual. Above the protectors are located the loading unit, the line filters and high frequency patching jacks. The miscellaneous bay at the end of the row mounts fuse panels for miscellaneous power supplies and the alarm trunk unit.

Power Supplies.—The J system is designed to use the 24-volt filament and 130-volt anode batteries which normally serve existing C type carrier apparatus at main repeaters and terminals. The valves have indirectly heated cathodes so that it is possible to utilize a plate potential of 154 volts obtainable from the two batteries in series.

At auxiliary repeater stations where it is desirable that the apparatus should work without attention over a considerable period, a new type of power plant is used. The main battery consists of 70 cells connected in series and main-

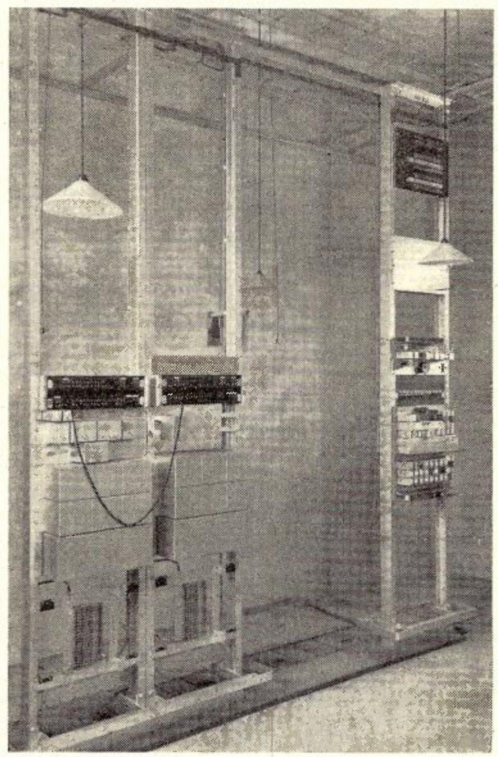


Fig. 6.—Line Filter Bays—Euroa.

tained at 152 volts by a floating charge from a mains operated rectifier. The battery is tapped every 10 cells and the various heater circuits for the valves are connected across the sections of 21.7 volts in such a way that a uniform drain is obtained on all sections. Variable rheostats are bridged across each segment of the battery in order to balance out departures from uniformity due to minor differences in valve heater elements.

The negative end of the battery is earthed and the full potential of 152 volts is available for the anode circuits. A simplified schematic of the arrangement is shown on Fig. 7 and the right-hand bay in Fig. 5 illustrates how the equipment is mounted at Euroa.

The rectifier for the main battery is mounted near the top of the bay. This unit consists essentially of two three-element mercury vapour

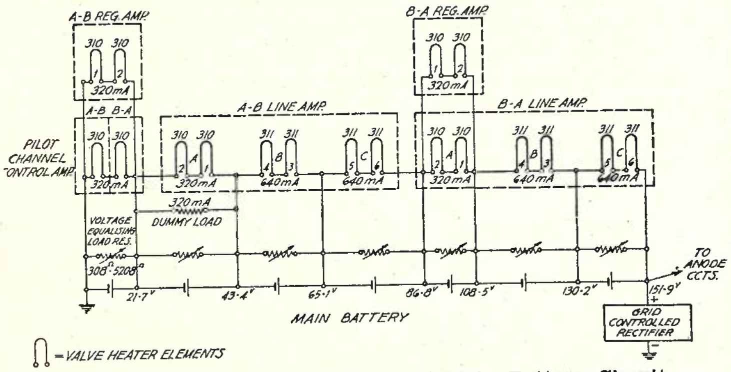


Fig. 7.—Simplified Schematic of Main Battery Circuit at Auxiliary Repeaters.

tubes operating as a full-wave rectifier from a single phase a-c supply. The output current depends on the phase relation of the voltage applied to the grids of these tubes with respect to their plate voltages. When a heavy load is demanded from the rectifier, the grid voltages are arranged to be in phase with the plate voltages. As less current is required, the control circuits adjust the grids towards the out-of-phase condition. Control of the charging rate may be manual or automatic as desired. In normal operating conditions the rectifier is charging under automatic control to maintain the battery at a constant voltage of 152 and the rate, therefore, is just sufficient to supply the repeater and to make up any losses.

In the event of a mains failure the repeater load is taken from the battery and if the failure exists for some time the battery voltage will be lowered and the available reserve may be considerably depleted. Restoration of the supply would cause the rectifier to charge at an excessive rate unless adequately safeguarded and so, after a power failure, it automatically charges at a constant safe current of approximately 8 amperes until the battery reaches 156, whereupon a high voltage contact is operated on a voltmeter relay and the rectifier returns to its normal condition to supply a floating charge which will maintain a constant voltage of 152 again. Automatic regulation involves the use of two additional valves and associated apparatus which are replaced by a simple rheostat circuit when it is desired to control the charge by hand.

Faulty operation of the plant is indicated by alarms which are registered locally if the office is attended or in the case of an unattended office are relayed to the nearest main repeater station. In Fig. 5 the main distributing panel can be seen located between the upper and lower rectifier panels on the right-hand bay. Push buttons on this panel enable the voltage to each section of the battery to be read separately while the balancing rheostats are adjusted by means of a screwdriver from the front. The total drain on the 152-volt battery at an auxiliary station is approximately 1 ampere for each type J1 repeater.

The lower rectifier panel shown in the photograph is used to charge the small 24-volt battery which can be seen at the extreme left on the lower shelf. This battery is used to supply the relays of the repeater regulators and certain other miscellaneous circuits in which the drain is intermittent and which could not be uniformly spread over the 152-volt battery. The 24-volt rectifier is a single valve type which automatically holds the battery to a mean constant voltage although it does not supply sufficient current to cope with the momentary drains on the battery.

The small motor generator at the bottom of the bay is used as an emergency source of A.C. supply for the synchronous motors, which drive the pilot channel regulating condensers, when the main supply fails. Under such conditions it starts automatically and runs from the 152-volt battery until the mains supply is restored.

Of the six auxiliary repeaters on the route, five are equipped with this type of power plant. At Cootamundra use is made of 24 and 130-volt batteries which already existed. Cootamundra is, therefore, treated as a main repeater station in this respect and uses filament circuits designed to operate from an unregulated 24-volt battery. The valves used at both main and auxiliary repeaters have identical electrical characteristics but differ slightly in heater construction and power consumption. Ballast lamps are necessary at main repeaters and terminals where unregulated 24-volt filament batteries are employed.

Problems Involved in Equipping One J System

General.—In considering the Sydney-Melbourne route it was decided that initially one J system should be installed on the line with as little additional work and expense as possible. Existing offices would be used for repeater stations, even if these were not necessarily the most suitable from a transmission point of view. The final choice of stations and the distances between them in route miles are given in Fig. 8 together with the lengths of "open wire" loops on which the lines are brought in from the trunk route to the repeater station buildings. At one station only, i.e., Euroa, was a new building erected, and this was constructed and equipped as a complete unattended auxiliary repeater following the latest practice.

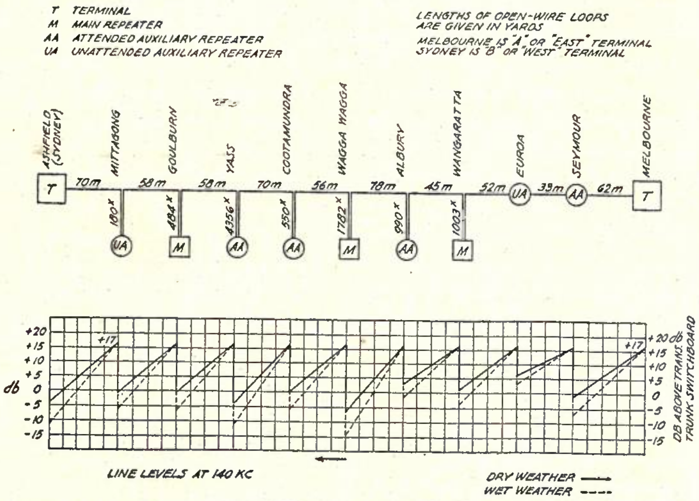


Fig. 8.—Line Layout and Level Diagrams.

It is not proposed to deal here in detail with the problems which arise due to the extension of the frequency range on the line from 30 to 140 kc. These have been adequately described in a previous article(3). Briefly, the chief difficulties to be met are the general increase in line attenuation at the higher frequencies, the possible irregularities due to absorption and the increase in crosstalk. Short lengths of terminal and intermediate cable become more critical.

Line Attenuation. — Typical attenuation-frequency characteristics are shown in the table for the various wire gauges found on the route.

TABLE 1
TYPICAL MEASURED LINE ATTENUATION VALUES (DRY WEATHER)

Frequency	Loss in db per Mile		
	200 lb.	300 lb.	600 lb.
30 kc	.145	.130	.095
50 kc	.180	.160	.115
100 kc	.250	.228	.170
140 kc	.295	.268	.205

Fig. 8 also shows the wet and dry weather losses at 140 kc for the pair which was ultimately chosen as the normal working line for the J system (pr. 3499-0).

The density of the wires on the crossarms falls away somewhat over the centre portion of the route but four through pairs were considered as possible working or patching pairs for a J system. From an inspection of the transposition diagrams and the results of certain measurements made along the route by the Department, the opinion was formed that circuits would be subject to absorption peaks in the following order:—

1. 200 lb. Pair No. 3499-0 (Best).
2. 600 lb. Pair No. 399-0.
3. 300 lb. Pair No. 521-2.
4. 200 lb. Adjacent to No. 3499-0 (Worst).

The relative positions of these pairs over a considerable portion of the route is shown in Fig. 9. In planning the system, consideration was given to the use of the 600 lb. pair for the J. system owing to its lower attenuation and suitable location on the top crossarm. However, as most of the pairs on this route are 200 lb. and as the measured attenuation characteristics favoured 3499-0 it was eventually decided to use 3499-0 as the normal line. The age of the 600 lb. pair was a further argument against its use for regular operation. This left the 600 lb. pair

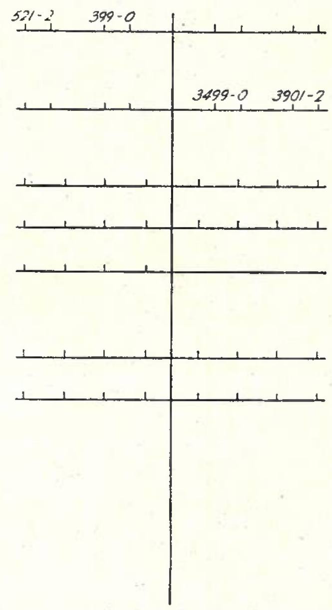


Fig. 9.—Typical Pole Head Diagram.

as the first choice for the spare line, but because it was desirable to have fairly close similarity of impedance and attenuation characteristics between the normal and spare lines, it was not chosen. Eventually the 300 lb. pair was used as the spare line. This had good characteristics except for a slight absorption peak at about 90 kc.

During the initial line-up of the system it was necessary to take into account the difference in size between the regular and spare pairs. As the 300 lb. pair offered less attenuation than the normal 200 lb. pair, the setting of the regulating condenser for the normal pair had to be such that it could introduce enough loss to compensate for the change to the patch line. This, of course, reduced the available range of compensation for severe weather conditions but only to the extent of about 8-10 per cent., and sufficient range is therefore available to meet any conditions likely to be encountered on this route.

Crosstalk.—In dealing with one system the crosstalk problem is not acute but is confined to keeping down the coupling between the two sides of a repeater in order to provide an adequate singing margin. As can be seen from Fig. 8, at most stations open-wire loops are required to bring the J and other pairs from the main route into the stations. The problem was thus complicated by the introduction of near-end crosstalk between the "in" and "out" pairs on the loop. In places where long loops occurred, it was necessary to retranspose and select pairs. At Wangaratta a new loop for the J normal and spare leads had to be erected as previously all the carrier pairs entered the station through a continuously loaded cable. A typical "Y" pole arrangement at the junction of the main route and open-wire loop is shown in Fig. 10.

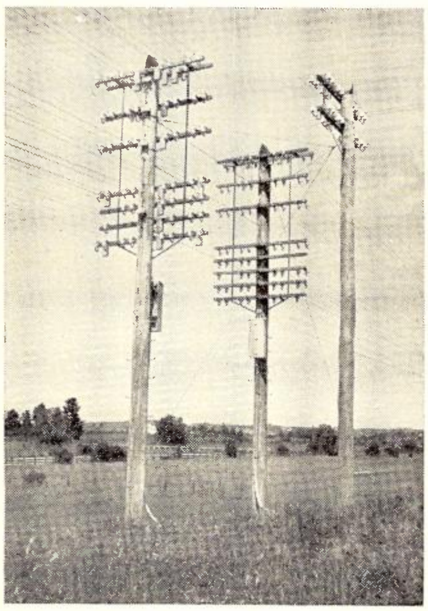


Fig. 10.—Typical "Y" Pole Arrangement.

The crosstalk paths involved are indicated in Fig. 11, which illustrates the arrangement at an auxiliary station such as Yass. Here some pairs go straight through on the main line, while others, including the J pairs, are taken into the station over the loop. The type J repeater is shown. The direct near-end crosstalk path in the

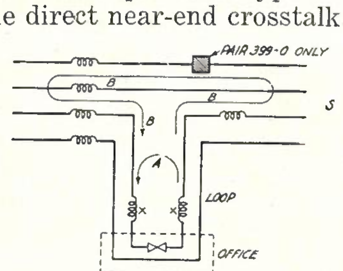


Fig. 11.—Crosstalk Paths—Auxiliary Office with Loop.

loop is shown by A and the interaction crosstalk path by B. One of the important components of the interaction crosstalk is that resulting from conversion of transverse currents in the J pair to longitudinal currents in that and other pairs on one side of the repeater. These currents then flow back to the other side and enter the J pair as transverse currents again. Such crosstalk is controlled by longitudinal choke coils which were inserted in all pairs on the north side of the repeaters and in the J normal and patch pairs on both sides of each repeater. The longitudinal choke coils marked X were used as additional protection for the lead-in cable, loading units and line filters where long open-wire loops existed.

Another important component in the interaction crosstalk is that due to near-end metallic circuit coupling between the J pair and other pairs on both sides of the office. In the case of multi-system operation this would require a crosstalk suppression filter in all pairs at the auxiliary stations. On the Sydney-Melbourne route, with only one system involved, this is a negligible factor except in the case of one pair combination. This particular path is from 521-2 (the spare J pair) back into itself on the other side of the office by way of 399-0. If the J system were operating on 521-2 on both sides of the office simultaneously, the singing margin would not be adequate. A special crosstalk suppression filter was inserted in 399-0 at all auxiliary points to overcome this difficulty.

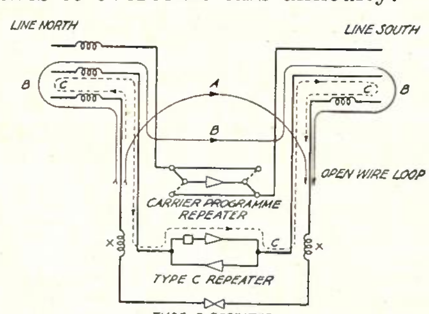


Fig. 12.—Coupling Paths affecting Singing Margin at Main Repeater Station.

The types of crosstalk paths which are of interest at a main repeater station in the case of a single system are shown in Fig. 12.

(1) Path A indicates the direct near-end coupling between the J pairs in the entrance loop and must be reduced by careful transposition and segregation.

(2) Path B shows the longitudinal currents in the north line returning and coupling longitudinally in the loop and on the south line and back again on the south entrance pair as transverse currents. Longitudinal choke coils were fitted on the line in the positions indicated to reduce this form of crosstalk.

(3) Path C shows crosstalk currents from the North J pair returning on another pair and being amplified in the B-A direction of a type C repeater. The amplified currents return on the south J pair due to coupling on the south line.

This type of crosstalk requires a "roof filter" in the type C repeater on the pair which is involved. Similarly a "roof filter" was necessary in the circuit of the carrier broadcast channel repeater.

For other through circuits, or terminating circuits which might be connected through at the switchboard, dependence is placed upon low line crosstalk and high losses in the office equipment or cord circuit to avoid the need for any special treatment. In particular cases the total coupling may be too high and require the use of crosstalk suppression filters as on pair 399-0 at the auxiliary offices.

Paths B and C mentioned above apply particularly to Wagga Wagga, as Goulburn and Wangaratta had separate loaded cables for the non-J type C pairs, and consequently less coupling.

Treatment of Cables.—On the assumption that satisfactory singing margin requirements for the first system could be met by suitable choice of pairs in the loops and the use of longitudinal choke coils, the utmost benefit from these loops was sought in order to bring the J pairs as close to the equipment as possible in open wire. This reduced the entrance and lead-in cables to a minimum. At all stations it was found more convenient to use a new type of disc-insulated cable for the J pairs rather than paper insulated cables where such existed.

The new cable consists of four 16 A. W. G. conductors in star-quad formation supported by hard rubber disc insulators so that the conductors occupy the corners of a square of quarter-inch size. The insulators are small and spaced at intervals of one inch so that the effective insulating medium is air or gas. The pairs in this cable, formed by the diagonals, have a capacitance of only .025 microfarad per mile, which enables their impedance to be matched with the open-wire line by loading at an interval of 600 feet. When loaded the cable introduces a loss of approximately 1.2 db per mile at 140 kc. Apart from the desirability of having low losses in the entrance cables it is also necessary, from consideration of crosstalk, to avoid reflection due to impedance mismatch at the junction of the open-wire line and entrance or intermediate cables. It was contrived that the majority of the lead-in cables on the Sydney-Melbourne route were quite short, that is, less than 150 feet in length, and these could be satisfactorily loaded by means of a single adjustable loading unit located at the equipment end of the cable. This unit was adjusted to give the best values over the J frequency range when measuring the return loss between the cable and a 600 ohm resistance, the cable being terminated in the equipment. The measurement was made on the cable at the junction of the open-wire line, 50 feet compensating leads being used in order to make the connection to the top of the pole. A 600-ohm resistance was used as a reference impedance in lieu of the line because it was impracticable to take the line out of service during these measurements. The general objective of these adjustments was to obtain return losses better than 26 db. which corresponds to a reflection co-efficient of 5 per cent.

Cables longer than 150 feet were necessary at the following places:—

Melbourne Entrance Cable	870 feet
Melbourne Intermediate Cable	468 feet
Yass In and Out Entrance Cables	871 feet
Seymour In and Out Entrance Cables	210 feet

The Melbourne entrance cable and the Yass cables were loaded with terminal loading units and one intermediate loading unit in each case. The presence of only one intermediate loading point enabled the building out of the sections to be made at the terminal only. The loading coils at the line end of the cable were mounted on the crossarms of the junction pole itself as near to the J pair terminal insulators as possible. In this way the leads from the coils to the longitudinal chokes, protectors and open wire connections were kept very short.

The intermediate cable under the railway crossing in North Melbourne required terminal loading coils only. Similarly at Seymour there was no necessity for an intermediate loading point but as the cable section was slightly greater than could be compensated by a single loading unit at the office end an additional coil was mounted on the pole.

Throughout the route one pair in the disc cable was used for the J pair and the other for the spare line. Terminal loading coils at the junction poles and intermediate loading coils were provided for the spare pair, but the loading unit and line filters at the equipment end were only provided for the main pair, patching being performed on the line side of the loading unit. With no crosstalk problem involved it was found that the adjustments of these units, when made for the main 200 lb. pair, were also satisfactory for the spare 300 lb. pair.

After the building-out adjustments on the various loading units were completed and the return loss requirements met, crosstalk measurements were made between the pairs in a quad and also between pairs in the "in" and "out" quads at repeaters. When necessary, crosstalk balancing condensers associated with the loading coils were adjusted to give optimum results.

Transmission Aspects.—Fig. 8 shows the power levels at 140 kc between Melbourne and Sydney. The output per channel from each terminal repeater is 17 db above the transmitting trunk testboard level and the pilot channel power at these points is 10 db. below 1 milliwatt. The circuits are lined up between the trunk boards to give an overall loss of 6 db.; which includes 3 db. switching pads and the loss in the cable between the Ashfield terminal and the Sydney office. Plug-in pads are inserted in the four-wire terminating sets to enable the system to work at its correct levels of —13 db to the modulator and +4 db output from the demodulator. The arrangement is illustrated in Fig. 13.

some additional tests were made by measuring the actual noise produced in the disturbed channels. These values also were within the desired limits. Under actual working conditions with traffic passing on 11 channels no appreciable increase in noise was noticeable on the remaining channel due to interchannel modulation.

As expected, crosstalk into the carrier broadcast channel operating in the range 34-42.5 kc

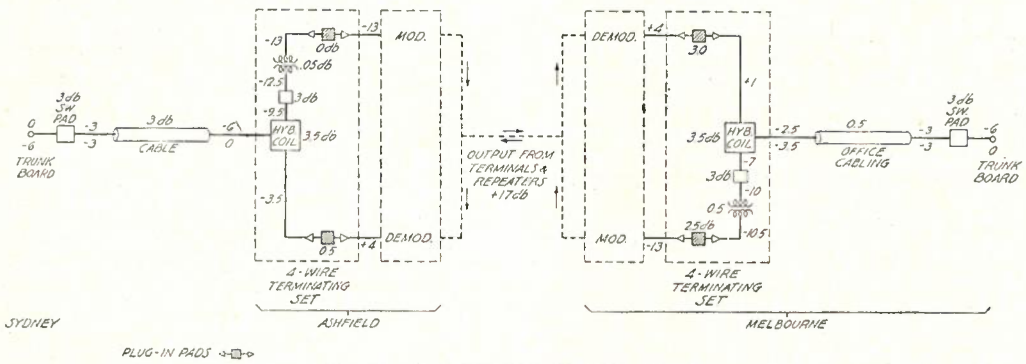


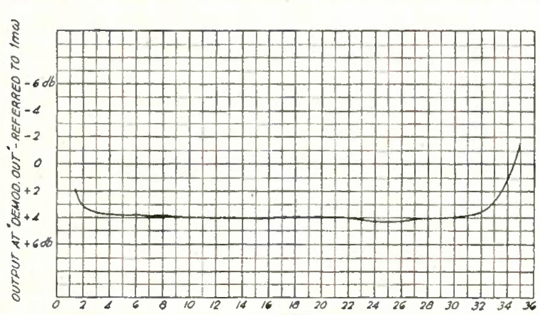
Fig. 13.—Overall Transmission Levels.

on one of the pairs on the route caused considerable difficulty and when this was in operation it was necessary to close channels 1 and 2 of the system to prevent interference. Although it might have been possible to modify the circuit arrangements to enable these channels and the broadcast system to work satisfactorily when the programme was being transmitted in the Sydney-Melbourne direction, the interference increased greatly when the direction of the programme circuit was reversed. The treatment of the broadcast channel is still under consideration.

Fig. 14 shows a typical loss-frequency characteristic measured from MOD IN to DEMOD OUT. The broad band obtained by the use of crystal filters is evident.

The noise measured on the individual channels at the time the system was placed in service was approximately 15 db above reference noise of 10^{-12} watt at a point corresponding to —6 db in the circuit. These measurements were made in October and it should be appreciated, therefore, that somewhat higher values of noise may be experienced during the bad static season.

Interchannel crosstalk was measured by observing the interference produced on the eight idle channels when zero volume talkers were speaking on four channels selected arbitrarily. The measurements were made by different observers using one of the disturbing channels for comparison. The values obtained were satisfac-



Input to Distant Modulator 1mw-13 db.
Fig. 14.—Typical Channel Quality Curve.

tory although this represented a severe test condition since the chance of obtaining a combination of such high volume talkers is very small. Such crosstalk was unintelligible, of course, and

Testing and Maintenance.—Very little routine testing is required for the maintenance of the system. The automatic gain controls maintain the repeaters at their proper output levels and the daily line-up as performed in the C type systems is unnecessary. A monthly check of the overall equivalent will usually be sufficient, small changes in the individual channels being corrected by the demodulator potentiometer at the receiving terminal. For this purpose the ordinary voice-frequency testing apparatus existing at the terminals is adequate.

In order to make the necessary installation tests and adjustments and for subsequent periodic and fault locating tests some newly developed high frequency measuring equipment was provided. This consisted of an oscillator, a transmission measuring set, an impedance bridge and an amplifier detector. The oscillator has a frequency range of 50 to 150,000 cycles. It is of the heterodyne type and is adjusted simply by rotating a handle, the frequency setting being observed on a moving cinematograph film. This greatly adds to the rapidity with which such tests as quality, crosstalk and return loss measurements can be made. The transmission measuring set employs a thermo-couple and is carefully shielded to enable its full attenuation range of 100 db. to be utilized at frequencies up to 150 kc. The amplifier-detector is employed where the sensitivity required is greater than that provided by the thermocouple in the transmission measuring set. The impedance bridge finds its chief use in adjusting the loading to meet return loss requirements.

The remaining important periodic tests are checks of the valves and grid battery voltages at monthly intervals. A testing socket is fitted on all panels containing valves and when the vacuum tube test set is plugged into the panel, heater and plate current and cathode activity measurements may be made on the valves without interfering with the operation of the system. The Sydney-Melbourne system is taken out of service for a certain period during each week, when traffic is at a minimum to provide an opportunity to change valves which may have been found to be ageing. When more valve test sets are available, it will be possible to make measurements at all stations at approximately the same time and to restrict this removal from service to a monthly interval.

Unattended auxiliary repeater stations are normally visited once a month on a routine basis in order to test the valves and check the power plant. Where attendance is fairly readily available, as at Euroa and Mittagong, more frequent visits for inspection purposes may be arranged as desired. In case a fault develops during normal operation of the system an alarm is relayed to the controlling main repeater station via the alarm trunk circuit. The various alarm circuits, e.g., blown fuse, power failure, etc., are connected to contacts of a selector switch at the auxiliary repeater. Another selector switch with its associated relays is located in the main repeater, the connection being provided between the two by means of a d-c telegraph circuit. The occurrence of an alarm condition at the auxiliary stations causes the main station selector switch to step and this in turn causes the auxiliary station selector to step under the control of the main station. On arrival at any alarm contact visual and audible signals are given at the main station indicating the particular alarm conditions prevailing at the auxiliary station. The attendant at the main station thereupon takes the necessary action.

The majority of the auxiliary repeaters on the Sydney-Melbourne route are located at points which already have some form of attention available and consequently at these stations the alarm trunk units are replaced by a simplified circuit working in conjunction with lamp indicators. Mittagong and Euroa are equipped as unattended stations and their alarms are taken to Goulburn and Wangaratta respectively.

The Sydney-Melbourne system is established to work on a 24-hour basis but this involves a maintenance problem since the spare line is not equipped with repeaters or line filters and consequently patching must be carried out on individual line sections. At attended stations in the daytime this operation is performed by a mechanic but at night-time when the mechanic is off duty the night telephonist is required to change the circuit under directions from the controlling station. At Mittagong the equipment is located in the same room as the telephonist who carries out the change-over to spare line at all times. At Euroa office, which is completely unattended and located above half a mile distant from the office, the mechanic is called in by Wangaratta station.

Provision of Future Systems.—The important consideration in establishing additional systems on the Sydney-Melbourne route is that of crosstalk between the systems. Crosstalk coupling tends to increase with frequency and unless a line is especially transposed for the higher frequencies, may reach very high values. Even when a line is so transposed there are additional requirements imposed on the symmetry of the line, particularly pole spacing and wire sag, and also on the accuracy of the impedance matching at the end of each line section.

Special provision must also be made for the suppression of interaction crosstalk at repeater stations since the problem is no longer one of merely providing a satisfactory singing margin. The treatment in this case calls for eliminating the present practice of operating north and south pairs over a common entrance loop. This can be done either by constructing a new repeater station at the end of the open-wire loop or by bringing one direction in over the loop and the other over cable which is available at all points in question. The use of the cable would require the erection of a small building at the open wire end to house the line filters. Crosstalk suppression filters would also be required at auxiliary stations on all non-J pairs and possibly at some of main repeaters.

Measurements which have been made over the Sydney-Melbourne route indicate that no more than minor transposition changes will be required to obtain line crosstalk conditions which will permit a second J system of the SA type to be operated. This gives the maximum staggering advantage with respect to the NA systems.

Acknowledgments.—The authors wish to express their appreciation for the invaluable cooperation of the engineering and installation staff of the Department during the planning, installation and testing of the system.

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TRANSMISSION LINE TO AERIAL COUPLING CIRCUITS FOR BROADCASTING STATIONS

A. J. McKenzie, M.E.E., A.M.I.E.(Aust.)

Introduction.—In modern medium wave broadcasting practice it has become usual to locate the transmitting aerial at some distance from the transmitter, and to feed the radio frequency power from the transmitter to the aerial over a suitable transmission line. There is a number of methods commonly employed for coupling such transmission lines to aerial systems, and they form an interesting part of radio transmission practice. The methods employed by the Department will be described in this paper, as well as the data necessary for the design of suitable coupling circuits and the methods adopted in lining them up.

Two types of transmission line are in general employed by the Department, either a two wire, balanced open wire line, of characteristic impedance 600 ohms, or a coaxial line of spacing suitable for the optimum impedance of 78 ohms, or of rather greater spacing and having a characteristic impedance of 100 ohms, with the advantage of better voltage flashover characteristics.

The object of a matching circuit is the presentation to the transmission line output of an impedance equal to its characteristic impedance. This, by the reduction of standing waves and large currents, reduces line losses, and also reduces the maximum voltage on the line, with consequent reduction in liability to flashover.

An interesting example of a coupling circuit, namely, the twin circuit employed at the 3LO-3AR station, where the power from the two transmitters is fed simultaneously to the one mast, will be described.

Coupling Circuits for Balanced Open Wire Lines.—Let us consider, first of all, two circuits suitable for use with a two wire balanced open wire line. The problem here is that of coupling a balanced impedance to an unbalanced one, and two types may be employed, either a balanced π circuit of the type shown in Fig. 1 and similar to that which may be employed in the unbalanced form with coaxial lines and described below, or a mutual inductance coupled circuit shown in simplified form in Fig. 2. The latter circuit has been employed in several broadcasting stations, viz., 3GI, 7NT, 4QN and 2NR. The theory employed in the design of this circuit is briefly given as follows:

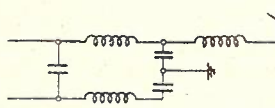

Fig. 1

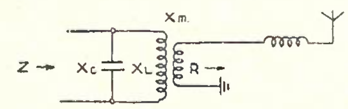

Fig. 2

The reactance of the secondary circuit must be reduced to zero by means of a suitable tuning inductance. The resistance introduced into the primary circuit may then be shown to be:

$$r = X^2_m/R \text{ ohms} \quad (1)$$

where X_m is the mutual reactance,
R is the aerial resistance.

It may also be shown that with the circuit correctly adjusted for a non-reactive input impedance Z, we have the relations:

$$Z = X_L X_C/r \quad (2)$$

$$\text{and } X_C = X_L + \frac{r^2}{X_L} \quad (3)$$

where X_L and X_C are the inductor and condenser reactances in the primary circuit.

These three equations give the necessary conditions for correct matching. Combining (2) and (3) we have:

$$r^2 - rZ + X_L^2 = 0 \quad (4)$$

It will be seen that r is imaginary, if $Z < 2X_L$.

The ratio Z/X_L is the ratio of kVA to kW in the primary circuit and since r must be real it must exceed 2 in order to produce correct matching. In designing or adjusting a coupling circuit it is usual to fix this quantity first of all. It must exceed 2, and the upper limit is usually fixed at about 10 in order to keep power losses and side band cutting within reasonable limits. These considerations make it desirable to reduce the kVA to kW ratio; on the other hand, a high kVA to kW ratio has the advantage of reducing harmonic radiation. Having fixed on the kVA to kW ratio, the magnitudes of X_L, X_C, r, and X_M are successively obtained from the equations 1-3. The voltage on the coupling condenser is $E = \sqrt{PZ}$, where P watts is the power transferred and the closed circuit current is equal to E/X_L or E/X_C in inductance and condenser respectively. Thus the values of coupling circuit components and circuit currents can be determined theoretically.

In a practical embodiment of such a circuit shown in Fig. 3 the inductance X_L of Fig. 2 is divided into two portions, one—a balanced inductance providing the necessary reactance for

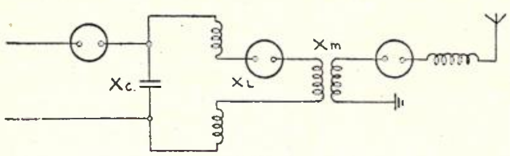

Fig. 3

tuning, and one—the primary of a mutual inductance. The tuning condenser takes the form of a number of mica condensers strapped in circuit as required, and an aerial tuning inductance completes the circuit. For a 10 kW station the inductances are generally helices of 10 or 20 turns of ½-inch diameter silver-plated copper tube about a foot in diameter. Inductance adjustment is effected by coil tappings and fine adjustment by means of a rotating short-circuited turn inside the coil.

Coupling Circuits for Coaxial Lines.—In coupling a coaxial line to an aerial we have the problem of coupling two unbalanced impedances. For this purpose a network [1] of inductances and

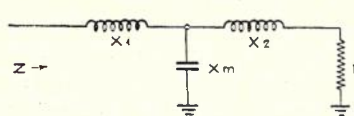

Fig. 4

condensers is employed and it may take the form of a T, π, or L network. Considering first the T circuit shown in Fig. 4, it may be shown that:

$$ZR = -(X_1X_2 + X_1X_m + X_2X_m) = X^2_m - X_pX_s \quad \text{.... (5)}$$

$$\frac{Z}{R} = \frac{X_1 + X_m}{X_2 + X_m} = \frac{X_P}{X_S} \quad \text{.... (6)}$$

where $X_P = X_1 + X_m$
$X_S = X_2 + X_m$

where the circuit is adjusted so that Z is a pure resistance.

It will be seen that since ZR must be positive, from equation (5) one of the arms must have the opposite sign to the other two. From (5) and (6) we have:

$$X_P = \pm\sqrt{\frac{Z}{R}(X_m^2 - ZR)} \quad \text{.... (7)}$$

$$X_S = \pm\sqrt{\frac{R}{Z}(X_m^2 - ZR)} \quad \text{.... (8)}$$

and hence a necessary condition is that $X_m < \sqrt{ZR}$. For design and adjustment it is usual to select X_m and determine X_P and X_S from (7) and (8). It is preferable to make X_m a capacitative reactance; this procedure results in a suppression of harmonic frequencies, whereas the use of an inductance would result in an accentuation of harmonics. The inductance X_2 may be combined with the aerial tuning inductance.

A modification of the T circuit frequently employed in practice occurs when we make one of the series arms equal to zero, the circuit becoming an L circuit. Considering equation (6), it will be seen that if $R < Z$, X_1 is the reactance reduceable to zero, and if $R < Z$, X_2 is the reactance. The case of $R < Z$ is considered first. From (5) and (6) we have:

$$X_2 = \pm\sqrt{Z\ (Z - R)} \quad \text{.... (9)}$$

$$X_m = \pm R\sqrt{\frac{Z}{Z - R}} \quad \text{.... (10)}$$

it being necessary that X_2 and X_m be of opposite sign. If harmonic suppression is desired, X_m is made a capacitance whose voltage rating depends only on the line impedance and the power transferred. X_2 is then an inductance which may be combined with the aerial tuning inductance. On the other hand, where a small aerial of low capacity is being used, the reactance of the aerial in series with an inductance may be employed as X_2 which is then capacitative, so that X_m becomes inductive. The coupling circuit then becomes a shunt inductance across the line, and an inductance in series with the aerial. Where $R < Z$, X_2 must become zero, and (5) and (6) become:

$$X_1 = \pm\sqrt{R\ (R - Z)} \quad \text{.... (11)}$$

$$X_m = \pm Z\sqrt{\frac{R}{R - Z}} \quad \text{.... (12)}$$

The circuit then employed is usually an inductance in series with the line, a shunt capacity, and an inductance in series with the aerial which tunes out the aerial reactance. If the aerial reactance is positive, an aerial series condenser is also necessary.

The L type coupling circuit forms a simple and convenient type which is in use at Stations 6WA, 3WV, 2CR and 2FC. In the case in which the aerial resistance is smaller than the line impedance, it employs one reactance element less than the T network, and in the case of the aerial resistance being greater, three reactances are necessary in any case, and the L network becomes merely a special case of the T.

Considering next the π network, as shown in

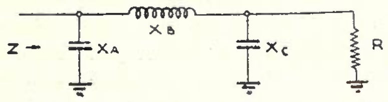

Fig. 5

Fig. 5, it may be shown that the conditions for matching are:

$$X_A = \frac{-Z X_B}{Z \pm \sqrt{ZR - X_B^2}} \quad \text{.... ....} \quad (13)$$

$$X_C = \frac{-R X_B}{R \pm \sqrt{ZR - X_B^2}} \quad \text{.... ....} \quad (14)$$

For X_A and X_C to be real we must have:

$$X_B < \sqrt{ZR}$$

and as in the case of the T network one of the reactance arms must have the opposite sign to the other two. X_B is usually an inductance and X_A and X_C capacities; this arrangement again resulting in harmonic suppression.

For the purpose of coupling a single transmission line to an aerial, a π network has the disadvantage that, including the aerial tuning reactance, four reactances in all are necessary, whereas using an L or T circuit only two or three reactances in all are necessary. For this purpose a π network is, therefore, seldom used.

Procedure Adopted in Lining Up Matching Circuits.—A matching circuit may, first of all, be lined up roughly by employing the expressions for circuit elements given above, for which it is necessary to know the aerial resistance and transmission line characteristic impedance.

The object to be attained in lining up is, as has been stated, the presentation to the line of an impedance equal to its characteristic impedance. There are several criteria for this condition. The ratio of aerial to line output current is, of course, known in terms of the aerial resistance and line impedance and must be correct. In the case of an open wire line the standing wave ratio in the line may be measured by means of a loop terminated in a milliammeter hung on either line wire and moved along the line. In the case of a coaxial line, only the input and output current are normally measured and these should be equal. Finally, the line should present the correct impedance to the transmitter, and where an artificial aerial of impedance equal to the transmission line characteristic impedance is available, the changeover from artificial aerial to transmission line should, therefore, effect no change in transmitter final stage currents, namely, line input, closed circuit and anode. The line-up procedure involves successive adjustments of the circuit elements until the above criteria are complied with.

In lining up such circuits, therefore, the resistance of the aerial circuit is first of all measured. This may be determined using a radio frequency bridge, or impedance meter, or alternatively by using the added resistance method. In this method a small amount of power is fed into the aerial circuit, and a thermal milliammeter and variable resistance connected in series with the aerial. The resistance and milliammeter should be adjacent at the position occupied by the aerial meter. The circuit is then resonated for maximum current, and the current values noted for several values of resistance added. A plot of resistance against reciprocal of current should be linear and cut the resistance axis at a negative value numerically equal to the total resistance of the aerial circuit. The resistance of the milliammeter (equal to the d.c. value) must be subtracted. General Radio decade boxes form satisfactory resistances for frequencies up to 1500 kC. When the aerial resistance is known, the aerial current for the correct aerial power is calculable. It is next necessary to ensure that the aerial is resonated. The simplest method is that mentioned above. Alternatively the ratio of aerial to closed circuit current may be plotted for a number of aerial tuning reactance settings and the setting for maximum ratio is the tune point. In the case of a π or L circuit, the current in the last shunt reactance replaces the closed circuit current. From a knowledge of the characteristic impedance of the line which may be taken as the theoretical value, the correct line current for the aerial power, as has been stated, is known. Thus equality of the input and output line currents and the ratio of aerial to line current must now be ensured by adjustment of the circuit elements. Before noting the ratio, however, it is necessary to ensure that the coupling circuit itself is in tune (apart from the aerial circuit). In other words, the input to the coupling circuit must be a true resistance. In the mutual inductance circuit the closed circuit inductance may be adjusted for minimum line current. Alternatively a three ammeter method may be used. Ammeters are connected at the junction of the line, and closed circuit condenser and inductance. The line current flows into a pure resistance, the condenser current into a pure reactance, and the inductance current into a complex impedance. The three currents should, therefore, form the sides of a right-angled vector triangle, the inductance current being the hypotenuse by an application of Kirchoff's laws. The three ammeter criterion may also be applied at the input of a π or L circuit in which the shunt condenser precedes the inductance. In the case of a T circuit the three ammeter criterion cannot be applied. It is necessary then to rely only on the ratio of aerial to line current. When the criteria of equality of input and output line currents, and ratio of aerial to line currents have been satisfied, the check of the transmitter currents with connection to the artificial aerial and transmission line may be made. Finally, in the case of an open wire line the standing wave ratio may be measured.

Case of a Twin Coupling Circuit.—The case in which two transmitters are to be coupled to one aerial system (2) will next be considered, and this is the arrangement employed at the 3LO/3AR station, and will be described in some detail. The circuit arrangement employed at this station follows that employed by Doolittle & Falkiner in some American stations (3), although no design data was available when the 3LO/3AR circuit was put into operation. The power from each transmitter is fed over a separate transmission line to the coupling circuit located in the tuning hut at the base of the mast. The mast employed has a height of 705 feet and the station incorporates two 10 kW transmitters having frequencies:

3AR — 620 kC
3LO — 770 kC

The modes of operation are respectively 0.44 of a wavelength (or 158°) and 0.55 of a wavelength (or 198°). The power is fed to the aerial tuning hut from each transmitter over a separate 80

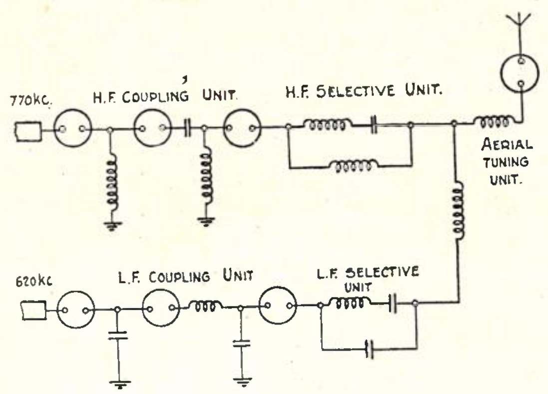

Fig. 6

ohm coaxial line. The coupling circuit employed is shown in Fig. 6. The circuit consists of five units, viz.:

H.F. Matching Unit
L.F. Matching Unit
H.F. Selective Unit
L.F. Selective Unit
Aerial Tuning Unit

The matching units are provided for matching the line characteristic impedance in each case to the aerial impedances at the appropriate frequency. π networks were selected for these circuits, since, as an examination of the circuit will indicate, in this case the aerial tuning inductors are separated from the networks, and no saving in the number of inductances would be effected by the use of T networks. Furthermore, the use of a shunt inductance at the output of the h.f. matching unit, and a shunt condenser at the output of the l.f. matching unit involves the presentation to the relative networks at the unwanted frequency of a low impedance with enhanced discrimination in consequence.

The selective units are three element networks each designed to be resonant to the frequency of its corresponding coupling unit, and anti-resonant to the other frequency. The network on the low frequency side thus presents a very low impedance to low frequency currents and allows low frequency power to be fed to the aerial. It, however, has a very high impedance at the high frequency, and prevents power at the high frequency from being fed back from the aerial to the low frequency coupling unit. The selective network on the high frequency side functions similarly. The low frequency selective unit must necessarily employ two condensers and one inductance, and the high frequency unit two inductances and one condenser.

The aerial tuning unit is provided to tune out the aerial reactance at each frequency so that a pure resistance is presented to the π network at its own frequency. In the 3LO/3AR case two inductances are employed.

The design of the π networks follows the theory above outlined for simple π circuits. The three element selective networks were designed more or less arbitrarily from the equations for resonance and anti-resonance of the networks, viz., for the low frequency circuit:

$$\omega_L^2 L_S C_S = 1 \qquad (15)$$

$$\omega_H L_S - \frac{1}{\omega_H C_S} = \frac{L}{\omega_H C_P} \qquad (16)$$

where ω_L is the low frequency
ω_H is the high frequency.
L_S is the inductance.
C_S is the series condenser
C_P is the parallel condenser

and similarly for the high frequency circuit:

$$\omega_H^2 L_S C_S = 1 \qquad (17)$$

$$\omega_L L_S - \frac{1}{\omega_L C_S} = \omega L_P \qquad (18)$$

the elements being similarly designated.

In each case there are only two equations for three unknowns, and one of the elements must be arbitrarily selected, and the other two calculated. The design resolves into selection of reactances which are of reasonable magnitude and satisfy the above equations. The voltages on the series elements must be watched as they become large at the anti-resonant frequency, since at this frequency the series elements are still partly resonant. An estimate of the anti-resonant impedance and the loss introduced by the circuit is also necessary, and this is made by assuming reasonable values of Q for the coils.

The inductances and condensers are mounted on angle iron frames located round the walls of the tuning hut, the front of the frames covered with polished timber and facing inwards. All coils are adjusted by means of tappings and short-circuited turns, the latter controlled from the front of the frames. The condensers are arranged in banks, and are adjusted by means of links strapping in or out condenser sections. In the case of the shunt condenser C_4 in the low frequency selective unit, fine tuning is supplied by means of a variable air condenser.

Line-up of Twin Coupling Circuit.—The procedure adopted in lining up the equipment is briefly described as follows: The aerial resistance was measured by added resistance method. The aerial was resonated at the high frequency with the low frequency coil L_8 disconnected at the aerial tuning unit, the high frequency selective unit short circuited, and the inductance L_4 short circuited. The high frequency selective circuit was now resonated, by disconnecting it, short-circuiting its terminals through a small meter, and adjusting the inductance L_5 for maximum current, when a very small amount of power is inductively fed into the circuit. The selective circuit was now connected in circuit and the high frequency coupling circuit adjusted for correct aerial and line currents. The high frequency selective circuit was now disconnected at the aerial tuning unit, and the low frequency selective circuit connected. The above procedure was repeated for the low frequency circuits.

It was now necessary to adjust the selective circuits for anti-resonance. In adjusting the high frequency circuit a low reading meter was connected across the output of the high frequency line and a small amount of power fed from the low frequency transmitter. The shunt element of the selective circuit was now adjusted for minimum current in the meter. The meter range was successively reduced, and the power increased until a meter reading was obtainable with full power. The procedure was then repeated with the low frequency circuit.

A few of the results of the measurements on the circuit are of interest. The anti-resonant impedances of the selective circuit were:

Low frequency circuit at 770 kC ... ... 22,500 ohms
High frequency circuit at 620 kC ... 29,000 ohms

The corresponding Q values being 120 at 770 kC and 150 at 620 kC. The current in the short-circuited meter on the high frequency line with full power of 10 kW on the low frequency line was 46 m.a., and that in the low frequency line was 77 m.a. These figures correspond to discriminations of:

620 kC → 770 kC, 47 db
770 kC → 620 kC, 44 db

The actual crosstalk produced between transmitters was measured on the monitoring sets using 400 cycle tone and a G.R. harmonic analyser. In each direction the interference was better than 85 db below 100% modulation. Similar tests were made using a National H.R.O. receiver, at a distance from the station where the field strength from each station was of the order of 75 mV/m. The interference was in this case:

620 kC → 770 kC, 63 db
770 kC → 620 kC, 50 db

The higher interference noted in the field was found to vary with location, and the sets used. This was attributed to inter-modulation sources near the receivers and it is considered that the figure of better than 85 db represents the true magnitude of the interference. In any case the interference is low enough to cause no appreciable annoyance to listeners.

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UNDERWATER INSPECTION OF THE MAINLAND-TASMANIA TELEPHONE CABLE

A. S. Watson

Until 1935 residents of Tasmania and King Island suffered the very real handicap of not having telephone communication with the Mainland, the only channels available being two telegraph cables laid direct from Victoria to Tasmania in 1909; but this disability was removed in 1935 by the installation of a submarine telephone cable.(1) Four channels were provided initially, but traffic increased at a phenomenal rate and two additional channels were added within two years. Tasmanians had definitely become "trunk line minded," and when a total failure of the cable occurred in 1937, it was in the nature of a national calamity for them.

The fault was located in the King Island-Tasmania section about six miles off the coast of King Island, and repairs were quickly carried out from the s.s. "Mernoo," the boat usually chartered by the Department for submarine cable work. Measurements taken after the repair operations showed an appreciable drop in insulation resistance, and this drop has very slowly but surely continued ever since, until at the present time the insulation resistance is about one-quarter of its original value.

Naturally this potential fault which is developing so surely caused great consternation, and one officer was heard to remark, "Oh, if we could only have a look now at the bottom of Bass Strait and see what the bottom and the cable is really like." Another said, "That's easy, just get a diver to walk along the cable and examine it," and thus the idea of an underwater examination was born.

The United Shipping Services Pty. Ltd. was approached and they deputed Mr. J. E. Johnstone, a veteran of the Naval Salvage Corps, to carry out the examination.

It was at this stage that the writer became interested in all the rumours that were flying about, and quite casually he asked a group of engineers at Central Office who was the poor victim who was to represent the Department on this novel undertaking. The answer, given with great gusto, was, "You are"; and he was also informed that a crayfish ketch had been chartered for the job.

The usual method of signalling between a diver and the boat is by means of a rope line between them, but it was considered that this would be inadequate and inappropriate and it was decided to design a suitable telephone system. This work was referred to the Research Laboratories of the Chief Engineer's Branch with a request that it be completed in 10 days. The circuit provided for four-wire working, that is separate transmission in each direction. One wire was used as a common for transmission in both directions to reduce the number of conductors to three, the arrangement having the great advantage of eliminating sidetone and also increasing the transmission level by approximately 6 db. in each direction. The layout in the diver's helmet consisted of two head receivers mounted on the sides, with a transmitter and a bell push in the front, the bell push being placed so that it could be easily operated by the diver's chin. The bell push is intended to operate an emergency buzzer circuit in the telephone box on the boat in the event of a breakdown of the telephone circuit. The three conductors from the helmet to the boat were accommodated in about 250 ft. of heavy rubber cabtyre flex, the batteries, induction coils, switches, etc., being concentrated in a small box on the boat. Provision was also made for two telephones in parallel to be operated at the box end, the general assembly in the helmet being shown in Fig. 1. A preliminary test of the telephone was made in the Yarra River with good results. The apparatus in the helmet is so

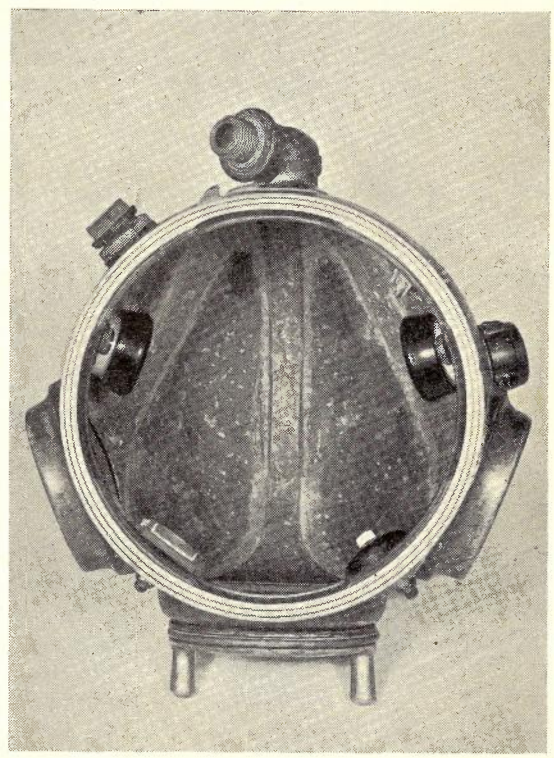

Fig. 1.—Assembly of Diver's Helmet.

(1) "Telecommunication Journal," Vol. 1, No. 2, December, 1935, p. 25, and Vol. 1, No. 3, June, 1936, p. 81.

mounted that the movement of the diver's head is not interfered with.

The operations to be carried out could be divided roughly into three sections, viz.:—

(1) Examination of the cable, particularly with reference to:—

(a) Extent of jute serving worn off (length).

(b) Extent of armour wear (length and depth of chafing).

(c) Buckling of armour, extrusion of core, kinks, etc.

(d) Condition of joints.

(2) Inspection of the sea floor.

(a) Where cable is laid at present with report on the position of rocks likely to damage the cable.

(b) Position of sand hills indicating heavy tidal movement.

(c) General survey of bottom to locate a new track if inspection of cable confirms the necessity for shifting the cable.

(3) (a) To ascertain if a suitable track could be made by clearing obstacles by explosives.

(b) To determine whether it would be practicable when repairing subsequent to fault condition, to locate the cable with the services of a diver and lift the end inboard, thus saving grappling for the cable from the cable ship.

Our new "cable ship" was the "Julie Burgess," a ketch-rigged fishing boat 70 ft. long, of about 40 tons and fitted with a 50 h.p. auxiliary engine running on power kerosene. (See Fig. 2.) All the gear which it was considered would be necessary was now selected, consisting of several 40 gallon drum buoys, shackles, swivels, sand grapnels, manilla rope of all sizes, large and small snatch blocks, ultra short wave telephone trans.-receivers for communication with the shore, wide angle field glasses, special charts, dividers and parallel ruler to assist the engineer with his navigation. All these articles were loaded on a motor truck for transhipment to the boat, and on Friday, 15/9/39 the engineer, wise in his generation, left by plane for King Island to await its arrival. On Sunday, the 17th, word was received from the cable station at Narracoopa that the boat was in sight, and our hero left for Narracoopa to greet it. It certainly made a very pretty picture as it sailed to its anchorage, but it was with a sinking feeling that the writer viewed the woebegone crew of divers and assistants as they climbed up the ladder at the jetty. They had had a very rough trip with results that can be imagined.

The shore end unit of the short wave telephone was brought ashore and set up at the cable station and everything was ready for the job to commence. The first operation was to grapple for the cable close inshore, and when located, to buoy it off. The original idea was to do this at ½ mile intervals, the diver then to go down and the boat to tow him along the line of cable marked by the buoys. This would enable him to make an examination of the bottom and the cable and to report on its condition. As probably very few readers have had much to do with diving operations, a brief description of a diver's dress will possibly be of interest. The suit proper consists of two layers of canvas with a middle layer of pure para rubber, brass boots weighing 16 lbs. each, lead front and back weighs 66 lbs., corselet

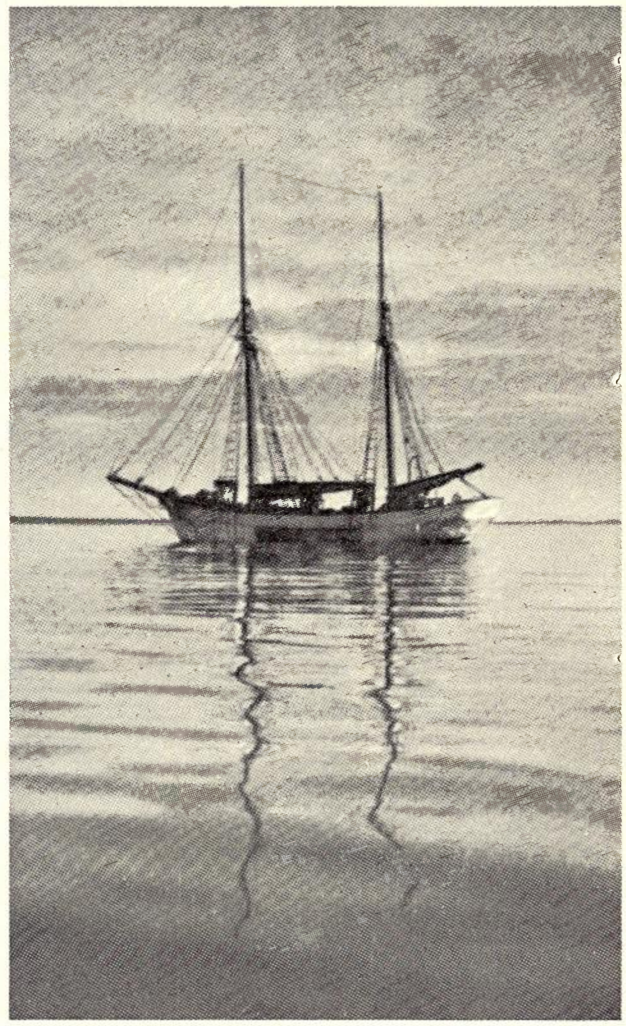

Fig. 2.—The "Julie Burgess."

and helmet 35 lbs. each; the weight complete being about 168 lbs. Under his suit the diver wears two very thick woollen guernseys and two pairs of woollen thigh stockings to protect him from the cold. All his clothing is fastened with tapes and all metallic articles such as coins, pocket knives, keys, etc., are taboo. The reason for this is that sea water exerts a pressure of .434 lbs. per sq. inch per foot depth, so that when the diver is working at, say, a depth of 100 feet, there is a total pressure of 43.4 lbs. per sq. in.

over the whole of his body. Under these conditions a lump of wax would not be necessary to get an impression of a key if he happened to have a bunch in his hip pocket.

The boat now proceeded to a point about 400 yards to the north of the cable, which here runs approximately east and west, and a sand grapnel attached to a 3 in. manilla rope was dropped to the bottom, the depth being about 7 fathoms. When about 12 fathoms of rope had been paid out it was made fast to the boat and the diver then descended, using the grapnel rope as a shot or direction line. The tide was setting to the south and the boat slowly drifted down across the line of the cable with the diver following the grapnel and describing the bottom. When the cable was hooked, a buoy line was sent down to the diver who made it fast to the cable. He then released the grapnel from the cable and came up on board, the grapnel was taken up and the boat then proceeded half mile out to sea. The previous operation was then repeated. As mentioned before, the first grappling was made close inshore, but as the boat worked out to sea it soon became evident that the tide was stronger. In addition, the seas were now much bigger as the shelter of Sea Elephant Bay was left behind. This soon created a new problem for the diver. Due to the stronger tide the boat drifted far quicker than before, so that the diver was travelling almost at a run. To help himself he tied himself to the grapnel with a short ranging line, and to use a small boy's term, "he whipped behind." As the seas became rougher, the engineer on his telephone could hear a series of loud grunts from the diver, and on enquiring the cause, was informed in rather strong words that when the boat lifted on a wave he was lifted anything up to 20 feet from the bottom, and on the boat dropping into a trough of the waves he was dumped rather forcibly on to the bottom which, fortunately, at this point consisted of sand. He suggested that more grapnel rope and air line be paid out to obviate this, but it was out of the frying pan into the fire for him. When the boat lifted he skidded along the bottom on his stomach like a baseballer making first base, and if there were rocks ahead it does not need much imagination to know what would happen to him—he soon issued instructions to shorten the grapnel rope.

Whilst speaking of rocks, it will probably be of interest to know how they were negotiated. As the boat drifted along the diver would occasionally mention the fact that there was a high wall of rock ahead of him, sometimes up to 20 ft. high. His range of vision is limited to about 16 to 20 feet, so that by the time the rocks were in sight there would not be time to stop the boat's headway before he would be dragged into them. To overcome this danger, as soon as he saw the rocks he would pick up the grapnel, close the air valve in his helmet, and blow his suit up so that he would gently float up to clear the obstacle. As soon as he had passed over the rocks and a sand bottom was again visible, he opened his air valve and gradually dropped to the sea bed again to continue his description per telephone for the benefit of the engineer. This versatile individual was meanwhile writing up his log-book, taking sights, and marking the position of rocks, sandhills, etc., on his chart, steering the boat, relaying instructions to the pump crew or deck hands, and also reporting progress per medium of the ultra short wave radio to the staff at the cable station. In other words, he was the modern conception of the old-time "one-man band." The skipper of the boat was keenly interested and kept asking if the diver could see many fish. He was informed that there were thousands of fish of all kinds, the smallest being about three feet between the eyes. From then on the skipper appeared rather sceptical when the diver described the fish he had seen.

The boat gradually moved out to sea, and the cable was buoyed at regular intervals, but it soon became evident that with the heavy tide broadside on, it would be impossible to follow the line of the cable at a speed which would enable the diver to examine it and also to keep steering way on the boat. At a conference on deck it was decided that the only way to examine the cable was to under-run it and to enable this to be carried out, a message was sent to Melbourne submarine cable depot asking that an under-running sheave be sent over at once. It arrived on the plane next morning at 9.30 and was on the boat by 10.30. An under-running sheave is simply a large snatch block, the roller being about ten inches wide and having a shallow groove.

The cable was picked up at the first buoy from the shore, and everything was made ready for under-running as follows:—The sheave was attached to a four-inch manilla rope, and after being fastened to the cable by the diver, the rope was taken through a fair lead on the port bow and then made fast, sufficient rope being paid out so that the sheave was lifting the cable about six feet from the bottom. The diver's air hose and life line were now taken over the stern of the boat and he made himself comfortable by sitting with the sheave between his legs and hanging on to the manilla rope. (Fig. 3.) The boat's engines were now started and out to sea we went. The whole operation was most successful, the sheave breaking the cable out of the sand and the diver describing its condition as it passed between his legs. A running commentary of the bottom was also given, all details of which the engineer entered in his log book and also charted on his plan.

The under-running was carried out at a speed of about three-quarters of a mile per hour, and as there was only about eight miles to examine, all hands had visions of finishing in a couple of days and returning to the comforts of their homes ashore. This, however, was not to be, as when half way over the course the diver suddenly called out to stop the engines. This was done, and the diver then stated that he had come upon a lot of coils in the cable, some of them standing vertically about sixteen feet from the sea floor. These proved to be the slack cable dropped overboard from the "Mernoo" when the final splice was made during the repair operations in 1937. The coils, in the centre of which was the final splice, took six working days to negotiate, and when it is remembered that only on about one day in four was the sea smooth enough to allow work to be carried out, it is easily understood why a cheer went up when the last coil was passed over, particularly when it is realized what the conditions are like for nine men on a ketch in one of the roughest stretches of water around the Australian coast.

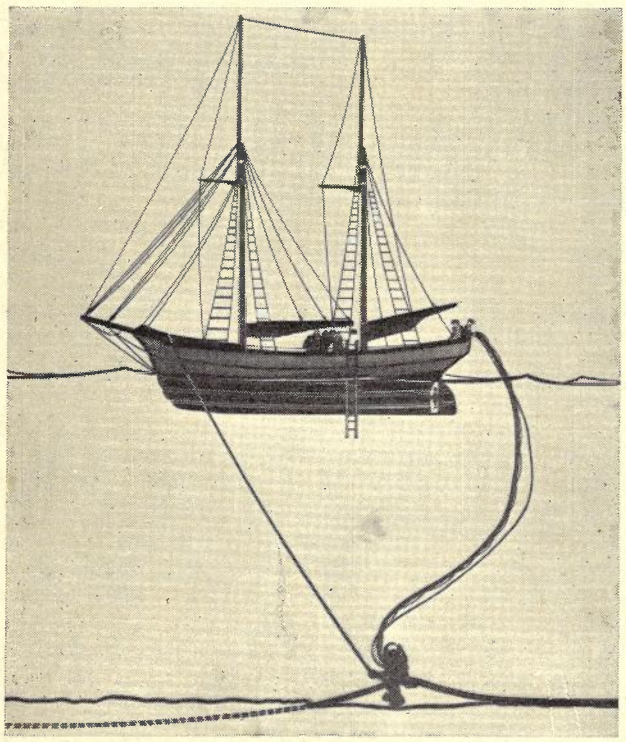

Fig. 3.—The Diver "Riding" the Cable.

The under-running was recommenced; but a new difficulty now had to be faced. The cable was not yet on its true course, and while the engineer was steering he would receive instructions from the diver to alter the course. When the new course asked for appeared to go back on the track already covered the engineer would tell the diver he was wrong and put it down to the fact that the diver loses all sense of direction under the water. The diver would deny this soft impeachment and a conversation something like this would take place:—

Diver: How is the boat laying?

Engineer: East North East.

Diver: Now where is the sheave line leading?

Engineer: Aft.

Diver: Where is my air hose leading?

Engineer: The tide is pulling it straight out to starboard.

Diver: Well, tell me where my bubbles are breaking the surface.

Engineer: Can't see them, it's too rough.

Diver: What a man wants down here is an underwater compass to settle these arguments.

This suggestion was acted on at once and by short wave radio, Melbourne was requested to send one over. The compass arrived on the plane next morning, and when the diver went down he had it attached to his arm like a wristlet watch, and peace reigned once more as the diver was now able to give the exact course of the cable.

The inspection of the cable proceeded for about another mile and a half, until the boat suddenly came to a stop. The diver reported that the cable appeared to go down almost vertically into the sand, and although the sheave line was lengthened and the boat went round in wide circles, all attempts to break the cable out of the sand were unsuccessful, the cable apparently being caught under a rock which was buried under a heavy layer of sand. Grappling on the seaward side of this point was now resorted to, but without success, the cable being buried too deeply in the sand to allow the grapnel to hook it, and further operations were abandoned. However, three-quarters of the cable to be examined was reported upon and a thorough examination of over twenty-seven miles of ocean floor had been made and the details charted.

Particularly valuable information was gained with respect to the sea bottom in the vicinity of the coils and the final splice. Here it was found that the splice was in the centre of a channel about 700 yards wide, and that the cable was moving up and down this channel with the tides, the maximum movement being about 500 yards. Along this channel the tide runs like a millrace, and it must be only a short time before the cable fails about this point. Except in this channel, the cable is laying snugly on a good bottom and is in excellent condition.

During the whole of this unique work, most of which was done at an average depth of 75 feet, two divers were employed, one relieving the other about every two hours. When coming up after such a prolonged period under high pressure, the ascent has to be made in stages in order to decompress gradually and thus avoid the risk of contracting diver's paralysis. While the divers are working at great depths the air is forced through their bodies and the whole system becomes saturated with minute bubbles. If he is brought up to the surface too quickly, these bubbles of air break up, the oxygen leaving his body and the nitrogen remaining in the bloodstream causes paralysis.

The time for decompressing is dependent on the depth of water and the duration of his work. The average time taken to come up on our job

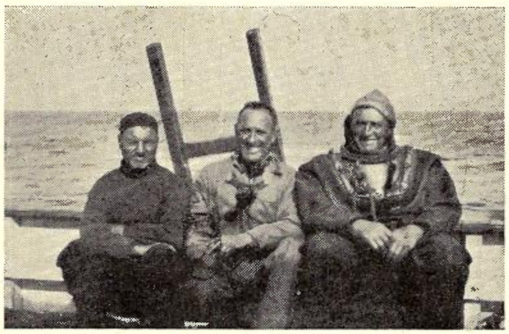

Fig. 4.—The Cook, the Author and the Diver.

was about 20 minutes and the diver would come up the sheave line hand over hand until he was about 30 feet from the surface, when he would tie himself to the rope for about 10 minutes. It was quite humourous to listen-in to the telephone while he was hanging there, lustily singing all the contemporary classics, such as "The Lambeth Walk," "Roll out the Barrel," etc. Another stage of 10 feet and then he would come inboard, usually demanding something to eat. Our cook, as can be seen from Fig. 4, was an old shellback, and certainly, in the writer's mind, had a lot to learn about the culinary art. His main dish was corned beef and cabbage, usually strongly flavoured with power kerosene through using a rubber hose to siphon water out of the tank for cooking; the hose also being used by the skipper to siphon kerosene for his engine.

One day, which incidentally was extremely rough, the captain, on being informed that it was the author's birthday, took the cook on one side and told him to let his head go and prepare a banquet worthy of the occasion. Our worthy chef disappeared into his galley for the best part of the afternoon, and then came up to the writer full of pride and informed him that: "I 'ave made a milk puddin' and there is a hegg init." One look at the masterpiece was sufficient to satisfy him that kerosene flavoured corned beef and cabbage takes a lot of beating for a birthday tea.

A final word in praise of the pump hands. The weather throughout the six weeks the job took can only be described as vile—strong winds and heavy seas being experienced for 75 per cent. of the time—with the result that our small craft rolled and pitched to such an extent that it was often impossible to stand upright. Each day two volunteers from the military guard at the cable station came aboard to man the pumps, and the way they stuck to their jobs despite violent attacks of mal de mer, evoked the admiration of all on board, even our taciturn cook being led to exclaim, "My word, they iss goot boys."

MR. R. A. TURNER

The Society and the Department suffered a severe loss when Mr. R. A. Turner, Chief Draftsman, Chief Engineer's Branch, died on May 3rd after a brief illness.

Mr. Turner, who was 47 years old at the time of his death, has been closely associated with the Society, and particularly with the Journal, since its inception, and all our readers have reason to be grateful to him for many of the illustrations, as well as for articles, on the "Northern Rivers Regional Station, Grafton, N.S.W., Radiator," and "The Strength of Porcelain Insulators and Cement Joints," which were published in Volume 1, No. 3, and Volume 2, No. 5. At meetings of the Society he read papers on "Drawings—Their Production and Reproduction" and on "Concrete Foundations for Radio Masts" (printed paper No. 19).

He will be remembered for his outstanding work as a design draftsman, for in that capacity he made valuable contributions to Australian engineering practice in the design of steel radio masts. His wide experience of drafting work and engineering design was always available and freely given to the many who sought it and, although no man sought publicity less, his obvious talents and his genial good nature earned him the respect and affection of many who might otherwise never have known him. His sympathetic understanding of his associates made him a natural leader and to his own staff he was both friend and adviser. It is they who will miss him most, for they knew him best, but all who knew him regret the loss of a good officer and mourn the passing of a good friend.

He was a valued member of The Postal Electrical Society and his departure from our ranks will leave a gap not easily filled. We extend to Mrs. Turner and to her family this expression of the esteem in which her husband was held, together with our deepest sympathy for their bereavement.

THE SYDNEY-NEWCASTLE-MAITLAND CABLE—PART 2 (contd)

W. Engeman, A.M.I.E. (Aust.)

This article is a continuation of that appearing in the February, 1940, issue of this Journal, wherein reference was made to the survey of the route, assembly of plant and personnel, preparation of estimates, methods used and procedure generally associated with the work. This portion describes the methods followed in drawing cable, laying cable by various means (including the mole plough and trailer method), laying submarine cables, and reinstatement.

Drawing Cable.—The two cables were drawn into the one duct in the one operation with a single draw wire and no trouble was experienced through the cables twisting. The ends of the cable grips were placed through a common shackle, and petroleum jelly was liberally applied to the cables. A swivel was connected between the shackle on the grips and the eyelet on the draw wire. The two cables were securely tied together at the open ends of the grips. A mechanical fuse of six turns of 60 lb. G.I. wire was placed between the shackle and swivel. On most of the duct routes, the two drums of unarmoured cable were mounted side by side on a common spindle on a large cable trailer. Where-ever possible, the cables were pulled through intermediate manholes or jointing pits and were set around the inside walls on suitable rests. At times lengths of over 200 yds. were drawn through earthenware ducts, but it was not possible to draw such lengths through concrete pipes owing to friction. A motor truck equipped with power winch and capstan head was used for drawing. As the draw wire left the capstan head, it was taken up on a hand-operated barrel mounted on a light portable framework so that the draw wire was readily available for use on the next section or was straight away drawn into the next adjacent section after the duct had been cleaned.

Generally a party of 10 men, including the leader, was able to place 10 or 12 drums, approximately one mile of cable, into 0.5 mile of ducts each day. This includes the labour required to transport the drums to the work from the depot as well as cleaning and rodding where required.

Laying Cable in Open Trench.—On many miles of the route, especially in the vicinity of the Hawkesbury River, it was necessary to cut an open trench, lay the cables therein and fill in the trench. The rocky or rough nature of the country, generally a combination of both, prevented the use of mole plough methods. In some places, where conditions were favourable, it was possible to draw a plough on a hawser from the winch-equipped tractor in order to assist in the opening of the trench. Various methods were employed in laying the cables in the open trench. Where possible, a light cable trailer was drawn by a motor truck alongside the trench and the cable was paid off by hand into the trench. Where the country was too rough for a truck, use was made of a tractor. Where neither truck nor tractor could travel alongside the trench, wooden rollers large enough to take two cables side by side and mounted on suitable shallow wooden frames, were laid at intervals of 10 or 12 feet over or alongside the trench and the ends of the cables were pulled from the winch on a tractor or truck. When neither truck nor tractor could be used, the cables were pulled by man-power along the rollers. It was found that a team of 12 men could pull a 200 yds. single length of cable in such circumstances.

On Dangar Island in the Hawkesbury River, the length of trench to be excavated was approximately 1200 yds. Fortunately, a narrow roadway had been built on this island for some distance many years ago, but had never been used, and it was possible to lay the cables in the side thereof for a distance of approximately 600 yds. Cable, material and tools had to be transported by boat to the island, but there was no vehicular means of transport on the island. A three-ton truck with motor winch was placed on a punt and taken from Brooklyn to the island and good use was made of the roadway. Except on two steep rocky places on the island, most of the cable was laid out from a drum mounted on jacks on the truck, which travelled alongside the open trench. The winch on the truck was used, among other purposes, to facilitate ploughing of the trench wherever possible.

From the Hawkesbury River to the Woy Woy-Patonga road, a distance of nearly two miles, the cables were laid through Crown land in very difficult country devoid of roads and, in places, very rocky and precipitous. From the river to Patonga Creek, a distance of 1400 yards, no form of transport, other than by foot, was possible. In addition to excavating a trench, it was necessary to make a pathway adjacent thereto for workmen to walk along in safety. On the steep rise up from the river, posts were erected in places through the top of which a stout iron wire was threaded for use as a hand rail. At one point a stout manilla rope was suspended from an overhead beam so that men could swing over a rocky chasm. From the top of a rocky cliff overlooking the creek, to the Woy Woy road, motor transport was made possible only after a roadway was built by employees on the work. Although this roadway was not up to main roads specifications, it served its purpose well and permitted the safe passage of trucks loaded with cable, a testing van, touring cars, etc. Sections were cut through solid rock, and to provide transport in all weathers, some sections were corduroyed and gravelled. Drainage trenches had to be cut at the sides in places. The road was adjacent to the cable route for practically the whole of the distance.

Across Patonga creek, it was necessary to build a pontoon bridge to permit easier access to the country between the creek and the river. This bridge was used by the workmen who excavated the trench from the creek to the river. Later it was used to enable four length of cable to be laid on the river side of the creek and in laying submarine cables in the creek. It was also used for the transport of cable jointers with their equipment. The floats for this bridge were empty 44 gall. drums. Stakes for the bridge

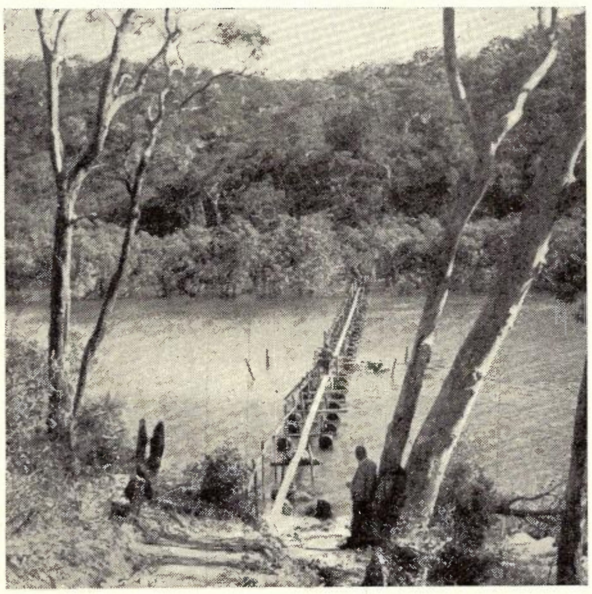

Fig. 9.—View of Pontoon Bridge across Patonga Creek.

were cut in the locality, and a small supply of blackbutt timber was purchased for planking. The floating portion of the bridge was 160 yds. long and it was extended over a mangrove swamp on one side for a further 100 yds. A section in the middle of the bridge could be opened as required to permit the through passage of small boats, and as the rise and fall of the tide averaged 3 to 4 ft., the bridge was built so that it was free to rise and fall accordingly. Fig. 9 shows a view of this bridge.

From the edge of the Hawkesbury River on the Patonga side, the ground rose abruptly for a height of 300 ft. up a grade steeper than 1 in 2, mostly consisting of huge rocky boulders. From the top of this cliff towards the creek, the ground was comparatively level for the first 500 yds. with large isolated patches of rock, but for the next 500 yds. to the flat adjacent to the creek, a very rough, steep and rocky downward grade was encountered. Two drums of steel wire armoured cable had to be placed in the open trench on the steep grade rising up from the river, and eight drums of steel tape armoured cable had to be placed in the rest of the trench towards the creek. Various methods whereby the cables could be transported into position and placed in the trench were considered, but the method finally adopted was comparatively simple and involved a minimum amount of gear, man-power and cost. A shallow draught steam lighter fitted with a steam winch and a well-stayed mast and derrick, was used to lay the submarine cables across the Hawkesbury River. This lighter unloaded the ten drums of cable on the water's edge above high water mark. Up the rise, pairs of channel irons were set vertically in the ground, braced together and set sufficiently apart to hold a wooden cable roller at the top in a horizontal position. These channel iron supports were of varying heights but were graded so as to maintain a uniform slope. Halfway up the slope there was an angle in the run and on a convenient tree, a special support was bolted and fitted with two horizontal and one vertical roller. An endless steel messenger wire was drawn into position on the rollers from the winch on the ship, and at the top it passed through a snatch block on a tree returning downhill via one snatch-block on an angle half way down. The wire was wound for four turns on the barrel of the steam winch on the ship. Each drum was set up in turn on jacks at the base and the cable lashed to the messenger wire at intervals of 12 ft. or so as the messenger wire was pulled up. In this manner, no undue tension was placed on the cables. As each length of cable arrived at the top, the lashings were cut and the cable coiled in large figure of eight coils. It took about 30 minutes for each length to be pulled up. Later each length was pulled out on rollers and laid into the open trench, the rollers being carried forward as the work progressed.

On the Woy Woy side of Patonga creek, the cable drums were placed in position on the top of the steep rise and each cable length was practically gravitated down on the channel iron and roller supports to the pontoon bridge. Each length was then pulled by man-power over the bridge on rollers on wooden supports placed on the planking at intervals of 12 ft. It was necessary to pull four drums across the bridge in this manner and into the open trench on the flat to the foot of the rise leading to the river.

Except for the assistance given on four days by a few trainees, the whole of the work from the Woy Woy road to Patonga creek and through to the Hawkesbury River, was carried out by a team of 12 men under the direction of a Line Inspector, and in very good time, considering the excessive amount of rock and the rough and precipitous nature of the country. It is also pleasing to note there were no accidents.

On all very steep grades, lengths of steel wire armoured cable were laid. Wherever possible the continuity of a steep downward grade was broken by laying the cable in a horizontal position for a short distance either in the direct line of the route or across it. At the beginning of each downward step the cable was held against creeping by attaching light flexible steel wire in the form of a cable grip for a distance of 10 ft. or so, and the end of each grip was securely held by an attachment to an eyebolt let into rock in the trench bottom.

Mole Plough and Trailer Method of Cable Laying.—The first section upon which the Mole plough and trailer method was used on this work was a level sandy length of 5 miles immediately south of Woy Woy. Although the section was of a sandy nature, it was rather heavily timbered and an advance party preceded the cable laying party removing trees, stumps and roots and ploughing a track to a depth of over 20 inches with a deep rooter plough. The cable-laying outfit consisted of a winch-equipped tractor for hauling, two cable drum trailers in tandem, and a mole drain type of plough placed under the leading trailer and attached thereto in such a manner as to permit a limited side-to-side movement of the vertical ploughshare. This movement was controlled by a traversing screw carriage with worm drive attached to the trailer. Two tubes were arranged at the rear of the ploughshare, one behind the other, in the form of a quadrant bend, and the two cables were automatically fed through these tubes from each of the two trailers into the ground as the trailers and plough were pulled along by the tractor. This method was first used on the Melbourne-Geelong work and is described in Volume 2, No. 2, page 93.

As each of the two Sydney-Maitland buried armoured cables was only 203 yds. per drum length and the drums weighed 18 cwt., it was possible to convey four drums at a time on a motor lorry from the nearest cable depot and unload them two at a time at the places where they were required to be placed on to the trailers. To expedite the unloading of the empty drums from the trailers and the loading of full drums, the motor winch equipped truck used for the transport of the drums was fitted with a short derrick over the winch behind the driver's cabin, and a swinging boom. This was not a very satisfactory arrangement, as unloading from the side of the truck on to the trailers presented difficulties, and owing to the generally rough nature of the route, the truck could not be used for this purpose in many places. This method was soon discarded and a jib crane was fitted to the rear of the winch-equipped tractor used for hauling the mole plough and trailers. The tractor, after taking off the empty drums from the trailers, picked up each full drum in turn from the place where it had previously been unloaded from the motor truck and travelled with it to the trailer, where it was lowered into position. Fig. 10 shows the

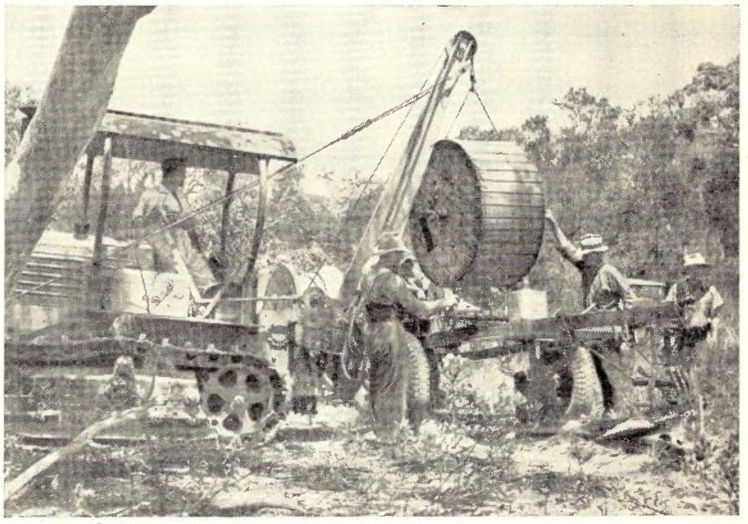

Fig. 10.—Lowering a drum of Armoured Cable into position in Cable Trailer by means of a Jib Crane fitted to rear of Tractor.

crane in action. At times, it was necessary to shift the mole plough and trailer from one position to another, for example, over an intervening section when the use of the plough was not practicable. The crane was used to lift the plough out of the ground while still attached to the trailer and to carry both at the one time along the route to a new position.

A team of seven men took from 20 to 30 minutes to lay two drum lengths of cable in the ground for a distance of 200 yds. and about the same time to replace the empty drums with full drums, excavate a small trench behind the plough, thread the ends of the cables on the full drums through the tubes into the trench and hold them in position until the cables were laid for a distance of 5 to 10 yds. in the ground and thus securely held against moving forward in the ground. Back filling was completed by an attachment on the rear of the drop axle on the leading trailer in the form of two blades arranged in the form of an open "V" and weighted down. The seven men included the tractor driver and party leader, as well as one workman who travelled behind the unit effecting final reinstatement, fitting spalls in the trench, etc., as required. When two cables were being laid, this squad would place an average of 18 drums of cable in the ground per day under average conditions.

On many miles of the route it was necessary to lay three cables. This was accomplished by fitting a third tube behind the ploughshare and using a third trailer. The third or subsidiary cable was brought through the rear tube from the leading trailer and was therefore laid in the ground immediately above the two main trunk cables. Figs. 11 and 12 are views of the cable-laying unit at work.

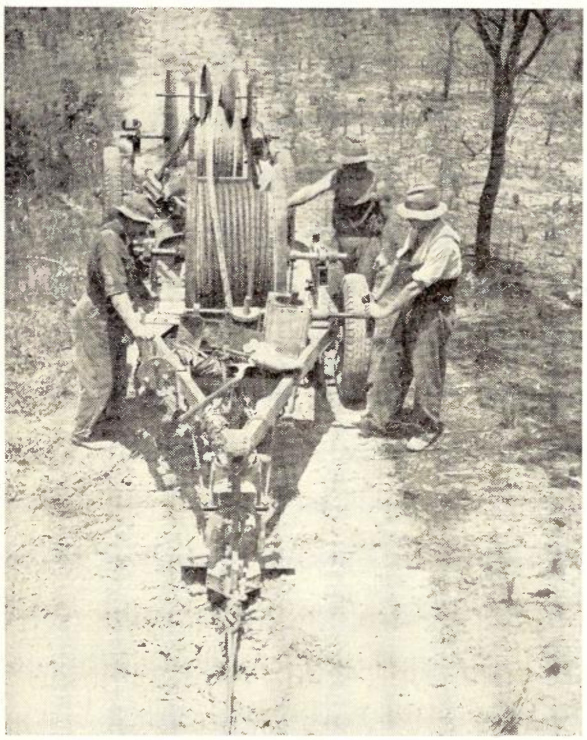

Fig. 11.—Front view of Cable-laying Unit. The Mole Plough is fitted beneath the fork of the leading Trailer and is pulled by a winch-equipped Tractor.

Instead of using tubes at the rear of the plough-share, it might be better to use separate compartments, each rectangular in cross-section and of a size such as to permit the passage through them into the ground of two cables each lashed to the other. This is necessary when starting off a full drum as the running end of the new drum can be lashed to the tail of the cable from the drum just emptied for the length of overlap required for jointing purposes and both are then pulled into the ground. This would avoid having to dig a hole and hold the end of the cable from the full drum each time full drums are exchanged for empty drums on the trailers. Detachable and adjustable guide pieces would be necessary at the front end of each such compartment. At times it becomes necessary to cease ploughing before reaching the end of a section. The cables must then be pulled through the bottom end of the tubes and the remaining lengths manhandled into an open trench or perhaps under some obstruction such as a water main. With detachable compartments in lieu of tubes, this would be facilitated. At the time of writing, experiments are about to be made with a plough embodying this and other modifications.

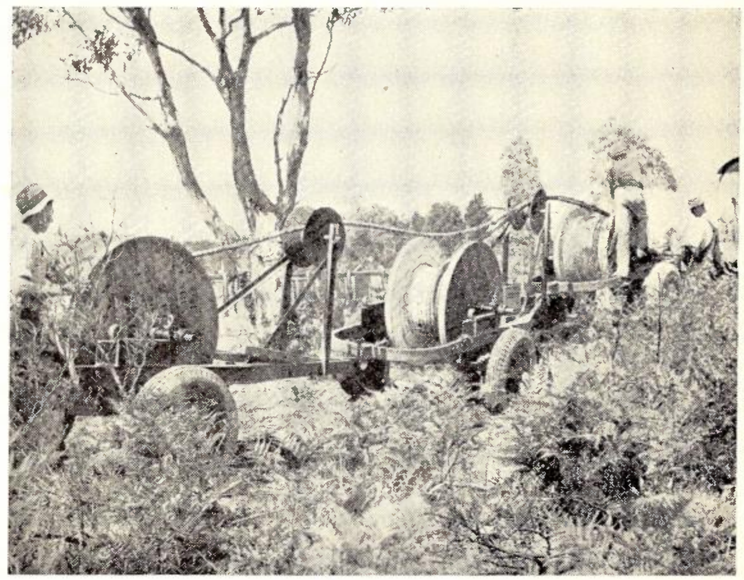

Fig. 12.—Laying three Cables simultaneously by the Mole Plough and Trailer method.

The minimum depth of cover of sixteen inches was over the trunk cables. In soft or swampy ground, a much greater depth was maintained. No great difficulty was experienced in laying two or three cables through creek beds or in stretches of swampy ground. In some places where the ground was soft or of a slippery nature, and where there was excessive cross fall, there was a tendency for the third trailer to slide sideways and pull the train out of line. This was counteracted wherever possible by travelling a three-ton truck parallel to the third trailer to which it was attached by means of a steel wire from the motor-driven winch on the truck through a snatch block at the rear of the truck. As each drum length of cable was laid, sufficient overlap was provided for jointing and testing and concrete cover boards were placed over the ends of the cable in the ground as a form of protection when the jointing squad later excavated to locate the ends. These cover boards were subsequently left in position over the split couplings on the joints. A concrete cable marker was placed immediately over the cable ends to indicate to the jointers the position of the buried ends.

Reinstatement.—Back-filling spoil into an open trench by mechanical means presents difficulties when the surface is broken and uneven, or when large masses of vegetation or lumps of clay require to be handled. On an even surface, such as a macadamized road, loose spoil can be backfilled with the usual single blade grader. On uneven surfaces, a horse or truck-drawn light type single side mouldboard plough is useful. A wooden framework supporting two blades, one behind the other, and set at an angle to the line of the trench, was used successfully at times. A cable trailer loaded with a full drum and with two blades beneath at the rear in the form of a "V" but opened out at the apex for the width of the trench was one of the best methods. The blades were braced together at the top and were attached to the rear axles in such a manner as to prevent them drifting from side to side, but free to move vertically to a limited extent. This latter method was always used when cable laying with the mole plough and trailers. The spoil to be returned to the trench was small in quantity as compared with that from an open trench. A weight in the form of a concrete block was placed across the top of the blades. Sometimes a roller was drawn immediately behind the blades, but generally it was found better to leave a small mound of spoil over the trench to allow for settlement and to discard the roller. The attachment was made to the leading trailer to ensure back filling over the trench.

In many places it was necessary to pack the trench with stone spalls, concrete over watercourses, and take various steps to prevent subsequent scouring or erosion after heavy rains. Reference has already been made to the use of concrete cover boards over the cables in certain places, and the action taken to prevent creeping of the cables on steep grades.

In restoring large masses of vegetation, such as paspalum grass roots and soil, also heavy clay, into a trench, pronged hoes were found very useful.

Submarine Cables.—Several lengthy submarine crossings were necessary on the route, the longest being the Sydney Harbour (760 yds.) and the Hawkesbury River (800 and 1300 yds.). Heavily armoured lead-sheathed and rubber-covered cable, a little over 2½ inches in diameter, was used for these crossings as well as for several others on the route varying from 100 to 330 yds. In other places where the rate of current flow was not excessive, such as small rivers or creeks, an intermediate type of submarine cable with lighter armouring was used. On the whole route twelve submarine cable crossings were made.

In the case of the Sydney Harbour and Hawkesbury River crossings, where the cables were to be paid off from drums suitably mounted on a boat, a shallow draught steam lighter fitted with a steam winch, mast and derrick, was used. It was possible to mount the two drums in the hold of this vessel and pay off the two lengths over the stern simultaneously. The heaviest drums of cable were those for the 1300 yds. crossing in the Hawkesbury River, and each weighed 15 tons. The drums for the 800 yds. crossing at the Hawkesbury River and the 760 yds. crossing in the Sydney Harbour weighed approximately 9 tons each. To accommodate these, special stands were built from oregon pine baulks securely bolted together and special chrome steel spindles, each 8 ft. long and 4 inches in diameter, were used. The bottom bearer for the spindle on the stands was made of hardwood, and the top bearer of steel plate suitably shaped, actually steel stay plates. Suitable wooden brake shoes bearing on the underside of each cheek of each drum were fitted, pivoted at one end and applied by an upward pull on the other end.

The first lengths of heavy type submarine cable laid were in the Sydney Harbour. This presented no great difficulty as the route was already well established and a number of other submarine cables were already in position. Cable huts and runways were in position at each end at Dawes Pt. and Blues Pt.

In the case of the Hawkesbury River crossings, it was first necessary to unload the four drums from an overseas boat on to a lighter at Sydney. The drums were then reloaded on to the stands in the steam lighter used for the Harbour crossing and transported two at a time up the coast to the Hawkesbury River, a distance of 30 miles. Very special care was necessary in stowing these drums as any tendency to roll or shift when outside the Heads would have meant disaster. A number of smaller drums of tape-armoured cable were transported at the same time with the heavy drums and this facilitated stowage. Some anxious moments were experienced when these drums were on the open sea. Shortly after the lighter carrying the two 15-ton drums left the Heads after midnight, an unexpected severe squall with heavy seas was encountered, and it was necessary to turn about and run for shelter into the Harbour. When the weather abated, a second attempt was successful.

Concrete manholes were built at each end of the cable crossings at the river. These were made large enough to hold gas-sealed joints and contactor alarm apparatus required for the gas pressure alarm system, and were arranged to have the floors above high-water mark. From the manholes reinforced concrete troughing with concrete slab covers were constructed so as to enter the water below the low water tide level, and these were suitably pinned down on rock bottoms where possible.

The shorter crossing of 800 yds. from Brooklyn to Dangar Island presented some difficulty due to the presence of a narrow sand spit across the proposed route of the cable some 200 yds. from Dangar Island. The steam lighter with the two drums aboard was moored just off this sand spit on the Brooklyn side. A manila rope was paid out from the island to the lighter and a steel wire was pulled ashore by a motor winch on a truck on the island. This rope was passed through a snatch block, securely anchored on a large rock on the island and returned to the steam winch on the lighter. Each end of the cable was then passed over wide wooden rollers fitted on the combing of the hatch, along the decks and over a large wooden sheave projecting over the stern. A spreader was fitted between the two ends and an empty 44-gall. drum lashed to each end. The wire rope was then pulled in by the winch, and as the cables were paid overboard empty drums were lashed to each cable at intervals of 20 yds. When the shore ends were landed on the island and held, the lighter steamed towards Brooklyn, paying out the two cables at the rate of approximately 80 yds. per minute. A motor vessel stood by, as should wind or tide have deflected the bow of the lighter, it would have been difficult to regain steerage way with two heavy cables laying over the stern. The Hawkesbury River is noted for strong tidal currents and eddies and there is very little slack water time between tides.

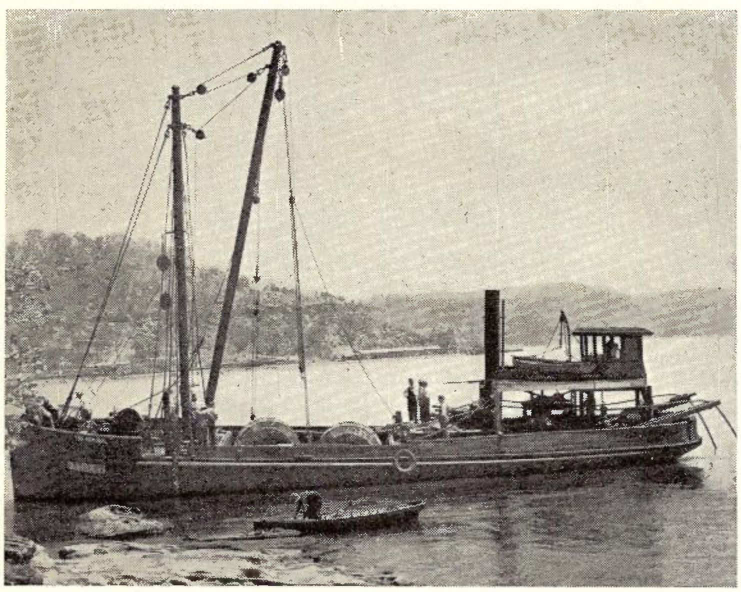

Fig. 13.—Cable Boat arriving at Brooklyn from Dangar Island, Hawkesbury River, after paying out 800 yards of Submarine Cable from each of two drums.

The longer crossing of 1300 yds. from the mainland on the Patonga side to Dangar Island was made a week later. The cables were paid out from the mainland side, where there was a good depth of water. After travelling nearly 1200 yds., which distance was covered in under 15 minutes, the boat was stopped about 100 yds. off the island, where the water became shallow. An old vehicular punt was moored alongside the steam lighter, and by means of the steam winch and boom, one of the two drums with remaining length of cable thereon, together with the spindle and stand, weighing in all about 3 tons, was lifted bodily on to the punt. The latter was pulled ashore by a steel wire from a motor winch on a truck on the island, and the paying out of cable was continued. The cable then remaining on the drum was manhandled into the trench. The second drum was then dealt with in a similar manner. The whole job took a little over two hours to complete from the time cable laying commenced. Fig. 13 is a typical view of work in progress.

All cables were well entrenched at low water and at the deep water ends on the mainland, each cable was fitted with suitable clamps separately attached by stout steel wire or galvanized chain to ring bolts securely set through the flooring of the manholes. A certain amount of zig-zagging of the course was carried out at each end of the run in the deep water to provide a little slack for subsequent settlement.

At most of the other smaller crossings, after placing a steel wire in position, the cables were drawn, one at a time, by a power winch on a truck or tractor. An empty creosote drum was lashed to the leading end of the cable to ease the strain and prevent dragging on the bed of the stream. At several crossings, it was necessary beforehand to locate and remove obstructions such as old trees and logs in the bed of the stream in the path of the cables. The winch-equipped tractor was particularly useful for this work. Generally, the heavier cables were pulled, one at a time, after having first been paid off the drum and laid on wooden rollers laid on the ground in the direction of the pull across the water.

[Editor's Note: This part will be concluded in the next issue. Reference will be made to testing (including overall tests), jointing and balancing procedure, gas pressure alarm system, etc.]

FAULT LOCATION TESTS ON TRUNK LINES

M. Bowden

Trunk line faults for which location tests may be made without elaborate apparatus may be divided into the following groups:

(1) Contact between the two wires of the circuit and known as a Short Circuit.
(2) Contact between one wire of a trunk line and another circuit, and referred to as a Cross.
(3) Contact between one side of a trunk line and an earthed circuit or object and usually called a Ground.
(4) A very high resistance contact or a leakage to another conductor or ground and referred to as L.I.R. (Low Insulation Resistance) between the pair; L.I.R. to another circuit or "ground," as the case may be. This is distinct from the normal distributed insulation resistance of the circuit.

Before an attempt is made to determine the location of a fault, it is necessary to know the line characteristics, i.e.:

(a) The type of wire—Copper, Cadmium Copper, Bronze or Galvanised Iron.
(b) The weight per mile of the conductors.
(c) The locations of any sectional and leading in cables and the resistance of the pair in each piece of cable through which the trunk line is routed.
(d) The intermediate stations through which the line passes either for testing only or for service and if active or dummy heat coils are in circuit.

The details mentioned should be recorded on the Trunk Line Master Card at the Testing Station.

Generally it will be sufficient if the resistances of the various parts of the circuit be known approximately, as the actual resistance values will vary appreciably throughout the year and along the route, due to temperature changes. The resistance of a metal increases as the temperature is raised, the increase for copper being approximately 0.23 per cent. for each degree Fahrenheit, temperature rise. The effect of this may be illustrated by considering, say, a trunk line 200 miles long and constructed throughout of 200 lb. copper conductors. At a temperature of 60° F. a 200 lb. copper line has a resistance of 4.46 ohms per mile of single wire or 8.92 ohms per mile of loop, and the resistance of a 200 mile line would be 1784 ohms. If the temperature of the line wires throughout the whole length be increased to 80° F. the resistance of the circuit would be increased by $1784 \times 0.23 \times 20/100 = 82.06$ ohms, which would be equivalent to adding approximately 9 miles to the length of the line as at 60° F.

It is not practicable to make corrections for temperature when making a fault location test, as the temperature may vary considerably along the trunk line route. It is sufficient for practical purposes and will simplify calculations if round figures for loop mile resistances be accepted for the basic calculations.

From the foregoing it will be seen that the original location will be an approximation and that the longer the section of line tested the greater will be the likely error. It will be of material assistance, particularly when dealing with faults on the longer circuits if the fault lineman after an examination in the vicinity of the advised location calls the testing officer and obtains a check test. In this manner the error due to the variables can be reduced, if not eliminated, and a very accurate location given.

Hereunder are resistance values which will be found satisfactory for general use:

600 lb. Copper	3	ohms per loop mile
300 lb. Copper	6	,,
200 lb. Copper	9	,,
100 lb. Copper	18	,,
100 lb. Bronze	40	,,
70 lb. Bronze	58	,,
70 lb. Cadmium Copper	30	,,
400 lb. Gal. Iron	27	,,
200 lb. Gal. Iron	54	,,
100 lb. Gal. Iron	108	,,
40 lb. Cable	88	,,
20 lb. Cable	176	,,

Either the Varley or the Murray Loop Test may be used for the location tests. The Varley test is simple to apply and is the more convenient method, particularly if an elaborate switching arrangement is not a feature of the test set. The Varley Test, therefore, is recommended and will be discussed at some length. The location of a "Ground" fault will be taken first.

Ground Fault.—The first step is to determine between which stations the fault exists and which is the faulty wire. This test can be made with a galvanometer or detector and battery and does not need further discussion. The station beyond the fault should be asked to loop the line after any intermediate stations have been disconnected by patching at the test panel or section switches. The location test, of course, can be made by looping at the distant terminal, but, as mentioned previously, the initial error will be reduced by keeping the section under test as short as is practicable. If the faulty line be too noisy to use for issuing instructions to the various stations, another circuit should be used for the purpose.

When the line has been looped as indicated, the test circuit should be arranged as in Fig. 1. If a Wheatstone Bridge be not available, resistance boxes may be wired to serve the same purpose.

a and b are the ratio arms of the Bridge, r the variable arm, G a sensitive galvanometer, K1 and K2 keys for closing the galvanometer and battery circuits respectively, and S a change-over switch to disconnect one side of the battery from line and to connect it to ground when

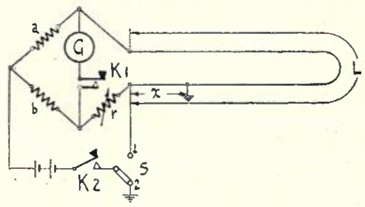

Fig. 1

required. The line is connected as shown with the faulty side to the "r" arm of the Bridge and the switch S in No. 1 position. K2 and K1 should be closed in that order and r adjusted until the closing of the keys in the order mentioned results in no deflection of the galvanometer needle. When this condition is reached the resistance r will be equal to the resistance L of the looped trunk line, providing that the resistance of ratio arm a equals the resistance of ratio arm b.

Referring to Fig. 1, the condition for a state of balance is $bL = ar$. If $a = b$, then $L = r$.

K2 should always be closed before K1 so that the line will be charged before the galvanometer circuit is closed. Should K1 be closed first, the surges due to the charging of the line when K2 is pressed may result in the galvanometer needle being deflected, although the circuit may be balanced as regards resistance. Similarly, K1 should be released before K2.

After the loop resistance of the line has been determined, the switch S is moved to No. 2 position and r varied until a second balance (r) is obtained. The condition then is:

$$b(L - x) = a(r + x)$$

$$\text{and } x = (bL - ar)/(a + b).$$

When the ratio arms a and b are equal, as is generally the case,

$$x = (L - r)/2.$$

The resistance of the fault forms part of the battery circuit and, therefore, does not affect the location test provided that the resistance is low compared with the normal insulation resistance of the line; it may be necessary to increase the voltage of the testing battery.

Having obtained a resistance value for x, i.e., the resistance of the faulty wire from the testing station to the fault, the distance to the fault may be calculated from the data held for the particular line. It will be observed that the value of x only is under consideration and, therefore, the result is independent of any resistance outside the faulty section. It is not necessary that both sides of a line under test should be of the same gauge. If both sides of a line are grounded, a test may be made after joining one side of any good line to one of the faulty wires, and after having obtained a resistance value for x the distance may be easily calculated.

It is frequently helpful to determine the distance of the fault from the distant end of the looped line, particularly if the fault be nearer to that end. **If both sides of the line under test are of similar construction** this may be determined from the data available after the two readings previously mentioned have been taken. It has been shown that $x = (L - r)/2$. From this $r = L - 2x$ and it will be seen (Fig. 1) that if we deduct 2x from the loop resistance, r equals the resistance of all the wire in circuit between the distant station and the fault. 2x, therefore, equals the resistance of the faulty pair from the testing station to the fault and r equals the loop resistance of the line between the fault and the distant station.

An example will serve to illustrate:

$$\text{Let } L = 400 \text{ ohms}$$

$$r = 60 \text{ ohms}$$

$$\text{then } 2x = 400 - 60 = 340 \text{ ohms,}$$

which is the resistance of the faulty pair between the testing station and the fault. $r = 60$ ohms is the total resistance of both wires between the fault and the distant station. The resistance of one wire would be 30 ohms if both sides of the line are of equal gauge.

This short cut provides a simple means for making a check test with a lineman. Assume that a lineman has examined the line in the vicinity of the given location and has not found

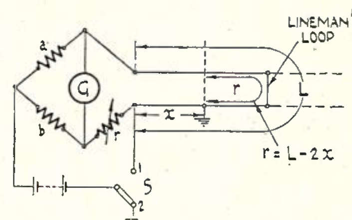

Fig. 2

the trouble. On communicating with the testing officer the fault man will be asked to loop the faulty line and ensure that a good contact is made. The condition then may be as shown in Fig. 2. Galvo. and battery keys have been omitted.

With the switch S in No. 2 position, r is adjusted to obtain a balance. If the lineman's loop is beyond the fault, the resistance r will

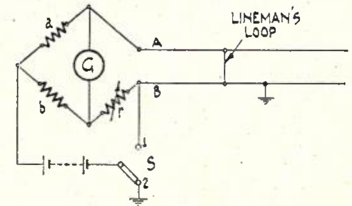

Fig. 3

indicate the loop resistance of that portion of the line between the lineman's loop and the fault and towards the testing station. If a balance is obtained with $r = 0$, then the lineman has looped the line between the testing station and the fault. Remember, however, that this result only holds when both sides of the line are of equal resistance per mile and that quite a small resistance unbalance will affect it.

In Fig. 3 the lineman's loop is shown between the testing station and the fault. For a condition of balance:

$$bA = a(r + B) \text{ and when } A = B,\ r = 0.$$

If, for example, the resistance of the A leg to the lineman's loop be 3 ohms greater than that of the B leg, a balance will be obtained when $r = 3$, although the actual fault is beyond the loop. If the resistance of the B leg be greater than that of the A leg it will not be possible to obtain a balance. When r is small, therefore, a further check is desirable with the lineman's loop placed at a different location and the two results compared.

Short Circuit.—A rough test may be made by measuring the resistance of the circuit through the fault and calculating the distance represented by the resistance value obtained. Generally this method may be reasonably accurate, but the resistance of the fault itself is included. In some instances this may be considerable as, for instance, when a piece of rusty iron wire is causing the fault. It is preferable to set up the circuit for a Varley test after having one side of the line earthed beyond the fault as shown in Fig. 4.

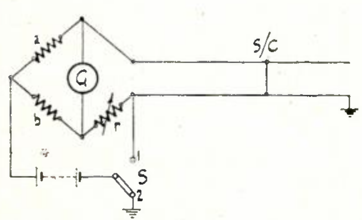

Fig. 4

The loop through the fault is measured and a second reading taken with switch S in position 2. If $r = 0$, then $L =$ the loop resistance to the fault. If there is any resistance in the r arm when the second balance is obtained, it will indicate the resistance of the fault itself if the line is balanced. An unbalanced line will result in either some resistance in r when the Bridge is balanced or else inability to obtain a balance even though there may be no measurable resistance in the fault itself. This aspect has been discussed in connection with Fig. 3. The degree of unbalance, if any, is usually small and an r reading of 2 or 3 ohms when testing for a short circuit fault may be neglected in the initial test for any but 400-lb. and 600-lb. copper circuits. If the r reading is appreciable it should be deducted from the loop resistance before calculating the distance to the fault.

Cross.—The lines in contact should be determined; one circuit should be looped at a station beyond the fault and the faulty wire of the other circuit earthed either at the distant end or the testing station (Fig. 5). The conditions then are equivalent to a ground fault and the same test is applicable. A reference to both Fig. 1 and Fig. 5 will illustrate this.

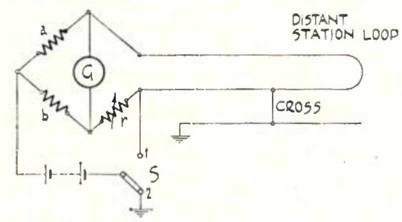

Fig. 5

Low Insulation Resistance. — The tests discussed are applicable to contacts where the fault resistance is very low compared with the Insulation Resistance of the line. As the fault resistance becomes higher and approaches the I.R. of the line, the location as determined by the methods discussed becomes less accurate. This will be apparent by a reference to Fig. 6.

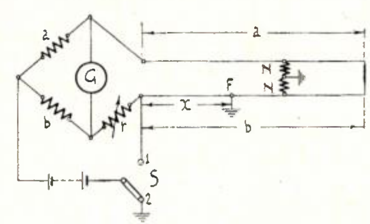

Fig. 6

The normal distributed insulation resistance of each wire may be regarded as a high resistance contact to earth located at the centre of the line and is represented by N in Fig. 6. If a fault to ground develops and the resistance of the fault be low, the effect of the normal insulation resistance of the circuit will not affect the accuracy of the test. If the fault resistance be appreciable in relation to the normal distributed insulation resistance the normal test $x = (L - r)/2$ will indicate the fault to be between the actual point of contact and the centre of the line. The higher the resistance of the fault the greater will be the error.

For the condition shown in Fig. 6 and with equal ratio arms the arrangement when a balance is obtained is such that:

$$x = \frac{A + B - r}{2} - \frac{F}{N}\left(\frac{B - A}{2} + r\right)$$

If both sides of the circuit under test are of similar construction, i.e., $A = B$ and $A + B = L$ (the loop resistance of the circuit), the formula may be written:

$$x = \frac{L - r}{2} - \frac{F}{N}\,r.$$

where F/N is the ratio of the fault resistance to the normal insulation resistance of the circuit. In practice, this relationship will not be known with sufficient accuracy and may be eliminated by making a test from each end of the line and combining the results.

If A = resistance of good wire
B = resistance of faulty wire
r = balancing resistance at reference end
r_1 = balancing resistance at distant end
x = resistance to fault of the faulty wire from the reference end.

$$\text{then } x = \frac{A + B - r}{2} - \frac{A - (r + r_1)/2}{B - A + r + r_1}\left(\frac{B - A}{2} + r\right)$$

where A = B, let A + B = L;

$$\text{then } x = \frac{L - r}{2} - \frac{L/2 - (r + r_1)/2}{r + r_1}\, r$$

$$\text{which may be reduced to } x = \frac{L}{2}\left(\frac{r_1}{r + r_1}\right)$$

Example:

Let L = 600
r = 300
r_1 = 200

$$x = \frac{L}{2}\left(\frac{r_1}{r + r_1}\right)$$
$$= 300 \times 200/500$$
$$x = 120 \text{ ohms.}$$

If a test had not been made from both ends and the correction formula not used the normal Varley test x = (L — r)/2 would have indicated x = 150 ohms, which would have introduced an error of 25% for the particular case under discussion.

Murray Loop Test.—The Bridge connections for locating a "ground" fault by the Murray method are shown in Fig. 7.

The loop resistance should be determined first and the Bridge connections altered as shown with the "a" ratio arm plugged out and the "b" arm set at 100 ohms or 1000 ohms for convenience in calculating. The faulty wire is connected to the "a" arm terminal and not to the "r" arm, as is the case for the Varley test. The positions of the galvanometer and test battery are reversed with respect to those for the Varley tests. If the same positions were used the battery would

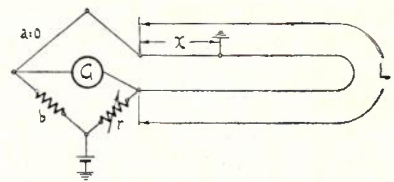

Fig. 7

be practically short-circuited by a low resistance fault close to the testing station. When a state of balance is obtained the condition is such that:

$$rx = b(L - x)$$
$$\text{or } rx + bx = bL;$$
$$\text{therefore, } x = bL/(r + b).$$

As for the Varley Tests, the value determined for x is the resistance of the faulty wire from the testing station to the fault. It is not necessary, therefore, for both sides of the line under test to be of the same construction.

Example:

Let L = 600
b = 100
r = 400

$$\text{then } x = bL/(r + b)$$
$$= (600 \times 100)/(400 + 100)$$
$$= 120 \text{ ohms.}$$

It will be seen that in the Murray Test the balancing resistance r bears no direct relation to the position of the fault from either end of the line in the manner that the balancing resistance does in the Varley Test (see Fig. 1, Fig. 2 and text). The Murray Test may be used for "Short Circuit" and "Cross" faults by suitable modifications to the line connections shown in Fig. 4 and Fig. 5, but for the Murray Test the faulty wire must be connected to the "a" ratio arm terminal as shown in Fig. 7.

USE OF ASBESTOS CEMENT TROUGHING IN 2000 TYPE AUTOMATIC EXCHANGES

Evan Sawkins, B.Sc.

Asbestos cement is a material which is being increasingly used for pipes and ducts in the building industry. This article briefly describes two examples of its use in exchange installation practice.

At Castle Hill (N.S.W.) Exchange it is used in the form of troughing to accommodate all inter-suite and distributing frame cabling. This exchange was recently placed in service and is designed to accommodate a maximum of 1000 lines. Suites of 2000 type racks lend themselves very well to the support of a transverse run of troughing, and if cable slats are bridged across the wiring aisle of adjacent racks a convenient means of feeding suite cables out of the duct is obtained. Except when about to leave the troughing, the cables are not laced, and floor space for ultimate cable is left only near exit holes where necessary. It will be seen from the illustrations that all turns are made wholly within the troughing and that cables leave in a plane at right angles to a troughing face. This has resulted in a slight increase in the space required for the ultimate cabling, but has made all the difference to the appearance of the finished job. Each exit hole was cut to take the ultimate cables and when the initial cables were run the remainder of the opening was closed with a neat fitting wooden stop. All the troughing is fitted with a moulded asbestos cement cover.

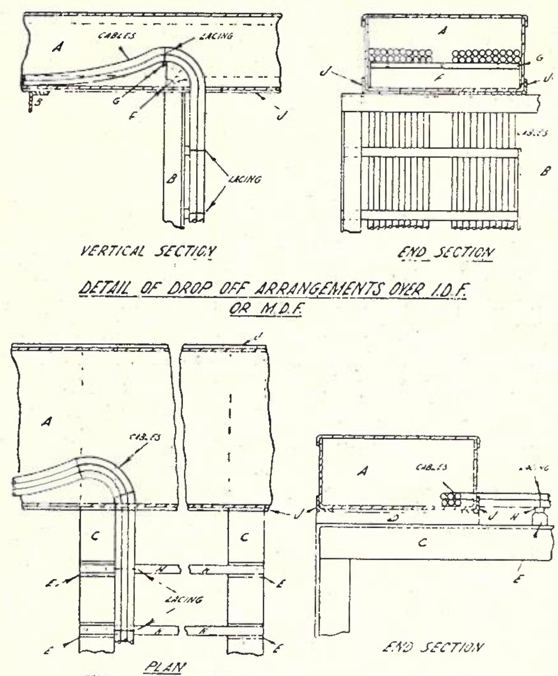

Fig. 1.—Method of using Troughing.

Detail showing Turn Off to Suite of Racks.
Reference:

A.—Asbestos cement troughing, 15″ x 7″ x ⅜″, with removable cover.
B.—M.D.F. or I.D.F. ironwork.
C.—Rack ironwork.
D.—Wood block, 15⅜″ x 3½″ x 1″.
E.—Wood block, 3½″ x 1¼″ x 1¼″.
F.—Wood block, 2½″ x 2½″ for cable turning.
G.—Wood slat screwed to item "F" for cable lacing.
H.—1″ x ¼″ M.S. flat for cable support.
J.—1½″ x 1½″ M.S. angle.

The main advantage derived from the use of troughing is that once a run of laced cable enters the troughing it may be re-oriented at will and cable runs transposed if required. Furthermore, where desirable, cables from different runs which are destined for the same rack and strip at the same point may be placed together before leaving the troughing. These facilities enable a reduction to be made in the number of cabling routes used and may affect the need for feeding tiers at an I.D.F. Also, assuming it is possible to face certain racks in the desired direction, it can be arranged that most cable runs turning on to racks from the horizontal will do so with straight right angular turns. The reduction in the amount of lacing required and the simplification of turns would result in appreciable saving of installation time.

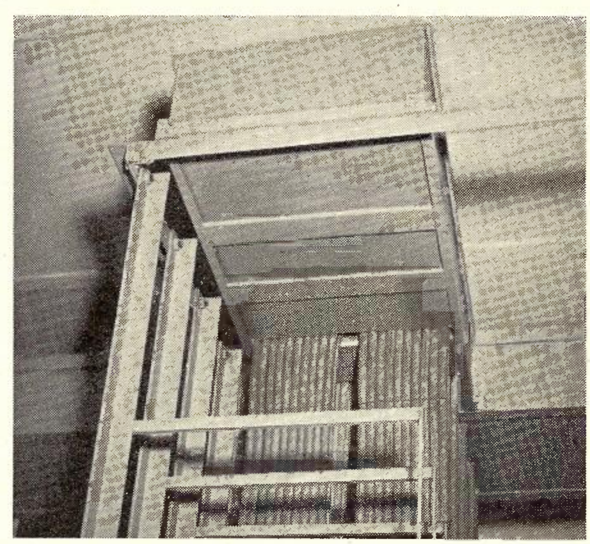

Fig. 2.—Cables leading down to M.D.F.

Although the use of troughing in this way in larger exchanges would not be practicable because of the size of individual cable runs, a scheme whereby cables leaving racks or suites immediately enter a low-hung ceiling and then proceed direct to their destination is a logical and practical development of the troughing idea. Such a ceiling with good reflecting qualities and suitably flood-lit from the top of racks would also provide first-class general lighting for the exchange.

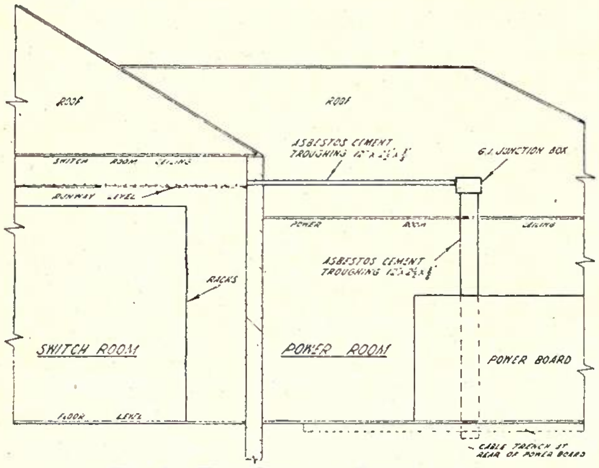

Fig. 3.—Troughing for Power Cable.

The second example of the use of asbestos cement troughing is to be found at Rockdale (N.S.W.) Exchange now in course of installation. It is used here to carry battery discharge cables and ring and tone and miscellaneous leads from the power board to the switchroom. It will be seen from the diagram that advantage has been taken of the fact that the switchroom ceiling is considerably higher than the power room ceiling (which is generally the case with new buildings). The troughing leaves the trench at the back of the power board, runs up the wall of the power room to the ceiling, and enters the switchroom at the level of the runways. A G.I. junction box is provided for the troughing above the ceiling of the power room.

It would have been an improvement if a troughing recess with a flush mounting cover had been provided in the power room wall (at the back of the power board) when it was being constructed. Troughing would then only have been required above the ceiling. The arrangements at Rockdale, however, serve the useful purpose of keeping cables out of sight near the power board and providing ready access to the runways and busbar in the switch room.

Ringing Machines and Inductor Tone Generators for Telephone Exchanges

W. H. Westwood

Introduction.—Before describing the machines a brief outline of the earlier means of ringing supply may be of interest.

The first practical form of ringer was the hand operated magneto generator as used on small switchboards. To improve efficiency and, on larger exchange switchboards, to eliminate manual operation, continuously driven generators were employed. These generally consisted of slightly larger magneto generators driven by small electric motors. In some cases a water motor was used to provide the motive power for the driven generator. A motor-generator of this type was utilized during periods of light load to provide ringing power for the Wills Street, Melbourne, Exchange. Vibratory equipment such as the battery operated polechanger was also used to eliminate the manual ringing operation where it was inconvenient or impossible to use a motor driven generator.

In the earlier automatic exchanges, harmonic ringers and tone equipment were used. Ringing frequencies of 16-2/3, 33-1/3, 50 and 66-2/3 cycles per second were used to provide for party line ringing.

In the larger C.B. and automatic exchanges, motor-generators and dynamotors were installed. These machines were fitted with gear driven interrupter drums and had associated transformer equipment for the supply of signalling tones.

16 and 33 cycle Ringing Current.—In C.B. manual exchanges the frequency of the ringing current is 16-2/3 cycles per second. When automatic working was introduced the four ringing frequencies referred to above were used for party line working. The bells of the straight line telephone were designed to operate on 33-1/3 cycles and although they could be adjusted to operate on 16-2/3 cycles the tone of the bells was not as satisfactory as when 33 cycles was employed.

As there was a very limited demand for "four party services" in the metropolitan networks, for some years party line services have been restricted to two parties per line. Standard straight line telephones are used and the bells of the two telephones are operated over either positive or negative sides of the line to ground. Thus, four ringing frequencies are no longer necessary, but owing to the large number of telephones with 33 cycle bells in service, the provision of ringing machines with a 33 cycle output has been continued.

Since the introduction of handset telephones, the number of telephones in service which are fitted with 33 cycle bells has decreased considerably. Although the bells on handset telephones are designed for 16 cycle working, they will operate satisfactorily on 33 cycles, but as the telephones with 33 cycle bells do not now constitute a serious problem, all new ringing machines provided will have a 16-2/3 cycle output and this will be the standard frequency. Ringing tone will now be 133 cycles/sec. superimposed on

16-2/3 cycles/sec. in lieu of 133 cycles/sec. superimposed on 33-1/3 cycles-sec.

Ringing Machines with Inductor Tone Generators.—For some years machines of this type have been provided in new exchanges and as replacements in exchanges in which harmonic ringers were installed.

Two machines are usually installed and are associated with the other power equipment necessary for exchange operation. One machine is a motor generator set. The motor is operated from the commercial supply mains and is direct coupled to a generator providing the ringing current. The second machine is operated from the exchange battery and for an output up to 2 amps a dynamotor is used. Where a greater output than 2 amps is required, the next size in output range usually manufactured is 4 amps and this machine is generally a motor generator set.

In all battery driven machines, an impedance or choke coil is included in series with the motor side to reduce the noise in exchange circuits which the machine would tend to produce when operated direct from the battery. This battery driven ringer provides for continuity of ring and tone supply in the case of commercial power failure. A changeover switch is provided in conjunction with the two machines to enable either machine to be connected to the exchange load. Automatic changeover from the mains operated (No. 1 machine) to the battery operated (No. 2 machine) on failure of No. 1 machine is provided, including the automatic start of No. 2 machine and operation of change over switch to enable this machine to take the exchange load.

Associated with each ringing machine is an inductor tone generator and a cam operated spring interrupter equipment. The tone generator is described later.

Ringing current at from 75-100 volts is supplied by the generator, and as interrupted ringing is found to be more effective for calling than continuous and represents an economical means of supply, the distribution of the output is carried through special interrupter spring sets provided to give ringing cycles as follows:—

0.4 seconds on, 0.2 seconds off, 0.4 seconds on, and 2 seconds off.

This cycle occupies three seconds and during the 2 seconds silent period of the cycle, it is possible to introduce two other ringing periods so that although the machine has a continuous output the actual load on the machine is equal to approximately one-third of the total exchange ringing load. This distribution arrangement is provided for by the cam and interrupter spring sets shown in Fig. 1.

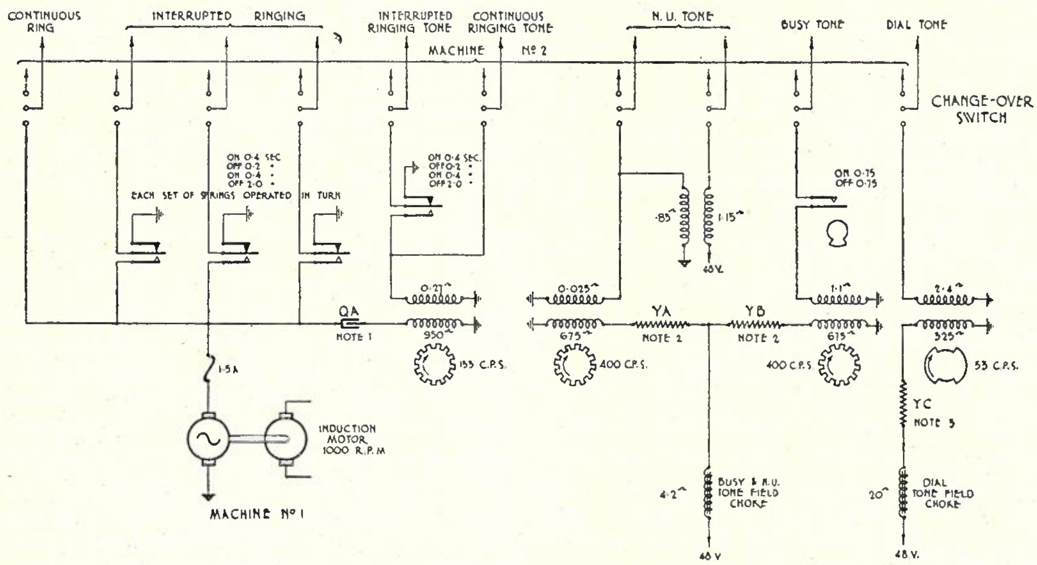

Fig. 1.—Ringing and Tone Distribution Circuits, Inductor Type Machine.

NOTES:

1. Three condensers provided, 2, 1, & 0.5μF respectively, to give suitable volume control.
2. Three resistances provided 200Ω, 500Ω, and 800Ω, respectively.
3. Three resistances provided 500Ω, 1,000Ω and 2,500Ω respectively.

The output voltage from the ringer is important as the satisfactory operation of line indicators on standard P.B.X.'s necessitates a machine voltage of at least 80 volts with 33-1/3 cycle ringing current. After operating under full load conditions for several hours, a decided drop in output voltage was experienced on some mains operated machines which were installed recently, although the battery operated machines functioned satisfactorily. These machines operating under full load conditions showed a considerable temperature rise with a corresponding decrease in voltage output. This temperature rise, although within the limits of standard specification for this type of machine, caused an increase in resistance and a resultant decrease in current in the field coils, the nett result being a decrease in output voltage. This decrease was sufficient to create concern when it was found that P.B.X. indicators were failing to operate. The design of the indicators and circuits was reviewed and the question of increasing the 2000 ohm shunt was considered, but as a change in this respect was not desirable, it was necessary to increase the output voltage of the ringer. This was achieved by connecting the ringer field coils in parallel pairs with a series resistance inserted in the circuit to limit the resultant increase in field current.

The value of the series resistance was adjusted to increase the output voltage under full load conditions by approximately 15 volts, so that 80 volts was obtained.

Tone Generators.—The inductor tone generator is built on to the end of the ringing generator and is operated at the normal machine speed from an extension of the main armature shaft. It generates by direct electro magnetic means, tones similar to those obtained by the earlier interrupter drum and transformer equipment arrangement.

The tone generator consists of a multi-toothed rotor rotating in a multipole stator. The stator carries both the generating and exciting windings. With this arrangement, there is no electrical connection to the rotor and no make or break of the electrical circuit; the output of the generating windings being taken to terminal blocks on the machine.

Fig. 2 shows a battery driven ringing machine fitted with a tone generator, the end plate and rotor of which are shown detached. The rotor consists of four sets of stamped soft iron discs, the front two each with 24 slots for busy and NU tones (400 cycles per second), the next with eight slots for ringing tone (133 cycles per second) and the last with two slots for dialling tone (33 cycles per second). These discs are keyed to the armature shaft and when rotated at the normal machine speed of 1000 r.p.m. produce tone waves of the required frequencies.

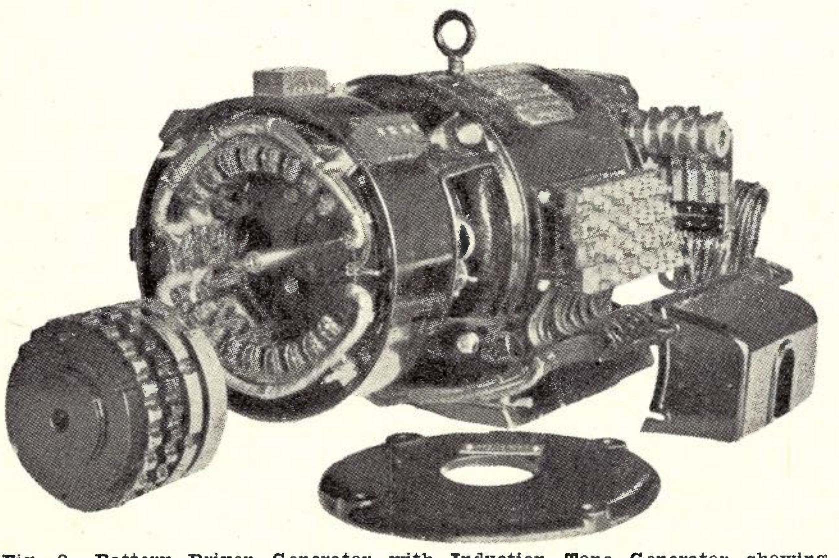

Fig. 2.—Battery Driven Generator with Induction Tone Generator showing End Plate and Rotor detached.

The stator is also built of soft iron stampings. There is an independent set of stampings for each tone to correspond with the four sets of slotted discs on the rotor. Each pole piece of the stator has a generating winding wound on it and the group of wound pole pieces constitute the generating winding for that particular tone. The exciting winding consists of two coils, each coil embracing half the pole pieces for the particular tone. The exciting winding for busy tone can be seen in Fig. 2.

The exciting windings for the busy, NU and dialling tones are energized from the exchange battery, each through control resistances and chokes. The ringing tone winding is energized from ringing current in series with a control condenser as generally shown in Fig. 1. In all cases the path of the magnetic lines is from the top down across the discs and back round the yoke of the stator. Thus the magnetic flux embraces both the exciting winding and the generating winding and flux variations will consequently generate an E.M.F. in both windings. If the exciting winding were fed direct from the battery without any series impedance, it would be practically short circuited for A.C. and this would seriously reduce the E.M.F. in the generating winding. The choke coil already referred to in the battery feed circuit for each tone, is of 5000 ohms impedance and materially assists in avoiding this loss of power. The busy tone is fed through cam operated spring sets to give the standard interruptions, 0.75 sec. on, 0.75 sec. off. The tone volume is controlled by the series resistances in the separate battery feeds to the exciting windings. These resistances may be cut in or out as required and form a ready method of regulating the loudness of the particular tone.

Tones produced with a generator of this particular type do not vary under all conditions of service, and are much more reliable than tones obtained by the drum type method of tone generation. The maintenance of the tone side of the machine should be negligible.

Line Finder Equipment for P.A.B.X.'s Types E and F

A. R. Gourley, A.M.I.E.(Aust.)

Introduction.—The development of unit types of Private Automatic Branch Exchanges enabled subscribers with relatively modest telephone requirements to enjoy the advantages of full automatic service. These types were described in Volume 2, No. 1, and provide for a basic unit for four both-way exchange and 25 extension lines which can be extended readily by means of an auxiliary unit to provide for eight both-way exchange and 50 extension lines. For the 25 line (type C) unit, four local connecting circuits are provided and for the 50 line (type CA) unit, eight local connecting circuits are available for extension to extension calls. These units meet the requirements of the majority of subscribers with up to 50 extension lines. Considered from the economic aspect, any unit type equipment must be designed to cater for the requirements of subscribers with average calling rates. If equipment is provided to meet the requirements of subscribers with high calling rates the necessarily increased capital and rental charges will limit the demand. The cost of the type CA unit approaches the economic limit for this class of plant.

To provide for subscribers with up to 50 extension lines and with from 50 to 90 extension lines with originating traffic of up to 0.12 A per extension, an open rack type line finder system has been developed. Two sizes have been standardized:—

Type E—for a maximum of approximately 16 exchange and 50 extension lines.

Type F—for a maximum of approximately 30 exchange and 90 extension lines.

The design is such that, if required, a type E unit can be extended readily to a type F unit. The requirements of subscribers with higher calling rates can be met either by limiting the number of extensions connected to a type E or F unit or by utilizing a standard 100 line uniselector unit as used in public exchanges, as a basis for a P.A.B.X.

Numbering and Trunking. — The numbering scheme is:—

Extensions	—type E	10–59
	type F	10–99
Information	—type E	9
	type F	91
Exchange		0

For calls to the exchange, the prefix "O" must be dialled prior to the number listed in the telephone directory. The exchange lines are single track, that is, separate groups are provided for incoming and for outgoing exchange calls. The number of incoming exchange lines determines the number of manual positions; in general on a type E not more than eight, and on a type F not more than 15 incoming exchange lines would be required. For each type, one manual switchboard would suffice. The number of outgoing exchange lines is limited by the number of final selector repeaters but the maximum requirements are not likely to exceed eight lines for a type E and 15 for a type F equipment.

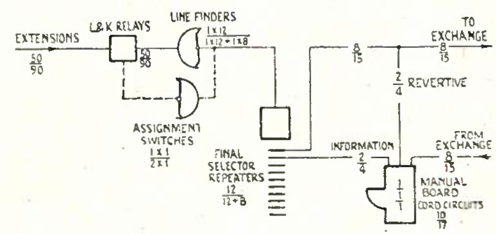

Fig. 1.—Trunking Scheme for Types E and F P.A.B.X.'s.

The trunking arrangements are shown in Fig. 1. The upper figure listed against each group of switches or relay sets denotes the number of switches provided for a 50-line equipment whilst the lower figure refers to a 90-line equipment. Types E and F are fully equipped with L and K relays, line finders and assignment switches for 50 and 90 extensions respectively, but the number of final selector repeaters and manual switchboard and exchange line relay sets installed, is determined by the traffic requirements of particular service. The switch quantities shown in Fig. 1 are typical for complete 50 and 90-line P.A.B.X.'s.

The scope of this article is limited to the line finder equipment but the following notes on other equipment shown in the trunking scheme, may be of interest.

The final selector repeater is a 100-outlet switch which functions as a straight line final selector on levels 1 to 9 but on level 0 which is reserved for outgoing exchange lines, an automatic search is provided and after a free outlet is located, subsequent impulses are repeated. Thus on level 0, the switch functions as a selector repeater and a battery feed is provided for the calling extension. When required, the automatic rotary search can be provided readily on any level and for type E units, this feature is employed on level 9 also.

The information trunks to the manual switchboard enable extensions to contact with the telephonist for information, requests for exchange service from extensions prevented direct exchange access, etc. On a type E service, level 9 can be made available for "information" but, on a type F service, as it is necessary to conserve extension numbers, a level cannot be released and 91 is allotted. If more than one information trunk is required, the 91 final selector bank multiple is split.

Revertive call circuits provide for access from the manual switchboard to the outgoing exchange lines to permit the telephonist to revert calls, i.e., to obtain an exchange call for an executive or an extension barred exchange access and to revert it to the particular extension via the multiple jack on the manual switchboard.

The incoming exchange lines are connected to the extensions via the multiple jacks on the manual switchboard.

Rack Layout. — The mounting arrangements have been designed with regard to accessibility from both the installation and maintenance aspects. All terminations are made on the front of the rack whilst bank and relay wiring is accessible from the rear. The equipment is

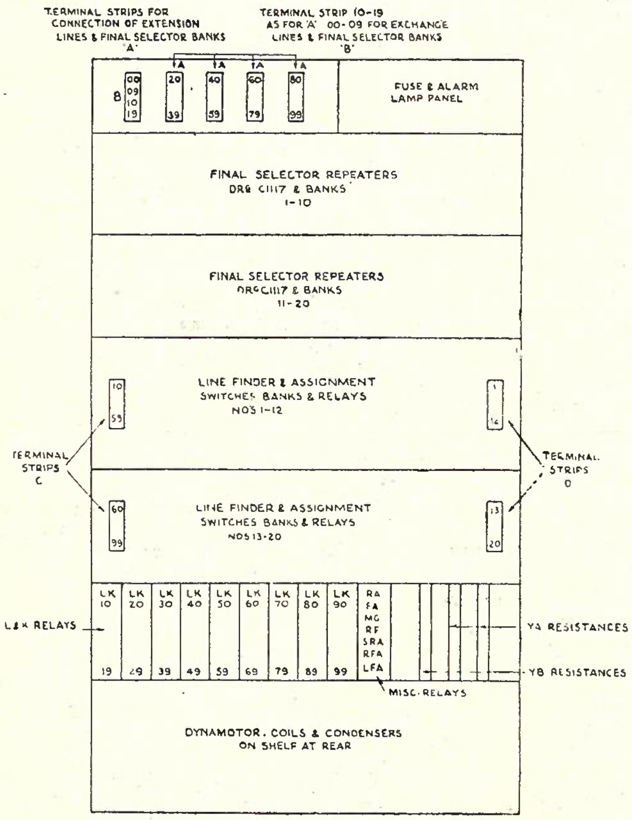

Fig. 2.—Rack Layout.

mounted on a standard single-sided rack 8 ft. 6 ins. high x 4 ft. 6 ins. wide of similar construction to racks used in 2000 type automatic exchanges. A sketch of the assembly is shown in Fig. 2. The rack provides a self-contained P.A.B.X. equipment which is complete except for the manual switchboard relay sets which are mounted on another rack of similar construction.

Referring to Fig. 2, the terminal strips at the top of the rack provide for the termination of cables from the M.D.F. and the manual switchboard. Terminal strips A and B are each fitted with six sets of 20 terminals. The panel for alarm type fuses and alarm lamps for the unit is fitted adjacent to the terminal strips. The main cables from the battery are terminated at the rear of this panel. Beneath the terminal strips, two shelves, each equipped with a set of 10 banks, are mounted for the final selector repeaters. Bank levels 1-9 are cabled in series to terminal strips A and the lower 10 rows of terminals on terminal strip B. The "0" level bank multiple from each set of 10 banks is cabled separately to the upper 10 rows of terminals on strip B. For up to 10 outgoing exchange lines, the respective positive, negative and private terminals on the block are strapped but if more than 10 exchange lines are in use, some individual trunks are provided from each set of banks and the common trunks only are strapped. Thus if 12 outgoing exchange lines are required, there would be two lines individual to each shelf of final selector repeaters and a group of eight outlets, common to all switches.

The line finder and assignment switches and associated relays are mounted on the next two lower shelves. The upper shelf of the two provides for 12 line finder switches and the assignment switch for 50 extensions and the lower for eight line finder switches and the assignment switch for 40 extensions. The standard rack width of 4 ft. 6 ins. will accommodate final selector repeater banks in sets of 10, hence the limitation to 20 line finders. The line finder banks are terminated on terminal strips C from which the positive, negative and private terminals are cabled to the extension line terminals on strips A and B, whilst the R terminals are cabled to the YA resistances mounted below. Outgoing trunks from the line finders to the final selector repeaters are cabled from terminal strips D. The L and K relays for extension lines, miscellaneous relays for ringing, tone and alarm control and the YA resistances for prevention of exchange access and YB resistances for testing circuits for the final selector repeater "0" level trunks are strip mounted below the line finders. As it is unlikely that more than 60 extensions would be prevented from obtaining direct access to the exchange, YA resistances are provided for extensions 10-39 and 60-89 only. A jack-in ringing dynamotor with associated choke coils and condensers is mounted on a shelf at the bottom and rear of the rack.

Equipment.—The L and K relays are of the 600 type whilst all other relays are of the 3000 type. The only special relay used is a 3000 type relay fitted with a thermostat. Three relays of this type are used in alarm control circuits in which an operating lag of 20 to 30 seconds is required.

The uniselectors used for assignment and line finder switches are of 25 and 50 outlets respectively, and are of the B.P.O. standard type described in Vol. 2, No. 4, page 213. As not more than 12 of the 25 outlets on the allotter switch are required for a group of line finders, the bank contacts are multiplied to reduce hunting.

The final selector repeaters used to date are of the pre 2000 type, but at a later stage 2000 type switches may be used.

Conversion to 3 Figure Working.—If more than 90 extensions are required, the system can be extended by the installation of a second line finder rack, together with a rack on which selector repeaters are mounted. Final selectors are installed on each line finder rack instead of final selector repeaters. Each line finder is connected to a selector repeater instead of a final selector repeater as in the standard two figure system, that is, the cable from terminal strips D is run

21.22 connect ground to the start wire to the allotter switch to operate relay S in the line finder.

Relay S operates and completes the line finder DM and test circuits.

1.2 complete DM circuit from ground at E 21.22.

3.4 prepare a hold circuit for relay H.

21.22 complete the test circuit for relay E.

23.24 prepare an alarm circuit.

The DM steps the line finder until a trunk is found to which battery is connected. Relay E then operates from ground, E 1000 S 21.22, P bank, L1.2, K1300, battery. Relay E operates to battery. As the circuit is arranged for battery testing the switch will step over open or grounded trunks.

When relay E operates,

1.2 complete a circuit for relay H.

21.22 open DM circuit to stop the drive.

Relay H operating:—

1.2 provide a holding circuit for H, firstly to S3.4 which provides a holding ground during the

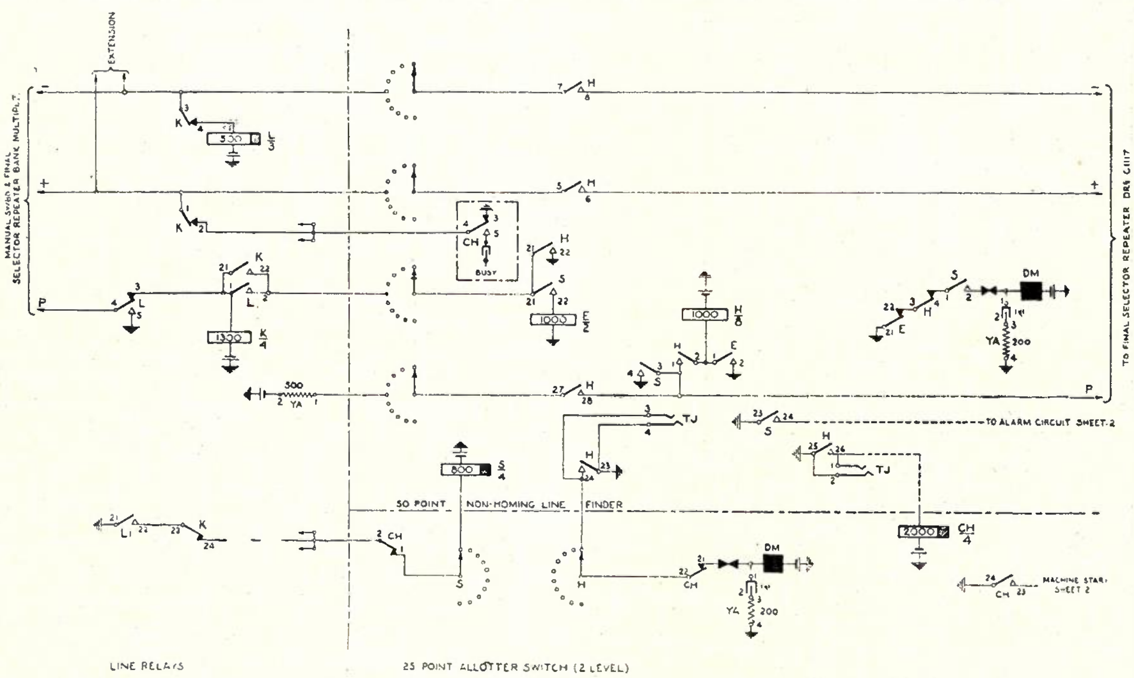

Fig. 3.—P.A.B.X. Line Finder Equipment Circuit.

to the selector repeaters and the local cable from the selector repeater bank outlets is connected final selectors on each line finder rack.

Extension and Line Finder Circuit.—The schematic circuit is shown in Fig. 3. The method of operation is as follows:—

Outgoing Calls from an Extension.—Extension removes handset, relay L operates.

1.2 connect battery to P bank via K 1300.

3.4.5 connect ground to private wire to manual switchboard and final selector repeater banks to busy the calling extension line.

slow release of S which holds the connection until ground is returned over the P trunk from the final selector repeater.

3.4 open the DM circuit to cover release of relay E.

5.6 switch the positive trunk to the final selector repeater.

7.8 switch the negative trunk to the final selector repeater.

21.22 ground the incoming P wire to operate relay K.

23.24 ground the allotter switch H bank to step the allotter to the next free line finder.

25.26 prepare CH relay circuit for all trunks busy.

27.28 switch YA 500 to the P trunk to the final selector repeater.

Relay K operates.

1.2 and 3.4 clear relay L and ground from the positive and negative trunks to the line finder.

21.22 provide a holding circuit for K.

23.24 open the start circuit.

Relay L releases and the guarding earth for the manual switchboard and final selector repeater banks is furnished from H 21.22 in the line finder circuit.

Relay S releases, opens the DM, alarm and test circuits and removes the holding ground for H which is held by ground over the P trunk from the final selector repeater.

The allotter switch steps to next idle line finder —ground, H 23. 24, allotter H Bank, CH 21.22, DM, battery. The common equipment is now ready for the next call. The step on feature is of advantage particularly during off peak periods in that it ensures that any extension will obtain a different trunk on successive calls. Thus an extension cannot be held up because of a defective trunk.

All Trunks Busy.—If all outlets are engaged relay CH operates via the H 25.26 chain contacts.

1.2 open the start circuit.

3.4.5 connect busy tone to calling extensions.

21.22 open the allotter DM circuit to prevent hunting.

23.24 provide a start circuit for the ringing machine so that busy tone is generated.

Incoming Calls.—When an extension is called either via the manual switchboard or a final selector repeater, ground is connected to the P wire to operate relay K and clear relay L from the extension line. Under this condition the P bank will test busy to a searching line finder.

Miscellaneous.—If a final selector repeater is busied by grounding the P wire on the switch test jack, the associated line finder is still free. To prevent seizure, it is necessary to insert clips in the line finder test jacks and so provide a busy condition on the allotter switch H bank and also prepare the chain relay circuit. If it is desired to check the trunking, a meter can be connected in parallel with relay CH to record the number of times all trunks are busy.

Conclusion.—Line finder equipment of the type described is in service throughout the Commonwealth. Although some installations differ in respect to both circuit and rack arrangements, the basic features are as described herein.

Unit Automatic Exchange No. 12

C. Faragher, A.M.I.E.(Aust.)

General.—Two U.A.X.'s No. 12 have been installed in Queensland, one at Sunnybank trunking into the Brisbane metropolitan automatic network, and the other at Freshwater, trunking into Cairns automatic exchange about five miles away. There are only two other units of this type in the Commonwealth, one at Fern Tree, Tasmania, having trunks direct to the Hobart automatic exchange, and the other at Kallista, Victoria. The latter operates under different conditions to those mentioned previously in that outgoing calls are routed either to the Melbourne manual trunk exchange or to Belgrave manual exchange. The equipment is, however, capable of handling calls direct to an automatic network.

The term U.A.X. is an abbreviation for Unit Automatic Exchange. It is the British Post Office equivalent of the Australian R.A.X. The British Post Office standardized three sizes of U.A.X., Nos. 12, 13 and 14, of 100, 200 and 800 lines ultimate capacity. It might be of interest to mention that the term R.A.X. was used originally by the British Post Office, but some residents in districts in which the units were installed objected to the stigma they felt was implied by "Rural," and for diplomatic reasons the word was changed to "Unit." The first types of Country Automatic Exchanges in Britain were designed to trunk to a manual exchange. There was a development requiring small exchanges in the outer areas of automatic networks catering particularly for self-contained groups of subscribers on the outskirts of big cities. The British Post Office combined the requirements of such units with those of the country automatic exchange in the U.A.X.

Besides the ability to work direct to an automatic exchange, the U.A.X. provides a much wider range of functions than does an R.A.X., but all its possible functions need not be used in any particular installation. For instance, the U.A.X. is designed for multi-metering any call, the charge for which is 1d., 2d., 3d. or 4d. In Great Britain the unit fee is 1d. and it is the ultimate intention that all calls to a maximum of 4d. will be dealt with on an automatic basis and debited against the subscriber by the subscriber's meter being operated by an appropriate number of pulses. For calls valued at more than 4d. a manual exchange is dialled by the U.A.X. subscriber and the call docketed and handled manually. This facility is not used in the exchanges installed in Queensland.

Some general details of the Queensland installations may be of interest. The building at Freshwater is shown in Fig. 1, which is typical of the country buildings used for U.A.X.'s or R.A.X.'s.

Assembly of Units and Capacity.—The type 12 unit, i.e., one having a maximum of 100 lines when fully equipped, consists of an auxiliary unit and four line units. The latter can be added one at a time as required. The first of these line units has a capacity of 25 subscribers' lines and four both-way junctions to the parent exchange. The second is a 20 line unit which includes equipment to increase the both-way junctions from four to six. At this stage the capacity is 44 subscribers and six junctions, or 45 subscribers and five junctions, one line being adapted for use as either a junction or a subscriber's termination. The third and fourth units are similar respectively to the first and second. The complete unit has a capacity of 100 lines, of which any number up to 12 may be junctions, the balance to a maximum of 90 being subscribers.

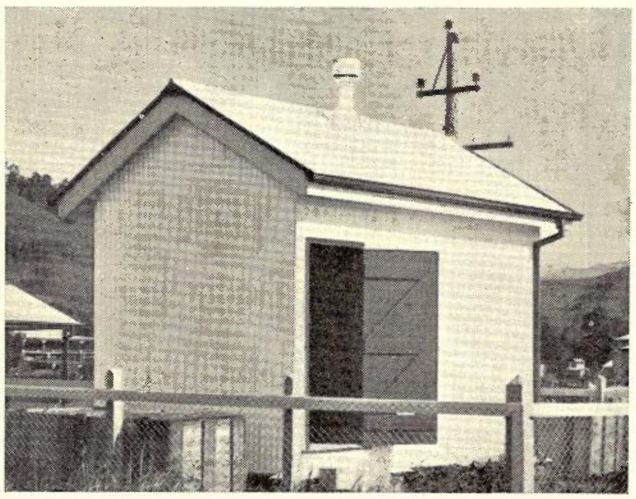

Fig. 1.—Freshwater U.A.X. Building.

The auxiliary unit houses the main frame with fuse mountings for 160 lines and protector strips for 120 lines. Also the ringing and metering pulse, tone and time pulse equipment, jacks for common multi-metering relay sets and miscellaneous equipment for testing subscribers' lines are included in this unit. Like the line units the auxiliary unit is completely enclosed in a sheet steel cabinet and the protection thus afforded adds to the reliability of the service given.

Dimensions and Construction of Units.—The cabinet enclosing the auxiliary unit and each 20 line unit is 6 ft. $10\frac{1}{4}$ ins. high by 1 ft. $7\frac{1}{2}$ ins. wide by 1 ft. 9 ins. deep. The width of the 25 line units is increased to 2 ft., the other dimensions being as for the other cabinets. The units line up so that they can be installed side by side and sections of the side of the cabinets can be removed to allow for the cables between them. Frames are fitted around these openings and bolted so that the whole is totally enclosed and therefore dust-proof. Doors in the front and back of the cabinets press against rubber tubing to maintain the efficient sealing of the cabinets. There is a horizontal bulk-head dividing each unit into two compartments, the upper containing the I.D.F., miscellaneous terminals and fuse panels, and the lower housing the switching equipment. All cabling is, therefore, separated from the equipment and connections can be made without exposing the switches.

The cabinets are constructed with double air spaced sheet steel panels to retard the rate of temperature change inside the unit. The floor of the auxiliary unit consists of a number of narrow boards with chamfered edges. When the cables are brought into the M.D.F. one or two boards are cut to fit neatly round the cables, after which the floor of the unit is made dustproof and airtight by pouring bitumastic compound into the "V" formed by the chamfer.

Trunking Scheme.—A line finder system is employed, and the equipment is trunked as shown in Fig. 2. The line finders are 50 line uniselectors, the subscribers' lines and the junctions being terminated on the banks. The wipers of each uniselector are wired to a final selector which is a bimotional switch operating on a standard 100 line switch bank.

The first 25 line unit installed is provided with 25 subscribers' line circuits, four line finder circuits, each including its 50 line uniselector and bimotional final selector, one line finder allotter and four both way junction relay sets with associated multi-metering relay sets. The next unit installed, i.e., 20 line, is provided with 20 subscriber's line circuits, two line finder circuits, each including its 50 line uniselector and bimotional final selector, and two both-way junction relay sets with associated multi-metering relay sets. This second unit is not fitted with a line finder allotter, that installed in the 25 line unit being used for this 20 line unit also.

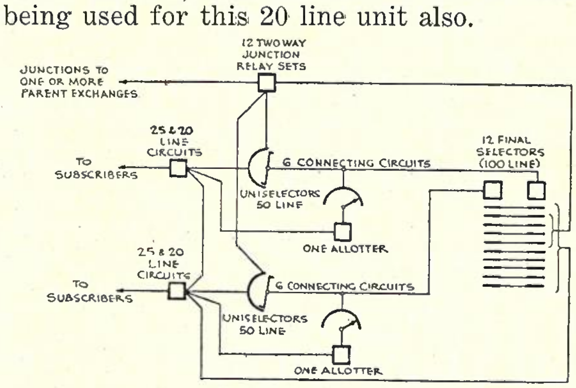

Fig. 2.—U.A.X. Trunking Scheme.

From the above it will be seen that, as there is a total of 45 subscribers' line relay circuits, that number of subscribers can be connected, but, as the uniselector banks are 50 line and both-way junctions as well as subscribers have to be accommodated on them, the full number of subscribers' lines can be used, i.e., 45, if the number of both-way junctions is not more than five. If six both-way junctions are required, the balance of 44 contact sets on the uniselector banks are available for subscribers.

The second 25 line unit, which may be installed at a later date, has equipment identical with that of the 25 line unit installed initially. Similarly, the second 20 line unit to be installed is identical with the 20 line unit installed previously.

In a complete installation, therefore, the first two units installed include 45 subscribers' line relay sets, four line finder circuits, one line finder allotter, and six both-way junction relay sets. The last two units installed include the same number of items of equipment, the 50 line uniselectors not being multipled with those of the first two units but including 100 line bimotional switch banks which are multipled throughout the whole installation for terminating traffic.

Numbering Scheme.—Subscribers are allotted three figure numbers, the hundreds figure being 2. The digit "9" is dialled to call the parent exchange. Levels 6, 7 and 8 are also available if required for junctions to other exchanges. If the first digit dialled is one which raises the switch shaft to a level, the early choices of which are junctions or on which there are only junctions, automatic search occurs over the junctions until a free junction is found. If the call is for a subscriber, the first digit dialled will be "2." This digit is absorbed and the shaft restores to normal and alters the relay setting so that rotary movement on any level will not now be automatic, but will be directed by the third digit dialled. This allows junctions and subscribers to be connected to the same level, the junctions being first choices. The first and second contacts of level "9" of the bimotional switch banks are slipped to reduce the possibility of a subscriber calling the parent exchange and being unable to obtain service due to a first choice junction line being out of order. The allotter provides for the connecting circuits to be taken into use in sequence; consequently the subscriber whose junction call is unsuccessful on the first attempt will be given a different choice of junction on a later attempt.

It might be mentioned here that the subscriber connected to a U.A.X. requires local knowledge in order to make successful calls in the local automatic network. For example, in the Cairns district, the Freshwater U.A.X. subscriber when calling a local number will dial a three figure number commencing with "2." In order to call a Cairns Exchange subscriber he must prefix by "9" the four figure number of the Cairns subscriber required. If, however, he visits Cairns and makes a local call to a Cairns subscriber he must remember to omit the prefix "9" while out of the Freshwater area, and if, while in Cairns, he wishes to call his own telephone connected to the Freshwater U.A.X. he must dial "9" followed by the three figures of his home telephone number.

Installation Features.—The U.A.X. as delivered does not include any provision for an alarm extension circuit to the parent exchange. The only provision made is a U.A.X. number which can be dialled from the parent exchange, after which an audible signal designated "inverted ring" indicates that there is no alarm condition at the U.A.X. "Inverted ring" is the opposite to the ordinary ringing tone received, i.e., during the silent periods of ordinary ringing conditions, ringing tone is heard under "inverted ring" conditions. If this signal is not received, N.U. tone is received instead and indicates an alarm condition but does not classify it. Absence of "inverted ring" or "N.U. tone" indicates failure of the ringing supply. A circuit was devised locally, arranged so that in the event of charge failure, sticking release or release alarm, fuse alarm, or earthed busy circuit, a signal is transmitted to the parent exchange over No. 6 both-way junction. (There are 10 both-way junctions and choices Nos. 1 to 10 for a call outgoing from the U.A.X. are choices Nos. 10 to 1 for a call outgoing from the parent exchange.) If No. 6 junction is in use when an alarm condition is to be signalled to the parent exchange, nothing happens until the subscriber clears the junction, at which stage the alarm extension circuit takes the junction and busies it at both the U.A.X. and the parent exchange to prevent seizure by another subscriber's call. The parent exchange is signalled by ringing current fed from the U.A.X. over No. 6 junction to a tuned relay circuit. The tuned circuit is necessary because a relay is normally connected across the junction circuit at the parent exchange and would operate on the alarm signal current if the tuned circuit were not connected as a low impedance shunt to ringing current at normal frequency. This tuned acceptor circuit, which is not connected across the junction while it is in use for a subscriber's call, operates an audible and visual alarm at the parent exchange which is continuously staffed. The mechanic there dials an allotted number and is connected to the U.A.X. equipment. He receives one of four tones which have been arranged to indicate the section of the U.A.X. equipment in which the failure has occurred.

When the U.A.X. equipment is prepared for dialling, the calling subscriber receives dial tone. When a junction call is made from the parent exchange, the U.A.X. line finder bank contact of that junction is marked. When a line finder has located the marked contact and the U.A.X. equipment is prepared for acceptance of the three digits of the U.A.X. subscriber's number, dial tone is provided for in the design. As each subscriber to a Siemens No. 16 exchange in Brisbane receives dialling tone before dialling the first digit of his number, the receipt of a second dialling tone after dialling two of the five digits would cause confusion. A circuit alteration was made at the U.A.X. so that dialling tone is not received on incoming junction calls at the stage where three digits remain to be dialled.

In the R.A.X.'s now being delivered it is possible to test subscribers' lines from the parent exchange and this also will be a useful addition to the U.A.X.'s.

The both-way junction relay sets delivered for installation in the parent exchange included a number of relays not required, e.g., the relay sets included facilities for outgoing calls from the U.A.X. to be completed to a manual parent exchange or alternatively an automatic parent exchange. At Sunnybank, the relay sets were rewired for operation into a No. 16 Siemens automatic system and a number of relays was recovered.

As a complete 100-line U.A.X. consists of an auxiliary unit and four line units there are several wiring forms; e.g., there is a selector multiple form between each of the four line units. There is also a line finder bank multiple form from the first to the second line unit and from the third to the fourth line unit; there is also a form for inter-unit connections for miscellaneous purposes. To save time, these forms were made up on the bench complete at headquarters, where the best facilities are available and were supplied to the job.

Although the 100 subscribers can be connected by one cable between the M.D.F. and the terminal strips of the final selector multiple of line unit No. 1, the junctions must be wired individually from the M.D.F. to each of the four line units. The junctions appear on the bank contacts of the line finder in the same way as the subscribers' lines. A slip for the junctions has been provided between the units so that the first choice junction will differ on each unit. There is no slip between units for subscribers' line finder or final selector multiple as this is wired straightforward.

The line finder bank multiple to which subscribers' line circuits are tied has to be jumpered to the final selector multiple. The first and second units are fitted with 25 and 20 subscribers' line circuits respectively. These have to be jumpered to the final selector multiple on either No. 1 or No. 2 line unit. To reduce the mass of jumpers, 25 circuits were jumpered on Unit No. 1 and 20 circuits on Unit No. 2, these numbers agreeing with the number of line relay sets on each unit. Similar remarks apply to the subscribers' line circuits of line units Nos. 3 and 4.

The number of both-way junction relay sets is six and the number of subscribers' line circuits per pair of line units is 45. If, therefore, only five both-way junctions are required, one junction relay set is left spare. If six junction circuits are required, one (the first) subscriber's line circuit is left spare. The option of using the sixth line finder bank contact for a junction or, alternatively, for a subscriber is provided for by wiring the first six bank contacts to a terminal strip. The balance of 44 bank contacts is wired permanently to subscribers' line circuits.

Miscellaneous.—Standard tones as used in automatic exchanges in the metropolitan networks are provided, including dial tone. Straight line subscribers, P.B.X. subscribers (two to 10 lines) and junctions may be connected indiscriminately in the numbering scheme, but junctions are given early choice positions to avoid excessive hunting. All relay sets and bi-motional switches are of "jack-in" type. B.P.O. 3000 type relays are used.

The Characteristics and Applications of Protection Equipment for Telecommunication Services in Australia

J. H. T. Fisher, B.E.

PART II.—Characteristics and Construction of Protective Devices (Continued)

Lightning Arresters (Continued)

Gas-Filled Arresters.—(a) Characteristics: In general, gas-filled arresters consist of two or three metallic electrodes enclosed in a glass tube containing an inert gas or mixture of gases such as Neon, Argon or Helium, at reduced pressure, and fitted with suitable metal caps connected to the electrodes for mounting purposes. Inert gases are used because they are chemically inactive and do not form compounds with or become absorbed by heated metals. Active gases are liable to become absorbed by the metal electrodes under the influence of a discharge through the arrester, thus changing the gas pressure. The breakdown voltage of such arresters depends chiefly on:—

(i) The nature and pressure of the gas;
(ii) The spacing of the electrodes;
(iii) The shape and material of the electrode surfaces.

These factors are all under the control of the manufacturer, and as the arrester body is of glass and comparatively long, leakage is small under all atmospheric conditions and the insulation resistance high. As the electrodes are totally enclosed, dust cannot enter the discharge gap and the breakdown voltage is not affected by atmospheric conditions as is that of air gap arresters. Also, the reduced gas pressure means that the electrode spacing for a given breakdown voltage is much greater than for the same breakdown voltage in an air-gap arrester; therefore minute variations in electrode spacing affect the breakdown voltage of a gas-filled arrester to a very much smaller extent, and in a gas-filled arrester, gaps to give very low breakdown voltage become a practical manufacturing possibility.

Hence, the breakdown voltage of gas-filled arresters is much more definite than with air-gap arresters, and they may be obtained with breakdown voltages as low as 80 V. A typical D.C. voltage-current characteristic for a gas-filled arrester is shown in Fig. 4, the specimen in this case being of the type shown in Fig. 5e (and of the 150-200 V. breakdown range).

Briefly, the theory of gas-filled arrester operation is as follows:—

When a D.C. potential difference is applied between two electrodes in the arrester, the electrostatic field set up between them causes stray electrons and negative ions in the gas to move towards the positive electrode (anode) and causes positive ions to move towards the negative electrode (cathode). The electric current so constituted is extremely minute when the potential difference is small. If the potential difference is

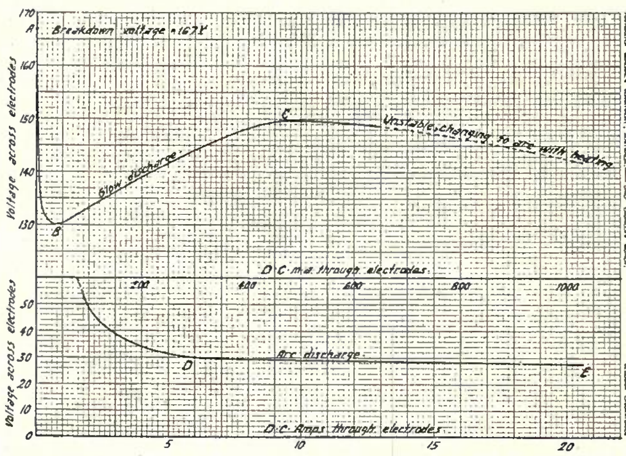

Fig. 4.—D.C. voltage-current discharge characteristic of a Gas-filled Arrester. (Specimen of Type 4369, shown in Fig. 5e.)

increased, the velocities of these electrons and ions also increase, until a critical velocity is reached at which electrons and ions colliding with neutral molecules cause these to be split up into pairs of positive and negative ions, which in turn collide with other neutral molecules producing more ions so that a sudden very large increase of current is produced, and the gas is said to "break down." The potential difference required to produce this "ionization by collision" is called the "breakdown voltage" of the arrester and the current discharge, which is accompanied by a glow of a colour depending on the nature of the gas, is called a "glow discharge." (Neon gives a pink and Argon a blue glow.)

The breakdown voltage is represented by the ordinate at the point A in Fig. 4. As soon as this discharge current begins to flow, the voltage drop across the arrester decreases until equilibrium is reached at a voltage and current depending on the external resistance in the circuit. If the applied voltage is then further increased, the voltage across the arrester after falling to a minimum value at B, will increase almost linearly with the current (B to C), the intensity and volume of the accompanying glow increasing accordingly. When the voltage across the electrodes reaches a certain value at C the velocity and number of the ions and electrons constituting the discharge current reach a stage where the positive particles bombarding the cathode cause it to heat up considerably and emit electrons. (The voltage and current values at this stage are different for different types of arrester, but the current value in most cases is a few hundred milliamperes). This condition is unstable and the character of the discharge suddenly changes and an "arc" discharge occurs, accompanied by the familiar intense light and heat. The arc current is like an avalanche, the more electrons liberated irregularly between glow and arc conditions. If the external applied voltage is now reduced the discharge will revert to glow conditions and retrace the characteristic from C to B. When the voltage B is reached, further decrease in voltage will reduce the velocity of the gas ions below the value necessary to sustain ionization by collision and the discharge will then suddenly cease. This voltage at B, therefore, is the "glow extinguishing voltage," and is always less than the "breakdown voltage." It is now necessary

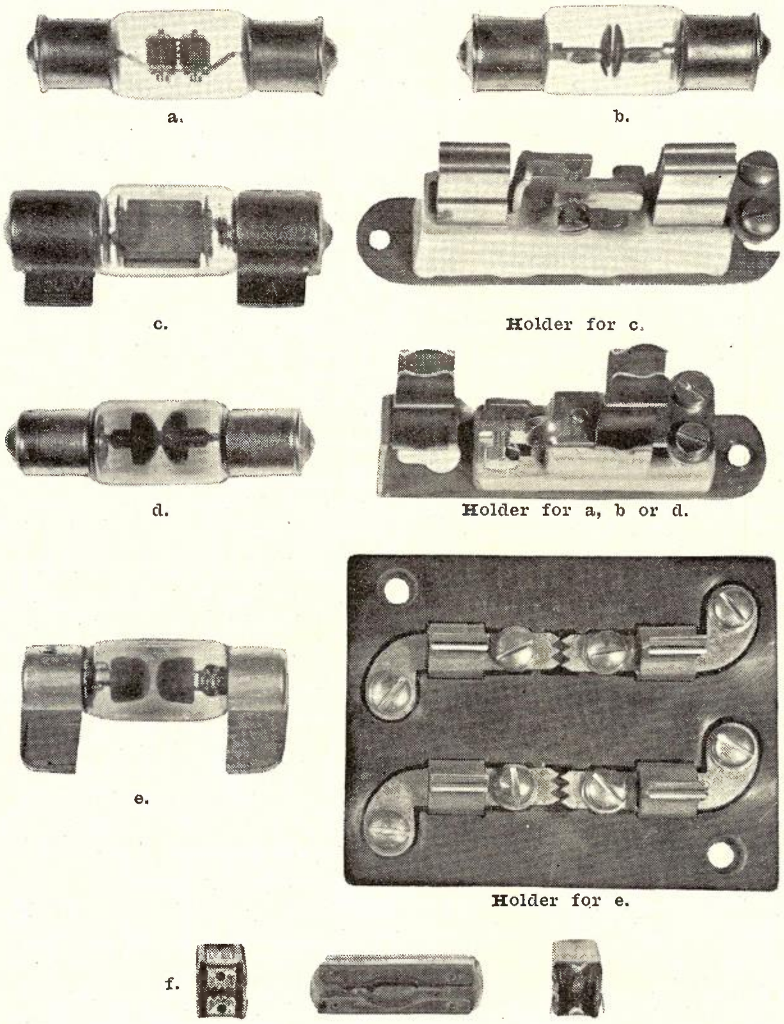

Fig. 5.—Two-electrode Gas-filled Arresters and Holders.

the heavier the current, and consequently the greater the heating and the still greater the number of electrons liberated. Thus the arc discharge rises to very high current values and the impedance of the arrester becomes very small, the voltage across it falling to about 20 to 40 V. This discharge is represented by the negative slope characteristic from D to E. In the transition stages from glow to arc the discharge is very unstable, and if the external applied voltage is constant, the discharge may alternate

for the voltage to be raised to the breakdown value before discharge will again occur.

The breakdown voltage depends to some extent on the condition of the electrode surfaces which may undergo minor changes with successive discharges and on the amount of ionization existing in the gas before any external voltage is applied to the arrester; this ionization depends on various factors such as temperature, radiation passing through the gas, and residual electrostatic charges on the glass walls of the tube. Therefore, successive readings of breakdown voltage must be expected to vary to some extent, though not nearly as much as with air-gap arresters.

When a gas-filled arrester discharges a lightning surge, or a heavily charged condenser in laboratory tests, the arc condition will generally be reached, and due to the negative arc characteristic the discharge will then continue until only about 20 volts or so of charge potential remain. With some heavy discharges the arc condition may be produced almost immediately, and the glow discharge may be so transitory as to be inappreciable. With small energy condenser discharges in the laboratory, the current may not reach values sufficient to form an arc

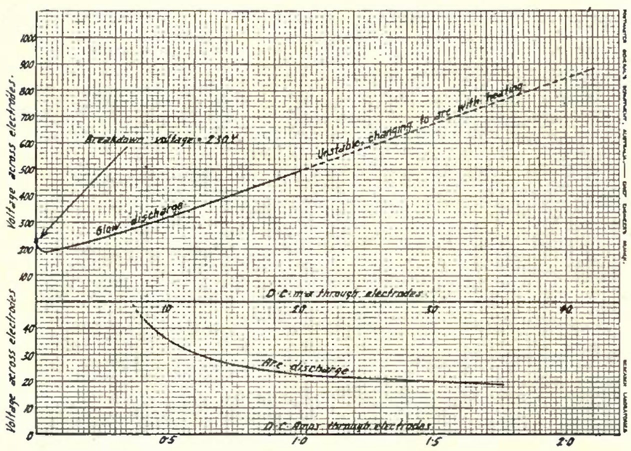

Fig. 6.—D.C. voltage-current discharge characteristic of one side of a three-electrode Gas-filled Arrester, Type H.51. (Shown in Fig. 7a.)

discharge, and the discharge will then cease when the charge potential has fallen to the glow extinguishing voltage.

In some types of gas-filled arrester, the voltage associated with the current producing unstable glow conditions when arc formation becomes possible may be greater than the breakdown voltage value. Fig. 6 shows such a characteristic, the specimen in this case being of the type shown in Fig. 7a and of the 200-300 V. breakdown range.

The advantages of gas-filled arresters over air gap types are:—

(i) Lower breakdown voltages possible.

(ii) Smaller variations in successive breakdown voltage values.

(iii) High insulation resistance under all working conditions, giving absence of leakage noise.

(iv) Totally enclosed gap giving freedom from trouble due to atmospheric changes and dust.

(v) Absence of tendency to "earth" or develop permanent short circuits in service.

Their principal disadvantage is their higher cost, a two electrode gas-filled arrester costing about thirty times as much as a pair of carbon blocks and for this reason their use in Australia so far has been confined to some unattended exchanges and important trunk lines. Their greater size is also a disadvantage compared with carbon arresters, especially at protected points where large numbers are required, and the energy of discharge required to damage a gas-filled arrester is generally somewhat less than that required to damage an air-gap arrester. Particulars of some types will be given briefly.

(b) **Two Electrode Gas-Filled Arresters.**—These have been used by the Department to a limited extent for some years, and Fig. 5 shows five types used, the characteristics of these types being given in Table I.

(i) The earliest type of gas-filled arrester used in Australia was the so-called "Vacuum" arrester (Fig. 5a). This contained carbon electrodes in an atmosphere of gas at low pressure, but had the disadvantage that the carbon absorbed some of the gas at certain discharge temperatures, causing the gas pressure to fall and the breakdown voltage to rise to dangerously high values after only a few discharges. Further, the current carrying capacity was low and for these reasons their use was discontinued.

(ii) The next type of gas-filled arrester introduced contained Argon (Fig. 5b) but the breakdown voltage constancy of this type was not very satisfactory.

(iii) The type shown in Fig. 5c, containing Argon, was introduced about 1933 (Refs. 6 and 11). The knife type contacts on this arrester are considered to give a more positive connection than other types. The breakdown voltage is 315 to 385 volts and while this arrester gave satisfactory service, it is considered desirable in the majority of cases to employ arresters having a lower breakdown voltage in order to obtain a greater degree of protection for equipment and to obtain arrester operation in cases of line contacts with 230 V. power lines.

(iv) Neon gas-filled arresters (Ref. 12) of the types shown in Fig. 5d and e, have also been used with satisfactory results. These will carry a current of 50 mA continuously or a current of 10 A for 2 seconds without damage. Supplies of both these types have been obtained recently in the voltage breakdown ranges represented by Nos. 11C, 11F, and 4369 and 4379 (Table I.).

(v) A miniature type of gas-filled arrester (Fig. 5f) has recently been developed to fit into the ordinary main frame protector clips in exchanges in place of carbon arresters. This consists of a small two electrode neon gas-filled tube contained in a plated metal frame which is in two parts separated by mica sheets at the sides, and to which the electrodes are connected. The ends of these metal sides are bent over at one end to form an auxiliary air gap with saw-tooth edges. This auxiliary gap provides a rough means of protection in the event of failure of the gas filled tube, but no attempt is made to adjust the air gap to a definite spacing. Supplies of these arresters in two ranges have also been obtained for trial in exchanges for comparison with carbon arresters. Being of less robust construction than the types in Fig. 5d and 5e, they will not withstand the current tests of 10 A. for 2 seconds and 50 mA continuously, and as they are damaged by discharges of comparatively low energy, they should not be employed in protected cable boxes.

Breakdown Symmetry of Protected Lines.—It is not possible to manufacture two-electrode arresters of the same type so that all specimens have exactly the same breakdown voltage. This is partly due to the difficulty of obtaining the same gas pressure and composition in all specimens, and partly because the breakdown voltage of a single specimen is not constant, for reasons given in (a) above. Thus, when a telephone line is protected by a pair of two-electrode arresters, whether they be air-gap or gas-filled types, the breakdown voltage to earth will not be the same for the two wires of the line. This means that when a high voltage surge is produced on the line, the instantaneous voltage being in general the same on both wires, the arrester having the lower breakdown voltage will commence to discharge to earth first and the voltage on the other wire will cause a current surge to flow to this discharging arrester through the equipment connected to the end of the line. This surge may cause insulation breakdown in the equipment and will certainly produce noise in the receiving equipment possibly resulting in acoustic shock to persons using the circuit.

In an endeavour to overcome this difficulty the three-electrode gas-filled arrester was introduced.

(c) Three-Electrode Gas-Filled Arresters

The construction and characteristics of these are similar to the two-electrode type, but there are three electrodes in the tube, the outer two being connected to the two wires of a line and the central one to earth. Thus the discharge gaps for both lines are in the same gas atmosphere and hence one of the factors controlling breakdown voltage is common to both gaps. Also, the degree of ionization existing before breakdown is likely to be the same in both gaps and should one gap commence to discharge first under the influence of a voltage surge on the line, the ionization by collision set up in this gap will spread and assist breakdown of the other gap also, greatly decreasing the breakdown assymmetry of the two gaps.

Such arresters, of course, require a different type of mounting to the two-electrode type.

(i) One type of three-electrode gas-filled arrester is shown in Fig. 7a (Ref. 5). This type is available in several breakdown voltage ranges and will carry a current of 50 mA continuously. Supplies of three ranges having characteristics as listed in Table I. have recently been obtained for trial in service. The cost of this type is approximately the same as that of a pair of two-electrode gas-filled arresters. Fig. 6 shows the D.C. voltage-current characteristic of one specimen of the 200-300 V. breakdown range. This type of arrester has also a short circuiting feature. To each line electrode inside the tube is welded a short curved bi-metallic strip supporting a contact arm. Should heavy discharges between the line and earth electrodes due to contacts with or induction from power lines cause the arrester to overheat, the bi-metallic strips bend until their contact arms touch fixed

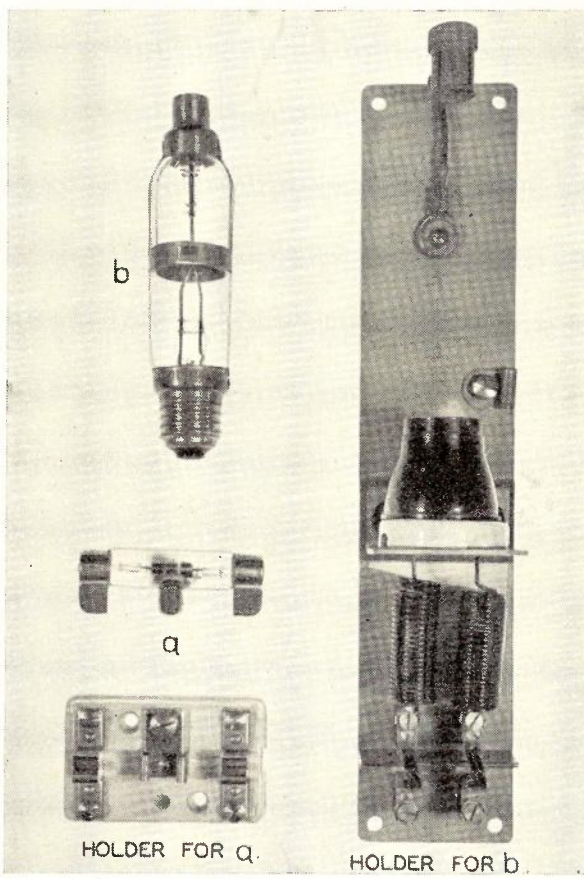

Fig. 7.—Three-electrode Gas-filled Arresters and Holders.

contact arms which are welded to the earth electrode, and thus short circuit the discharge gaps, preventing further heating of the arrester. When the power contact or induction ceases, these contacts re-open with cooling and the arrester becomes normal again. This feature prolongs the life of the arrester and assists the operation on power current of fuses, when these are installed on the line side of the arrester.

(ii) Fig. 7b shows another type of three-electrode gas-filled arrester containing a mixture of Neon and Helium. This type has been used by the B.P.O. for protection of telephone lines in Northern Ireland against induction from parallel high tension power lines under fault conditions. (Refs. 4, 13 and 14.) They are manufactured in two ranges, one of which will carry 10 amperes and the other 1 ampere arc discharge through each outer electrode to earth simultaneously for 10 seconds without damage. The breakdown and extinguishing voltage characteristics are given in Table I. The 10 ampere tubes are installed on open wire lines and the 1 ampere tubes on underground cables on affected routes at intervals such that the induced power voltage in any one protected section is not likely to exceed 300 V. These tubes are not intended for protection against lightning. To reduce the possibility of lightning surges damaging them and so removing the protection they afford against induced power surges, the manufacturers connect the outer electrodes of the 10 ampere tubes to the line wires via H.F. chokes. These chokes consist of 15 turns of 16 S.W.G. enamelled wire coiled in a ¾ in. diameter helix, with approximately 0.008 in. air gap lightning arresters between earth and the line side of the chokes. Specimens of these tubes have been tested in the Research Laboratories. The degree of symmetry between the two discharge gaps under glow discharge conditions is considerably less than that obtained with the type shown in Fig. 7a, and in addition the tubes shown in 7b are very costly. For these reasons they are not considered suitable for use as three-electrode lightning arresters.

Failure of Gas-Filled Arresters.—Induced lightning surges or high energy condenser discharges in the Laboratory, may damage gas-filled arresters in either or both of the following ways:—

(i) The wires supporting the electrodes inside the glass tube may fuse, leaving the arrester "open circuit."

(ii) The glass tube may crack, usually at the pinch where the wires enter, but sometimes in the outside wall. Sometimes such cracks are so fine as to be invisible to the eye and the air leaks in so slowly that the resulting rise in breakdown voltage is very gradual.

Heavy currents from power contacts on the line may also produce either of the above failures, and sometimes may fuse the electrodes together, producing a permanent short circuit which will carry heavy currents for a long time.

Lightning Conductors

These have sometimes been fitted to wooden poles at intervals on lines in districts where lightning is particularly severe and frequent. They consisted of a vertical 400 lb. G.I. wire stapled to the pole, with the top end projecting 6 ins. above the pole top, and with the bottom end coiled in a flat spiral containing about 6 ft. of wire and stapled against the bottom end of the pole before erection. In general, the tendency of

TABLE I.

CHARACTERISTICS OF GAS-FILLED ARRESTERS

Illustration	Type No.	Overall Length	D.C. Breakdown Voltage	D.C. Glow Extinguishing Voltage	Energy of Condenser Discharge which will just damage Arrester
	Two-Electrode				
Fig. 5b	—	2¾″	300-350 V	Approx. 265	30 joules
Fig. 5c	350 V."A."	2⅞″	315-385 V	180-200 V	
Fig. 5d	11 F	2¼″	140-210 V	120 V min.	
,,	11 A	,,	210-280 V		
,,	11 B	,,	280-350 V		
,,	11 C	,,	350-420 V		
,,	11 D	,,	420-490 V		
,,	11 E	,,	490-570 V		
Fig. 5e	4369	2⅜″	150-200 V	110 V min.	32 joules
,,	4379	,,	280-350 V	130 V min.	32 joules
,,	4397	,,	400-500 V	250 V min.	
Fig. 5f	MCD 2	1½″	200-600 V	150 V min.	4-20 joules
,,	MCD 4	,,	500-900 V		
	Three-Electrode				
Fig. 7a	I 23	3″	150-250 V	120-160 V	
,,	H 51	3″	200-300 V	140-180 V	12 joules
,,	I 31	3″	250-350 V	160-200 V	
Fig. 7b	10 amp. or 1 amp.	5¾″	210-350 V	140 V	

lightning is to strike the highest point in the vicinity, which may sometimes be the top of a telephone pole, and lightning conductor wires may prevent the major portion of the lightning current from flowing through the wood of a pole which is struck, and so prevent shattering by the sudden vaporization of moisture in the pole produced by such currents (Refs. 3 and 4). The fitting of lightning conductors is costly, and they have considerable trouble due to staples falling out of the sapwood and allowing the wire to hang loose, and due to the rusting through of the wire near the ground. For these reasons, their use has been discontinued in all but the very worst lightning districts, where they may be fitted to every fifth pole.

Chokes

It is not standard practice in Australia to fit these on lines, but in some districts they have been installed at terminal poles between the drip points on the terminal insulators and the cleats on the crossarms, when such poles are equipped with gas-filled arresters in protected cable boxes. The chokes consist of 10 turns of 0.044 in. R.I. braided wire wound in a helix of $\frac{5}{8}$ in. internal diameter and 4 ins. long. They were intended to limit the current value and to absorb some of the energy of lightning surges passing from the line to earth via the arresters and so minimize damage to the latter. Laboratory tests indicate that when condenser discharges simulating lightning surges are passed through such chokes in series with gas-filled arresters and fuses, the energy absorbed by the chokes is negligible and therefore it is very doubtful whether they afford any protection to the arresters.

In subsequent issues, heat coils, fuses and the application of the Protective Devices already described to Telecommunication Services in Australia will be discussed, and the design of several new Protection units developed in the Department and incorporating these devices will be described. Special protective devices designed for noise reduction, such as Drainage Coils, Surge Equalizer Coils, Anti-Click Devices, will be dealt with, and also methods of measuring and recording the nature, intensity, voltage and frequency of occurrence of lightning surges on telephone lines.

Errata.—In Part I., Volume 2, No. 5, page 316, column 2, insert between lines 27 and 28, ". . . ten successive surges of 10 joules each without . . ."

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(References 1 to 10 appeared with Part I. of the paper.)

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Editor's Note.—Part I. of this series appeared in Volume 2, No. 5.

The series of articles which Mr. C. McHenry is writing on "The New Melbourne Trunk Exchange" will be continued in Vol. 3, No. 2.

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. 2270—MECHANIC, GRADE I.—TELEPHONE INSTALLATION AND MAINTENANCE

C. CRUTTENDEN

Q. 1.—Define the following terms:—

(a) Milliampere.
(b) Conductance.
(c) Magnetic field.
(d) Megohm.
(e) Microfarad.

A.—(a) A milliampere is one-thousandth of an ampere, the practical unit of current strength or rate of flow of electricity. The ampere is defined as the current which deposits silver at the rate of 0.001118 grammes per second when passed through a solution of nitrate of silver.

(b) Conductance is the property of a material which permits it to conduct electricity. The unit is the Siemens (previously the mho) and is the reciprocal of the ohm, the unit of resistance.

(c) A magnetic field is all the space surrounding a magnet or a conductor carrying current which is pervaded by magnetic lines of force.

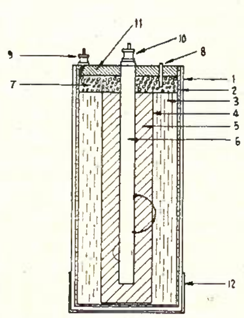
(d) A megohm is one million ohms. The ohm is the practical unit of electrical resistance and is represented by the resistance of a uniform column of mercury 106.3 cms. long and 14.4521 grammes in mass at 0°C.

(e) A microfarad is one-millionth of a farad, the practical unit of electrical capacity. The farad is defined as the capacity of a condenser which is charged to a potential of one volt by one coulomb of electricity.

Q. 2.—Draw a diagram showing the construction of a dry cell. Indicate each component, giving the name of the substance and the function it performs in the operation of the cell. State also:—

(a) The E.M.F. developed by the cell;
(b) The approximate internal resistance.

A.—



Q. 2, Fig. 1.

Each component of a dry cell as shown in Fig. 1 is indicated by a number. The name of each part and its function is:—

1.—Cardboard carton or outer case and paper wrapping for mechanical protection and electrical insulation of the cell.

2.—Zinc case to serve as the negative electrode, and also a container for the other elements of the cell.

3.—Electrolyte, consisting of a white paste of ammonium chloride and an inactive substance such as flour and gum.

4.—Muslin sac containing the elements referred to under (5) and (6), to prevent mixture with the electrolyte.

5.—Black paste consisting principally of manganese dioxide and powdered carbon. The former acts as a depolarizing agent, while the latter improves the conductivity.

6.—Carbon rod to serve as the positive electrode of the cell.

7.—Wheat husks or similar packing material to provide an expansion space for the cell gases.

8.—Glass tube to allow cell gases to escape.

9.—Negative terminal consisting of a brass screw and knurled nut.

10.—Positive terminal consisting of a brass screw and knurled nut.

11.—Sealing compound to retain cell components in container.

12.—Wax coating to improve insulation.

(a) The open circuit E.M.F. developed in a new cell is nominally 1.5 volts, but is normally about 1.62 volts.

(b) The internal resistance of a new cell varies from about 0.10 ohms to 0.15 ohms.

Q. 3.—Describe the protective apparatus provided on a subscriber's line, at the exchange and at the subscriber's premises, stating also the function of each part of the apparatus.

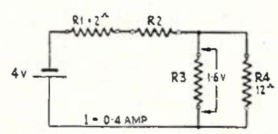
A.—The standard protection for a subscriber's line at the exchange and the subscriber's premises is fuses, heat coils and lightning arresters. The function of this protective apparatus is to safeguard the exchange and sub-station equipment against damage from electrical hazards. The hazards concerned are generally lightning or accidental contact with or induction from electric power lines. The fuses are of the tubular glass or porcelain type with tinned brass ends and a centrally located fuse wire having a nominal current carrying capacity of 1.5 amps and an operating current not greater than 3 amps nor less than 2.25 amps. The purpose of the fuse is to protect the equipment against high currents arising from power contacts or other sources.

The heat coils in service are of two general types, and their purpose is to protect the equipment from damage by foreign currents of insufficient magnitude to operate the fuses but which if continued for a long period would damage apparatus through overheating and may cause a fire. The break type opens the circuit when operated, whilst the earthing type earths it and diverts the foreign currents to earth. The heat coil consists of a coil of fine insulated wire wound on a metal bobbin, which is enclosed by a metal or fibre cover. A central metal stem is fixed to the coil bobbin by means of a special soft solder. Operation of the heat coil is caused by the cumulative heating effects due to the passage of current through the fine wire causing the soft solder to melt and the stem to release under spring pressure or tension. The earthing type of heat coil is designed to carry 0.35 amps for 3 hours and to operate within 3½ minutes with a current of 0.5 amps. The D.C. resistance is from 3.5 to 4.1 ohms. The break type of heat coil is designed to carry a current of 0.3 amps for 3 hours and to operate within one minute with a current of 0.5 amps. The D.C. resistance is from 4.5 to 5.5 ohms.

The present standard lightning arrester is made up of two moulded carbon blocks, the active surface of which is treated with an anti-dust varnish and then given a uniform coating 1.5 mils thick of insulating varnish. When assembled, the insulation resistance between the carbons should be not less than 1000 megohms when tested with 250V. D.C. at 90 per cent. relative humidity, and should break down by sparking when the voltage is increased to 500-750 D.C. The purpose of the lightning arrester is to protect the apparatus against high voltages usually arising from lightning discharges, and less frequently from power crosses or induction from high tension electric supply lines.

Q. 4.—From the data furnished in Fig. 1, calculate the following:—

(a) The resistance of R2 and R3.
(b) The voltage drop across R1.
(c) The current in R3.
(d) The current in R4.



Q. 4, Fig. 1.

A.—

Impressed voltage .... 4 volts
Current in circuit .... 0.4 amps
Therefore—
equivalent series resistance of circuit =
$4^V/0.4$ amp = 10 ohms
The voltage drop across R4 is the same as that across R3, i.e. .... 1.6 volts
The voltage across R1 =
2 ohms × 0.4 amp = 0.8 volts (b)
The voltage across R2 =
4V. — (1.6V. + 0.8V.) = 1.6 volts
The resistance of R2 =
$1.6^V/0.4$ amp = 4 ohms (a)
The current in R4 =
1.6V./12 ohms = 0.133 amp (d)
The sum of the currents in R3 + R4 = 0.4 amp
Therefore, the current in R3 =
(0.4 amp — 0.133 amp) = 0.267 amp (c)
The resistance R4 = 12 ohms
Therefore, the resistance R3 = 6 ohms (a)
since R3 carries twice the current carried by R4 for the same drop of volts.

Q. 5.—Describe the functions of a straight line final selector switch in an automatic exchange.

A.—The functions are:—

(a) Provides access to a group of 100 subscribers' lines (or for a 200 outlet switch, 200 lines).

(b) Applies holding and busying earth to the private wire to hold the previous switches in the train and prevent the switch being seized by another hunting group selector.

(c) Steps the switch shaft and wipers vertically and then horizontally on receipt of the final impulse trains from the calling subscriber's dial.

(d) Tests the called line to determine whether it is engaged or free. If the line is engaged, busy tone is returned to the calling subscriber.

(e) Applies busy conditions to the called party's line if it is disengaged, to prevent intrusion by other switches.

(f) Applies ringing current to the called line and ringing tone to the calling line.

(g) Cuts off the ringing current and operates calling subscriber's meter immediately the called party answers.

(h) Reverses the direction of battery on the calling subscriber's loop for supervisory purposes when required.

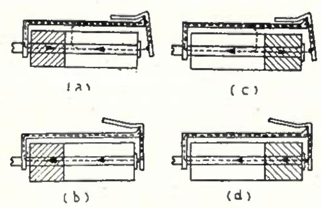
(i) Connects the subscribers and supplies battery for transmission.

(j) Releases the connection on completion of the call. The switch is guarded against seizure during the release period.

(k) Operates supervisory alarms at the end of a delay period if either subscriber fails to clear at the end of a conversation.

Q. 6.—Explain with the aid of diagrams, the operation of a slow release (slugged) relay. Give an example of the use of such a relay and the reason why it is used in the instance quoted.

A.—



Q. 6, Fig. 1.

Fig. 1 (a) shows diagrammatically a relay fitted with a copper slug at the heel end. The slug is an annular ring of solid copper and is equivalent to a short circuited winding having one turn of very low resistance. When the circuit of the coil winding is closed the lines of force of the rising magnetic field induce a current in the slug, the magnetic field of which will, in accordance with Lenz's law, oppose the field due to the coil current. The resultant effect is to delay building up of magnetic flux in that portion of the core enclosed by the slug whilst portion of the coil flux leaks across the gap between the core and the yoke and completes the magnetic circuit to operate the relay through the armature and air gap. The effect on the operating lag of the relay is negligible because the opposing flux of the slug reduces the inductance of the coil winding allowing more rapid increase of the current in the initial stages, and this compensates for the added magnetic reluctance.

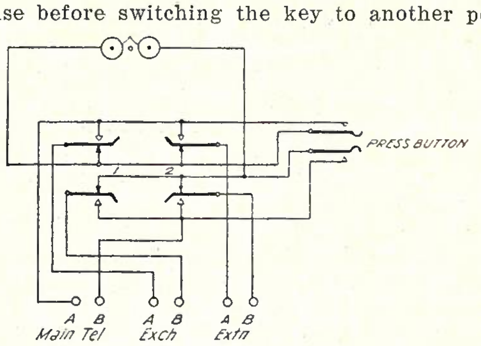
When the coil circuit is opened, the collapse of the magnetic field induces a current in the coil and in the slug in the same direction. As indicated in Fig. 1 (b) the resultant magnetic field is now in agreement and in the same direction as the original field due to the coil. Flux through the armature is thus prolonged and the relay slow to release.

Fig. 1 (c) shows the copper slug fitted at the armature end of the core. With the slug in this position the electrical and magnetic effects are the same as previously described except that when the relay circuit is first closed, the opposing flux due to the slug delays the growth of flux across the armature air gap, that is, the relay is slow operating. The result is that the relay does not operate until the reaction between the two fields has subsided sufficiently to allow enough of the coil flux to traverse the air gap to attract the armature. When the relay circuit is opened, the effects as shown in Fig. 1 (d) are the same as when the slug is fitted at the heel end and the relay is slow to release.

An example of the use of a slow release relay is the B (guarding) relay in a group selector. This relay receives current during the "make" period of the dial impulses and the slow release feature is used to hold the relay and therefore the circuit during the "break" period.

Q. 7.—Describe with the aid of diagrams the operation of a magneto extension switch.

A.—Magneto extension switches are fitted with a 1000 ohm magneto bell, a 3 position switching key and a non-locking press-button switch. Fig. 1 shows the circuit condition for each of the three positions of the switching key. The switch is fitted near the main telephone and for exchange to extension calls the subscriber places the key in position 1. In this position, the switch bell is across the line so that it will act as a ring-off signal or as a calling signal should a subsequent call be received while the switch is in the "through" position. The press-button enables the "main" to supervise the line and to ascertain if it is in use before switching the key to another position.



Q. 7, Fig. 1.

Position 1.—All groups of springs normal. Exchange to extension. Switch bell across line. Main telephone open circuit unless press button operated.
Position 2.—No. 1 group of springs operated. Main telephone to exchange. Extension to switch bell.
Position 3.—No. 2 group of springs operated. Main telephone to extension. Exchange to switch bell.

With the key in position 2, the exchange line is connected to the main telephone and the extension line to the switch bell so that the extension can raise the main.

The switching key is placed in position 3 to enable the main to speak to the extension. In this position the switch bell is connected to the exchange line so that incoming calls from the exchange can be received.

Q. 8.—What circuit functions are performed by the dial in an automatic telephone? What part is played by the following components?

(a) Slipping cam;
(b) Finger plate;
(c) Impulse wheel;
(d) Governor.

A.—The circuit functions of an automatic telephone dial are:—

(i) To interrupt the loop circuit formed by the telephone, the telephone line and the impulsing relay at the exchange. The interruptions provide the means of controlling the exchange selecting switches and take place at approximately 10 per second. Standard impulses consist of a break period of $66\frac{2}{3}$ milliseconds and a make period of $33\frac{1}{3}$ milliseconds.

(ii) to introduce changes in the telephone circuit when the dial is "off normal" which, in general, result in the transmitter and receiver being short circuited to remove the resistance of these components from the dialling loop and prevent the impulses being heard in the receiver. Also, the telephone 2 mF condenser in series with a resistance is placed across the impulse springs as a spark quench circuit to limit the surge voltages during dialling to approximately 180 volts. In sidetone telephones, the spark quench resistance is one winding of the induction coil, but in later ASTIC telephones, a special 50 ohm resistance is provided on the induction coil.

(a) The slipping cam masks the impulse lever from the impulse wheel and prevents the generation of impulses on the outward motion of the dial. When the dial is returning to normal under control of the main spring, the slipping cam moves with the impulse wheel until arrested by the forked stop. During this movement, the slipping cam masks two indentations of the impulse wheel. This is known as the "lost motion" feature and provides a space of approximately 200 milliseconds, plus the time taken to turn the dial off normal, between successive trains of impulses to allow the exchange switches time to complete their selecting and hunting functions. When the slipping cam is arrested by the forked stop, the impulse wheel indentations are unmasked and the impulse lever is operated a number of times according to the number dialled.

(b) The dial finger plate provides a ready means of selecting any of the 10 numbers or letters which appear on the dial number plate. When the number or letter selected is dialled by placing a finger in the selected finger hole and pulling the plate round in a clockwise direction until the finger strikes the finger stop, a clock spring is wound up and this provides the motive power for the return of the finger plate to normal.

(c) The impulse wheel is fixed rigidly to the main spindle and revolves with it when the finger plate is rotated. The periphery of the wheel is cut with 10 evenly spaced indentations which pass under the impulse lever and cause it to operate except when masked by the slipping cam.

(d) The governor controls the speed of the dial when it is moving under the motive power of the main spring. The governor is of the centrifugal type and is adjusted so that impulses are generated at an approximately uniform rate of 10 per second.

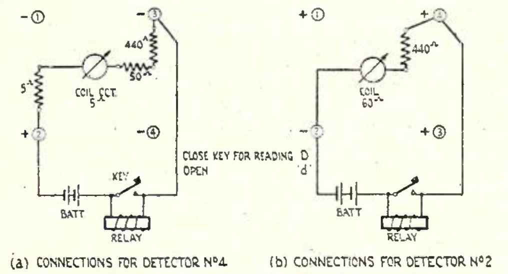
Q. 9.—Describe with the aid of a diagram, how you would ascertain the resistance of a relay coil using a Post Office Detector and two dry cells. Assume any values of detector readings you require and show your calculations.

A.—

Fig. 1 is a schematic diagram showing the connections for making the test. The connections are shown for both of the standard detectors, that is, Detectors Nos. 2 and 4. The 5 volt scale is used in each case and the dry cells are connected in series. A reading is first taken with the cells connected directly to the detector—call this D. A reading is then taken with the relay coil in series with the cell and detector

—call this d. The resistance R of the relay is calculated from the formula R = (D/d — 1) 500 where 500Ω is the resistance of the 5 volt scale of the detector.

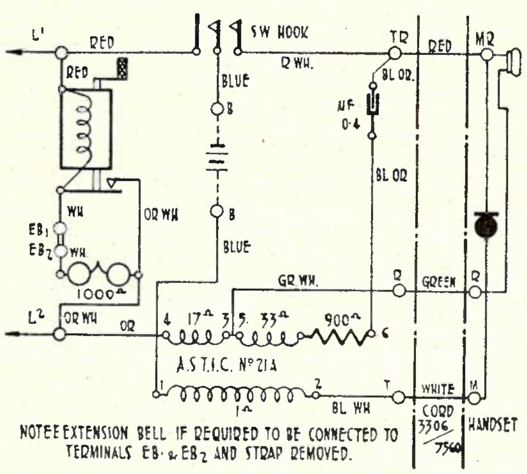
Assuming D = 40
d = 10
then R = (40/10 — 1) 500 = 1500 ohms.



Q. 9, Fig. 1.

Q. 10.—Draw a schematic circuit of a magneto wall telephone and state briefly the function of each piece of apparatus shown.

A.—



Q. 10, Fig. 1.

The generator supplies ringing current of approximately 16 cycles per second at 75 volts for signalling purposes.

The magneto bell provides a calling signal and responds to 16 cycle ringing current.

The switch hook operated by the handset changes the telephone circuit from signalling to speaking conditions.

The receiver converts speech currents into audible sound waves.

The battery of two dry cells supplies current for the operation of the transmitter.

The transmitter responds to the sound waves of speech, and produces corresponding variations in the current flowing in the local circuit, comprising the battery, induction coil primary winding 1-2, and the transmitter.

The functions of the induction coil are to improve the transmission efficiency of the telephone and provide a reduction of sidetone. For maximum efficiency, the transmitter and receiver of a local battery telephone should be connected to loads approximating to their respective impedances. As the impedance of the line is nominally 600 ohms, the correct load on the transmitter is obtained by a suitable choice of ratio between the number of turns on the primary and secondary windings of the induction coil. The receiver, which has an impedance of approximately 400 ohms matches the combined impedance of the line and network in parallel. The direct current through the transmitter should be as large as practicable so that the resultant magnetic field will be large and any change in the current strength produced by variation in the transmitter resistance will result in the maximum current being induced in the secondary winding, and, therefore, into line. The D.C. resistance of the primary winding is kept low so that the desired current can be obtained with a small E.M.F.

The telephone circuit shown in Fig. 1 includes a network in the balance winding of the inductance coil consisting of a 900 ohms non-inductive resistance and a 0.4 mF condenser. In the sending condition, power is dissipated in the network instead of in the receiver as in the case of sidetone circuits, and on a balanced connection no sidetone is heard in the receiver as it is then connected to equipotential points in the circuit. In this telephone, the balance network has been designed to obtain balance conditions and maximum sidetone reduction on long lines where it is most required.

[Editor's note.—See Vol. 2, No. 3, page 147, for further particulars.]

TECHNICAL EXAMINATION FOR TRAFFIC OFFICERS IN TRAINING

J. A. KLINE, B.Sc., A.M.I.E.E.

SECTION A.

Q. 1.—Describe briefly a primary cell and a secondary cell, indicating the difference in the use and operation of each.

A.—There are several different forms of primary cell, but these may be divided into two main groups—wet and dry. Of the wet types the Leclanche is the most common, and the usual dry cell is a special form of the Leclanche in which the electrolyte is in a paste form so that it does not flow and therefore the cell is easily handled. The elements are zinc and carbon with ammonium chloride as the electrolyte. The negative pole of zinc is in the form of a cylindrical container with a terminal fixed to the top edge. The positive pole is a carbon rod fixed in the centre of the cell and insulated from the bottom of the zinc container. The carbon rod is surrounded by a mixture of powdered manganese dioxide and carbon moistened with ammonium chloride contained in a cloth bag or sack tied up to make a single unit. This porous sack is surrounded with flour well mixed as a moist paste with ammonium chloride solution. The top is sealed with bitumen with vent holes to permit the escape of gas resulting from the chemical action. The complete unit is enclosed in a cardboard covering impregnated with wax. The voltage is approximately 1.5 V.

Editor's Note.—See also Answer to Q. 2, Exam. 2270, p. 49, this Vol.

A secondary cell consists of negative plates of chemically pure lead and positive plates of peroxide of lead formed into a paste with sulphuric acid and held in place in a framework or grid of lead antimony alloy. The electrolyte or liquid is sulphuric acid of specific gravity about 1.210. The material in the plates is changed when the cell is discharged, both plates then having a proportion of lead sulphate. They can be changed back to the original when recharged. The plates are arranged alternately negative and positive with a negative on each outside. The plates are separated by wooden or glass separators to prevent internal short circuits. All like plates are connected together and the positives are brought out to one side and negatives to the opposite side. The elements are contained in a glass, wood or plastic moulded case, which for smaller cells is closed at the top, but is open in the larger types. The nominal voltage of each cell is 2 V.

Secondary cells must be charged from some external source, their main value being that when discharged they can be brought back to their original capacity by recharging; that is they are capable of changing electrical to chemical energy as well as the reverse. Primary cells convert chemical to electrical energy, but their energy is self-contained, therefore they can be used where no external power is available and they have the advantage of requiring no maintenance. Their capacity is limited and therefore they are not suitable for use except for low energy requirements. A particular feature of secondary cells is their low internal resistance, so that heavy currents can be drawn from them for short periods.

Q. 2.—State the units in which the main electrical characteristics of the following pieces of apparatus would be measured:—

(a) Resistance;
(b) Relay or choke coil;
(c) Condenser.

Discuss in a general way the different effect of each in an A.C. and a D.C. circuit.

A.—Resistance—in Ohms.

Relay or choke coil—resistance in ohms; inductance in henries.

Condenser—Capacity in microfarads.

A non-inductive resistance gives the same effect whether in an A.C. or D.C. circuit. A special case is the action of a resistance in a high frequency A.C. circuit, when the effective resistance differs with frequency and is higher than the resistance as measured under D.C. conditions.

A coil which has inductance generates a back e.m.f. when current is increasing or decreasing, consequently when in a direct current circuit the rise of current is opposed, but once it reaches a steady state only the resistance is effective. In an A.C. circuit, as the current is changing continuously, there is a consequent continuous back e.m.f. The resultant current is inversely proportional to the impedance which is the combined effect of the inductance and the effective resistance at the applied frequency.

A condenser prevents the flow of a direct current, allowing the passage of only the surge which charges it to the potential of the applied battery. When an alternating potential is applied, current will be allowed to flow inversely proportional to the impedance at the applied frequency. The impedance varies inversely as the capacity.

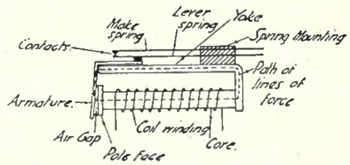
Q. 3.—What are the laws of attraction and repulsion of magnets? How is electricity used to produce magnets? Describe the main features of any piece of apparatus used in telephony or telegraphy in which this conversion is employed.

A.—Like poles repel.

Unlike poles attract.

The force between two poles in air $= (m_1 \times m_2)/d^2$ where m_1 and m_2 are the strength of the poles and "d" the distance between them.

A current flowing in a conductor produces a magnetic field around the conductor. If the conductor is wound in the form of a helix the magnetic field will be concentrated and the helix is similar to a bar magnet with the south pole at the end where the current appears to flow in a clockwise direction. If a piece of iron is placed inside the helix it will come into the influence of the field and the lines of force passing through it will make it a magnet. If it is soft iron it will lose its magnetism when removed from the helix or the current is stopped. If it is steel some of the magnetism will be retained.



THE ELEMENTS OF A TELEPHONE RELAY.

Q. 3, Fig. 1.

The telephone relay operates as a result of the electric current producing a magnet. See Fig. 1.

The current controlling the operation of the relay flows in the winding of insulated copper wire. The magnetic circuit is composed of the core, yoke and armature so that opposite poles are formed at the pole face and the armature. The latter is attracted and hinges on its knife edge to move the springs and make the contacts fitted on the yoke. The flow of current in the winding makes the magnet, thus converting electrical to magnetic energy. This in turn is changed to mechanical energy in the movement of the armature which is used to operate springs controlling other electrical circuits.

SECTION B.

Q. 1.—An order has been issued to install a simple exclusive exchange service. Discuss briefly what is required and the connections to be made:—
(a) In the exchange;
(b) Between the exchange and the subscriber's premises;
(c) In the subscriber's premises;
for a metropolitan automatic subscriber and for a subscriber to a small country magneto exchange.

A.—Besides fitting the telephone instrument it is necessary to provide a metallic circuit between the exchange apparatus and the subscriber's telephone. The equipment at the exchange will be in situ and connected to the main frame but it is necessary to jumper on the frame from the switchboard terminals to the line terminals. In practically every installation there will be a cable from the frame to a terminal point in the street. In the metropolitan area this will be close to the subscriber's premises, in the country it may be just outside the exchange. For the metropolitan connection the line may be completed fully underground by running a 1 pair lead covered cable jointed into the cable running past the premises. Alternatively the circuit may be completed by open wire from the cable terminal to the subscriber's house. Protection is required in the subscriber's premises only if there is open wire in the external line. If a protector is fitted it is necessary to connect the earth by running a bare copper wire to the protector. The type of instrument required by the subscriber is fitted in the most suitable position as determined after ascertaining the subscriber's desires.

If it is a local battery service as in a magneto area two dry cells are fitted in the instrument or in a battery box in a convenient position.

The connections to be made in each type of installation will, therefore, be:—

	Metropolitan Automatic Service	Country Magneto Service
(a) At the Exchange	Jumper on the M.D.F.	Jumper on the M.D.F.
(b) Between the Exchange and the subscriber's premises.	1 pair lead covered cable jointed into lateral cable and run into premises completely underground; or Pair of open wires from cable terminal to subscriber's premises.	Pair of open wires from exchange or nearby terminal pole to subscriber's premises.
(c) In the subscriber's premises.	Install automatic telephone and also protector if there is any open wire in the circuit.	Install magneto telephone, subscriber's protector and two dry cells.

Q. 2.—What is the approximate range of frequency of voice currents? Describe as you would to an interested subscriber how speech is transmitted from the speaker over a telephone to the hearer, referring to the various conversions of forms of energy that take place.

A.—The voice frequency range is approximately from 80 to 10,000 cycles per second, though any one voice is unlikely to cover all of this scale. A bass voice may range from 80 to 8000, and a soprano from 200 to 10,000 cycles per second.

Sound is produced by vibrations within the audible range of frequency and power. In speech, the air in the throat and mouth is caused to vibrate, and if a transmitter is placed within the influence of these vibrations the diaphragm will move in synchronism with the speech waves. Thus the acoustic energy is converted to mechanical energy. The transmitter is constructed so that the movement of the diaphragm varies the pressure on carbon granules enclosed in a small chamber with electrodes connected to complete an electrical circuit from the transmitter to the distant receiver. The resistance of the granules varies according to the pressure exerted by the diaphragm. The mechanical movement of the diaphragm thus varies the current in this circuit, so converting the mechanical energy into variations of electrical energy.

The current changes pass over the connecting line and through the coils of the receiver at the distant station. The coils of the receiver are wound on iron pole pieces with a diaphragm of magnetic material fixed in front of them. The attraction of the diaphragm depends on the magnetic strength of the pole pieces which in turn depends on the current flowing in the coils. The receiver therefore converts the changes in the current flowing in the line into magnetic energy and then back into mechanical energy by varying the tension on the receiver diaphragm. The movement of the diaphragm causes the surrounding air to vibrate in unison with it and thus to produce sound waves similar to those affecting the transmitter diaphragm.

Q. 3.—Indicate briefly the function of each of the following pieces of apparatus in a subscriber's telephone:—

(a) Switchhook;
(b) Bell;
(c) Dial;
(d) Condenser;
(e) Batteries.

A. — (a) Switchhook: — The main purpose of the switchhook is to operate springs which alternately switch the circuit to the ringing or the speaking condition. As the receiver is on its rest in the ringing condition and is removed when speech conditions are required, it is convenient to associate the receiver with the switchhook and thus make the changes automatic with the lifting or replacement of the receiver. In the ringing condition the comparatively low impedance receiver circuit is switched out so as not to bridge the bell. In the magneto telephone the transmitter circuit is closed through the local battery only when the speaking conditions are required, that is, when the receiver is off the switchhook.

(b) Bell:—This provides the means for attracting the attention of the subscriber. It is operated by alternating current within a narrow band of frequencies and is selective to the standard ringing frequency. Because of the high impedance to voice frequencies, the bell coils can be bridged permanently across the line with little transmission loss.

(c) Dial:—This piece of apparatus is the means given subscribers for operating automatic switches to effect the desired connection. When operated by the subscriber it produces the required number of impulses at a predetermined speed of 10 per second and a ratio of 2 to 1 break to make. It also automatically effects circuit changes to give the optimum impulsing conditions at the telephone and prevent annoying clicks in the receiver. Further it provides for a minimum time interval between impulse trains as required by the switching apparatus.

(d) Condenser:—This is included in C.B. manual and automatic telephones. It prevents the flow of direct current but allows alternating current to pass, the impedance offered varying inversely with frequency. In the ringing condition, a 2 μF condenser is in series with the bell and while permitting reception of ringing avoids giving a D.C. loop on the line. In the dialling condition it is used as part of the spark quench circuit and in the speaking condition combines with the inductive circuits of the induction coil to give appropriate impedance for the speech circuits.

(e) Batteries: — These are fitted in local battery telephones only, the great majority of which are connected to magneto services. The batteries provide the potential necessary for the operation of the transmitter. The circuit includes the primary of the induction coil, the change in potential across the winding of which induces a potential in the line circuit. The batteries supply the power for speech transmission in a local battery telephone.

Q. 4.—Give a conversational explanation of how a call is made through an automatic exchange, naming the switches and indicating the frequency and period of interruption of the busy and other such tones.

A.—In a manual exchange the calling subscriber's line is connected to the wanted subscriber's circuit by a telephonist, but in an automatic exchange this operation is carried out by switches. It is often referred to as the machine switching system. As verbal advice cannot be given a subscriber regarding the progress of his call, and as a subscriber needs to know if the connection has been made or if there is any abnormal condition, the required advice is given by a system of tones which, if properly understood, indicate the action required of a subscriber. When the telephonist is ready to give the connection she asks for the number. In an automatic exchange this is done by sending dialling tone to the caller when the switches are ready to set up the connection. Instead of speaking the number required, the subscriber sends out the information from the dial. If the connection cannot be given at the moment, a busy tone is sent to advise the subscriber to hang up and call again shortly, while a number unobtainable tone indicates that the number called cannot be connected.

When the receiver is lifted to call, say, B1234, the line wires are looped in the telephone set and the apparatus on the line at the exchange detects this condition, so it operates to extend the line to a switch which can take the dial signals. This switch is called a first selector. For economical reasons there is not a first selector for every line, but the number provided depends on the simultaneous connections during the busy hour. As this 1st selector switch is ready to be operated by the dialled impulses, dialling tone—a low pitched continuous noise of 33 cycles per second—is sent to the subscriber. It is important that this tone should be heard before dialling is commenced, as it indicates that the circuit is ready for this action. The operation of the dial breaks the electrical circuit to the 1st selector at the predetermined rate and ratio required to operate the switching mechanism to level B (2). The selector automatically searches over ten contacts in that level to find a line to a disengaged second selector and by the time the 2nd digit is dialled this switch is ready to be operated to the required level (1) to search over the ten contacts to find a free third selector. The 3rd digit is dialled to this switch, which operates as the previous numerical switches to level 2. The last two figures are both accepted by the final selector, the first (3) operating the switch vertically, and the second (4) stepping it rotarily to make contact with the circuit leading directly to the wanted subscriber's line. Ringing conditions are automatically established to send out an alternating current on the called line to ring the bell of the subscriber's telephone. While this is being done a tone is sent back to the calling subscriber. This ringing signal is 33 cycles per second superimposed on which is 133 cycles per second, the tone being interrupted, that is, 0.4 seconds on, 0.2 seconds off, 0.4 seconds on, 2 seconds off. When the called subscriber lifts his receiver to answer, a loop is placed on the line which starts the metering operation in the exchange, a signal being sent over the circuit to operate the meter of the calling subscriber.

According to the relative situation of the calling and called subscribers, the switches used in the connection may be in one or more exchanges, the call being directed over appropriate junction circuits between exchanges where necessary. If any of the switches referred to is unable to connect to a free switch in the next rank after searching over the 10 contacts in the selected level, then the busy tone will be sent to the calling subscriber. This will also happen if the called subscriber's line is already engaged in a connection. The busy tone is a high pitched note of 400 cycles per second interrupted to give 0.75 second on and 0.75 off.

If the number called is not connected, then a continuous high-pitched note of 400 cycles per second is transmitted to the caller. This is the Number Unobtainable tone or N.U. tone, which indicates to the caller that the call should be abandoned or enquiries made concerning the number dialled.

Q. 5.—Describe briefly the method of metering in use in an automatic exchange in your State and the steps taken to check the accuracy of recordings.

A.—The booster battery metering system to be described is in use in all main networks except Brisbane. When the called subscriber lifts the receiver to answer a call, a positive potential is applied momentarily to replace the earth on the private wire of the connection, and thus pass the metering signal from the final selector to the line circuit of the calling subscriber. The meter is connected to the negative side of battery and to the private wire in the line circuit of the calling subscriber. With the private wire earthed, the current flowing in the meter is insufficient to make it operate, but when a positive potential of 50 volts is applied to the private wire in place of the busying earth, this, in series with the normal battery voltage, gives a potential of 100 volts across the meter, to operate it. After operation, the normal battery potential is sufficient to hold the meter operated when the earth is replaced on the private wire.

The accuracy of recordings is dependent on the meter and the complete booster circuit. Routine tests are regularly applied to both of these. Meters are checked every three months when a ten impulse test is applied to each one. In addition, if there is any reason to suspect uncertain operation of any meter, the line is connected to a special observation circuit so that the effect of every call can be observed, including the meter operation.

SECTION C.

Q. 1.—What is meant by the term "Three-channel Carrier"? How many wires are used for transmission? Indicate the main principles of operation.

A.—Three Channel Carrier is the name given to a system of transmitting three telephone circuits superimposed on an existing physical telephone channel by using high frequency carrier currents modulated by the telephone frequencies. Therefore, over one pair of wires or physical channel, there will be transmitted three other connections in addition to the normal circuit.

The principle of operation is to generate three different frequencies of carrier currents, each of which is modulated by the speech frequencies it is desired to transmit. The modulated carriers are fed to line, and at the receiving end, filters separate the bands of frequencies appropriate to each circuit. Each band is then demodulated to separate the speech frequencies from the carrier. It is necssary, of course, to transmit simultaneously in both directions for each channel and it is usual to allot separate carrier frequencies for the come and go circuit of each channel, the appropriate circuits being fed through hybrid transformers to form a normal 2-wire circuit to the instrument. It is necessary to have low pass and high pass filters to effectively separate the normal voice frequency circuit from the combined carrier circuits. Other than this the normal circuit is not interfered with.

The normal low frequency ringing currents are not efficiently passed by the transformers it is necessary to have in the circuits, therefore higher frequencies are used—generally 1000 cycles. When the telephonist rings, the 16 cycle current operates relays which apply the 1000 cycles in spurts of 20 impulses per second. The carrier is thus modulated for transmission, and at the receiving end is de-modulated to give the spurts of 1000 cycle current. As the transmitted frequency is within the voice range there is no difficulty of transmission and, at the receiving end, a tuned circuit picks out the interrupted 1000 cycle signal and by relay operation passes on 16 cycles normal ringing current to the circuit.

Q. 2.—What is a Rural Automatic Exchange? What

are the facilities offered to subscribers by such a unit, and what signals are transmitted to the control centre to indicate any special condition of the apparatus?

A. — A self-contained automatic exchange with a capacity of 200 lines or less, dependent only on a parent manual exchange as its trunk centre, is known as a Rural Automatic Exchange or R.A.X. The main facilities given to subscribers are the same as for a metropolitan automatic exchange, that is, continuous secret service between subscribers. Service to and from other exchanges is obtained through the parent manual exchange. Standard dialling, ringing, busy and number unobtainable tones are provided. In addition, a line developing a permanent loop is automatically locked out of service and a tone is sent to any line calling the faulty service. Party lines are given special facilities providing inter-communication between parties and automatic registration against the particular party making a call to another subscriber's line. Single wire lines can be connected. Public telephones are fitted with the Hall type multi-coin collector so that calls can be made beyond the unit fee area and the amount deposited checked by the telephonist at the parent exchange. The batteries for supplying the exchange power are charged from the electric mains through an automatic charger if there is local power, or over a junction if the power comes from the parent manual exchange. In the latter case, the charging current is automatically cut off when a call is made over the junction and reconnected when the circuit is free.

Since there is no attention normally available, provision is made for automatically sending a signal to the telephonist at the parent exchange when any abnormal condition occurs at the R.A.X. The faults which can occur are divided into urgent and non-urgent. With an urgent fault a call is automatically made to the parent exchange and when the telephonist plugs into the junction jack a tone is received which indicates the type of fault. To detect non-urgent faults routine tests are made at regular intervals by the telephonist dialling a special fault number, the existence of a fault being denoted by an appropriate tone. Subscribers' lines can be tested from the parent exchange over the trunk line.

Q. 3.—What is the function of a Repeater? Discuss the economics of their use. Why do most long circuits have a number of repeaters instead of one giving a very high gain?

A.—A repeater raises the power level on a telephone circuit. Attenuation occurs in any circuit and may reach such a degree that there is insufficient power at the receiver to produce audible speech. In such circumstances the inclusion in the circuit of a repeater will increase the transmitted power, and with a perfect unit all frequencies are amplified in the same proportion. A similar effect could have been obtained by improving the transmission of the circuit by larger conductors. In considering the economics of a circuit it is therefore necessary to balance the cost of the requisite line for the results required against the cost of a line allowing greater loss, but including repeaters. If the power of the speech is allowed to get so low that the extraneous noise is comparable to the speech, that is, if the signal to noise ratio is low, then equal amplification of whatever is received will give a high volume of background noise in the receiver. It is therefore inadvisable to allow the signal to be excessively attenuated, and it is good practice to instal a repeater at points where the signal is still well above the noise level. For this reason a number of repeaters in a long circuit is preferable to one with a high gain. Further, if the power is stepped up too high the possibilities of cross-talk to other circuits on the same route is increased. Moreover, at high gain, most repeaters lose stability and increase the danger of singing.

Q. 4.—What is Frequency? Why is it desirable to have special land line circuits for the transmission of programmes for broadcast purposes?

A.—In any regular recurring phenomenon, the number of times the same thing recurs in a second is called the frequency of that phenomenon. In wave motion, the wave length divided into the velocity of propagation gives the frequency; that is, the number of waves per second. In order to obtain a reasonable standard of intelligible speech it is only necessary to transmit a band of frequencies between 300 and 2700 over the normal telephone circuit, and it would be uneconomical to design the equipment and the line with improved characteristics for any unnecessary extension of these frequency limits. The usual land line circuits and the apparatus associated with them, can be relied upon only for this band of frequencies. Broadcast programmes include music and sound effects which go beyond these frequency limits and to obtain accurate reproduction it would be necessary to transmit an audio frequency band width of approximately 20 to 15,000 cycles per second. Experience has shown, however, that reasonably satisfactory results can be obtained by providing channels which transmit frequencies from 35 to 5000 c.p.s.

In order to secure the requisite quality for programme transmission, special circuits and, where necessary, special repeaters and equalizers are provided. The latest practice is to include heavy gauge conductors in each long distance cable, the circuits being electrostatically screened to shield them from cross talk interference.

EXAMINATION NO. 2194—ENGINEER—TELEGRAPH EQUIPMENT (Continued)

V. St.G. MAGNUSSON

SECTION C.

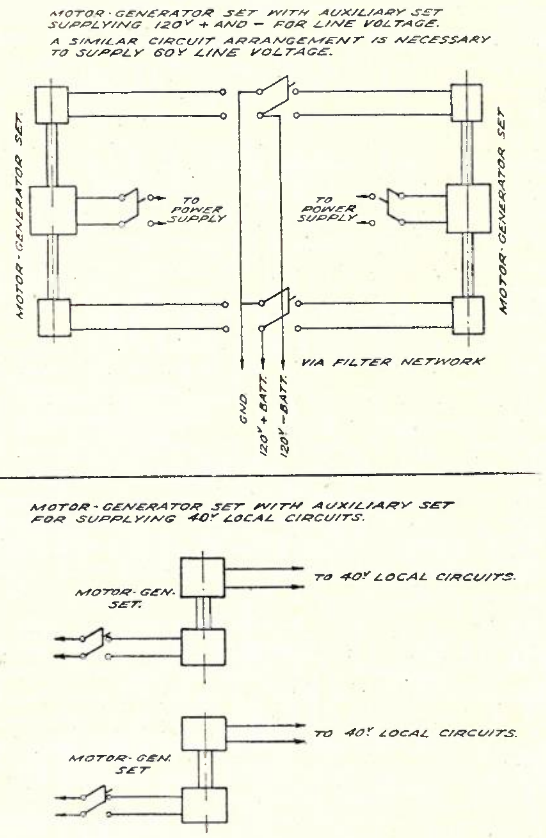
Q. 1.—Describe with the aid of a sketch, a power plant installation other than using secondary cells for a Chief Telegraph Office, indicating clearly how the necessary voltages would be obtained and the distribution arrangements. Briefly compare the advantages and disadvantages of your proposed arrangements with a secondary cell installation.

A.—Fig. 1 shows a circuit arrangement whereby the power may be obtained direct from generators. A maximum voltage of 120 volts is assumed. Four motor generator sets would be required to supply the line voltages. Each set consists of a motor directly coupled to two generators. Two motor generator sets would be connected to the 120 volt line circuits in such a way that whilst one set is supplying the line voltage the second set is a standby. A similar arrangement would apply to the 60 volt motor generator sets. Across the output would be placed filter networks to smooth out any ripple that may be present. The generators supplying the line voltages should be of such characteristics that variations in load do not affect appreciably the voltage across the terminals.

The 40 volts for the local supply is obtained from a separate motor generator set which is also duplicated for emergency purposes.

The distribution of the various line voltage supplies and the local voltage supply would be similar to that obtaining with a secondary cell installation. Each line is fed through a fuse and a resistor.

It would be essential when generators are used for an alternative power supply to be available or for a prime mover coupled to a generator to be installed, in case of a failure of the commercial power supply. The prime mover would need to be of a type that could be set in motion with a minimum of delay. A petrol driven engine would be suitable.



Q. 1, Fig. 1.

As an alternative to direct coupling, the generators could be "V" belt-driven from the one shaft, which in turn could be connected to a motor. The suggested scheme, however, is particularly flexible and provides for most emergencies.

Secondary cells possess the advantage of having a smooth output and ease of tapping without waste of power, but they have the disadvantage of requiring recharging. The outstanding advantage is that they are not directly dependent on the power supply. Therefore, if power supply fails, continuity of service may under most circumstances be maintained. Maintenance charges are higher when batteries are used and it is necessary to make special building provision to accommodate the cells. With a battery installation it is necessary to provide charging equipment such as motor generators or rectifiers.

Whilst the initial cost and maintenance charges would be less with motor generator sets as compared with batteries, and less space would be occupied for power requirements, the provision of a high grade telegraph service can be more satisfactorily given by a secondary cell installation, particularly at a Chief Telegraph Office.

Q. 2.—It is desired to meet all main and local battery requirements in a busy office from a secondary battery installation. The following systems are in operation regularly each day (except Sundays) from 9 a.m. to 6 p.m.:—

10 Long omnibus morse channels;
3 manually operated duplex systems;
4 local point to point leased teleprinter services;
1 double multiplex.

Calculate the capacity in ampere hours of the batteries, assuming that charging can be arranged on only one day per week. What general arrangements would you make? NOTE: The vibrators and motors of the multiplex system would be worked from the supply mains and not connected to the battery.

A.—The office concerned is relatively small and it would be desirable to avoid any complex battery circuits and also to reduce battery and associated equipment to a minimum. All line circuits should be connected to a voltage of 120 and no intermediate tappings taken from the battery. If necessary, limiting resistances may be introduced into the morse circuits if it is desirable to reduce the line voltages. The "local battery" would be supplied by a separate bank of cells having a voltage of 40 volts.

Considering first the current required for the local or sounder circuits—

10 Morse Sounder Circuits (estimated current)	400 m.a.
3 Duplex Sets (estimated current)	350 m.a.
Total	750 m.a.

The working day at the office concerned is 9 hours and as the batteries can only be charged once a week, the batteries would be on discharge for a period of 54 hours. The drain on the battery in ampere hours per week would be—

$$(54 \times 750)/1000 = 40.5 \text{ Ah.}$$

To provide a reasonable margin for development and depreciation a 40 volt battery of 60 Ah. capacity should be installed.

Dealing now with the main or line batteries the following working currents would need to be provided:—

Single Current Systems—

10 long morse lines (allowing for leakage) .... 500 m.a.

As the total working hours is 54 per week, therefore total current drain would be:

$$(54 \times 500)/1000 = 27 \text{ Ah.}$$

It is assumed that the drain will be evenly distributed over the positive and negative line batteries and in this case the approximate drain on either battery would be 14 Ah. for single current working.

Double Current Systems—

3 manually operated duplex systems	150 m.a.
4 local point to point teleprinter services	320 m.a.
1 multiplex set (assuming that the selector and cadence magnets are also operated from the supply mains)	60 m.a.
Total	530 m.a.

The weekly drain for double current sets would be:

$$(530 \times 54)/1000 = 29 \text{ Ah. approx.}$$

The drain is distributed over the positive and negative batteries in double current working, but it is usual to assume that the positive battery will supply $^2/_3$ of the drain. This would be—

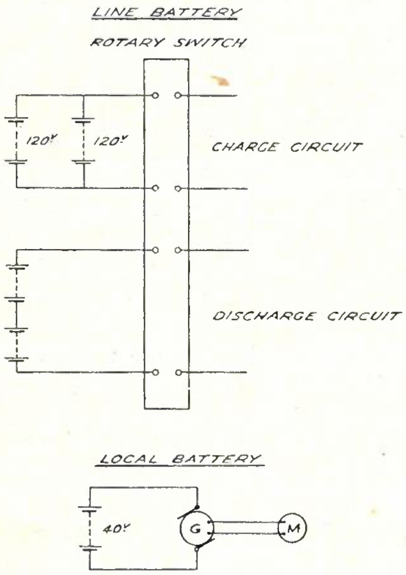
$$^2/_3 \times 29 = 20 \text{ Ah. approx.}$$

The drain on the positive line battery for both single and double current sets would be 14 + 20 Ah. = 34 Ah. The positive and negative batteries installed would be of equal capacity.

It would be necessary to consider depreciation of batteries and provision for development, and under such circumstances the installation of line batteries having a capacity of 50 Ah. would be desirable. The line batteries would be duplicated for emergency and charging purposes.

The battery provision would be—

1 Local battery of 40 volts 60 Ah.
2 Positive line batteries of 120 volts 50 Ah.;
2 Negative line batteries of 120 volts 50 Ah.



Q. 2, Fig. 1.

With regard to the charging of the line batteries, as commercial power supply is available, it should be used for the purpose. The best arrangement would be to charge one line battery whilst the second battery is on discharge. See Fig. 1. The local battery could be charged from a small motor-generator set as shown. The local battery has not been duplicated as this can be floated on the day of charging at a sufficient rate to charge the battery and supply the working load. Duplicate batteries have been provided in the case of the line batteries as these could not be floated on account of the increase in line voltage. The increase in the voltage of the local battery during the period of floating would not affect working.

Q. 3.—Discuss the various types of power arrangements for a large workshop in which there are a number of lathes and other machine tools, also some large machines for use in the carpenters' section. The types of drive you would suggest should be stated together with your reasons.

A.—Modern mechanical power transmission may be classified into two general systems, the "flexible" and the "rigid." Each of these two systems may be further sub-divided into various methods. Of the two systems, the "flexible" would be the one normally resorted to in a Departmental Workshop, and the more important methods included under this group are:—

(i) Group system employing shafting.

(ii) Individual drive using belt, V-belt or chain drive.

The "rigid" system, which includes such methods as direct-coupled motors, worm gear reduction units, etc., are not thought to be applicable to this discussion, and will not be discussed further.

The "flexible" system may be considered as shock absorbing, and would naturally tend to reduce the effects of load impact and vibration. With the belt drive particularly, the inherent characteristic "slip" may be looked upon as an element of protection both to the driving motor and driven apparatus.

Before dealing with the problem of providing power transmission facilities for the workshop in question, it is proposed to consider the advantages and disadvantages of the group system as compared with the individual drive. The group system is extensively used in industrial operations, and its economy of operation is generally accepted where a number of machines are to be driven, each requiring running energy from fractional to 7 H.P. The system is practised for combined running loads from 5 to 50 H.P. With group driving, the power capacity of the driving motor is based on the sum of the running loads of the machines rather than on the sum of the starting loads. The disadvantages associated with the group systems are:—

(a) A group of machines is dependent on the correct functioning of one driving motor.

(b) Danger of exposed belting to machine operators and other employees.

(c) More total floor space required in a workshop.

(d) A workshop equipped with a group drive system does not have as good an appearance as one equipped with individually driven machines. In addition, the general lighting is adversely affected.

(e) Not convenient or suitable where the individual loads are above 7 H.P. or high belt speeds are required.

The direct drive, if economy is the first consideration, is normally confined to the heavier machinery such as wood-working machines and compressors, etc. On such machines the V-belt or chain drive is the more efficient as compared with the flat belt, as maximum efficiency of operation is obtained. The use of V-belt drives also permits of short driving centres. This is an outstanding advantage insofar as it permits the motor being mounted integral with the machine in most cases, thus conserving space.

Dealing with the power transmission in a workshop equipped with the machinery referred to, we may consider first the lathes and machines other than those in the woodworking section collectively. If the individual requirements of these machines does not exceed 7 H.P., and the prime mover power demand is not in excess of 50 H.P., they could be included in the one group system.

The group method requires a prime mover with a power rating equal to the sum of the running loads of the machines plus friction of the assembly. To individually drive each of the machines, the total prime mover requirements must equal the sum of the starting loads. This primarily affects the capital and the power supply costs. Regarding the latter since motors operating below their rating are inefficient, the group system is considered best for the purpose. If the H.P. of the prime mover required is high, some thought should be given to the use of a V-belt drive to the head shaft.

With regard to the large machines for use in the carpentering section, individual drives employing V-belts would better suit the requirements, particularly where high power is required at belt speeds up to 6000 feet per minute. V-belts would be preferred to chain drive, as a positive velocity ratio is not necessary. The V-belt drive is more elastic and is better able to take shock and pulsating loads.

In conclusion, it may be found more convenient, depending on the layout of the room, to treat the lathes and machine tools as two group systems, and even arrange for one or two machines such as jewellers' lathes, etc., if such are installed, to be individually driven. If such treatment would better suit the requirements, light duty lathes and like machines could be placed in one group system, and the remaining machines in a second group.

Q. 4.—What apparatus would you provide in a large Chief Telegraph Office to enable the maintenance staff to test:—

(a) Lines (Physical and Carrier);
(b) Manual Morse Equipment;
(c) Multiplex Systems and equipment;
(d) Teleprinters; and
(e) General Power Supply.

A.—The supply of efficient and suitable testing equipment and instruments is essential if a good grade of service is to be maintained. Not only should testing instruments be provided, they should be readily available for immediate use. All test sets should be designed so that the minimum of time is lost when applying tests; mechanics' test benches should be wired so that line voltages and power may be obtained by the insertion of a plug or the throwing of a key, and buzzer sets with battery or head receivers with leads should be provided for point to point testing. All maintenance mechanics should be supplied with spring tension meters and feeler gauges.

With regard to the testing of the lines and equipment some instruments mentioned in the following may not be duplicated for the various purposes, particularly if they are expensive, but for the sake of clearness they have been included under each section where necessary. The testing instruments required are:—

(a) Lines (Physical and Carrier): An insulation resistance test set or voltmeter calibrated to measure resistance, would be required for the measurement of insulation resistance of lines and other resistances of high value. For the measurement of line currents a milliammeter central zero 75-0-75, and also a milliammeter 0-100 to read reversals of line currents and unidirectional currents. To measure line voltages a voltmeter 0-150, 0-300 should be available.

A Wheatstone Bridge with shunts and equipped to read Varley and Murray loop, and capacity tests, is necessary to enable fault localization tests to be carried out.

The following test sets should be available for the testing of lines:—

Morse Simplex Test Set,
Duplex Test Set,
Carrier Channel Test Set,

and also a reversal generator for the testing of carrier channels for bias.

(b) Manual Morse Equipment:—For the testing of morse equipment on the bench a simple form of test set could be provided for the testing of keys, sounders and relays after adjustment and to determine whether they are functioning satisfactorily. To ensure that the resistance of windings, and the insulation resistance between windings is correct, a bridge megger would be useful. When testing instruments in working circuits, i.e., fault location, a portable voltmeter or head receiver, would be required for point to point testing.

(c) Multiplex Systems and Equipment:—The various milliammeters and voltmeters already referred to would be required for general testing. Higher range instruments may be required for the measurement of commercial power supplies. At times the use of a bridge megger would be of advantage when measuring insulation resistance in wiring and equipment.

A test position or bench is necessary for the testing of Murray perforators, transmitters, and printers. In addition, after faults are cleared facilities should be available whereby the apparatus may be "run-in" and checked for any possible recurrence of faults before it is placed into working circuits.

(d) Teleprinters:—A test set should be provided to enable teleprinters to be placed under a running test after repair and adjustment. Preferably the test set should incorporate a tape transmitter so that the trial runs may be made over an extended period without the necessity for a mechanic to punch trials.

After test, it is desirable that a loop circulating through a cable network and terminated at the test bench be available so that teleprinters when adjusted may be tested under actual working conditions. Better still, would be the provision of a distortion measuring test set with which the amount of distortion that a teleprinter will accept, may be determined. The result of any tests made by a distortion measuring set would be more positive than cable loop tests.

(e) General Power Supply:—The electrical measuring instruments such as Voltmeters, etc., mentioned in previous sections, would be required for general power supply testing. Usually the instruments mounted on the power panels are sufficient for all normal tests.

For secondary cell testing, a cell testing meter with cadmium stick, hydrometer, and thermometer should be provided.

EXAMINATION NO. 2194—ENGINEER—TRANSMISSION—LINE AND RADIO (Continued)

J. W. READ, B.Sc., A.M.I.E.E., A.M.I.E.(Aust.)

SECTION 3—LONG LINE EQUIPMENT

Q. 8.—(a) Briefly describe what you understand by the term "negative feedback."

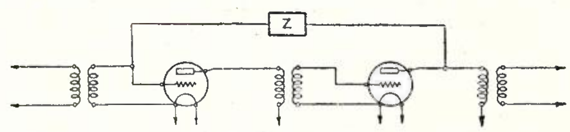
(b) Give a circuit of an amplifier incorporating negative feedback.

(c) State its effect on the performance of the amplifier with respect to:—

(i) Overall amplification;
(ii) Frequency characteristics;
(iii) Stability;
(iv) Harmonic distortion;
(v) Internally generated noises, e.g., hum.

A.—(a) "Negative feedback" as applied to an amplifier means that some of the output from the amplifier is fed back via an impedance Z which adjusts the amount of feed back to the desired value, and also its phase so that the feedback enters the input to the amplifier in opposite phase to the original input, and thereby somewhat reduces the gain of the amplifier. The feedback is applied to the amplifier as a whole, which may include one, two or more stages of amplification.

(b)



Q. 8, Fig. 1.

(c) (i) The overall amplification of the amplifier is considerably reduced.

(ii) The frequency response of the resulting amplifier is extremely flat over a wide frequency range.

(iii) The stability is very greatly enhanced, the gain of the amplifier being nearly independent of valve changes and voltage fluctuations, within limits.

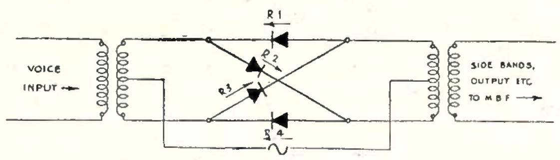
(iv) The harmonic distortion is greatly reduced, the harmonic output being reduced more than the amplified signal by the application of negative feedback.

(v) Internally generated noise, including hum, could be grouped with the harmonic distortion under the general heading of distortion and is very much reduced by negative feedback.

Q. 9.—(a) Give a circuit diagram of a metal rectifier modulator, such as is used in a carrier telephone system.

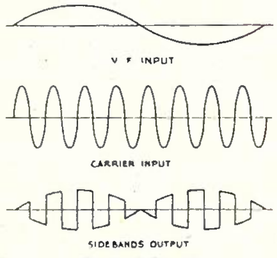
(b) Give an explanation of the manner in which modulation is effected and the carrier is suppressed.

A.—(a)



Q. 9, Fig. 1.

(b) The operation depends on the fact that the voltage of the carrier is high compared with that of the V.F. and the "pass" or "blocking" condition of each rectifier element is controlled by the direction of the carrier and is unaffected by the small variation in voltage due to the voice frequency current. With the carrier applied to the centre point of the input and output transformer windings, rectifiers R1 and R4 become conducting in the direction shown by the arrows when the carrier current is in a direction from right to left of the figure. With this condition, rectifiers R2 and R3 are blocking. The comparatively low voltage and low frequency of the V.F. will pass freely around the circuit, through rectifiers R1 and R4 because the voltage added does not affect the conducting condition of the rectifiers. While the V.F. is still in this direction the carrier reverses and makes rectifiers R2 and R3 conducting while R1 and R4 are blocking, and the incoming voice is therefore reversed in the output transformer with every alternation of the carrier. This process is repeated so that the carrier acts as a high speed commutator continually reversing the direction of the voice. This is shown in Fig. 2. At a comparatively slow rate the V.F. changes direction as shown in the figure. The result is that side-bands are produced in the output transformer, but the carrier is not transmitted as it is fed in differentially to the centre point of the output transformer. The wanted sideband can be separated from the other sidebands and similar unwanted products of the modulator by the filter which follows the modulator.



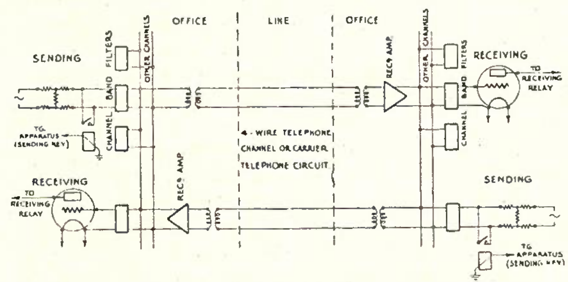
Q. 9, Fig. 2.

Q. 10.—Describe with the aid of a block schematic diagram a voice frequency carrier telegraph system.

Discuss the considerations which make the use of such a system desirable.

A.—The basic V.F. telegraph system is made to provide 18 frequencies on the C.C.I. frequency allocation in the band of frequencies available in the ordinary telephone channel of good quality. If the telephone channel is a four wire circuit throughout, this can provide 18 channels in each direction, i.e., 18 duplex channels. If the telephone channel is a two wire circuit frequency discrimination is necessary and only half this number can be provided. In Fig. 1, the 4 wire arrangement is assumed.

The system is usually designed with 120 cycle separation to give a telegraph channel capable of transmitting 45 bands with not greater than 25 per cent. distortion. This is satisfactory for teleprinter operation.



Q. 10, Fig. 1.

The voice frequency telegraph carrier is useful for the provision of a number of channels to larger centres. Its use may be justified by:—

(a) Providing a larger number of connections than previously, allowing direct connection of many stations to the capital city with a large reduction in telegraph repeating at the large centres, and consequent labour savings. It allows teleprinter operation, permitting the elimination of copying out messages, etc.

(b) Combining several circuits in one system, eliminating a number of costly open wire circuits. Modern machine telegraphy operates with difficulty over composites, and the use of cailhos has limited application on account of phantom operation. The use of physical telegraph lines is a very uneconomical use of the line plant.

More usually both (a) and (b) apply, the installation of a voice frequency system then allows the elimination of costly telegraph open wire lines combined with telegraph labour economies. The V.F. carrier telegraph system is frequently operated over one channel of a three-channel carrier telephone system which, being in effect a 4-wire circuit, allows the 18 duplex channels to be operated. Compared with the high frequency carrier telegraph system (type B) the voice frequency system occupies only one-third of the carrier spectrum of a good open wire pair if superimposed on a three channel carrier instead of completely occupying the pair, and it provides 18 channels instead of 10. The channels of the voice frequency system are designed for rather lower speed than the B system, but this is not a serious objection, except where the system forms an intermediate link on which Murray Multiplex operation is considered.

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